IUMRS-ICEM 2026

Chiang Mai, Thailand

# Abstract Book

The International Union of Materials Research Societies -
The 19th International Conference on Electronic Materials 2026
(IUMRS-ICEM 2026)

**June 28 - July 1, 2026**

The Empress Convention Center, Chiang Mai, Thailand

# WELCOME MESSAGE

On behalf of the Materials Research Society of Thailand (MRS), it gives me great pleasure to wish a very warm welcome to all participants to:

## The International Union of Materials Research Societies-
## The 19th International Conference on Electronic Materials 2026
## IUMRS-ICEM 2026

I would also like to express my most sincere gratitude for your presence on this conference.
In brief, The **IUMRS-ICEM 2026** will feature 13 technical sessions covering a broad range of topics, including Semiconductors, Photonic Materials and Devices; Polymers, Biomaterials and Medical Devices; Biosensors, Flexible, and Wearable Electronics; Ferroelectric and Piezoelectric Electronic Materials; Solar Cells, Materials and Devices for Energy Harvesting; Batteries, Materials and Devices for Energy Storage; Materials Processing for Advanced Packaging Technologies and Applications; Instrumentation and Advanced Materials Characterization; AI-driven Electronics, IoT and Digital Technologies for Next-generation Innovations; Recycling Materials and Environmentally-friendly Processing; Quantum Materials and Technologies; Industrial Perspectives in Materials and Innovation; Rare Earth, Critical Materials and its Applications. Attendees will have the opportunity to engage in stimulating discussions, presentations, and networking opportunities with experts from the international academic community and industry.

For this IUMRS-ICEM 2026 conference, the distinguished speakers including 6 plenary speakers, 71 keynote speakers and 69 invited speakers are invited from all over the world. The participants are over 600 from 23 countries.

The goal of this conference is to bring together, a multi-disciplinary group of scientists from all over the world to present and exchange breakthrough ideas relating to materials science. The conference promotes the globalization of quality research, focusing attention on recent achievements in both fundamental and applications of advanced materials as well as the future trends and needs in Materials Science Research.

Thanks are also due to our sponsors, exhibitors and supporters for their contribution which have made this conference possible. Recognition should also go to Materials Science Research Center, Faculty of Science, Chiang Mai University and the Local Organizing Committee members who have worked tirelessly to ensure the best quality experience for the delegates during the technical sessions. Finally, I would like to thank each of you for attending our conference and bringing your expertise to our gathering.

I sincerely hope that this conference will meet everyone's highest expectations.

Thank you very much for your participation.



**Prof. Santi Maensiri**
Suranaree University of Technology
Conference Chair & President of MRS-Thailand



**Assoc. Prof. Winita Punyodom**
Chiang Mai University, Vice President
Conference Co-chair

# WELCOME ADDRESS



## Professor Pongruk Sribanditmongkol, M.D., Ph.D.

President of Chiang Mai University

On behalf of Chiang Mai University, may I add my own very warm welcome to the Plenary Lectures, Keynote Speakers, Invited Speakers and all participants to this international conference entitled:

**The International Union of Materials Research Societies-**
**The 19th International Conference on Electronic Materials 2026**
**IUMRS-ICEM 2026**

To have been chosen to host this important conference at which such a distinguished group of internationally recognized speakers has been assembled is an honour not only for Chiang Mai University but for the city of Chiang Mai as a whole.

In recent years, Materials Science in Chiang Mai University has played an important part in raising our research profile, both nationally and internationally, through attracting research grants and producing journal publications. We are now recognized as one of the leading Materials Science Centers in Thailand, both for teaching and research. The conference will focus on fundamental and applied research, innovation and current developments within related applications in materials science.

I would like to thank Materials Research Society of Thailand, Materials Science Research Center, Faculty of Science, Chiang Mai University, our co-organizers and sponsors for their respective contributions. I believe that organizing an international conference of this importance requires months of planning and preparation. I therefore commend the committees from various universities for their efforts in bringing us to this point. Hopefully, their efforts will be rewarded throughout the conference, and the event will meet everyone's highest expectations.

Thank you very much.

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| 3. | Assoc. Prof. Doldet Tantraviwat | Chiang Mai University |
| 4. | Asst. Prof. Thutiyaporn Thiwawong | King Mongkut's Institute of Technology Ladkrabang |
| 5. | Prof. Tosawat Seetawan | Sakon Nakhon Rajabhat University |

**Symposium 2: Polymers, Biomaterials and Medical Devices**

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| 2. | Assoc. Prof. Sukunya Ross | Naresuan University |
| 3. | Assoc. Prof. Panya Sunintaboon | Mahidol University |
| 4. | Asst. Prof. Patchara Punyamoonwongsa | Mae Fah Luang University |
| 5. | Dr. Sorapat Niyomsin | Chulalongkorn University |

**Symposium 3: Biosensors, Sensors, Flexible, and Wearable Electronics**

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| 1. | Dr. Adisorn Tuantranont | Thai Microelectronics Center (TMEC), National Science and Technology Development Agency (NSTDA), Thailand |

Co-chairs

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**Symposium 4: Ferroelectric, Piezoelectric, and Triboelectric Materials and Devices**

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| 4. | Assoc. Prof. Jessada Chureemart | Mahasarakham University |

**Symposium 5: Solar Cells, Materials and Devices for Energy Harvesting**

Chair

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| 3. | Dr. Pisist Kumnorkeaw | NANOTEC |

**Symposium 6: Batteries, Materials and Devices for Energy Storage**

Chair

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| 1. | Dr. Pinit Kidkhunthod | Synchrotron Light Research Institute |

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| 2. | Assoc. Prof. Soorathep Kheawhom | Chulalongkorn University |
| 3. | Asst. Prof. Prasit Pattananuwat | Chulalongkorn University |

**Symposium 7: Innovative Material Processing for Technological Applications**

Chair

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2. Asst. Prof. Niti Yongvanich — Silpakorn University

**Symposium 8: Instrumentation and Advanced Materials Characterization**

Chair

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1. Assoc. Prof. Viyada Harnchana — Khon Kaen University
2. Dr. Yingyot Poo-Arporn — Synchrotron Light Research Institute

**Symposium 9: AI-driven Electronics, IoT and Digital Technologies for Next-generation Innovations**

Chair

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2. Asst. Prof. Ittipon Fongkaew — Suranaree University of Technology, Thailand

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**Symposium 10: Recycling Materials and Environmentally-friendly Processing**

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2. Assoc. Prof. Oratai Jongprateep — Kasetsart University
3. Asst. Prof. Niti Yongvanich — Silpakorn University

**Symposium 11: Quantum Materials and Technologies**

Chair

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2. Asst. Prof. Sukrit Sucharitakul — Chiang Mai University
3. Dr. Nithiwadee Thaicharoen — Chiang Mai University
4. Dr. Phatthamon Kongkhambut — Chiang Mai University

**Symposium 12: Industrial Perspectives in Materials and Innovation**

Chair

1. Dr. Anchalee Manonukul — MTEC, NSDTA

Co-chairs

1. Prof. Hathaikarn Manuspiya — PETROMAT, Chulalongkorn University
2. Assoc. Prof. Sirithan Jiemsirilers — Chulalongkorn University

**Symposium 13: Rare Earth, Critical Materials and its Applications**

Chairs

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2. Prof. Jakrapong Kaewkhao — Nakhon Pathom Rajabhat University and Vice President of Rare Earth and Minerals Association (Thailand)

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3. Assoc. Prof. Patarawagee Yasaka — Nakhon Pathom Rajabhat University
4. Asst. Prof. Narit Triamnak, — Silpakorn University
5. Dr. Wutthikrai Busayaporn — Synchrotron Light Research Institute (Public Organization)
6. Dr. Phakkhananan Pakawanit — Synchrotron Light Research Institute (Public Organization)

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### Special Symposia

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2. Asst. Prof. Pawin Iamprasertkun — Sirindhorn International Institute of Technology (SIIT)
3. Assoc. Prof. Wassanai Wattanutchariya — Chiang Mai University
4. Assoc. Prof. Kittisak Jantanasakulwong — Chiang Mai University
5. Assoc. Prof. Kamonwad Ngamchuea — Suranaree University of Technology

**Symposium 15: Frontier Research of Quantum Beam and Material Applications in Japan and Thailand**

Chair

1. Prof. Hiroyuki Nishikawa — Shibaura Institute of Technology (SIT), Japan

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1. Assoc. Prof. Duangmanee Wongratanaphisan — Thailand Center of Excellence in Physics, Chiang Mai University
2. Asst. Prof. Sakhorn Rimjaem — Chiang Mai University
3. Dr. Nitipon Puttaraksa — Chiang Mai University

## KEYNOTE SPEAKERS

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2. Prof. Sinn-Wen Chen — President of MRS-Taiwan, National Tsing Hua University (NTHU), Taiwan
3. Prof. Ana Cecilia Noguez Garrido — National Autonomous University of Mexico, Mexico
4. Prof. Sanjay Mathur — University of Cologne, Germany
5. Dr. Luan Tran — Formerly with Micron, TSMC and Bell Labs, Taiwan
6. Emeritus Prof. Jenq-Gong Duh — National Tsing Hua University (NTHU), Taiwan
7. Prof. Jenn-Ming Song — National Chung Hsing University, Taiwan
8. Prof. Hsin-Jay Wu — National Taiwan University, Taiwan
9. Prof. Deok-Kee Kim — Sejong University, Korea

**Thermoelectrics: Theories, Materials, Devices and Applications**

1. Dr. Ryoji Funahashi — National Institute of Advanced Industrial Science and Technology (AIST), Japan

**Symposium 2: Polymers, Biomaterials and Medical Devices**

1. Prof. Alejandro J. Müller — University of the Basque Country UPV/EHU, Spain
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6. Assoc. Prof. Sarawut Kumphune — Chiang Mai University, Thailand

**Symposium 3: Biosensors, Sensors, Flexible, and Wearable Electronics**

1. Prof. Jae Young Lee — Gwangju Institute of Science and Technology, South Korea
2. Prof. Maning Liu — Lund University, Sweden

**Symposium 4: Ferroelectric, Piezoelectric, and Triboelectric Materials and Devices**

1. Prof. Fei Li — Xi'an Jiaotong University, China

**Symposium 5: Solar Cells, Materials and Devices for Energy Harvesting**

1. Prof. Thomas Anthopoulos — University of Manchester, United Kingdom
2. Prof. Soo-Wohn Lee — Sun Moon University, South Korea
3. Distinguished Prof. Handong Sun — University of Macau, China

**Symposium 6: Batteries, Materials and Devices for Energy Storage**

1. Prof. Ru-Shi Liu — National Taiwan University, Taiwan
2. Prof. Seong-Min Bak — Yonsei University, South Korea
3. Prof. Mengyu Yan — Wuhan University of technology, China
4. Prof. Huaiyu Shao — University of Macau, China
5. Prof. Jae-Hyun Kim — Daegu Gyeongbuk Institute of Science & Technology, South Korea
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10. Prof. Somrerk Chandra-ambhorn — King Mongkut's University of Technology North Bangkok
11. Prof. Liqiang Mai — Wuhan University of Technology, China
12. Prof. Chia-Chih Chang — National Yang Ming Chiao Tung University, Taiwan

**Symposium 7: Innovative Material Processing for Technological Applications**

1. Asst. Prof. Dr.-Ing. Sakhob Khumkoa — Suranaree University of Technology, Thailand
2. Prof. Hui Pan — University of Macau, China
3. Distinguished Prof. Hyacinthe Randriamahazaka — Université Paris Cité CNRS, France
4. Prof. Daniel H.C. Chua — National University of Singapore, Singapore
5. Prof. Tohru Sekino — University of Osaka, Japan
6. Assoc. Prof. Theeranun Siritanon — Suranaree University of Technology, Thailand
7. Prof. Samuel Chigome — Botswana Institute for Technology Research and Innovation, Bostswana
8. Prof. Jyotsna Dutta Majumdar — Indian Institute of Technology Kharagpur, India
9. Prof. Kandalam Ramanujachary — Rowan University, NJ, USA

**Symposium 8: Instrumentation and Advanced Materials Characterization**

1. Dr. Chanchana Thanachayanont — MTEC, Thailand
2. Dr. Annop Klamchuen — NANOTEC, Thailand
3. Prof. Ravi Kumar — Indian Institute of Technology (IIT) Madras, India
4. Dr. Benjamin Victor Odari — Masinde Muliro University of Science and Technology, Kenya
5. Prof. Yuhui Dong — Institute of High Energy Physics, Chinese Academy of Sciences, China
6. Dr. Chanyong Hwang — Korea Research Institute of Standards and Science, South Korea

**Symposium 9: AI-driven Electronics, IoT and Digital Technologies for Next-generation Innovations**

1. Prof. Hirofumi Tanaka — Kyushu Institute of Technology, Japan
2. Dr. Norbert Radacsi — The University of Edinburgh, United Kingdom
3. Prof. Yusuke Sakemi — Chiba Institute of Technology, Japan
4. Assoc. Prof. Suwit Suthirakul — Suranaree University of Technology, Thailand
5. Dr. Adriana Martinez Oviedo — Instituto Potosino de Investigación Científica y Tecnológica - IPICYT, Mexico

**Symposium 10: Recycling Materials and Environmentally-friendly Processing**

1. Prof. Zoubeida Ounaies — Pennsylvania State University, United States
2. Assoc. Prof. Paiboon Sreearunothai — SIIT, Thammasat University, Thailand
3. Prof. Benjamin Agyei-Tuffour — African MRS, University of Ghana, Ghana
4. Prof. Wenbin Cao — University of Science and Technology Beijing
5. Dr. Sakprayut Sinthupinyo — SCG Cement Co. Ltd., Thailand
6. Prof. Hideki Ono — University of Toyama, Japan

**Symposium 11: Quantum Materials and Technologies**

1. Prof. Pierre Ferdinand P. Poudeu — University of Michigan, United States
2. Prof. Leong Chuan Kwek — National University of Singapore, Singapore
3. Prof. Masato Yoshiya — MRS-J, University of Osaka, Japan
4. Prof. Yasutaka Kitagawa — University of Osaka, Japan

# KEYNOTE & INVITED SPEAKERS

**Symposium 12: Industrial Perspectives in Materials and Innovation**

1. Assoc. Prof. Boonrat Lohwongwatana — Chulalongkorn University, Thailand
2. Dr. Jirut Wattoom — SCG Chemicals Co.Ltd, Thailand
3. Dr. Narin Kaabbuathong — Life Science Innovation Department, PTT Innovation Institute, Thailand
4. Prof. Yuttanant Boonyongmaneerat — Chulalongkorn University, Thailand
5. Asst. Prof. Teerakiat Kerdcharoen — Mahidol University, Thailand

**Symposium 13: Rare Earth, Critical Materials and its Applications**

1. Prof. David Bradley — University of Surrey, United Kingdom
2. Prof. C.K. Jayasankar — Vice president, Rare Earth Association of India, India

**Special Symposia**

**Symposium 14: Consortium for Advancing High Performance Industrial Postdoctoral and Postgraduate Researchers in Novel Materials to Drive High Impact Technology for Future Industry (PMU-B)**

-none

**Symposium 15: Frontier Research of Quantum Beam and Material Applications in Japan and Thailand**

1. Prof. Tadao Tanabe — Shibaura Institute of Technology, Japan
2. Assoc. Prof. Duangmanee Wongratanaphisan — Chiang Mai University, Thailand
3. Dr. Isao Watanabe — Riken, Japan

## INVITED SPEAKERS

**Symposium 1: Semiconductors, Photonic Materials and Devices**

1. Assoc.Prof. Sakon Rahong — King Mongkut's Institute of Technology Ladkrabang, Thailand
2. Assoc.Prof. Sakuntam Sanorpim — Chulalongkorn University, Thailand
3. Assoc. Prof. Chun-Yi Chen — Tokyo Institute of Technology, Japan
4. Dr. Yuttana Intaravanne — National Science and Technology Development Agency (NSTDA), Thailand

**Thermoelectrics: Theories, Materials, Devices and Applications**

1. Dr. Chul-Ho Lee — National Institute of Advanced Industrial Science and Technology (AIST), Japan
2. Dr. Yosuke Goto — AIST, Japan
3. Dr. Hiroyasu Matsuura — AIST, Japan
4. Dr. Qingshuo Wei — AIST, Japan
5. Dr. Kenji Kamide — AIST, Japan
6. Dr. Mikami Masashi — AIST, Japan
7. Dr. Yasutaka Amagai — AIST, Japan
8. Assoc.Prof. Athorn Vora-ud — Sakon Nakhon Rajabhat University, Thailand
9. Prof. Supree Pinitsoontorn — Khon Kaen University, Thailand
10. Prof. Aparporn Sakulkalavek — King Mongkut's Institute of Technology Ladkrabang, Thailand
11. Prof. Atsuko Kosuga — Osaka Metropolitan University, Japan

**Symposium 2: Polymers, Biomaterials and Medical Devices**

1. Dr. Xu Li — A*STAR Institute of Materials Research and Engineering, Singapore
2. Assoc. Prof. Benchaporn Lertanantawong (Ph.D., SHFEA) — Mahidol University, Thailand
3. Asst. Prof. Rattapol Pinnaratip — Chiang Mai University, Thailand

**Symposium 3: Biosensors, Sensors, Flexible, and Wearable Electronics**

1. Dr. Weerakanya Maneeprakorn — National Nanotechnology Center (NANOTEC), NSTDA, Thailand
2. Assoc. Prof. Chatchawal Wongchoosuk — Kasetsart University, Thailand
3. Asst.Prof. Nadnudda Rodthongkum — Chulalongkorn University, Thailand
4. Prof. Boon Tong Goh — University of Malaya, Malaysia

**Symposium 4: Ferroelectric, Piezoelectric, and Triboelectric Materials and Devices**

1. Asst. Prof. Hyunwook Nam — Tokyo University of Science, Japan
2. Assoc. Prof. Viyada Harnchana — Khon Kaen University, Thailand
3. Prof. Nengneng Luo — Guangxi University, China

**Symposium 5: Solar Cells, Materials and Devices for Energy Harvesting**

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|---|---|---|
| 1. | Prof. Marina Freitag | University of Newcastle, United Kingdom |
| 2. | Prof. Daniel Packwood | Kyoto University, Japan |
| 3. | Assoc.Prof. Safakath Karuthedath | Tsing Hua University (Shenzhen), China |
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| 17. | Assoc. Prof. Jongsung Park | Gyeongsang National University, South Korea |

**Symposium 6: Batteries, Materials and Devices for Energy Storage**

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|---|---|---|
| 1. | Prof. Zhao Xiaoxu | Peking University, China |
| 2. | Prof. Do-Heyoung Kim | Chonnam National University, South Korea |
| 3. | Prof. Kabeer Jasuja | Indian Institute of Technology Gandhinagar, India |
| 4. | Assoc. Prof. Ruohan Yu | Wuhan University of Technology, China |
| 5. | Prof. Hee Jung Park | Dankook University, South Korea |
| 6. | Asst. Prof. Jitti Kasemchainan | Chulalongkorn University, Thailand |

**Symposium 8: Instrumentation and Advanced Materials Characterization**

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|---|---|---|
| 1. | Prof. Zhao Xiaoxu | Peking University, China |
| 2. | Assoc. Prof. Seungwon Lee | University of Toyama, Japan |
| 3. | Asst. Prof. Sakhorn Rimjaem | Chiang Mai University, Thailand |
| 4. | Assoc. Prof. Poramed Wongjom | Thammasart University, Thailand |

**Symposium 9: AI-driven Electronics, IoT and Digital Technologies for Next-generation Innovations**

| | | |
|---|---|---|
| 1. | Prof. Takuya Matsumoto | Osaka University, Japan |

**Symposium 10: Recycling Materials and Environmentally-friendly Processing**

| | | |
|---|---|---|
| 1. | Asst. Prof. Jai Prakash | National Institute of Technology, India |
| 2. | Prof. Wilaiwan Leenakul | Rajamangala University of Technology Phra Nakhon |

**Symposium 11: Quantum Materials and Technologies**

| | | |
|---|---|---|
| 1. | Asst. Prof. Narupon Chattrapiban | Chiang Mai University, Thailand |
| 2. | Dr. Raúl Esquivel-Sirvent | National Autonomous University of Mexico, Mexico |
| 3. | Asst. Prof. Salinporn Kittiwatanakul | Chulalongkorn University, Thailand |

**Symposium 13: Rare Earth, Critical Materials and its Applications**

| | | |
|---|---|---|
| 1. | Prof. Jeong-hwan Lee | Inha University, South Korea |
| 2. | Assoc. Prof. Patarawagee Yasaka | Nakhon Pathom Rajabhat University, Thailand |
| 3. | Assoc. Prof. Somsak Dangtip | Thailand Nuclear Institute of Science and Technology, Thailand |
| 4. | Dr. Nuttawadee Intachai | Chiang Mai University, Thailand |
| 5. | Asst. Prof. Piyachart Meejitpaisan | Nakhon Pathom Rajabhat University, Thailand |
| 6. | Dr. Phieraya Pulphol | Srinakharinwirot University, Thailand |

# INVITED SPEAKERS

**Special Symposia**

**Symposium 14: Consortium for Advancing High Performance Industrial Postdoctoral and Postgraduate Researchers in Novel Materials to Drive High Impact Technology for Future Industry (PMU-B)**

1. Assoc.Prof. Hyung-Mo Jeong — Sungkyunkwan University, South Korea
2. Mr. Atsuyoshi Maeda — Murata Electronics (Thailand) Co., Ltd.
3. Mr. Prusapa Wikanaiz — Murata Electronics (Thailand) Co., Ltd.

**Symposium 15: Frontier Research of Quantum Beam and Material Applications in Japan and Thailand**

1. Prof. Akira Baba — Niigata University, Japan
2. Assoc. Prof. Yugo Nagata — Tokyo University of Marine Science and Technology, Japan
3. Assoc. Prof. Dita Puspita Sari — Shibaura Institute of Technology, Japan
4. Asst. Prof. Sukrit Sucharitakul — Chiang Mai University,
5. Asst. Prof Haruka NAKANO — Kyushu University, Japan
6. Dr. Zijiang Yang — Tokyo University of Marine Science and Technology, Japan

# PLENARY SPEAKERS



## Prof. Rodrigo Ferro Paiva Martins

NOVA School of Science and Technology, University Lisbon, Portugal

Abstract: Pioneering Sustainable Solutions: The Rise of Eco-Friendly Materials in Electronics

**PL1: June 29, 2026 (9:45-10:30)**

## Prof. Ying-Hao Chu

National Tsing Hua University, Chinese Taipei

Abstract: Soft Technology Beyond Polymers: Muscovite Mica as a Universal Platform for High-Performance Flexible Sensors and Actuators

**PL2: June 29, 2026 (10:45-11:30)**





## Prof. Xing Yi Ling

Nanyang Technological University, Singapore

Abstract: Machine Learning-Assisted SERS Nanosensors for Predictive Applications

**PL3: June 29, 2026 (11:30-12:15)**

## Prof. Chihaya Adachi

OPERA, Kyushu University, Japan

Abstract: Advanced Organic Optoelectronic Devices by Controlling Precise Charge Transfer Phenomena

**PL4: June 30, 2026 (9:00-9:45)**





## Assoc. Prof. Soorathep Kheawhom

Chulalongkorn University, Thailand

Abstract: Beyond materials: Understanding electrochemical energy systems through operando science

**PL5: June 30, 2026 (9:45-10:30)**

## Dr. Adisorn Tuantranont

Thai Microelectronics Center (TMEC), NSTDA, Thailand

Abstract: Graphene Electronics for Next Generation of Sensors and Energy Storages

**PL6: July 1, 2026 (9:00-9:45)**



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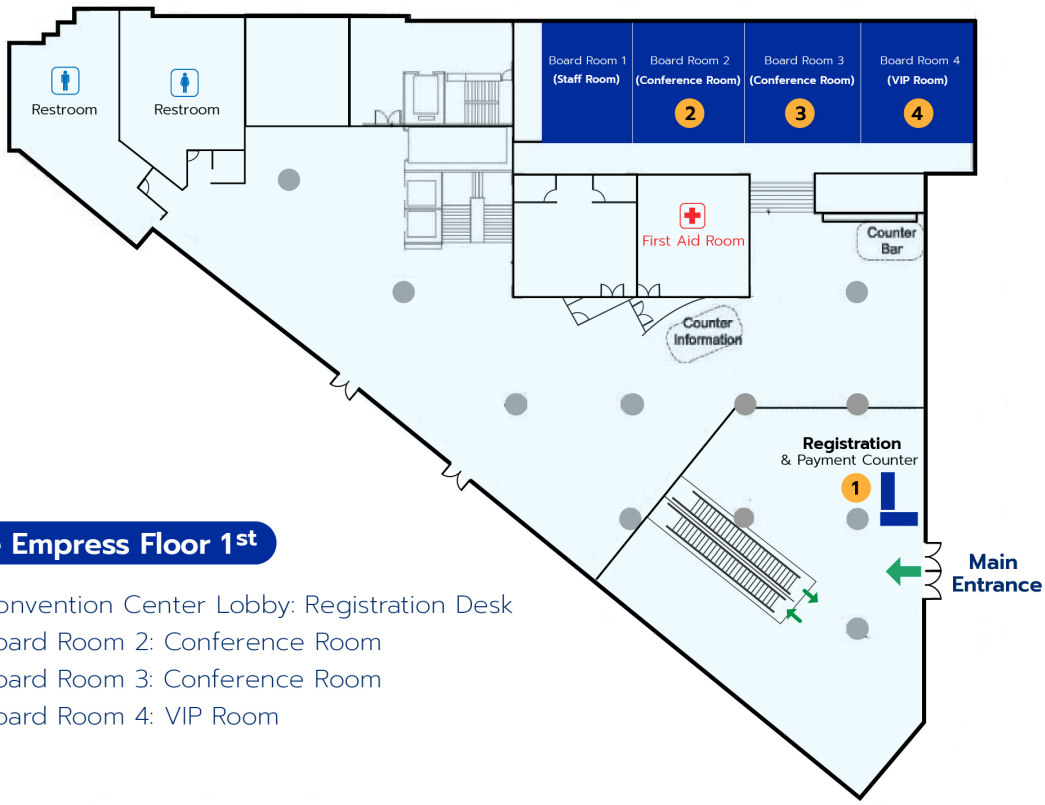
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2. Board Room 2: Conference Room
3. Board Room 3: Conference Room
4. Board Room 4: VIP Room



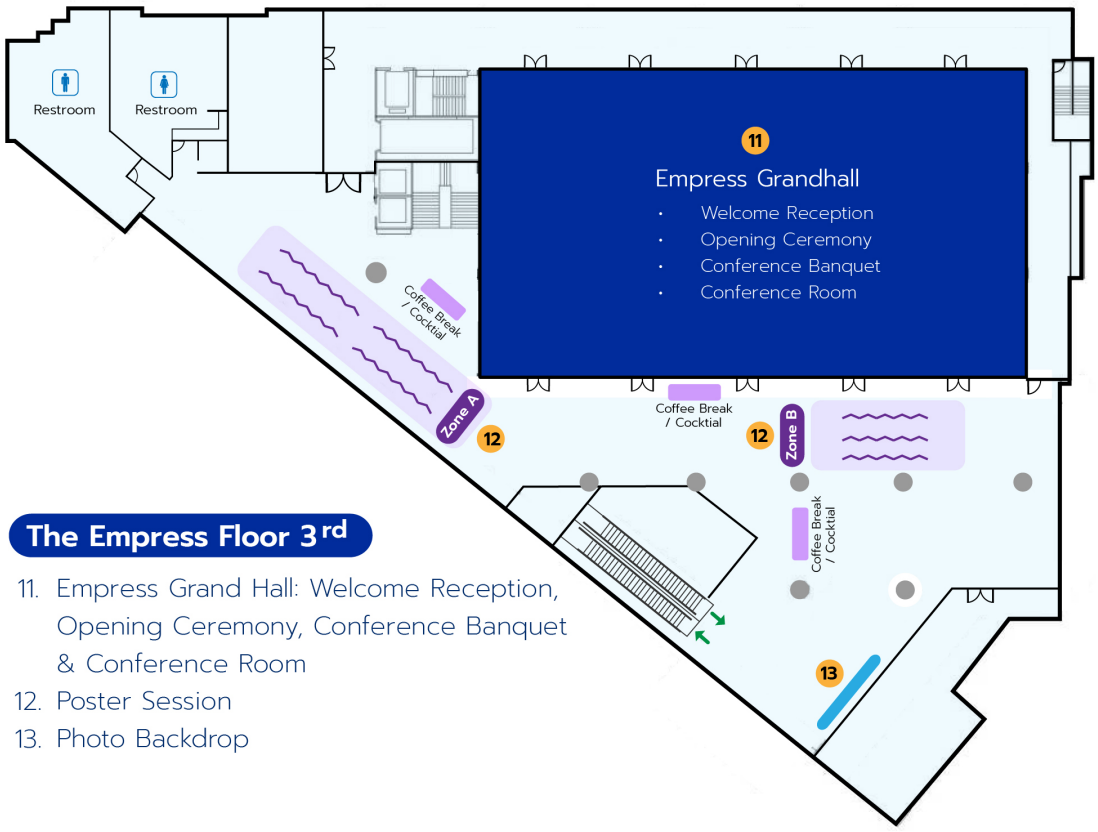

### The Empress Floor 2nd

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7. Chiang Mai 3: Conference Room
8. Chiang Mai 4: Conference Room
9. Chiang Mai 5: Conference Room
10. Exhibition Area

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- C2 Materials Science Research Center (MSRC), Chiang Mai University
- C3 Hub of Talents in Bioplastics for Use in Medical Applications, NRCT
- C4 Hub of Talents in Advanced Ceramics(HAC), NRCT
- C5 PBP-CMU Electron Linac Laboratory (PCELL), Chiang Mai University
- C6 King Mongkut's University of Technology North Bangkok

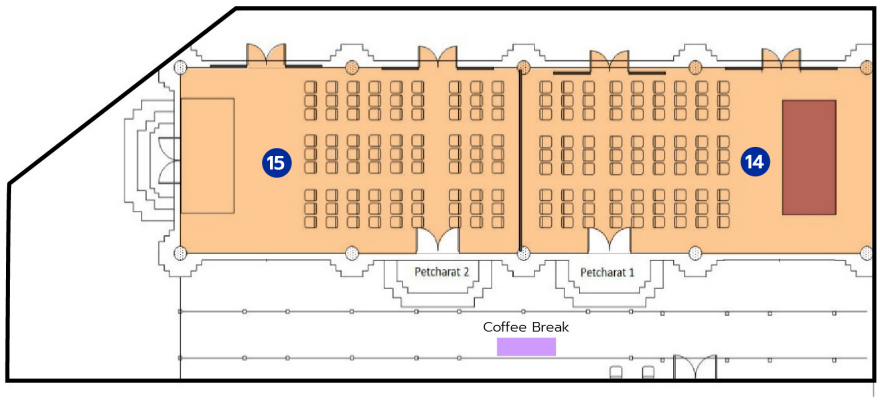
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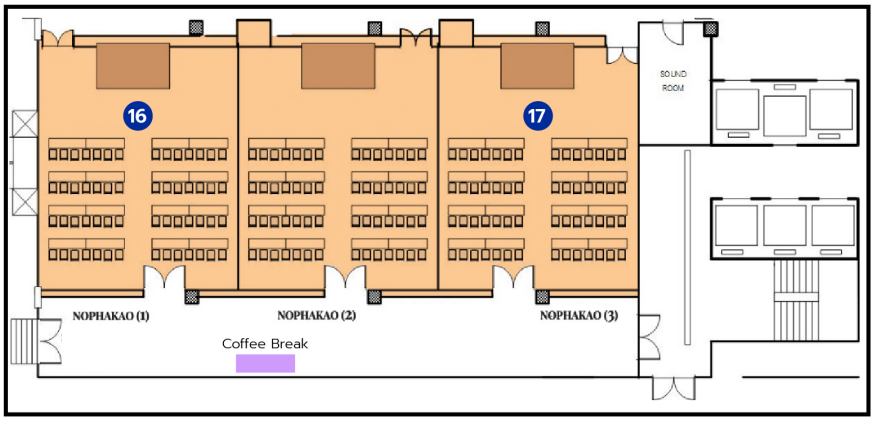
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12. Poster Session
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# Pioneering Sustainable Solutions: The Rise of Eco-Friendly Materials in Electronics



Rodrigo Martins, P. Barquinha, L. Pereira, R. Silva, D. Vieira, E. Carlos, A. Kiazadeh, J. Santanu, D. Gaspar, E. Fortunato

[a] *CENIMAT\i3N, Department of Materials Science, School of Science and Technology, NOVA University Lisbon and CEMOP/UNINOVA, Caparica, Portugal*

*Corresponding Author's E-mail: rfpm@fct.unl.pt

**Abstract**

In today's digital age, our rapid technological advancements confront us with critical sustainability challenges, including material scarcity, mounting waste, and environmental pollution, often exacerbated by high-temperature manufacturing processes. The socio-economic growth driven by the demand for smart electronics and non-recyclable materials contributes to climate change and resource depletion.

As we embrace the Internet of Things (IoT) and wearable technology, the need for sustainable materials becomes more urgent. Emerging nanoscale devices provide promising alternatives to silicon-based options, particularly in the field of so called transparent and paper electronics, which have the potential to revolutionize our approach to electronic devices, transforming it.

This presentation explores strategies to minimize electronic waste while advancing eco-friendly technology solutions. We are committed to developing green electronic products that meet consumer needs and promote environmental stewardship, going from micro to nanoscale approaches. Our efforts also focus on raising social awareness about sustainable technologies, engaging with communities and policymakers to advocate for practices that harmonize technology with environmental responsibility.

Join us in this exploration of innovative approaches to sustainability, as we aim to significantly impact our environment and foster a resilient future empowered by green technology.

**Keywords:** Advanced Functional Materials for Electronics; Electronics beyond Silicon; Sustainable Electronics

# Soft Technology Beyond Polymers: Muscovite Mica as a Universal Platform for High-Performance Flexible Sensors and Actuators



Ying-Hao Chu[a],[b,*]

[a]*Department of Materials Science & Engineering, National Tsing Hua University, Hsinchu 30043, Taiwan*
[b]*Department of Materials Science & Engineering, National Yang Ming Chiao Tung University, Hsinchu 30043, Taiwan*

*Corresponding Author's E-mail: yhchu@mx.nthu.edu.tw

**Abstract**

With the rapid evolution of the Internet of Things, Artificial Intelligence, and soft robotics, there is a surging demand for high-performance electronic components that possess mechanical flexibility, optical transparency, and environmental robustness. Conventional flexible substrates, such as polymers, are often limited by poor thermal tolerance and lattice mismatch, hindering the integration of high-quality functional oxides or semiconductors that require high-temperature processing. This plenary talk introduces "MICAtronics"—an emerging soft-technology platform based on muscovite mica, designed to overcome these limitations and enable high-performance sensing and actuation. By leveraging van der Waals heteroepitaxy, we demonstrate the direct growth of high-quality functional materials on mica, thereby circumventing strict lattice-matching constraints. This talk will highlight breakthrough advancements in two key areas: Sensors and Actuators. In the realm of sensors, we present ultra-high-responsivity, solar-blind, deep-UV photodetectors based on $Ga_2O_3$ heterostructures that maintain superior optoelectronic performance under bending and at high temperatures. We will also demonstrate ZnO/mica heteroepitaxial strain sensors that exhibit a giant piezoresistive effect, with a gauge factor exceeding 1000. Furthermore, by integrating magnetostrictive and piezoelectric materials, we have developed flexible proximity sensors with high magnetoelectric coupling coefficients for non-contact human-machine interfaces. Additionally, we will discuss the development of 3D Ag nanocrystal-intercalated mica mesocrystals as highly sensitive Surface-Enhanced Raman Spectroscopy platforms for chemical sensing. Regarding actuators, we will introduce thermal actuators based on metal/mica quasi-van der Waals epitaxy. Exploiting the thermal expansion mismatch and robust interface, these structures exhibit giant thermal actuation with fast response times, offering new power sources for soft robotics. Additionally, we will discuss PVDF/mica bimorph structures that significantly enhance the pyroelectric response through thermal stress engineering, paving the way for advanced thermal harvesting and sensing/actuation. In summary, the MICAtronics platform not only preserves the transparency and high-temperature stability of mica but also opens a new avenue for next-generation transparent, durable, and multifunctional soft electronic systems through precise strain engineering and heterogeneous integration.

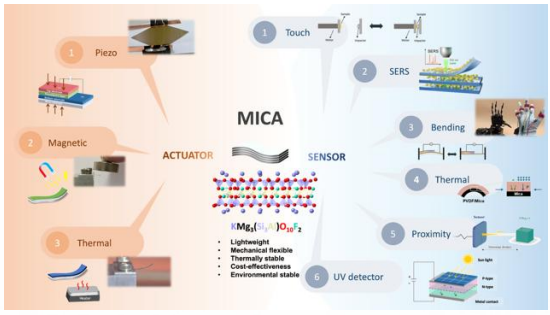



Fig.1 Sensors and actuators based on MICAtronics

**Keywords:** MICAtronics, van der Waals Heteroepitaxy, Flexible, Soft Technology

# Machine Learning-Assisted SERS Nanosensors for Predictive Applications



Xing Yi Ling

School of Chemistry, Chemical Engineering and Biotechnology, Nanyang Technological University, 21 Nanyang Link, Singapore.

E-mail: xyling@ntu.edu.sg

**Abstract**

Nanomaterial-based sensors ("nanosensors") are attractive detection tool to detect multiple disease biomarkers swiftly and at point-of-care. These nanosensors make use nanometer-sized particles with unique physical, optical, and electrical properties to induce enhanced output signals in response to the detection and/or changes in concentrations of analytes. In this talk, I will discuss my group's effort in using one of the nanosensors, surface-enhanced Raman scattering (SERS) nanosensors for various biomedical applications. SERS utilizes metallic nanoparticles such as Ag and Au to harness incoming light excitation, concentrate surface plasmon resonances, and boost the Raman vibrational signatures of biomarkers for ultrasensitive detection. Firstly, I will discuss various SERS platform fabrication strategies to bestow desirable chemoselectivity and increase target analyte/biomarker affinity to achieve higher detection sensitivity and selectivity. I will also highlight various emerging research strategies which utilize machine learning algorithms for rapid on-site prediction of disease infection. Specifically, how chemometrics and machine learning algorithms can transform the assimilation and interpretation of complex spectral data in biological samples by discerning more patterns hidden within the data, to achieve high throughput data analysis, sensitivity, and disease prediction. Collectively, these advances underscore the potential of SERS nanosensors and hybrid analytical strategies to address longstanding challenges in biomarker sensing and to accelerate innovation in biomedical diagnostics.

# Advanced Organic Optoelectronic Devices by Controlling Precise Charge Transfer Phenomena

Chihaya Adachi*

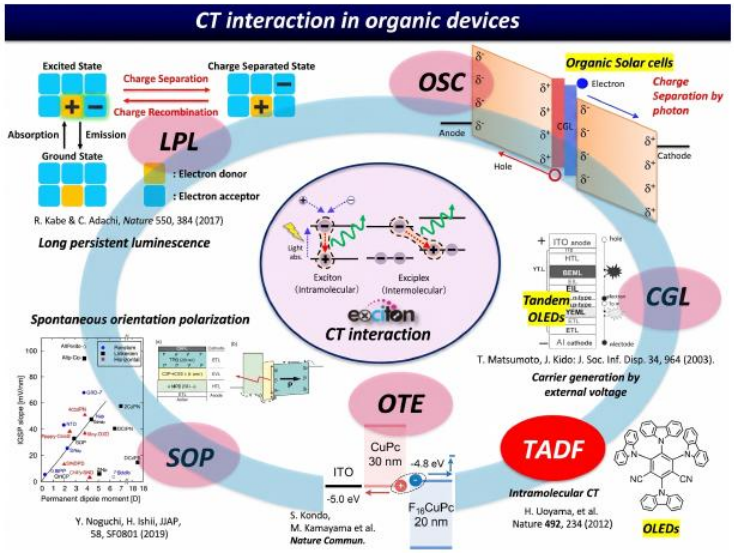
*Center for Organic Photonics and Electronics Research (OPERA) and Organic Photonics and Electronics International Laboratory (OPHELIA), Kyushu University, Fukuoka 819-0395, Japan*

*Corresponding Author's E-mail: adachi@opera.kyushu-u.ac.jp



**Abstract**

In the last 10 years, there has been a wide variety of studies on thermally activated delayed fluorescence (TADF)-OLEDs, focusing on the limitless possibilities of molecular design[1]). Furthermore, hyperfluorescence (HF)-OLEDs have been developed because they can achieve high efficiency and a narrow spectral width, which is ideal for practical display applications. The advanced HF-OLEDs realized high light-emitting performance by engineering host, TADF, and terminal emitter (TE) molecules. Firstly, we present the comprehensive design principles for the materials and device architectures used in HP-OLEDs, focusing on fast T-S upconversion, negative gap, efficient FRET, GSP, and carrier trapping, aimed at high-performance OLEDs[2-5]). In addition, we underscore the crucial role of CT in organic optoelectronic devices, shedding light on its importance in future organic devices such as organic thermoelectrics[6]).




**References:**
[1] T. Uoyama et al., Nature, **492**, 234 (2012), [2] C.-Y. Chan et al., Nat. Photonics, **15**, 203 (2021), [3] Y.-T. Lee et al., Adv. Elect. Mater., **7**, 2001090 (2021), [4] M. Tanaka et al., ACS Appl. Mater. & Inter., **12**, 50668 (2020), [5] Y.-T. Lee et al., Nat. Commun., **15**, 3659 (2024), [6] S. Kondo et al., Nat. Commun., **15**, 8115 (2024)

**Keywords:** OLED, TADF, Hyperfluorescence, CT

# Beyond materials: Understanding electrochemical energy systems through operando science



Soorathep Kheawhom[a,*]

[a]*Department of Chemical Engineering, Faculty of Engineering, Chulalongkorn University, 254 Phayathai Road, Pathum Wan, Bangkok 10330, Thailand*

*Corresponding Author's E-mail: soorathep.k@chula.ac.th

**Abstract**

The past decade has witnessed extraordinary progress in the discovery of electrochemical materials. Yet the realization of energy technologies that are simultaneously efficient, durable, and scalable remains disproportionately slow relative to the pace of materials discovery. This persistent gap between materials innovation and technological deployment points to a deeper limitation in how electrochemical systems are commonly understood. Performance does not arise from materials in isolation. It emerges from dynamic, coupled, and often unstable interactions among interfaces, phases, transport pathways, and reaction environments during operation. A central challenge for the field is therefore not only to develop better materials, but also to understand how electrochemical systems evolve, degrade, and fail in real time, and how that knowledge can be translated into predictive design.

This talk will present operando science as a unifying framework for addressing that challenge. By integrating real-time spectroscopy, multimodal imaging, theory, modelling, and data-driven analysis, operando approaches make it possible to capture electrochemical function as an evolving process rather than a static endpoint. This perspective reveals that durability, efficiency, and scalability are governed by multiscale dynamics, spanning atomic rearrangements, interfacial evolution, mesoscale heterogeneity, and device-level instability. The emphasis, therefore, moves beyond incremental benchmarking and chemistry-specific optimization toward a broader scientific agenda centered on dynamic interface science, mechanistic insight, and process-aware understanding.

The broader argument of this lecture is that electrochemical energy research must now move beyond the era of empirical materials discovery alone. The next frontier lies in building predictive electrochemical systems, in which fundamental understanding, real-time observation, and intelligent engineering are brought into direct alignment. In this context, operando science is not merely a characterization strategy. It is an essential foundation for the future design of electrochemical energy systems.

**Keywords:** Operando science; Electrochemical energy systems; Dynamic interfaces; Multiscale characterization; Predictive design

# Graphene Electronics for Next Generation of Sensors and Energy Storages



Adisorn Tuantranont[a,*], Chanpen Karuwan[b], Chakrit Sriprachuabwong[c]

[a]*Thai Microelectronics Center (TMEC),*
[b]*National Nanotechnology Center,*
[c]*National Energy Technology Center, National Science and Technology Development Agency (NSTDA), Thailand*

*Corresponding Author's E-mail: adisorn.tua@nstda.or.th

**Abstract**

Carbon nanomaterials, particularly two-dimensional graphene and three-dimensional graphene foams, provide a versatile platform for next-generation electronic and electrochemical systems due to their high electrical conductivity, large surface area, and tunable physicochemical properties. This presentation focuses on the engineering of graphene across multiple length scales, emphasizing scalable synthesis methods such as electrolytic exfoliation and chemical vapor deposition (CVD).

For biochemical sensing, functionalized graphene electrodes fabricated via inkjet and screen-printing are integrated with loop-mediated isothermal amplification (LAMP) and portable electrochemical analyzers to enable rapid, point-of-care diagnostics. These platforms demonstrate high sensitivity and selectivity for a wide range of targets, including foodborne pathogens (Vibrio parahaemolyticus, Salmonella spp.), infectious agents (Mycobacterium tuberculosis, SARS-CoV-2), narcotics (methamphetamine, THC), glucose, and environmental microplastics. Enhanced performance is attributed to tailored surface functionalization and improved charge transfer kinetics.

In parallel, beyond-lithium energy storage systems are explored, focusing on zinc-ion (ZIBs) and sodium-ion batteries (SIBs). A key innovation is the development of nanoporous hard carbon derived from sustainable agricultural bio-waste, such as spent coffee grounds and bamboo, hybridized with graphene and $MnO_2$. These materials mitigate dendrite formation while enhancing ion transport, enabling improved safety, sustainability, and cycling stability.

Additionally, nitrogen- and sulfur-co-doped reduced graphene oxide (N,S-rGO) is employed in high-performance supercapacitors with ionic liquid polymer electrolytes. Devices fabricated in coin, pouch, and cylindrical formats exhibit high power density, fast charge–discharge rates, and long cycle life. Scalable manufacturing approaches, including roll-to-roll electrode processing and semi-automated assembly, are also demonstrated.

Overall, this work highlights graphene engineering as a scalable and sustainable pathway toward advanced sensors and next-generation energy storage technologies. Moreover, the current work at Thai Microelectronics Center (TMEC) which is a specialized semiconductor foundry dedicated to the design and fabrication of customized MEMS devices and advanced sensors are presented. TMEC's mission is to serve as a strategic partner for MEMS and sensor startups, enabling their successful transition from prototype to production. TMEC achieve this by providing comprehensive design and process support, ensuring that our customers meet stringent quality standards and time-to-market requirements.

**Keywords:** Graphene, Carbon, Sensors, Battery, Supercapacitor

# Transition Metal Dichalcogenides as Emerging Semiconductors: Growth, Doping/Alloying, Optical Properties, and Light-driven Applications



Li-Chyong Chen[a,b,c*], Tadios Tesfaye Mamo[a], Chih-Yang Huang[a], Yu-Chung Yeh[a], Mohammad Qorbani[d], Kuei-Hsien Chen[a,e]

[a]*Center for Condensed Matter Sciences, National Taiwan University, Taipei 10617, Taiwan*
[b]*Department of Physics, National Taiwan University, Taipei 10617, Taiwan*
[c]*Center of Atomic Initiative for New Materials, National Taiwan University, Taipei 10617, Taiwan*
[d]*Institute of Electro-Optical Engineering, National Taiwan Normal University, Taipei 11677, Taiwan*
[e]*Institute of Atomic and Molecular Sciences, Academia Sinica, Taipei 10617, Taiwan*

*Corresponding Author's E-mail: chenlc@ntu.edu.tw

**Abstract**

Two-dimensional (2D) transition metal dichalcogenides (TMDCs) have emerged as benchmark materials for fundamental studies and hold potential for practical applications, due to their adjustable optoelectronic properties and extremely high surface-to-volume ratio. Since 2D TMDC films are highly confined in the out-of-plane direction, the only chance of modification to tune their optoelectronic properties is *via* the introduction of heteroatom doping, alloying, defect engineering, adatom incorporation, strain modulation, and so on. Among these, introducing dopant or alloying elements is particularly attractive because it enables fine-tuning of the electronic density of states (DOS) and transport properties. Therefore, scalable and versatile synthesis routes are still required to achieve reproducible, uniform, wafer-scale TMDC films with precise control over dopant and alloy concentrations. Here, we present several growth methods, such as physical vapor deposition, polymer-assisted chemical vapor deposition, ion-implantation, room-temperature hydrogen plasma treatment, and stacked-layer solid precursor sulfurization methods. Specific examples to present here include 20-nm $S_{vac}$-$SnS_2$:F, one-layer Janus WSSe, and 5-nm Ce:$WS_2$. We found that a controllable dopant/alloying element has a big impact on the optical properties *via* altering the UV-visible and photoluminescence (PL) spectra. Moreover, we observed that different types of dopants can significantly modify the transport properties, resulting in improved photoconductivity (PC) of the fabricated electrodes. In addition, in situ PL and PC measurements through exposing the electrodes to $CO_2$ or $H_2O$ molecules could even assist us in understanding their photocatalytic properties to pave the way toward a carbon net-zero roadmap (Fig. 1).

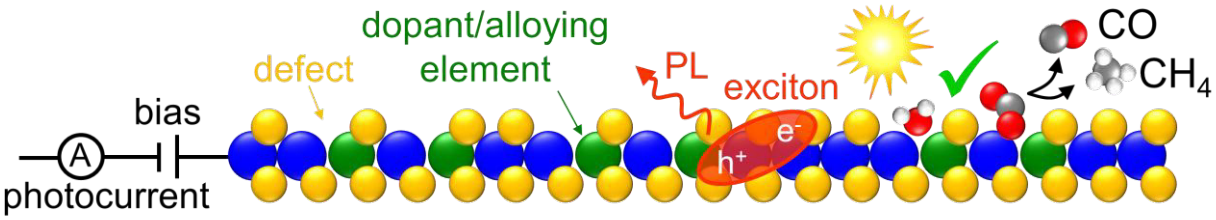



Fig. 1 Novel growth method toward a controllable modification of TMDC toward enhanced PC properties.

**Keywords:** TMDC, Growth method, Optoelectronic properties, Photocatalysis, Solar fuel

# Structure–Chirality–Optical Response Relationships in Semiconducting Carbon Nanotubes



Cecilia Noguez

*Instituto de Física, Universidad Nacional Autónoma de México, Ciudad de México 04530, Mexico*

*Corresponding Author's E-mail: cecilia@fisica.unam.mx

**Abstract**

Chiral single-walled carbon nanotubes (SWCNTs) provide a unique platform for helicity-dependent light–matter interactions, with direct effects on chiral photonics, enantioselective sensing, and polarization-sensitive optoelectronics. However, a predictive understanding at the materials level that links nanotube structure to circular dichroism (CD) response has remained limited. Here, we establish a reliable relationship among structure, chirality, and optical functionality across different semiconducting nanotube families.

Through analytical modeling and density functional theory calculations across various type I and type II semiconducting nanotubes, we demonstrate that the sign and magnitude of circular dichroism during successive interband transitions are determined by two structural parameters: the family index and the chiral angle. This relationship enables precise control of helicity-selective absorption through chirality selection. Enantiomeric nanotubes exhibit inverted CD spectra, providing a direct optical method for handedness discrimination and chirality sorting.

These results establish circular dichroism as a non-destructive tool for nanotube identification and open avenues for chirality-engineered photonic components, including polarization-sensitive photodetectors, circularly polarized light emitters, and nanoscale chiral metasurfaces. More broadly, the work demonstrates how the geometrically defined electronic structure in low-dimensional carbon materials can be used to design helicity-responsive optoelectronic systems.

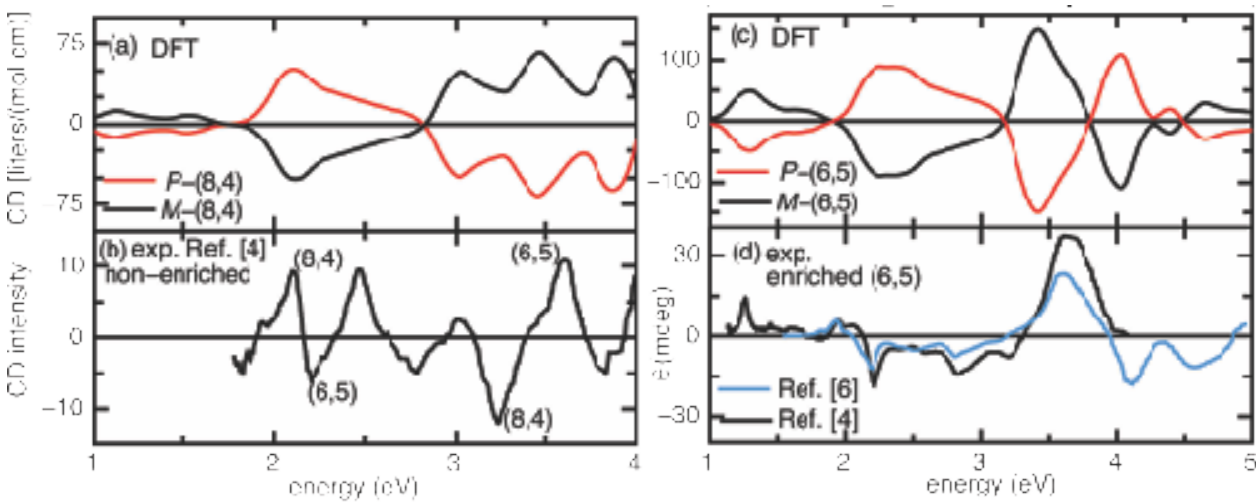



**Figure.** Calculated and experimental circular dichroism of chiral nanotubes

**Keywords:** Single-Walled Carbon Nanotubes (SWCNTs), Chirality-Controlled Electronic Structure, Structure–Property Relationships, Optical Activity in Low-Dimensional Materials, Chirality-Selective Materials Design.

# Interesting phenomena observed in electronic materials and at their joints: thermodynamics and kinetics



Sinn-wen Chen[a,b,c*]

[a] *Department of Chemical Engineering, National Tsing Hua University, Hsinchu, Taiwan*
[b] *High Entropy Materials Center, National Tsing Hua University, Hsinchu, Taiwan*
[c] *College of Semiconductor Research, National Tsing Hua University, Hsinchu, Taiwan*

*Corresponding Author's E-mail: swchen@mx.nthu.edu.tw

**Abstract**

Electronic devices usually consist of joints made of various materials. Interesting microstructures and phase formations are observed within the electronic materials and at their joints. The driving forces for microstructural evolution and phase formation can be classified into thermodynamic and kinetic factors. The thermodynamic driving force refers to the tendency of a system to reach an equilibrium state with the lowest Gibbs free energy through reactions. Phase diagrams are the most concise way to describe phase equilibria in materials and provide insight into the thermodynamic driving forces.Examples of interesting and peculiar phenomena are discussed in terms of their thermodynamic and kinetic factors. The examples discussed are listed below. (1) Formation of extra phases at the joints: Three phases, δ-($Cu_4Sn$), ε-$Cu_3Sn$, and η-$Cu_6Sn_5$, are observed in the Sn–3.5 wt.% Ag/Cu couple reacted at 450 °C, including η-$Cu_6Sn_5$, which is not stable at this temperature. (2) Abnormal melting: The melting point of the Sn–5 wt.% Sb alloy is 240 °C. However, peculiar melting of the Sn–5 wt.% Sb solder is observed when Sn–5 wt.% Sb/Ag devices are reflowed at only 230 °C; that is, the solder melts at a temperature lower than its melting point. (3) Peculiar reaction rates: The dissolution rate of Fe in molten Sn–Pb at 500 °C is lower than that at 400 °C, and it is peculiar that the reaction rate decreases with increasing reaction temperature. (4) Formation of spherical shape microstructures: Although none of the three constituent binary systems exhibits a liquid miscibility gap, very interesting spherical microstructures are observed in the as-quenched Sn–Bi–Cu alloys. (5) Uphill diffusion: Based on the compositional analysis results in the Cu/Sn/Ni sandwich specimen, the Cu content appears to diffuse from a lower-concentration phase to a higher-concentration phase; however, is this truly uphill diffusion?

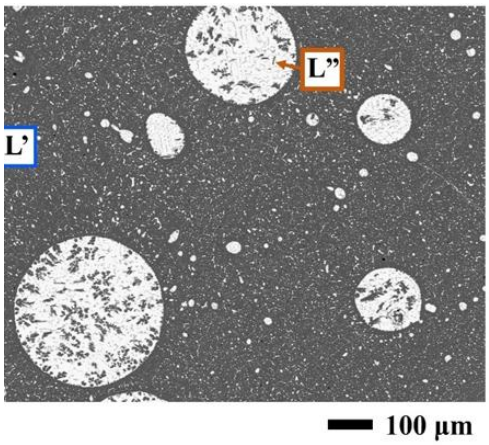



Figure 1: BEI micrograph of the as-solidified alloy (Sn-14.0Bi-61.0Cu, at. %).

**Keywords:** Electronic materials; Interfacial reactions; Liquation; Phase diagrams; Kinetics

# Semiconductor Oxide Materials Steering Hydrogen Transition

Sanjay Mathur

*Institute of Inorganic and Materials Chemistry*
*University of Cologne, Greinstrasse 6, D-50939 Cologne, Germany*

E-mail: sanjay.mathur@uni-koeln.de



**Abstract**

Advanced materials are driving innovation across all fields of technology, ranging from construction and mechanical engineering, automotive and electromobility, to medical technology, energy storage and conversion technologies, and microelectronics. Given their technological impact, functional materials represent an essential segment of industrial technologies with significant value creation potential for both established markets and emerging technologies. Especially in the context of sustainable production techniques, substitution of critical raw materials, and energy- and resource-efficient manufacturing, tailored surfaces and interfaces are gaining increasing importance in the future. In this context, chemical processing of nanostructured ceramics in tuning the functional and interfacial properties for better charge transport, higher corrosion protection and enhanced performance. The examples will include the role of functionalized inorganic surfaces in electrolysers for hydrogen production, and advances in photon-harvesting technologies for perovskite-based photovoltaics. This talk will emphasize the power of chemical synthesis in designing new materials for energy transition.

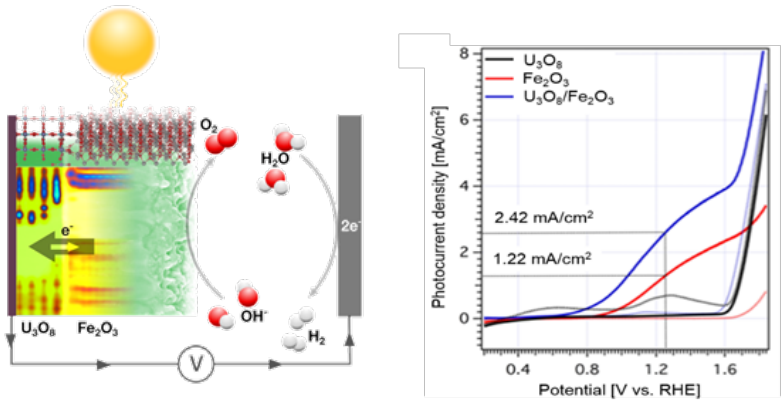



Figure1. Electronically coupled oxide-oxide junctions for efficient hydrogen production

**Keywords:** Oxide Semiconductors, Thin Films, Energy Harvesting, Hydrogen and Ammonia Production

**References.**

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# Influences of $Cu_{1-x}Ni_x$ on the Rapid Formation, Grain Refinement, and Orientation Diversification of TLPB Microbumps in 3D-IC microelectronic packaging

Jenq-Gong Duh[a,b,c*], Yin-Ku Lee [a]

[a]*Department of Materials Science and Engineering, National Tsing Hua University*
*No. 101, Section 2, Kuang-Fu Road, Hsinchu 300044, Taiwan*
[b]*Department of Materials Science and Engineering, National United University*
*No. 2, Lianda, Miaoli 360302, Taiwan*
[c]*Department of Materials Science and Engineering, National Chung Hsing University*
*No. 145, Xingda Rd., South Dist., Taichung 402202, Taiwan*

*Corresponding Author's E-mail: jgd@mx.nthu.edu.tw



**Abstract**

The burgeoning demand for high-power electronics and the persistent miniaturization of interconnects, particularly in electric vehicle and portable device applications, have significantly elevated the thermal requirements for solder joints. Traditional lead-free solders, constrained by their 200°C melting points, often struggle in high-temperature environments. Transient Liquid Phase Bonding (TLPB) has emerged as a robust alternative, offering the unique advantage of low-temperature processing to form high-melting-point intermetallic compounds (IMC) joints that remain thermally stable well above their bonding temperature. However, standard Cu/Sn/Cu TLPB systems typically necessitate prolonged thermal exposure at high temperatures to ensure the full transformation into a continuous IMC layer. Such an extensive thermal budget can be detrimental, as coefficient of thermal expansion (CTE) mismatches between dissimilar materials often induce warpage, mechanical fatigue, and structural cracking. To mitigate these reliability risks, the implementation of Cu–Ni substrates offers a strategic advantage. The presence of Ni not only accelerates IMC formation kinetics—thereby significantly reducing the required reflow duration—but also effectively suppresses the excessive growth of the brittle $Cu_3Sn$ phase. By minimizing the total thermal exposure, this approach simultaneously limits material degradation and enhances the thermomechanical integrity of the microbump joints. Moreover, the grain refinement and orientation diversification also enhanced the shear strength of the joints from 50.9 MPa to 74.3 MPa.

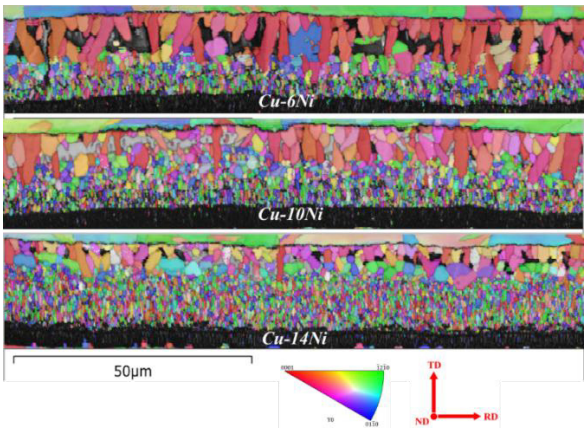



Fig. 1. EBSD orientation maps of Cu/Sn-Ag/$Cu_{1-x}Ni_x$ microbumps

**Keywords:** Transient Liquid Phase Bonding, intermetallic compounds, CTE mismatch, microbump,3D-IC

# Novel Materials Enabling DUV Extension in Device Scaling During the First Quarter of 21st Century A Historical Case Study



Luan Tran

*Former Micron Fellow, TSMC Sr Dir, Bell Labs MTS*

luan.tran@ieee.org

**Abstract**

In this talk, multi-patterning or pitch multiplication techniques are described, thanks to the two enabling film depositions (amorphous carbon, and low temperature ALD oxide) coupled with innovative process integration that has extended semiconductor industry continuous scaling since 2005, while EUV lithography maturity for high volume production was developed.

The author will describe the key material aspects that had allowed this technology to be used in high volume production, starting in Flash memory and later extended to DRAM and advanced logic nodes.

An exemplary case study was the development and implementing in production of 50nm NAND Flash, it was first known double patterning technology, employed in 3 critical layers, in volume manufacture ever realized.

At the present time the double- and quadruple patterning are routinely being used in critical layers of high density Flash and DRAM technologies, with advanced logic node adaptation in 14nm to 2nm nodes

The pitch multiplication techniques not only extended the DUV and iDUV lithography, but also enabling the state-of-the-art EUV technology to form finer features.

**Keywords:** Pitch Multiplication, Double/Quadruple Patterning, amorphous carbon, ALD oxide, iDUV extension

# Energy and carbon cycling by combustion of agricultural residue

Ryoji Funahashi*, Tomoyuki Urata, Hiroyo Murakami, Hitomi Ikenishi

*Research Institute of Core Technology for Materials Innovation, National Institute of Advanced Industrial Science and Technology,*
*Ikeda, Osaka 563-8577, Japan.*

*Corresponding Author's E-mail: funahashi-r@aist.go.jp



**Abstract**

Thermoelectric power generation has been investigated using a biomass burner. The fuel was dried wheat residue. The iron heat collector has a side of 15 x 15 x 15 cm and a honeycomb structure composed of 91 through holes with a diameter of 1cm. The thermoelectric converter is composed of twelve pieces of oxide thermoelectric modules, which shows good durability against high temperature and oxidation. The four pieces of the modules were put on each of the three sides. The aluminum alloy water jacket with a 14 cm square surface and a thickness of 2.6 cm (the volume of water is about 200 $cm^3$) was placed on the modules. The combustion gas flow can be controlled by opening and closing the through holes. The maximum heat and electrical outputs are obtained 7.3 kW and 63 W, when the combustion output and temperature are about 70 kW and 830 ℃. Temperature of the coolant water by 6 L/min of flow rate was increased from 76.6 ℃ to 94.2 ℃. In the honeycomb structure, the heat flux can be controlled by opening and closing the through holes. By closing the through holes, the heat recovery rate, the output power and efficiency of thermoelectric generation can be increased even at low combustion temperatures.

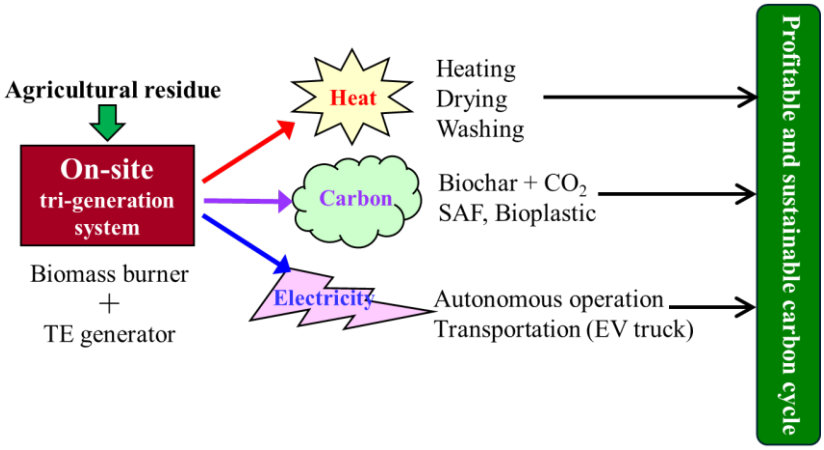



Fig. 1 Small-scale energy and carbon cycle using agricultural residue

**Acknowledgment**
The biomass burner used in this study was provided with the cooperation of Dr. Toshiki Sato of Kotobuki Recycling LLC. The authors gratefully acknowledge this support.

**Keywords:** Thermoelectric generation, Biomass, Energy recycling, Thermal supply, Carbon recycling

# Anisotropic Crystals for High-performance Room-Temperature Thermoelectrics



Hsin-Jay Wu

*Department of Materials Science and Engineering, National Taiwan University*

*Corresponding Author's E-mail: hjwu0211@ntu.edu.tw

**Abstract**

This study investigates the thermoelectric properties of highly anisotropic Bridgman-grown crystals to enhance energy conversion near room temperature. Focused on p-type SnSe and n-type $Bi_2Te_3$, the work demonstrates that dilute doping significantly boosts the figure-of-merit (zT) of SnSe from 0.07 to 0.34 (300 – 500 K) by improving carrier concentration and conductivity. In parallel, our n-type $Bi_2Te_3$ exhibits excellent performance at 323 K, owing to its high electrical conductivity and low thermal conductivity along the growth direction. The pronounced anisotropy in $Bi_2Te_3$ highlights the importance of controlling crystallographic orientation. Additionally, SnSe single-leg shows enhanced efficiency and mechanical integrity. These results emphasize the potential of anisotropic crystals for efficient thermoelectric generators and coolers in sustainable energy applications.

**Keywords:** $Bi_2Te_3$, SnSe, Bridgman growth, Thermoelectrics, Anisotropic

# Light Enhanced Direct Metal Bonding for Advanced Electronic Assembly



Jenn-Ming Song

*Department of Materials Science and Engineering, National Chung Hsing University, Taichung 402, Taiwan*

*Corresponding Author's E-mail: samsong@nchu.edu.tw

**Abstract**

This presentation introduces photonic-enhanced surface modification as a solution for low-temperature, high-reliable metal direct bonding for 3D IC integration. Conventional direct bonding technologies require high temperatures and vacuum; however, Light irradiations like pulsed Xenon flash, NIR, VUV, etc. enable robust bonding in ambient environments. In the case of Cu-Cu bonding, pulsed flash and NIR irradiation induce surface compressive stresses through rapid thermal cycles, accelerating copper atom diffusion. This physical modification enhances joint shear strength by over 50–60%. Microstructural analysis further reveals a linear relationship between grain boundary density and joint strength. It was also demonstrated that flash-treated joints exhibit excellent drop shock resistance superior to impact-resistant solder joints like SAC0307. Moreover, hybrid pre-treatments combining $N_2$ plasma and flash irradiation are developed. $N_2$ plasma forms a $Cu_4N$ passivation layer that inhibits oxidation during flash exposure. The following flash irradiation can further strengthen the joints. As illustrated in Fig. 1, controlling oxide thickness below 7 nm is identified as critical for maintaining bonding integrity. As for Al-Al ultrasonic bonding**,** VUV irradiation in formic acid (FA) creates hydrophilic Al-OH groups and formate ligands. During bonding, high-frequency friction triggers a dehydration reaction**,** forming a strong Al-O-Al oxide layer that can almost triple the joint strength. In summary, light-enhanced technologies offer a rapid, vacuum-free pathway for advanced electronic assembly, achieving superior mechanical performance and reliability through the synergy of surface activation and stress control

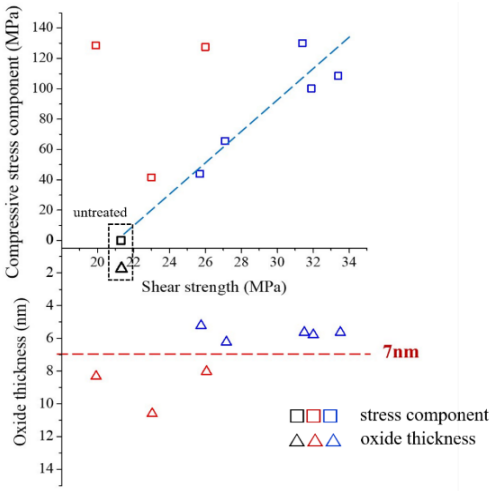



Fig. 1 The relationships between joint strength, residual stresses and oxide layer thickness

**Keywords:** Light irradiation, Cu to Cu bonding, Thermal compression bonding, Al-Al ultrasonic bonding.

# Analog Synaptic Computing Using Janus WSSe Memristors for next generation Neuromorphic Systems

Faisal Ghafoor[a,b],, Muneeb Ahmad[a], Muhammad Wajid Zulfiqar[a,c], Hammad Ghazanfar[a], Honggyun Kim[a], Deok kee Kim*[a]

[a] *Department of Semiconductor Systems Engineering, Sejong University, Seoul, 05006, Republic of Korea*
[b] *Department of Semiconductor Engineering, Gachon University, 1342 Seongnam-daero,, Gyeonggi-do, Republic of Korea*
[c] *Department of Optical Engineering, Sejong University, Seoul 05006, Republic of Korea*

*Corresponding Author's E-mail: deokkeekim@sejong.ac.kr



**Abstract**

The rapid growth of data-intensive artificial intelligence has highlighted the intrinsic limitations of conventional von Neumann computing architectures, where the physical separation of memory and processing units leads to significant latency and energy consumption during data transfer. Memristor-based neuromorphic systems have emerged as promising candidates to overcome this bottleneck through in-memory computing, parallel information processing, and synapse-like analog conductance modulation. Nevertheless, achieving low-power operation, reliable switching behavior, analog tunability, and scalable device integration within a single platform remains a major challenge.

Here, we report a multilayer two-dimensional Janus WSSe-based memristive device employing Ag and Au electrodes for neuromorphic computing applications. Owing to its intrinsic structural asymmetry, tunable surface dipole, and defect-mediated ion transport, Janus WSSe provides an effective platform for controlled resistive switching. The fabricated Ag/WSSe/Au memristor exhibits electroforming-free bipolar resistive switching with a distinct ON/OFF ratio, stable analog conductance modulation, robust pulse endurance exceeding 10,000 cycles, and excellent data retention up to $10^4$s. Electrical transport analysis reveals that the switching mechanism is dominated by conductive filament formation and rupture, strongly influenced by the intrinsic dipole characteristics of the Janus WSSe structure.

Furthermore, the device successfully emulates essential synaptic functions, including long-term potentiation/depression (LTP/LTD) and paired-pulse facilitation (PPF), demonstrating its capability as an artificial synapse. Experimentally obtained conductance states were implemented as dynamic synaptic weights in a feedforward artificial neural network for handwritten digit recognition. The system achieved a recognition accuracy of approximately 98% for the MNIST dataset, approaching ideal software-based performance. These results position Janus WSSe as a promising channel material for next-generation neuromorphic hardware.

**Keywords:** Memristor, Neuromorphic computing, Artificial Synapse

# Sustainable Polymers with Built-in Circularity



Minna Hakkarainen[a,*]

[a]*KTH Royal Institute of Technology, Department of Fibre and Polymer Technology, Sweden*

*Corresponding Author's E-mail: minna@kth.se

**Abstract**

In many applications biobased plastics can positively impact the environment, however, in order to make a real difference they need to have managed and sustainable end-of-life. This can be facilitated, if we from the start design our materials for chemical, mechanical and/or organic (biological) recycling by molecular design or additives that initiate degradation under specific conditions. In our recent work we focused on i) design of biobased thermoplastics and thermosets for mechanical and/or chemical recyclability by utilizing different dynamic covalent chemistries, such as Schiff-base/imine, disulfide and boron ester chemistries and ii) development of materials with enhanced degradability in targeted end-of-life environment through degradation promoting additives, such as biobased carbon dots or embedded enzymes. Polyesters and polyamides are generally well suited for chemical recycling due to the presence of reversible ester bonds. Inclusion of a second even more easily reversed bond could further facilitate the chemical recyclability back to monomeric products under mild conditions or enable mechanical recycling of crosslinked thermoset materials. In the second approach, we have evaluated different degradation triggers to promote the (bio)degradation of materials in compost or under environmentally relevant conditions. As an example, we showed that cellulose-derived carbon dots function as effective photocatalysts triggering the deacetylation of cellulose acetate (CA) under UV-radiation. This could resolve the bottleneck for biodegradation of highly substituted CA or other chemically modified biopolymers with reduced environmental degradability. Recently, we further demonstrated the effectiveness of embedded enzymes for triggering the deacetylation and subsequent biodegradation of CA and aliphatic polyesters under simulated composting conditions and in contact with external enzymes. This could facilitate the development of materials with tailored degradation rate to promote applications such as biodegradable mulching films or electronics.

**Keywords:** biobased materials, circular materials, dynamic covalent chemistry, recycling, biodegradation

# Development of phosphorus-containing macromolecular therapeutics for the treatment of bone diseases



Yasuhiko Iwasaki*, Sayako Takai, Hitomi Iisaka, Yota Okuno

[a] *Faculty of Chemistry, Materials and Bioengineering, Kansai University*
*3-3-35 Yamate-cho; Suita-shi, Osaka 564-8680, Japan*

*Corresponding Author's E-mail: yasu.bmt@kansai-u.ac.jp

**Abstract**

As the population ages, musculoskeletal disorders, including osteoporosis, are becoming increasingly prevalent. Research and development aimed at treating these conditions is therefore becoming increasingly important.

We have discovered that polyphosphodiesters (PPDEs), a type of polyphosphoester (PPE), have a high affinity for minerals in vivo. This has led us to hypothesize that PPDEs could be used for the selective delivery of drugs to bone tissue, as well as for bone tissue engineering. In my presentation, I will talk about the targeted delivery of estrogen or anti-cancer drugs to bone tissue for the treatment of osteoporosis or bone carcinoma. I will also mention the enhancement of bone regeneration with PPDEs/BMP-2 complexes.

PPDEs can be synthesized via ring-opening polymerization using any alcohol as an initiator. Therefore, estradiol valerate (E2V) was used as the initiator to produce E2V-PPDEs with different levels of polymerization. It was observed that E2V-PPDEs effectively reduced the differentiation of osteoclasts from bone marrow-derived mononuclear cells. Furthermore, bone resorption in ovariectomized mice was significantly reduced following the intravenous injection of E2V-PPDE with a high molecular weight. Consequently, E2V-PPDE emerges as a promising new macromolecular drug for preventing osteoporosis. Alternatively, cholesterol can be used as the initiator to obtain amphiphilic PPDEs, known as Ch-PPDEs. Ch-PPDEs are effective in solubilizing lipophilic anti-cancer drugs such as docetaxel (DTX) and delivering them to bone tissue. The anticancer activity of DTX/Ch-PPDEs has also been observed. Furthermore, Ch-PPDEs can form complexes with bone morphogenetic protein-2 (BMP-2) through simple heat treatment. These complexes can be obtained in an aqueous medium by simple heat treatment and demonstrate a high affinity for bone tissue. When these complexes were mixed with bone chips and used to promote bone union in a rat lumbar fusion model, continuous release of BMP-2 from the complexes was observed, resulting in spinal fusion and new bone formation.

**Keywords:** Polyphosphoester, DDS, osteoporosis, bone carcinoma, bone regeneration

# Long-chain branches in linear semicrystalline polymers enhance overall crystallization by promoting homogeneous nucleation



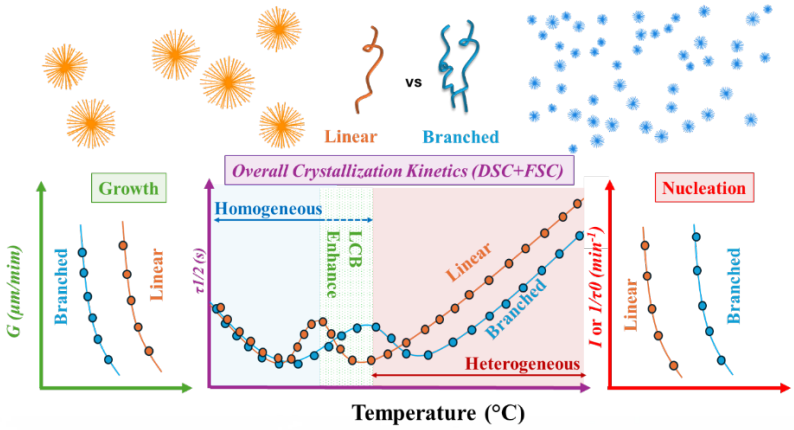
Ricardo Pérez-Camargo[a], Alejandro J. Müller[a,b*]

[a]*POLYMAT and Department of Polymers and Advanced Materials: Physics, Chemistry and Technology, Faculty of Chemistry, University of the Basque Country UPV/EHU, Paseo Manuel de Lardizabal, 3, 20018 Donostia-San Sebastián, Spain*
[b]*IKERBASQUE, Basque Foundation for Science, Plaza Euskadi 5, Bilbao, 48009, Spain*

*Corresponding Author's E-mail: alejandrojesus.muller@ehu.es

**Abstract**

Long-chain branches (LCBs) are introduced within linear chains to enhance their melt strength and improve rheological performance during film blowing operations. However, the influence of LCBs on crystallization has not been studied in detail, especially the molecular mechanisms underlying these effects. This presentation reviews recent results from our group about the effect of introducing LCBs on the nucleation, crystal growth rate, and overall crystallization kinetics of isotactic polypropylene (iPP) and poly(lactic acid) (PLA). A consistent trend was found as LCBs accelerate nucleation, as indicated by higher nucleation densities, faster nucleation rates, and higher crystallization temperatures. However, LCBs reduce spherulitic growth by restricting chain mobility. Despite these opposing contributions, the overall crystallization kinetics are enhanced because of the dominant role of primary nucleation. The long-standing belief that branching points serve as heterogeneous nuclei is challenged by results from fast scanning chip calorimetry (FSC), which demonstrate that LCBs instead promote nucleation via conformational stabilization and homogeneous nucleation. This presentation and the graphical abstract below are derived from reference 1 and references therein.




**Keywords:** Long-chain branch polymers, nucleation, spherulitic growth, crystallization kinetics, homogeneous nucleation mechanisms

(1) Pérez-Camargo, R. A.; Müller, A. J. Polymer, 2026, 345, 129575, 1-16.

# Valorization of Biochemicals for the Development of Bio-based Elastomers

Suwabun Chirachanchai[a,*], Seema Agarwal[b], Autchara Pangon[c], and Ratthapit Wuttisarn[a]



[a] *Center of Excellence in Bioresources to Advanced Materials (B2A-CE), The Petroleum and Petrochemical College, Chulalongkorn University, Bangkok 10330, Thailand*
[b] *Advanced Sustainable Polymers, Macromolecular Chemistry II, and Bavarian Polymer Institute, University of Bayreuth, Universitätsstrasse 30, Bayreuth 95440, Germany*
[c] *National Nanotechnology Center (NANOTEC), National Science and Technology Development Agency (NSTDA), Pathum Thani 12120, Thailand*

*Corresponding Author's E-mail: csuwabun@chula.ac.th

**Abstract**

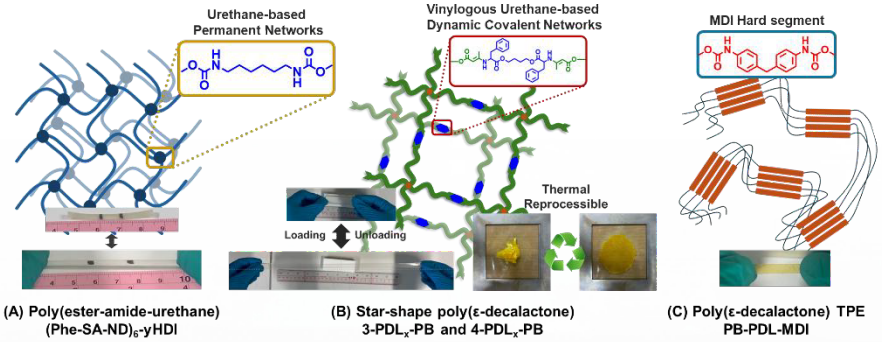
The development of sustainable elastomers with tunable mechanical properties and controlled end-of-life behavior is essential for advancing circular polymer materials. This work presents three distinct elastomer designs: two based on crosslinked network structures and one based on thermoplastic elastomer (TPE) architecture. The materials are developed from amino acid–derived building blocks in combination with potentially bio-based chemicals, including glycidyl ether, succinic anhydride, and ε-decalactone (DL).

A phenylalanine-based poly(ester-amide-urethane), (Phe-SA-ND)$_6$-yHDI **(Scheme (A))**, is synthesized via conventional covalent crosslinking, forming a stable network. The material exhibits glass transition temperatures ($T_g$) from -15 to -12 °C, tensile strength up to 1.5 MPa, and elongation at break up to 300%. It undergoes efficient methanolysis at ambient temperature.

Star-shaped poly(ε-decalactone) (PDL) networks, 3-PDL$_x$ and 4-PDL$_x$ **(Scheme (B))**, incorporate vinylogous urethane bonds as dynamic crosslinking points using diphenylalanine as a multifunctional crosslinker, yielding vitrimeric elastomers. These materials enable associative bond exchange and thermal reprocessability while maintaining network integrity. They exhibit $T_g$ values from -49°C to -39°C and elongation at break up to 2100%, retaining approximately 75% of their initial mechanical performance after multiple reprocessing cycles.

The PDL-based TPE, PB-PDL$_x$-MDI **(Scheme (C))**, is formed by combining DL-derived building blocks as the soft segment with methylene diphenyl diisocyanate (MDI) as the hard segment. The resulting material exhibits a $T_g$ of approximately 0 °C, below room temperature, and demonstrates a tensile stress of 0.8 MPa with an elongation at break of up to 250%. Additionally, it withstands more than 50 consecutive loading-unloading cycles at 150% strain. Moreover, after thermal recycling, it retains a comparable level of mechanical properties.

This study highlights the complementary advantages of permanent, dynamic, and TPE architectures in the design of sustainable bio-based elastomers, providing molecular-level insights into balancing mechanical performance, recyclability, and degradability in next-generation soft materials.




**Scheme**

**Keywords:** Bio-derived elastomer, Sustainable elastomer, Vitrimers, Thermoplastic elastomer

# Commercialization of biomaterials with a biodegradable polymer particle technology platform

Hsu-Wei Fang[a, b*]

[a]*High-value biomaterials research and commercialization center, National Taipei University of Technology, 1, Sec. 3, Chung-Hsiao E. Rd., Taipei, TAIWAN,*
[b]*Department of chemical engineering and biotechnology, National Taipei University of Technology, 1, Sec. 3, Chung-Hsiao E. Rd., Taipei, TAIWAN,*

*Corresponding Author's E-mail: hwfang@ntut.edu.tw



**Abstract**

In the rapidly evolving landscape of regenerative medicine, the transition from benchtop innovation to clinical application requires not only biological efficacy but also extreme structural precision. This plenary lecture discusses a systematic "Design-by-Outcome" approach to the development of advanced biomaterials. Central to this strategy is a sophisticated biodegradable polymer particle technology platform that integrates advanced emulsification and microfluidic techniques.

By leveraging these fabrication methods, we achieve unprecedented control over particle characteristics, including precise size distribution, tailored morphology, and optimized porosity. These parameters are critical for modulating cell attachment, controlled release kinetics, and predictable in vivo degradation.

The session will share the successful commercialization journey of two high-risk (Class III) medical devices derived from this precision platform:

- Neofilera (Diamond Biomedical): A next-generation dermal filler utilizing calibrated microspheres to optimize bio-stimulation and aesthetic longevity.
- Starch-based Hemostatic and Anti-adhesion Materials (Biosight Biomaterials): An innovative solution employing porous particle architecture to accelerate hemostasis and optimize surgical recovery.

This presentation aims to provide a roadmap for transforming precision polymer engineering into globally competitive healthcare solutions. Please limit your abstract to less than 300 words. (Abstract Example file may be used as template.)

**Keywords:** Biodegradable Polymers, Microfluidics, Emulsification, Microsphere Engineering, Class III Medical Devices.

# Smart Surfaces: Enhancing Bone-Implant Integration while Combating Bacterial Adhesion with SLPI Peptides

Sarawut Kumphune[a,b*]

[a] *Biomedical Engineering Institute, CMU-BIOPOLIS building, Chiang Mai University– Mae Hia campus, Mueang Chiang Mai District, Chiang Mai, 50100 Thailand.*
[b] *Biomedical Engineering and Innovation Research Centre, CMU-BIOPOLIS building, Chiang Mai University– Mae Hia campus, Mueang Chiang Mai District, Chiang Mai, 50100 Thailand*

*Corresponding Author's E-mail: sarawut.kumphune@cmu.ac.th



**Abstract**

The long-term success of dental and orthopaedic titanium (Ti) implants depends on rapid osseointegration and the prevention of device-associated infections. While Ti is the gold standard due to its mechanical properties, its bioinert surface lacks inherent osteoinductive properties, often leading to stability issues in compromised patients. Thus, the development of biofunctionalisation surfaces has involved using bioactive molecules to immobilise them onto the implant's surface.

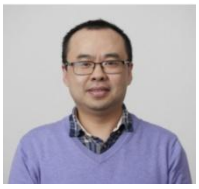
Secretory leukocyte protease inhibitor (SLPI) is a multifunctional protein widely recognised for its anti-inflammatory and antimicrobial functions. While these properties are highly advantageous for mitigating implant-associated infections, previous studies have additionally revealed a potent, direct role for SLPI in osteogenesis, promoting osteoblast adhesion, proliferation, and the expression of key osteogenic differentiation markers via a simple coating technique. We present the first *in vivo* validation of these strategies. In a rat model, rhSLPI-functionalised Ti screws demonstrated significantly higher bone volume fraction and enhanced biomechanical stability. Collectively, these findings provide a robust proof-of-concept for SLPI-based coatings as a dual-action strategy to accelerate bone healing and reduce bacterial complications in clinical implant applications.

To improve SLPI immobilisation of the Ti surface, a novel immobilisation strategy utilising alkaline etching combined with plasma polymerisation to covalently couple recombinant human SLPI (rhSLPI) to Ti was performed. This combined platform (TiOHS) significantly improves surface hydrophilicity and roughness, resulting in superior human osteoblast adhesion and mineral deposition compared to untreated controls.

To address the limitations of full-length proteins, we further explored SLPI-derived small peptides (SDSPs). Screening of in silico-digested fragments identified the P7 peptide as a standout candidate. When coated on Ti, P7 not only enhanced osteoblast spreading and proliferation by over 50% but also demonstrated a concentration-dependent reduction in the adhesion of Gram-negative bacteria. Therefore, this study presents initial findings indicating that SDSP-coated titanium may enhance the results of orthopaedic and dental implants.

**Keywords:** Functionalised Biomaterials, Secretory leukocyte protease inhibitor (SLPI), Osseointegration, Bioactive implant, Therapeutic Short Peptides

# Quasi-2D Layered Double Perovskite Nanocrystals: A New Game Changer for Eco-Friendly Flexible Light-Converting Applications



Maning Liu[a,b,c*]

[a]*Centre for Analysis and Synthesis, Department of Chemistry, Lund University, Lund 221 00, Sweden*
[b]*Wallenberg Initiative Materials Science for Sustainability, Department of Chemistry, Lund University, Lund 221 00, Sweden*
[c] *NanoLund, Lund University, Professorsgatan 1, Lund 223 63, Sweden*

*Corresponding Author's E-mail: maning.liu@chem.lu.se

**Abstract**

Recently, quasi-2D lead-free layered double perovskites (LDPs) with formula $Cs_4M(II)M(III)_2X_{12}$ (e.g., M(II) = $Cu^{2+}$; M(III) = $Sb^{3+}$) have been discovered and developed, demonstrating several intriguing characteristics such as direct and tunable bandgap nature (down to ~1.0 eV in theory), low- or none-toxicity, low effective masses and superior structural stability.[1] The crystal structure of LDPs within one unit cell consists of one layer of $[M(II)X_6]^{4-}$ octahedra sandwiched by two layers of $[M(III)X_6]^{3-}$ octahedra, which forms an anisotropic conformation. To date, colloidal $Cs_4M(II)M(III)_2Cl_{12}$ nanocrystals (NCs) or even quantum dots (QDs) have been primarily synthesized as attractive light absorber or emitter for diverse flexible and wearable optoelectronics as well as photocatalysis.[2]

In this talk, I will present several of our relevant works regarding the tuning of optoelectronic properties in novel LDP NCs. We first proposed a new system by replacing Sb with In at M(III) site, resulting in $Cs_4CuIn_2Cl_{12}$ NCs (denoted as CCuI), which show an almost 2% photoluminescence quantum yield (PLQY) in the near UV range.[3] We attributed the PL enhancement to the radiative transition of featured self-trapped excitons (STEs). We then conducted lattice engineering on the established CCuI NCs, by replacing $Cu^{2+}$ with other transition metal ions, including $Co^{2+}$ and $Zn^{2+}$, to synthesize first-ever $Cs_4CoIn_2Cl_{12}$ (CCoI) and $Cs_4ZnIn_2Cl_{12}$ (CZnI) NCs with a wide bandgap of 3.5-3.8 eV.[4] Benefiting from the formation of more STEs that relax in a radiative way, a broad PL spectrum was observed with a highest PLQY of 11.4% for CZnI NCs. To further reduce the bandgap, M(III) site engineering was investigated with $Bi^{3+}$ and $Sb^{3+}$ in the case of emissive Co-based NCs, i.e., forming $C_4CoBi_2Cl_{12}$ (CCoB) and $Cs_4CoSb_2Cl_{12}$ (CCoS) with a lowered bandgap of 2.8-3.2 eV, which excited state lifetimes have also been extended.[5] We believe upon further structural and compositional engineering the LDPs with a wide range of tunable bandgaps can be a promising light emitter or absorber for eco-friendly, stable and efficient light-converting applications such as light-emitting diodes (LEDs), photocatalytic reactions and solar cells.

**Keywords:** Lead-free perovskites; colloidal nanocrystals or quantum dots; photoluminescence quantum yield; self-trapped excitons; optoelectronics

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# Multifunctional Conductive Hydrogels for Biomedical Applications



Jae Young Lee[a,b,*]

[a] *School of Materials Science and Engineering, Gwangju Institute of Science and Technology (GIST), Gwangju, Republic of Korea*
[b] *GIST InnoCORE AI-Nano Convergence Institute for Early Detection of Neurodegenerative Diseases, GIST, Gwangju 61005, Republic of Korea*

*Corresponding Author's E-mail: jaeyounglee@gist.ac.kr

**Abstract**

Hydrogels can closely mimic the mechanical and biological properties of native soft tissues and have been widely used for various biomedical applications, including tissue engineering scaffolds and bioelectrodes. Recently, extensive efforts have been made to include new functions, such as electrical conductivity to hydrogels, to hydrogels. Our research group has elaborated to develop graphene-incorporated hydrogels containing well-dispersed reduced graphene flakes within the hydrogel matrices. Depending on the graphene content and polymer matrix type, the resulting composite hydrogels exhibit diverse, tailorable characteristics, including electrical conductivity. Leveraging the unique properties inherent to these graphene/hydrogel composites, we have successfully demonstrated their utility in a wide range of biomedical applications. In this talk, I will discuss topics including muscle-mimicking conductive hydrogel scaffolds, conductive nerve guidance conduits for peripheral nerve regeneration, 3D graphene network-embedded hydrogels, and injectable conductive hydrogel electrodes. Furthermore, I will briefly introduce our recent focus on MXene-based conductive hydrogels, highlighting how we take advantage of MXene's inherent hydrophilicity and biodegradability.

**Keywords:** Conductive hydrogel, graphene, MXene, biomedical application

# Ultrahigh Piezoelectric Response in Relaxor Ferroelectric Ceramics and Crystals from Local Structural Heterogeneity



Fei Li*

*Electronic Materials Research Lab, Xi'an Jiaotong University, Xi'an, China*

*Corresponding Author's E-mail: ful5@xjtu.edu.cn

**Abstract**

Perovskite ferroelectrics (general formula, $ABO_3$) exhibit the highest electromechanical activity among all known piezoelectrics. One of the most remarkable breakthroughs in perovskite ferroelectrics is the discovery of ultrahigh piezoelectricity ($d_{33}^*$=1500~2500 pC $N^{-1}$) and electromechanical coupling factors ($k_{33}^*$ >0.9) in domain-engineered relaxor-ferroelectric solid solution crystals with MPB compositions, e.g., $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ (PMN-PT) and $Pb(Zn_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ (PZN-PT) crystals.

A key signature of relaxor-ferroelectrics is the existence of polar nanoregions (PNRs), a nano-scale inhomogeneity, that coexist with normal ferroelectric domains. In our recent research, we quantitatively characterized the contribution of polar nanoregions to the dielectric/piezoelectric responses of relaxor-ferroelectric crystals using a combination of cryogenic experiments and phase-field simulations. A mesoscale mechanism was proposed to reveal the origin of the high piezoelectricity in relaxor-ferroelectrics, where the polar nanoregions can be regarded as "seeds" to promote the polarization rotation.

Based on this mechanism, we have modified the local structure of relaxor ferroelectric crystals and ceramics by adding samarium dopants. Both modified polycrystalline ceramics and single crystals showed ultra-high piezo $d_{33}$ coefficients and dielectric permittivities. The impact of these property improvements on applications, including ultrasound transducers and sensors, will be presented.

In this presentation, meanwhile, I will show our recent progress on the transparent relaxor-ferroelectric crystals with ultrahigh piezoelectricity, which are expected to find a wide range of applications in coupled electro-optical–mechanical devices

**Keywords:** Relaxor ferroelectrics, piezoelectric materials, ferroelectric domains

# Advancing the performance of printed organic photovoltaics



Thomas D. Anthopoulos[a,*]

[a]*Henry Royce Institute, Photon Science Institute, Department of Electrical and Electronic Engineering, The University of Manchester, Alan Turing Building, Oxford Road, United Kingdom*

*Corresponding Author's E-mail: thomas.anthopoulos@manchester.ac.uk

**Abstract**

Organic semiconductors offer numerous attractive characteristics that push the frontiers of semiconductor technology and promise to expand their use far beyond displays. Examples include printed electronics, photovoltaics, and sensors for a plethora of existing and emerging applications. A notable example is printable photovoltaics, which combine low-cost manufacturing with truly green energy generation, paving the way for a healthier, carbon-free future. Other important applications are optoelectronics and sensors, which promise to ease our reliance on polluting inorganic technologies by developing greener products. Despite the enticing possibilities that organic semiconductors offer, numerous technological bottlenecks remain.

In this talk, I will present our recent work on organic photovoltaics with particular emphasis on our efforts to advance their performance and reliability. I will discuss our effort to push the efficiency of organic photovoltaics (OPVs) to over 20%. I will show how the use of innovative charge-extracting interlayers can enhance the overall performance of the cells and their operating lifetime. Moreover, I will describe the use of antireflection coatings and molecular dopants to improve power conversion efficiency (PCE) and demonstrate how their combination with innovative charge-extraction interlayers and appropriate cell designs can enhance material utilisation and device sustainability, all while delivering record PCE.

**Keywords:** organic semiconductors, organic photovoltaics, printed solar cells, organic bulk-heterojunction

# Upconversion Behavior for Energy Harvest and High-Temperature Spectral Properties of Yb/Ho- SiAlON, and Yb/ER-$BiVO_4$ Ceramics



Soo Wohn Lee[a,*], Yuwaraj K Ksehettri[b]

[a]*Department of Chemical Engineering, Sun Moon University, Asan, ChungNam, 31460, Korea*
[b] *Institute of Green Materials, Sun Moon University, Asan, ChungNam, 31460, Korea*

*Corresponding Author's E-mail: swlee@sunmoon.ac.kr

**Abstract**

Traditionally, NaYF4 and glass-based materials are considered the most efficient upconversion materials. However, those materials may show signs of thermal warping or risks of fracture during long-term service life in extreme environments. In contrast, SiAlON ceramics preserve their spectral and physical integrity during continuous use due to their ultra-low thermal expansion coefficient (~3.0 ×10 6/K) even at extreme temperatures. Here, we investigate the upconversion photoluminescence **properties for energy harvest of** Ho and Yb co-doped SiAlON (Ho/ Yb-SiAlON) ceramics, prepared by hot-press method, at room temperature and at high temperature (298–1023 K). At room temperature, Ho/Yb-SiAlON ceramics show intense red upconversion emission under 980 nm excitation. At the high-temperature range, the spectral shift is absent in Ho/Yb-SiAlON indicating that the SiAlON ceramics have high-temperature spectral stability, which may be attributed to the low thermal expansion coefficient of SiAlON ceramics.
Here also, we report a BiVO4-based upconversion ceramic material for high-sensitivity and high-temperature optical thermometry. Yb/Er-doped BiVO4 (BiVO4:Yb/Er) ceramic is prepared by microwave hydrothermal synthesis. The as-synthesized sample exhibits intense green and red emissions under 980 nm and 490 nm excitations. Temperature-dependent emission properties are investigated using 980 nm excitation in the temperature range of 298–873 K and the fluorescence intensity ratio method is used to study the temperature sensing properties of BiVO4:Yb/Er ceramics with reference to the thermally coupled as well as non-thermally coupled energy levels of $Er^{3+}$.

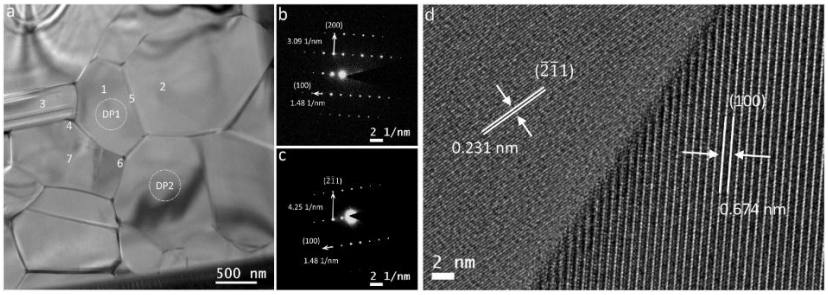



Fig. 1. Microstructure and TEM analysis of Ho/Yb-SiAlON ceramics. (a) TEM micrograph. (b) and (c) are SAED patterns corresponding to the circular regions DP1 and DP2, respectively, shown in (a). (d) HRTEM image showing two different α-SiAlON grains separated by a thin grain boundary phase.

**Keywords:** Sialon, BiVO4, Upconversion, Energy harvest, Fluorescence intensity ratio, Thermal sensitivity, Optical thermometry

# Colloidal Semiconductor Topological Lasers

Handong SUN*

*Institute of Applied Physics and Materials Engineering, University of Macau, Macao SAR 999078, China*

*Corresponding Author's E-mail: hdsun@um.edu.mo



**Abstract**

Topological photonics, exploiting topologically nontrivial structures to support defect-robust photonic states, paves a promising way in developing microlasers. Conventionally, fabrication of topological lasers relies on the combination of complicated epitaxial growth and precise processing technology at nanoscale. On the other hand, colloidal semiconductor nanostructures have attracted a great deal of attention because of their intrinsic advantages over traditional epitaxy-based semiconductor heterostructures in luminescent device applications. In this talk, the speaker will first present the motivation of developing microlasers from colloidal semiconductor nanostructures and the state of art in topological lasers. He will then show the latest progress in 1D and 2D colloidal topological lasers by taking advantage of advanced colloidal semiconductor nanostructures and facile soft matter technology. The talk will conclude with summary and sharing future research prospective.

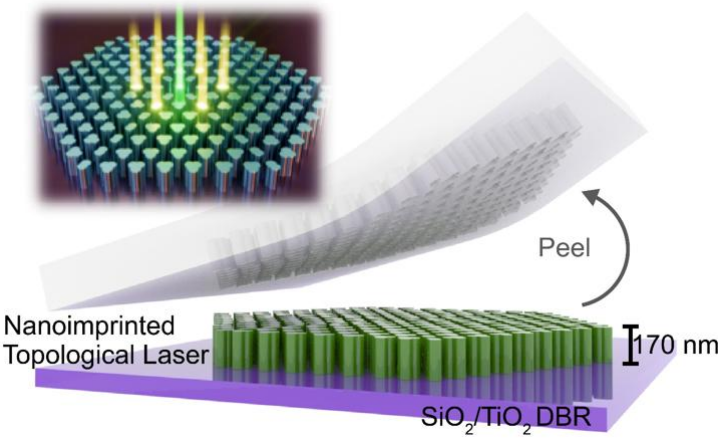



Fig.1 Illustration diagram of a topological laser fabricated by nanoimprinting technology

**Keywords:** Topological Photonics, Colloidal Nanostructures, Microlasers

# Engineered Polymer Electrolytes for Solid-State Lithium Metal Batteries



Jae Hyun Kim*

*Division of Energy & Environmental Technology, Daegu Gyeongbuk Institute of Science & Technology, Daegu, 42988, Republic of Korea*

*Corresponding Author's E-mail: jaehyun@dgist.ac.kr

**Abstract**

To meet the growing demand for high-energy and safe solid-state lithium-metal batteries (SS-LMBs), polymer electrolytes with robust interfacial stability and improved ionic transport are required. In this work, complementary polymer electrolyte strategies based on PEO and PEGDME are integrated to address temperature-dependent limitations. A YNa zeolite–reinforced PEO-based composite polymer electrolyte with high Li-salt content exhibits an enhanced work function, forming a stable interfacial layer with lithium metal that suppresses dendrite growth and delivers a high Li-ion transference number of 0.84, enabling stable cycling and high capacity at elevated operating temperatures. However, the intrinsically limited low-temperature ion transport of PEO motivates the incorporation of a fluorinated-ether–anchored PEGDME semi-interpenetrating network. Molecular anchoring via hydrogen bonding suppresses crystallization, weakens $Li^+$–ether coordination, and promotes inorganic-rich interphase formation, resulting in high ionic conductivity down to −20 °C, intrinsic nonflammability, and durable cycling. Together, these synergistic polymer designs provide a practical pathway toward safe, high-performance SS-LMBs across an extended operating temperature range.

**Keywords:** Lithium-metal batteries, Zeolite, Polymer

# Degradation Mechanisms and Surface Modification of Ferritic Stainless Steels as Interconnect Materials for Solid Oxide Fuel Cells



Somrerk Chandra-ambhorn

*High Temperature Corrosion Research Centre, Department of Materials and Production Technology Engineering, Faculty of Engineering, King Mongkut's University of Technology North Bangkok*

E-mail: somrerk.c@eng.kmutnb.ac.th

**Abstract**

Solid Oxide Fuel Cells (SOFCs) convert chemical to electrical energy by electrochemical means with the feed of fuel to an anode side and oxygen presented in air to a cathode side. To collect more current from the device, a stack comprising several single cells must be fabricated. In such fabrication, an element called interconnect is inserted between the cathode of one cell and the anode of an adjacent cell to separate gases fed to both sides. Ferritic stainless steels are promising materials to be used as interconnects for SOFCs operated at 800 ºC or lower mainly because of their relatively low cost and thermal expansion coefficient comparable to that of the single cell [1–3]. However, the use of stainless steel in high-temperature environments can cause the oxidation of metal leading to the formation of thermal oxide scale particularly chromia on the stainless steel. The parabolic rate constant of the chromia growth due to the diffusion of each cationic defect, i.e. chromium interstitial and chromium vacancy, as a function of oxygen partial pressure and temperature was explicitly expressed in our work [4] and will be reviewed in the talk. Exposure of chromia to humidified atmospheres can also cause the oxide volatilisation. The volatilisation behaviours of thermal scale on the stainless steel exposed to humidified oxygen [5] and humidified $CO_2$ [6] have been recently reported. To mitigate material degradation, surface modification should be done such as by the pre-oxidation [7] or Mn-Co spinel coating techniques [8,9] which will be reviewed in the lecture.

**Keywords:** Ferritic stainless steel, Solid Oxide Fuel Cells, Interconnect, Oxidation, Volatilisation

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# Frontier Engineering of Solid-State Li-Ion and Metal-Air Batteries for High-Energy-Density Storage



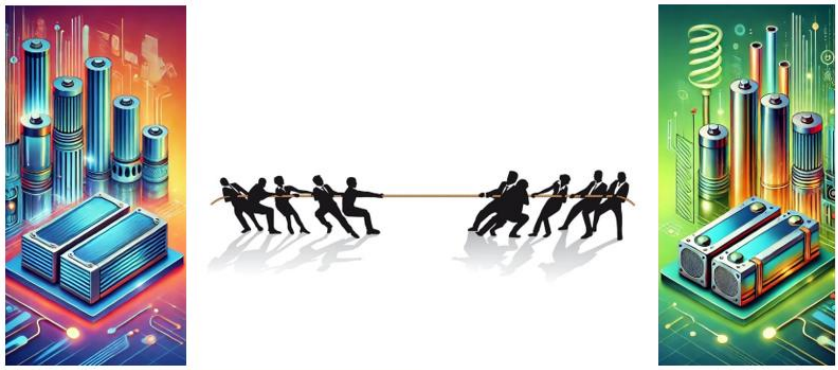
Ru-Shi Liu*

*Department of Chemistry, National Taiwan University, Taipei, Taiwan*

*Corresponding Author's E-mail: rsliu@ntu.edu.tw

**Abstract**

Achieving carbon neutrality by 2050 requires a rapid transition to renewable energy supported by advanced energy storage technologies. Conventional lithium-ion batteries (LIBs) have reached a practical energy density limit of ~300 Wh $kg^{-1}$, driving the development of solid-state lithium-ion batteries (SSLBs) targeting >500 Wh $kg^{-1}$. Central to SSLBs is the solid-state electrolyte, which critically determines ionic conductivity and interfacial stability. This work highlights recent advances in electrolyte materials and interface engineering. Meanwhile, rechargeable metal–air batteries have emerged as promising candidates due to their ultra-high theoretical energy densities and compatibility with carbon-neutral cycles. Here, we provide a comparative perspective on SSLBs and metal–air systems, addressing their mechanisms, challenges, and future prospects for next-generation energy storage.



• Solid-state lithium-ion batteries use solid electrolytes instead of traditional liquid electrolytes, which is expected to significantly improve the safety and energy density of batteries. However, solid-state batteries still face challenges in terms of cost and industry chain maturity.

• The theoretical energy density of metal-air batteries is extremely high, and they are expected to break through the current energy density bottleneck of lithium-ion batteries. However, there is still room for breakthroughs in terms of cycle life and charging speed.

**Keywords:** Solid-state Li-Ion battery, metal-air battery, energy storage

# Field-effect electrochemical energy storage devices

Mengyu Yan[a,*]

[a] *Wuhan University of Technology, Wuhan, 430070 China*

*Corresponding Author's E-mail: ymy@whut.edu.cn



**Abstract**

Nanosized energy storage, energy harvesting, and functional devices are the three key components for integrated self-power systems. Here, we introduce nanoscale electrochemical devices with a nearly 3-fold-enhanced stored charge under the field effect. We demonstrated the field-effect transistor can not only work as a functional component in nanodevices but also serve as an amplifier for the nanosized energy-storage blocks. This unusual increase in energy storage is attributed to having a wide range of accessible electronic density of states (DOS), hence, redox reactions are occurring within the nanowire and not being confined to the surface. Initial results with $MoS_2$ suggest that this field-effect-modulated energy-storage mechanism may also apply to many other redox-active materials. Our work demonstrates the novel application of the field effect in energy-storage devices as a universal strategy to improve ion diffusion, which can greatly enhance the charge storage ability of nanoscale devices.

These exotic phenomena discovered with electrochemical nanodevices enlightened the manufacture of quantum capacitance spectrometers (QCS). It is able to detect the DOS of vary material defects/impurities and the spatial distribution at ambient conditions. This self-made QCS shows a high DOS sensing throughput of 1 hour per spectrum, compared to the current ~1-week duration of quantum capacitance devices. Additionally, the QCS extends the available energy range of quantum capacitance from 1.0 eV to 3.2 eV, enabling a much broader range of semiconductor materials. The QCS reported here provides a new tool for material defect/impurity detection using the DOS spectra at ambient conditions, and shows flexibility for other significant applications, such as band-alignment analysis and energy storage research.

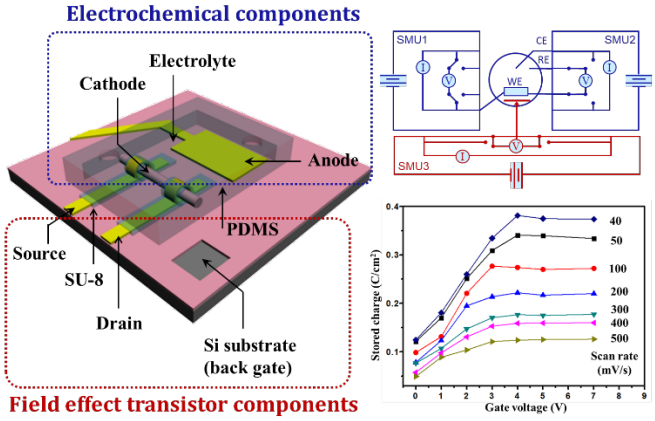



Figure 1. The schematic diagram and the electric circuit of the field-effect electrochemical energy storage devices. It shows a 3 times higher energy/power density with the back gate voltages.

**Keywords:** Energy storage devices, field effect, density of states, quantum capacitance spectrometer

# Hydrogen vs. Lithium Ion Batteries for Energy Storage -from Mobile to Stationary Applications



Huaiyu Shao*

*University of Macau, Macau SAR, China*

*Corresponding Author's E-mail: hshao@um.edu.mo

**Abstract**

In this talk, the research on the hydrogen storage materials and anode materials of Lithium ion batteries will be summarized and the possible application occasions and the potentials of these two technologies for energy storage will be discussed.

To investigate hydrogen storage properties of magnesium-based materials, especially to improve the kinetics, thermodynamics and thermal conductivity properties, we found that kinetics can be greatly improved through nanostructures (downsizing) and catalysis. However, for magnesium-based materials, the direct thermodynamics (desorption enthalpy and entropy change) do not change significantly in the size range of 5 to 300 nanometers in our study. This means that it is difficult to achieve the goal of using magnesium-based materials for on-board hydrogen storage because it is almost impossible to desorb hydrogen at a pressure of about 1 bar hydrogen pressure below 100°C. However, magnesium-based materials are very promising for high-temperature energy storage, including heat storage or hydrogen storage for systems combined with high-temperature fuel cells. Furthermore, if we use magnesium-based materials to store hydrogen produced from renewable energy sources, the energy density is even higher. In this report, we will demonstrate some materials and system thinking based on this concept, including the hydrogen storage and thermal conductivity properties of materials, as well as research on thermal balance simulation verification between fuel cells and Mg-based storage systems.

The low initial coulombic efficiency (ICE) and cycling stability of silicon (Si)-based anodes are the core bottlenecks restricting their practical commercialization. Overcoming these challenges is crucial for boosting the energy density and cycling lifespan of lithium-ion batteries. To improve ICE, we systematically elucidate the cross-scale active lithium compensation and irreversible reaction suppression mechanism across the material-interface-electrode levels. A multi-dimensional pre-lithiation strategy system is constructed, encompassing lithium/magnesium thermal reduction (material level), Si-based pre-lithiation additives (interface level), and chemical pre-lithiation (electrode level). Furthermore, fluorination-functionalized interface engineering enhances the commercial scalability of the anode pre-lithiation technology. The developed pre-lithiation materials maintain long-term stability in conventional anode fabrication environments with relative humidity (RH) > 40%. Regarding enhanced cycling stability, the structural failure mechanism of commercial Si/C composite anodes induced by localized stress concentration is analyzed in depth. A deposited Si/C anode with an omnidirectional interface is further constructed to realize the discretization of localized stress. Benefiting from this structural design, the anode delivers an average capacity decay rate of less than 0.005% over 2000 cycles, thus exhibiting exceptional cycling stability.

**Keywords:** Energy storage, hydrogen energy, Mg-based, Si-based anodes

# Enhancing the electrochemical efficiency of N-rGO using coal fly-ash derived $SiO_2$ nanoparticles and m-COF for advanced supercapattery applications

Katlego Makgopa[a,*], Mpho Sofnee Ratsoma[a], Daniel Malesela Teffu[b]

[a]*Department of Chemistry, Faculty of Science, Tshwane University of Technology (Acardia Campus), Pretoria 0001, South Africa*
[b]*Department of Chemistry, Faculty of Science and Agriculture, University of Limpopo, Polokwane, Sovenga 0727, South Africa*

*Corresponding Author's E-mail: makgopak@tut.ac.za



**Abstract**

Electrochemical energy storage systems, including batteries and supercapacitors (SCs), are advancing rapidly and are poised to support the Just Energy Transition (JET)'s initiative by reducing power intermittency, facilitating peak shaving, and reducing reliance on fossil fuels. SCs stand out as highly promising energy storage devices capable of aiding the integration of renewable energy into the energy grid, thanks to their fast charging and discharging, long cycle life, and environmental friendliness. The performance of SCs mainly relies on the active material in their electrodes. Consequently, meticulous design, customisation, and precise adjustment of the active material's properties, such as chemical composition, particle size, surface area, pore size, and morphology, have been shown to effectively improve SCs' performance. Hence, this study reports on the role of coal fly-ash-derived silica nanoparticles and melamine-based COF modified with nitrogen-doped reduced graphene oxide ($SiO_2$/NrGO and mCOF/NrGO nanocomposite) as electrodes for advanced supercapattery applications. Due to the observed synergistic effects between mCOF and NrGO, the mCOF/NrGO composite showcased an impressive maximum specific capacity of 387 C/g (measured at 2.0 A/g current density) and 191 C/g (at a scan rate of 40 mV/s), as determined by GCD and CV techniques, respectively, in a three-electrode configuration. Furthermore, an asymmetric cell setup featuring mCOF/NrGO as the positive electrode alongside AC as the negative electrode (i.e., AC//mCOF/NrGO) demonstrated an energy density of 7 Wh/kg at a power density of 225 W/kg at a current density of 0.3 A/g. The practicality of the $SiO_2$/NrGO nanocomposite for ASC applications was evaluated with the nanocomposite as the anode and AC as the cathode. A device which can operate up to 2.2 V was realised from this configuration, which achieved a high $C_a$ of 178.6 mF cm$^{-2}$ and a high maximum areal energy ($E_{a,max}$) of 120 µWh cm$^{-2}$, with a low maximum areal power ($P_{a,max}$) of 47.8 mW cm$^{-2}$ at 0.5 mA cm$^{-2}$. The device further achieved a high $P_{a,max}$ of 195.3 mW cm$^{-2}$ with a low $E_{a,max}$ of 33.6 µWh cm$^{-2}$, and a low $C_a$ of 50 mF cm$^{-2}$ at a high areal current of 10.0 mA cm$^{-2}$.

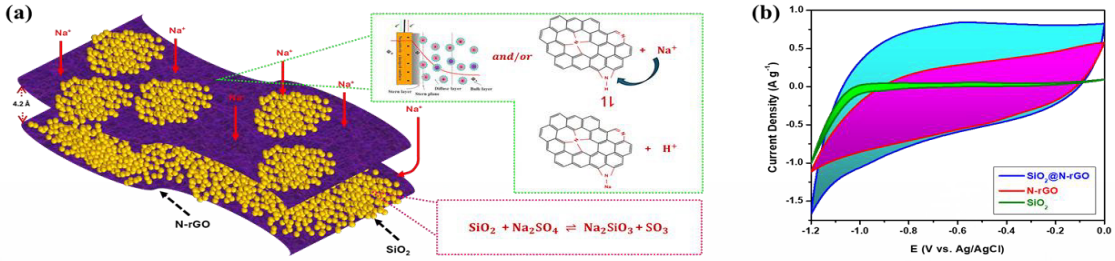



Fig.1 (a) the interaction of $SiO_2$@N-rGO with electrolyte ions, (b) CV curves of $SiO_2$@N-rGO, N-rGO, and $SiO_2$

**Keywords:** Silica Nanoparticles, Covalent Organic Frameworks, Reduced Graphene Oxide, Energy Storage, Supercapattery, Battery-type Electrode

# Electronic Structure Evolution and Reaction Heterogeneity Across Battery Interfaces



Seongmin Bak[a,b,*]

[a]*Department of Materials Science and Engineering, Yonsei University, Seoul 03722, Republic of Korea*
[b]*Department of Battery Engineering, Yonsei University, Seoul 03722, Republic of Korea*

*E-mail: smbak@yonsei.ac.kr

**Abstract**

Electrochemical reactions in battery materials are inherently heterogeneous, evolving non-uniformly across multiple length scales from local atomic coordination to particle surfaces and buried interfaces. Conventional bulk-averaged characterization often obscures these local imbalances, limiting mechanistic understanding of capacity fade and interfacial instability.

In this presentation, depth-sensitive electronic structure analysis is integrated with spatially resolved X-ray characterization to resolve such heterogeneity. Surface-sensitive soft X-ray absorption spectroscopy (sXAS) at transition-metal L-edges reveals pronounced surface–bulk decoupling in Ni-rich layered cathodes. During cycling, surface Ni reduction and modified metal–oxygen hybridization evolve distinctly from bulk redox processes, demonstrating that electrochemical stability cannot be interpreted solely from averaged transition-metal valence states, but must explicitly account for surface-localized electronic imbalance.

To probe buried interfaces, spatially resolved tender X-ray fluorescence (XRF) microscopy combined with X-ray absorption spectroscopy (XAS) directly visualizes mobile-ion depletion and concentration heterogeneity in multiphase polymer electrolytes. These results reveal how interfacial phase separation and ionic redistribution govern degradation pathways.

By bridging depth sensitivity with spatial resolution, this work establishes a unified framework for understanding multiscale reaction heterogeneity in battery systems. The insights emphasize the critical role of interface-specific electronic and chemical evolution, offering actionable design principles to stabilize next-generation energy storage materials. This presentation highlights how advanced synchrotron X-ray methodologies can uncover hidden interfacial dynamics and redefine structure–property relationships in complex electrochemical systems.

**Keywords:** Batteries, Reaction Heterogeneity, Synchrotron X-ray Characterization, Interfaces, XAS

# High-Performance Hydrogen Storage Alloys for Microgrids and Remote Area Power Supply Systems



M-W Lee[1], Y-C Kuo[1], R. Guo[2], K.L. Lim[3], , S.L.I. Chan[1,2*]

[1] *Department of Chemical and Materials Engineering, National Cntral University, Jhongli, Taiwan*
[2] *School of Materials Science and Engineering, University of New South Wales, Sydney Australia*
[3] *Fuel Cell Institute, Universiti Kebangsaan Malaysia, Selangor, Malaysia*

*Corresponding Author's E-mail: sli.chan@unsw.edu.au

**Abstract**

Presently the trend in developed countries is to take remote communities away from electricity grid and replace it with disconnected microgrids with renewables such as solar and wind power. Micro-grids can also be connected to the main grid to enhance the electricity supply stability, to provide high efficiency, and to reduce transmission and distribution losses. However, solar and wind power are inherently intermittent and seasonal. To overcome this problem, we were the first to propose a new concept of solar-hydrogen system for energy storage in microgrid and remote area power supply. Here the solar hydrogen system uses surplus energy generated by the photovoltaic panels to produce hydrogen via a proton exchange membrane electrolyzer. The hydrogen is stored in hydrogen storage materials housed in a hydrogen tank. When there is insufficient solar power to supply the load, a fuel cell in the system will cover the deficiency by drawing hydrogen from the hydrogen storage material. In this presentation, we will cover several important hydrogen storage alloy systems, their characteristics, advantages and limitations in meeting the specific energy storage requirements of the solar-hydrogen system in microgrids or independent remote area power applications. We propose the application of Ti-Fe and $AB_3$ La-Mg-Ni hydrogen storage alloy as the starting materials to blend with other alloy systems, so as to develop new high-performance, cost-effective hydrogen storage composite alloys for use in the solar hydrogen system. Compared with other alloy systems, TiFe alloys offer the advantages of cost-effectiveness and abundance. They can operate at room temperature with moderate plateau pressures (under 40 bar) to absorb and desorb hydrogen; and have a hydrogen storage capacity higher than 2 wt.%. $AB_3$ La-Mg-Ni hydrogen storage alloys offer more favourable plateau pressures (around atmosphere pressure) for gaseous hydrogen applications as compared to traditional $AB_5$ series. However, for large-scale application of these Ti-Fe and $AB_3$ alloys, there are several challenges that needed to overcome, such as difficulties in alloy activation and re-activation; poor structural stability; prone to poisoning by gas impurities etc. We will discuss several effective methods to overcome these challenges, and to develop new high-performance, cost-effective hydrogen storage composite alloys for use in the solar hydrogen system. Finally, several examples of the applications of the solar-hydrogen systems will be given in the presentation.

**Keywords:** Hydrogen Storage, Remote Power Supply, Small Grid

# End of Life Electric Vehicle Battery NMC for Circular Economy: Repurposing and Recycling



Evvy Kartini[a,b*], Bagus Aggraini[a], Muhammad Fakhrudin[a,b]

[a]*Nano Technology and Material Research Organization, National Research and Innovation Agency, KST. B.J. Habibie, Puspitek, Setu, South Tangerang 15314, Indonesia*
[b]*National Battery Research Institute, Indonesian Life Science Center, Technology Business Zone BRIN Puspitek Area, Bogor 16340, West Java, Indonesia*

*Corresponding Author's E-mail: evvy001@brin.org

**Abstract**

The rapid global adoption of electric vehicles (EVs) is expected to generate substantial volumes of end-of-life (EoL) lithium-ion batteries (LIBs), with projections reaching 11–12 million metric tons annually by 2030 [1]. EV batteries are typically retired at 70–80% state of health after 8–15 years of use, yet retain sufficient capacity for second-life applications such as stationary energy storage [2]. Repurposing strategies can extend battery service life by 5–10 years and reduce lifecycle greenhouse gas emissions by up to 30% [3]. Recycling remains essential for recovering critical materials, including lithium, cobalt, and nickel, which constitute 5–20% of battery mass depending on chemistry [4]. Current recycling technologies, such as pyrometallurgical and hydrometallurgical processes, achieve recovery efficiencies above 90% for cobalt and nickel, though lithium recovery remains lower at 50–80% [5]. However, challenges remain in collection logistics, economic viability, safety risks, and standardization of battery design. Despite technological progress, challenges persist in economic feasibility, safety risks, logistics, and lack of standardization. Policy instruments such as extended producer responsibility (EPR) and design-for-disassembly approaches are critical to enabling a circular battery economy. This study underscores the importance of integrating reuse and advanced recycling pathways to reduce environmental impacts and support sustainable EV deployment.

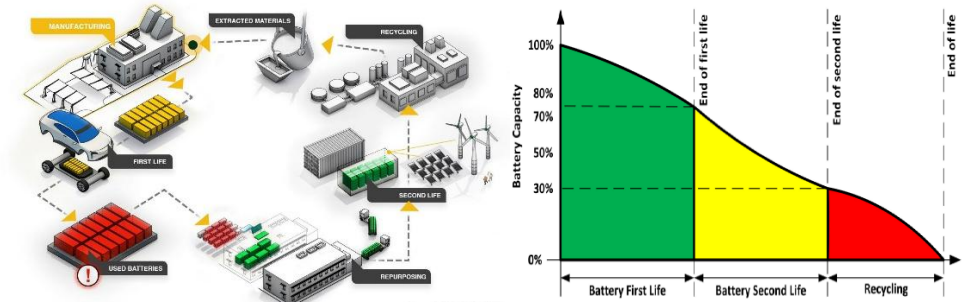



Figure: Shows the **full lifecycle** of an EV battery

**Keywords:** End of life, Battery EV, Lithium-ion battery, NMC Cathode, Repurposing, Recycling

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# Nanostructured Energy Storage Materials and Devices



Liqiang Mai[a,*], Ruohan Yu[a,b]

[a]*State Key Laboratory of Advanced Technology for Materials Synthesis and Processing, Wuhan University of Technology, Wuhan, 430070, P.R. China*
[b]*The Sanya Science and Education Innovation Park of Wuhan University of Technology, Sanya, 572000, P.R. China*

*Corresponding Author's E-mail: mlq518@whut.edu.cn

**Abstract**

Energy storage materials and devices represent a strategically prioritized field in China's development agenda and a critical interdisciplinary frontier in materials and energy sciences. To address the persistent challenge of traditional energy storage batteries, where key metrics are constrained by multiscale material/interface coupling, we achieved the following breakthroughs: We developed the world's first single-nanowire energy storage devices and in-situ characterization platform for probing electron/ion transport, enabling real-time decoupling of synergistic dynamics and revealing intrinsic degradation mechanisms. By integrating nanowire devices with electron microscopy, we established a high-resolution, non-destructive, in-situ electrochemical characterization system that concurrently resolves atomic structures and electrochemical signals under operando conditions. In addition, we proposed a novel energy storage mechanism leveraging field-effect regulation of electron/ion transport, shifting carrier behavior from static intrinsic properties to dynamic external-field modulation. This paradigm transcends traditional electrochemical systems' theoretical capacity limits. Key technologies were invented to surpass static theoretical performance ceilings, demonstrating the universality of field-effect-enhanced energy storage across material classes. Moreover, we proposed the innovative strategies of surface-contact reinforcement and high-safety flame-retardation to enhance interfacial stability and ion diffusion kinetics. Critical barriers in high-safety composite current collectors and femtosecond laser precision regulation were overcome, synergistically boosting energy density, safety, and cycle life. Collectively, these technologies establish a pivotal theoretical foundation and accelerate industrial advancement across the broader new energy sector, particularly in large-scale energy storage and electric vehicles.

**Keywords:** Nanomaterials; Energy storage devices; In-situ characterization; Ion transport

# Light-Driven Polymerization to Afford Functional Hydrophilic Polymers with Antifouling Property, Programmable Degradation and Thermoresponsiveness



Chia-Chih "George" Chang*

*Department of Applied Chemistry, National Yang Ming Chiao Tung University, Hsinchu, TAIWAN*

*Corresponding Author's E-mail: cchang113ac@nycu.edu.tw

**Abstract**

Development of functional hydrophilic polymers with tailorable properties is essential for biomedical research. α-Lipoic acid (LA) has emerged as a versatile and cost-effective monomer for constructing degradable polymers because of cleavable disulfide bonds are present along the polymer backbone. LA and its derivatives undergo radical ring-opening polymerization via both conventional and controlled radical processes. The disulfide bonds can readily undergo bond scission under mild reductive conditions. While reversible addition–fragmentation chain transfer (RAFT) copolymerization of LA with vinyl monomers provides degradable polymers with controlled molecular weights, conventional thermally initiated RAFT systems often suffer from oxygen sensitivity and limited LA incorporation. Herein, we report the synthesis of degradable vinyl copolymers incorporating α-lipoic acid derivatives via photoiniferter-RAFT polymerization. This light-mediated approach eliminates the need for external initiators and exhibits enhanced oxygen tolerance, enabling a simplified and spatiotemporally controlled polymerization process under ambient conditions. The method demonstrates broad comonomer compatibility and allows efficient block copolymer synthesis with predictable molecular weight. Introduction of Isopropyl group to the terminal of LA impart thermoresponsivness to hydrophilic poly(N,N'-dimethylacrylamide), such that lower critical solution temperature can be adjusted by the polymer composition. Furthermore, our recent efforts on antifouling amine-oxide containing polymer will be discussed.

**Keywords:** Antifouling, Controlled Radical Polymerization, Degradable Polymer, Amine-oxide

# Predictive Design of Electrocatalysts for $CO_2$ Reduction



Hui Pan

*Institute of Applied Physics and Materials Engineering, University of Macau.*

*E-mail: huipan@um.edu.mo

**Abstract**

*The uncontrollable reconstruction in electrochemical processes, leading to the destruction of well-defined structure and subsequence low durability, is the main obstacle to the performance of catalysts toward highly electrochemical $CO_2$ reduction ($eCO_2R$). In this work, we present a novel approach to address this issue by in-situ reconstruction of pre-catalysts. (1) A durable β-$Bi_2O_3$/$Bi_2O_2CO_3$ composite was designed and fabricated, which showed w a structural evolution from a Janus junction to a multi-interface heterojunction in the $eCO_2R$ process. In situ Raman spectroscopy demonstrated that the electrochemical reduction of Bi-based materials to metallic Bi can be effectively resisted by modulating a more alkaline local environment. The synergistic interactions and directional electron transfer between the β-$Bi_2O_3$ and $Bi2O_2CO_3$ components within the heterojunction play a critical role for its superior activity and selectivity for the production of formate, and a remarkable durability. (2) A novel core-shell nanowire catalyst, composed of bismuth oxyformate nanowires encapsulated by a hydrophobic polypyrrole (PPy) layer (BiOCOOH NWs@PPy-2) achieved exceptional performance toward eCO2R, which was ascribed to the unique design of the bismuth-based catalyst, which facilitates: (i) the confined reconstruction of BiOCOOH within the PPy shell, preserving the highly active Bi (101) facets and one-dimensional nanowire morphology; (ii) the enhanced $CO_2$ adsorption brought by the surface hydrophobicity of PPy; and (iii) a self-regulated microenvironment with local acidity and stable water hydrogen-boding networks to promote efficient proton utilization and transfer. (3) The Sn/Zn ratios in Sn-Zn alloy precursors were modulated to promote $CO_2$-to-formate ($HCOO^-$) conversion through a self-adaptive reconstructed structure with potential changing. Notably, the electrocatalyst exhibited exceptional $CO_2$-to-$HCOO^-$ performance at a Sn/Zn ratio of 1:1 (SnZn-55), achieving a Faraday efficiency (FE) >82% across a wide potential range (-0.73 to -1.13 V), a high $HCOO^-$ partial current density of 45.75 mA $cm^{-2}$ at potential of highest FE formate (92% at -0.93 V) and stability for up to 2000 hours. These findings provide deep insights into the interplay between elemental composition, reconstructed structure, and $eCO_2R$ performance, offering valuable guidance for designing advanced electrocatalysts for efficient $CO_2$ reduction in broad potential range.*

# Cold Sintering Processing of Ceramic-based Hybrids and Functional Oxides



Tohru Sekino[a,*], Yeongjun Seo[a], Shotaro Doi[a], Seungmi Lee[a], Yoshifumi Kondo[c], Tonoyo Goto[b,a]

[a]*Author1's affiliation, address, country SANKEN, The University of Osaka, Ibaraki, Osaka 567-0047, Japan*
[b]*Graduate School of Science and Technology, Nara Institute of Science and Technology (NAIST), Ikoma, Nara 630-0192, Japan*

*Corresponding Author's E-mail: sekino@sanken.osaka-u.ac.jp

**Abstract**

Sintering of ceramics typically requires high temperature heating exceeding 1000 °C, which consumes a large amount of energy, and is therefore unfavorable from a carbon neutral perspective. Recently, a novel low-temperature methods – namely cold sintering process (CSP) [1,2] – has been developed to fabricate dense and bulky inorganic material below 300 °C. In CSP, a transient solvent such as acidic or alkaline solution is added to powder compacts under applied pressure and temperature. This promotes partial dissolution and re-precipitation of inorganic substances at/between particles to densify by filling interparticle spaces and bonding each particle. Further process development was carried out based on more proactive water-assisted mineralization and densification using simulated body fluid (SBF) containg electrolytes. These promote the formation of supersaturated solution between particles, accelerate re-precipitation, and generate grain boundary phases. This low-temperature mineralization sintering process (LMSP) realized dense bulky bioactive glass bodies with the density of over 90% at temperature below 120 °C[3], as well as high density (98%) hydroxyapatite (HAp) with excellent visible light transparency approximately 80% at 180 °C - 800 MPa[4]. These findings suggest that the CSP-based methods are energy-efficient and eco-friendly processes. Furthermore, low fabrication temperature is suitable for creating inorganic-organic hybrids because it can overcome the process temperature gap between them. This paper provides an overview of the design and fabrication of ceramic-based inorganic-organic hybrids and functional oxides using the CSP method.

TEMPO-oxidized cellulose nanofiber (CNF) was mixed with HAp nanoparticles, and then cold-sintered at 130 °C, 800 MPa for 1h. Obtained samples exhibited the relative density of over 90%, and the CNF remained in the sintered HAp matrix. The Vickers hardness decreased with increase in CNF fraction; however, the biaxial flexural strength was enhanced up to 100 MPa for 30 vol% CNF, which is approximately 3.3 times higher than that of pure CSPed HAp sample. NMR measurement revealed the strong interfacial bonding between the HAp and TEMPO-CNF due to the ionic interactions between $Ca^{2+}$ and $COO^{-}$, as well as electrostatic interactions between surface $OH^{-}$ groups.

When CSP was applied to prepare $V_2O_5$-based disks for $Li^{+}$ ion secondary battery (LIB) cathode, CSPed $V_2O_5$ electrode exhibited excellent high-rate capability under fast charge-discharge cycle compared to the conventional dry-pressed $V_2O_5$ electrode. It was found that CSPed samples contained amorphous grain boundary phase and mixed-valence states of $V^{5+}$ and $V^{4+}$; these contribute to a reduction in interparticle contact resistance, resulting in enhanced $Li^{+}$ ion diffusion and electron transport characteristics.

These results collectively demonstrate that the use of CSP enables the fabrication of inorganic-based bulk materials and hybrids that were usually difficult to fabricate using conventional sintering, suggesting potential applications in the design of new material with enhanced properties. Detailed fabrication processing, micro/nanostructures and various properties and functions of a series of materials will be discussed.

**Keywords:** cold sintering, ceramics, inorganic-organic hybrids, secondary battery electrodes, high-rate capability

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# Fabrication and Processing of scalable Electro-catalytical Materials for water splitting and fuel cells



Daniel HC Chua

*National University of Singapore, Department of Materials Science and Engineering, Singapore 117575*

*Corresponding Author's E-mail: danielchua@nus.edu.sg

**Abstract**

Multifunctional Electro-catalytical nanocomposite materials have been receiving a lot of attention from both scientific academia as well as industry for their potential in the green future we envision in the coming years ahead. The uniqueness of these nanomaterials often relies on their intrinsic, physical and material properties and is also highly dependent on their tunability green catalyst for hydrogen, ammonia and other energy applications such as fuel cells. Going beyond unique materials are the materials processing where scalability, reliability and effectiveness matters a lot. As such, one would need a good combination of rational design and appropriate synthesis techniques such that one would be able to fulfill the above criteria.

We will show that advancement in formation of multifunctional nanocomposites in carbon-backed and metal-based materials substrates, and with different combination, will give rise to superior electrochemical performances with unique properties. Through a series of design mix and match, we are able to form hybrid/composites which we can engineer into a fully integrated membrane electrode assembly. This has shown to have the desired properties required for PEM fuel cells. In addition, a whole new class of metal dichalcogenides and phosphides are available and equally as reactive for photoelectrochemical and electrochemical water splitting. In all the work done, a series of in-situ tests are also performed. We will also touch on the significance of material characterization in further understanding their materials interface and structural properties.

**Keywords**: Novel nanomaterials, Multifunctional, Energy

# Advancement of Electrospun Nanofiber based Research in Africa

Samuel Chigome[a,b*]



[a]*Botswana Institute for Technology Research and Innovation, Nanomaterials Division, P Bag 0082, Gaborone, Botswana*
[b]*Botswana University of Agriculture and Natural Resources, Department of Agricultural and Biosystems Engineering, P Bag 0027, Gaborone, Botswana,*

*Corresponding Author's E-mail: schigome@bitri.co.bw

**Abstract**

Electrospinning has the unique ability to produce continuous nanofibers from a wide range of materials in various fibrous assemblies. Due to their ability to form a highly porous mesh, their large surface area to volume ratio, and the ease of their fabrication and functionalization, electrospun nanofibers find use in the development of a wide range of membrane-based products for a wide range of sectors. The wide range of materials that can be electrospun, simplicity and low cost of the most basic electrospinning setup, the ease of transition from lab scale, through pilot scale to industrial scale makes electrospinning a plausible fabrication technique for nanofiber membrane-based prototype development and product manufacturing. This makes electrospinning highly attractive to both academia and industry. Therefore, electrospinning is seen as a material fabrication technique that holds the future of nanofiber membrane-based product development. Consequently, electrospinning is seen as a material fabrication technique that can contribute significantly to addressing the major challenges that Africa is facing in the areas of energy, health and water.

The presentation will give an overview of the presenting Author's experience of conducting electrospinning research in Africa over the past 18 years which will include continental and global collaborative efforts towards developing electrospinning setups and electrospun nanofiber-based membranes for a variety of applications including energy, water and health. This will also include the central role that the Botswana Institute for Technology Research and Innovation, the African Materials Research Society are playing to promote the growth of electrospinning research in Africa.

**Keywords:** Electrospinning, Membrane, Functionalization, Scaling, Product

# Engineering Charge Carrier Pathways in Photocatalysts: From Defects to Interfaces

Theeranun Siritanon[1,*], Anurak Waehayee[1], Praphaiphon Phonsuksawang[1], Teera Butburee[2], Suwit Suthirakun[1]



[1]*School of Chemistry, Institute of Science, Suranaree University of Technology, 111 University Avenue, Muang, Nakhon Ratchasima, 30000, Thailand.*
[2]*National Nanotechnology Center, National Science and Technology Development Agency, 111 Thailand Science*

*Corresponding author's e-mail address: theeranun@sut.ac.th

**Abstract**

The potential of photocatalytic technologies is widely recognized. However, their real-world applications remain limited by insufficient efficiencies. An important issue in photocatalytic materials is carrier separation and transfer. In this talk, I will present a materials chemistry perspective in which photocatalytic function is rationalized and tuned through deliberate control of carrier generation, migration, and reaction pathways. Rather than focusing solely on charge separation efficiency, this work emphasizes how electrons and holes are directed toward specific surface. Three complementary strategies are considered. First, ion substitution and defect engineering are used to regulate carrier density, Fermi level position, and trapping behavior. For example, in Bi-based oxides, iodate substitution modifies carrier concentration and enables polaron-mediated transport, which in turn influences reduction reactions. Second, facet and morphology control introduce anisotropic carrier migration; variations in exposed facets, such as in BiOCl systems, lead to distinct charge transport behavior and surface reactivity. Third, interface engineering in heterostructures is examined, where the nature of interfacial contact affects recombination pathways and the formation of reactive oxygen species. By integrating spectroscopic, electrochemical, and computational insights, these studies show that photocatalytic performance is governed not only by band alignment or light absorption, but by the specific pathways through which charge carriers are transported and consumed. This perspective provides a basis for designing photocatalysts with improved activity and selectivity for energy and environmental applications.

**Keywords:** Photocatalysis, defects, heterojunctions

# End-of-Life Lithium-Ion Battery Management through Recycling Technology



Sakhob Khumkoa[a,*]

[a]*School of Metallurgical Engineering, Institute of Engineering, Suranaree University of Technology, Thailand*

*Corresponding Author's E-mail: sakhob@sut.ac.th

**Abstract**

The rapid growth of the electric vehicle and electronics industries has generated vast quantities of spent lithium-ion batteries. Rather than viewing these as mere waste, they represent a valuable resource awaiting recovery, containing critical metals such as lithium, cobalt, nickel, and manganese - all globally classified as Critical Materials. Effective management of these batteries presents a significant opportunity to reintroduce valuable metals into the production cycle, generate added value, and reduce dependence on imported raw materials.

Seizing this opportunity requires developing recycling technologies tailored to the country's own context - accounting for battery types circulating in the system, infrastructure readiness, and the capabilities of Thai industry. The focus must be on building domestic knowledge and developing pilot-scale prototypes that can be scaled up domestically, rather than directly transplanting foreign technologies.

This direction aligns with Thailand's policy framework, including Carbon Neutrality targets by 2050, Net Zero Carbon Emissions by 2065, circular economy principles embedded in the 13th National Economic and Social Development Plan, and comprehensive government measures supporting end-of-life battery management, reflecting Thailand's serious commitment to addressing this challenge.

Our research team has developed a comprehensive lithium-ion battery recycling technology that covers both EV and consumer electronics batteries, validated through experiments at laboratory and pilot-plant scales. The process spans Black Mass extraction via pre-treatment, through valuable metal recovery using Hydrometallurgy, to the production of Precursor materials for Cathode Material synthesis - culminating in prototype lithium-ion battery cells successfully demonstrated in small electric motorcycles and household energy storage systems.

These pilot-scale achievements provide a solid technical foundation ready for transfer to the public sector for national policy development and serve as a practical blueprint for industry players entering the battery recycling sector - paving the way toward a self-reliant and sustainable battery management ecosystem in Thailand.

**Keywords:** Spent Li-ion battery, Black mass, Critical metal, Recycling, Hydrometallurgy

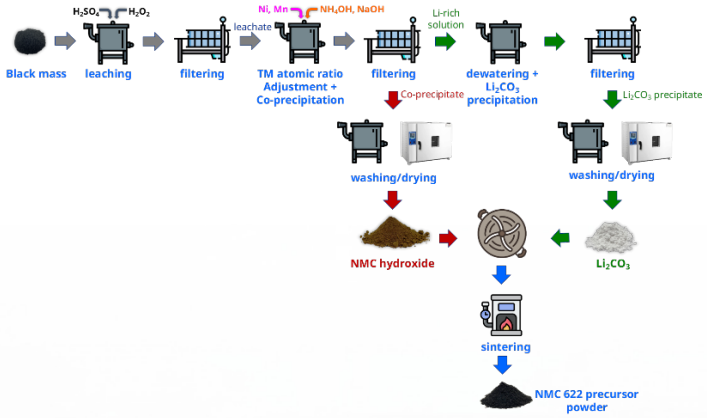



Figure 1: Extraction of critical metals from black mass and subsequent synthesis of precursors for Li-ion cathode materials

# Electroactive Materials for Sustainable Energy: From basic Research to Applications



Hyacinthe Randriamahazaka

*ITODYS, CNRS, Printup Institute, Université Paris Cité, Paris, 75006, France*

*Corresponding Author's E-mail: hyacinthe.randria@u-paris.fr, hyacinthe.randria@gmail.com

**Abstract**

Energy is at the heart of our society and civilization. Nowadays, the energy sustainability is crucial to support our future development. In this context, the materials properties play key roles in the various aspects of the energy storage and energy conversion [1-5]. Particularly, it is the case of the electrocatalytic processes such oxygen evolution reaction (OER), oxygen reduction reaction (ORR), hydrogen evolution reaction (HER) and chorine evolution reaction (CER) which involve many electrochemical and chemical steps. Indeed, the materials properties determine the performance of the electrochemical energy storage devices such as supercapacitors and batteries. Herein, I present our recent works on the electroactive materials for energy applications such as the electrocatalytic water oxidation [6-7], oxygen reduction [8], hydrogen evolution processes [9], chlorine evolution reaction [10], and quasi-solid flexible supercapacitors [11]. I will present some remaining challenges to bridge the gap between the academic research and industrial applications.

**Keywords:** Electrocatalysis, mechanisms, energy storage.

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# Laser Surface Engineering Magnesium and its Alloys for Improved Corrosion Resistance



Jyotsna Dutta Majumda[r*]

*Dept. of Metall. & Maters. Engg., Indian Institute of Technology Kharagpur, West Bengal-721302, India*

*Corresponding Author, e-mail: jyotsna@metal.iitkgp.ac.in, duttamajumdarjyotsna@gmail.com

**Abstract**

Magnesium and its alloys have a wide range of applications in the electronics sector, primarily as casings in smartphones, laptops, and tablets due to its exceptional strength-to-weight ratio, thermal conductivity, and electromagnetic shielding capabilities and heat-dissipation components. However, the lifetime of magnesium and its alloys when used as components in different sectors, faces the challenges of premature failure due to its poor corrosion resistance and hydrogen evolution from the surface exposed to aqueous environment. The kinetics of corrosion and hydrogen evolution is influenced by surface microstructure and composition. A large number of magnesium-based alloys are developed to improve their corrosion resistance and to reduce hydrogen evolution. Surface engineering refers to the tools that are used to modify the microstructure and/or composition of the near-surface region of a finished component for improving the properties that are surface-dependent. As corrosion and hydrogen evolution start from the surface only, it may be controlled by tailoring the surface microstructure and composition, by the application of surface engineering tools, which is an economical, materials and energy-saving one. Among all surface engineering tools, laser surface engineering refers to modifying microstructure and/or composition of the near-surface region of any component using a laser as a source of heat. In the past, laser surface melting has been extensively applied for microstructural modification of magnesium-based alloys to improve its corrosion resistance. Microstructural and compositional modifications of the surface may be achieved by surface alloying by laser melting of the alloying elements (delivered through a nozzle or pre-deposited on the substrate surface) and part of the underlying substrate to develop an alloyed zone confined to the surface of a substrate. The compositional modification of the surface may be achieved by laser surface cladding. In the present contribution, with a brief introduction to different laser surface engineering techniques, the application of laser surface melting and alloying on corrosion resistance and hydrogen evolution rate would be discussed in details. Finally, the future scope of research in this direction would be stated.

**Keywords:** Magnesium and its alloys, surface engineering, corrosion, hydrogen evolution.

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**Reference:**

Gray, J.E. and Luan, B. (2002) Protective Coatings on Magnesium and Its Alloys—A Critical Review. Journal of Alloys and Compounds, 336, 88-113. http://dx.doi.org/10.1016/S0925-8388(01)01899-0

# Design of Novel Electro-Catalysts for the Cost-Effective Generation of Hydrogen



Kandalam V. Ramanujachary

*Department of Chemistry and Biochemistry, 201 Mullica Hill Road Rowan University Glassboro, NJ, 08028, USA*

*Corresponding Author's E-mail: chary@rowan.edu

**Abstract**

The rapid depletion of non-renewable fossil resources is posing an imminent threat to the energy and supply of fine chemicals that are vital to the global economy. Currently, efforts are underway at an accelerated pace to develop technologies that would help us address the disastrous consequences. We have been working in the areas of biomass conversion to renewable fuels/chemicals as well as the production of hydrogen through the electrocatalytic splitting of water using non-noble metals. In both areas, there is a dire need to develop cost-effective materials to increase process efficiency. We have been exploring the use of anionically modified molybdenum oxides and phosphides for the efficient splitting of water in both acidic and alkaline conditions. The presentation will summarize our findings and the opportunities for exploring inorganic materials for the production of value-added chemicals and fuels.

**Keywords:** Hydrogen, Novel Electrodes, Electro-catalysis, Phosphides

# Advanced Materials Characterization of Environmental Materials



Chanchana Thanachayanont

*National Metal and Materials Technology Center (MTEC), National Science and Technology Development Agency, 114 Thailand Science Park, Paholyothin Rd., Klong 1, Klong Luang, Pathumthani 12120, Thailand*

*Corresponding Author's E-mail: chanchm@mtec.or.th

**Abstract**

As the world accelerates commitments under the Paris Agreement, the UN Sustainable Development Goals, and emerging net-zero policy frameworks, the development and deployment of advanced environmental materials has become a scientific and industrial imperative. Advanced materials characterization plays a foundational role in this endeavor, bridging the gap between atomic-scale structure and macroscopic performance to enable rational design of materials for environmental remediation, water treatment, air quality management, circular economy, and clean energy applications.

This talk highlights the critical significance of advanced materials characterization in understanding the structure-properties-performance relationships of environmental materials. Without comprehensive characterization, the design and optimization of functional materials — whether metal oxides for photocatalytic water purification, biochar for carbon sequestration and pollutant adsorption, or hybrid electrode materials for electrochemical sensing — remains largely empirical. Characterization provides the mechanistic insight necessary to move from trial-and-error synthesis to knowledge-driven materials engineering.

A suite of complementary characterization techniques is discussed in the context of environmental materials research. Transmission Electron Microscopy (TEM) and Scanning Electron Microscopy (SEM), including energy-dispersive X-ray spectroscopy (EDS) mapping, provide nanoscale and microstructural imaging of active phases, interfaces, and defect structures. X-ray Diffraction (XRD) and Selected-Area Electron Diffraction (SAED) elucidate crystal structure, phase purity, and crystallinity — parameters directly linked to catalytic and adsorptive performance. Surface area and pore size analysis via BET and porosimetry characterize the accessible active surface critical for adsorption and catalysis. X-ray Photoelectron Spectroscopy (XPS) and synchrotron-based techniques reveal surface chemistry, oxidation states, and electronic structure, providing insight into reaction mechanisms at material interfaces. Electrochemical characterization methods, including cyclic voltammetry and electrochemical impedance spectroscopy (EIS), are indispensable for assessing the performance of sensor electrodes and energy-harvesting devices.

Selected case studies drawn from ongoing research programs will illustrate how multi-technique characterization strategies have guided the development of materials for heavy metal sensing, pesticide detection, photocatalytic water treatment, and biochar-based carbon capture. These examples demonstrate that a holistic characterization approach — correlating structural, compositional, and functional data across multiple length scales — is essential for accelerating the translation of advanced environmental materials from laboratory innovation to real-world deployment in support of global sustainability goals.

**Keywords:** materials characterization, environmental materials, transmission electron microscopy, photocatalysis, electrochemical sensors, net-zero, circular economy

# Small-scale deformation and insitu characterization of advanced ceramic materials: from high entropy oxides to additively manufactured ceramics



Ravi Kumar[a,*]

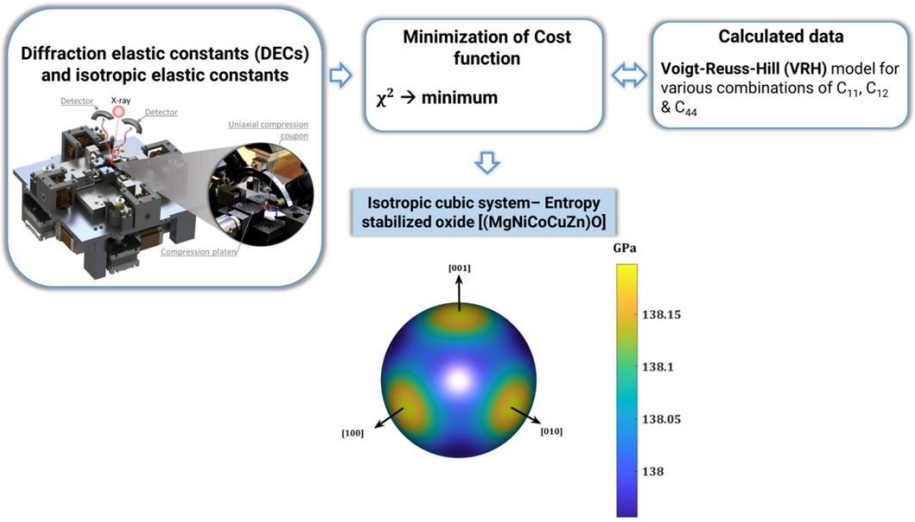
[a]*Laboratory for High Performance Ceramics, Department of Metallurgical and Materials Engineering, School of Sustainability, Indian Institute of Technology Madras (IIT Madras), Chennai 600036, India*

*Corresponding Author's E-mail: xxx@yyy.zzz

**Abstract**

In this presentation, we present a robust micromechanical approach based on the Voigt-Reuss-Hill model to estimate Single Crystal Elastic Constants (SECs) from polycrystalline ceramic materials. This method requires only two diffraction elastic constants and isotropic elastic constants for materials with cubic symmetry. Experimental investigations were made using a custom-built small-scale mechanical testing set-up. Validation using phase-pure nickel showed excellent agreement with literature values, with a maximum deviation of 8.8 % for $C_{12}$. Applying the methodology to [(MgNiCoCuZn)O], the calculated SECs were: $C_{11}$ = 219 GPa, $C_{12}$ = 116 GPa and $C_{44}$=51 GPa. This study not only introduces a reliable and straightforward methodology for SEC estimation for cubic materials but also provides the first experimental SEC values for [(MgNiCoCuZn)O] entropy-stabilized oxides under ambient conditions.

In the second part of my talk, we present our recent work on the influence of print orientation and sintering temperature on the microstructure and mechanical performance of fused filament fabricated alumina using miniaturized mechanical testing, whose versatility enables high-throughput studies across different print orientations. A post-debinding precursor infiltration step resulted in increased density to ≈98.8%, producing nearly pore-free microstructures and increased mechanical properties.




**Keywords:** small-scale deformation, in situ characterization, additive manufacturing

# Advanced Characterization of ZrN Thin Films for Durable and High-Sensitivity Surface Enhanced Raman Substrate (SERS)

Annop Klamchuen[a,*], Winadda Wongwiriyapan[b], Nguentra Sucheewa[b], Narathon Khemasiri[b], Jiti Nukeaw



[a]*National Nanotechnology Center (NANOTEC) NSTDA 111 Thailand Science Park, Paholyothin Rd., Klong Nueng, Klong Luang,Pathum Thani 12120, Thailand*
[b]*College of Materials Innovation and TechnologyKing Mongkut's Institute of Technology Ladkrabang (KMITL) Chalongkrung Rd., Ladkrabang, Bangkok 10520, Thailand*

*Corresponding Author's E-mail: annop@nanotec.or.th

**Abstract**

Transition metal nitrides have emerged as promising alternatives to noble metals for plasmonic applications; however, achieving high-performance surface-enhanced Raman spectroscopy (SERS) requires a comprehensive understanding of the interplay between composition, crystallinity, and electronic structure. In this work, zirconium nitride (ZrN) thin films are systematically engineered via reactive gas-timing (RGT) rf magnetron sputtering and extensively investigated through advanced characterization techniques to elucidate the origin of their plasmonic activity. Grazing-incidence X-ray diffraction (GIXRD) reveals the evolution of crystallographic texture, highlighting the critical role of (200)-oriented growth. X-ray photoelectron spectroscopy (XPS) and Auger electron spectroscopy (AES) provide quantitative insights into non-stoichiometric composition and bonding states, while spectroscopic ellipsometry (SE) coupled with Drude–Gaussian modeling deciphers the dielectric response and localized surface plasmon resonance (LSPR) behavior. Nanoscale electrical heterogeneity, probed by conductive atomic force microscopy (C-AFM), uncovers the formation of discrete conductive domains that act as plasmonic hotspots. These correlated structural, chemical, optical, and electronic characteristics govern the SERS performance, yielding an enhancement factor of $1.24 \times 10^6$ with excellent signal uniformity comparable to optimized Au SERS thin films. Furthermore, the ZrN substrates demonstrate outstanding durability, including reusability over 30 cycles and stability beyond 6 months, attributed to their robust mechanical and chemical properties. This study establishes a direct structure–property–function relationship in ZrN and provides a comprehensive framework for designing high-performance, durable plasmonic materials beyond noble metals.

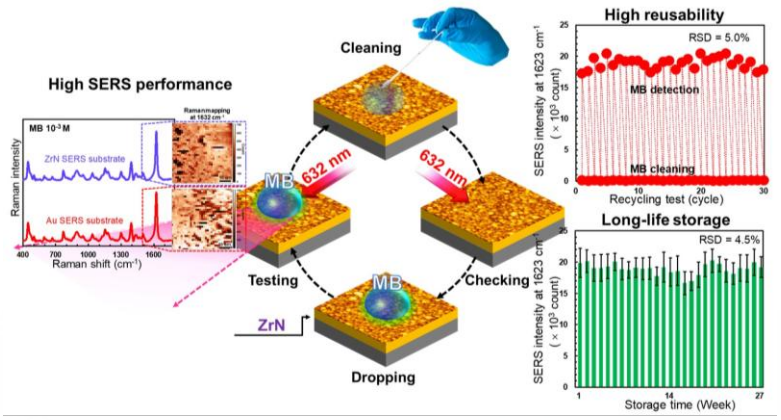



Fig.1 Reusable and long- life time ZrN SERS thin film compared with optimized Au thin film

**Keywords:** Transition metal nitrides, Surface enhanced Raman spectroscopy Localized surface plasmon resonance (LSPR) and Advanced thin film characterization

# Spin Probe for Spintronics



Chanyong Hwang[a,*]

[a]*Korea Research Institue of Standards and Science, Daejeon 34113, Republic of Korea*

*Corresponding Author's E-mail: cyhwang@kriss.re.kr

**Abstract**

Recent advances in spin-related phenomena have significantly accelerated the development of spin-based electronics, widely known as spintronics. Unlike conventional microelectronics, which primarily exploits the charge of electrons, spintronics utilizes the intrinsic spin degree of freedom and associated magnetic moments, enabling novel functionalities such as non-volatility, ultra-low power operation, and high-speed information processing. Furthermore, the field has recently expanded toward quantum regimes, where coherent spin manipulation and quantum spin interactions open new opportunities for quantum spintronics and next-generation information technologies.

Over the past decade, we have developed and optimized several advanced experimental probes for the characterization and visualization of spin systems across multiple length and time scales. These techniques have enabled direct observation of spin textures, magnetic dynamics, and spin-dependent interactions in a wide range of magnetic materials and spintronic devices.

The first technique is scanning electron microscopy (SEM) for spin characterization. Spin-polarized SEM has a long history originating from Mott spin detectors developed several decades ago. However, conventional Mott detectors suffer from low efficiency, limiting their practical application for high-resolution spin imaging. To overcome this limitation, we adopted an exchange-scattering-based spin detector, which has been extensively utilized in spin- and angle-resolved photoemission spectroscopy (spin-ARPES). This approach significantly improves spin detection efficiency and enables real-space spin imaging with enhanced sensitivity and spatial resolution. Using this system, we successfully investigated various magnetic phenomena ranging from nanoscale magnetic domains in spintronic materials to magnetic structures in conventional electrical steel systems. The second characterization method is Brillouin light scattering (BLS), which is a powerful spectroscopic technique for probing spin waves, phonons, and magnetization dynamics. Through BLS measurements, we investigated several intriguing spin-related phenomena. One important example is the handedness transition in ferrimagnetic materials, where the chirality of spin precession changes depending on magnetic compensation conditions and spin configurations. Another example is the observation of chiral phonons, which have recently attracted considerable interest due to their coupling with spin angular momentum and potential implications for spin-lattice interactions and quantum information systems. These studies provide deeper understanding of angular momentum transfer mechanisms and dynamic spin-phonon coupling in complex magnetic systems. Lastly, we introduce magneto-optical Kerr effect (MOKE) microscopy, one of the most widely used optical techniques for studying magnetic materials and spin textures. MOKE microscopy allows direct visualization of magnetic

domain evolution under external stimuli such as magnetic field and electrical current. Using this technique, we have extensively studied magnetic skyrmions, which are nanoscale topological spin structures considered promising candidates for future low-power spintronic devices. Our work includes the generation, manipulation, transport, and deletion of skyrmions under various electrical and magnetic conditions. In addition to fundamental studies, this technique has recently been extended to industrial-scale applications, particularly for the inspection and characterization of 12-inch wafer magnetic thin-film systems. Such capability is highly important for large-scale manufacturing and process monitoring in spintronics industries, including MRAM and probabilistic computing hardware platforms.

Overall, these advanced spin characterization techniques provide comprehensive experimental platforms for understanding spin-dependent phenomena from fundamental physics to industrial device applications. They play an increasingly important role in the development of next-generation spintronic, quantum spintronic, and probabilistic computing technologies.

# Interface Study and Charge Carrier Dynamics in 2D-3D Heterostructured Mixed-Cation Lead Mixed Halide $FA_{0.75}Cs_{0.25}Pb(I_{0.77}Br_{0.23})_3$ Perovskite



Amos Milimo Nalianya[a,b,c]*, Henry Barasa[a], Miller Shatsala[a,d], Victor Odari[a,c]

[a].*Department of Physics, Masinde Muliro University of Science and Technology, Kenya.*
[b].*Clarendon Laboratory, Department of Physics, University of Oxford, Oxford, UK.*
[c].*Imaging and Nanofabrication, Molecular Foundry; Lawrence Berkeley National laboratory.*
[d].*Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, CA, USA.*

*Corresponding Author's E-mail: amuoso@gmail.com

**Abstract**

Two-dimensional/three-dimensional (2D/3D) perovskite heterostructures offer a promising route to stable and efficient photovoltaics, yet their performance is limited by poor tolerance to ambient conditions. In this work, we address this challenge through controlled engineering of binary organic spacer cations at the atomic scale. To systematically investigate spacer effects, we compared three systems: divalent ethylene diammonium iodide (EDAI2), monovalent n butylammonium iodide (BAI), and the bulky chiral spacer S-Methylbenzylammonium Iodide (S MBAI) on $(FA_{0.75}Cs_{0.25}Pb(I_{0.77}Br_{0.23})_3$. This framework contrasted bidentate versus monodentate coordination and the steric impact of chirality. Comprehensive optoelectronic characterization (UV-Vis, PL, TRPL, EDS) indicate that the achiral EDAI2:BAI system consistently exhibited superior performance relative to both pristine 3D and chiral spacer films, delivering an optimized halide distribution, compact morphology, and extended carrier lifetimes. With this benchmark established, systematic variation of the EDAI2:BAI ratio (3:1, 1:1, 1:3) revealed that excess EDAI2 disrupted crystal growth, while higher BAI improved passivation but introduced pinholes. The equal ratio (1:1) achieved the best stability, with enhanced PLQE, smooth pinhole free morphology, and improved crystallinity sustained for ~1700 hours. Our results demonstrate the critical influence of spacer chemistry and ratio in regulating crystallization pathways, defect passivation, and charge carrier dynamics, establishing binary achiral spacers as the most effective route to stable, high performance 2D/3D perovskite heterostructures.

**Keywords:** Two-Dimensional perovskite (2D), Ethylene diammonium diiodide (EDAI2), n-butyl ammonium iodide (BAI), Passivation

# Commissioning and current status of High Energy Photon Source (HEPS)



Yuhui Dong[a,*]

[a]*Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, China*
*Particle Accelerators and Laser Technology Research Group,*
*Chiang Mai University, Chiang Mai, 50200, Thailand*

*Corresponding Author's E-mail: dongyh@ihep.ac.cn

**Abstract**

One of the important tends in the development of synchrotron radiation sources is low emittance. Low-emittance storage rings can provide higher brilliance and better coherence, which are very important for almost all kinds of experiments in synchrotron radiation facilities. The 4th generation synchrotron radiation facilities can provide 2 or 3 orders of higher brilliance and coherence comparing with 3rd generation ones. In the meantime, the successful construction of Shanghai Synchrotron Radiation Facility and the great achievements in the research in this facility, inspire the users to build the new and high-performance light sources in China. In the view point of regional factors, the vast in territory of China requires the reasonable distribution of synchrotron radiation facilities which support the scientific and technological research, in order to farthest satisfy the demands of users from different regions. Based on the above reasons, we are building a new synchrotron radiation facility in the region around Beijing: High Energy Photon Source (HEPS). The designed electron energy of HEPS is 6 GeV and the emittance is lower than 0.1 nmrad. This machine can provide hard X-rays with brilliance higher than 1022ph/s/mm2/mrad2/0.1%BW and photon energy higher than 300 keV. The construction of HEPS started in June 2019, including a 500MeV LINAC, a 6 GeV booster, a 1360 m- circumference storage ring, 14 public beamlines and 1 test optical beamline, as well as auxiliary facilities and building. Before the start-up of HEPS, the R&D project (HEPS-TF) was supported during 2016 - 2019. The Platform for Advanced Photon Source (PAPS) was supported in 2017 in order to provide a field for technology research and the assembling of instruments of HEPS. The installation of LINAC started in March 2022, commissioning in March 2023. In June 2023, the electron energy of LINAC reached 500 MeV, and the bunch charge reached 7 nC. The installation of booster started in August 2022, commissioning in July 2023. After 4 months of commissioning, the electron energy reached 6 GeV and bunch charge reached 5 nC, in November 2023. The installation of storage ring started in February 2023. In July 23, 2024, we started the commissioning of storage ring. Now the beam current can reach 100 mA and the emittance can reach 56.8 pmrad. The first synchrotron light from insertion device was first obtained in October 12, 2024.Totally 14 user beamlines and 1 test beamline were constructed in phase I. During the installation of storage ring, the front-ends of beamlines were installed in October 21, 2022. The first monochromator was installed in December 15, 2023. The commissioning of beamlines was started in September 2024. Now all beamlines have reached the key-performance-parameters (KPPs) and turned into operation phase. On October 29, 2025, HEPS passed the performance acceptance organized by the Chinese Academy of Sciences. A suite of world-class performance beamlines has been commissioned, such as state-of-the-art the hard X-ray imaging beamline and the structural dynamics beamline. Early experiments have fully demonstrated HEPS's exceptional capabilities: deep penetration, ultra-high brightness and coherence. HEPS is now poised to serve as a premier platform for original and innovative research across basic and engineering sciences and will open to global users in August 2026.

**Keywords:** High Energy Photon Source, Fourth-generation synchrotron radiation facility, Low-emittance storage ring, Synchrotron radiation

# From Nanofibres to Intelligent Systems: Advanced Functional Materials Powering AI-Driven Electronics and Digital Health Technologies

Norbert Radacsi[a,b,c,*]



[a]*School of Engineering, Institute for Materials and Processes, University of Edinburgh, Robert Stevenson Road, EH9 3FB, Edinburgh, UK*
[b]*School of Engineering, Institute for Bioengineering, University of Edinburgh, The King's Buildings, EH9 3JL, Edinburgh, UK*
[c] *Centre for Cardiovascular Science, The Queen's Medical Research Institute (QMRI), University of Edinburgh, BioQuarter, 47 Little France Crescent, Edinburgh, EH16 4TJ, United Kingdom*

*Corresponding Author's E-mail: n.radacsi@ed.ac.uk

**Abstract**

Electrospinning is a scalable technique for generating nanofibers with large specific surface areas and tunable electromechanical properties.[1] Owing to its ability to produce architectures that mimic the extracellular matrix, it has become a key platform for advanced biomaterials, wearable sensors, and bioelectronic interfaces.[2] However, electrospinning remains a highly nonlinear and sensitive process, where small variations in voltage, flow rate, humidity, or polymer concentration can dramatically alter fibre morphology. Traditionally operated in an open-loop mode, optimization relies heavily on empirical trial-and-error, limiting scalability and reproducibility.

In this keynote lecture, I will present recent advances in electrospinning and hybrid 3D fabrication strategies for producing functional nanofibrous systems, including solid-state lithium-ion batteries,[3] sponge-like 3D conductive scaffolds for physiological monitoring,[4] nanofiber-based sweat and strain sensors,[5] and piezoelectric structures for energy harvesting and sensing.[6] These materials form the foundation of next-generation wearable and AI-enabled electronic platforms. When integrated with wireless communication modules and distributed sensing networks, such systems provide a materials-level foundation for Internet of Things (IoT) architectures in healthcare and smart environments.

Beyond materials development, I will outline a new vision for intelligent nanomanufacturing. By integrating real-time fiber analysis and reinforcement-learning-based control, we can develop a closed-loop adaptive electrospinning system that continuously monitors fiber properties and autonomously adjusts processing parameters. This approach transforms electrospinning from a manually tuned process into a self-optimising, physics-informed manufacturing platform.

By bridging nanofiber engineering with adaptive machine intelligence, this work demonstrates how advanced functional materials can power AI-driven electronics, IoT-connected systems, and digital health technologies, paving the way toward autonomous fabrication systems and intelligent next-generation devices.

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**Keywords:** Electrospinning, Functional Nanomaterials, Sensing, Wearable Electronics, Intelligent Nanomanufacturing


IoT
Wearables
3D
Energy storage
Energy harvesting
Real-time
fiber analysis
Electrospinning

# Ultra-Low-Power AI through Analog In-Memory Computing



Yusuke Sakemi[a,b*]

[a]*Chiba Institute of Technology, 2-17-1 Tsudanuma, Narashino, Chiba, 275-0016, Japan*
[b]*The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, 113-8654, Japan*

* yusuke.sakemi@chibatech.ac.jp

**Abstract**

Recent AI systems demand enormous computational resources, and the associated power consumption has become a major bottleneck for practical deployment. Analog in-memory computing (AIMC) offers a promising route to ultra-high energy efficiency by performing computation directly within memory arrays. In this presentation, I will first compare conventional digital hardware, such as GPUs, with AIMC architectures (Fig.1). I will then introduce mathematical design methodologies for AIMC circuits that explicitly account for device and circuit nonidealities, including probabilistic/precise modeling, physical modeling, and hardware-in-the-loop training [1] (Fig.2). Finally, I will discuss recent trends in circuit implementation and future directions for ultra-low-power AI hardware [2].

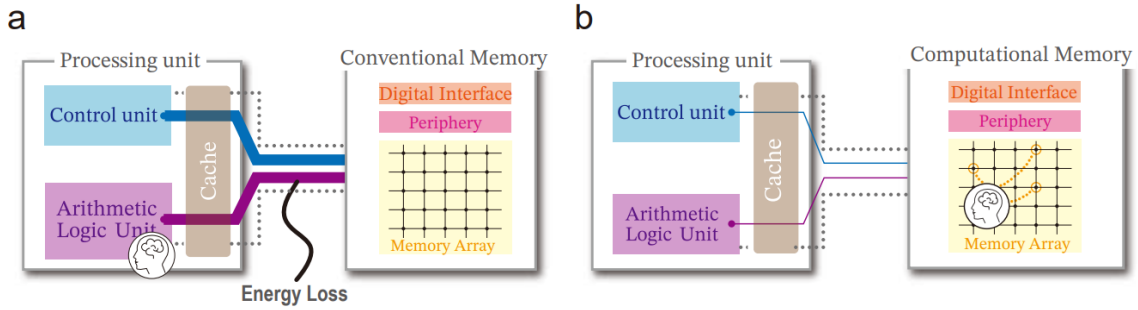



Fig. 1: Computer architectures. a: conventional architecture, b: AIMC architecture. Reproduced from [1].

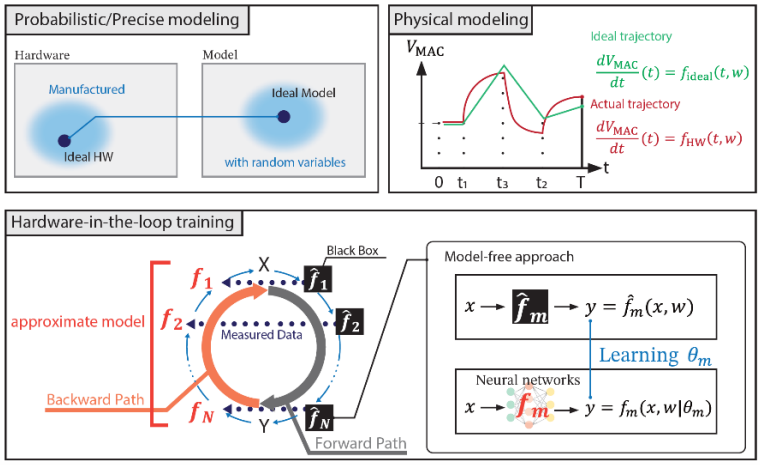



Fig. 2: Mathematical techniques for designing AIMC circuits. Reproduced from [1].

**Keywords:** analog in-memory computing, nonidealities, hardware-aware training, physical modeling

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# Machine learning-augmented DFT for computational design of energy materials

Lappawat Ngamwongwan[a], Poobodin Mano[b], Kwanchanok Kaewkwan[c], Keerati Keeratikarn[a], Ittipon Fongkaew[a], Suwit Suthirakun[c],*

[a]*School of Physics, Suranaree University of Technology, Nakhon Ratchasima, Thailand*
[b]*National Nanotechnology Center (NANOTEC), National Science and Technology Development Agency (NSTDA), Pathum Thani, Thailand*
[c]*School of Chemistry, Suranaree University of Technology, Nakhon Ratchasima, Thailand*

*Corresponding Author's E-mail: suthirak@sut.ac.th



**Abstract**

Accelerating the discovery of next-generation energy materials requires computational frameworks that are both physically rigorous and data-efficient. This talk presents how density functional theory (DFT) combined with machine learning (ML) can address key challenges across two classes of energy materials: battery anodes and hydrogen storage. For battery anodes, a systematic DFT screening of $M_2B_2$ MBene monolayers spanning 26 transition metals and four crystal phases was performed, where a consistent framework evaluating cohesive energy, phonon stability, electronic conductivity, and ion diffusion reduced the candidate pool by half. Electrochemical analysis identified two promising groups: Sc-, Ti-, and Y-based phases with high gravimetric capacity and low open-circuit voltage, and V-, Cr-, Mn-, and Fe-based phases with low diffusion barriers and moderate open-circuit voltages, with interpretable ML models further extracting key structural descriptors that govern these properties. For hydrogen storage, machine learning interatomic potentials (MLIPs) replace computationally expensive DFT calculations, enabling large-scale Grand Canonical Monte Carlo and molecular dynamics simulations to access thermodynamic and kinetic properties of magnesium-based hydrides, including hydrogen uptake, Pressure–Composition–Isotherm curves, diffusion coefficients, and activation barriers. Together, these works illustrate two distinct but complementary roles of ML in materials design: as an interpretability tool for extracting physical descriptors and as a computational accelerator for large-scale simulations.

**Keywords:** Density functional theory, machine learning interatomic potentials, MBene, energy materials

# Interpretable Machine Learning Mapping of the Defect-Induced Electronic Structure Continuum in Reduced $TiO_2$

Adriana Martinez-Oviedo[a,*], Cesare Ovando-Vazquez[b], Jose Tuxpan-Vargas[c]



[a] *División de Geociencias Aplicadas, Instituto Potosino de Investigación Científica y Tecnológica A. C., Camino a la presa San José 2055, C.P. 78216, San Luis Potosí, México.*
[b] *Centro Nacional de Supercomputo, Instituto Potosino de Investigación Científica y Tecnológica A. C., Camino a la presa San José 2055, C.P. 78216, San Luis Potosí, México.*
[c] *CONAHCYT, Investigadores por México, Av. Insurgentes Sur 1582, Col. Crédito Constructor, Demarcación Territorial Benito Juárez, C.P. 03940, Ciudad de México, México.*

*Corresponding Author's E-mail: adriana.martinez@ipicyt.edu.mx

**Abstract**

Defect engineering in titanium dioxide ($TiO_{2-x}$) induces significant modifications in electronic and optical behavior through the formation of oxygen vacancies, $Ti^{3+}$ centers, and localized electronic states. Although reduced $TiO_2$ is commonly categorized into discrete forms such as pristine, blue, or black $TiO_2$, its physicochemical properties evolve continuously across a defect-density spectrum. Here, we propose a physics-informed and interpretable machine learning framework capable of quantitatively describing the continuous evolution of electronic behavior in reduced $TiO_2$ systems.

A structured database is being developed by integrating first-principles defect calculations with curated experimental and literature-derived datasets containing oxygen vacancy concentration, $Ti^{3+}$ fraction, Urbach energy, optical absorption characteristics, and transport-related descriptors. Random Forest models combined with SHAP-based interpretability are employed to identify dominant defect descriptors, nonlinear transition regimes, and structure–property relationships governing the evolution of $TiO_{2-x}$ across different reduction states.

Particular emphasis is placed on understanding the role of defect-state band tailing, Fermi-level modulation, and localized electronic states in the optical band-gap narrowing observed in reduced $TiO_2$, which is often attributed primarily to intrinsic valence–conduction band collapse. The resulting defect–electronic mapping is expected to provide predictive insight into carrier transport, optical response, and disorder-driven electronic transitions in oxide semiconductors.

This work reframes reduced $TiO_2$ as a defect-modulated electronic phase continuum and demonstrates the potential of interpretable machine learning for the predictive design of defect-engineered functional oxide materials for energy and environmental applications.

**Keywords:** Oxygen vacancies, $Ti^{3+}$ centers, Machine learning, Electronic structure, Urbach energy

# Material Computation Devices for Physical Reservoir AI and Security Systems



Hirofumi Tanaka[a,b,*]

[a] *Research Center for Neuromorphic AI Hardware, Kyushu Institute of Technology (Kyutech), 2-4 Hibikino, Wakamatsu, Kitakyushu 8080196, Japan.*
[b] *Graduate School of Life Science and Systems Engineering, Kyutech, Japan.*

*Corresponding Author's E-mail: tanaka@brain.kyutech.ac.jp

**Abstract**

Recent advances in deep learning have significantly accelerated the development of artificial intelligence (AI). However, the rapidly increasing computational and memory demands of modern AI models have exposed fundamental limitations of conventional silicon CMOS technologies. As device miniaturization and energy efficiency approach their physical limits, alternative computing paradigms that exploit the intrinsic dynamics of physical systems have attracted growing attention. Among them, in-materio physical reservoir computing utilize nonlinear responses and collective phenomena emerging from materials to perform information processing with high energy efficiency [1–3]. Nanomaterials are attractive candidates for physical AI hardware because their complex network structures naturally exhibit nonlinear dynamics, memory effects, and stochastic behaviors that can be harnessed for computation [1,2,4]. In particular, self-organized nanocarbon networks provide rich physical reservoirs capable of transforming temporal information into high-dimensional representations while maintaining low power consumption and simple device architectures [5–8]. Recent studies have further demonstrated multifunctional carbon-based electronic devices that integrate sensing, memory, and computing functionalities within a single material platform [9–12]. We investigate nanomaterials as building blocks for next-generation AI hardware. Our research encompasses the design and fabrication of random network architectures [5–10], development of unconventional computing devices and system-level implementations [13–15], and their integration into embodied AI platforms. In parallel, we have established advanced robotic systems through participation in world-wide international competitions [10], providing practical testbeds for evaluating physical AI technologies in real-world environments. Here, we introduce representative nanomaterials and network architectures, discuss key functionalization strategies, and review recent progress toward robotic applications. Particular attention is given to a carbon nanotube (CNT) sponge-based tactile sensor integrated into a robot hand [16]. The device simultaneously performs sensing, memory storage, and on-sensor computation, demonstrating a promising route toward compact, low-power, and highly efficient AI hardware for future autonomous robotics and broader physical AI applications.

**Keywords:** Physical Reservoir; Random Network; In-materio computing; Physical AI; Chemical dynamics

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# Phase Segregation Effects in Conjugated Polymer Blends on the Performance of Organic Solar Cells



Benjamin Agyei-Tuffour [a,*]

[a]*Department of Materials Science and Engineering, School of Engineering Sciences, College of Basic and Applied Sciences, University of Ghana, Off Anne Jiaggi Road, Legon, Accra, Ghana*

*Corresponding Author's E-mail: bagyei-tuffour@ug.edu.gh

**Abstract**

This study employs a combination of experimental and computational methods to investigate the influence of quenching temperature on optical properties of organic photovoltaic materials (OPV's). The fabricated OPV's were quenched either at 200°C or initially cooled to 50, 100, 120, and 150°C before quenching. These samples were then characterized for their structural, microstructural, optical, and electrical properties. Also, the influence of PCBM particles sizes on optical properties were observed. Finite element analysis was used to predict and also confirm the influence of PCBM particle sizes on the multilayered OPVs. The results showed that lowering the quenching temperature i.e., 50°C and 150°C, improves the optical absorbance to 0.767 and 0.242 A.U respectively compared with the sample quenched at 200°C (~0.162 A.U). This was corroborated by the microstructural results where the samples quenched at lower temperatures were made up of many large aggregated needle-like PCBM particles which absorbs much light compared with the dot-like particle observed to be present in the sample quenched at higher temperatures. The results for changes in size of the PCBM particles as quenching temperature reduces was confirmed by the calculation of crystallite sizes from the XRD data. It was reported that, the sample quenched at lower temperatures, i.e., 50, 100, 120, and 150°C reported crystallite sizes 1871.3, 1839.3, 1834.5 and 1834.5 nm respectively compared with sample quenched at 200°C (~1810.4 nm). The results from the electrical analysis showed that, the best device performance was obtained from the sample quenched at 50°C with a PCE of 0.3674% and a Jsc of 6.515 [mA/cm2]. Finally, the influence of varying PCBM particle size on the stress distribution around the particles was modelled and the results showed that when the particle size was 0.01 mm, the upper film completely covers the particle and the maximum stress distribution is seen to be 0.99 MPa. Also, when the particle size increased, i.e., 0.01, 0.1, 0.2, 0.4, 0.6, and 1.0 mm, the upper film does not completely cover the particle and the maximum stress distribution increased with values of ~3.12, 4.64, 6.94, 6.96, and 7.50 MPa respectively. This implies that the size of the PCBM particle strongly affects the stress distributions and concentration, as well as creating gaps where light can transmit through the material, thereby improving the optical properties. This corroborates results from the optical properties where larger PCBM particles (100 nm) absorbed much light compared to smaller PCBM particles (5 nm).

**Keywords:** Conjugated Polymers, Bulk Heterojunctions, Quenching, Current-Voltage Characteristics, DFT calculations

# Bridging Fundamental Discovery and Scalable Engineering: A Translational Pathway for $TiO_2$-Based Photocatalytic Systems in Environmental Remediation



Wenbin Cao[a,*]

[a] *School of Materials Science and Engineering, University of Science and Technology Beijing, Beijing 100083, China*

*wbcao@ustb.edu.cn

**Abstract**

The scalable synthesis of high-efficiency visible-light photocatalysts is pivotal for mitigating global environmental challenges, yet practical deployment remains constrained by inherent bottlenecks such as limited light absorption, sluggish charge carrier migration, and nanoparticle aggregation. To overcome these barriers, we established a comprehensive strategy for the precision engineering of $TiO_2$-based materials, commencing with mechanistic investigations into hydrothermal formation and the tailored synthesis of anatase, rutile, and brookite through the regulation of $[Ti(OH)_h(H_2O)_{6-h}]^{4-h}$ monomers. By modulating electronic structures via $Mo^{6+}$ and $Fe^{3+}$ doping and designing hierarchical $TiO_2$/SnO p–n heterojunctions, we markedly augmented visible-light response and facilitated efficient charge separation. Transitioning from laboratory breakthroughs to industrial realization, we overcame critical technical barriers in large-scale production and dispersion stability by eliminating residual ammonium ions to formulate highly stable $TiO_2$ sols. This enabled the establishment of kilogram-scale production capabilities, demonstrated by a Mo-$TiO_2$ catalyst with a 4.8-fold enhancement in benzene degradation. These advancements have translated into the successful pilot-scale application of functional photocatalytic coatings in diverse public environments, including offices, schools, and hospitals, providing a high-performance, scalable platform for gas-phase pollutant degradation and microbial sterilization that effectively bridges the trajectory from fundamental research to sustainable environmental remediation.

**Keywords:** Photocatalysis; $TiO_2$-based nanomaterials; Large-scale preparation; pollutant degradation

# Upcycling of Metal and Plastic Wastes into Functional MOFs for $CO_2$ Adsorption and Pollution Mitigation



Paiboon Sreearunothai*

*Functional Advanced Materials Engineering Research Center (FAME), School of Integrated Science and Innovation (ISI), Sirindhorn International Institute of Technology (SIIT), Thammasat University, Thailand*

*Corresponding Author's E-mail: paiboon@siit.tu.ac.th

**Abstract**

The development of circular material systems that enable the valorization of heterogeneous waste streams into functional materials remains a critical challenge in sustainable materials science. This work reports a dual-waste upcycling strategy for the synthesis of metal–organic frameworks (MOFs) using metal-containing industrial residues (e.g., metal plating sludge and dross) as metal sources and polyethylene terephthalate (PET) from various waste sources as an organic linker precursor. Through microwave and solvothermal-assisted processes, terephthalic acid (TPA) recovered from PET depolymerization is coordinated with aluminum species derived from waste streams to produce TPA-based MOF structures.

The resulting materials exhibit Brunauer–Emmett–Teller (BET) surface areas of up to ~600–1000 $m^2\ g^{-1}$ and demonstrate effective performance in both gas- and liquid-phase applications. In some waste streams, the $CO_2$ adsorption capacities can be up to ~1.5–2.5 mmol $g^{-1}$ at ambient conditions, while aqueous-phase removal of model organic pollutants (e.g., nitrobenzene) exceeds 95% under representative conditions. Notably, materials synthesized from waste-derived precursors show comparable or enhanced performance relative to those produced from commercial reagents, which is attributed to the presence of structural defects and residual impurities that act as additional adsorption or catalytic sites.

These findings suggest that high-purity precursors are not a prerequisite for functional performance in environmental applications, particularly where material stability and leaching are controlled. The study further examines the influence of synthesis conditions, waste composition, and post-treatment on material properties, as well as limitations related to yield, reproducibility, and scalability.

Overall, this work demonstrates a viable pathway for converting low-value and hazardous waste streams into functional porous materials for pollution mitigation and carbon capture. It provides insights into defect-engineered materials derived from non-conventional feedstocks and highlights key considerations for advancing waste-to-material strategies toward practical implementation within a circular economy framework.

**Keywords:** waste PET, multilayer plastic bag, magnetic MOFs, $CO_2$ adsorption, advanced oxidation

# Cellulose-Enabled Multifunctional Material Systems



Zoubeida Ounaies

[a]*Department of Mechanical Engineering, The Pennsylvania State University, University Park, PA*
[b]*Convergence Center for Living Multifunctional Material Systems, The Pennsylvania State University, University Park, PA*

*Corresponding Author's E-mail: zxo100@psu.edu

**Abstract**

Nature offers extraordinary examples of hierarchical multifunctional materials in which nanoscale organization gives rise to adaptive mechanical, optical, and electromechanical behavior. Plant cell walls, composed of cellulose fibrils organized across multiple length scales, are particularly compelling biological systems that combine lightweight architectures, anisotropic mechanics, transport functionality, and environmental responsiveness. Inspired by these natural systems, cellulose nanostructures such as cellulose nanocrystals (CNCs) and nanofibrillated cellulose have emerged as sustainable building blocks for next-generation hierarchical composites with tunable multifunctional properties. This presentation discusses recent advances in cellulose nanostructure-based hierarchical composites with emphasis on the interplay between nanoscale ordering, interfacial interactions, and emergent electromechanical and anisotropic behavior. Particular focus is placed on field-directed assembly approaches, including electric and magnetic field alignment, liquid crystalline self-organization, and advancede manufacturing strategies that enable controlled orientation of cellulose nanostructures within soft polymer matrices. These approaches create bioinspired architectures capable of exhibiting anisotropic dielectric, triboelectric, piezoelectric-like, optical, and mechanical responses.
The talk will discuss emerging opportunities at the convergence of sustainable materials, multifunctional composites, and bioinspired systems engineering. By leveraging cellulose as both a structural and functional nanoscale building block, hierarchical composites can move beyond conventional passive materials toward living and adaptive material systems capable of sensing, responding, and interacting dynamically with their environment. The work aligns strongly with current efforts in environmentally friendly processing, sustainable advanced materials, and multifunctional electronic materials.

**Keywords:** cellulose nanostructures, hierarchical composites, electromechanical coupling, bioinspired materials.

# Metallurgy for A Sustainable Future – Development of a New Method of Impurity Removal for Up-grading Recycling of Aluminum



Hideki Ono[a,*], Kengo Kato[a]

[a]*Department of Materials Science and Engineering, Faculty of Sustainable Design, University of Toyama, Toyama, Japan*

*Corresponding Author's E-mail: ono@sus.u-toyama.ac.jp

**Abstract**

The smelting of primary aluminum from ore requires a large amount of electricity, whereas recycling aluminum scrap consumes significantly less energy. Consequently, aluminum recycling is a critical issue for achieving carbon neutrality. Recycled aluminum contains not only the alloying elements originally present in the scrap but also various impurities introduced during the collection and recovery processes. As a result, recycled aluminum is currently used mainly for cast alloys, which can tolerate higher impurity levels.

To further increase aluminum recycling rates, it is essential to recycle aluminum scrap into wrought aluminum alloys. However, major alloying and impurity elements in aluminum—such as Si, Mn, Fe, Ni, Cu, and Zn—are difficult to remove using conventional pyrometallurgical processes. Therefore, the development of new methods to remove impurities or suppress their harmful effects on aluminum alloys is required to enable the up-grading recycling of aluminum scrap into high-performance wrought aluminum alloys. The concept of up-grading aluminum recycling is illustrated in Fig. 1.

In this study, a method for removing Fe and Si from aluminum using extraction and phase separation with a molten tin bath was investigated. At 873 K, while aluminum is soluble in molten tin, silicon and iron exhibit very low solubility. By exploiting the differences in solubility of Al, Fe, and Si in molten tin, aluminum can be selectively extracted into the tin bath from an Al–Fe–Si alloy, while Fe and Si precipitate and can be separated via phase separation.

Experiments were conducted to evaluate the effectiveness of this removal method. Precipitates of Si and $Al_3Fe$ were observed in the upper region of the sample, whereas these phases were not detected in the bulk Al–Sn alloy. The concentrations of Fe, Si, and Al in the Al–Sn alloy were quantified using ICP-AES analysis, and the results confirmed the effectiveness of the proposed method for removing Fe and Si from aluminum.

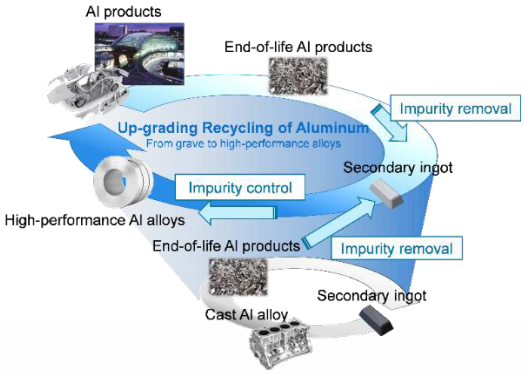



Fig .1 Concept of upgrade recycling of Al with new methods for removing impurities and suppressing their harmful effect on Al alloy

**Keywords:** Al recycling; Iron removal; Silicon removal; Extraction; Phase Separation

# Comparative Assessment of Thermal and Mechanical Recycling Pathways for End-of-Life Crystalline Silicon Photovoltaic Panels: Material Recovery Quality, Economic Feasibility, and Valorization Potential



Ubonwan Khopongpaiboon[a,*], Sakprayut Sinthupinyo[b]

[a]*Innovation and Technology, SCG Cement Co. Ltd., 51 Moo 8, Tub Kwang, Kaeng Khoi, Saraburi 18260, Thailand*
[b]*Innovation and Technology, SCG Cement Co. Ltd., 51 Moo 8, Tub Kwang, Kaeng Khoi, Saraburi 18260, Thailand*

*Corresponding Author's E-mail: ubonwank@scg.com

**Abstract**

The rapid expansion of photovoltaic (PV) deployment is expected to generate a substantial volume of end-of-life (EoL) solar panels, creating an emerging challenge for waste management, resource security, and circular economy development. Effective recycling strategies are therefore essential not only to reduce environmental burdens but also to recover valuable materials from discarded PV modules. This study presents a comparative assessment of thermal and mechanical recycling processes for end-of-life crystalline silicon photovoltaic panels, focusing on material recovery quality, impurity levels, economic feasibility, process scalability, and the valorization potential of recovered materials.

Thermal recycling was applied through controlled heat treatment to decompose polymeric encapsulants, particularly ethylene-vinyl acetate (EVA), enabling more effective separation of glass, silicon cells, metallic contacts, and back-sheet materials. The results indicate that thermal treatment produces cleaner recovered fractions with lower organic contamination, making them more suitable for high-value applications such as advanced material synthesis, metallurgical recovery, construction materials, and industrial reuse. However, the process is constrained by high energy consumption, increased operating costs, and potential emission control requirements, which may limit large-scale commercial adoption.

Mechanical recycling, based on crushing, grinding, sieving, and physical separation, offers a more cost-effective and scalable alternative due to its lower energy demand and operational simplicity. Nevertheless, mechanically recovered materials typically contain higher levels of residual EVA, polymer fragments, mixed glass, and fine metallic impurities, reducing their direct applicability in high-value material recovery routes.

Overall, this study demonstrates a clear trade-off between material quality and process economics. Thermal recycling offers superior recovery quality and valorization potential, while mechanical recycling provides stronger commercial scalability. A hybrid recycling strategy combining mechanical pre-processing with targeted purification or selective thermal treatment may provide the most practical pathway toward sustainable and economically viable PV waste management.

**Keywords:** End-of-life photovoltaic panels; crystalline silicon solar modules; PV recycling

# Deep Neural Network in Integrated Photonic Architecture



Leong Chuan Kwek

*Nanyang Technological University and National University of Singapore*

Corresponding Author's E-mail: cqtklc@nus.edu.sg

**Abstract**

The growing computational demands of classical neural networks have intensified the search for energy-efficient and powerful computational alternatives. Quantum neural networks (QNNs) implemented on integrated photonic platforms present a compelling reason, offering enhanced computational power with inherent programmability and scalability of integrated architecture. Here, we briefly sketch some of our work in this area.

**Keywords:** Neural networks, Alternatives, Programmability, Integrated architecture.

# $Cu_2Se$-based Hierarchical Composites through Nanoscale Engineering



Pierre F.P. Poudeu[a,*]

[a]*Laboratory for Emerging Energy and Electronic Materials ($LE^3M$), Department of Materials Science and Engineering, University of Michigan, Ann Arbor, MI, 48109, USA*

*Corresponding Author's E-mail: ppoudeup@umich.edu

**Abstract**

$Cu_2Se$-based materials are promising thermoelectric (TE) materials due to their decent electrical properties and intrinsically low thermal conductivity owing to the liquid-like behavior of Cu ions in β-$Cu_2Se$. However, the superionicity of Cu ions also lead to poor chemical stability, which along with the structural instability arising from the drastic volume change at the α to β transition temperature, have hampered successful deployment of $Cu_2Se$-based materials into TE power generation devices. Although composite strategy has proven to be an effective approach to tune transport properties, poor engineering of the nanoscale interfaces between the $Cu_2Se$ matrix and the selected inclusion phase often diminished its capacity to optimize electrical properties. Here, we show that the mutual hierarchical integration of heavily doped p-$Cu_2Se$ with semiconductors such as p-$CuMSe_2$ (M = In, Ga) and p-$Cu_4TiSe_4$ enables the engineering of electronic defects distribution within the resulting composites. By leveraging native defects in $Cu_2Se$, $CuMSe_2$, and $Cu_4TiSe_4$ phases, we demonstrate careful tunability of the concentration and energy distribution of active electronic defects in bulk hierarchical (1-x)$Cu_2Se$-(x)$CuMSe_2$(CMS) and (1-x)$Cu_2Se$-(x)$Cu_4TiSe_4$ (CTS) composites. We found that the carrier density in CMS composites decreases with increasing $CuMSe_2$ content, reaching a minimum at x = 0.45 before suddenly increasing near equimolar composition, which is attributed to shallow defects hybridization within the bandgap of the composites. Conversely, the carrier density in CTS composites increases upon incorporation of the $Cu_4TiSe_4$ phase, which is attributed to type-I band alignment at the $Cu_2Se$/$Cu_4TiSe_4$interface. These findings indicate that coexisting "active" electronic defects are distributed over a broad energy range in bulk hierarchical CMS and CTS composites, consistently with nondegenerate behavior. This finding is not consistent with the degenerate semiconducting behavior from the temperature dependent electrical conductivity. In this talk, I will discuss these results, emphasizing the correlations between microstructure, electronic band alignment, and electronic transport properties.

**Keywords:** Polymorphism, nanostructuring, thermoelectric, chalcogenides, dynamic doping

# Key Essential Governing Factors behind Materials Properties for Data Science and AIs



Masato Yoshiya

*Division of Materials and Manufacturing Science, Graduate School of Engineering, University of Osaka*

*Corresponding Author's E-mail: yoshiya@mat.eng.osaka-u.ac.jp

**Abstract**

While data science has driven solid materials exploration to new stages, possibly further assisted by AIs, it still remains immature, limited only to the one with perfect crystals with some fluctuations in compositions or point defects. One of the primary reasons behind it is that our understanding of the mechanisms behind materials properties or key essential governing factors needed for data science remains conventional or phenomenological, disconnecting quantum materials from conventional materials. A good example is practical materials with ubiquitous crystal lattice defects including 0D defects like impurity atoms and atomic vacancies, 1D defects like dislocations and 2D defects like grain boundaries and interfaces.

It is well known that phonon thermal conductivity, which becomes increasingly crucial for downsized semiconductor devices and also for quantum materials, can be significantly altered by the lattice defects. The theory to elucidate physics behind it has been tabulated in a pioneering review article by Klemens in 1958 and it is still widely used today. However, experimental studies, especially in this century, have revealed that newly-found materials do not obey the theory and thus additional elucidations become necessary, though they remain phenomenological or they are specific only to the target materials. Specifically for thermal conductivity of materials, variations in thermal conductivity are attributed only to "anharmonicity" of phonons without details, disabling us to further exploring materials. Electronic and atomic level computations ab initio calculations, lattice dynamics and molecular dynamics calculations provide key information for it.

In this keynote talk, discussion will be focused on information that has been missing and we can easily acquire if we use computational approaches without relying on existing theories, to connect explorations of conventional materials and quantum materials, based on concurrent data science and emergent AIs.

# Molecular electron conductivity in open-shell systems and their applications

Yasutaka Kitagawa[a,b,c,d,e*]



[a] *Graduate School of Engineering Science, The University of Osaka.*
[b] *Center for Quantum Information and Quantum Biology (QIQB), The University of Osaka.*
[c] *Research Center for Solar Energy Chemistry (RCSEC), Graduate School of Engineering Science, The University of Osaka.*
[d] *Innovative Catalysis Science Division, Institute for Open and Transdisciplinary Research Initiatives (ICS-OTRI), The University of Osaka.*
[e] *Spintronics Research Network Division, Institute for Open and Transdisciplinary Research Initiatives (OTRI-Spin), The University of Osaka.*

*Corresponding Author's E-mail: kitagawa.yasutaka.es@osaka-u.ac.jp

**Abstract**

Microfabrication technology for integrated circuits has been developed according to Moore's Law. However, it has been suggested that the miniaturization of silicon (Si)-based devices is approaching its physical limit. As an alternative to this "top-down approach," the use of single molecules for electronic components has attracted considerable attention as a "bottom-up approach". Molecular electronics is a field that aims to use single molecules as electronic components. The first idea of assembling electronic devices from atoms or molecules using a bottom-up approach was proposed by von Hippel in 1956.[1] Current interest in molecular electronics originated from the theoretical proposal of a molecular rectifier by Aviram and Ratner in 1974.[2] Since the proposal of the molecular rectifier, various functional single-molecule components, such as molecular wires, transistors, switches, and diodes, have been proposed. To realize such single-molecule components, we focus on the open-shell nature of the molecules. For example, our group proposed that certain extended metal atom chains (EMACs) can be used as single-molecule transistors controlled by an external magnetic field.[3-5] Furthermore, we also suggested that the open-shell nature is crucial for designing molecular circuits by integrating single-molecule components. For example, the total current in a molecular circuit is affected by the spin polarization of the system.[6] In this presentation, we illustrate the simulated difference in the I-V characteristics between the spin states of diradical $Ni_5$ EMACs, as shown in Figure 1(a). Subsequently, we focus on the electrical conductivity of [18]annulene derivatives (Figure 1(b)) as the simplest example of a molecular parallel circuit to demonstrate the relationship between diradical character and quantum interference.

**Keywords:** electron conductivity, single-molecular device, molecular circuit, open-shell system

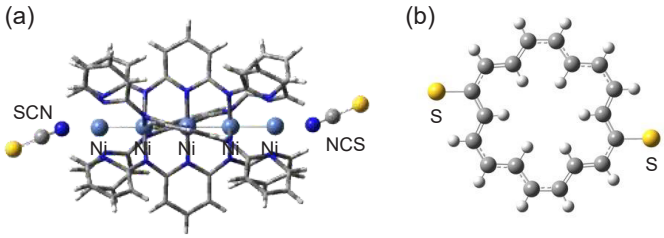



**Figure 1.** Molecular structures of (a) $Ni_5$ EMACs and (b) [18]annulene derivatives.

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# Enabling Next-Generation Sensing via Novel 2D Material Platforms



Shankeerthan Kalyanasundaram , Anais Ducray, Sudha Mokkapati

*Department of Materials Science and Engineering, Faculty of Engineering, Monash University, Clayton, Victoria, Australia - 3800*

Corresponding Author's E-mail: sudha.Mokkapati@Monash.edu

**Abstract**

Two-dimensional (2D) materials have emerged as a transformative frontier for quantum technology, offering unique advantages in structural confinement, tunable electronic properties, and exceptional surface-to-volume ratios. In this talk, we present the discovery of a novel quantum materials platform that bridges the gap between fundamental condensed matter physics and practical device integration. We further demonstrate a high-performance sensing platform developed upon a 2D material system, which leverages position controlled, wafer scale growth to achieve unprecedented sensitivity.

Central to these advancements is a novel synthesis technique that enables mass manufacturing. We will discuss how this innovation resolves critical bottlenecks in limits of detection and scalability. Our platform provides a versatile architecture for the next generation of scalable, CMOS-compatible point-of-care diagnostic sensors. Our findings open new pathways for applications ranging from biomedical diagnostics to advanced quantum information processing.

**Keywords:** 2D materials, biosensors, photodetectors

# Navigating the Great Realignment: Engineering Petrochemical Innovation for a New Industrial Order



Jirut Wattoom, Ph.D.

*SCG Chemicals Co.Ltd, Thailand*

**Abstract**

The petrochemical industry is at a definitive inflection point. The era of frictionless globalization has been superseded by a fragmented "New World Order" defined by US trade tariffs, Middle Eastern volatility, and a cooling European economy. As heavy industry grapples with these geopolitical headwinds and the rapid ascent of AI, the sector must transition from a volume-driven commodity model to a high-value, innovation-led strategy centered on three critical pillars:

1. Scaling Circular & Renewable Feedstocks: To decouple growth from virgin carbon, the industry must move beyond pilot-scale sustainability. This requires the industrial integration of chemical recycling (pyrolysis) and bio-based feedstocks into existing cracker infrastructures, ensuring both ESG compliance and long-term resource security in a decarbonized economy.

2. Material Engineering for Frontier Industries: Petrochemicals are the foundational layer of the next industrial revolution. Our R&D must pivot toward the specialized technical demands of "Frontier" sectors, including thermal management polymers for AI data centers and EV battery systems, and high-performance composites engineered for the extreme environments of the burgeoning space economy.

3. AI-Driven Material Informatics: The traditional decade-long R&D cycle is no longer competitive. By leveraging Material Informatics (MI) and Generative AI, we can now simulate molecular properties and predict performance in real-time. This digital leap allows for the "discovery-to-market" of novel materials at a speed that matches the current pace of global disruption.

The New Innovation Paradigm: This transition demands more than just new technology; it requires a fundamental shift in the industrial paradigm. Success in this era will not be defined by scale alone, but by agile innovation and the ability to bridge the gap between molecular science and macro-economic resilience. This talk will explore how shifting from a "capacity-first" to a "solution-first" mindset is the only viable path to sustaining leadership in an increasingly complex global landscape.

# From Surface to Sound: Multidisciplinary Pathways for Industrial and Cultural Innovation



Yuttanant Boonyongmaneerat [a,*]

[a]*Metallurgy & Materials Science Research Institute (MMRI), Chulalongkorn University, Patumwan, Bangkok*

*Corresponding Author's E-mail: yuttanant.b@chula.ac.th

**Abstract**

Bridging the gap between laboratory-scale research and real-world industrial implementation remains a central challenge in materials science. This talk highlights how multidisciplinary collaboration can serve as a powerful engine to accelerate innovation, enhance scalability, and extend impact beyond traditional industrial domains. Drawing on expertise in metallurgy and surface coating technologies, three case studies are presented to illustrate distinct yet interconnected innovation pathways.

The first case, BoilerPlate, demonstrates how coordinated collaboration across the surface coating and boiler manufacturing value chain enabled the development of high-temperature erosion-resistant coatings. Progressing from Technology Readiness Level (TRL) 4 to 8, this project underscores the importance of early stakeholder alignment, addressing scale-up challenges, and integrating feedback loops between material development, industrial operation, and market needs.

The second case, Bioplate, explores how stepping beyond disciplinary boundaries can unlock unconventional materials science solutions. In developing metallization processes for biopolymers, a critical breakthrough emerged not from traditional electroplating approaches, but from a technique introduced by enzymatic polymer scientists. This example highlights the value of cross-domain knowledge exchange in addressing complex materials challenges.

Finally, the talk extends into an unconventional domain: the revitalization of traditional gong sound. By integrating metallurgy with acoustics, finite element modeling, and psychoacoustics—alongside collaboration with national artists—this project reimagines material processing routes to recover the tonal qualities of historically forged gongs, which are absent in modern casting methods.

Through these examples, key lessons are drawn on how to initiate, structure, and sustain effective collaborations. The discussion emphasizes the evolving role of materials scientists as integrators within innovation ecosystems, contributing not only to industrial competitiveness and sustainability, but also to the preservation and advancement of cultural heritage.

**Keywords:** Surface coating technology, Metallurgy, Industrial impacts, Cultural heritage, Cross-domain innovation

# Sensory AI – augmenting the senses of human and artificial intelligence: from academic lab to spin-off company



Teerakiat Kerdcharoen

*Department of Physics, Faculty of Science, Mahidol University, Bangkok 10400, Thailand*
*MUI ROBOTICS CO., LTD., 888 Moo 4, Bang Khun Kong Sub-district, Nonthaburi 11130, Thailand*

*Corresponding Author's E-mail: teerakiat.ker@mahidol.ac.th

**Abstract**

Large language models (LLMs) have demonstrated impressive capabilities in language-based reasoning and interaction, yet they remain weakly grounded in the physical world. For artificial intelligence (AI) to operate effectively in real industrial environments, it must be able to perceive, measure, and interpret physical signals beyond text and images. This creates an important opportunity for Sensory AI, where electronic materials, sensors, and data-driven models are integrated to give machines human-like sensory capabilities such as smell and taste.

In this talk, I will present the development of artificial nose (AI-nose) and artificial tongue (AI-tongue) technologies at Mahidol University, and their translation into industrial applications through the university spin-off startup, MUI Robotics. These technologies combine sensor materials, signal processing, machine learning, and application-specific product design to digitize sensory information that has traditionally depended on human experts. Key use cases include food and beverage quality control, product authentication, process monitoring, and odor pollution detection from factories and communities.

The talk will also discuss the innovation pathway from a university laboratory prototype to a commercial deep-tech product. From a startup perspective, I will share practical lessons on product standardization, system reliability, industrial validation, manufacturing readiness, customer discovery, and business scaling. Particular emphasis will be placed on how research outputs in electronic materials and sensing technologies can be transformed into scalable industrial solutions through commercialization strategy, intellectual property management, and capitalization.

By bridging electronic materials research with real-world industrial needs, Sensory Artificial Intelligence offers a new pathway for creating machines that can better understand and interact with the physical world. This approach not only expands the role of artificial intelligence in industry, but also highlights how university research can become a platform for innovation-driven entrepreneurship.

**Keywords:** sensor materials, chemical sensor, electronic nose, smell, artificial sense, artificial intelligence

# From Atoms to Markets, from Thermodynamics to AI, and from 3D Printing to Organs. Navigating Materials Innovation Across Academic, Industrial, and Entrepreneurial Frontiers

Boonrat Lohwongwatana[a,b], Chedtha Puncreobutr [a,b], Chetarpa Yipyintum[b] and Thanawat Petchratanarungsri [a,b]



[a] *Department of Metallurgical Engineering, Chulalongkorn University, Bangkok, Thailand.*
[b]*Meticuly, Co. Ltd., Bangkok, Thailand.*

*Corresponding Author's E-mail: boonrat.l@chula.ac.th

**Abstract**

Materials innovation today is no longer confined to laboratories or journal publications. The real and growing challenge lies in translating scientific discoveries into scalable technologies that can withstand the demands of manufacturing, regulation, commercialization, and global deployment, and in doing so, unlock substantial enterprise value.

Drawing from over fifty industrial research collaborations and my firsthand experience leading technology development from university lab to global market, this talk explores how materials science is evolving across multiple high-impact roles: researcher, industrial collaborator, entrepreneur, and global technology innovator. At the heart of this journey is the ability to treat research knowledge and intellectual property not merely as academic outputs, but as strategic assets that drive revenue, differentiation, and long-term competitive advantage.

A central focus of this session is the role of the Chief Technology Officer (CTO), and how a well-positioned CTO function can directly enhance enterprise value, revenue, and intangible assets. I will share how to build a high-performance CTO office that combines deep technical excellence with sharp business acumen: one capable of constructing a defensible intellectual property moat, accelerating commercialization traction, and aligning R&D investment with market opportunity. For companies seeking to move faster from innovation to revenue, and from invention to market leadership, the CTO office is not a support function, but rather is it a growth engine.

This talk is designed for materials scientists, researchers, executives, founders, and innovation leaders who understand that the next wave of industrial competitiveness will be won at the intersection of materials science, intellectual property strategy, and bold technology commercialization.

**Keywords:** Additive Manufacturing, Materials Innovation, 3D printing, Deep-Tech Entrepreneurship and Intellectual Property

# In-House Development and Knowledge Transfer for Accelerated Commercialization of Medical Devices



Narin Kaabbuathong[a,*]

[a]*PTT Innovation Institute, PTT Public Company Limited, Thailand*

*Corresponding Author's E-mail: narin.k@pttplc.com

**Abstract**

PTT Innovation Institute has developed medical device products across multiple categories, including of wound care and enzymatic detergents, advancing innovations from laboratory-scale concepts to commercialization. This study distills the institute's approach to leveraging internal competencies and facilities to accelerate product development and market entry.

A structured in-house development program was employed, integrating design, prototyping, and regulatory-aware workflows within existing facilities. Core competencies and modular processes were documented to support repeatable development cycles. Knowledge transfer mechanisms to external partners were implemented to facilitate process up-scaling, including documentation, training, and technology transfer plans. The approach evaluates time-to-market metrics and deployment efficiency for downstream manufacturing and commercialization.

The integrated approach supported rapid progression from lab-scale concepts to market-ready products. By consolidating development activities within the organization and systematically transferring capabilities to external partners for scale-up, the time required to launch innovative products into the market decreased markedly.

Conclusion: The current methodology-combining in-house development with structured knowledge transfer for external scale-up-facilitates accelerated commercialization of medical devices. The observed outcome demonstrates that the utilization time of innovative products can double the speed to market, underscoring the value of integrated internal capabilities and strategic partnerships in medical device innovation.

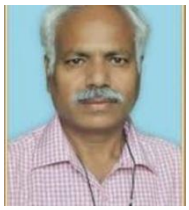
**Keywords:** Medical Devices, Wound Care, Enzymatic Detergent

# Bridging Spectral Conversion and Device Integration: Rare-Earth Doped Photonic Materials for Silicon Solar Cells

Keenatampalle Suresh[a], C.R. Kesavulu[b], Rella Reddappa[c], Wanichaya Mekprasart[a], Wisanu Pecharapa[a], Y. Ruangtaweep[d], J. Kaewkhao[d], C.K. Jayasankar[e,b,*]

[a]*College of Materials Innovation and Technology, King Mongkut's Institute of Technology Ladkrabang, Ladkrabang, Bangkok-10520, Thailand.*
[b]*Department of Physics, Amrita School of Engineering, Amrita Vishwa Vidyapeetham, Amaravati Campus, Amaravati- 522 502, A.P., India.*
[c]*Department of Physics, Government Polytechnic College, Kalikiri-517 234, A.P., India.*
[d]*Center of Excellence in Glass Technology and Materials Science (CEGM), Nakhon Pathom Rajabhat University, Nakhon Pathom-73000, Thailand.*
[e]*Department of Physics, Sri Venkateswara University, Tirupati-517 502, India*

*Corresponding author: ckjaya@yahoo.com



**Abstract**

Rare-earth doped glasses and phosphors have been extensively explored for quantum cutting, down-conversion, and up-conversion to mitigate spectral mismatch losses in silicon solar cells. Many reports demonstrate strong photoluminescence from ions such as $Eu^{3+}$, $Tb^{3+}$, $Ce^{3+}$, $Er^{3+}$, $Yb^{3+}$, and $Ho^{3+}$, typically concluding with high spectral conversion efficiencies at the material level. However, limited attention is given to how these photonic materials can be realistically integrated onto working silicon devices without introducing optical losses, interface defects, parasitic absorption, or long-term instability. This talk shifts the emphasis from luminescence efficiency to device-level applicability. It examines the practical challenges of implementing rare-earth based spectral converters as thin coatings or interlayers, including transparency, scattering from surface roughness, spectral overlap with silicon absorption, and performance under real solar illumination. By linking photonic conversion mechanisms with surface science and integration strategies, this work evaluates whether rare-earth spectral converters can be intigrated from laboratory demonstrations to viable components in silicon photovoltaics.

**Keywords:** Si- Solar Cell, Down- and Up- conversion, Rare earths based phosphors and glasses, Photovoltaic efficiency.

# Ultra-thin PTFE sheets: a radiation responsive material for polymer-based rare earths production dosimetry

D.A. Bradley [a,b,*], A. Taheri [a], J. Kaewkhao[c]

[a] *Applied Physics and Radiation Technologies Group, CCDCU, Sunway University, Malaysia*
[b] *School of Mathematics and Physics, University of Surrey, Guildford, United Kingdom*
[c] *Center of Excellence in Glass Technology and Materials Science (CEGM), Nakhon Pathom Rajabhat University, Nakhon Pathom, 73000, Thailand*

*Corresponding Author's E-mail: d.a.bradley@surrey.ac.uk



**Abstract**

Polytetrafluoroethylene (PTFE) is a chemically stable fluoropolymer whose physical and electronic properties make it a candidate material for radiation-responsive applications. Its low effective atomic number ($Z_{eff}$ ≈ 7.7), near-tissue-equivalent density (ρ ≈ 1.2 g/cm$^3$ ), and commercial availability in ultra-thin sheet form allow radiation-matter interactions to be studied at micrometer scales. This work examines the photoluminescence (PL) response of ultra-thin PTFE sheets (~70 µm) to ionizing radiation, with particular focus on dose-dependent optical alterations as an intrinsic material property.

Within the context of the safe handling of naturally occurring radioactive material (NORM) present scope is limited to situations aimed at measurement of ionizing radiation exposures associated with rare earth elements (REE) production. Such processes of production include beneficiation (physical concentration of ores) and *in-situ* leaching (chemical extraction), the latter sometimes being referred to as non-radioactive rare earths (NR-REE).

Noting the above, exploration has been undertaken focusing on sustainable low dose radiation detectors, irradiation of commercial PTFE film being carried out via a photoluminescence (PL) spectroscopy system. Radiation-induced changes in optical emission are found. The results show measurable, dose dependent variations in PL and absorbance intensity, indicating that PTFE is sensitive to radiation-induced structural modifications. The observed behavior is consistent with defect formation or molecular rearrangements within the polymer matrix, although the precise mechanisms need further investigation.

These findings position ultra-thin PTFE as a promising radiation-responsive material suitable for passive optical readout down to low levels of exposure. Its chemical inertness, biocompatibility, and hypoallergenic nature, combined with the radiation-induced optical sensitivity reported here, support its further exploration as a basis for commercially interesting polymer-based dosimetric and sensing systems. More broadly, this work contributes to the understanding of radiation-matter interactions in fluoropolymers and to ongoing efforts in developing optically readable polymer detectors.

**Keywords:** PTFE, photoluminescence, polymer materials, radiation response, dosimetry, rare earths production

# Advances in Terahertz Technologies for Environmental Solutions to Marine Plastic Pollution



Tadao Tanabe[a,b,*]

[a] *Social Informatics Design Course, Department of Design Engineering and*
[b] *Research Center for Advanced Terahertz Technology, SIT Research Laboratories,*
*Shibaura Institute of Technology, 3-7-5 Toyosu, Koto-ku, Tokyo 135-8548, Japan*

*Corresponding Author's E-mail: tanabet@shibaura-it.ac.jp

**Abstract**

Terahertz(THz) technology is attracting increasing attention as a platform for non-contact, non-destructive detection of material composition, internal states, and molecular-level interactions[1]. This presentation introduces recent advances in the development of THz technology aimed at providing environmental solutions to marine plastic pollution. To effectively utilize plastic waste washed onto coastal regions, it is essential not only to identify the materials but also to assess their chlorine concentration in order to select appropriate recycling and treatment processes[2]. THz measurement devices designed for plastic identification and chlorine concentration assessment have been developed as shown in Figure 1, with a particular focus on practical system integration that utilizes high-frequency radar devices—originally developed for autonomous vehicle applications—as compact THz sources.

From a more fundamental perspective, plastics drifting in marine environments undergo degradation and fragmentation, eventually forming nano-scale particles. As research on the biological impacts of nanoplastics(NPs) is rapidly expanding worldwide, elucidation of their physicochemical properties has become increasingly important. To address this issue, a method has been developed to generate NPs by laser ablation using a nano-second laser, which is also employed as an excitation source for broadband THz-wave generation based on nonlinear optical mixing of near-infrared beams in semiconductor crystals. The generated NPs are characterized by X-ray photoelectron spectroscopy(XPS) using the synchrotron radiation facility NanoTerasu for surface chemical-structure analysis and by Atomic Force Microscope based Infrared Spectroscopy(AFM-IR) for evaluation of particle size and vibrational properties[3].

In summary, THz-based technology demonstrates the potential to provide both a practical sensing platform for recovering marine plastic as a resource and a scientific foundation for understanding NPs, thereby contributing to the resolution of environmental issues from both applied and fundamental perspectives.

**Keywords:** terahertz, non-destructive testing, plastic identification, laser ablation

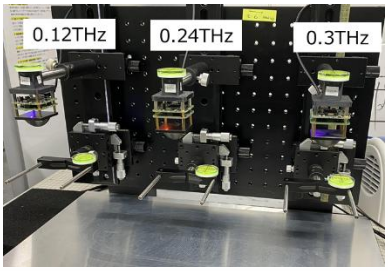



Figure 1 Terahertz spectrometer using a compact radar device with three frequencies

# Quantum Beam Science for Sustainable Materials and Energy: From Collaboration to Action

Duangmanee Wongratanaphisan[a,b,c*]

[a]*Thailand Center of Excellence in Physics (ThEP Center), Ministry of Higher Education, Science, Research and Innovation, Bangkok 10400, Thailand*
[b]*Hub of Talents for Particle Accelerators, 239 Huay Kaew Rd. Muaeng District, Chiang Mai 52000, Thailand*
[c]*Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*

*Corresponding Author's E-mail: duangmanee.wong@cmu.ac.th and dwongrat@thep-center.org



**Abstract**

The second SIT–ThEP International Joint Symposium on "Frontier Research of Quantum Beam and Material Applications in Japan and Thailand" builds upon the successful foundation established during the inaugural meeting and the formalized collaboration under the Memorandum of Understanding (MoU) between the Thailand Center of Excellence in Physics (ThEP) and Shibaura Institute of Technology (SIT) Research Laboratories. This keynote highlights the evolving role of quantum beam science, including ion, electron, photon, and accelerator-based platforms, as a strategic enabler for next-generation materials research, advanced instrumentation, and cross-disciplinary innovation. Emphasis is placed on how integrated capabilities in quantum beam technologies can address critical challenges in energy, sustainability, and advanced manufacturing, while fostering resilient and long-term international research ecosystems. The symposium serves not only as a platform for presenting cutting-edge scientific advancements, but also as a bilateral innovation hub connecting researchers, infrastructure, and talent between Thailand and Japan. Focus is given to emerging collaborative directions, including shared research facilities, joint graduate programs, and coordinated funding mechanisms. A key feature of this second meeting is the transition from dialogue to action: structured roundtable discussions and thematic working groups are designed to catalyze joint research proposals, co-development of large-scale projects, and strategic alignment of national research priorities. This initiative positions the symposium as a sustained engine for high-impact collaboration in quantum beam and materials science.

**Keywords**: Quantum Beam Science; Accelerator-Based Research; Materials Innovation; Thailand–Japan Collaboration; Joint Research Programs

# Metal@Semiconductor Yolk@Shell Nanostructures for Broadband Solar-to-Hydrogen Conversion



Chun-Yi Chen[a,*], Jung-hoe Her[a], Tso-Fu Mark Chang[a], Masato Sone[a], Yung-Jung Hsu [a,b,*]

[a]*Materials and Structures Laboratory, Institute of Science Tokyo, Midori-ku, Kanagawa 226-8501, Japan*
[b]*Department of Materials Science and Engineering, National Yang Ming Chiao Tung University, Hsinchu 300-10, Taiwan*

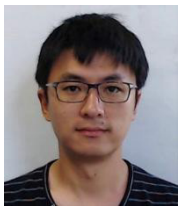
*Corresponding Author's E-mail: chen.c.ac@m.titech.ac.jp

**Abstract**

Photocatalytic hydrogen production offers a promising pathway for sustainable energy conversion; however, efficiently utilizing the full solar spectrum remains a fundamental challenge due to limited light absorption and inefficient charge separation. In this work, we present recent progress in engineering metal@semiconductor yolk@shell nanostructures as a versatile platform for broadband solar-to-hydrogen conversion. Enabled by a synthetic toolbox including galvanic replacement, Kirkendall diffusion, and ion exchange, the yolk composition, void space, and shell thickness can be precisely tailored, allowing systematic control over light absorption, charge separation pathways, and interfacial reaction kinetics. The yolk@shell architecture not only provides a confined nanospace that promotes multiple light scattering and enhanced photon utilization, but also spatially separates active sites to suppress charge recombination and extend carrier lifetimes. In particular, the incorporation of dual-plasmonic components enables broadband light harvesting from the visible to near-infrared region via synergistic localized surface plasmon resonance, facilitating hot carrier generation and subsequent interfacial charge transfer. Notably, combined with the advantageous features of the yolk@shell architecture, Au@$Cu_7S_4$ achieves a peak apparent quantum yield of 9.4% at 500 nm and a record-breaking apparent quantum yield of 7.3% at 2200 nm for hydrogen production in the absence of additional co-catalysts. This result demonstrates not only efficient hydrogen evolution under deep near-infrared excitation but also the feasibility of co-catalyst-free systems driven by plasmonic enhancement. These findings highlight the critical role of structural and plasmonic engineering in overcoming spectral and kinetic limitations, and provide general design principles for developing efficient, durable, and broadband-responsive yolk@shell photocatalysts for next-generation solar-to-hydrogen conversion.

**Keywords:** hydrogen production; photocatalysts; localized surface plasmon resonance; solar energy conversion

# Organic Thermoelectric Modules for Sustainable Low-Grade Thermal Energy Harvesting



Qingshuo Wei [a,*]

[a] *National Institute of Advanced Industrial Science and Technology (AIST), 1-1-1, Higashi, Tsukuba 305-8565, Japan*

*Corresponding Author's E-mail: qingshuo.wei@aist.go.jp

**Abstract**

We present a fully metal-free, all-polymer thermoelectric module composed of PEDOT:PSS (p-type) and poly(benzodifurandione) (PBFDO) (n-type). PBFDO, a recently developed conducting polymer with high oxidative stability, enables the construction of laminated polymer–polymer junctions without the need for metallic electrodes or conductive pastes. Detailed evaluation of the anisotropic thermoelectric properties of PBFDO reveals distinct in-plane and through-plane transport behaviors, providing insight into structure–property relationships critical for module design. Importantly, direct lamination of the p–n polymer layers yields low and stable interfacial resistance over periods exceeding one year, addressing a long-standing stability challenge in organic TE devices. Under natural cooling conditions, the all-polymer module delivers power densities exceeding 30 μW $cm^{-2}$, representing a substantial improvement over previously reported polymer-based modules using the same material system. Beyond performance, the module exhibits a unique sustainability advantage: it thermally decomposes above 400 °C, allowing disposal as burnable waste and offering a compelling pathway toward eco-friendly and disposable energy harvesting devices.

**Keywords:** Thermoelectric, Organic, IoT, Sensors

# Development and evaluation of $MgAgSb/Mg_3(Sb,Bi)_2$ thermoelectric modules



Kazuo Nagase, Hironori Ohshima, Yosuke Goto, Masayuki Murata, and Chul-Ho Lee*

*National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan*

*Corresponding Author's E-mail: c.lee@aist.go.jp

**Abstract**

Recently, $MgAgSb/Mg_3(Sb,Bi)_2$ modules were found to be a promising device that can replace $Bi_2Te_3$ system. Intense efforts have been taken to improve their efficiency and stability in the atmosphere. Establishing fabrication process that is suitable for mass production is also a challenge. Most reported $MgAgSb/Mg_3(Sb,Bi)_2$ modules were fabricated using elements synthesized by mechanical alloying.

We established synthesis process of MgAgSb and $Mg_3(Sb,Bi)_2$ compounds using a melting method that is easy to scale up [1,2]. As-grown boules were annealed to maximize their thermoelectric properties. As resluts, the dimensionless figure-of-merit (ZT) was ZT = 0.84 (T = 495K) and 1.39 (T = 708K) for MgAgSb and $Mg_3(Sb,Bi)_2$, respectively. Modules of two-pair legs were fabricated using thus obtained elements. Electrical power comparable to $Bi_2Te_3$ modules was generated when the lower side was cooled with an air-cooled heat exchanger. Durability test of the moules was conducted in the atmosphere showing stable performance for 2000 h. Details will be discussed in the conference.

[1] K. Nagase, H. Ohshima, K. Kihou, H. Kunioka, U. Anazawa, R. Sakagami, Y. Goto, M. Murata, and C. H. Lee, Adv. Eng. Mater. (2026).
[2] K. Kihou, H. Kunioka, H. Nishiate, and C.H. Lee, J. Mater. Res. Technol. 10, 438 (2021).

**Keywords:** Thermoelectric module, Mg compounds, melting method

# Recent theoretical progress of phonon-drag effect and magnon-drag effect



Hiroyasu Matsuura*

*National Institute of Advanced Industrial Science and Technology, Tsukuba, Ibaraki 305-8568, Japan*

*Corresponding Author's E-mail: hiroyasu.matsuura@aist.go.jp

**Abstract**

The phonon-drag effect, a phenomenon in which the heat flow caused by phonons drags the flow of electrons through the electron-phonon interaction, has been intensively studied since the 1950s as the origin of the large thermoelectric effect in doped semiconductors [1]. As a phenomenon similar to the phonon-drag effect, the magnon-drag effect caused by the momentum transfer between electrons and magnons has also been observed in ferromagnetic metals such as iron. Recently, these effects have attracted attention in terms of the origin of the colossal Seebeck effect in $FeSb_2$ and the large thermoelectric effect at room temperature in Fe-Heusler thin films and natural chalcopyrite $CuFeS_2$. The microscopic thermoelectric theory based on Kubo-Luttinger's response has been discussed in recent years, and its formalism has been extended to the phonon-drag effect [2,3] and the magnon-drag effect [4]. In this presentation, I will introduce a recent theoretical progress in phonon-drag effect and magnon-drag effect.

[1] As a recent review: H. Matsuura, H. Takahashi, and T. Katase, Appl. Phys. Rev. 13, 011321 (2026) [2] H. Matsuura, et al., J. Phys. Soc. Jpn. 88, 074601 (2019). [3] J. Endo, H. Matsuura, and M. Ogata, Phys. Rev. B 110, 205121 (2024) [4] H, Matsuura et al, Phys, Rev, B 104, 214421 (2021).

**Keywords:** Phonon-drag effect, Magnon-drag effect

# Development of Heusler alloys and rapid sintering technique for practical thermoelectric power generation



Masashi Mikami[a,*], Hidetoshi Miyazaki[b], Yoichi Nishino[b,c]

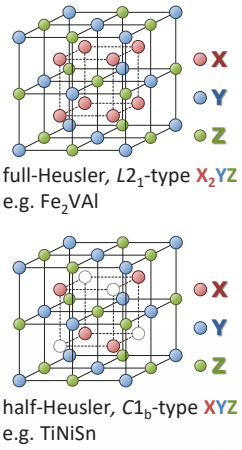
[a] *National Institute of Advanced Industrial Science and Technology, Nagoya, Japan*
[b] *Nagoya Institute of Technology, Nagoya, Japan*
[c] *Nagoya Industrial Science Research Institute, Nagoya, Japan*

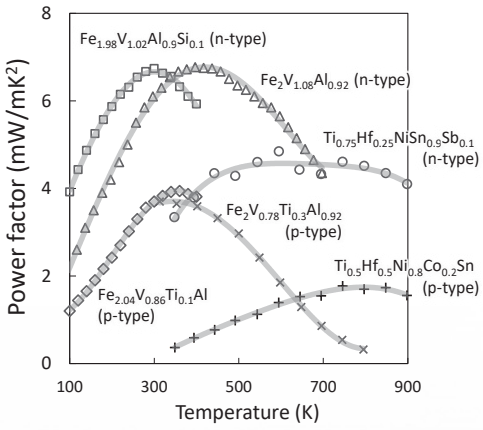
*Corresponding Author's E-mail: m-mikami@aist.go.jp

**Abstract**

Thermoelectric power generation (TEG) using waste heat is expected to serve as one of the energy recovery systems to improve energy utilization efficiency and reduce $CO_2$ emissions. To facilitate the practical application of TEG, durable thermoelectric devices are indispensable because the place around exhaust heat is a harsh environment for electronic devices. In this study, thermoelectric modules consisting of Heusler alloys were fabricated. For the low temperature waste heat below 600 K, the Heusler alloy of $Fe_2VAl$ having a high thermoelectric power factor, such as around 6 mW/mK$^2$, is employed. The $Fe_2VAl$ alloy also exhibits high mechanical strength and excellent oxidation resistance until 850 K. To achieve high durability for the thermoelectric module, $Fe_2VAl$-Cu electrode joint is directly formed by diffusion bonding without joining material. Using this bonding technique, a durable $Fe_2VAl$ thermoelectric module without electrical output loss at the electrode joint can be fabricated. The $Fe_2VAl$ module consisting of 18 p-n pairs can exhibit power density of 0.7 W/cm$^2$ on the heat source of 673 K. We have demonstrated that the durable $Fe_2VAl$ thermoelectric module is suitable for the construction of TEG for automotive waste heat recovery. For the middle temperature waste heat around 900 K, the half-Heusler alloys of TiNiSn are examined. To construct thermoelectric modules composed solely of TiNiSn-based alloys, thermoelectric performance in p-type TiNiSn is improved by the modification of electronic band structure owing to Hf substitution for Ti site.

For the practical application of TEG, we have been studying the rapid densification of thermoelectric materials by flash sintering (FS) based on the electric current sintering technique. Fully densified thermoelectric materials, such as tellurides and Heusler alloys, can be obtained by a current feed duration of only 1 s. By using FS, therefore, energy and time consumption for sintering process can be extremely reduced.




**Keywords:** thermoelectric materials, Heusler alloys, thermoelectric power generation, powder metallurgical processes, flash sintering.

# Development of $Mg_3(Bi,Sb)_2$ with axis-dependent conduction polarity for transverse thermoelectric devices



Yosuke Goto[a,*], Yuji Takahashi[a], Hironori Ohshima[a], Kazuo Nagase[a], Masayuki Murata[a], Hidetomo Usui[b], Chul-Ho Lee[a]

[a]*National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki, 305-8568, Japan*
[b]*Department of Engineering Science, The University of Electro-Communications, Chofu, Tokyo, 182-8585 Japan*

*Corresponding Author's E-mail: y.goto@aist.go.jp

**Abstract**

A thermoelectric device with a transverse configuration offers a promising pathway to mitigate long-standing challenges associated with conventional thermoelectric modules, including long-term thermal instability and intrinsic structural complexity. One design strategy for transverse thermoelectric devices involves the use of materials exhibiting axis-dependent conduction polarity, in which p-type and n-type charge transport occur simultaneously along different crystallographic directions. Recently, we demonstrated that the layered Zintl phases $Mg_3Sb_2$ and $Mg_3Bi_2$ possess this unique property, arising from pronounced band anisotropy characterized by an isotropic conduction band and an anisotropic valence band [Goto et al., Chem. Mater. 36, 2018 (2024)]. $Mg_3Sb_2$ exhibits axis-dependent conduction polarity at low charge carrier concentrations below $10^{18}$ $cm^{-3}$, consistent with its semiconducting electronic structure. In contrast, semimetallic $Mg_3Bi_2$ shows the same behavior over a significantly broader doping range, with carrier concentrations exceeding $10^{19}$ $cm^{-3}$. Furthermore, we demonstrate transverse thermoelectric power generation using these materials and discuss the current state of development, remaining challenges, and future prospects of transverse thermoelectric devices.

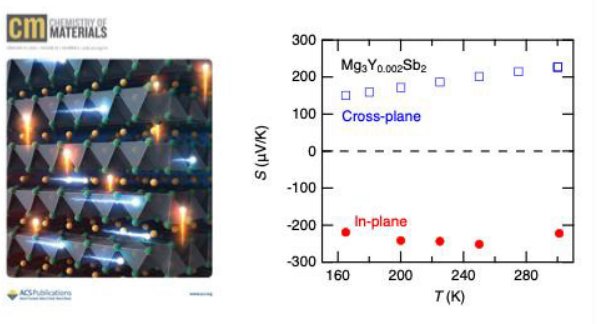
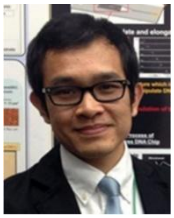



Fig. 1 Axis-dependent conduction polarity of $Mg_3Sb_2$.

**Keywords:** Thermoelectric material, Electronic structure, Energy harvesting

# From Low-Dimensional Metal Oxide Semiconductors to Bio-Integrated Systems: Bridging Sensing, Thermal Switching, and Functional Platforms



Sakon Rahong*

*School of Integrated Innovative Technology, King Mongkut's Institute of Technology Ladkrabang, Chalongkrung Rd., Ladkrabang, Bangkok 10520, THAILAND*

*Corresponding Author's E-mail: sakon.ra@kmitl.ac.th

**Abstract**

Low-dimensional metal oxide semiconductors exhibit tunable electronic, optical, and surface properties that enable a wide range of photonic and sensing applications. In this talk, we present a unified perspective on nanostructured oxides including vanadium dioxide ($VO_2$) thin films, antimony-doped tin oxide (Sb:$SnO_2$), and CuO nanowires underlining how dimensionality, defect engineering, and phase behavior govern their functional performance. $VO_2$ thin films are explored as prototypical phase-change materials exhibiting a thermally induced metal–insulator transition (MIT), with implications for thermal switching and adaptive photonic devices. Sb:$SnO_2$ systems demonstrate how dopant-mediated carrier modulation and oxygen vacancy control enhance sensitivity in gas sensing platforms. In parallel, CuO nanowires illustrate the advantages of one-dimensional architectures for humidity and breath sensing, driven by high surface-to-volume ratios and rapid charge transport modulation. A central theme of this work is the role of surface interaction and signal transduction as unifying principles across these systems. Building on this foundation, we extend the discussion toward emerging bio-integrated platforms, including organ-on-a-chip systems, where analogous sensing and response mechanisms are applied to complex biological environments.

**Keywords:** Low-dimensional metal-oxide semiconductors, Chemiresistive gas sensors, Metal–insulator transition, Nanowires, Bio-integrated sensing platform

# Geometric Metasurfaces for Advanced Photonic Devices

Yuttana Intaravanne



*National Electronics and Computer Technology Center (NECTEC), National Science and Technology Development Agency (NSTDA)*
*111 Thailand Science Park, Phahonyothin Road, Khlong Nueng, Khlong Luang, Pathum Thani, 12120 THAILAND*

*Corresponding Author's E-mail: yuttana.intaravanne@nectec.or.th

**Abstract**

Light's properties, including amplitude, phase, and polarization, enable the extraction of rich information and play a critical role in applications such as material characterization, biomedical diagnosis, imaging, and optical communication. However, conventional optical systems rely on bulky and complex components, which limit their suitability for miniaturized and integrated technologies. Optical metasurfaces, consisting of planar nanostructured interfaces, provide a compact and versatile platform for manipulating light within an ultrathin form factor. Metasurfaces can control light through several phase modulation mechanisms, including resonant phase, propagation (dynamic) phase, and geometric phase. Among these, geometric metasurfaces based on the Pancharatnam–Berry (PB) phase offer distinct advantages due to their simple design and fabrication. By controlling the orientation of anisotropic meta-atoms, geometric metasurfaces enable precise manipulation of phase and polarization without relying on propagation effects. In this presentation, geometric metasurfaces are employed to design and experimentally demonstrate advanced photonic devices for phase and polarization control, as illustrated in Fig. 1. These devices enable a range of functionalities, including polarization generation, detection, and imaging. Their ultrathin, lightweight, and multifunctional characteristics make geometric metasurfaces highly promising for next-generation photonic systems. Furthermore, the underlying design principles are compatible with semiconductor materials and silicon photonics platforms, providing a pathway toward compact and integrated optical devices. The showcase in this presentation also aligns with the growing global emphasis on advanced electronics and photonics technologies, supporting the development of high-performance, miniaturized optical systems for applications in healthcare, communications, and emerging semiconductor-driven industries.




(a) (b) (c) (d) (e)

Fig.1 (a) SEM image of an example geometric metasurface. Experimental demonstration of advanced photonic devices using geometric metasurfaces for (b) generation of a 3D polarization structure, (c) image concealment, (d) hybrid hologram, and (e) superposition of light's orbital angular momentum.

**Keywords:** Phase control, Wavefront shaping, Polarization control, Flat optics, Novel optical devices

# Measuring Key Thermoelectric Parameters from Materials to Modules — Absolute Seebeck coefficient and Module Efficiency

Yasutaka Amagai[a,b,*]



[a] *National Institute of Advanced Industrial Science and Technology (AIST), National Metrology Institute of Japan (NMIJ), 1-1-1 Umezono, Tsukuba, Ibaraki 305-8563, Japan.*
[b] *National Institute of Advanced Industrial Science and Technology (AIST), Global Research and Development Center for Business by Quantum-AI technology (G-QuAT), 1-1-1 Umezono, Tsukuba, Ibaraki 305-8560, Japan*

*Corresponding Author's E-mail: y-amagai@aist.go.jp

**Abstract**

Thermoelectric materials and modules have attracted significant attention as key technologies for solid-state energy conversion. While substantial progress has been achieved in material development and device fabrication, the reliable and comparable evaluation of thermoelectric performance remains a critical challenge. In particular, the Seebeck coefficient plays a central role, as it directly determines derived quantities such as the power factor, figure of merit, and ultimately the conversion efficiency of thermoelectric modules. However, in many studies, the Seebeck coefficient is obtained using relative or comparative methods that rely on reference materials or setup-dependent calibration procedures. Although these approaches are suitable for internal comparison, they can introduce systematic errors and inconsistencies, limiting the reliability and comparability of reported data.

This talk presents our recent work on the absolute measurement of the Seebeck coefficient using the Thomson effect. By ensuring traceability to fundamental electrical and thermal quantities and by rigorously evaluating measurement uncertainty, the Seebeck coefficient can be treated as a well-defined measurand. This enables reproducible and comparable measurements across different experimental platforms and laboratories, particularly for materials with a small Seebeck coefficient. Furthermore, we address the evaluation of thermoelectric module efficiency using a thermal guard surrounded by the thermoelectric module. We demonstrate the impact of the heat loss from the lateral surface of the module to reliable performance assessment. Finally, some implications of absolute measurement for industrial application are discussed, highlighting the essential role of metrology in bridging advanced thermoelectric materials research and practical energy conversion technologies.

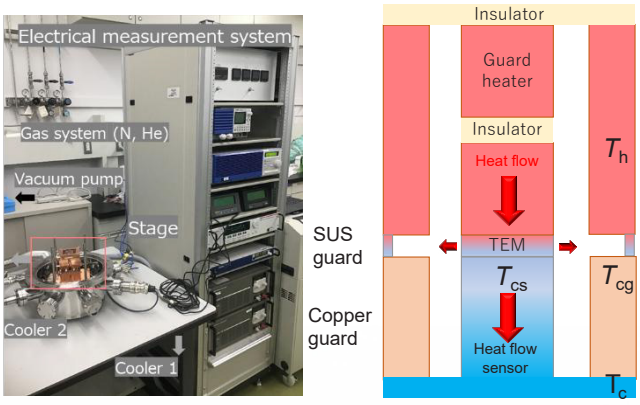



Fig.1 Guard-ring-based developed apparatus for thermoelectric module efficiency evaluation

**Keywords:** Metrology, Thermoelectric material, Thermoelectric module, Seebeck effect, efficiency

# Thermal Utilization and Thermal Management Technologies in Photovoltaic Systems



K. Kamide [a,*], R. Funahashi[b], T. Urata[b], J. Sakuma[c], H. Akiyama[c], K. Tanahashi[a]

[a]*The National Institute of Advanced Industrial Science and Technology (AIST), Koriyama, Fukushima 963-0298, Japan*
[b]*The National Institute of Advanced Industrial Science and Technology (AIST), Ikeda, Osaka 563-8577, Japan,*
[c]*The University of Tokyo, Kashiwa, Chiba 277-8581, Japan*

* kenji.kamide@aist.go.jp

**Abstract**

The energy conversion efficiency of photovoltaic systems based on photoelectric conversion is typically below 30%, with most of the remaining solar energy dissipated as waste heat. This unused thermal energy has the potential to be harvested as additional electrical power through integration with thermoelectric devices. We present our recent technological developments toward photovoltaic–thermoelectric hybrid systems and discuss the associated challenges [1–3]. In addition, because thermal effects critically affect photovoltaic performance and operational lifetime, we introduce thermal modeling technologies that enable effective thermal management and thermal utilization for diverse photovoltaic module applications [4].

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**Keywords:** Photovoltaic-thermoelectric hybrid, heat recovery, thermal modeling, outdoor measurement

# Thermoelectricity of Iron–Titanium–Antimony Distorted Heusler Alloy Thin Films



Athorn Vora-ud[a,b*]

[a]*Program of Physics, Faculty of Science and Technology, Sakon Nakhon Rajabhat University, 680 Nittayo Road, Mueang District, Sakon Nakhon, 47000, Thailand*
[b]*Thin Films Research Laboratory, Center of Excellence on Alternative Energy, Research and Development Institute, Sakon Nakhon Rajabhat University, 680 Nittayo Road, Mueang District, Sakon Nakhon, 47000, Thailand*

*Corresponding Author's E-mail: athornvora-ud@snru.ac.th

**Abstract**

Iron–Titanium–Antimony (Fe-Ti-Sb; FTS) system is a ternary intermetallic Heusler compound with compositions $Fe_2TiSb$ ("full" Heusler) and FeTiSb ("half" Heusler), which has been reported to exhibit good TE and magnetic properties, as well as spintronic properties. Moreover, the distorted Heusler alloy $FeTi_{1.5}Sb$ highlights considerable potential as a promising material for thermoelectric device applications. Hence, the present work focuses on the thermoelectricity of an FTS-distorted Heusler alloy in thin-film form, starting with the spintronic thermoelectric properties of amorphous FTS thin films. The amorphous FTS thin film was prepared on a 0.3-μm $SiO_2$/Si wafer by a DC magnetron sputtering method to investigate the spintronic thermoelectric (STE) properties based on the anomalous Nernst effect (ANE) and spin Seebeck effect (SSE). Also, the spin Seebeck effect and large spin conversion in amorphous $Fe_2TiSb$/ polycrystalline $Y_3Fe_5O_{12}$ thin films were presented. Then, the thermoelectric device using FTS thin films was fabricated by DC magnetron sputtering onto glass substrates in Ar and $N_2$ atmospheres. The thermoelectric thin film (TETF) module of the FTS p–n junction consisted of five couples. The results showed that the highest open-circuit voltage was 0.24 mV, and $P_{max}$ was 7.0 pW at a temperature difference of 20K. Finally, the thermoelectric figure of merit of the distorted Heusler alloy $TiFe_{1.5}Sb$ was investigated by first-principles calculations of lattice thermal conductivity. The combination of low lattice thermal conductivity and a high Seebeck coefficient result in a high thermoelectric figure of merit (ZT) of 0.88 and 0.91 at 300K and 500K, respectively.

**Keywords:** Thermoelectricity, distorted Heusler alloy thin films, Fe-Ti-Sb compound, magnetron sputtering

# Scalable Flexible Thermoelectric Modules for Self-Powered IoT and Wearable Thermal Management

Jakrit Gobpant[a,b], Chalermpol Rudradawong[a], Takahito Ono[b,c], Nguyen Van Toan[b,c], Aparporn Sakulkalavek[a,d]*



[a]*Department of Physics, School of Science, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand*
[b]*Graduate School of Engineering, Tohoku University, Sendai, Japan*
[c]*Micro System Integration Center, Tohoku University, Sendai,Japan*
[d]*Electronic and Optoelectronic Device Research Unit, School of Science, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand*

*Corresponding Author's E-mail: aparporn.sa@kmitl.ac.th

**Abstract**

Flexible thermoelectric technologies are emerging as promising platforms for harvesting low-grade waste heat and enabling self-powered electronic systems, particularly for Internet of Things (IoT), wearable sensors, and personalized thermal management. This invited talk presents our recent progress in the design, fabrication, and system-level integration of high-performance flexible thermoelectric modules based on inorganic thermoelectric legs embedded in silicone rubber matrices.

First, a high-performance flexible thermoelectric generator (FTEG) was developed using an optimized copper electrode architecture and bendable substrate design. Finite-element analysis was employed to balance electrical conductivity and mechanical flexibility, leading to the selection of a 0.1 mm copper electrode. By integrating a graphite sheet as a thermally conductive yet flexible cover layer, the 5 × 5 $cm^2$ FTEG achieved an output voltage of 1.1 V and a maximum power output of 162.4 mW, corresponding to a power density of 6499 $\mu W\ cm^{-2}$ at a temperature difference of 65 °C.

Building on this device concept, the fabrication process was further optimized toward scalable production. The effects of silicone encapsulant thickness and fabrication pressure were systematically investigated to improve mechanical stability, contact quality, and power generation. The optimized series–parallel FTEG configuration achieved a power density of 5.2 mW $cm^{-2}$ at $\Delta T$ = 50 °C and was successfully demonstrated as a self-powered IoT platform capable of harvesting waste heat, charging a battery, and powering real-time monitoring of temperature, humidity, and carbon monoxide.

Finally, selected application examples will be discussed, including body-heat-driven Bluetooth Low Energy sensing using radiative-cooling-enhanced FTEGs and low-power flexible thermoelectric coolers for wearable thermal management. These demonstrations highlight the potential of flexible thermoelectric modules as scalable, sustainable, and maintenance-free energy solutions for next-generation electronic materials and devices.

**Keywords:** Flexible thermoelectric generator, silicone rubber, self-powered IoT, wearable electronics, thermal management

# Development of bulk Silver Selenide-based Thermoelectric Materials through Cold Sintering Process Approach

Supree Pinitsoontorn[a,*], Dulyawich Palaporn[a], Dejwikom Theprattanakorn[a], Piyawat Piyasin[a], Peeranut Kitthonbancha[a], Nuttapon Kongsip[a], Wanida Duangsimma[a], Wei-Di Liu[b], Zhi-Gang Chen[b]

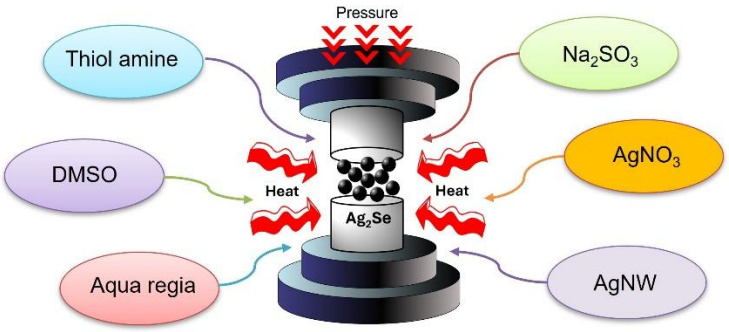


[a]*Institute of Nanomaterials Research and Innovation for Energy (IN-RIE), Department of Physics, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand.*
[b]*School of Chemistry and Physics, ARC Research Hub in Zero-emission Power Generation for Carbon Neutrality, and Centre for Materials Science, Queensland University of Technology, Brisbane, QLD 4000, Australia.*

*Corresponding Author's E-mail: psupree@kku.ac.th

**Abstract**

Silver selenide ($Ag_2Se$) has emerged as a promising material for near room-temperature energy harvesting via thermoelectric conversion. With its lower toxicity, greater abundance, and superior mechanical stability, $Ag_2Se$ offers a sustainable alternative to conventional bismuth telluride-based compounds. This presentation will provide an overview of recent advancements in silver selenide-based thermoelectric materials. In addition, numerous strategies have been employed to enhance the thermoelectric efficiency of bulk $Ag_2Se$, including doping, carrier concentration control, stoichiometry optimization, and nanostructuring. In our research group, we have employed the cold sintering process (CSP) to consolidate bulk $Ag_2Se$, offering a fast and efficient method to fabricate materials with improved thermoelectric properties. As a proof-of-concept, we have applied CSP to fabricate bulk $Cu_2Se$ achieving a large dimensionless figure-of-merit (ZT) value >2.0. However, in the case of $Ag_2Se$, it turned out to be challenging since $Ag_2Se$ is not soluble in most solvents. Thus, the CSP process has been modified by attempting various solvents or by addition of extra silver-based solutions. By utilizing CSP, we have engineered multi-scale hierarchical structures in $Ag_2Se$, facilitating wide-range phonon scattering and significantly reducing thermal conductivity. Through careful tuning of CSP parameters, we have manipulated carrier concentration via defect engineering, leading to enhanced transport properties and power factors. These advancements have yielded dimensionless figure-of-merit (ZT) values exceeding unity, with an average ZT of approximately 1.0 from room temperature to around 400 K, positioning bulk $Ag_2Se$ as a viable material for thermoelectric power generation in room-temperature energy harvesting applications.




**Keywords:** Thermoelectric materials; ZT; $Ag_2Se$; Energy Harvesting; Cold Sintering Process

# Enhanced Cubic Phase Stability in Epitaxial Lateral Overgrowth GaN on [110] Stripe-Patterned GaAs (001) Grown by MOVPE



Sakuntam Sanorpim[a,*], Pattana Suwanyangyaun[b]

[a]*Department of Physics, Faculty of Science, Chulalongkorn University, Pathumwan, 10330, Bangkok, Thailand,*
[b] *Nanoscience and Technology Interdisciplinary Program, Graduate School, Chulalongkorn University, Phyathai Rd., Pathumwan, 10330, Bangkok, Thailand*

*Corresponding Author's E-mail: Sakuntam.S@chula.ac.th

**Abstract**

High cubic phase purity of epitaxial lateral overgrowth (ELOG) cubic GaN (c-GaN) films was achieved on [110] mask-stripe-patterned GaAs (001) substrates by metalorganic vapor phase epitaxy (MOVPE). The influence of growth time and film thickness on crystal structure, morphology, and hexagonal phase inclusion was systematically investigated. ELOG c-GaN films were grown at 900 °C with a mask fill factor of approximately 0.8, producing stable trapezoidal stripes with smooth (111)B sidewalls and flat (001) top surfaces. Film thicknesses of 1.4, 3.5, and 12.0 µm were obtained by varying the growth time from 10 to 120 min. Cross-sectional SEM revealed that longer growth promoted lateral overgrowth and coalescence while maintaining the (001) top surface, which is essential for stabilizing the cubic phase. High-resolution X-ray diffraction (HRXRD) showed improved structural coherence with increasing thickness, evidenced by the narrowing of the c-GaN (002) rocking curve and 2θ–ω scan full width at half maximum (FWHM). The narrowest 2θ–ω FWHM of 5.96 arcmin was obtained for the 12.0 µm film. Reciprocal space mapping (RSM) around the cubic (002) and hexagonal (10-11) reflections confirmed that hexagonal phase inclusion preferentially formed on the (111)B planes as stacking-fault-related defects. To accurately quantify the hexagonal phase fraction in films with large thickness variation, corrections for X-ray absorption and diffraction geometry were incorporated into the intensity analysis. The hexagonal phase inclusion decreased significantly from 55.5% for the 1.4 µm film to 3.1% for the 3.5 µm film, then increased to 21.1% for the 12.0 µm film. These results demonstrate that maintaining a flat (001) top surface during growth is a key condition for achieving high cubic phase purity in ELOG c-GaN films.

**Keywords:** cubic GaN, epitaxial lateral overgrowth, MOVPE, high-resolution X-ray diffraction, hexagonal phase inclusion

# Manipulation of crystal symmetry and crystallinity in germanium-antimony-tellurides as thermoelectric bulk materials



Atsuko Kosuga*

[a]*Osaka Metropolitan University, Sumiyoshi-ku, Osaka-city 558-8585, Japan*

*Corresponding Author's E-mail: a-kosuga@omu.ac.jp

**Abstract**

Thermoelectric materials of germanium-antimony-tellurides with $(GeTe)_m(Sb_2Te_3)_n$ (where *m* and *n* are natural numbers) composition have been extensively studied. Initial research focused on stable homologous phases with long-periodic structures, aiming for low thermal conductivity. Recently, highly symmetric metastable structures in GeTe-rich compositions, which are expected to exhibit high electrical performance, have been investigated. At high temperatures or with high GeTe concentrations, GeTe-rich compositions display a cubic structure (*Fm*-3*m*). The 4*a* site is randomly occupied by Ge, Sb, and vacancies, whereas the 4*b* site is occupied by Te. At low temperatures and low GeTe concentrations, these compositions transform to a rhombohedral structure (*R*3*m*). Thus, germanium-antimony-tellurides exhibit a variety of structures depending on composition and temperature, and it is significant to investigate the relationship between these structures and thermoelectric properties. In this presentation, I will introduce my group's recent research on this material system, particularly a metastable phase of $(GeTe)_{12}Sb_2Te_3$ ($m$=12; $n$=1), focusing on the optimization of the crystal symmetry and electronic structure through band convergence [2,3]. Additionally, I will present our recent trial to prepare crystalline and amorphous mixtures of germanium-antimony-telluride-based materials and their structure and thermoelectric properties.

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**Keywords:** Thermoelectric, germanium-antimony-tellurides, crystal structure, crystallin

# From liquid gallium to functional nanomaterials: Applications in electrochemical biosensors and biomedical devices



Benchaporn Lertanantawong[1,*], Devi Govindaraj[1], Pornnapat Tungtrakarnkul[1], Anthony P. O'Mullane[2]

[1]*Department of Biomedical Engineering, Faculty of Engineering, Mahidol University, Thailand*
[2]*School of Chemistry and Physics, Queensland University of Technology, Australia*

*E-mail: benchaporn.ler@mahidol.ac.th

**Abstract**

Liquid gallium and its alloys represent emerging platforms for synthesizing functional nanomaterials through sustainable methods. We have developed green synthesis routes to produce fluorescent gallium oxyhydroxide (GaOOH) nanoparticles from liquid Ga using electrochemical oxidation [1], $H_2O_2$ oxidation [2], and probe sonication techniques. The morphology and aspect ratio of GaOOH nanoparticles can be controlled by adjusting pH, oxidant concentration, probe energy, and sonication time. Surface modification with metal-phenolic networks creates biocompatible Ga@MPN core-shell nanostructures exhibiting 68.4% enhanced fluorescence, excellent cellular uptake, and potent antimicrobial activity against MRSA while maintaining low cytotoxicity for biomedical applications [3].

These gallium-based nanomaterials have been integrated into advanced nanocomposite electrode coatings for electrochemical biosensors. We developed all-in-one platforms combining redox-active metal-organic frameworks with conductive polyaniline nanowires embedded in glutaraldehyde-crosslinked protein matrices [4]. The nanocomposite architecture provides intrinsic redox activity, antifouling capability with 84% signal retention in biofouling conditions, and efficient charge transport through percolated nanowire networks. As proof-of-concept, an aptamer-based biosensor achieved label-free circulating tumor cell detection with linearity from 5-800 cells/mL and high specificity in simulated serum and urine.

This work demonstrates the versatility of liquid gallium-derived nanomaterials in creating next-generation biosensing platforms with applications in fluorescence imaging, antimicrobial materials, and electrochemical point-of-care diagnostics. The modular design offers pathways toward flexible, wearable medical devices for real-world clinical applications.

Keywords: liquid gallium; GaOOH nanoparticles; nanocomposites; electrochemical biosensors; biomaterials

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# Design and Synthesis of Antibacterial Coating from Natural Materials and Phenolic Compounds



Anchitta Sangsawang [a], Rattapol Pinnaratip [a, b,*]

[a] *Biomedical Engineering Institute, Chiang Mai University, Thailand*
[b] *Department of Industrial Engineering, Faculty of Engineering, Chiang Mai University, Thailand*

*Corresponding Author's E-mail: rattapol.pinn@cmu.ac.th

**Abstract**

Infection is a common complication of skin wounds, requiring antibiotic treatment. Chemical disinfectants like povidone-iodine are currently popularly used as an antiseptic for skin wounds. However, it also has some drawbacks, such as damaging skin tissue and causing scarring. Therefore, the research team sought alternatives to reduce the use of antibiotics and replace them with natural extracts. In addition, the research team recognized the problem of large amounts of agricultural waste in Thailand and therefore studied the recycling of agricultural waste into an antibacterial coating, such as chitosan that derived from crustacean waste, and caffeic acid that derived from coffee berry waste. This study focused on modifying conventional gauze by coating with caffeic acid and chitosan (CCC). To obtain CCC, cotton gauze was dip-coated in caffeic acid-conjugating chitosan solution and lyophilized. The morphology of CCC was observed through Scanning Electron Microscope (SEM). Chemical characteristics of CCC were identified via Fourier Transform Infrared Spectroscopy (FTIR). The results show that CCC has a multilayer thin-film on the cotton gauze, and FTIR confirmed the successful conjugation of caffeic acid and chitosan. CCC showed no toxicity on BJ-5ta cells. The antibacterial activity shows an excellent performance against *E.coli* and *S.aureus*. In conclusion, this study has successfully demonstrated the effectiveness and safety of the antibacterial coating on cotton gauze with a potential for medical applications.

**Keywords:** Biomaterials, Wound dressing, Coating, Antibacterial

# Quantum Dots–Based Gas and Chemical Sensors: From Fundamental Mechanisms to Real-World Applications



Chatchawal Wongchoosuk[a,*]

[a]*Department of Physics, Faculty of Science, Kasetsart University, Bangkok, 10900, Thailand*

*Corresponding Author's E-mail: chatchawal.w@ku.ac.th

**Abstract**

Quantum dots (QDs) have emerged as highly promising functional materials for gas and chemical sensing due to their tunable electronic structure, high surface-to-volume ratio, and abundant active surface sites. Their quantum confinement effects enable controllable band alignment and charge transfer characteristics, which are critical for enhancing sensitivity, selectivity, and low-concentration detection. This presentation will focus on the fundamental mechanisms governing QD-based gas and chemical sensors including adsorption-induced charge transfer, surface defect engineering, heterojunction formation, and modulation of carrier transport. The role of surface states and quantum size effects in determining sensor response, recovery behavior, and detection limits will be discussed. Theoretical approaches such as self-consistent charge density functional tight-binding (SCC-DFTB) will be highlighted to provide mechanistic insight into gas–QD interactions and sensing performance optimization. In addition, synthesis strategies for tailoring QD size, composition, and surface functionality will be addressed to improve selectivity toward specific target gases and volatile organic compounds (VOCs). Practical demonstrations will include QD-based sensors for humidity, ammonia, methanol, and pesticide detection, with emphasis on flexible platforms and environmentally relevant monitoring.

**Keywords:** Quantum dots, gas sensor, chemical sensor, SCC-DFTB, flexible sensor.

# Engineering Morphology and Interfacial Properties of Silicide-based Nanowires for Electrochemical Energy Storage and Magnetic Applications



Boon Tong Goh*, Xiaoxi Li, Najwa binti Hamzan, Mohammad Mukhlis Ramly

*Low Dimensional Materials Research Centre (LDMRC), Department of Physics, Faculty of Science, Universiti Malaya, 50603 Kuala Lumpur, Malaysia*

*Corresponding Author's E-mail: gohbt@um.edu.my

**Abstract**

One-dimensional (1D) metallic and semiconducting nanowires have emerged as promising materials for energy storage and conversion due to their large surface-to-volume ratios, tunable electronic properties, and excellent electrochemical performance. In this work, we have developed a diverse set of 1D nanowires, including single-crystal silicon and silicide nanowires, as well as a variety of core–shell heterostructures, using custom made CVD vacuum systems. Metallic silicide nanowires such as $Ni_3Si$ and $Mn_4Si_7$, along with their heterostructures (e.g., $Ni_3Si_2$/Si and $Ni_2Si$/SiC), exhibit highly uniform, high-aspect-ratio morphologies and dense surface-active sites. These properties contribute to strong electrochemical behavior, as demonstrated by a $Ni_3Si_2$ nanowire/activated-carbon asymmetric supercapacitor that achieved high specific capacity, notable energy and power densities, and good cycling stability, effectively bridging the performance gap between traditional batteries and supercapacitors. Additional functionalities were also observed; for example, $Mn_4Si_7$ nanowires exhibited room-temperature ferromagnetism, while $Ni_2Si$/SiC core–shell nanowires showed enhanced electrical conductivity and improved electrochemical durability compared to intrinsic Si and SiC nanowires. Collectively, these advances highlight the broad potential of engineered 1D nanowire architectures for use in next-generation nanoelectronic and energy-related devices.

**Keywords:** Nanowires, $Ni_3Si_2$, $Mn_4Si_7$, Electrochemical Supercapacitor, Ferromagnetism

# AI-Augmented Wearable Bioelectronics: A Flexible, Sweat-Based Glucose Monitoring System for Precision Diabetes Management

Nadtinan Promphet[a], Chusak Thanawattano[b], Thidarut Laochai[a], Panlop Lormaneenopparat[a], Wiwittawin Sukmas[d], Pranee Rattanawaleedirojn[c,d], Pumidech Puthongkham[a,c], Pranut Potiyaraj[d], Nadnudda Rodthongkum[a, c*]

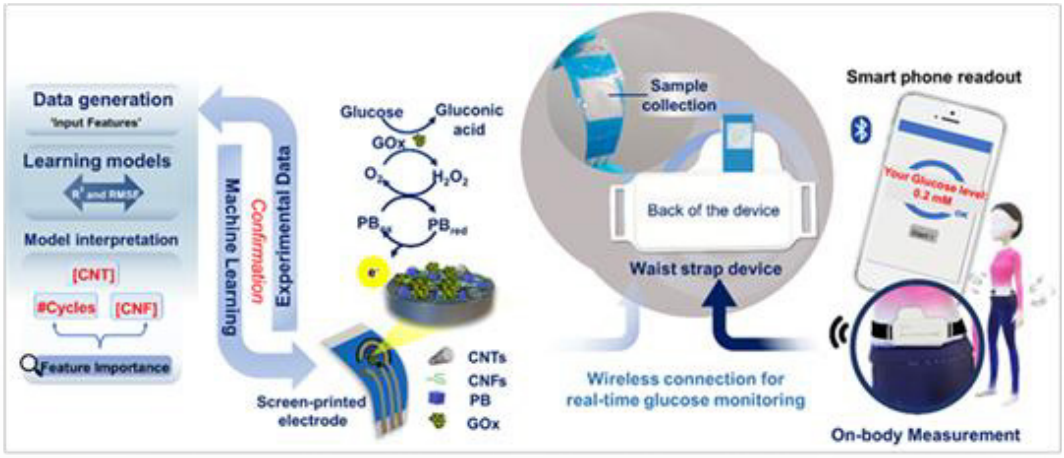


[a]*Department of Chemistry, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand*
[b]*National Electronics and Computer Technology Center, Pathumthani 12120, Thailand*
[c]*Metallurgy and Materials Science Research Institute, Chulalongkorn University,, Phayathai Road, Pathumwan, Bangkok 10330, Thailand*
[d]*Center of Excellence in Responsive Wearable Materials, Chulalongkorn University, Soi Chula 12, Phayathai Road, Pathumwan, Bangkok, 10330, Thailand*

*Corresponding email: Nadnudda.R@chula.ac.th

**Abstract**

This study presents an integrated, flexible electrochemical biosensing platform for non-invasive, real-time sweat glucose monitoring. The sensing interface utilizes a synergistically engineered nanocomposite of Prussian blue (PB), carbon nanotubes (CNTs), and cellulose nanofibers (CNF). Functionalized with glucose oxidase (GOx), this architecture maximizes electroactive surface area and catalytic sensitivity, with morphological and electrochemical characterizations confirming superior charge-transfer kinetics and structural stability. The biosensor is integrated into a miniaturized, wearable potentiostat system featuring Bluetooth connectivity for seamless smartphone-based analytics. The device exhibits high linearity (0–1.2 mM) and a limit of detection (LOD) of 0.1 mM, enabling precise diabetic screening relative to the 0.3 mM clinical threshold. To optimize performance, Machine Learning (ML) regression models were deployed to map the complex correlations between nanomaterial composition, electrodeposition cycles, and peak current responses. This ML-driven framework facilitates predictive sensor design, effectively bypassing traditional trial-and-error methodologies. Validated through clinical trials with diabetic and healthy cohorts, the platform demonstrates a strong correlation with gold-standard diagnostic methods. This work establishes a scalable, smartphone-integrated architecture adaptable for multi-analyte detection and next-generation decentralized healthcare.




**Keywords:** Electrochemical biosensing, Sweat glucose, Machine learning, Non-invasive, Diabetes

# Toward Simple and Deployable Nano-Enabled Sensing Platforms for Diagnostics and Environmental Monitoring

Aurachat Lert-itthiporn[a], Tik Ouiram[a], Nararat Yong[a], Satita Gerdsapaya[a], Suwussa Bamrungsap[a], Dechnarong Pimalai [a], Weeraphat Pon-On[b], Weerakanya Maneeprakorn[a,*]



[a]*National Science and Technology Development Agency (NSTDA), Pathum Thani 12120, Thailand.*
[b]*Department of Physics, Faculty of Science, Kasetsart University, Bangkok 10900, Thailand.*

*Corresponding Author's E-mail: weerakanya@nanotec.or.th

**Abstract**

Nano-enabled sensors have strong potential for real-world use in medical diagnostics and environmental monitoring. In this talk, we present our design approach for developing deployable sensing systems, with an emphasis on starting from simplicity, even though achieving truly simple systems in practice remains challenging. In translating sensors toward real-world applications, not only sensitivity but also the simplicity of the sensor must be considered alongside cost, robustness, and usability. Our strategy is to move away from complex, multi-step designs and instead develop multifunctional nanomaterials that can perform several roles within a single system. By reducing the need for extensive surface functionalization and multiple components, we aim to simplify workflows, lower cost, and improve reliability for use outside the laboratory. We use gold nanoparticles as a representative platform for materials with multiple sensing modalities, supporting both colorimetric and electrochemical detection based on their intrinsic properties. In addition, we explore hybrid nanoparticles, such as carbon dots and magnetic nanoparticles integrated within a single structure (e.g., silica-encapsulated systems), to combine multiple functions, including signal generation and sample handling, within one particle. These materials are applied in colorimetric sensors for rapid screening, particularly nano-enabled lateral flow assays, as well as electrochemical sensors for more sensitive and quantitative analysis. Example applications include monitoring chemical contaminants in water, especially heavy metals such as arsenic, lead, mercury, and cadmium, as well as pesticide residues. We further integrate these sensing elements into portable and miniaturized platforms for on-site use. Key challenges, including matrix effects, stability, and manufacturability, are addressed as part of the design process. Overall, this work highlights a practical direction for sensor development, where simplicity, multifunctionality, and usability are prioritized to enable real-world deployment.

**Keywords:** Nano-enabled sensors, Lateral flow assay, Electrochemical sensors, Environmental monitoring, Heavy metal

# Quenching-Driven Enhancement of Thermal and Piezoelectric Stability in Bi-based Ferroelectrics



Hyunwook Nam*, Yuka Takagi, Hajime Nagata

*Tokyo University of Science, Noda, Chiba 278-8510, Japan*

*Corresponding Author's E-mail: h-nam@rs.tus.ac.jp

**Abstract**

Lead-free Bismuth (Bi)-based piezoelectric ceramics have been extensively studied because of their relatively large piezoelectric characteristics. However, their practical thermal and piezoelectric performance is often limited by poor thermal stability. To overcome this drawback, a rapid-cooling (quenching) process has been considered an effective approach, although the role of the quenching process is still not fully understood. In this talk, the origin of the quenching effect will be discussed by correlating structure with properties. Specifically, A-site Bi ion off-centering displacement will be presented as a key factor strongly governing both piezoelectric properties and phase stability of quenched Bi-based ferroelectric ceramics.

We studied $(Bi_{0.5}Na_{0.5})TiO_3$ (BNT)-based and $BiFeO_3$-$BaTiO_3$ (BFBT)-based ferroelectrics as representative lead-free Bi-based system. Both systems exhibited significantly enhanced thermal stability and piezoelectric characteristics after quenching. Preliminary experiment results showed that the depolarization temperature ($T_d$) can be tuned by controlling the quenching rate. Synchrotron X-ray diffraction (SR-XRD) and pair distribution function (PDF) analyses demonstrated that increased displacement of off-centered Bi ions enhances lattice distortion, thereby stabilizing the ferroelectric *R*3*c* phase. Further studies confirmed a strong correlation between A-site Bi ion off-centering displacement and piezoelectric characteristics. In addition, variations in Bi ion off-centered displacements were found to be consistent with changes in piezoelectric properties. These finding provide useful insights for the design of high-performance BNT- and BF-based piezoelectric ceramics.

**Keywords:** Lead-free Bi-based system, Piezoelectric, Ferroelectrics, Depolarization temperature, Quenching process

# Development of sustainable functional materials for triboelectric nanogenerators



Viyada Harnchana [a,*]

[a]*Department of Physics, Khon Kaen University, Khon Kaen, 40002, Thailand*

*Corresponding Author's E-mail: viyada@kku.ac.th

**Abstract**

The development of clean and sustainable energy technologies has become increasingly important in addressing global energy and environmental challenges. Among emerging energy harvesting technologies, triboelectric nanogenerators (TENGs) have attracted considerable attention due to their ability to convert abundant mechanical energy from the environment into electrical energy through the coupled effects of triboelectrification and electrostatic induction. This study presents the development of high-performance triboelectric materials through the incorporation of nanomaterials derived from biowaste. These nanomaterials play a crucial role in enhancing the intrinsic properties of triboelectric materials, including improved dielectric characteristics, surface morphology, and charge-trapping capability, which collectively contribute to enhanced electrical output performance of TENG devices. In particular, the biowaste-derived nanomaterials exhibit notable photoinduced charge properties, where light irradiation can stimulate additional charge generation and facilitate charge transfer within the triboelectric layers. This photoinduced effect enhances charge density, thereby significantly boosting the electrical output of the TENG under illumination conditions. The results demonstrate that biowaste-derived nanocomposites not only function as efficient triboelectric materials but also introduce a synergistic light-assisted energy harvesting mechanism. Such multifunctional materials support the concept of sustainable resource utilization while providing a promising strategy for improving the performance of TENG-based systems. The development of these materials therefore offers strong potential for advancing next-generation energy harvesting technologies and enabling self-powered electronic systems for smart and sustainable devices.

**Keywords:** Energy harvesting, Triboelectric nanogenerator, Biowaste, anomanterials, Photoinduced charges.

# Ordered Heterogeneous Interfaces Enable Temperature-Insensitive and Ultrahigh-Energy-Storage Multilayer Ceramic Capacitors



Nengneng Luo*, Xiafeng He

*School of Resources, Environment and Materials; Guangxi University, Nanning 530004, China*

*Corresponding Author's E-mail: luonn1234@163.com

**Abstract**

Achieving both high energy storage density and excellent thermal stability in lead-free multilayer ceramic capacitors (MLCCs) has long been a critical challenge for advanced electronic systems. To address this issue, we propose an innovative strategy to simultaneously improve both properties by constructing ordered heterogeneous interfaces, through embedding parallel-aligned $Al_2O_3$ plates in $0.6SrTiO_3$-$0.4Bi_{0.5}Na_{0.5}TiO_3$ (0.6ST-0.4BNT) lead-free ceramics. This approach effectively suppresses the charge carrier injection and transport, yielding an ultrahigh recoverable energy storage density of 16.0 J $cm^{-3}$ with a giant breakdown strength of 1140 kV $cm^{-1}$ in $Al_2O_3$ modified 0.6ST-0.4BNT based MLCCs, which outperforms most state-of-the-art dielectric ceramics. Furthermore, the MLCCs exhibit superior thermal stability with variation less than 3% across a broad temperature range of 20-160 ℃. The overall superior performance underscores the potential of the ordered heterogeneous interface engineering in advancing the thermally stable high-density energy storage materials for next-generation MLCC applications.

**Keywords:** Multilayer ceramics capacitors; Parallel-aligned $Al_2O_3$ plate; Heterogeneous interfaces; Breakdown strength; Energy storage application

# Charge Generation in Organic Solar Cells



Safakath Karuthedath*

*Institute of Materials Research, Tsinghua Shenzhen International Graduate School, Tsinghua University, Shenzhen, 518055, China*

*safakath@sz.tsinghua.edu.cn*

**Abstract**

Y-family acceptors have propelled organic solar cell (OSC) power conversion efficiencies to beyond 21%, yet the reason for the high efficiency is a matter of ongoing debate. This progress is largely due the improved device design and a better understanding of photophysics non-fullerene acceptors. Since organic semiconductors are excitonic, their active layer must combine an electron donor and acceptor to form a heterojunction that splits excitons and separates charges. But,Y6-derivatives challenge this model, as their spectroscopic characteristics suggest direct charge formation in the material itself. Notably, solar cells using Y6 alone have achieved over 4.5% PCE. This work investigated OSCs based on either Y6 or ZY-4Cl as acceptor, both having very similar ionization energies, combined with one of 11 different electron donor materials, spanning an ionization energy offset (ΔIE) range from 0.2 to 0.9 eV. We find that near-unity quantum (charge generation) efficiency is obtained in D:Y6 blends at IE offsets as low as ~0.3 eV, while D:ZY-4Cl blends require double the ΔIE, i.e., at least ~0.6 eV. Density functional theory (DFT) calculations attribute this substantial difference to a lower interfacial charge-transfer (CT) energy in D:Y6 blends. The results rule out intrinsic free charge generation in Y6 or exceptionally long exciton delocalization in Y6 aggregates as the main origin of efficient charge separation. Instead, the stronger electron-withdrawing acceptor group in Y6 appears to reduce the interfacial CT energy more than it reduces the local exciton energy, a trend that holds also for seven other Y-family derivatives, explaining their high efficiency.

**Keywords:** Organic Solar Cells, Charge Carrier Dynamics, Non-fullerene acceptors, IE offset

# NIR and SWIR light detection: next-generation organic photodetectors for imaging and biometric applications



Nicola Gasparini

*Department of Chemistry and Centre for Processable Electronics, Imperial College London, W12 0BZ, UK.*

n.gasparini@imperial.ac.uk

**Abstract**

The current success of organic semiconductor technology is mainly driven by the development of organic light-emitting diodes (OLED), which are now routinely employed in display technologies. In the last decade, however, organic photovoltaics (OPV), leveraging the impressive improvement in device efficiency and stability, have gradually moved from a lab curiosity to a niche market. Organic photodetector (OPD), a technology based on organic photodiodes and thus closely related to OPV, is a new exciting avenue.

OPDs capable of detecting near-infrared (NIR) and short-wave infrared (SWIR) light are emerging as promising candidates for low-cost, large-area optoelectronic applications. Achieving efficient NIR detection with solution-processed organic semiconductors remains challenging due to their inherently limited absorption bandwidths. However, the advent of nonfullerene acceptors (NFAs) and ultra-low bandgap polymers has enabled precise control over molecular energy levels and optical band gaps, paving the way for extended infrared responsivity > 1000 nm. Building on advances in organic photovoltaics, the design of optimised donor:acceptor blends and the mitigation of charge carrier recombination are now central strategies for achieving high-efficiency and durable NIR–SWIR OPDs. This talk outlines material and device design principles that drive effective light-to-current conversion in this spectral range, highlighting pathways for the next generation of infrared organic photodetectors.

**Keywords:** Organic Phototedectors; SWIR; NIR; imaging

# Design and Synthesis of Semiconducting Polymers for Solar-driven Hydrogen Evolution from Water



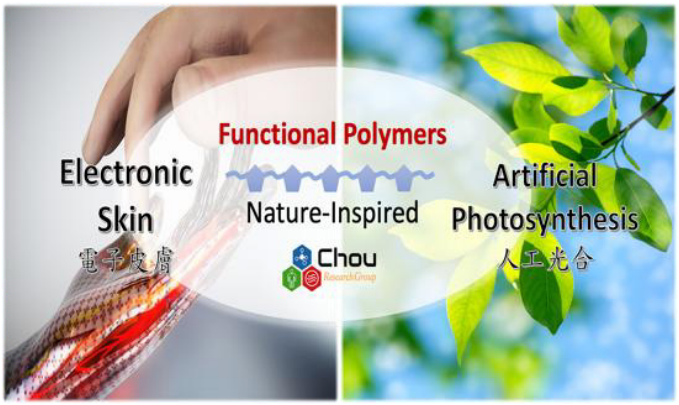
Ho-Hsiu Chou [a,b,c*]

[a] *Department of Chemical Engineering, National Tsing Hua University, Hsinchu, Taiwan*
[b] *College of Semiconductor Research, National Tsing Hua University, Hsinchu, Taiwan*
[c] *Department of Chemical Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand*

*hhchou@mx.nthu.edu.tw

**Abstract**

By mimicking natural photosynthesis, artificial photosynthesis using polymer photocatalysts for the visible-light-driven hydrogen generation through water splitting is an almost ideal process for converting abundant solar energy into useable fuel in an environmentally friendly and high-energy-density manner. Solar-driven photocatalytic hydrogen evolution has gained significant attention due to the inexhaustible supply of solar energy. Extensive efforts have been made to develop highly efficient photocatalytic materials, with organic semiconductors being a prime focus due to their low-cost production, adjustable molecular structures, and tunable bandgaps, which offer distinct advantages over inorganic counterparts. Since the successful use of graphitic carbon nitride in photocatalytic hydrogen evolution systems in 2009, research on polymeric photocatalysts—including linear conjugated polymers, conjugated microporous polymers, polymer dots, covalent triazine frameworks, and covalent organic frameworks—has steadily increased. In this presentation, we discuss the development of new conjugated polymers and polymer dots (Pdots) as photocatalysts for hydrogen evolution, exploring their molecular design, photophysical properties, mechanisms, and applications. This talk will present a clear strategy for the design and recent advancements in polymer photocatalysts for artificial photosynthesis.




**Keywords:** Semiconducting Polymer; Photocatalysis; Solar-driven; Hydrogen Evolution; Water-splitting

# Automated Experiments and Digital Transformation in Next-Generation Solar Cell Research



Akinori Saeki[a*]

[a] *Graduate School of Engineering, The University of Osaka, 2-1 Yamadaoka Suita Osaka 565-0871, Japan*

*Corresponding Author's E-mail: saeki@chem.eng.osaka-u.ac.jp

**Abstract**

Solution-processed inorganic solar cells with less toxic and earth-abundant elements are emerging as viable alternatives to high-performance lead-halide perovskite solar cells (PSCs). However, the wide range of elements and process parameters impedes the rapid exploration of vast chemical spaces. Here, we developed an automated robot-embedded measurement system that performs photoabsorption spectroscopy, optical microscopy, and white-light-flash time-resolved microwave conductivity (TRMC). By using these systems along with machine learning (ML) analysis, we explored nonlead solar cell materials and conducted device characterizations and analyzes. The advantages of combining ML and automated experiments are demonstrated as high-throughput exploration of photovoltaic materials. Refs.) *JACS Au* **2023**, *3*, 3194. DOI:10.1021/jacsau.3c00519; *ACS Materials Lett.* **2022**, *4*, 1124. DOI: 10.1021/acsmaterialslett.2c00229; *Polym. J.* **2020**, *52*, 1307. DOI:10.1038/s41428-020-00399-2.

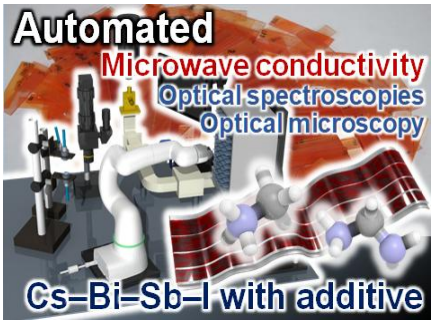



Fig. 1 Automated evaluation of next-generation solar cells.

**Keywords:** Perovskite solar cells, organic solar cells, time-resolved spectroscopy, automated experiments, machine learning

# Emerging Organic Semiconductors for Photovoltaics



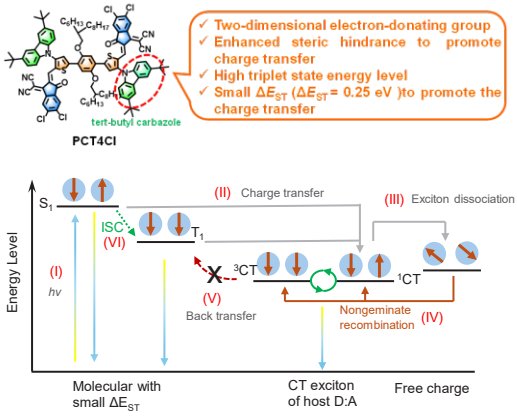
Aung Ko Ko Kyaw[a*]

[a]*Southern University of Science and Technology, China*

*Corresponding Author's E-mail: aung@sustech.edu.cn

**Abstract**

Organic semiconductors have been central to the evolution of organic photovoltaics (OPVs), progressing from fullerene acceptors that enabled efficient exciton dissociation, to high-performance donor materials, and more recently to non-fullerene acceptors that enhance the harvesting of long-wavelength photons. In this talk, I will highlight emerging classes of organic semiconductors for OPVs, with focus on metal complexes and non-fused ring electron acceptors (NFREAs). Compared to pure organic materials, metal-containing conjugated organic molecules offer a broader and more versatile semiconductor platform. They provide unique advantages, including access to triplet excitons, metal-metal and metal-ligand interactions, high photoluminescence quantum yields, and tunable energy levels. By incorporating a simple Pt-complex block into the PM6 polymer backbone, we developed terpolymers that exhibit high triplet energy ($E_{T1}$) and small singlet-triplet energy gap ($\Delta E_{ST}$). These characteristics enable generation of triplet excitons with extended lifetimes and diffusion lengths, thereby suppressing non-radiative recombination via terminal triplet loss channels. We further introduced metal-complex-based acceptors and selectively incorporated them into the host acceptor layer of pseudo planar heterojunction (PPHJ) architectures. This approach effectively suppresses self-aggregation and enables precise morphology control. In addition, crystalline metal complexes were employed as solid additives to strengthen intermolecular interactions, leading to enhanced crystallinity and improved long-term morphological stability. Inspired by the small $\Delta E_{ST}$ of metal complex, we also designed NFREA featuring tert-butyl carbazole side chains. Their high triplet energy levels facilitate efficient transfer of triplet excitons to the host acceptor in ternary blends, inhibiting the back transfer from the charge transfer (CT) state to the triplet state. Furthermore, we reveal that morphology-dependent donor-acceptor contact configurations critically govern energy alignment among ternary components. This interplay gives rise to the rarely observed "PCE roller coaster" behavior in ternary OPVs with varying blend ratios.




**Keywords:** Organic Photovoltaics, Metal Complex, Triplet Exciton, None-Fused Ring Electron Acceptor, Terpolymer

# Bridging 3D Carbon Foams and COF-Based Composites: A Multi-Scale Approach to Next-Generation Energy Storage



Hugo Lavillunière, Cécile Jouanne, Thuan Pham-Truong, Cédric Vancaeyzeele and Pierre-Henri Aubert*

*CY Cergy Paris Université, Laboratoire LPPI, 5 mail Gay Lussac, F-95000 Cergy, France,*

*Corresponding Author : pierre-henri.aubert@cyu.fr

**Abstract**

The quest for high-performance energy storage systems requires a multi-scale approach, balancing macroscopic structural integrity with microscopic charge-storage efficiency. This presentation details two complementary strategies for developing advanced supercapacitor electrodes, moving from self-standing 3D scaffolds to precisely engineered organic frameworks. First, we discuss the development of self-standing 3D carbon foams, termed CarboHIPEs,[1] synthesized through the sulfonation and pyrolysis of High Internal Phase Emulsions (PolyHIPEs). By systematically optimizing sulfonation duration and pyrolysis temperature (up to 800 °C), we developed a hierarchical porous structure that balances microporosity for charge storage (SSA up to 579 $m^2 g^{-1}$) and electrical conductivity (1.05 S $cm^{-1}$). These cost-effective, binder-free electrodes demonstrate reliable performance in aqueous electrolytes (80 F $g^{-1}$ in $H_2SO_4$) and excellent long-term cycling stability, providing a robust platform for scalable energy storage devices.

While these carbon foams provide an ideal macroscopic framework, enhancing the specific capacitance further requires the integration of high-surface-area active materials. In this way, Covalent Organic Frameworks (COFs) are prime candidates due to their chemical tunability, yet their application is often limited by poor electrical conductivity and slow synthesis kinetics.

To address these limitations, the presentation will report another approach utilizing a rapid one-pot microwave-assisted solvothermal synthesis.[2] This method enables the direct formation of core-shell structures where multiwalled carbon nanotubes (MWCNTs) are coated with a homogeneous, well-organized COF film. [3] By reducing synthesis time 40-fold, we achieved precise thickness control (up to 50 nm), resulting in a composite with exceptional surface area (1,113 $m^2 g^{-1}$) and high electrical conductivity (130 S $cm^{-1}$). These optimized nanostructures deliver a remarkable gravimetric capacitance of 406 F $g^{-1}$ and withstand over 200,000 cycles, outperforming state-of-the-art materials. Together, these two studies demonstrate a transition from structural engineering of 3D carbon scaffolds to the molecular precision of COF/carbon hybrid interfaces. This dual approach offers a comprehensive roadmap for achieving the high power and energy densities required for the next generation of supercapacitors.

**Keywords:** carboHIPEs, Covalent Organic Framework, Supercapacitors

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# Modeling coordination polymer interfaces for device simulations

Daniel Packwood[a,b*], James Scott[a], Joseph Nelson[c,d] , Pichaya Pattanasattayavong[e]

[a] *Institute for Integrated Cell-Material Sciences (iCeMS), Kyoto University, Kyoto 606-8302, Japan*
[b] *Center for Integrated Data-Material Sciences (iDM), MacDiarmid Institute for Advanced Materials and Nanotechnology, Wellington 6010, New Zealand*
[c] *Lincoln Agritech Ltd, Lincoln University, Christchurch 7674, New Zealand*
[d] *MacDiarmid Institute for Advanced Materials and Nanotechnology, Wellington 6010, New Zealand*
[e] *Department of Materials Science and Engineering, School of Molecular Science and Engineering, Vidyasirimedhi Institute of Science and Technology (VISTEC), Rayong 21210, Thailand*

*Corresponding Author's E-mail: dpackwood@icems.kyoto-u.ac.jp



**Abstract**

Copper thiocyanate (CuSCN) is a wide bandgap coordination polymer semiconductor that is often used as a hole transport material in optoelectronic devices. While bulk CuSCN is relatively straightforward to model using density functional theory (DFT), the surfaces of CuSCN can be challenging due to the presence of a dipole moment. This dipole moment can cause unwanted electric fields to occur in finite slab models, leading to unphysical effects such as band energy drifts and the loss of a bandgap (Figure). Accurate modeling of these surfaces is essential for understanding how CuSCN and other coordination polymer semiconductors operate as optoelectronic materials, as the surface dipole will have a decisive influence on exciton dissociation, charge transport, and other processes that take place during device operation.

In this presentation, we will introduce a new passivation scheme for modeling CuSCN surfaces with DFT. Our passivation scheme essentially involves doping a CuSCN slab with a fractional number of electrons. These electrons are supplied by adding 'pseudohydrogen' atoms to the bottom of the slab, which are built using the so-called virtual crystal approximation (VCA). By correcting the unwanted electric field within a CuSCN(001) slab, we prevent the loss of the band gap but find that the slab exhibits n-type semiconducting behavior, in contrast with experimental results. We then show that surface reconstructions of CuSCN(001) exhibit a self-passivation mechanism, reducing both the internal electric field and surface energy, and producing the correct p-type semiconducting behavior. These results strongly suggest that reconstructed CuSCN(001) slabs should be employed for future modelling studies.

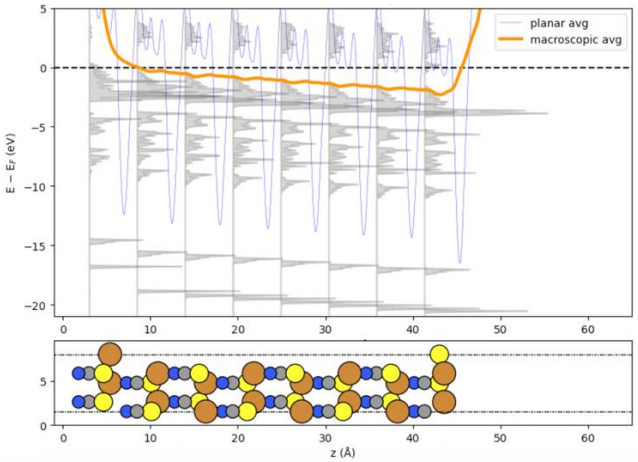



Figure: Layer-resolved density of states for a CuSCN(001) slab showing that band energies drift through the slab as a result of the dipole moment.

**Keywords:** coordination polymer, semiconductor, dipole moment, density functional theory, device modeling

# Towards Ultrahigh Osmotic Energy Harvesting by MOF and COF Based Ionic Diode Membranes



Li-Hsien Yeh*

*Department of Chemical Engineering, National Taiwan University of Science and Technology, Taipei, Taiwan*

*Corresponding Author's E-mail: lhyeh@mail.ntust.edu.tw

**Abstract**

The chemical energy stored between seawater and river water, the so-called osmotic energy (or blue energy), can be harvested by an ion-selective membrane. However, previously reported membranes suffer from insufficient ion selectivity and inferior transmembrane ionic flux (low conductance), thus impeding practical application. For example, the output osmotic power density reported by most of existing ion selective membranes is typically below the commercial benchmark of 5 W/m$^2$. Taking the inspiration from electrocytes in electric eel, which consist of a large number of sub-nanoscale rectified ion channels that allow unidirectional ion transport with amplified flux, we engineered two types of sub-2 nm-scale covalent-organic framework (COF) and metal-organic framework (MOF) (Figure 1) based ionic diode membranes for osmotic energy harvesting. We show that the two COF and MOF-based heterogeneous membranes can rectify ionic current even in high salt concentration. We then probe application of these membranes in harvesting energy from salinity gradients. Notably, in addition to ultrahigh ion selectivity, these sub-2 nm-scale ionic diode membranes can achieve an unprecedented power density, higher than the commercial benchmark bandgap and outperforms all the state-of-the-art ion selective membranes. Our works would open up new avenues of using pinhole-free COF and MOF membranes towards next-generation highly selective and ultrahigh-performance sustainable energy harvesting.

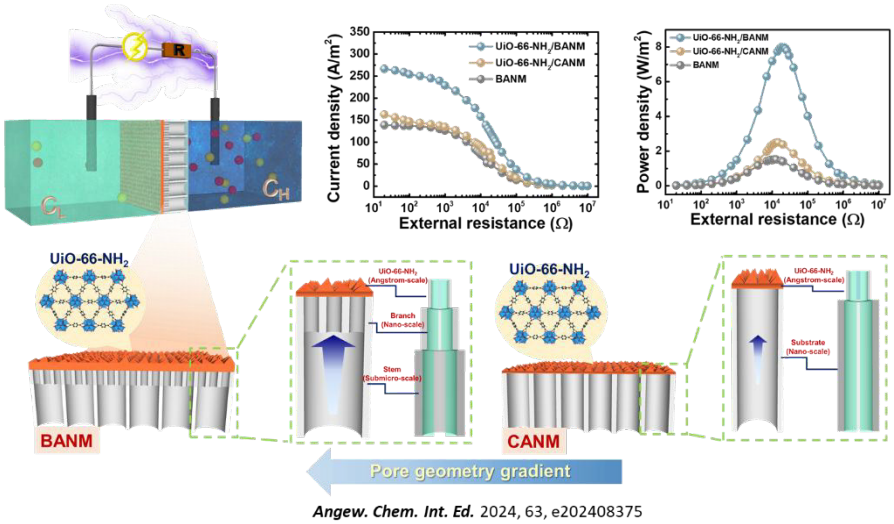



Fig.1 Schematic of MOF-based ionic diode membrane with large pore geometry gradient for high-performance osmotic energy harvesting.

**Keywords:** Nanofluidic membrane, Blue energy, Metal-organic framework (MOF), Covalent-organic framework (COF)

# Low-temperature(≤100°C) Processed p-i-n structured AgBis2 Solar cell via Co-evaporation



Minho CHOI[a] , Suhwan KIM[a], Jongsung PARK [a,*],

[a]*Department of Energy System Engineering, Future Convergence Technology Research Institute, Gyeongsang National University, Jinju, 52849, Republic of Korea*

*Corresponding Author's E-mail: j.park@gnu.ac.kr

**Abstract**

Low-temperature, lead-free thin-film photovoltaics are key to realizing flexible and lightweight energy-harvesting platforms with reduced environmental impact. In this work, we demonstrate the first $AgBiS_2$ PIN solar cells based on MeO-2PACz as the hole-selective contact, enabled by direct thermal co-evaporation of Ag, Bi, and S. By introducing in-situ sulfur co-deposition during film growth, we achieve sulfurization-free processing while promoting robust phase formation at just 100 °C far below the temperatures typically required in prior $AgBiS_2$ thin-film approaches. The best-performing devices reach Jsc = 29.38 mA $cm^{-2}$, Voc = 282 mV, and PCE = 4.15%. Beyond simplifying fabrication, this low-temperature evaporation route offers a practical and scalable pathway for compatibility with flexible substrates and for accelerating stable, high-efficiency, lead-free chalcogenide photovoltaics.

**Keywords:** AgBiS2, Thin-film, co-evaporation, photovoltaics

# Triplet Formation and Photo-Switching in Flexible Molecular Electron Acceptors



Paul A. Hume[a,*], Sai Shruthi Murali[b], Aditi Kumar,[c] Justin M. Hodgkiss

[a]*School of Chemical and Physical Sciences, Victoria University of Wellington, Wellington 6012, New Zealand.*
[b]*MacDiarmid Institute for Advanced Materials and Nanotechnology, Wellington 6012, New Zealand*
[c]*The Dodd-Walls Centre for Photonic and Quantum Technologies, Dunedin 9016, New Zealand*

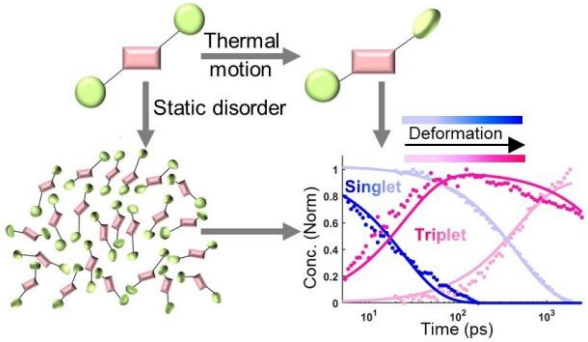
*Corresponding Author's E-mail: paul.hume@vuw.ac.nz

**Abstract**

Control over the populations of singlet and triplet excitons is central to organic semiconductor technologies, such as solar cells, light-emitting diodes, and lasers. In particular, there is a growing recognition of the role of triplets in organic solar cells / photovoltaics (OPVs), due to the rise of non-fullerene electron acceptors. These high performance materials have propelled OPV efficiency to >19 %, but they have also altered fundamental light-to-electricity conversion processes in a way that increases the relevance of triplets to device performance.

This talk will survey our recent studies of triplet processes in a novel series of non-fullerene electron acceptors using a combination of ultrafast spectroscopy (transient absorption and ultrafast broadband photoluminescence) and quantum-chemical modelling. We demonstrate that in these materials, intramolecular triplet formation is accelerated by structural disorder in solution-processed films to an extent where it can compete with charge formation in modern organic solar cells. This implicates triplets in intrinsic exciton loss channels in addition to their more widely known role in charge recombination.

We also report the unanticipated visible-light photo switching behavior of one of these electron acceptors ('NIDCS-A') which is conformationally strained. This compound exhibits an unusual dual photo-switching mechanism via both singlet and triplet excited states. In the singlet state, photoisomerisation precedes geometric relaxation, which enables the molecule to overcome a surprisingly large energy barrier. At later times, photoisomerisation is mediated by long-lived triplet states.




**Keywords:** photovoltaics, non-fullerene electron acceptors, photo-switching, organic semiconductors, solar energy

# Light to Logic: Ambient Photocapacitors for Battery-Free Edge Computing



Marina Freitag

*School of Natural and Environmental Sciences, Newcastle University, NE1 7RU, UK*

*Corresponding Author's E-mail: marina.freitag@newcastle.ac.uk

**Abstract**

Powering continuous artificial intelligence at the network edge demands energy harvesting and storage under indoor light, where batteries impose finite lifetimes and maintenance costs incompatible with billions of distributed sensors. We present a three-terminal photocapacitor that converts ambient photons into stored charge and delivers it directly to an edge microcontroller, closing the loop from light to logic without batteries or grid connection [1].

The device monolithically integrates a dye-sensitised solar cell (DSC) with a polyviologen/carbon asymmetric supercapacitor through a shared PEDOT electrode. Molecular design governs performance at every interface. $Cu^{II/I}(tmby)_2$ redox shuttles with sub-0.3 eV reorganisation energies drive DSC power conversion efficiencies beyond 30% under 1000 lux [2]. For the storage component, we introduce the polyviologen PVN, whose DFT-predicted V-shaped conformation is 0.1 eV more stable than the U-shaped alternative, translating into 100% capacitance retention over 3000 cycles. Bio-derived fungal membranes replace commercial Nafion, delivering higher capacitance and longer discharge times, while computed internal reorganisation energies of 0.1–0.2 eV for the radical cations confirm minimal structural distortion during redox cycling.

Under 1000 lux the photocapacitor produces 920 mV photocharging voltage and 18% overall efficiency. A three-layer wireless IoT network powered exclusively by these devices sustained 72 hours of continuous edge computing, executing 137 inferences at 1000 lux (3.5 times the throughput of commercial amorphous-silicon modules) and reaching 93% accuracy on CIFAR-10 at 0.81 mJ per classification.

To extend this platform toward scalable deployment, flash infrared annealing now sinters mesoporous $TiO_2$ on 12.5 µm polyimide, yielding ultralight flexible DSCs at 255 mW $g^{-1}$ specific power, 51 times the glass equivalent [3], while dopant-free coordination polymer hole conductors reaching 1 mS $cm^{-1}$ [4] and a $C_{60}$-derived ionic-salt electron shuttle at 26% perovskite efficiency [5] broaden the materials toolkit for autonomous indoor energy systems.

**Keywords:** photocapacitors, ambient photovoltaics, polyviologens, dye-sensitised solar cells, edge AI, Internet of Things

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# Compositional Engineering on Metal Halide Perovskites for Efficient Tandem Photovoltaics



Dong-Won Kang[a,*]

[a] *School of Energy Systems Engineering, Chung-Ang University, Republic of Korea*

*Corresponding Author's E-mail: kangdwn@cau.ac.kr

**Abstract**

To meet long-term energy requirements, the utilization of renewable energy is essential for mitigating environmental pollution and achieving carbon neutrality. Among various renewable sources, solar energy is the most abundant and critical for next-generation technologies. Despite the high efficiency of silicon-based technology, significant challenges remain, such as high processing costs and limited application versatility. Organic-inorganic metal halide perovskites (OIHPs) have emerged as promising candidates, showing rapid progress over the last decade due to their wide bandgap tunability, ease of dopant-induced optoelectronic modification, long carrier diffusion lengths, and high carrier mobility. Perovskite solar cells (PSCs) have already achieved a certified power conversion efficiency (PCE) of 27.3%, approaching the Shockley-Queisser limit. However, a portion of solar energy remains unutilized as spectral loss due to the limited optical response of photo-absorbers. Single-junction solar cells cannot avoid excess thermalization losses or exploit photons with energies below the bandgap, which limits their optical response. To further enhance efficiency, tandem PSC architectures have been proposed to harness a broader range of the solar spectrum. In this presentation, various sub-cell technologies employing OIHPs and lead-free (Pb-free) perovskite light harvesters are discussed to realize high-performance perovskite-based tandem PSCs.

**Keywords:** Solar Cells, Perovskites, Tandem

# Sustainable Routes for the Synthesis and Circularity of Metal Halide Perovskite Materials and Devices



Martyn A. Mclachlan

*Department of Materials, Molecular Sciences Research Hub, Imperial College London, London, W12 0BZ*

*Corresponding Author's E-mail: xmartyn.mclachlan@imperial.ac.uk

**Abstract**

Metal halide perovskites (MHPs) have emerged as a highly versatile materials platform for photovoltaics and next-generation optoelectronics. Their rapid development is driven by an exceptional combination of properties, including bandgap tunability, strong optical absorption, long charge-carrier diffusion lengths, and high charge-carrier mobilities, alongside compatibility with low-cost and scalable processing. Despite this promise, the sustainable manufacture of MHP-based devices remains limited by processing routes that often depend on toxic or environmentally hazardous solvents, complex multi-solvent systems, and thermal annealing steps to achieve the desired crystalline phases. Addressing these limitations is essential if MHP technologies are to move towards scalable, low-impact manufacturing.

Here, we present a range strategies developed in our laboratory for the low-temperature synthesis of MHP thin films, nanocrystals, and single crystals using environmentally benign solvent systems. Central to this work is a water-based route that enables the ambient, room-temperature preparation of size-tunable and compositionally controlled $CsPbBr_3$ nanocrystals. The resulting nanocrystals exhibit photoluminescence quantum yields of <60%, and post-synthetic anion exchange further enables access to $CsPbX_3$ nanocrystals, where X = Cl, Br, or I, with emission tunable across 450–660 nm. Finally, we show how these solvent systems can be applied to the recovery and reuse of MHP thin films, enabling the fabrication of efficient devices from recycled perovskite materials and highlighting their potential for more circular, sustainable MHP manufacturing. This approach provides a scalable, low-cost, and more sustainable pathway to MHP nanomaterials with controlled optical properties, advancing the development of greener processing strategies for future optoelectronic technologies.

**Keywords:** Metal Halide Perovskites: Characterization: Green Synthesis: Sustainability

# (Macro)molecular materials based on through-space donor-acceptor interactions



Fabrice Mathevet[a,b,c,*] Dizheng Liu[c] Chao Wu[c] Lihua Chen[d] Lucas Frederic[e] Lydia Sosa-Vargas[c] David Kreher[c] Shaodong Zhang[d] Chihaya Adachi[a,b]

[a]*Organic Photonics and Electronics International Laboratory (OPHELIA), CNRS-Kyushu University, IRL 2043, Fukuoka 819-0395, Japan*
[b]*Center for Organic Photonics and Electronics Research (OPERA), Kyushu University, Fukuoka 819-0395, Japan*
[c]*Sorbonne Université, CNRS, Paris Intitute of Molecular Chemistry (IPCM), Paris 75005, France*
[d]*School of Chemistry and Chemical Engineering, Shanghai Jiao Tong Univ., Shanghai, China*
[e]*ENS Paris-Saclay, PPSM, Université Paris-Saclay, CNRS, Gif-sur-Yvette, France*

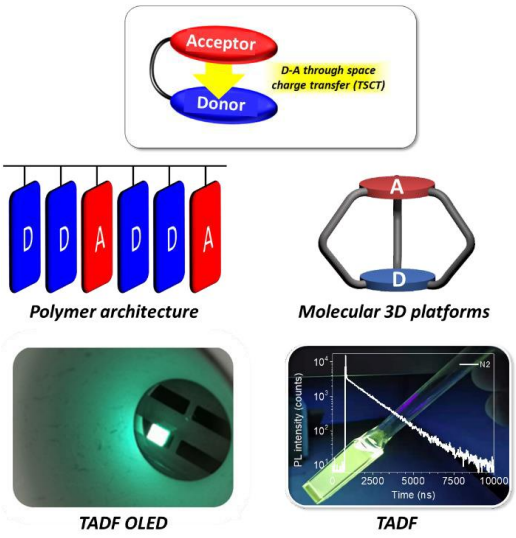
*Corresponding Author's E-mail: fabrice.mathevet@sorbonne-universite.fr, fabrice.mathevet@opera.kyushu-u.ac.jp

**Abstract**

TADF materials have been intensively studied over the last decade because they can achieve 100% internal quantum efficiency (IQE) in OLEDs through efficient up-conversion of triplet excitons into singlet excitons via reverse intersystem crossing (RISC), driven by thermal energy.[1] In general, the key strategy involves reducing the overlap between the highest occupied molecular orbital (HOMO) and the lowest unoccupied molecular orbital (LUMO), which are generally distributed onto the electron-donating (D) and electron-accepting (A) units, respectively. Thus, the common design strategy for TADF emitters is to spatially separate the D and A groups using a central core. A limited overlap between the HOMO and LUMO is nevertheless preserved through weak electronic communication mediated by a highly twisted conjugated linker.[1]

Recently, a novel molecular design, based on through-space interactions has emerged as an effective route toward highly efficient TADF emitters. This alternative approach allows the physical separation of the D and A moieties, thereby minimizing HOMO-LUMO overlap.[2] In such systems, intramolecular through-space D-A interactions occur, and the D and A electronic clouds mainly communicate via spatially mediated charge-transfer interactions. This strategy leads to very small ΔEST values and can simultaneously enhance radiative decay rates.

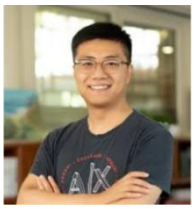
In this context, we aim to explore new (macro)molecular designs for the preparation of through-space TADF emitters (see Figure). For the polymer-based approach, we propose to design side-chain copolymers incorporating controlled ratios of D and A side groups, enabling through-space interactions and self-host TADF properties. For the molecular approach, we propose to use versatile 3D platforms that position donor and acceptor units in close spatial proximity to promote through-space D-A interactions and TADF emission properties.[3][4][5].




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**Keywords:** Organic emitting materials, through-space charge transfert, TADF, OLEDs

# Atomic Defects in 2D Materials: Single-Image-Based Deep Learning Identification & Catalytic Platinum Anti-Substitutions



Xiaoxu Zhao[a,*], Kangshu Li[a], Jun Zhao[a]

[a]*School of Materials Science and Engineering, Peking University, China, 100871*

*Corresponding Author's E-mail: xiaoxuzhao@pku.edu.cn

**Abstract**

Atomic defects are central to understanding and engineering functionality in two-dimensional (2D) transition-metal dichalcogenides (TMDs), but two practical challenges remain: precise atomic defect identification at atomic scale from noisy experimental images and the controllable creation of catalytically active atomic configurations. In this report, we present two complementary advances. First, we introduce a single-image-based deep learning strategy for precise atomic defect identification in atomic-resolution scanning transmission electron microscopy (STEM). By using a single experimental STEM image to generate image-specific training data (via augmentation/translation) and then performing pixel-level defect segmentation, the approach enables robust identification of diverse defect motifs across representative TMD systems. This single-image-based workflow is designed to reduce the reliance on large labeled datasets while maintaining high sensitivity to subtle defect signatures in real experimental conditions. Second, we highlight atomically dispersed catalytic platinum anti-substitutions in molybdenum ditelluride, where electrochemical synthesis yields isolated Pt configurations associated with defective 1T'-$MoTe_2$. Atomic-resolution STEM imaging directly reveals platinum anti-substitutions and their local coordination environments, and theory supports the stabilization of these motifs in the presence of intrinsic defects. Electrochemical measurements demonstrate excellent hydrogen evolution reaction (HER) performance, including a low overpotential of 12.9 mV at 10 mA $cm^{-2}$ and strong durability. These results connect single-image-based deep learning for precise atomic defect identification with atomically dispersed catalytic platinum anti-substitutions in a prototypical 2D TMD, providing a practical route from defect discovery and statistical analysis to defect-enabled catalytic functionality.

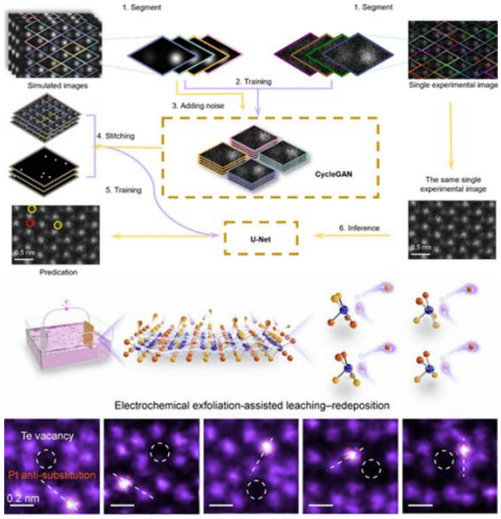



Fig.1 Schematics and STEM images showing defects and anti-substitutions in 2D materials.

**Keywords:** Scanning Transmission Electron Microscopy, Deep Learning, Defect Engineering, Transition Metal Dichalcogenides, Anti-substitutions, Hydrogen Evolution Reaction.

# Reimagining Titanium Diboride: From Inert Ceramic to 2D Electrodes for Next-Generation Batteries



Kabeer Jasuja

*Corresponding Author's E-mail: kabeer@iitgn.ac.in

**Abstract**

Transition-metal borides, long regarded as chemically inert ceramics, are emerging as an unconventional platform for two-dimensional (2D) materials through non-classical synthesis routes. In this work, we demonstrate a scalable, room-temperature dissolution–recrystallization strategy to transform titanium diboride ($TiB_2$) into oxy-functionalized nanosheets with tunable chemistry and hierarchical structure. The resulting nanosheets form stable aqueous dispersions and can be assembled into macroscopic architectures, enabling versatile processing for device integration.

Leveraging their high surface area, mixed Ti–O/B–O functionality, and structural robustness, $TiB_2$-derived nanosheets exhibit outstanding performance as battery electrodes. As lithium-ion anodes, they deliver high reversible capacity, excellent rate capability, and ultrafast charging at current densities up to 15–20 A $g^{-1}$, while maintaining long-term cycling stability over 10,000 cycles. Extending this platform, the same nanosheets demonstrate promising sodium-ion storage, with high capacity and stable cycling, and enable full-cell operation with competitive energy and power densities.

These results highlight a synergistic charge-storage mechanism arising from surface-controlled reactions and the adaptable nanosheet architecture. More broadly, this work redefines metal borides as a new class of 2D functional materials and establishes a pathway to bridge fundamental materials chemistry with scalable energy storage technologies.

**Keywords:** 2D materials, Borophene, XBenes, Titanium Diboride, Transition Metal Diborides

# From Semiconductors to Energy: ALD-Enabled Interface Engineering



Amarnath T. Sivagurunathan[a], Sangeeta Adhikari [a, b], Do-Heyoung Kim[a]*

[a]*School of Chemical Engineering, Chonnam National University, 77 Yongbong-ro, Buk-gu, Gwangju 61186, Republic of Korea*
[b]*Department of Chemistry, School of Advanced Sciences, VIT-AP University, Beside AP Secretariat, Amaravati, 522241, Andhra Pradesh, India*

*Corresponding Author's E-mail: kdhh@chonnam.ac.kr

**Abstract**

Atomic layer deposition (ALD) has long been a key technique in the fabrication of advanced semiconductor integrated circuit (IC) devices, owing to its ability to provide atomic-scale thickness control and excellent conformality over complex three-dimensional structures. Its use has recently extended beyond microelectronics to emerging applications in energy storage and conversion.

A major advantage of ALD is the precise control of interfacial properties through self-limiting surface reactions. This presentation demonstrates the versatility of ALD in electrochemical energy systems, with a focus on supercapacitor and water-splitting electrodes. Ultrathin, conformal coatings introduced by ALD improve both performance and stability. ALD-modified supercapacitor electrodes exhibit increased capacitance and improved cycling stability, while water-splitting electrodes show enhanced catalytic activity and long-term durability.

These results highlight the importance of interface engineering in determining device performance and reliability, and position ALD as a practical approach linking semiconductor processing with next-generation energy technologies.

**Keywords:** Atomic layer deposition, Interface Engineering, Electrochemical Energy Systems

# Metastable Silicon-based Anode Materials for Stable Lithium-Ion Batteries



Ruohan Yu[a], [b*], Liqiang Mai[a], [b]

[a]*Wuhan University of Technology, The Sanya Science and Education Innovation Park Sanya 572000, People's Republic of China.*
[b]*State Key Laboratory of Advanced Technology for Materials Synthesis and Processing, Wuhan University of Technology, Wuhan 430070, P. R. China.*

*Corresponding Author's E-mail: yuruohan@whut.edu.cn

**Abstract**

Silicon is a leading anode candidate owing to its exceptional theoretical specific capacity of ~3579 mAh/g, nearly an order of magnitude higher than that of commercial graphite. However, this immense potential is severely undermined by the colossal volume expansion (~300%) during lithiation. This leads to a cascade of failure mechanisms, including electrode pulverization, chronic instability of the solid electrolyte interphase (SEI), and loss of electrical integrity, culminating in rapid capacity decay. Our research has systematically addressed this central challenge through the strategic design and control of metastable states within spatially confined architectures.

To provide direct, mechanistic insight into these designs, we employed a multi-modal electron microscopy workflow. Atomic-resolution details of delicate, beam-sensitive phases were revealed using aberration-corrected scanning transmission electron microscopy (AC-STEM) under low-dose conditions. This was complemented by electron 3D tomography, which mapped their intricate three-dimensional architectures. These advanced characterization tools have enabled us to discover and develop a series of metastable material systems that impart remarkable stability to silicon anodes. Our findings are structured around two key paradigms. The first is "static" metastability, where protective architectures with pre-designed voids are rationally engineered into the pristine material. The second, more transformative, strategy is "dynamic" metastability. Here, we present materials pre-designed to be intentionally "unstable," which are then induced during cycling to self-organize into a functionally robust, cyclable architecture. This cycling-induced structural adaptation represents a novel pathway toward in-situ material reinforcement and exceptional durability.

Collectively, this presentation will establish that harnessing both engineered and cycling-induced metastability is a highly effective paradigm for creating durable silicon anodes. We will demonstrate how these fundamental insights, backed by compelling visual evidence from advanced microscopy, pave a cost-effective and scalable pathway toward the commercial realization of Si-based energy storage.

**Keywords:** Lithium-ion battery, electron microscopy, self-adaptive evolution, metastable materials, electron 3D tomography.

# The highly active catalyst for the fuel electrode of solid-oxide cells



Zheng dao Jin, Hee Jung Park*

*Department of Materials Science and Engineering, Dankook University, Dandae-ro 119, Dongnam-gu, Cheonan-si, Chungnam 31116, Korea*

*Corresponding Author's E-mail: parkjang@dankook.ac.kr

**Abstract**

In this study, we propose a novel infiltration strategy in which pre-synthesized ultra-nanosized ceria sol is directly infiltrated onto a reduced porous Ni-Fe metal support and the fuel electrode surface in solid-oxide cells(SOCs), enabling electrochemical testing without any additional thermal treatment. This method results in the formation of a uniform and ultrathin ceria layer with improved interfacial connectivity across the electrode surface. The area-specific resistance (ASR) of the pristine electrode is approximately 1.0 Ω $cm^2$, whereas that of the nano-$CeO_2$ infiltrated electrode is reduced to 0.2 Ω $cm^2$. Meanwhile, the ASR degradation rate during durability testing decreases from 6.4 Ω $cm^2$ per 100 h for the catalyst-free electrode to 0.5 Ω $cm^2$ per 100 h for the nano-$CeO_2$ infiltrated electrode, representing an approximately thirteenfold enhancement in operational stability. Furthermore, in full-cell tests operated in electrolysis mode, the current density measured at 800 °C under a 50% $H_2O$ / 50% $H_2$ atmosphere and an applied voltage of 1.3 V increases from 1.56 A $cm^{-2}$ for the catalyst-free electrode to 3.48 A $cm^{-2}$ for the nano-$CeO_2$ infiltrated electrode, corresponding to an enhancement of approximately 220%. This result clearly demonstrates the effectiveness of the proposed strategy in simultaneously improving electrochemical activity and durability in SOCs.

**Keywords:** Solid-Oxide Cells, Fuel electrode, Catalyst, Nano $CeO_2$, Electrochemical performance

# Single-crystal-like $Na_xMnO_2$ for high-performance sodium-ion batteries



Weeraporn Treerittiwittaya[a], Mongkol Tipplook[b], Sidra Jamil[c], Chayanon Atthapak[d,e], Pinit Kidkhunthod[f], Jintara Padchasri[f], Krongthong Kamonsuangkasem[f], Suttipong Wannapiboon[f], Pimpa Limthongkul[g], Hongyi Gao[h], Annop Ektarawong[d,e], Nuria Tapia-Ruiz[c,i], Katsuya Teshima[b], Jitti Kasemchainan[a,j,*]

[a]*Department of Chemical Technology, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand*

[b]*Research Initiative for Supra-Materials, Shinshu University, 4-17-1 Wakasato, Nagano 380-8553, Japan*

[c]*Department of Chemistry, Molecular Sciences Research Hub, Imperial College London, White City Campus, London, W12 0BZ, United Kingdom*

[d]*Extreme Conditions Physics Research Laboratory and Center of Excellence in Physics of Energy Materials, Department of Physics, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand.*

[e]*Chula Intelligent and Complex Systems Center of Excellence, Department of Physics, Faculty of Science, Chulalongkorn University, Bangkok 10330*

[f]*Synchrotron Light Research Institute, Nakhon Ratchasima, 30000, Thailand*

[g]*National Energy Technology Center, 114 Thailand Science Park, Pathumthani, 12120, Thailand*

[h]*Beijing Advanced Innovation Center for Materials Genome Engineering, Beijing Key Laboratory of Function Materials for Molecule & Structure Construction, School of Materials Science and Engineering, University of Science and Technology Beijing, Beijing 100083, PR China*

[i]*The Faraday Institution, Quad One, Harwell Science and Innovation Campus, Didcot, OX11 0RA, UK*

[j]*Center of Excellence on Advanced Materials for Energy Storage (CE-AMES), Chulalongkorn University, Bangkok, Thailand*

*Corresponding Author's E-mail: jitti.k@chula.ac.th

**Abstract**

Na-ion batteries (NIBs) are deemed as promising alternatives to Li-ion batteries thanks to the widely acceptable facts of the natural abundance of sodium resources as well as the feasibility of using mass-production friendly constituents like Al current collector and Mn-based positive electrode materials. Sodium manganese dioxide ($Na_xMnO_2$) is one of the most common positive active materials being explored on the basis of availability and non-toxicity in addition to its attractive cost. In our work, we synthesized single-crystal-like $Na_xMnO_2$ from a flux-growth method. After electrode fabrication and cell assembly, the Na-ion battery performances were tested with galvanostatic cycling at different C-rates. The charge-discharge curves indicate that the insertion and extraction behavior of Na ions within the host structure during cycling is significantly unique. This study also discusses the application of synchrotron in-situ X-ray absorption spectroscopy (XAS) and X-ray diffraction (XRD) in understanding the electrochemical reactions of $Na_xMnO_2$, focusing on the alterations in oxidation states and the evolution of the crystal structures. This will pave a way to enable high-performance NIBs for various energy storage applications.

**Keywords:** Na-ion batteries; single crystal; sodium manganese dioxide; in-situ XAS & XRD

# Atomic Structure of Novel Precipitates in Low Zn/Mg Ratio Al–Zn–Mg Alloys

Seungwon Lee[a, *], Wanlalak Sanphiboon[b], Calin D. Marioara[c], Norio Nunomura[a], Taiki Tsuchiya[a], Abrar Ahmed[a], Susumu Ikeno[a], Tomoo Yoshida[d], Randi Holmestad[e], Kenji Matsuda[a]

[a]*Faculty of Sustainable Design, University of Toyama,3190 Gofuku, Toyama, Japan*
[b]*Graduate School of Science and Engineering for Education, University of Toyama, 3190 Gofuku, Toyama, Japan*
[c]*SINTEF Industry, N-7465 Trondheim, Norway*
[d]*Aisin Keikinzoku Co., Ltd, 12-3, Toyama, Japan*
[e]*Department of Physics, Norwegian University of Science and Technology (NTNU), N-7491 Trondheim, Norway*

*Corresponding Author's E-mail: swlee@sus.u-toyama.ac.jp



**Abstract**

Al–Zn–Mg alloys are widely used as medium- to high-strength age-hardenable aluminum alloys, where the precipitation behavior strongly depends on the Zn/Mg ratio. In alloys with low Zn/Mg ratios, precipitation sequences differ significantly from conventional η′/η phase formation, yet the detailed atomic structures of metastable precipitates in such systems remain insufficiently understood . In this study, a previously unreported precipitate was identified in a peak-aged Al–Zn–Mg alloy with a low Zn/Mg ratio aged at 120 °C. Transmission electron microscopy (TEM) observations revealed that the precipitate exhibits a lath- or plate-like morphology, with habit planes parallel to $\{110\}_{Al}$ and a longitudinal direction along $\langle 100\rangle_{Al}$. Selected area electron diffraction (SAED) patterns showed characteristic streaks and additional reflections along $\langle 110\rangle_{Al}$, indicating the presence of a distinct phase not corresponding to conventional η′/η or T′/T precipitates. To determine the atomic structure, high-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM) observations were conducted along $\langle 100\rangle_{Al}$ and $\langle 110\rangle_{Al}$ zone axes. The atomic-scale contrast revealed a periodic structure coherently aligned with the Al matrix. Based on these observations, several candidate structural models were constructed. The models were subsequently evaluated using first-principles calculations based on density functional theory (DFT), where the formation energies were calculated to assess their thermodynamic stability. Among the proposed models, the $Al_9Zn_{24}Mg_9$ configuration exhibited the lowest formation energy (−0.0376 eV/atom), indicating the highest thermodynamic stability among the candidates. Although this value is higher than those of the equilibrium η and T phases, it confirms that the precipitate is a metastable phase that can form under specific aging conditions . Structurally, the newly identified precipitate consists of truncated cube octahedron (TCO) units, which are also known as the fundamental building blocks of GP zones. Unlike conventional GP1 zones, where TCO units are primarily connected along $\langle 411\rangle_{Al}$, the present precipitate exhibits lateral connections along $\langle 330\rangle_{Al}$, resulting in a distinct crystallographic configuration and morphology. This structural difference suggests a unique precipitation pathway in low Zn/Mg ratio alloys. The present findings provide new insights into precipitation behavior and atomic-scale structure in Al–Zn–Mg alloys with low Zn/Mg ratios. The identification of this novel metastable precipitate contributes to a deeper understanding of phase evolution and may offer new perspectives for tailoring mechanical properties through microstructure control in these alloys.

**Keywords:** Al–Zn–Mg alloy, HAADF-STEM, Precipitation, Atomic structure, First-principles calculation

# Infrared-THz free-electron lasers and femtosecond lasers for materials research



Sakhorn Rimjaem[a,*]

[a]*PBP-CMU Electron Linac Laboratory, Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
*Particle Accelerators and Laser Technology Research Group, Chiang Mai University, Chiang Mai, 50200, Thailand*

*Corresponding Author's E-mail: sakhorn.rimjaem@cmu.ac.th

**Abstract**

In the field of materials research, there is a growing need for advanced techniques that can probe and modify materials at the atomic and molecular levels. The development of Infrared (IR) and Terahertz (THz) Free-Electron Lasers (FELs), alongside femtosecond laser system, has revolutionized our ability to investigate materials with unprecedented temporal and spatial resolution. These technologies are essential for probing ultrafast dynamics in complex materials systems. This talk will highlight the advancements in the use of IR-THz FELs and femtosecond lasers for materials characterization and modification. The synergistic combination of these two laser sources enables detailed spectroscopic analysis, including time-domain and pump-probe spectroscopy, which allows for the study of material properties across a broad range of temporal scales—from femtoseconds to picoseconds. The talk will explore how these techniques are applied to materials such as semiconductors, perovskites, and ionic liquids. Additionally, the tunable and coherent IR-THz FELs are key tools for exploring the modification of materials, particularly for driving nonlinear phenomena, manipulating atomic-level structure, and altering surface properties. Applications in material modification include nonlinear phononics, crystal structure control, modification of semiconductor and electronic properties, as well as surface and material treatments. The talk will also introduce the IR-THz FEL and ultrashort pulse laser facility at Chiang Mai University, a platform for ultrafast materials characterization and modification. The facility provides unique experimental capabilities, empowering researchers to explore the frontiers of materials science and gain novel insights into both fundamental and applied research.

**Keywords:** Free-electron laser, Femtosecond laser, Ultrafast spectroscopy, Materials characterization, Materials modification

# Impact of Fe Film Thickness and Si(B) Substrate on Spin Current and Shunting Effects in Longitudinal Spin Seebeck Effect Studies



Poramed Wongjom[a,*], Benjarong Samransuksamera[a]

[a]*A aDivision of Physics, Faculty of Science and Technology, Thammasat University, Pathum Thani 12120, Thailand.*

*Corresponding Author's E-mail: pwongjom@tu.ac.th

**Abstract**

This work investigates the longitudinal spin Seebeck effect (LSSE) in ferromagnetic Fe/Pt bilayer systems, examining the role of Fe layer thickness and substrate type on spin current dynamics and signal characteristics. Thin Fe films (3–20 nm) were sputtered onto Si/$SiO_2$ and Si(B) substrates and analyzed for their structural, magnetic, and spin transport behaviors. The study identifies an optimal Fe thickness below 5 nm for effective spin injection, corresponding to a spin diffusion length of 4.7 nm, a spin Hall angle of 0.094, and a spin injection coefficient of -1.6 V/K•Ω•m. Beyond 15 nm, the LSSE signal reverses due to dominant shunting effects. Substrate interactions significantly affect spin scattering, particularly at the Fe/Si(B) interface, where an insulating layer is necessary to stabilize magnetic and spin properties. These results provide insights into optimizing ferromagnetic metal-based LSSE systems for advanced spintronic applications.

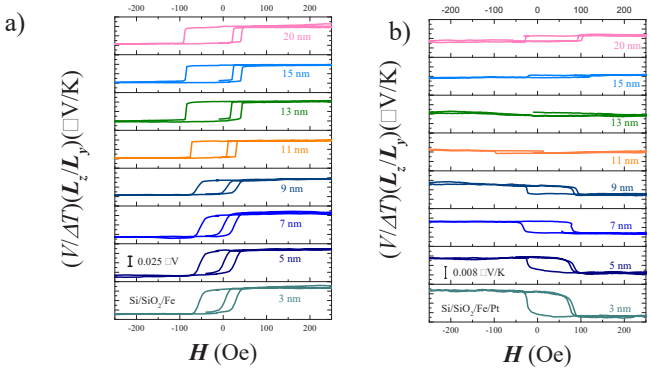



Fig.1 a) Variation of the anomalous Nernst effect ($V_{ANE}$) in Fe as a function of film thickness b) Combined anomalous Nernst effect ($V_{ANE}$) and inverse spin Hall effect (VISHE) in Fe/Pt bilayers as a function of film thickness

**Keywords:** spin Seebeck effect, spin caloritronics, anomalous Nernst effect, shunting effect, inverse spin Hall effect, Si(B) substrate, SiO2 substrate, Fe film

# Neuromorphic Computation using Nano-Molecular Networks



Takuya Matsumoto[a,*]

[a]*Department of Chemistry and Forefront Research Center, Graduate School of Science, The University of Osaka*
*1-1 Machikaneyamacho, Toyonaka, Osaka, 560-0043 Japan*

matsumoto-t@chem.sci.osaka-u.ac.jp

**Abstract**

In recent decades, studies on molecular electronics have made significant advances and single molecular transistors have been demonstrated. Such investigations, however, have not directly led to actual molecular-scale electronic devices, due to the lack of effective technologies for wiring between molecules. Beyond single molecular transistors, the exploration of device architecture is a central issue in molecular-scale electronics. One of the attractive directions is the realization of neural networks that utilize self-assembled molecular systems. As shown in Fig. 1, nonlinear electric properties corresponding to neuron firing realize spoken-digit classification at room temperature [1].

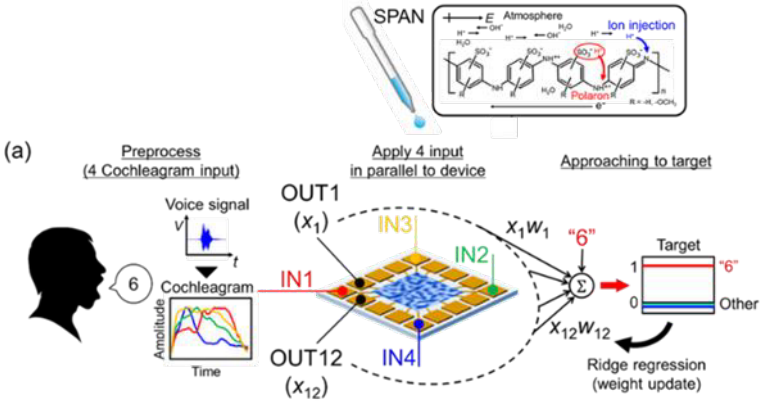



Fig.1. Schematic of spoken-digit classification. The spoken-digit time series signals in the dataset were converted to cochleagrams were normalized and applied to the sulfonated polyaniline network device.

Conductive polymer films typically contain two types of regions: conducting grains in which the molecules are mutually aligned and insulating region surrounding them. Electrical conduction can be considered to take place by the variable range hopping (VRH) through localized conducting grains. In macroscale, the I-V measurements indicate ohmic behavior due to averaged electronic properties through multiple hopping paths. However, in nanoscale, the observed I-V characteristics shows various nonlinear properties reflecting the size and doping levels of each conducting grains. We have reported that nonlinear I-V characteristics of conducting grain using bottle neck structure fabricated by fountain-pen lithography [2]. These results mean that nanoscale devices of conducting polymers network itself is natural neural networks.

**Acknowledgements**
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**Keywords:** neuromorphic computation, physical computation, nanoscale polymer networks, classification reservoir computing

# Emerging Photocatalysts as Sustainable and Recyclable Nanomaterials: Multifunctional Applications from Environment to Health



Jai Prakash*

*Department of Chemistry, National Institute of Technology Hamirpur, Hamirpur –177005 (H.P.), India*

*Email: jaip@nith.ac.in

**Abstract**

Light harvesting characteristic of nanomaterials have revolutionized the multidisciplinary research field in a great extent. In this context, the ease of modification of semiconductor photocatalysts and also availability of huge amount of solar light are the two major factors. Semiconductor nano-photocatalysts are promising materials under the influence of solar radiation for various field including energy production, controlling the environmental pollution and improving the health of the society etc. Particularly, plasmonic photocatalysts, composed of photocatalyst semiconductors and plasmonic nanostructures, are promising multifunctional nanomaterials which have gained considerable attention in the field of interdisciplinary research. These nanomaterials show multifunctional applications in the field of health, energy and environment due to the synergetic contribution from the photocatalytic and plasmonic properties of the constituents. This invited talk will include about the fundamentals, tailoring of their optical properties and multifunctional applications of plasmonic photocatalysts including emerging 2D based semiconductor nanomaterials in the field of photocatalysis and surface enhanced Raman Scattering (SERS) for ultra-detection/sensing of organic pollutant in water treatment [1-4]. It will also cover other multifunctional applications of such sustainable and recyclable nanomaterials for their practical real applications.

**Keywords:** Plasmonic-photocatalysts; Health and environment; Sensing/bio-sensing; Recyclable SERS substrates; Sustainability.

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# Characterization of Glass Fabricated from Biomass Ash and waste marine shells



Chonlathit Pitipoomsuksan[a] and Wilaiwan Leenakul[b],[c,*]

[a] *Department of Industrial Engineering, Faculty of Industrial Education, Rajamangala University of Technology Phra Nakhon, Bangkok 10300*
[b]*Division of Industrial Materials Science, Faculty of Science and Technology, Rajamangala University of Technology Phra Nakhon, Bangkok 10800, Thailand*
[c]*Hub of Advanced Ceramics, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*

*Corresponding Author's E-mail: wilaiwan.l@rmutp.ac.th

**Abstract**

This research aims to synthesize artificial gemstones primarily from natural waste materials, specifically silicon dioxide ($SiO_2$) derived from biomass ash and calcium oxide (CaO) obtained from waste marine shells (cuttlebones and mollusk shells) from the food industry. Manganese oxide (MnO) was introduced as a dopant in varying concentrations (0.00–0.18 wt%) to act as a coloring agent. Phase analysis of the rice husk ash using X-ray Diffraction (XRD) revealed a predominantly amorphous structure. Chemical composition analysis indicated a high $SiO_2$ content of 90.8%. Similarly, analysis of the cuttlebone revealed a high calcium content (90.14%), primarily in the form of calcium carbonate ($CaCO_3$), confirming its suitability as a precursor for gemstone synthesis. The results demonstrated that increasing the concentration of the coloring agent led to a corresponding increase in both the density and Vickers hardness of the synthesized glass samples.

**Keywords:** Crystal, Glass, Biomass ash, Cuttlebone

# First-Principles Insights into Near-Field Radiative Heat Transfer in Quantum Materials



R. Esquivel-Sirvent[1], F. Sánchez-Ochoa[1] and A. Gusso[2]

[1]*Instituto de Física, Universidad Nacional Autónoma de México, Cto. De la Investigación SN, CDMX* 01000.
[2] *Departamento de Ciências Exatas-EEIMVR, Universidade Federal Fluminense, Volta Redonda 27255-125 Brazil*

*Corresponding Author's E-mail: raul@fisica.unam.mx

**Abstract**

Near-field radiative heat transfer (NFRHT) enables energy exchange between bodies separated by nanometric gaps that can exceed the blackbody limit by several orders of magnitude. This enhancement originates from evanescent electromagnetic modes, including surface plasmon polaritons, phonon polaritons, and other collective excitations that emerge from the electronic and vibrational structure of materials. Consequently, understanding and engineering NFRHT requires an accurate description of the optical response of materials at infrared and terahertz frequencies.

In this work we present a first-principles framework for studying near-field thermal radiation in quantum materials, where dielectric functions derived from electronic-structure calculations are combined with fluctuational electrodynamics. This approach enables predictive modeling of nanoscale heat transfer based directly on the microscopic properties of materials rather than empirical optical models. We apply this methodology to several classes of materials relevant for quantum and polaritonic technologies, including metallic thin films, polar dielectrics, and emerging two-dimensional materials.

Our results reveal how nanoscale heat transfer is strongly controlled by surface polaritonic modes and by modifications of the electronic structure induced by confinement, temperature, and interfacial effects. In particular, first-principles calculations show how changes in carrier scattering, lattice vibrations, and anisotropic dielectric response can significantly alter the spectral and spatial distribution of near-field heat flux. These effects provide new opportunities for tailoring thermal radiation using quantum materials and nanostructured interfaces.

The ability to predict and engineer NFRHT from first-principles calculations opens new directions for thermal management in nanoscale devices, thermophotonic energy conversion, and quantum materials platforms where electromagnetic fluctuations play a central role.

# Overview of Siam Quantum Square ($SQ^2$) and Experimental Work toward Superconducting Qubit



Salinporn Kittiwatanakul

*Siam Quantum Square ($SQ^2$), Faculty of Science, Chulalongkorn University, Bangkok, Thailand*

*Corresponding Author's E-mail: salinporn.k@chula.ac.th

**Abstract**

Preparing to move toward Quantum Era, Siam Quantum Square ($SQ^2$) is Chulalongkorn University's new flagship program dedicated to advancing quantum technology research and cultivating future talent. It convenes an interdisciplinary group of experts and students across physics, mathematics, computer science, materials science, chemistry, and engineering. The program's mission is to explore the fundamental nature of quantum physics and translate those insights into the development of quantum technologies.

Our main research focus is categorized into two main areas: (1) Quantum Computing & Applications (QCA)—utilizing algorithms to solve complex problems, i.e. logistic, energy grid including Quantum Simulation, Quantum Optimization, Quantum Machine Learning and Quantum Cryptography; (2) Quantum Materials & Devices (QMD)—focused on exploring and engineering novel materials with unique quantum properties, i.e. superconducting Qubits; and on measurement and control of quantum properties in devices. In addition of research, we also provide academic programs (Master, PhD, executive and short course training—under development), together with consulting service to prepare business in Quantum Era.

The second part of the talk will include the experimental work of design and lithography, including thin film fabrication toward superconducting qubit, one of the platforms of quantum computer such as Google, IBM, IQM etc.

**Keywords:** Quantum, Superconducting Qubit, Siam Quantum Square ($SQ^2$)

# Progress toward a neutral-atom-based platform for quantum technology at Chiang Mai university



Narupon Chattrapiban, Nithiwadee Thaicharoen, Phatthamon Kongkhambut

*Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*

*Corresponding Author's E-mail: narupon.ch@cmu.ac.th

**Abstract**

Rapid global advances in quantum science and technology highlight the need for Thailand to strengthen its capabilities in this strategic field. Neutral atoms in highly excited Rydberg states offer a powerful and versatile platform for quantum computing, quantum simulation, and precision sensing, owing to their strong controllable interactions, high electric-field sensitivity, and long-lived quantum coherence. At Chiang Mai University, we are developing a neutral-atom–based quantum technology platform, aiming to establish infrastructure that supports both research and future industrial applications. Our current work consists of three coordinated efforts: (i) developing microwave-based preparation and control of Rydberg-atom qubits for quantum information and many-body simulation; (ii) building broadband electric-field sensors that exploit Rydberg-atom electrometry for metrological and applied-physics use; and (iii) establishing domestic capability to fabricate vapor cells for portable quantum devices. Significant milestones have already been achieved, including the successful trapping and cooling of rubidium atoms, the first demonstration of Rydberg excitation in Thailand, and initial in-house vapor-cell production. These developments mark a critical step toward a national quantum-technology ecosystem. Expected outcomes include prototype quantum sensors, neutral-atom qubit modules for education and research, and a platform that can be shared with collaborators across Thailand and abroad. This effort lays the groundwork for Thailand to participate competitively in the emerging quantum era and to cultivate a new generation of highly skilled scientists and engineers.

**Keywords:** Rydberg Atoms, Neutral-Atom Quantum Technology, Quantum Sensing, Quantum Simulation

# Role of Thailand Institute of Nuclear Technology in Thailand's Rare Earth Element Ecosystem



Somsak Dangtip*, Dussadee Rattanaphra, Sasikarn Nuchdang, Wilasinee Kingkam

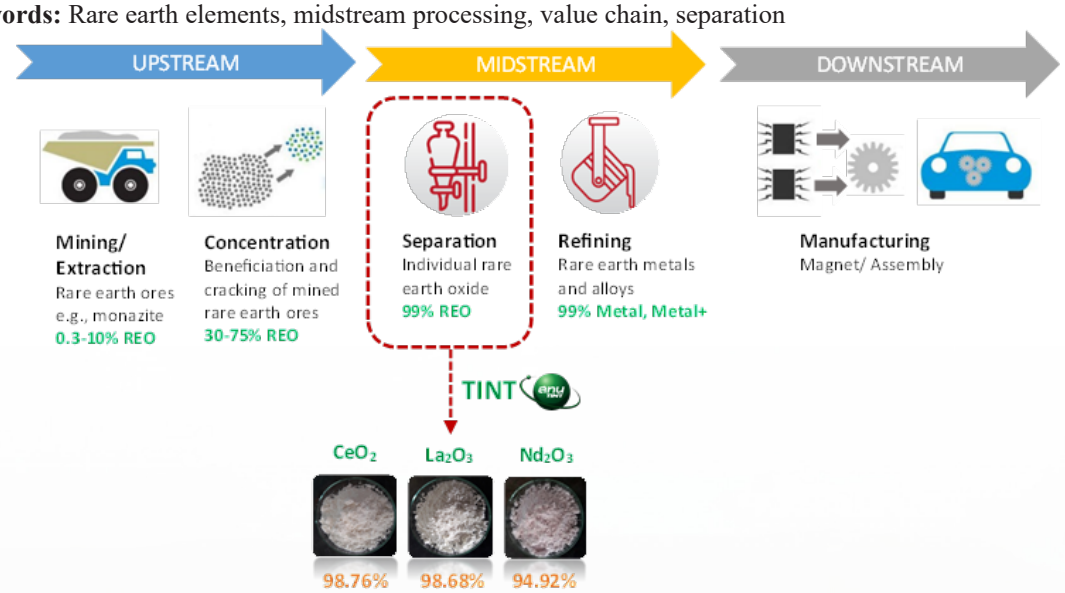
*Nuclear Technology Research and Development Centre, Thailand Institute of Nuclear Technology, Nakorn Nayok, 26120, Thailand*

*Corresponding Author's E-mail: somsakd@tint.or.th

**Abstract**

Thailand ranked as the world's sixth-largest producer of rare earth minerals, with production reaching approximately 13,000 metric tons—an increase of 261% compared to the previous year. A significant portion of this production results from the import of raw ores, which are processed domestically and re-exported as rare earth products. Currently, China maintains dominant control over the global rare earth supply chain, spanning raw material extraction, separation and refining, and downstream manufacturing. Thailand is emerging as an increasingly important player in both upstream and downstream segments of the rare earth value chain, including the export of rare earth concentrates and the production of rare earth alloys and permanent magnets. However, the country's involvement in midstream activities—particularly separation and refining—remains limited. The Thailand Institute of Nuclear Technology (TINT) plays a critical role in addressing this gap through its research on the separation and purification of rare earth elements, especially from monazite ores. Pilot-scale research was previously conducted at the Rare Earth Research and Development Center (REDC), although operations ceased in 2006. Despite this, TINT has continued its research efforts in rare earth separation, purification, and utilization technologies. High-purity individual rare earth elements, including Ce, La, and Nd, with purities exceeding 95%, have been successfully achieved. Current efforts focus on optimizing solvent extraction and ion-exchange processes to improve separation efficiency while minimizing hazardous waste generation. In parallel, research on the utilization of radioactive by-products, such as uranium and thorium, is being explored to support sustainable nuclear energy development. Leveraging its expertise in midstream technologies, TINT has strong potential to integrate with allied partners to strengthen Thailand's role in rare earth separation and purification within the national and global REE value chain.

**Keywords:** Rare earth elements, midstream processing, value chain, separation



# Comparative Study of Spectroscopic and Luminescence Properties of $Tb^{3+}$-Doped Tellurite Glasses with $ZnF_2$ and ZnO

Patarawagee Yasaka[a,b*], Winut Wongwan[a,b], Seubsakun Khondara[a,b], Kitipun Boonin[a,b] and Jakrapong Kaewkhao[a,b]



[a]*Center of Excellence in Glass Technology and Materials Science (CEGM), Nakhon Pathom Rajabhat University, Nakhon Pathom, 73000, Thailand*
[b]*Physics Program, Faculty of Science and Technology, Nakhon Pathom Rajabhat University, 73000, Thailand*

*Corresponding Author's E-mail: pyasaka@hotmail.com, pyasaka@webmail.npru.ac.th

**Abstract**

$Tb^{3+}$-doped tellurite glasses with compositions of $52.5TeO_2$: $10ZnF_2$: 35BaO: $2.5Tb_2O_3$ and $52.5TeO_2$:10ZnO: 35BaO: $2.5Tb_2O_3$ were prepared using the conventional melt-quenching technique. This work focuses on the differences between the glass systems containing $ZnF_2$ and ZnO. The density, molar volume, and refractive index were measured to examine variations between the two glass compositions. Structural features were analyzed using Fourier transform infrared (FTIR) and Raman spectroscopy to identify the vibrational characteristics and network structure of the glasses. Absorption spectra were recorded to observe the characteristic transitions of $Tb^{3+}$ ion. Photoluminescence properties were investigated under appropriate excitation, revealing emission bands associated with $Tb^{3+}$ transitions. In addition, X-ray induced luminescence was studied to evaluate the emission behavior under high-energy excitation. A comparative analysis of spectral features and emission intensities was carried out for both glass systems. The results show distinct differences in physical, structural, and optical properties between the two compositions, which are reflected in their luminescence characteristics. These findings highlight the influence of $ZnF_2$ and ZnO on the overall behavior of $Tb^{3+}$-doped tellurite glasses and provide useful information for further development of glass materials for photonic and scintillation applications.

**Keywords:** Tellurite glasses, Zinc fluoride, Zinc oxide, Terbium oxide, Scintillation

# Development of Dual-Functional $Gd^{3+}$-doped Glass with UVB Emission and Radiation Shielding Properties



W. Rachniyom[a,b], N. Wantana[a,b], W. Chaiphaksa[a,b], C. Mutuwong[a,b], S. Kothan[c], H.J. Kim[d], J. Kaewkhao[a,b], N. Intachai[c,*]

[a]*Center of Excellence in Glass Technology and Materials Science (CEGM), Nakhon Pathom Rajabhat University, Nakhon Pathom 73000, Thailand*
[b]*Physics Program, Faculty of Science and Technology, Nakhon Pathom Rajabhat University, Nakhon Pathom, 73000, Thailand*
[c]*Center of Radiation Research and Medical Imaging, Department of Radiologic Technology, Faculty of Associated Medical Sciences, Chiang Mai University, Chiang Mai, 50200, Thailand*
[d]*Department of Physics, Kyungpook National University, Daegu, 41566, Republic of Korea*

*Corresponding Author's E-mail: nuttawadee.i@cmu.ac.th

**Abstract**

This research focuses on the development of multifunctional glass that can serve both as an ultraviolet (UV) emitter and as a radiation shielding material through the incorporation of $Gd^{3+}$ ions into the glass matrix. The $Gd^{3+}$ ions exhibit two key properties: (1) they provide strong ultraviolet emission arising from the electronic transition from the $^6P_{7/2}$ to the $^8S_{7/2}$ energy level, resulting in emission at approximately 310 nm, and (2) they possess a high atomic number (Z = 64) along with a large thermal neutron absorption cross-section, which significantly enhances the shielding efficiency against X-rays, gamma rays, and neutron particles. In this work, glass compositions with high-density oxide components will be designed and synthesized to improve both density and radiation shielding capability. Various concentrations of $Gd_2O_3$ were doped in glass matrix to create luminescent centers responsible for ultraviolet B (UVB) emissions around 310 nm, which attributed from $^6P_{7/2} \rightarrow {}^8S_{7/2}$ transition from $Gd^{3+}$ ion. The relationship between $Gd_2O_3$ concentration, luminescence, optical and radiation shielding properties were systematically investigated. The newly developed glass demonstrates dual functionality, serving both as a radiation shielding material and as an ultraviolet emitter. This offers promising potential for applications in medical phototherapy and radiation protection.

**Keywords:** Gadolinium, UVB emission, Radiation shielding, Glass

# Fast Luminescence Decay Characteristics and X-ray Imaging of $CeF_3$ doped Alkaline Earth Phosphate Oxyfluoride Glasses for Medical X-ray Application



P. Meejitpaisan[a,b,*], Ramachari Doddoji[c,d], S. Kothan[e], H.J. Kim[f], J. Kaewkhao[a,b]

[a]*Physics Program, Faculty of Science and Technology, Nakhon Pathom Rajabhat University, Nakhon Pathom, 73000, Thailand*
[b]*Center of Excellence in Glass Technology and Materials Science (CEGM), Nakhon Pathom Rajabhat University, Nakhon Pathom, 73000, Thailand,*
[c]*Institute of Research and Development, Duy Tan University, Da Nang, 550000, Viet Nam*
[d]*Faculty of Natural Sciences, Duy Tan University, Da Nang, 550000, Viet Nam*
[e]*Center of Radiation Research and Medical Imaging, Department of Radiologic Technology, Faculty of Associated Medical Sciences, Chiang Mai University, Chiang Mai, 50200, Thailand*
[f]*Department of Physics, Kyungpook National University, Daegu 41566, Republic of Korea*

*Corresponding Author's E-mail: meejitpaisan@webmail.npru.ac.th, piyachat_mee@hotmail.com

**Abstract**

Alkaline earth phosphate oxyfluoride glasses doped with different concentrations (0.0 - 1.0 mol%) of $CeF_3$ have been fabricated using melt-quenching method. Transmittance spectra, photoluminescence spectra, X-ray-induced luminescence spectra, and decay time characteristics were systematically examined. CeF3 doped glasses exhibited transmittance spectra in the UV-visible region with a transmittance of approximately 80%. A gradual shift of the absorption edge toward longer wavelengths was observed at higher $CeF_3$ concentrations. According to the photoluminescence results, an emission band centered in range 334-345 nm was observed under excitation at 310 nm, corresponding to the 5d→4f transition of $Ce^{3+}$ ions. The emission intensity of the broad emission band of $Ce^{3+}$ increased up to 0.10 mol%, after which it decreased at higher $Ce^{3+}$ concentrations due to concentration quenching. The scintillation efficiency was assessed by comparing the X-ray induced luminescence peak area of the $CeF_3$-doped glasses with that of a BGO crystal, with the highest value reaching 23% for 0.10 mol% of $CeF_3$. The decay time profiles of $CeF_3$-doped glasses were measured in the 334–345 nm emission range under 270 nm excitation using a laser diode, and the non-exponential decay behavior was well described by a double-exponential function. The decay times of all glasses were found to be in the nanosecond range. Additionally, X-ray imaging performance of the $CeF_3$-doped glasses was evaluated using a Cu-target X-ray source. The glasses exhibited clear radiographic imaging with a spatial resolution of approximately 10 LP/mm and allowed the internal features of biological objects to be visualized. Taken together, these results highlight the potential of $CeF_3$-doped glasses for medical X-ray application.

**Keywords:** $CeF_3$, Phosphate oxyfluoride glass, Scintillating, X-ray imaging

# Platinum(II)-complexes for Efficient Organic Light-Emitting Diodes



Jeong-Hwan Lee[1,2,*]

[a]*Department of Materials Science and Engineering, Inha University, Incheon 22212, Republic of Korea*
[b]*Program in Semiconductor Convergence, Inha University, Incheon 22212, Republic of Korea*

*Corresponding Author's E-mail: jeong-hwan.lee@inha.ac.kr

**Abstract**

Achieving high-efficiency and stable deep-blue emission remains a critical challenge for next-generation organic light-emitting diodes (OLEDs). In this regard, tetradentate Platinum(II) (Pt(II)) complexes have emerged as superior alternatives to conventional iridium(III) emitters due to their intrinsic square-planar geometry, which facilitates a high horizontal emitting dipole orientation (EDO) exceeding 90%. This structural advantage significantly enhances light outcoupling efficiency without requiring external optical structures.

This study presents a series of novel Pt(II) complexes, including PtON7-BzPhTMS and PtON-QBn, bearing bulky substituents to suppress intermolecular aggregation and enhance solubility. Through precise engineering of interfacial energy levels and spin-orbit coupling (SOC), we successfully shortened the triplet radiative lifetime to approximately 1.0–1.2 μs. This rapid triplet decay effectively minimizes efficiency roll-off by suppressing triplet-triplet annihilation (TTA) under high electrical excitation.

Furthermore, we demonstrate the versatility of these Pt(II) complexes as sensitizers in phosphor-sensitized fluorescent (PSF) architectures. By combining a Pt(II) sensitizer with a multi-resonance (MR) fluorescent terminal emitter, we achieved a benchmark-setting external quantum efficiency (EQE) of up to 36.7% in solution-processed devices, with an ultra-narrow full width at half maximum (FWHM) of 19 nm and CIEx,y coordinates of (0.130, 0.122). These results are further enhanced by a templating effect of underlayers such as PVK, which optimizes molecular alignment. Our findings provide a robust framework for developing scalable, high-performance deep-blue OLEDs through the rational molecular design of Pt(II) complexes, bridging the performance gap between vacuum-deposited and solution-processed optoelectronic devices.

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by Ministry of Science and ICT (RS-2025-24533872), and was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education (RS-2022-NR070869).

**Keywords:** Platinum (II)-complex, organic light-emitting diodes, orientation, light outcoupling

# Low-Temperature Co-Fired Microwave Dielectric Ceramics: Emerging Roles of Rare-Earth Elements



Phieraya Pulphol[a,b], Naratip Vittayakorn[b,c,*]

[a]*Department of Materials Science, Faculty of Science, Srinakharinwirot University, Bangkok 10110, Thailand*
[b]*Advanced Materials Research Unit, School of Science, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand*
[c]*Department of Chemistry, School of Science, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand*

*Corresponding Author's E-mail: naratip.vi@kmitl.ac.th

**Abstract**

With the rapid evolution of wireless communication technologies from 5G toward 6G, the demand for high-performance microwave dielectric ceramics with reduced processing temperatures has significantly increased, particularly for Low-Temperature Co-fired Ceramic (LTCC) applications. Among various materials design strategies, rare-earth elements have attracted considerable attention due to their multifunctional roles in tailoring dielectric properties, phase stability, densification behavior, and temperature coefficient control in microwave dielectric systems. This work provides an overview of the emerging roles of rare-earth ions in microwave dielectric ceramics, focusing on their influence on crystal structure modification, defect engineering, low-temperature sintering behavior, and dielectric loss optimization. Recent developments in LTCC-compatible and ultra-low-temperature co-fired ceramic systems are discussed, including rare-earth-containing molybdates, tungstates, borates, and composite-assisted densification approaches. Particular attention is given to the performance trade-offs among dielectric constant, $Q \times f$ value, sintering temperature, and thermal stability.

**Keywords:** Microwave dielectric ceramics; Low-Temperature Co-Fired Ceramic; 5G communications; Rear-Earth Elements

# Multi-Scale Ion Accessibility Engineering for Advanced Electrochemical Energy Storage and Conversion Systems



Hyung Mo Jeong[a,b*]

[a]*School of Mechanical Engineering and Department of Smart Fab. Technology, Sungkyunkwan University, 16419, South Kore*
*Lithiway Co. Ltd. 104-301, SK Ventium, 166 Gosan-ro, Gunpo, 15850, South Korea*

*Corresponding Author's E-mail: hmjeong@skku.edu

**Abstract**

To address the rapidly increasing demand for high-energy and high-power electrochemical systems in future industries, advanced material platforms capable of controlling interfacial electrochemical reactions are critically required. Among emerging energy storage technologies, active material-free (anodeless or anode-free) battery systems have attracted significant attention due to their low redox potential and ultrahigh theoretical energy density. However, uncontrolled dendritic growth and unstable electrochemical interfaces remain major barriers to practical implementation.

In this work, we present a structure-driven ion accessibility control strategy based on porous and defect-engineered electrode architectures incorporating ion-affinitive active sites. By regulating local ion distribution and concentrating ion flux within nanoscale confined spaces, the proposed system enables controlled electrochemical reactions and uniform Li metal growth behavior. Recent advances suggest that electrochemical kinetics can be significantly modulated through multi-scale structural engineering, where ion transport, surface accessibility, and reaction pathways are strongly coupled to the electrode structure.

In particular, artificial interfacial layers and defect-rich porous media are introduced as key platforms for controlling ion transport behavior under electric fields. The nanoscale confinement effect beyond conventional microporous systems facilitates localized ion regulation and enhanced reaction kinetics, enabling improved electrochemical stability and high-rate capability in anode-free battery systems. Furthermore, the proposed ion accessibility engineering concept can be broadly extended to electrochemical energy conversion systems, including electrocatalytic reactions involving ionic intermediates.

This presentation highlights how multi-scale interface and structural engineering can provide a scalable materials design strategy for next-generation electrochemical energy storage and conversion technologies with potential industrial impact.

**Keywords:** Anodeless, Li-metal Electrode, Electro-kinetic, Ion-flux

# Quantifying the age of environmental microplastics and its applications



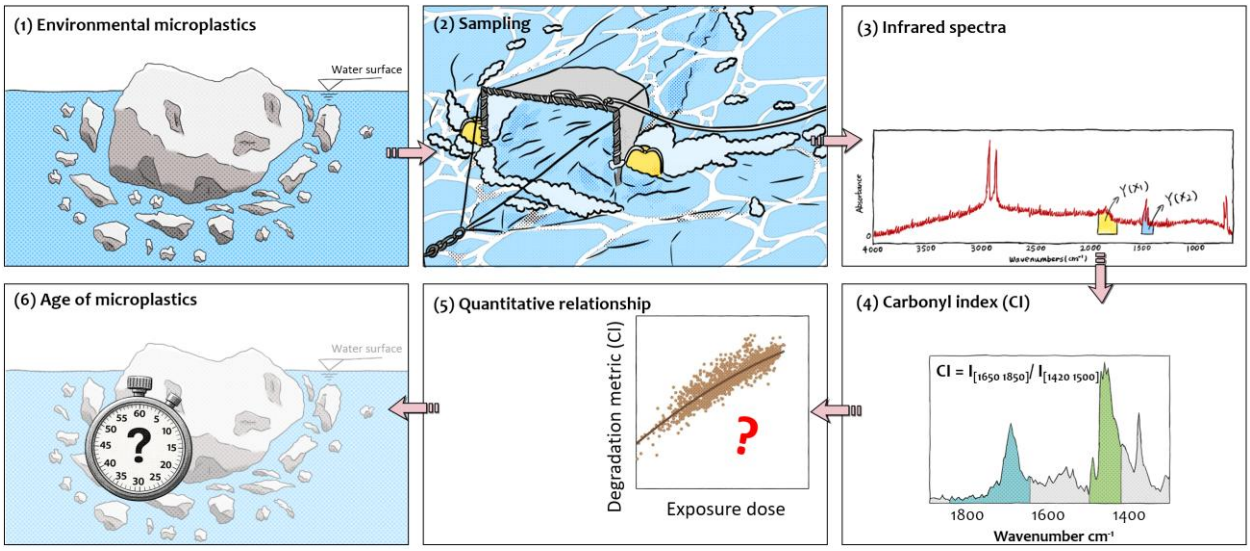
Zijiang Yang[a,*], Hisayuki Arakawa[a]

[a] *Department of Ocean Sciences, Tokyo University of Marine Science and Technology, Konan 4-5-7, Minato-Ku, Tokyo, 108-8477, Japan*

*Corresponding Author's E-mail: zyan001@kaiyodai.ac.jp

**Abstract**

Microplastics, commonly defined as plastic particles smaller than 5 mm, are of increasing environmental concern due to their potential impacts on human health and ecosystems. Understanding their environmental fate requires not only characterization of their degradation state but also estimation of their environmental aging, defined as the cumulative exposure history to environmental stressors such as ultraviolet radiation. Currently, the carbonyl index (CI) and related metrics derived from infrared spectra are widely used to assess the degradation level of environmental microplastics. However, these metrics are typically applied in a relative manner, and there is a lack of quantitative frameworks to relate degradation level to environmental aging. In particular, a calibrated relationship between CI and exposure history under realistic environmental conditions remains lacking. In this presentation, we first introduce the fundamental degradation mechanisms of microplastics, with emphasis on oxidation processes and their spectroscopic signatures. We then introduce a typical environmental microplastic study that utilizes CI, demonstrating how degradation status informs interpretations of environmental transport, fate, and potential sources. Finally, we discuss current approaches to quantitatively link spectroscopic degradation indices with exposure histories, highlighting current challenges. Establishing such quantitative frameworks can improve the interpretation of microplastic aging under environmental conditions and contribute to the development of standardized methodologies for assessing their environmental fate.




**Keywords:** marine pollution, microplastics, infrared spectroscopy, carbonyl index, degradation

# Microstructure-assisted Nanoimaging by Proton Beam Writing Fabrication

Nitipon Puttaraksa[a,b*], Hironori Seki[c], Yasuyuki Ishii[d], Tatsunosuke Matsui[e], Hiroyuki Nishikawa[b,c]

[a]*Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Thailand*
[b]*College of Engineering, Shibaura Institute of Technology, Japan*
[c]*SIT Research Laboratories, Shibaura Institute of Technology, Japan*
[d]*Takasaki Institute of Advanced Quantum Science, National Institutes for Quantum Science and Technology, Japan*
[e]*Department of Electrical and Electronic Engineering, Graduate School of Engineering, Mie University, Japan*

*Corresponding Author's E-mail: nitipon.p@cmu.ac.th

**Abstract**

Nanotechnology has advanced in modern science and technology, especially in healthcare, energy, environment, agriculture, semiconductor, and quantum computing. In principle, a standard light microscope could not be applied directly to image a nanomaterial/nanostructure because of its size (1-100 nm), smaller than the diffraction limit of visible light (approximately 200 nm). As a result, super-resolution microscopy techniques, such as fluorescence and stimulated-emission-depletion (STED) microscopy, have been developed to enhance the imaging resolution. Nevertheless, those methodologies still rely on the fluorescent labelling.

In our work [1,2], a label-free microscopic technique has been presented to utilize polymeric microstructures for assisting in the imaging of nanostructured gratings of commercialized Blu-ray discs. The polymeric microstructures were made on the nanostructured gratings using a 1 MeV proton beam writing approach. A laser confocal microscope (Olympus LEXT OLS 4000) was then applied to acquire the microstructure-assisted nanoimaging, which will be discussed in this symposium.

**Keywords:** Microstructure-assisted nanoimaging, proton beam writing

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# Positronium diffraction experiment using graphene



Yugo Nagata[a,*], Riki Mikami[b], Yasuyuki Nagashima[a]

[a]*Department of Physics, Tokyo University of Science, 1-3 Kagurazaka, Shinjuku, Tokyo, Japan*
[b]*Institute of Materials Structure Science, High Energy Accelerator Research Organization, KEK, 1-1 Oho, Tsukuba, Ibaraki, Japan*

*E-mail: yugo.nagata@rs.tus.ac.jp

**Abstract**

The observation of matter-wave diffraction has demonstrated the wave–particle duality and quantum superposition, which are central concepts of quantum mechanics. For electrons, this has been demonstrated in the 1920s by Davisson and Germer, and it has also been confirmed for other particles such as neutrons, atoms, molecules and clusters. In the case of positron, which was the first antiparticle to be discovered in 1932 [1], the matter wave has been demonstrated by diffraction from a Cu surface in 1980. In recent years, positrons are applied to the top most surface structure analysis using positron diffraction like electrons [2]. However, there has been no diffraction experiments with exotic systems including antiparticles yet.

We focus on positronium (Ps) atom, which is a bound state of an electron and a positron. In Tokyo University of Science, a high-quality energy-tunable Ps beam has been developed [3,4]. Since the positron carries a positive charge, the Ps atoms are electrically neutral and cannot be accelerated. Instead of accelerating Ps atoms, Ps negative ions, which are bound systems consisting of two electrons and one positron, are accelerated and then photodetached to remove one electron to produce the energy-tunable Ps beam. The energy spread of this beam is less than a few percent, and its angular divergence is suppressed by an aperture, resulting in a coherent beam. The beam energy lies in the keV region, which is suitable for observing crystal diffraction.

We report the first observation of Ps diffraction through graphene using the high-quality energy-tunable Ps beam. The diffraction pattern indicates clear signatures of the first order diffraction peak, whose position is consistent with the theoretical prediction [5].

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**Keywords:** Positronium, diffraction, positron, positronium negative ion

# Observation of Pyroelectric effect using Nanoterasu

Seiya Miyazaki[1], Kazuma Iwasaki[1], Kim hyun Jue[1], Sho Hujii[2], Tsuyoshi Kimura[3], Masaya Yamamoto[4], Tadao Tanabe[1]*

[1]*Shibaura Institute of Technology, 3-7-5 Toyosu, Koto-ku, Tokyo 135-0061, Japan*
[2]*Yamagata University, 4-3-16 Jonan, Yonezawa-shi, Yamagata 992-8510, Japan*
[3]*Toyo University, 2100 Kujirai, Kawagoe-shi, Saitama 350-8585, Japan*
[4]*Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai-shi, Miyagi 980-8577, Japan*

*Corresponding Author's E-mail: cy21021@shibaura-it.ac.jp

**Abstract**

Triglycine sulfate (TGS) is a material used as a pyroelectric infrared detector in applications such as FT-IR. The pyroelectric effect, which underlies this detection principle, is a phenomenon in which temperature changes caused by infrared absorption disrupt the equilibrium state of spontaneous polarization within the crystal, thereby generating electric charges [1]. However, the specific structural changes occurring within the crystal during this process have not yet been fully elucidated.

Therefore, the objective of this study was to evaluate the time-dependent changes in TGS crystals over short time scales of less than 1 seconds upon irradiation with mid-infrared light, with the aim of confirming the structural changes within the crystal caused by the pyroelectric effect.

In this study, we performed XRD measurements on TGS at Nanoterasu. Nanoterasu is a 3 GeV high-brightness synchrotron radiation facility located in Japan. At Nanoterasu, it is possible to observe and analyze nanometer-scale structures and material states, as well as perform measurements with high temporal resolution.

This study is a result of the JST-CREST (Core Research for Evolutionary Science and Technology) project "Integrated Understanding of Biodegradable and Degradable Nanomaterials Coexisting with the Life Cycle" (Principal Investigator: Masaya Yamamoto).

**Keywords:** Pyroelectric effect, Triglycine sulfate (TGS), Nanoterasu

# Microplastics in the ocean environment —International initiative

Haruka Nakano[a]

[a]*Kyushu University, Kasuga Koen 6-1, Kasuga city, Fukuoka Prefecture, Japan*

*Corresponding Author's E-mail: nakano.hrk@riam.kyusyu-u.ac.jp



**Abstract**

This study aims to advance the understanding of marine microplastic (MP) pollution through integrated monitoring, methodological development, and international standardization. Field observations were conducted in coastal and coral reef environments, including Tokyo Bay (Japan) and Si Chang Island (Thailand), to investigate the spatial and seasonal distribution of MPs. The results revealed clear seasonal variability, with higher MP abundance during wet seasons, suggesting the importance of monsoon-driven river discharge and surface currents in Southeast Asia. In addition, ultraviolet-induced fragmentation during dry periods was identified as a key mechanism accelerating MP generation.

To improve detection and quantification of MPs, particularly small-sized particles, we developed fluorescence-based analytical methods combined with machine learning techniques. These approaches enable rapid and efficient screening compared to conventional spectroscopic methods, while maintaining compatibility with FTIR-based identification. Complementary use of Py-GC-MS and Raman spectroscopy further enhances analytical reliability.

A systematic review of 165 studies across ASEAN countries highlighted significant variability in monitoring strategies and a lack of standardized methodologies, limiting data comparability at the international level. Based on these findings, we have actively contributed to international standardization efforts, including ISO 5667-27 and ISO 16094 series, through drafting and negotiation processes.

This study demonstrates that integrating field observations, analytical innovation, and international collaboration is essential to accurately assess MP pollution and to establish globally harmonized monitoring frameworks.

**Keywords:** Microplastics, Oceanography, AOMI

# Muon-Based Quantum Beam Studies of Organic Superconductors and Quantum Criticality



Dita Puspita Sari[a,b,c*]

[a]*College of Engineering, Shibaura Institute of Technology, 3-7-5 Toyosu, Koto-ku, Tokyo 135-8548, Japan*
[b]*SIT Research Laboratory, 307 Fukasaku, Minuma-ku, Saitama City, 337-8570, Japan*
[c]*Nuclear Structure Research Group, RIKEN Nishina Center, 2-1 Hirosawa, Wako, 351-0198, Japan*

*Corresponding Author's E-mail: dita@shibaura-it.ac.jp

**Abstract**

Quantum beam techniques, particularly muon spin rotation/relaxation (μSR), provide a powerful microscopic approach to probe superconductivity, magnetism, and emergent electronic behavior in advanced materials. In this invited talk, we present a systematic study of molecular-based organic superconductors enabled by coordinated use of major quantum beam facilities worldwide, including ISIS (UK), J-PARC (Japan), PSI (Switzerland), and TRIUMF (Canada).

In representative quasi two-dimensional dimer-Mott organic superconductors, μSR measurements reveal unconventional superconducting gap structures associated with anisotropic electronic states and spin fluctuations, indicating complex pairing mechanisms beyond standard descriptions [1]. Complementary investigations in related compounds demonstrate magnetic ordering and establish a unified phase diagram connecting insulating and superconducting states through electron correlation effects [2].

Furthermore, μSR Knight shift and relaxation measurements in the two-dimensional doped organic conductor uncover unconventional electronic behavior near phase transitions, highlighting the role of spin dynamics in the emergence of superconductivity [3]. Additional studies confirm superconducting states that preserve fundamental symmetries in proximity to these regimes [4].

These results demonstrate how quantum beam techniques enable a unified understanding of superconductivity, magnetism, and phase evolution in molecular materials. By integrating experimental access across multiple international facilities, this work establishes a scalable and versatile quantum beam platform for molecular-based superconductors. Such a framework provides a foundation for advancing quantum beam–driven research in organic materials and expanding their role in next-generation materials innovation.

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**Keywords:** Quantum Beam, Molecular Superconductor, Quantum Phase Transitions, Spin Dynamics, Advanced Materials

# Infrared FEL-Induced Alteration of Zeta Potential in Electrochemically Grown Quantum Dots: Ion Modification and Applications in PSCs

Sukrit Sucharitakul[a,b,c,d*], Siripatsorn Thanasanvorakun[a,b], Vasan Yarangsi[a,b], Suparoek Yarin[a,b], Kritsada Hongsith[a,b], Monchai Jitvisate[e], Hideaki Ohgaki[f], Surachet Phadungdhitidhada[a,b], Heishun Zen[f], Sakhorn Rim-jaem[a,c,d,g], Supab Choopun[a,b]

[a] *Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[b] *Physics of Low-dimensional Systems for Opto-electronic Applications, Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, 50200, Thailand*
[c] *Research Unit for Development and Utilization of Electron Linear Accelerator and Ultrafast Infrared/Terahertz Laser, Chiang Mai University, Chiang Mai, 50200, Thailand*
[d] *Thailand Center of Excellence in Physics, Ministry of Higher Education, Science, Research and Innovation, Bangkok 10400, Thailand, Bangkok, Thailand*
[e] *School of Physic, Institute of Science, Suranaree University of Technology, 111 University Avenue Muang Nakhon Ratchasima 30000, Thailand*
[f] *Institute of Advanced Energy, Kyoto University, Gokasho, Uji, Kyoto, 611-0011, Japan*
[g] *PBP-CMU Electron Linac Laboratory, Plasma and Beam Physics Research Facility, Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*

*Corresponding Author's E-mail: sukrit.sucharitakul@cmu.ac.th

**Abstract**

This study investigates the use of mid-infrared (MIR) free-electron laser (FEL) irradiation as a post-synthetic strategy for tuning the surface and optoelectronic properties of electrochemically synthesized $TiO_2$–graphene quantum dots ($TiO_2$–GQDs) for potential application in perovskite solar cells (PSCs). The quantum dots were synthesized in colloidal form using a low-cost electrochemical route in a KCl–citric acid electrolyte and subsequently irradiated at wavelengths of 5.76, 8.02, and 9.10 μm using the Kyoto University FEL facility. Following irradiation, the QDs exhibited a substantial inversion in zeta potential of approximately 40–50 mV together with an approximately 10% decrease in hydrodynamic size, suggesting contraction of the electrical double layer and redistribution of surface ions at the QD–solvent interface. Photoluminescence measurements revealed enhanced emission intensity in both graphene quantum dots and $TiO_2$–GQD nanocomposites, while optical bandgap analysis showed slight blue shifts of 0.04–0.08 eV, indicating reduced defect density, trap-state passivation, and improved band-edge definition. Transmission electron microscopy confirmed that the crystalline structure of the QDs remained intact after irradiation, indicating that the FEL treatment primarily altered surface chemistry without causing bulk structural damage. These findings suggest that MIR FEL irradiation can serve as a resonance-based, non-contact approach for modifying interfacial charge behavior, reducing surface defects, and improving the electronic quality of $TiO_2$–GQDs. Such improvements may be beneficial for enhancing charge extraction and transport in PSC electron transport layers, while also demonstrating the broader utility of MIR photonic processing for advanced nanomaterial and interface engineering.

**Keywords:** MIR, FEL, QDs, TiO2, Graphene

# Plasmonic Nanostructures for Enhanced Organic Photoelectric Conversion



Akira Baba[a,*], Yuting Miao[a], Naritsara Kornkanlaya[a,b], Kanet Wongravee[b], Sachiko Jonai[a], Kazunari Shinbo[a], Sanong Ekgasit[b]

[a] *Graduate School of Science and Technology and Faculty of Engineering, Niigata University 8050 Ikarashi 2-nocho, Nishi-ku, Niigata 950-2181, Japan.*
[b]*Sensor Research Unit (SRU), Department of Chemistry, Faculty of Science, Chulalongkorn University, 254 Phaya Thai Rd, Bangkok 10330, Thailand*

*Corresponding Author's E-mail: ababa@eng.niigata-u.ac.jp

**Abstract**

In organic photoelectric conversion devices, surface plasmon resonance (SPR) phenomena have attracted considerable attention since many years because of the extremely strong enhancement and confinement of electric fields near metal surfaces which enhanced the device efficiencies such as organic solar cells (OSCs), photoelectochemical sensors photothermal-electric conversion systems and so forth. Efficient light-trapping strategies involving the use of both non-plasmonic and plasmonic micro/nanostructures have been introduced to improve the device performance.[1-3] This improved light trapping at a specific wavelength, charge generation, and charge extraction. Textured or rough surfaces fabricated at active layer/electrode interfaces in OSCs devices could enhance absorption by diffuse scattering within the active layer. In this study, we introduce our recent progress on surface plasmon enhanced photoelectric conversion systems. The cooperative multiple plasmonic effect exhibits advantages, including broader light absorption enhancement, enhanced exciton generation rate and dissociation efficiency, and increased charge carrier density and lifetime.

A schematic of fabricated OSCs devices in this study is shown in Figure 1, which also shows the current density-voltage (*J–V*) curve of the fabricated OSCs devices under solar light illumination. Photovoltaic parameters of OSCs without and with AuNS are shown in Table1. It can be observed that performance of OSCs devices was improved after introducing AuNS. Compared with the reference devices, we successfully improved the PCE of OSCs with AuNS from 10.83% to 11.80%. The results indicate that improved performance of OSCs originates from the enhanced LSPR effect of AuNS in organic solar cells.

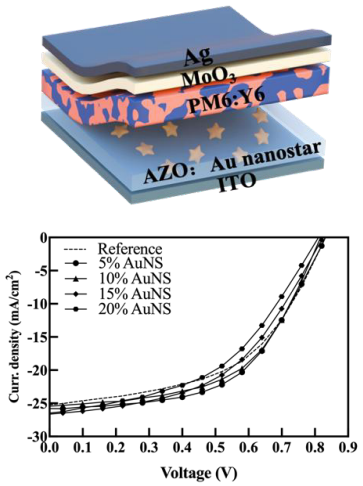



Fig. 1. A schematic of fabricated OSCs (left) and the current density-voltage properties of the fabricated OSCs devices under sunlight simulation using a solar simulator (right).

**Keywords:** Organic solar cells, Surface plasmon, Gold nanoparticles

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# Fabrication and UV Photodetection Characterization of Annealed $Cu_3N$/CuO Micro-sensors Using Maskless Lithography

Ekkaphop Ketsombun[a,*], Apinan Jantee [a], Hudsadin Chantarpiromporn [a],
Weerawut Hongtongdee [a] , Benjarong Samransuksamer [a]

[a] *Department of Physics, King Mongkut's University of Technology Thonburi, Bangkok 10140, Thailand*

*Corresponding Author's E-mail: ekkaphop.ket@kmutt.ac.th

**Abstract**

Thailand is actively striving to enhance its role in the global semiconductor ecosystem by advancing from traditional back-end operations into more capital-intensive front-end processes, such as wafer fabrication and chip design. To support this industry transition, the Department of Physics at King Mongkut's University of Technology Thonburi is developing specialized training courses aimed at increasing workforce capacity in semiconductor front-end technologies. As a practical model system for this training, copper nitride ($Cu_3N$) thin films were investigated due to their high potential in photodetection applications. In this study, $Cu_3N$ films were deposited onto silicon wafers via reactive DC magnetron sputtering at room temperature. Subsequent post-annealing analysis, utilizing Raman spectroscopy and X-ray diffraction, confirmed the coexistence of both $Cu_3N$ and CuO phases within the material. Initial photodetection experiments revealed that the annealed devices demonstrated a significant current response under ultraviolet (UV) exposure. Building upon these preliminary results, the $Cu_3N$ and CuO thin films that exhibited this high UV current response were further patterned into micro-sensors, ranging from 10 to 100 micrometers in size, utilizing maskless lithography techniques. The current response of these newly fabricated micro-devices was then re-evaluated under UV exposure. Ultimately, these findings suggest that annealed $Cu_3N$ thin films possess promising structural and electrical properties, making them not only strong candidates for future photodetection devices but also highly effective educational tools for hands-on semiconductor process training.

**Keywords:** Photodetection, Micro-sensors, Sputtering, Maskless Lithography

# Deep Eutectic Solvent-Assisted Passivation of $TiO_2$ Electron Transporting Layers for Enhanced Carbon Electrode-based Perovskite Solar Cell Performance

Warunee Khampa[a], Woraprom Passatorntaschakorn[a, b], Wongsathon Musikpan[a], Chukwuebuka Emmanuel Usulor[b], Isaac Chinaza Ogbuagu[b], Athipong Ngamjarurojana[b], Pongsakorn Kanjanaboos[c], Anusit Kaewprajaki[d], Pisist Kumnorkaew[d], Pipat Ruankham[a], [b, e], Duangmanee Wongratanaphisan[a, b, e, *]

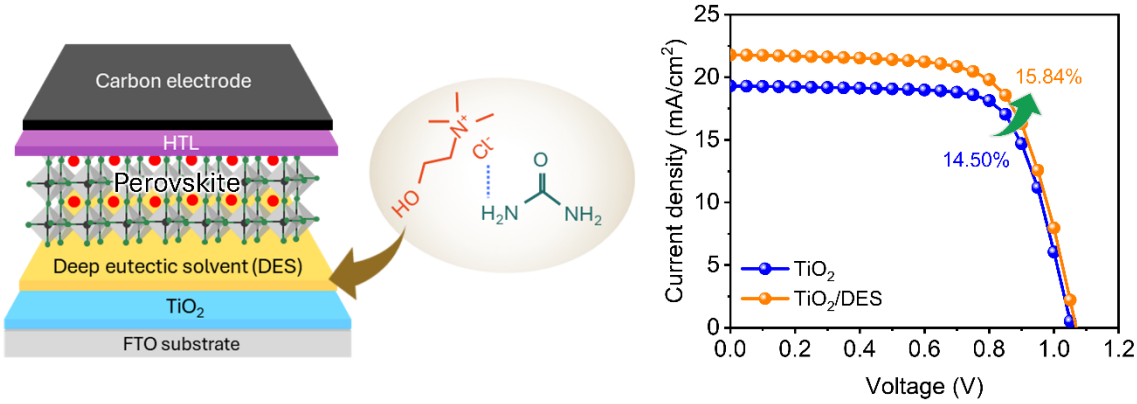
[a]*Materials Science Research Center, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[b]*Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[c]*School of Materials Science and Innovation, Faculty of Science, Mahidol University, Nakhon Pathom 73170, Thailand*
[d]*National Nanotechnology Center (NANOTEC), National Science and Technology Development Agency (NSTDA), 111 Thailand Science Park, Pathum Thani 12120, Thailand*
[e]*Thailand Center of Excellence in Physics (ThEP Center), Ministry of Higher Education, Science, Research and Innovation, Bangkok 10400, Thailand*

*Corresponding Author's E-mail: duangmanee.wong@cmu.ac.th

**Abstract**

Carbon electrode-based perovskite solar cells (C-PSCs) have attracted significant attention as a cost-effective and stable alternative to metal-electrode devices, owing to the excellent chemical stability and low fabrication costs of carbon materials. However, their performance is often limited by interfacial defects and suboptimal charge extraction at the $TiO_2$ electron transporting layer (ETL). Herein, an effective interfacial engineering strategy is introduced using a deep eutectic solvent (DES) composed of choline chloride and urea to passivate the $TiO_2$ surface. The DES treatment induces strong interfacial coordination, effectively passivating oxygen vacancies and optimizing the surface electronic properties for improved charge transfer. Consequently, enhanced charge extraction and suppressed non-radiative recombination are achieved, as evidenced by reduced trap density. In addition, the modified surface promotes improved perovskite crystallinity with more uniform grain distribution and better interfacial contact. As a result of these synergistic effects, the DES-modified C-PSCs achieved a notable power conversion efficiency (PCE) of 15.84%, a significant improvement over the 14.50% obtained by the control devices. This work highlights DES-assisted passivation as a highly effective yet straightforward strategy for advancing high-performance C-PSCs through tailored interfacial engineering.

**Keywords:** perovskite solar cells, $TiO_2$, deep eutectic solvent, interfacial passivation.



# Femtosecond pulsed laser deposition of W- doped $VO_2$ thin film with low temperature metal to insulator transition

Artitsupa Boontan[a,*], Eric Kumi-Barimah[b], David P. Steenson[c], Gin Jose[d]

[a]*School of Physics, Institute of Science, Suranaree University of Technology, Nakhon Ratchasima, 30000, Thailand*
[b]*Southwest Jiatong University and University of Leeds Joint School, Clarendon Road, Leeds, LS2 9JT, UK*
[c]*School of Electronic and Electrical Engineering, University of Leeds, Clarendon Road, Leeds, LS2 9JT, UK*
[d]*School of Chemical and Process Engineering, University of Leeds, Clarendon Road, Leeds, LS2 9JT, UK*

*Corresponding Author's E-mail: artitsupa.bo@sut.ac.th

**Abstract**

This study presents a post-annealing-free approach to fabricating and characterising vanadium dioxide ($VO_2$) thin films. While traditional fabrication methods typically yield amorphous films requiring secondary thermal treatment to achieve the $VO_2$ (M1) phase, we utilised high-repetition-rate (75 kHz) femtosecond pulsed laser deposition (fs-PLD) to deposit $VO_2$ and Tungsten-doped $VO_2$ thin films directly onto silica substrates. We employed temperature-dependent X-ray diffraction (XRD) as a primary analytical tool to investigate the structural evolution responsible for the metal-to-insulator transition (MIT). At room temperature, XRD patterns confirmed that $W^{6+}$ doping stabilises the monoclinic M2 phase. By tracking the *a* and *b* lattice parameters across a temperature gradient, we successfully mapped the transition from the monoclinic to the tetragonal (rutile) phase. Our results demonstrate that increasing $W^{6+}$ concentration significantly reduces the phase transition temperature from approximately 66°C to 38°C. This research highlights a streamlined fabrication route and establishes temperature-dependent XRD parameter analysis as a robust alternative for evaluating structural phase transitions in $VO_2$ thin films.

**Keywords:** fs-PLD, Vanadium dioxide, Tungsten doped vanadium dioxide

# Applications of Accelerator-Based Science Technique, mSR, to Energy-Storage Materials "What have been achieved and what is the future"



Isao Watanabe[a*]

[a]*Nuclear Structure Research Group, RIKEN Nishina Center, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan.*

*Corresponding Author's E-mail: nabedon@RIKEN.jp

**Abstract**

I will present recent applications of muon spin relaxation (mSR) to energy-storage materials. I will introduce preceding and recent mSR studies on these materials and explain the unique information obtained through such research. Based on these achievements, I will discuss long-standing problems in mSR that prevent a deeper understanding of the electronic states and macroscopic performance of energy-storage materials. Finally, I would like to suggest how we can solve these problems to overcome the limitations of mSR applications for the future green society.

The mSR technique uses particle detection methods developed in the field of accelerator-based science. It utilizes muons produced by large-scale accelerators and injected into materials. After a muon stops in the material, it interacts with surrounding electrons and nuclei, eventually emitting a positron with a lifetime of 2.2 ms. These positrons are detected using counters aligned upstream and downstream of the sample along the muon beamline. This detection system has been established more than 40 years ago by the Japanese group that pioneered the history of mSR. However, requirements from the muon community and industry are becoming increasingly detailed and sophisticated each year. In addition, as the performance of accelerator facilities continues to be upgraded, we need to further develop mSR detection techniques based on a fundamental scientific understanding.

In my talk, I would like to propose some technical developments of the mSR detection technique to make detection efficiencies higher and to carry out computational studies by using supercomputing networks to achieve deeper understanding of fundamental properties of energy-storage materials. I wish some participants are interested in my proposals and think to work together.

**Keywords:** mSR, DFT, PIMD, Machine Learning, Energy-Storage Materials

# Recent Progress in the Development of Terahertz Imaging Systems using Standing Wave Analysis for Non-Destructive Testing

Pacharamon Somboonsaksri[a], Seiya Miyazaki[b], Nantarat Srisuai[a], Patharakorn Rattanawan[a], Jia-Yi Chia[a], Nichakarn Termsaithong[a], Noppadon Nuntawong[a], Rungroj Jintamethasawat[a], Tadao Tanabe[b,*]

[a]*National Electronics and Computer Technology Center, National Science and Development Agency, Pathum Thani, Thailand 12120*
[b]*Department of Mechanical Engineering, Shibaura Institute of Technology, 3-7-5 Toyosu, Koto-ku, Tokyo 135-0061, Japan*

*Corresponding Author's E-mail: tanabet@shibaura-it.ac.jp

**Abstract**

Terahertz (THz) technology has emerged as a powerful tool for non-destructive testing (NDT) thanks to its high penetration to non-polar materials and high sensitivity to polar materials. As part of an ongoing collaboration between Shibaura Institute of Technology (SIT) and Thailand Center of Excellence in Physics (ThEP), this talk will present the progress of our joint development of a 0.1 THz continuous-wave (CW) imaging system capable of both transmission and reflection modes via a 2D array detector. The received signal intensities are analyzed by the standing wave method [1], where incident and transmitted/reflected signal intensities are recorded at various propagation path lengths. The standing wave patterns inherent in the recorded signal intensities improve the robustness of sample's optical transmittance and reflectance properties compared to standard intensity-based measurements. The developed imaging system also benefits from the use of the 2D array detector that is able to capture spatially resolved information, revealing localized optical variations across the sample's surface. Performance evaluation of the developed imaging system across diverse environmental and agricultural samples will be presented. The presentation also covers pixel-selection strategies designed to handle variations in detector responsivity, ensuring consistent measurement accuracy. The findings under collaborative research activities contribute to the strong foundation for development of efficient, cost-effective NDT systems towards monitoring and quality assessment applications.

**Keywords:** terahertz imaging, standing wave, non-destructive testing

# Development of Design rules for Minimizing Asymmetry Lateral Etch in MEMS Fabrication on Cavity-SOI Substrates

Anantachai Lakrathok[a] , Jakrapong Supadech[b], Watcharapong Paosangthong[b], Chana Leepattarapongpan[b], Nithi Atthi[b], Wutthinan Jeamsaksiri[b], Adisorn Tuantranont[b], Chinorat Kobdaj[a, *]

[a]*Suranaree University of Technology, 111 University Avenue, Muang Nakhon Ratchasima 30000, Thailand*

[b]*Thai Microelectronics Center (TMEC), National Science and Technology Development Agency (NSTDA), 111 Thailand Science Park, Phahonyothin Road, Khlong Nueng, Khlong Luang, Pathum Thani, 12120, Thailand*

*Corresponding Author's E-mail: kobdaj@g.sut.ac.th

**Abstract**

Asymmetrical lateral etching (ALE) is a significant defect in MEMS fabrication, primarily due to charging effects during deep silicon etching. The ALE undermines the structural integrity of MEMS components, specifically the beam springs and bars, resulting in mass loss and frequency alterations. This study presents design guidelines aimed at reducing ALE angles in cavity Silicon-On-Insulator, while it does not exist on Si bulk substrate, through the optimization of spacing between structures and the integration of isolation trenches on pedestals after the deep Si recipe optimizing. The test structures were constructed on cavity SOI (CSOI) wafers featuring device layer thicknesses of 100 and 150 µm, cavity depths of 10 µm, and bulk silicon substrates. The gap between the beam/bar and pedestal varied from 5 µm to 25 µm, with isolation trenches implemented at 100 µm, 200 µm, and 300 µm. Experimental findings indicate that augmenting the spacing diminishes the ALE angles by 12.5–50%, while isolation trenches further decrease the ALE by 7–50%, contingent upon the configuration. These findings provide initial design principles for improving the structural integrity of MEMS and mitigating ALE-related defects.

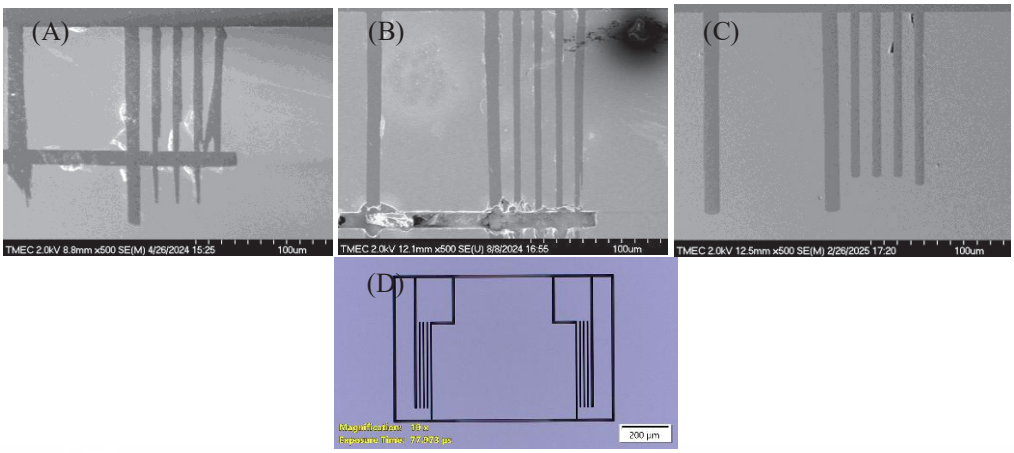



Fig.1 SEM cross section image (A) cavity SOI etch result on device thickness 100 um at 5 um spacing test structure and cavity depth 10 um (B) cavity SOI etch result on device thickness 150 um and cavity depth 10 um at 5 um spacing test structure (C) Si bulk etch result 5 um spacing test structure and (D) optical microscope top-view image of a 5 um spacing test structure designs, respectively

**Keywords:** Asymmetry Lateral Etch Angle (ALEA), Cavity Silicon-On-Insulator (CSOI), deep silicon etching, isolation trench on pedestal, MEMS design rules, MEMS fabrication

# Unveiling Noncollinear Antiferromagnetic and Altermagnetic Orders in Mn-based Materials

Pin Ho[a,*]

[a]*Institute of Materials Research and Engineering (IMRE), Agency for Science, Technology and Research (A*STAR), 2 Fusionopolis Way, Singapore (138634), Singapore*

*Corresponding Author's E-mail: *hopin@a-star.edu.sg*

**Abstract**

Unconventional antiferromagnets (AFs), such as noncollinear AFs (NCAF) and altermagnets (AM), have garnered significant interest due to their unique compensated spin structures and spin-splitting properties.[1] Notably, unconventional AFs combine the advantages of both conventional collinear ferromagnets (FMs) and AFs – offering field immunity, ultrafast spin dynamics, and energy-efficient operation – making them promising candidates for next-generation sustainable computing and sensor technologies.

First, we discuss the magnetic orders stabilized in the face-centered-cubic (*fcc*) $L1_2$-$Mn_3Pt$ NCAF material system grown using a multilayer stack technique.[2,3] By utilizing composition-, strain- and temperature-controlled growth, we demonstrate [111]- and [001]-stacked Kagome planes of frustrated triangular spin arrangements in epitaxial *fcc* $Mn_3Pt$. Further, we show the lattice parameter modulation in $Mn_3Pt$ multilayers as a means to tune the degree of spin canting within magnetic lattices. This tunability introduces an additional degree of freedom to manipulate the interplay between FM-like and NCAF contributions, enabling precise control over the magnitude and polarity of the anomalous Hall effect and x-ray magnetic circular dichroism response.

Second, we will introduce the transition metal disulphide manganese sulphides family as a chemically simple and experimentally accessible AM material platform.[4] First-principles density functional theory calculations reveal pronounced symmetry-driven spin splitting in momentum for both $MnS_2$ and $Mn_2S_3$. In particular, $MnS_2$ is identified as a hidden AM whose AF symmetry constraint encourages AM order in practice. Further, the growth-temperature dependent phase evolution of the reactive sputtered manganese sulphide thin films is examined. X-ray photoelectron spectroscopy unambiguously identifies the formation of disulphide bonding associated with AM $MnS_2$ for growth temperatures 300-400 °C, providing the first experimental confirmation to theoretically predicted thermodynamic phase diagram.

These findings offer a versatile platform to engineer magnetic and electronic transport characteristics of unconventional AF, paving new directions for advanced AF-based memory, computing and sensor technologies.

**Keywords:** noncollinear antiferromagnet, altermagnet, memory, sensor, computing

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# Low Cost, Room-Temperature Synthesis of High-Performance Ductile Thermoelectric Semiconductors

Dejwikom Theprattanakorn[a,b,c†], Tong Xing[a†], Tingwei Yin[a,d,e], Pengfei Qiu[a,d,e], Supree Pinitsoontorn[b,c*], Xun Shi[a,e*]

[a]*State Key Laboratory of High Performance Ceramics, Shanghai Institute of Ceramics, Chinese Academy of Sciences, Shanghai 200050, China*

[b]*Department of Physics, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand.*

[c]*Institute of Nanomaterials Research and Innovation for Energy (IN-RIE), Khon Kaen University, Khon Kaen 40002, Thailand.*

[d]*School of Chemistry and Materials Science, Hangzhou Institute for Advanced Study, University of Chinese Academy of Sciences, Hangzhou, 310024, China*

[e]*Center of Materials Science and Optoelectronics Engineering University of Chinese Academy of Sciences Beijing 100049, China*

†These authors contributed equally to this work. *: xshi@mail.sc.ac.cn,

**Abstract**

$Ag_2(Se,S)$-based ductile materials are promising candidates for flexible thermoelectric applications; however, conventional melting methods with high-temperature routes (> 1,000 ºC), which are commonly employed for the synthesis of such chalcogenide materials, are energy-intensive and inherently limited in achieving precise control over composition and homogeneity in complex systems. In this work, a simple chemical reaction route was employed to synthesize $Ag_2(Se,S)$-based compounds at room temperature, enabling highly homogeneous distribution and good stoichiometric control. Among the S-substituted compositions, $Ag_2Se_{0.7}S_{0.3}$ exhibited the best thermoelectric performance and was selected for further modification. Excess Ag was subsequently incorporated to regulate carrier transport. Although the Ag-excess bulk sample achieved a $zT$ value of 0.54 at 340 K due to reduced thermal conductivity, its power factor remained limited. Hot-rolling deformation was therefore introduced to promote an anisotropic microstructure, offering an effective route to optimize carrier transport. These microstructural features facilitated electron transport from excess Ag, resulting in enhanced electrical conductivity and an improved Seebeck coefficient in the $Ag_{2.05}Se_{0.7}S_{0.3}$ film sample, which achieved a maximum power factor of 13.88 μW $cm^{-1}$ $K^{-2}$ at 340 K. Furthermore, a six-couple in-plane thermoelectric device fabricated from this material delivered a normalized maximum power density of 0.44 W $m^{-1}$ under a temperature difference of 37.4 K, demonstrating the potential of this strategy for high-performance flexible thermoelectric applications.

**Keywords:** Thermoelectric; Hot-rolling; Silver selenide; Sliver sulfide; Flexible thermoelectric device;

# Enhanced Thermoelectric Performance of Ga-Doped AgCuTe

Nur Janna[a], Supree Pinitsoontorn[a,b*]

[a]*Department of Physics, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand*
[b]*Institute of Nanomaterials Research and Innovation for Energy (IN-RIE), Khon Kaen University, Khon Kaen 40002, Thailand*

*Corresponding Author's E-mail: psupree@kku.ac.th

**Abstract**

Thermoelectric materials capable of directly converting waste heat into electricity have attracted significant attention for sustainable energy technologies. Among various candidates, copper–silver chalcogenides have emerged as promising thermoelectric materials owing to their intrinsically low thermal conductivity and tunable electronic transport properties. In this study, Ga-doped AgCuTe compounds with nominal compositions of $AgCu_{1-x}Ga_xTe$ (x = 0–0.03) were synthesized to investigate the influence of Ga substitution on thermoelectric transport behavior. Temperature-dependent electrical conductivity and Seebeck coefficient were measured in the temperature range of 300–650 K. The results reveal that Ga incorporation effectively enhances electrical conductivity while maintaining relatively large Seebeck coefficients. Consequently, the sample with x = 0.02 exhibits the highest power factor of approximately 1.3 mW $m^{-1}$ $K^{-2}$ at elevated temperatures. The improved thermoelectric performance is mainly attributed to the increased carrier concentration induced by Ga doping and enhanced phonon scattering arising from the composite microstructure. These findings demonstrate that Ga doping is an effective strategy for optimizing the thermoelectric transport properties of AgCuTe-based materials and provide useful insights for the development of high-performance thermoelectric chalcogenides for high-temperature energy harvesting applications.

**Keywords:** Thermoelectric materials, AgCuTe, Gallium doping, Power factor, Chalcogenides

# Ab Initio Investigation of Polaron-Mediated Charge Carrier Transport in BiOBr, BiOI, and BiOBr–BiOI Heterostructures

Pathipat Latthiwan[a,*], Thanayut kaewmaraya[a, b]

[a]*Department of Physics, Khon Kaen University, Khon Kaen 40002, Thailand*
[b] *Institute of Nanomaterials Research and Innovation for Energy (IN-RIE), Khon Kaen University, Khon Kaen 40002, Thailand,*

*Corresponding Author's E-mail: pathipat.lat@kkumail.com

**Abstract**

Bismuth oxyhalides (BiOX; X = Br, I) represent a class of semiconducting materials with promising electronic and optical characteristics. Nevertheless, charge carrier transport in these compounds is primarily governed by polaron formation mechanisms, which remain inadequately characterized. In this work, we utilize density functional perturbation theory (DFPT) to examine how polaronic effects influence carrier mobility in BiOBr, BiOI, and their heterostructured interface. Our computational approach includes a wide range of transport-critical parameters, such as electronic band structures, carrier effective masses, dielectric properties, phonon dispersion relations, electron-phonon interaction strengths, and both polaronic and total carrier mobilities. Our findings reveal that these materials demonstrate anisotropic large polaron characteristics stemming from moderate coupling between charge carriers and longitudinal optical phonon modes. Electron polarons exhibit enhanced mobility in the [100] and [010] crystallographic directions, whereas hole polarons demonstrate preferential transport along the layered [001] axis. For the BiOBr–BiOI heterostructure, we observe reduced mobilities for both carrier types, attributed to stronger electron-phonon interactions arising from interfacial dipole fields. Through inclusion of multiple carrier scattering processes, including acoustic deformation potential scattering, ionized impurity scattering, and large polaron scattering, our calculated mobilities show excellent correspondence with experimental measurements for BiOI. This investigation delivers comprehensive understanding of polaron-mediated charge transport phenomena in bismuth oxyhalide systems and their heterostructures, providing valuable design principles for advanced optoelectronic and energy conversion applications.

**Keywords:** Bismuth oxyhalides, BiOBr–BiOI Heterostructure, Polaron transport

# High-Temperature PDIV Performance of Sinter-Free MgO Powder Encapsulation for SiC Power Devices

Wei Meng[a,b], Wenyuan Li[b], Xuebao Li[a,b*] , Yiping Wu[a] , Zhibin Zhao[a,b], Rui Jin[b]

[a]*Power System With Renewable Energy Sources, North China Electric Power University, Changping District, Beijing, China*

[b] *Beijing Huairou Laborary, Huairou District, Beijing, China,*

*Corresponding Author's E-mail: lxb08357x@ncepu.edu.cn

**Abstract**

The maximum operating junction temperature of high-voltage, high-power SiC devices has long been limited by the thermal degradation and insulation failure of conventional polymer encapsulants such as silicone gel. While inorganic nonmetallic materials like glass and ceramics offer superior thermal stability and dielectric strength, their encapsulation processes typically require high-temperature sintering, which risks damaging other packaging components. This paper proposes a sinter-free encapsulation approach using MgO powder with an average particle size of ~5 μm as an alternative encapsulant for SiC power devices. Two filling processes—loose packed and compacted are designed and applied to direct bonded copper (DBC) substrates, a typical structure in actual devices, with a minimum copper trace spacing of 3 mm. Partial discharge inception voltage (PDIV) and discharge magnitude are measured from 25 °C to 250 °C using a closed-loop temperature-controlled heating stage. Results show that PDIV decreases with rising temperature for both filling methods, while a stabilization or slight recovery is observed in the 150–250 °C range. Loose-filled samples exhibit a PDIV of approximately 6.7 kV at 25 °C, maintaining a range of 6.3–7.8 kV across the full temperature span with favorable voltage withstand stability; however, once partial discharge is initiated, the discharge magnitude can reach approximately 200 pC at elevated temperatures. In contrast, pressed samples show a lower PDIV of approximately 3.9–4.3 kV, but maintain discharge magnitudes consistently below 30 pC across the entire temperature range, exhibiting more stable and suppressed discharge behavior. These findings indicate that packing density critically governs the trade-off between partial discharge inception threshold and discharge energy. This work presents a preliminary exploration of sinter-free ceramic powder encapsulation, and the results suggest that this approach holds potential for enabling SiC power devices to operate reliably at junction temperatures of 250 °C and above.

**Keywords:** SiC power devices, Ceramic powder encapsulation, Magnesium oxide, High-temperature encapsulation, Partial discharge

# Transient Liquid Phase Bonding for High-Temperature SiC Power Devices: Materials, Processes, and Performance

Bo Zhao[a], Xuebao Li[a,b*] , Hao Li[a], Hongji Li[a], Yiping Wu[b] , Zhibin Zhao[a,b], Rui Jin[a]

[a] *Beijing Huairou Laborary, Huairou District, Beijing, China,*

[b]*Power System With Renewable Energy Sources, North China Electric Power University, Changping District, Beijing, China*

*Corresponding Author's E-mail: lxb08357x@ncepu.edu.cn

**Abstract**

As silicon carbide (SiC) power devices advance towards higher temperatures and power densities, the interconnect layer between the chip and the direct bonded copper (DBC) substrate becomes a critical bottleneck, governing both thermomechanical reliability and thermal performance. Conventional high-lead solders are increasingly inadequate under these demanding conditions. Transient liquid phase (TLP) bonding, with its characteristic low processing temperature and high service temperature, is a promising alternative. This study presents a systematic comparison of four high-temperature interconnect solutions for single-chip packages: high-lead solder, nano-silver sintering, nano-copper sintering, and Cu-Sn composite TLP bonding. A finite element thermal model was first established to simulate the junction-to-case thermal resistance for each material. Prototypes were then fabricated and inspected via X-ray and scanning acoustic microscopy (SAM), confirming sound interfaces with low porosity for all cases. Mechanical shear tests revealed that nano-copper sintering achieved the highest strength (~100 MPa), followed by Cu-Sn TLP bonding (~85 MPa), nano-silver sintering (~60 MPa), and high-lead solder (~35 MPa). Thermal characterization showed that nano-silver sintering yielded the lowest thermal resistance (~0.25 K/W), with nano-copper and Cu-Sn TLP bonding being comparable, while high-lead solder was the highest (~0.37 K/W). In summary, Cu-Sn TLP bonding offers a balanced performance, combining high shear strength with competitive thermal resistance. Its additional advantages of lower cost and suitability for large-area interconnections make it a promising and reliable die-attach solution for next-generation high-temperature SiC power devices.

**Keywords:** SiC power devices, Cu-Sn composite transient liquid phase (TLP) bonding, Mechanical shear tests, Thermal characterization

# Activating $WS_2$ for Enhanced $CO_2$ Reduction via Cerium Doping: A Combined Experimental and Theoretical Study

Chih-Yang Huang [a,b,c*], Kuei-Hsien Chen [d], Li-Chyong Chen[c,e,f]

[a] International Graduate Program of Molecular Science and Technology, National Taiwan University (NTU-MST), Taipei 10617, Taiwan
[b] Molecular Science and Technology Program, Taiwan International Graduate Program (TIGP), Academia Sinica, Taipei 11529, Taiwan
[c] Center for Condensed Matter Sciences, National Taiwan University, Taipei 10617, Taiwan
[d] Institute of Atomic and Molecular Sciences, Academia Sinica, Taipei 10617, Taiwan
[e] Center of Atomic Initiative for New Materials, National Taiwan University, Taipei, 10617, Taiwan
[f] Department of Physics, National Taiwan University, Taipei 10617, Taiwan

*Email: chenlc@ntu.edu.tw

**Abstract**

Doping engineering has emerged as a powerful strategy to modulate the electronic, optical, and catalytic properties of two-dimensional (2D) materials. In catalytic applications, 2D materials offer unique advantages such as high surface-to-volume ratios and tunable electronic structures. However, their intrinsic lack of active sites often hinders catalytic efficiency. In this study, we explore cerium (Ce) doping in $WS_2$ to enhance its photoelectrocatalytic $CO_2$ reduction performance.

Optical characterization reveals that Ce doping enhances B exciton absorption and suppresses A exciton emission, suggesting reduced charge carrier recombination and improved separation. This behavior implies a prolonged carrier lifetime, which is beneficial for catalytic reactions. X-ray photoelectron spectroscopy (XPS) confirms electron redistribution toward W and S atoms, indicating stronger electronic interactions. Furthermore, density functional theory (DFT) calculations show that Ce preferentially substitutes at S sites, creating chemically active centers that facilitate $CO_2$ chemisorption. These combined experimental and theoretical insights demonstrate that Ce doping is an effective approach to activate $WS_2$ and boost its catalytic performance in $CO_2$ reduction.

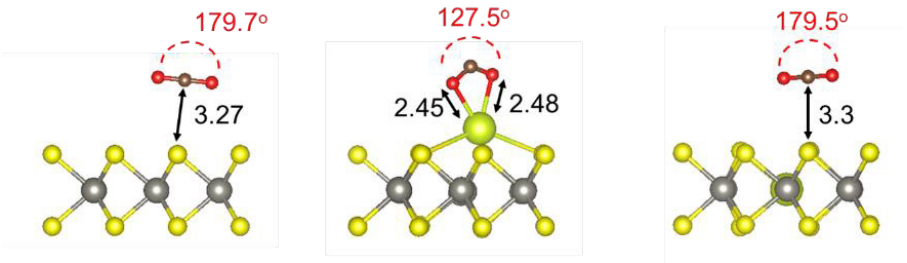



Figure 1. $CO_2$ adsorption on different $WS_2$ surface

**Keywords:** TMDC, photocatalyst, exciton, rare-earth element

# Impact of Substrate Carbon Impurities on MOSFET Breakdown Voltage via Enhanced Phosphorus Out-Diffusion in n/n$^+$ Epitaxial Wafers

Jinge Wang [a], Tong Zhao [a], Feihong Lu [b], Pengfei Gao [c], Junyuan Zhang [c], Xingbo Liang [c], Daxi Tian [c], Xiangyang Ma [a, *] and Deren Yang [a, *]

[a] *State Key Laboratory of Silicon and Advanced Semiconductor Materials & School of Materials Science and Engineering, Zhejiang University, Hangzhou 310027, China*
[b] *QL Electronics Science (Ningbo) Co., Ltd, No. 20, Gangdong Road, Ningbo 315800, Zhejiang Province, China*
[c] *QL Electronics Science (Quzhou) Co., Ltd, No. 52, Panlong South Road, Quzhou 324000, Zhejiang Province, China*

*Corresponding Author's E-mail: mxyoung@zju.edu.cn (Xiangyang Ma) and mseyang@zju.edu.cn (Deren Yang)

## Abstract

n/n$^+$ epitaxial wafers using heavily phosphorus-doped Czochralski (HP-CZ) silicon substrates are widely used for power MOSFET fabrication, and substrate impurities can affect device performance. This work investigates how carbon impurities in HP-CZ substrates influence phosphorus out-diffusion during MOSFET processing. Compared with devices fabricated on low-carbon (~$6.5\times10^{15}$ cm$^{-3}$, LC) substrates, MOSFETs fabricated on high-carbon (~$3.4\times10^{16}$ cm$^{-3}$, HC) substrates show a much lower mean breakdown voltage (BV) and a clear ring-shaped non-uniform distribution, with lower BV at the center and higher BV at the edge [left half of Fig. 1(a)]. In contrast, the BV distribution of devices on LC substrates is much more uniform [left half of Fig. 1(b)]. Further analysis shows that the ring-shaped BV distribution in HC wafers is consistent with the ring-shaped oxygen-precipitate distribution observed in the substrate [right half of Fig. 1(a)]. Correspondingly, the epitaxial layer on HC substrates exhibits significantly lower resistivity than that on LC substrates [Fig. 1(c)-(d)], accounting for the reduced mean BV. In HC wafers, the resistivity increases from center to edge [Fig. 1(c)], consistent with the radial increase in BV; in LC wafers, the resistivity varies only slightly from center to edge [Fig. 1(d)], matching the weak BV variation.

During medium-to-low temperature processing (700-1000 °C), the higher carbon concentration in HC substrates promotes oxygen precipitation. These precipitates emit a large number of non-equilibrium silicon self-interstitials, which diffuse into the epitaxial layer and enhance phosphorus out-diffusion from the substrate to the epitaxial layer. This reduces the epitaxial resistivity and consequently lowers MOSFET BV.

In conclusion, carbon impurities in HP-CZ substrates degrade the BV of MOSFETs on n/n$^+$ epitaxial wafers by enhancing phosphorus out-diffusion, providing a scientific basis for carbon control in HP-CZ silicon substrates.

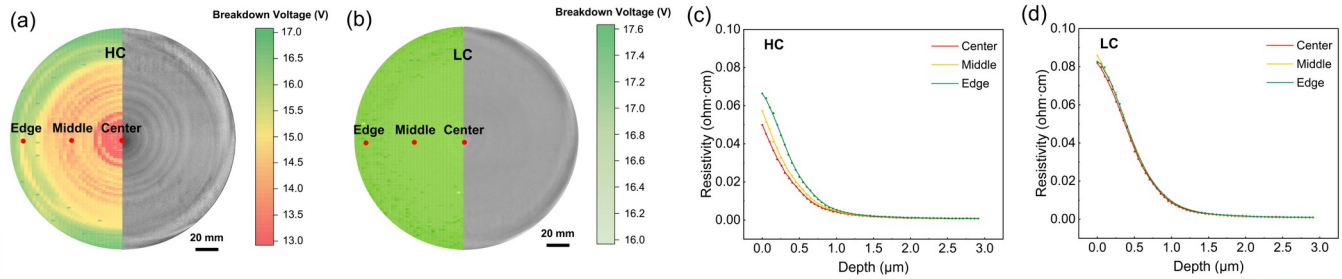



**Fig. 1.** (a) and (b) Combined maps of breakdown voltage (left half) and corresponding XRT images of oxygen precipitates (right half) for MOSFETs fabricated on n/n$^+$ epitaxial wafers using heavily phosphorus-doped substrates with high and low carbon concentrations, respectively. Red dots indicate the Center, Middle, and Edge positions selected for spreading resistance profiling. (c) and (d) Spreading resistance profiling curves measured at the Center, Middle, and Edge positions of the n/n$^+$ epitaxial layers on HC and LC substrates, respectively, after the MOSFET fabrication process.

**Keywords:** power MOSFET, carbon impurity, oxygen precipitation, phosphorus out-diffusion, breakdown voltage

# Plasmon-enhanced Au-decorated 3D semiconductor photocatalysts: Synthesis, optimization and enhanced optical properties for ultrasensitive detection and photocatalytic removal of organic pollutants

Rupam Sharma[$], Jai Prakash[*]

*Department of Chemistry, National Institute of Technology Hamirpur, Hamirpur-177005 (H.P.) India.*

***Corresponding author:** Jai Prakash (Email: jaip@nith.ac.in)

**Abstract**

Three-dimensional (3D) micro-nano Au-decorated semiconductor nanohybrid architectures have emerged as promising multifunctional platforms for simultaneous environmental monitoring and remediation. However, achieving a synergistic balance between ultrasensitive detection and efficient photocatalytic degradation remains a significant challenge. In this present work, the rational design and fabrication of 3D hierarchical architectures such as nanoflowers and tetrapods based on CdS, $TiO_2$, and ZnO semiconductors, decorated with Au nanoparticles (NPs) via a facile photodeposition approach have been reported. The resulting architectures exhibit interconnected micro-nano features with high surface area and abundant active sites, enabling enhanced light-matter interaction. Structural and morphological analyses confirm the formation of well-defined nanohybrid architectures, while optical studies reveal an improved visible-light absorption due to the surface plasmon resonance (SPR) effect of Au NPs. The fabricated architectures exhibited excellent photocatalytic performance, achieving more than 95% degradation of methylene blue (MB) within 60-180 min, depending on the 3D semiconductor architecture employed. The variation in degradation time is attributed to differences in band structure, light absorption, and charge carrier dynamics among CdS[1], ZnO[2], and $TiO_2$. In addition to photocatalysis, the platform demonstrated remarkable ultrasensitive detection capability toward MB dye, with a limit of detection as low as ~$10^{-12}$ M, indicating outstanding surface enhanced Raman scattering (SERS) activity [2]. Furthermore, the system was successfully extended to the degradation of various pharmaceutical contaminants, demonstrating its versatility for complex pollutant removal. The enhanced performance is attributed to the synergistic interaction between plasmonic Au NPs and 3D semiconductor matrices, which promotes efficient charge separation, suppresses electron-hole recombination, and enhances electromagnetic fields for sensing. Additionally, the architectures exhibit excellent stability and recyclability over multiple cycles, confirming their suitability for practical applications. This study presents a sustainable, recyclable, and high-performance platforms for integrated pollutant detection and photocatalytic remediation, offering significant potential for advanced environmental applications.

**Keywords:** Photocatalysts, Au photodeposition, 3D nanomaterials, Solar-driven photodegradation, SERS.

**[$]Presenting author:** Rupam Sharma (rupam_phdchem@nith.ac.in)

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# Effect of metal-doped $W_{18}O_{49}$ material on their structural and optical properties for their photochromic application

Junkrajang Wattana[a], Thanaphon Kansaard[a], Wanichaya Mekprasart[a], Kanokthip Boonyarattanakalin[a], and Wisanu Pecharapa[a],*

[a]*School of Intergrated Innovative Technology, King Mongkut's Institute of Technology Ladkrabang, Ladkrabang, Bangkok 10520 Tha iland*

*Corresponding Author's E-mail: wisanu.pe@kmitl.ac.th

**Abstract**

Monoclinic $W_{18}O_{49}$ is an oxygen-deficient tungsten oxide that attracted significant attention to its unique photonic property arising from abundant oxygen vacancies and high free-carrier concentration. Due to these synergistic defects, $W_{18}O_{49}$ can provide a strong near-infrared absorption from its localized surface plasmon resonance (LSPR) and small polaron hopping, which can be further enhanced by the coloring process of the photochromic mechanism owing to its increasing carrier from the photogenerated electron. Since metal incorporation is an efficient method to provide the enhancement of charge transfer behavior performance, thereby improving coloration efficiency and reversible photochromic response, this research reports the solvothermal synthesis of $W_{18}O_{49}$ particles with different contents of metal dopants to study the changes in structural and optical properties, especially photochromic application, of materials under each synthesis condition. The synthesized samples will be characterized by X-ray diffraction (XRD) for crystalline analysis and phase identification, field-emission scanning electron microscopy with energy-dispersive spectroscopy (FE-SEM/EDS) for morphology and elemental distribution, and UV-Vis-NIR spectroscopy for optical and photochromic performance evaluation. The preliminary results indicated that monoclinic $W_{18}O_{49}$ particles were successfully synthesized via the solvothermal method. Further details of results and discussion will be presented.

**Keywords:** $W_{18}O_{49}$ material, Solvothermal method, Structural property, Optical property, Photochromic property

# Comprehensive Electronic, Mechanical, and Vibrational Characterization of Orthorhombic $MgSiN_2$: A Comparative First-Principles Study

Anucha Yangthaisong[a,*]

[a]*Department of Physics, Ubonratchathani University, Ubonratchathani, THAILAND*

*Corresponding Author's E-mail: a.yangthaisong@gmail.com

**Abstract**

Orthorhombic magnesium silicon nitride ($MgSiN_2$) is a prominent wide-bandgap semiconductor for next-generation UV-optoelectronics and power electronics. In this work, we perform a systematic first-principles approach to provide a comprehensive characterization of its electronic, mechanical, and vibrational properties. Our electronic structure analysis establishes a definitive indirect bandgap of 5.57 eV using HSE06 and sX-LDA functionals, demonstrating a superior match to experimental spectroscopic data over standard GGA and modern rSCAN (4.781 eV) methods. Mechanical characterization through the full elastic tensor ($C_{ij}$) reveals a high bulk modulus of 176.2 GPa and a significant Universal Anisotropy Index ($A^U$), highlighting the material's pronounced directional structural stability. Furthermore, we confirm the dynamic stability of $MgSiN_2$ via phonon dispersion and provide a complete mapping of Raman and Infrared (IR) active modes, validated through the Lyddane-Sachs-Teller relationship and Born effective charge sum rules. By resolving existing literature discrepancies, this study provides the high-fidelity benchmarks essential for the targeted design of $MgSiN_2$-based electronic and optoelectronic devices.

**Keywords:** $MgSiN_2$, Wide-bandgap semiconductors, First-principles study, HSE06, Mechanical anisotropy, Phonon dispersion.

# A Unified Computational Framework for Physics-Based Semiconductor Material Ranking

Atchariya Phuangyod[1,*], Wirat Wongsrinak[2] and Watcharin Srirattanawichaikul[1]

[1]*Department of Electrical Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai, 50200 Thailand*
[2]*Ratchaburi Learning Park, King Mongkut's University of Technology Thonburi, Ratchaburi, Thailand*

*Corresponding Author's E-mail: atchariya.phu@cmu.ac.th

**Abstract**

This paper presents a physics-informed semiconductor material recommendation framework for application-centered ranking and engineering decision support. The proposed framework combines semiconductor physics, normalized material properties, computational ranking techniques, and application-specific weighting models to identify suitable semiconductor materials for different electronic applications. The study uses a public semiconductor database that includes conventional semiconductors, III-V compounds, wide-bandgap materials, and ultra-wide-bandgap materials, including Si, Ge, GaAs, InAs, InP, GaN, SiC, and AlN. The framework evaluates important physical parameters such as bandgap energy, intrinsic carrier concentration, electron mobility, dielectric constant, electrical conductivity, Hall sensitivity, and thermal stability. The proposed model calculates normalized physics-based scores and combines them with application-centered weighting functions to rank semiconductor materials for Hall sensors, power electronics, high-speed electronics, high-temperature electronics, and general-purpose devices. The framework also applies k-means clustering to classify semiconductor materials according to their physical characteristics and performance trends. In addition, the system visualizes material suitability through ranking maps, heatmaps, barplots, and radar charts to improve result interpretation and engineering analysis. The results show that InAs achieves the highest ranking for Hall sensor and high-speed electronic applications because of its extremely high electron mobility. GaN and SiC demonstrate strong suitability for power electronics and high-temperature applications due to their wide bandgap and excellent thermal stability. AlN exhibits outstanding thermal robustness among ultra-wide-bandgap materials, while Si maintains balanced performance for general-purpose applications. This framework provides a low-cost and scalable platform for intelligent semiconductor material selection using MATLAB without requiring expensive fabrication processes or laboratory facilities. This approach can support semiconductor education, material discovery, and future digital twin development for semiconductor manufacturing and electronic device engineering.

**Keywords:** semiconductor material ranking, physics-based modelling, wide-bandgap semiconductors, computational framework, material selection.

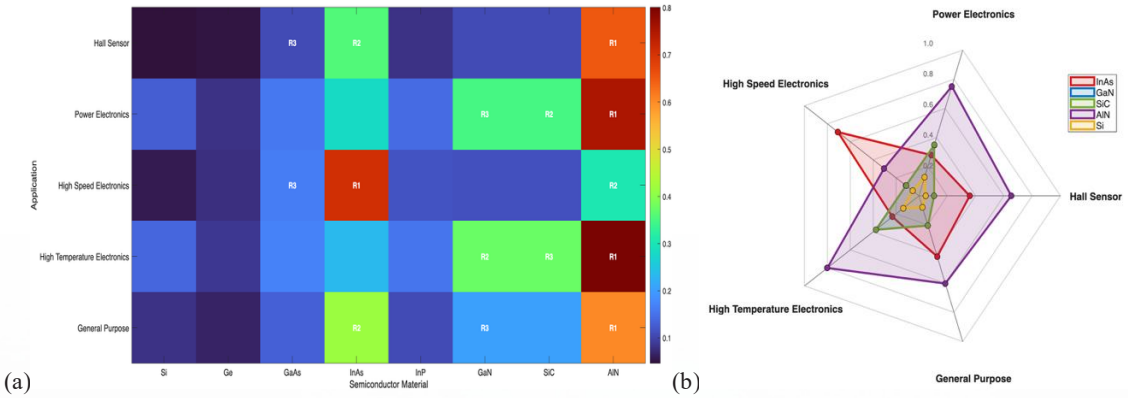



**Fig. 1.** Schematic overview of the visualization results produced by the proposed physics-informed semiconductor material ranking framework. (a) Application-centered semiconductor material ranking map based on physics-informed computational evaluation and (b) radar chart comparison of representative semiconductor materials across multiple applications.

# Analysis of Chlorophyll Fluorescence Emission and Photosynthetic Performance by Using Quantum Viewpoint of Radiation

Atirat Maksuwan[a,b], Arpapong Changjan[a,b], Warapol Kasemsan[a,b] and Nuttakorn Intaravicha[a,b*]

[a]*Department of Environmental Technology for Agriculture, Faculty of Science and Technology, Pathumwan Institute of Technology, Bangkok 10330, Thailand.*
[b]*Agricultural Technology and Innovation Research Cluster, Research and Academic Services Office, Pathumwan Institute of Technology, Bangkok 10330.*

**Abstract**

This research modified the vacuum-to-vacuum transition probability for describing radiation in an anisotropic medium in order to establish a link with radiation theory in a vacuum. The intrinsic property of such a system, with arbitrary current distributions, of producing photons via the Poisson distribution can be used to extract the power of radiation from the average number of photons emitted in such a medium. The study illustrates how pigments involved in UV-C effects absorb light and produce chlorophyll fluorescence emission and photosynthetic performance using the power of radiation released by a charged particle. *Wolffia globosa* (L.) Wimm was the first to demonstrate photosynthetic pigment separation.

**Keywords:** Wolffia globosa (L.) Wimm, Photosynthesis, UV−vis Spectroscopy, Fluorescence Spectroscopy, Classical and quantum probabilities, Electromagnetic radiation in a medium

# Visible light-induced formation of silver nanocomposites stabilizes with polyphosphodiesters

T. Jullabuth[a,*], Y. Okuno[b,c], and Y. Iwasaki[b,c]

[a]*Graduate School of Science and Technology*
[b]*Faculty of Chemistry, Materials and Bioengineering*
[c]*ORDIST, Kansai University, 3-3-35, Yammate, Suita, Osaka 564-8680, Japan*

*Corresponding Author's E-mail: yasu.bmt@kansai-u.ac

## Abstract

Nowadays, research worldwide is increasingly focused on the utilization of sustainable energy, particularly solar energy. One area that has attracted long-term interest is photocatalysis, with continuous efforts in the design and synthesis of highly efficient photocatalysts for a wide range of applications. In this study, we aim to enhance the performance of a hybrid system based on polyphosphodiesters (PPDEs) stabilized silver nanocomposites, as shown in Fig. 1. The PPDEs stabilized silver nanocomposites were successfully synthesized by treating poly(ethylene sodium phosphate) (PEP·Na) with silver acetate. Subsequently, visible light irradiation was applied to form a silver nanocomposites, denoted as PEP·$Na_aAg_b$-*l*, where *a* and *b* represent the feed molar ratio of [EP·Na]:[$CH_3COOAg$], respectively. The chemical structures were confirmed by proton nuclear magnetic resonance ($^1$H NMR), and the molecular weights were determined using gel permeation chromatography (GPC). The characteristics of PEP·$Na_aAg_b$-*l* were further verified by X-ray photoelectron spectroscopy (XPS), transmission electron microscopy (TEM), selected area electron diffraction (SAED), and high-resolution transmission electron microscopy (HRTEM). The colloidal stability was evaluated by measuring the percent transmittance (%T). Notably, the zeta potential of −45.7 mV confirms the presence of negatively charged PPDEs surrounding silver nanocomposites, forming a stabilizing layer that provides electrostatic repulsion. The photocatalytic activity of the PPDEs stabilized silver nanocomposites was assessed through the degradation kinetics of rhodamine B (RhB) under visible light irradiation. After 90 minutes, PEP·$Na_5Ag_1$-*l* achieved up to 89% RhB removal efficiency. In addition, the PEP·$Na_5Ag_1$-*l* demonstrated recyclability, maintaining 87% RhB removal efficiency after six cycles. Scavenger test indicated that the photocatalytic mechanism is mainly attributed to photogenerated holes ($h^+$) and superoxide radicals ($O_2^{-}\cdot$). Therefore, this system shows strong potential as an efficient and stable photocatalyst under visible light irradiation.

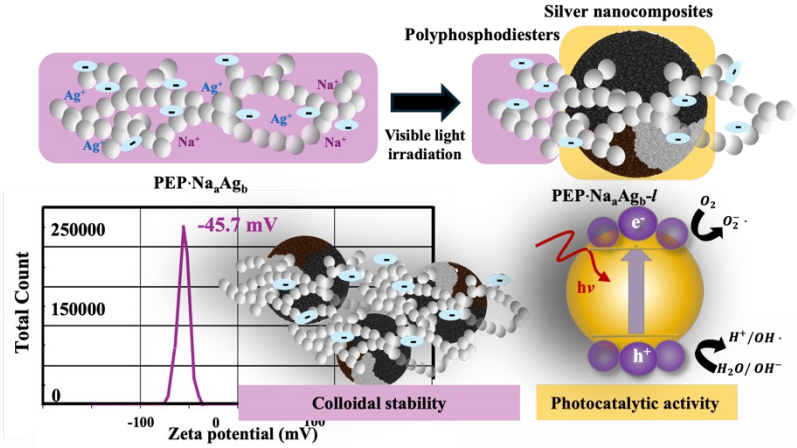



Figure 1 The schematic of PEP·$Na_aAg_b$-*l*

**Keywords:** Polyphosphodiesters, silver nanocomposites, visible light, colloidal stability, photocatalytic activity

# Highly active *bis*-lithium *N*-heterocyclic carbene complexes as lewis-acid organocatalysts for room-temperature ε-caprolactone ring-opening polymerization: a mechanistic investigation

Nathaporn Cheechana[a,b], Natthapol Akkravijitkul[c], Chawanakorn Kongsak[a,b],

Winita Punyodom[a,d,e] and Puttinan Meepowpan[a,d,e*]

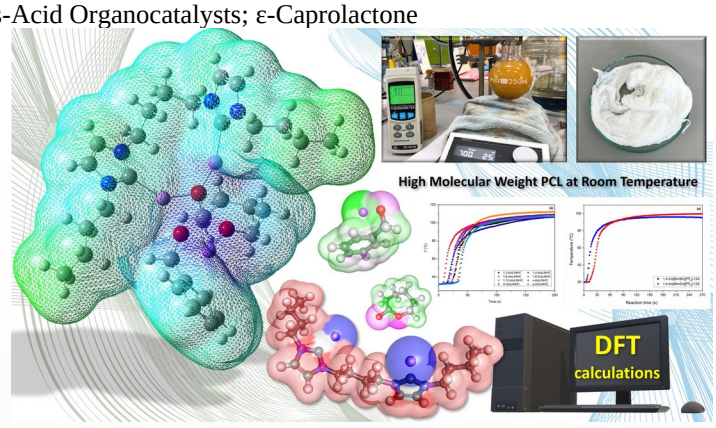
[a]*Department of Chemistry, Faculty of Science, Chiang Mai University, 239 Huay Kaew Road, Chiang Mai 50200, Thailand.*
[b]*Office of Research Administration, Chiang Mai University, Chiang Mai 50200, Thailand.*
[c]*University of Bristol, Beacon House, Queens Road, Bristol, BS8 1QU, United Kingdom.*
[d]*Center of Excellence for Innovation in Chemistry (PERCH-CIC), Faculty of Science, Chiang Mai University, 239 Huay Kaew Road, Chiang Mai 50200, Thailand.*
[e]*Center of Excellence in Materials Science and Technology, Chiang Mai University, 239 Huay Kaew Road, Chiang Mai 50200, Thailand.*

*Corresponding Author's E-mail: puttinan.m@cmu.ac.th

**Abstract**

*N*-heterocyclic carbenes (NHCs) are well established as highly effective organocatalysts for ring-opening polymerization (ROP), largely because they enable good molecular-weight control, narrow dispersity (*Đ*), and high catalytic activity. In this work, we prepared a series of alkyl/aryl-tethered *bis*-lithium NHCs (*bis*LiNHCs) and investigated their performance as catalysts for the ROP of *ε*-caprolactone (*ε*-CL). The corresponding *bis*NHC precursor salts were synthesized from imidazole and obtained in moderate yields (36–55%). Bulk polymerizations were conducted at room temperature using catalytic systems composed of the alkyl/aryl-tethered *bis*NHC precursors, benzyl alcohol (BnOH), and *n*-butyl lithium (*n*BuLi). Under these conditions, *ε*-CL conversion exceeded 95% in all cases. When the molar ratio of [*bis*[Bim][$PF_6$]]:[BnOH]:[*n*BuLi] was adjusted from 1:2:3 to 1:2:4, the 1:2:4 formulation led to a higher polymerization rate. The produced poly(*ε*-caprolactone) (PCL) displayed a range of molecular weights and dispersities; notably, the 1:2:3 ratio afforded the highest number-average molecular weight ($M_n$ = 103,057 g/mol) with $Đ \approx 1.8$. Structural features of the *bis*LiNHC catalysts strongly influenced reactivity. In particular, linker length and flexibility altered catalyst geometry and modulated chelation interactions between lithium centers and oxygen atoms. In addition, steric effects from *N*-substituents on the *bis*LiNHC side chains affected *ε*-CL initiation, where increased steric bulk was associated with a higher ROP energy barrier. Among the examined catalysts, 1,4-*bis*LiNHC delivered the best overall catalytic performance. Density Functional Theory (DFT) calculations at the B3LYP/6-31G(d,p) level supported an operative pathway consistent with a continuous/activated monomer mechanism (AMM) featuring a low activation barrier, in agreement with the experimental observations.

**Keywords:** Bis-Lithium N-Heterocyclic Carbenes Complexes; Activate-Monomer Mechanism; Ring-Opening Polymerization; Lewis-Acid Organocatalysts; ε-Caprolactone



# Effect of MOF Dimensionality on Proton Transport in SPEEK-Based Polymer Electrolytes

Teerapat Kotpatjim*, Yaowapa Treekamol, Kanjana Janmapraw

*Materials Science and Nanotechnology Program, Department of Physics, Faculty of Science, Khon Kaen University, Khon Kaen, Thailand 40002*

*Corresponding Author's E-mail: K_teerapat@kkumail.com

**Abstract**

Sulfonated poly(ether ether ketone) (SPEEK) is a promising polymer electrolyte due to its tunable proton conductivity and good physicochemical stability. In this study, a SPEEK membrane with a degree of sulfonation (DS) of 0.78 was selected as the polymer matrix. To enhance proton transport, Zn-based metal–organic frameworks (MOFs) with different dimensionalities (1D and 2D) were incorporated into the SPEEK matrix at loadings of 1–5 wt%. The incorporation of MOFs introduced acid–base interactions with sulfonic acid groups, leading to a decrease in ion exchange capacity; however, additional proton-conducting sites within the MOF structure contributed to improved proton transport at appropriate loadings. Electrochemical impedance spectroscopy results showed that pristine SPEEK exhibited a proton conductivity of $7.35 \times 10^{-9}$ S·cm$^{-1}$, while SPEEK/1D MOF composites reached up to $8.04 \times 10^{-7}$ S·cm$^{-1}$. Notably, the SPEEK/2D MOF composite at 1 wt% showed the highest conductivity on the order of $10^{-6}$ S·cm$^{-1}$, which is approximately 2.5 times higher than the best 1D system. This enhancement is attributed to the nanosheet morphology of 2D MOFs, which provides a larger interfacial area and promotes continuous proton transport pathways. At higher loadings, particle agglomeration and restacking reduced effective transport pathways and decreased conductivity. These results demonstrate that MOF dimensionality and optimal loading are key factors for improving proton transport in SPEEK-based polymer electrolytes.

**Keywords:** SPEEK, MOFs, Proton transport, Polymer electrolyte, Composite membrane

# Effect of the Degree of Substitution of Carboxymethyl Cellulose on Packaging Film Properties

Piyathida Sriudom[a], Yaowapa Treekamol [a,*]

[a]*Department of Physics, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand*

*Corresponding Author's E-mail: yaowaho@kku.ac.th

**Abstract**

This study investigates the synthesis of carboxymethyl cellulose (CMC) from corn cob cellulose as a value-added use of agricultural waste. The effects of sodium hydroxide (NaOH) concentration (30–50% w/v), monochloroacetic acid (MCA) amount (12–18 g), and reaction temperature (45–65 °C) on the degree of substitution (DS) were examined. The highest DS of 1.13 was achieved at 45 °C, yielding a high water solubility of 88.48% (w/w). FTIR analysis confirmed the successful carboxymethylation, exhibiting characteristic functional groups consistent with commercial CMC (e.g., C=O stretching at 1600-1590 $cm^{-1}$). The synthesized CMC possessed a weight-average molecular weight ranging from 21,889 to 59,727 g/mol, as determined by Gel Permeation Chromatography (GPC). Thermogravimetric Analysis (TGA) indicated good thermal stability, with the major thermal degradation stage occurring between 200 and 300 °C. Furthermore, uniform and translucent CMC films were prepared by solvent casting using 0.2 mL of glycerol as a plasticizer. The optimum film exhibited a maximum tensile strength of 2.42 MPa at a 30% NaOH concentration. These findings demonstrate that corn cob-derived CMC is a promising biopolymer for sustainable packaging applications.

**Keywords:** Carboxymethyl cellulose, Degree of substitution, Agricultural waste, Corn cob

# Enhancing Titanium Surfaces for Bone and Dental Applications

Chawan Manaspon[a,b,*], Traipob Korpanitchkul[a], Patipat Kamdenlek[c], Warit Powcharoen[d], Thantrira Porntaveetus[b], Thanaphum Osathanon[e], Shuichi Watanabe[f], Chavin Jongwannasiri[g,*]

[a]*Biomedical Engineering Institute and Biomedical Engineering and Innovation Research Center, Chiang Mai University, Chiang Mai, Thailand,*
[b]*Center of Excellence in Genomics and Precision Dentistry, Department of Physiology, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand,*
[c]*Department of Biomedical Engineering, Faculty of Engineering, Thaksin University, Phatthalung, Thailand,*
[d]*Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chiang Mai University, Chiang Mai, Thailand,*
[e]*Center of Excellence for Dental Stem Cell Biology, Department of Anatomy, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand,*
[f]*Department of Applied Chemistry, Faculty of Fundamental Engineering, Nippon Institute of Technology, Saitama, Japan,*
[g]*Princess Srisavangavadhana Faculty of Medicine, Chulabhorn Royal Academy, Bangkok, Thailand*

*Corresponding Author's E-mail: chawan.m@cmu.ac.th and chavin.jon@cra.ac.th

**Abstract**

The modification of titanium alloy (Ti-6Al-4V, Ti64) surfaces is essential for improving osseointegration, providing antibacterial properties, and modulating immune responses in dental and orthopedic applications. This study synthesized and compared various surface modification techniques, including diamond-like carbon (DLC) films (doped with fluorine or silicon), plasma-based ion implantation (PBII) for nitridation (TiN), and titanium–tantalum–nitride (TiTaN) coatings. Physicochemical characterization via AFM, SEM, and XPS revealed that while DLC coatings increased surface roughness and hydrophobicity, both TiN and TiTaN treatments significantly enhanced hydrophilicity and surface hardness. Biologically, all modified surfaces supported the adhesion, spreading, and proliferation of human primary alveolar bone cells (hAVs). DLC-modified surfaces—specifically F-DLC—enhanced initial cell spreading and mineral deposition. The TiN-Ti64 surface produced via PBII demonstrated superior osteogenic potential, significantly upregulating marker genes such as *BMP2*, *OCN*, *OPN*, and *RUNX2*, with a 20% increase in mineralization compared to untreated Ti64. Furthermore, these modifications addressed critical clinical challenges regarding infection and inflammation. DLC and F-DLC surfaces exhibited significant antibacterial activity against *Staphylococcus aureus*. Notably, the TiTaN coating demonstrated potent immunomodulatory properties, significantly attenuating nitric oxide production and downregulating pro-inflammatory cytokines (*Il-6*, *Tnf-α*, and *Il-1β*) in RAW264.7 macrophages under inflammatory conditions. In conclusion, while DLC and TiN coatings effectively enhance mechanical properties and osteogenic differentiation, the incorporation of tantalum (TiTaN) provides a superior anti-inflammatory milieu. These findings suggest that plasma-based nitridation and doped-DLC coatings are highly promising strategies for improving the clinical longevity and success of titanium-based implants.

**Keywords:** Bone Cells, Diamond-like Carbon, Nitriding, Surface Modification, Titanium

# DSC as a Fast Method to Determine the Activation Parameters for the Non-isothermal Ring-opening Polymerization of ε-Caprolactone : A Comparative Study

Wanich Limwanich[a,*], Puttinan Meepowpan[b,c,d], Winita Punyodom[b,c,d]

[a]*Faculty of Science and Agricultural Technology, Rajamangala University of Technology Lanna, Chiang Mai, 50300, Thailand*
[b]*Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[c]*Bioplastics Production Laboratory for Medical Applications, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[d]*Center of Excellence in Materials Science and Technology, Chiang Mai University, Chiang Mai, 50200, Thailand*

*Corresponding Author's E-mail: wanich.lim@rmutl.ac.th

**Abstract**

In this work, we introduce a fast, powerful, and alternative method based on differential scanning calorimetry (DSC) to determine activation parameters, including activation enthalpy ($\Delta H^{\neq}$) and activation entropy ($\Delta S^{\neq}$). The ring-opening polymerization (ROP) of ε-caprolactone (ε-CL) with different initiating systems under non-isothermal conditions was employed as a model system. The progress of ε-CL polymerization can be monitored in real time by observing polymerization exotherms during DSC measurements at four different heating rates. Prior to determining these activation parameters, the kinetic triplet, namely activation energy ($E_a$), pre-exponential factor ($A$), and rate constant ($k$), must be evaluated. From DSC kinetic analysis, the $E_a$ and $A$ values for the ROP of ε-CL are determined using the Kissinger–Akahira–Sunose (KAS) isoconversional method and a model-fitting technique, respectively. Based on classical transition state (TS) theory, a newly derived rate equation under non-isothermal DSC conditions can be conveniently applied to determine $\Delta H^{\neq}$ and $\Delta S^{\neq}$. For the ROP of ε-CL with metal-containing initiators, the obtained $\Delta H^{\neq}$ and $\Delta S^{\neq}$ values are positive and negative, respectively. These activation parameters are useful and can further support the evaluated kinetic parameters. The reactivity of initiators in the ROP of ε-CL can be rapidly compared using both kinetic and activation parameters. Furthermore, these results can be applied to assess the effectiveness of initiators in the large-scale synthesis of biodegradable poly(ε-caprolactone) (PCL).

**Keywords:** Activation parameter, Caprolactone, DSC, Kinetics, Ring-opening polymerization

# PLGA/PEO/TC Electrospun Membranes for Dental Application

Thannaphat Jenvoraphot[a],[b], Krissana Tangamatakul[c], Chayarop Supanchart[b],[d], Robert Molloy[b], Matthew J. Derry[e], Paul D. Topham[e], Brian J.Tighe[e], Patnarin Worajittiphon[b,f], Winita Punyodom[b,f], and Donraporn Daranarong[b,g],*

[a] *Office of Research Administration, Chiang Mai University, Chiang Mai, 50200 Thailand*
[b] *Center of Excellence in Materials Science and Technology, Chiang Mai University, Chiang Mai, 50200, Thailand*
[c] *School of Dentistry, Mae Fah Luang University, Chiang Rai, 57100, Thailand*
[d] *Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chiang Mai University, Chiang Mai, 50200 Thailand*
[e] *Aston Institute for Membrane Excellence, Aston University, Birmingham, B4 7ET, United Kingdom*
[f] *Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[g] *Multidisciplinary Research Institute, Chiang Mai University, Chiang Mai, 50200, Thailand*

* Corresponding: donraporn.d@cmu.ac.th

**Abstract**

Guided bone regeneration (GBR) is a standard strategy to promote bone regeneration around dental implants by blocking epithelial and connective tissue invasion into defect sites. Functionalization of barrier membranes with bioactive molecules has emerged as a promising approach to convert them from inert barriers into dynamic mediators of tissue regeneration. In this study, a biodegradable nanofibrous membrane incorporating tetracycline hydrochloride (TC) was developed to impart antimicrobial and anti-inflammatory properties. The membrane was fabricated by electrospinning a blend of poly(L-lactide-*co*-glycolide) (PLGA) and poly(ethylene oxide) (PEO), enabling precise control over fiber morphology to promote cell adhesion and proliferation. Adjusting polymer concentration and flow rate significantly influenced fiber diameter and surface characteristics. TC incorporation improved membrane hydrophilicity and effectively suppressed Streptococcus mutans growth. The release profile displayed a biphasic pattern, with an initial burst release followed by sustained release for up to 90 days. MTT assays demonstrated high cytocompatibility, with cell viability of 93.23±1.50% threshold for non-toxicity, and supported osteoblast proliferation. Although the mechanical strength was slightly lower in PEO-rich blends, the formulation maintained adequate mechanical properties for biomedical applications, offering soft yet resilient characteristics suitable for tissue scaffolding. The GBR membrane represents a promising formulation that exhibits high potential for dental application.

**Keywords:** poly(L-lactide-*co*-glycolide), poly(ethylene oxide), tetracycline, electrospinning, controlled release, bone regeneration barrier membranes

# Wavelength-Selective Macromolecular Reorganization and Chain Cleavage in Poly(lactide-*co*-ε-caprolactone) via Mid-Infrared Free-Electron Laser Irradiation

Jutamas Kongsuk[a,b], Nuttawut Khammata[a,b], Nuttawat Khammata[c,d], Hideaki Ohgaki[e], Heishun Zen[e], Sakhorn Rimjaem[c,d,f] and Winita Punyodom[a,b,g,*]

[a] *Department of Chemistry Faculty of Science Chiang Mai University, Chiang Mai 50200, Thailand*
[b] *Bioplastics Production Laboratory for Medical Applications, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[c] *PBP-CMU Electron Linac Laboratory, Plasma and Beam Physics Research Facility, Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[d] *Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[e] *Institute of Advanced Energy, Kyoto University, Kyoto, Gokasho, Uji, 611-0011 Japan*
[f] *Research Unit for Development and Utilization of Electron Linear Accelerator and Ultrafast Infrared/Terahertz Laser, Chiang Mai University, Chiang Mai, 50200, Thailand*
[g] *Center of Excellence in Materials Science and Technology, Chiang Mai University, Chiang Mai 50200, Thailand*

*Corresponding Author's E-mail: winita.punyodom@cmu.ac.th

**Abstract**

Achieving precise control over the microstructural evolution and macroscopic properties of biodegradable aliphatic polyesters remains a critical pursuit in advanced materials research. While conventional post-synthetic modification techniques, such as thermal annealing or indiscriminate gamma irradiation, often induce random bulk degradation, the demand for highly tailored structural matrices requires precision at the molecular level. In this study, we demonstrate a novel, solvent-free approach for the wavelength-selective photochemical tuning of medical-grade poly(L-lactide-co-ε-caprolactone) (PLC) copolymers utilizing a tunable mid-infrared free-electron laser (MIR-FEL). Melt-spun PLC filaments with varying initial comonomer feed ratios (60:40, 70:30, and 80:20 mole% of L-lactide to caprolactone) were subjected to narrow-band MIR-FEL pulses (~1% FWHM bandwidth). We systematically targeted specific vibrational modes within the polymer network, selectively exciting the C=O (5.8 μm) and C-O/C-OH (9.3 μm) stretching bands, and compared the microstructural consequences to those a non-resonant control (5.0 μm). Our structural analysis reveals that resonant vibrational excitation acts as a "molecular scalpel," inducing localized photochemical chain scission without widespread thermal damage. This targeted cleavage is evidenced by a pronounced reduction in inherent viscosity (e.g., from 1.13 dL/g to 0.94 dL/g at 9.3 μm). Crucially, this localized macromolecular degradation facilitates enhanced chain mobility, triggering significant thermodynamic reorganization and scission-induced crystallization. Differential scanning calorimetry (DSC) confirmed a marked increase in crystallinity, notably from 23.9% to 33.7% following 5.8 μm irradiation in the 71:29 composition. Consequently, these microstructural transformations dictate a predictable macroscopic mechanical embrittlement, characterized by drastically reduced elongation at break. This work establishes bond-selective MIR-FEL irradiation as a powerful, precision manufacturing pathway to program the structural integrity, crystallization kinetics, and degradation profiles of copolymer networks, opening new avenues in the design of customizable bio-based materials.

**Keywords:** Poly(L-lactide-co-ε-caprolactone), Mid-infrared free-electron laser (MIR-FEL), Vibrational excitation, Degradation-induced crystallization

# Sustainable Polymeric Biomaterials with Enhanced Mucoadhesion: Chitosan-Coated PLGA Nanoparticles towards Brain-Targeted Cannabidiol Delivery

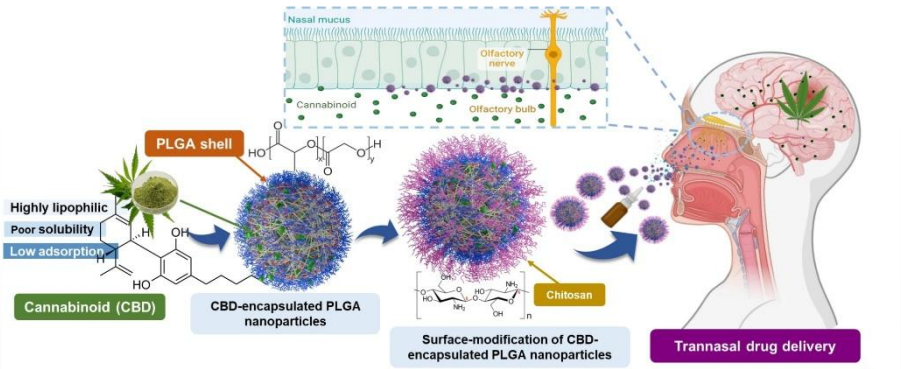
Sumontha Ramangkoon[a,b], Brian J. Tighe[c], Matthew J. Derry[c], Jutamas Jiaranaikulwanitch[d], Puttinan Meepowpan[a,b], Donraporn Daranarong[b,e], Paul D. Topham[c], Winita Punyodom [a,b,*]

[a] *Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[b] *Bioplastic Production Laboratory for Medical Application, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thaila nd*
[c] *Aston Institute for Membrane Excellence, Aston University, Birmingham, B4 7ET, United Kingdom*
[d] *Department of Pharmaceutical Sciences, Faculty of Pharmacy, Chiang Mai University, Chiang Mai 50200, Thailand*
[e] *Multidisciplinary Research Institute, Chiang Mai University, Chiang Mai 50200, Thailand*

**Corresponding author: winitacmu@gmail.com*

## Abstract

The development of sustainable polymeric biomaterials with tailored interfacial functionality is essential for advancing next-generation biomedical delivery systems. In this study, chitosan-coated poly(D,L-lactide-*co*-glycolide) (PLGA) nanoparticles, biodegradable and biocompatible polymers derived from renewable and bio-based sources, were engineered as a mucoadhesive nanocarrier platform for the delivery of cannabidiol (CBD), a bioactive compound derived from *Cannabis sativa L.* with promising therapeutic potential but limited by poor aqueous solubility and low bioavailability. A CBD-rich extract was sustainably obtained from hemp leaves via ethanol maceration, exhibiting high phenolic content and notable antioxidant activity. The extract was encapsulated into PLGA nanoparticles using a single emulsion-solvent evaporation method, followed by chitosan surface functionalization to modulate surface charge and interfacial properties. The optimized nanoparticles exhibited particle sizes below 200 nm, high encapsulation efficiency (~98%), and sustained release behavior governed by diffusion-controlled and first-order kinetics. Chitosan coating introduced a positive surface charge, enhancing mucoadhesion through electrostatic interactions with mucin and prolonging mucosal residence time. This structure-property relationship contributed to improved functional performance of the nanocarrier system. The nanoparticles demonstrated good biocompatibility in HT-29 cells while preserving the antioxidant and anti-inflammatory activities of CBD. Notably, enhanced anti-amyloidogenic activity was observed, indicating potential for neurodegenerative disease applications. Overall, this work presents a sustainable and scalable strategy for designing polymeric biomaterials with tunable surface functionality and controlled release characteristics. The developed system highlights the potential of mucoadhesive polymeric nanocarriers for advanced mucosal and brain-targeted delivery, supporting future biomedical and medical device-related applications.




**Keywords:** Sustainable polymeric biomaterials; PLGA nanoparticles; chitosan functionalization; mucoadhesion; controlled release; cannabidiol

# Formulation and Optimization of Curcumin-Loaded PDLGA Nanoparticles with Cationic Surface Functionalization for Enhanced Cartilage Targeting

Panta Pairsomran[a,b], Paveena Tikakosol[a], Chawan Manaspon[c], Winita Punyodom[a,b,d,e*]

[a]*Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[b]*Center of Excellence for Innovation in Chemistry (PERCH-CIC), Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[c]*Biomedical Engineering Institute, Chiang Mai University, Chiang Mai 50200, Thailand*
[d]*Bioplastics Production Laboratory for Medical Applications, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[e]*Materials Science Research Center, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*

*E-mail: winita.punyodom@cmu.ac.th

**Abstract**

Curcumin has strong anti-inflammatory activity, but its clinical use is limited by poor water solubility, low stability, and low bioavailability. To overcome these limitations, curcumin was encapsulated in poly(D,L-lactide-co-glycolide) (PDLGA, 75:25 molar ratio) nanoparticles. However, PDLGA nanoparticles carry a negative surface charge, which limits their interaction with negatively charged cartilage tissue. Surface modification with trimethyl chitosan (TMC), a hydrophilic cationic polymer, will introduce a positive surface charge and enhance intra-articular retention and cartilage targeting. In this study, curcumin-loaded PDLGA (Cur-PDLGA) nanoparticles were prepared using a single-emulsion solvent evaporation method. Key formulation parameters were systematically investigated, including polymer and drug concentrations, surfactant type and concentration, and sonication time. Their effects on particle size, polydispersity index (PDI), and morphology were evaluated. The results confirm that these parameters strongly influence nanoparticle properties. The optimized formulation, consisting of 2% (w/v) PDLGA and 0.5% (w/v) polyvinyl alcohol (PVA) with 5 minutes of sonication, produced nanoparticles with an average size of approximately 190 nm and a PDI of 0.5–0.6. These findings establish a robust and reproducible core nanoparticle system. The optimized Cur-PDLGA nanoparticles will enable effective TMC coating, resulting in positively charged nanoparticles and improved cartilage-targeted drug delivery for osteoarthritis treatment.

**Keywords:** Curcumin, Nanoparticles, Drug delivery, Poly(D,L-lactide-co-glycolide), Osteoarthritis

# Tailoring Electrospun PCL/PEO Fiber Morphology for 3D-Printed Composite Scaffolds in Parietal Bone Repair

Chanathip Pathit[a] , Manasanan Namhongsa[b,c], Tanyaluck Mekpothi[d], Tawan Chaiwon[d], Winita Punyodom [a,b,c*]

[a]*Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai, 50200 Thailand*
[b] *Bioplastics Production Laboratory for Medical Applications, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[c] *Center of Excellence in Materials Science and Technology, Chiang Mai University, Chiang Mai 50200, Thailand*
[d] *Office of Research Administration, Chiang Mai University, Chiang Mai 50200, Thailand*

*Corresponding Author's E-mail: winitacmu@gmail.com

**Abstract**

Chronic subdural hematoma (cSDH) is a common neurosurgical condition, particularly in elderly patients. Burr-hole trepanation is commonly performed for hematoma evacuation; however, the absence of suitable burr-hole covers often leads to postoperative scalp depression. This study aims to develop a biodegradable bi-layer scaffold for effective burr-hole defect coverage. A 3D-printed poly(ε-caprolactone) (PCL) scaffold was combined with electrospun membranes to form a functional bilayer system. To overcome the inherent hydrophobicity and slow degradation rate of PCL, it was blended with hydrophilic poly(ethylene oxide) (PEO) at various ratios (95:5, 90:10, 80:20, 70:30, 60:40, and 50:50 %w/w) and fabricated via electrospinning using a dichloromethane (DCM)/N,N-dimethylformamide (DMF) solvent system (7:3) as the first layer. Electrospinning conditions, including polymer concentration (6–14% w/v) and applied voltage (15–20 kV), were optimized to achieve uniform fiber morphology and well-controlled fiber diameters. The results showed that the optimal electrospinning condition was achieved at 20 kV, with polymer concentrations of 8, 10, 8, 8, 8, and 12% w/v for the respective PCL/PEO ratios. These conditions produced uniform fibers with diameters ranging from 0.360 ± 0.120 to 1.081 ± 0.238 µm, while pore sizes ranged from 0.237 ± 0.761 to 0.735 ± 1.66 µm. These findings demonstrate that polymer ratio and concentration significantly influence fiber morphology and pore structure, thereby affecting hydrolytic degradation, inflammatory response, and cell infiltration. Overall, this study supports the development of biodegradable and biocompatible materials to enhance postoperative recovery and improve cosmetic outcomes in the treatment of chronic subdural hematoma (cSDH).

**Keywords:** Burr-hole implant, Electrospinning, 3D printing, and Poly(ethylene oxide) (PEO)

# Bio-based Biodegradable Films with Spent Coffee Ground Extract for Light-Protective Pharmaceutical Packaging

Kanyanat Chaiyasat[a,b*], Sumontha Ramangkoon[a,b], Patnarin Worajittiphon[a,b], Puttinan Meepowpan[a,b], Paul D. Topham[c], Winita Punyodom[a,b]

[a]*Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[b]*Bioplastic Production Laboratory for Medical Application, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[c]*Aston Institute for Membrane Excellence, College of Engineering and Physical Sciences, Aston University, Birmingham, B4 7ET, United Kingdom*

*Corresponding Author's E-mail: winitacmu@gmail.com

**Abstract**

The extensive use of petrochemical-based packaging in the pharmaceutical industry raises environmental concerns because these materials are derived from non-renewable resources and are typically non-biodegradable and can be difficult to recycle after use. Poly(lactic acid) (PLA) has emerged as a promising sustainable alternative due to its biodegradability and renewable origin; however, its application is often limited by inherent brittleness and relatively poor barrier properties. Spent coffee grounds (SCG), an abundant agro-industrial waste rich in polyphenolic compounds, have been used in this study to enhance the UV light-protective and antioxidant properties of biodegradable PLA-based films. In addition, SCG extracts may act as natural plasticizers, improving film ductility and interfacial compatibility. A simple and efficient extraction method has been used to obtain phenolic-rich antioxidant compounds directly from SCG. The ethanol extract of SCG was incorporated into PLA-based films, and processing parameters were systematically investigated to optimize film performance. The developed films were evaluated for their physical and mechanical properties, barrier characteristics, and antioxidant activity. Resulting PLA-SCG films exhibited excellent light-shielding performance, with less than 10% spectral transmission in the 290-450 nm range. These films demonstrate improved functional performance and enhanced suitability for pharmaceutical packaging applications. Overall, this study supports the development of biodegradable films incorporating natural compounds to enhance functionality, particularly in protecting active pharmaceutical ingredients (APIs) from light-induced degradation and oxidation The results highlight the potential of PLA-SCG films for pharmaceutical packaging applications such as biodegradable opaque drug pouches that provide effective light protection. Moreover, the utilization of spent coffee grounds contributes to the valorization of an abundant agro-industrial waste, promoting resource efficiency and supporting circular economy principles while reducing plastic waste from single-use pharmaceutical packaging.

**Keywords:** Poly(lactic acid) (PLA); Spent coffee ground extract; Biodegradable films; Antioxidant activity; Light-protective pharmaceutical packaging

# Thermoresponsive Chitosan with Biomolecular Recognition: A Simple Platform for Low-Temperature Single-Phase Antigen Extraction

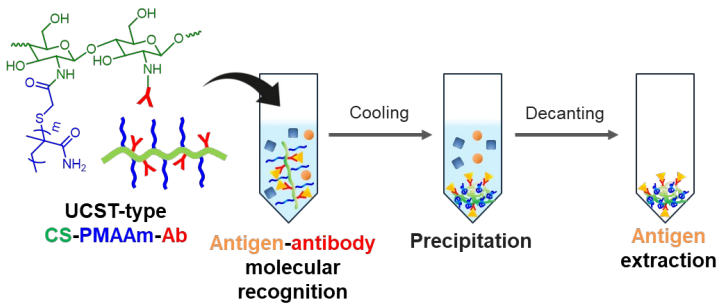
Thanit Kertsomboon[a], Chahya Kreangkaiwal[b], Kanitha Patarakul[b], Suwabun Chirachanchai[a,*]

[a]*Center of Excellence in Bioresources to Advanced Materials (B2A-CE), The Petroleum and Petrochemical College, Chulalongkorn University, Bangkok 10330, Thailand*
[b]*Department of Microbiology, Faculty of Medicine, Chulalongkorn University, Bangkok 10330, Thailand*

*Corresponding Author's E-mail: Suwabun.c@chula.ac.th

**Abstract**

Upper critical solution temperature (UCST) polymers display thermoresponsive behavior, remaining soluble above a critical temperature and undergoing phase separation upon cooling. This feature provides an approach for handling biomolecules under mild conditions, although achieving both reliable UCST performance and biofunctionality remains challenging. In this study, a water-based strategy is developed to fabricate antibody (Ab)-functionalized UCST biopolymers using chitosan (CS) as a reactive polysaccharide backbone. UCST-type poly(methacrylamide) (PMAAm) containing a terminal carboxyl group can be prepared via radical polymerization employing mercaptoacetic acid as a chain transfer agent. Subsequent carbodiimide coupling enables efficient conjugation of PMAAm and Ab onto CS under aqueous system, producing CS-PMAAm-Ab. The resulting product exhibits tunable UCST behavior in pure water, dependent on both composition and concentration, with cloud points ranging from 10 to 30 ˚C. Notably, CS-PMAAm-Ab selectively recognizes recombinant LipL32 antigen through antigen-antibody interactions. Cooling below the UCST (e.g., 4 °C) induces aggregation and precipitation of polymer-antigen complexes, enabling a simple single-phase extraction without additional processing steps. This work presents a biocompatible UCST platform integrating thermoresponsive behavior and molecular recognition for efficient and selective biomolecule extraction.




**Keywords:** chitosan, single-phase extraction, thermoresponsive, UCST, antigen

# Antimicrobial thermoplastic cassava starch composite with chlorhexidine gluconate and titanium dioxide nanoparticles

Araya Kodsangma[a], Pornchai Rachtanapun[a,b,d,e], Winita Punyodom[a,c,d], Pensak Jantrawut[d,f], Patnarin Worajittiphon[a,c,d], Sarinthip Thanakkasaranee[b,d], Nuttapol Tanadchangsaeng[g], Kittisak Jantanasakulwong[a,b,d,e*]

[a] *Nanoscience and Nanotechnology (International Program/Interdisciplinary), Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*

[b] *Faculty of Agro-Industry, Chiang Mai University 50100, Thailand,*

[c] *Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*

[d] *Center of Excellence in Materials Science and Technology, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand.*

[e] *Center of Excellence in Agro Bio-Circular-Green Industry (Agro BCG), Chiang Mai University, Chiang Mai 50100, Thailand.*

[f] *Department of Pharmaceutical Sciences, Faculty of Pharmacy, Chiang Mai University, Muang, Chiang Mai, 50200, Thailand.*

[g] *College of Biomedical Engineering, Rangsit University, Pathumthani, 12000, Thailand.*

*Correspondence to: Kittisak Jantanasakulwong Tel: +66 (0)53948274 Fax: +66 (0)53948230 (E-mail: kittisak.jan@cmu.ac.th)

**Abstract**

Reactive blending was used to prepare a novel thermoplastic starch (TPS) by melt mixing cassava starch with chlorhexidine gluconate (CHG) and titanium dioxide (TiO). TPS was melt-mixed with CHG (0.5, 1, 5, 10wt.%) and TiO (1 phr). Fourier-transform infrared spectra confirmed the reaction between the –OH groups of TPS and the –NH groups of CHG, with TiO acting as a catalyst. The tensile strength of the TPMS/CHG/TiO sample was highest for 1% CHG and decreased with further CHG addition. The TPS/CHG/TiO blend exhibited a smooth fracture surface with small TiO particles. Addition of 1% CHG increased the interfacial tension of the TPS/CHG/TiO samples owing to the optimal crosslinking density. CHG and TiO increased the thermal stability of TPS via the crosslinking reaction and exhibited antimicrobial behavior against *Streptococcus aureus*, *Escherichia coli* and *Aspergillus oryzae*. The reaction between the –OH groups of TPS and the –NH groups of CHG enabled by the TiO catalyst improved the mechanical, water-resistance, thermal, and antimicrobial properties of the composites. TPS/CHG/TiO composites have strong potential for application in packaging and biomaterials with high mechanical and antimicrobial properties, supporting sustainable agricultural, advancing sustainable industry, contributing to climate change mitigation, and aligning with evolving environmental regulations.

**Keywords:** Biopolymer, Thermoplastic starch, Nanometal, Chlorhexidine gluconate

# Biodegradable Thermo-responsive Hydrogels for Water Retention in Soil at Elevated Temperature

Sorapat Niyomsin[a,*], Pongsakorn Pandee[a], Suwabun Chirachanchai[a]

[a] *Center of Excellence in Bioresources to Advanced Materials (B2A-CE), The Petroleum and Petrochemical College, Chulalongkorn University, Bangkok 10330, Thailand*

*Corresponding Author's E-mail: Sorapat.N@chula.ac.th

**Abstract**

Biodegradable thermo-responsive hydrogels derived from cassava starch are potential for water-retention applications in agriculture. Starch hydrogels were first crosslinked with polyethylene glycol diglycidyl ether (PEGDGE) at different ratios to tune the network structure and mechanical properties. The optimized hydrogel was then methacrylated and subsequently grafted with poly(N-isopropylacrylamide) (PNIPAM) via free-radical polymerization to introduce temperature-responsive functionality. Dynamic mechanical analysis showed that all PEGDGE-crosslinked hydrogels exhibited storage modulus values higher than loss modulus values, confirming the formation of stable crosslinked networks, while the starch:PEGDGE ratio of 1:1 provided the most balanced mechanical and morphological properties. Fourier transform infrared spectroscopy confirmed successful methacrylation through the appearance of vinyl and ester carbonyl bands, and successful PNIPAM grafting through characteristic amide bands. PNIPAM incorporation significantly increased the swelling ratio from 933% for the pristine starch hydrogel to 2191–2476% for the grafted hydrogels, although the swelling behavior did not vary monotonically with NIPAM content. Water contact angle analysis showed that increasing NIPAM content enhanced the hydrophobicity of the hydrogel surface at 40 °C. In addition, PNIPAM-grafted starch hydrogel revealed delayed moisture loss at 40 °C compared with pristine starch hydrogel, consistent with the lower critical solution temperature behavior of PNIPAM. Overall, the developed PNIPAM-grafted starch hydrogel combines biodegradability, tunable wettability, and thermo-responsive water-release behavior, demonstrating promise as a smart hydrogel material for sustainable agricultural water management.

**Keywords:** Starch hydrogel, Thermoresponsive behavior, Moisture release, Smart hydrogel, Sustainable agriculture

# Functionalization of Silk Sericin for Biomedical Application

Witchaya Phasayavan[a], Gareth M Ross[a], Jirapas Jongjitwimol[c], Thanyaporn Pinthong[a], Sararat Mahasaranon[a], Pensri Charoensit[b], Jarupa Viyoch[b], Paul D Topham[d], Brian J Tighe[d], Sukunya Ross[a,*]

[a]*Biopolymer Group, Center of Excellence in Biomaterials, Department of Chemistry, Faculty of Science, Naresuan University, Phitsanulok 65000, Thailand*
[b]*Department of Pharmaceutical Technology, Faculty of Pharmaceutical Sciences and Center of Excellence for Innovation in Chemistry, Naresuan University, Phitsanulok 65000, Thailand*
[c]*Department of Medical Technology, Faculty of Allied Health Sciences, Naresuan University, Phitsanulok 65000, Thailand*
[d]*Aston Institute for Membrane Excellence, Aston University, Birmingham, B4 7ET, United Kingdom*

*Corresponding author. E-mail address: sukunyaj@nu.ac.th.

**Abstract**

Among naturally derived biopolymers, silk sericin (SS) has transitioned from an undervalued silk-processing residue to a value-added biomaterial, due to its biocompatibility and reactive chemical structure. Recent studies have demonstrated that chemical modification of SS can introduce beneficial properties, including enhanced hydrophilicity, antibacterial activity, and antioxidant capacity, thereby broadening its utility in modern biomaterial applications. This work synthesizes current advances in the chemical functionalization of SS, focusing on the role of key functional groups, including hydroxyl, carboxyl, and amine groups, as reactive sites for molecular modification. By consolidating different functionalization approaches such as methacrylation, acrylation, hydrazide functionalization, and carboxylation, we demonstrate how these strategies significantly tune the structural and physicochemical properties of SS. Notably, these modifications introduce additional crosslinking sites within the SS backbone, reducing the reliance on external crosslinkers during material fabrication and improving the overall network integrity. Furthermore, the development of functionalized SS into biomaterial platforms for drug delivery, tissue engineering, and wound healing is consolidated and presented. Together, these findings identify functionalized SS as a versatile and programmable biopolymer platform for next-generation biomedical applications.

**Keywords:** Silk sericin, Biopolymers, Chemical modification, Tissue engineering

# Visible-light-crosslinkable zwitterionic quaternized chitosan-based hydrogel coating with dual antibacterial and antifouling properties

Petchgaw Kanjanawattana[a] and Panya Sunintaboon[a*]

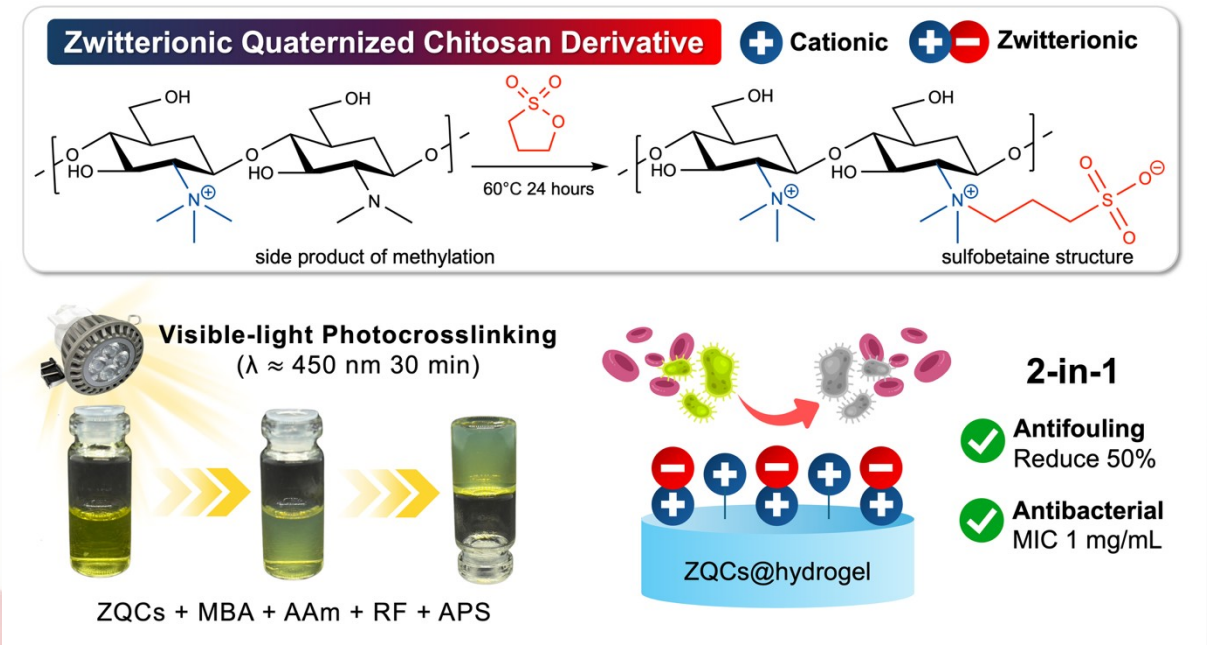
[a]*Department of Chemistry, Faculty of Science, Mahidol University, Bangkok 10400, Thailand*

*Corresponding Author's E-mail: panya.sun@mahidol.ac.th

**Abstract**

Medical device-associated infections remain a critical clinical burden, driving demand for advanced surface engineering strategies. This work presents the design and characterization of a zwitterionic quaternized chitosan-based hydrogel (ZQCs@hydrogel) as a multifunctional surface-coating platform, having combined antibacterial and antifouling properties. Quaternized chitosan (QCs) was synthesized through a methylation route, introducing quaternary ammonium groups and retaining residual $3^0$-amine functionalities along the polymer backbone. Subsequent ring-opening sulfonation incorporated sulfobetaine moieties, yielding a zwitterionic structure (ZQCs) containing both cationic and anionic domains within a polymer chain. Structural characterization was performed using FTIR, $^1$H-NMR, and HSQC spectroscopy. Hydrogel fabrication was achieved *via* visible-light-initiated photopolymerization under optimized conditions, employing ZQCs, *N*,*N'*-methylenebisacrylamide (MBA), acrylamide (AAm), riboflavin (RF), and ammonium persulfate (APS) as precursors. The residual $3^0$-amines, in conjunction with the photoinitiator system, are proposed to facilitate free radical generation under irradiation. However, the precise mechanistic pathway requires further investigation. The resulting hydrogel exhibited broad-spectrum antibacterial activity against *S. aureus* and *P. aeruginosa* at a minimum inhibitory concentration (MIC) of 1 mg/mL, along with a 50% reduction in bovine serum albumin adsorption. ZQCs@hydrogel also demonstrated strong adhesion to various hydrophilic surfaces, including glass, ceramic, and metal, underscoring its versatility as a coating material. Additionally, the coatings were stable for up to 14 days in phosphate buffer saline pH 7.4, indicating their durability in physiologically relevant environments. Collectively, these findings establish ZQCs@hydrogel as a promising dual-functional coating candidate, e.g. for blood-contacting medical device applications.

**Keywords:** Zwitterionic, Quaternized chitosan, Hydrogel, Antibacterial, Antifouling



# Silylated Bacterial Nanocellulose Aerogel via Chemical Vapor Deposition for Controlled-Release Cleaning in Painting Conservation

Norman Verschueren[a,d], Pichayada Katemake[b,d], Ochana Poonthongdeewatthana[c], Kamonwan Pacaphol[a,b,e*]

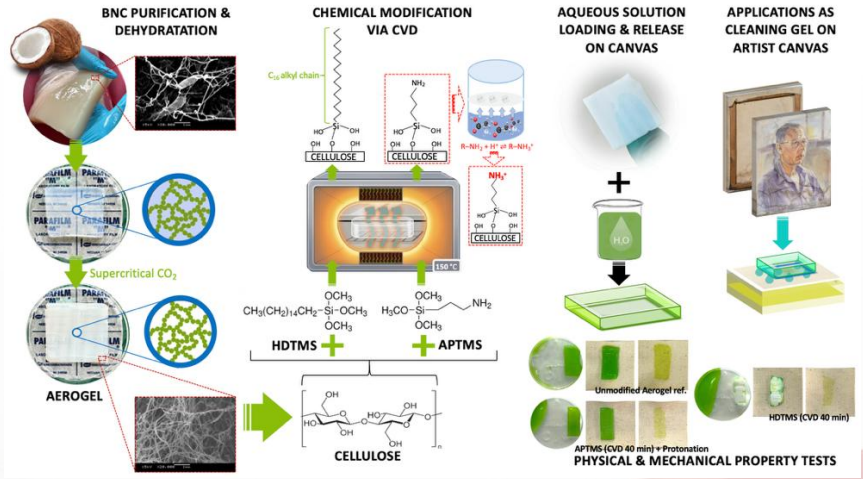
[a]*Science for Industry Program, Faculty of Science, Chulalongkorn University, Bangkok, Thailand.*
[b]*Department of Imaging and Printing Technology, Faculty of Science, Chulalongkorn University, Bangkok, Thailand.*
[c]*Department of Art Theory, Faculty of Painting Sculpture and Graphic Arts, Silpakorn University, Bangkok, Thailand.*
[d]*Science Conservation Centre for Art (SCICCA), Faculty of Science, Chulalongkorn University, Bangkok, Thailand.*
[e]*Center of Excellence in Responsive Wearable Materials, Chulalongkorn University, Bangkok, Thailand.*

[*]Corresponding Author E-mail: kamonwan.p@chula.ac.th

**Abstract**

In painting conservation, hydrogels used for cleaning require precise control of aqueous solution delivery to minimize tideline formation, surface swelling, physicochemical interactions with the substrate, and residue deposition. Conventional cleaning gels such as agarose, agar, and low-acyl gellan gum exhibit large pore structures and weakly bound water, limiting controlled release. Moreover, their low mechanical strength increases the risk of residue deposition on painting surfaces. This study developed functionalized bacterial nanocellulose (BNC) aerogels via chemical vapor deposition (CVD) using hexadecyltrimethoxysilane (HDTMS) and 3-aminopropyltrimethoxysilane (APTMS). BNC aerogels were biosynthesized by nonpathogenic bacteria cultured in coconut water, followed by purification and supercritical $CO_2$ drying. Silylation was performed in a closed system via CVD at 150 °C by varying silane concentrations (5-100 µL) and reaction times (10-40 min). For APTMS, protonation of the aerogels was investigated as an additional variable by varying exposure times (6-24 h) under acetic acid vapor at 30 °C and 70% RH to evaluate the effect of different $–NH_2$ to $–NH_3^+$ conversion levels on controlled-release performance. Water uptake after solution loading into the aerogels and subsequent release tests on artist cotton canvas showed that HDTMS-treated samples exhibited excessive hydrophobicity, reduced absorption, and decreased softness and flexibility of the hydrogels. In contrast, protonated APTMS-treated samples (CVD at 50 µL for 40 min) enabled a slower and more controlled release on the canvas, reducing solution release by approximately 52% compared with the untreated gel. The morphology of the treated aerogels was examined by SEM, while surface functionalization was characterized by ATR-FTIR and XPS. Rheological and mechanical properties of the resulting hydrogels, measured using a cone-plate rheometer, indicated optimized viscoelastic behavior for cleaning applications. Overall, silylated BNC aerogels prepared via APTMS vapor deposition followed by mild acid protonation improved controlled-release cleaning performance, demonstrating their potential as bio-based cleaning materials for painting conservation.

**Keywords:** bacterial nanocellulose, aerogels, chemical vapor deposition, silylation, painting conservation.



# Biodegradable Polymer–Ceramic Composite Scaffolds for Bone Tissue Engineering through Mechanical Design, Surface Engineering, and Stem Cell Response

Sonthikan Sitthisang[a]*, Xunan Hou[b], Udom Sae-Ueng[c], Chaobin He[b],[d] and Supansa Yodmuang[e]

[a]*Metallurgy and Materials Science Research Institute, Chulalongkorn University, Bangkok 10330, Thailand*
[b]*Department of Materials Science and Engineering, National University of Singapore, Singapore 117575, Singapore*
[c]*National Center for Genetic Engineering and Biotechnology (BIOTEC), National Science and Technology Development Agency (NSTDA), Pathum Thani 12120, Thailand*
[d]*Institute of Materials Research and Engineering, Agency for Science, Technology, and Research (A*STAR), Innovis 138635, Singapore*
[e]*Research Affairs, Faculty of Medicine, Chulalongkorn University, Bangkok 10330, Thailand*

*Corresponding Author's E-mail: sonthikan.s@chula.ac.th

**Abstract**

Bone defects exceeding critical size remain a major clinical challenge, demanding implants that replicate the mechanical integrity, surface bioactivity, and osteoinductive capacity of native bone. This work presents a comprehensive approach to developing biodegradable polylactic acid (PLA)/hydroxyapatite (HA) composite scaffolds through three interconnected strategies: mechanical design, surface engineering, and evaluation of stem cell response. To address the mechanical limitations of biodegradable polymer systems, a compatibilization strategy was employed to enhance interfacial adhesion within the polymer matrix, significantly improving toughness without compromising stiffness or strength. HA particles were systematically incorporated and three-dimensionally printed into gyroid scaffold architectures, yielding compressive properties comparable to trabecular bone at physiologically relevant porosity. Surface engineering through controlled HA content was found to critically govern scaffold nanomechanical properties, with atomic force microscopy mapping revealing that 10% HA scaffolds exhibit a homogeneous Gaussian distribution of surface stiffness and adhesive force, in contrast to the heterogeneous bimodal properties of other formulations. These distinct surface characteristics translated directly into stem cell behavior: human mesenchymal stem cells seeded on optimized scaffolds demonstrated strong attachment, active spreading, and filopodia formation, followed by sustained proliferation over four weeks and robust osteogenic differentiation confirmed by elevated alkaline phosphatase activity and progressive calcium mineralization. Together, these findings establish a materials-to-biology design framework for next-generation biodegradable composite scaffolds in bone regeneration.

**Keywords:** Biodegradable scaffold, hydroxyapatite, 3D printing, stem cell differentiation, bone tissue engineering

# Designing Stimuli Responsive and Injectable Hydrogel Scaffolds for Tissue Engineering Applications

Pawitchaya Madech[a] , Nuttawut Khammata[a], Ain Us Saba[a], Doraporn Daranarong[b], Chawan Manaspon[c], Winita Punyodom[a] and Kiattikhun Manokruang[a*]

[a]*Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[b]*Center of Excellence in Materials Science and Technology and Multidisciplinary Research Institute, Chiang Mai University, Chiang Mai 50200, Thailand*
[c]*Biomedical Engineering and Innovation Research Center, Biomedical Engineering Institute, Faculty of Engineering and Center of Excellence in Materials Science and Technology, Chiang Mai University, Chiang Mai 50200, Thailand*

*Corresponding Author's E-mail: kiattikhun.m@cmu.ac.th

**Abstract**

Injectable hydrogels are alternative materials to the conventional and pre-formed hydrogels that need surgical operation for implantation. *In situ* forming hydrogels offer minimally invasive scaffolds for musculoskeletal tissue repair. We report the synthesis and characterization of an injectable graft copolymer hydrogel combining carboxymethyl cellulose (CMC) and methoxy poly(ethylene glycol)-*block*-poly(ε-caprolactone) (mPEG-*b*-PCL). The resulting polymeric system, CMC-*g*-(mPEG-*b*-PCL), integrated CMC biocompatibility, PEG responsiveness, and PCL mechanical robustness and degradability. Hydrogels were formulated in aqueous media, and among the compositions tested, 32 wt% CMC-g-($mPEG_{17}$-b-$PCL_{12}$) exhibited optimal sol–gel phase transition, as determined by the test tube inversion method. In addition, rheological studies also showed the phase transition from the flowable sol state to the stable gel under physiological conditions, with storage moduli aligning well within the range of early-stage cartilage. Scanning electron microscopic images revealed an intrinsic porous structure, which is suitable for cell infiltration and nutrient transport. In vitro cytocompatibility was evaluated using L929 fibroblasts and MG63 osteoblast-like cells through MTT and live/dead assays. The results indicated stable cell viability and preserved morphology over 5 days of consecutive incubation. Overall, these findings highlight the potential of CMC-g-(mPEG-*b*-PCL) hydrogels as injectable scaffolds for bone and cartilage tissue engineering applications.

**Keywords:** Carboxy methylcellulose, Stimuli-responsive, Scaffold, Injectable hydrogel, articular cartilage

# Synergistic Reinforcement of Chitin Nanofibers in Chitosan Films: Enhancing Properties for Food Packaging

Supachok Tanpichai[a,*], Anyaporn Boonmahitthisud[b]

[a]*Learning Institute, King Mongkut's University of Technology Thonburi, Bangkok, Thailand.*
[b]*Department of Materials Science, Faculty of Science, Chulalongkorn University, Bangkok, Thailand.*

*Corresponding Author's E-mail: supachok.tan@kmutt.ac.th

**Abstract**

Petroleum-based polymers are widely used in food packaging; however, their persistence presents severe environmental challenges, including plastic waste accumulation and microplastic pollution. Furthermore, geopolitical instabilities have increasingly disrupted petrochemical supply chains. Consequently, biodegradable polymers have emerged as a promising solution. In this study, chitin nanofibers (ChNFs) derived from shrimp shell waste were incorporated into a chitosan matrix to develop high-performance films. The introduction of ChNFs significantly enhanced both mechanical and barrier properties of the chitosan-based films, attributed to the high intrinsic stiffness of ChNFs and strong interfacial interactions with the chitosan matrix. The films containing 25 wt% ChNFs exhibited a tensile strength of 113.7 ± 6.1 MPa and a Young's modulus of 4.15 ± 0.20 GPa. Increasing ChNF loading to 50 wt% further improved these values to 119.8 ± 7.3 MPa and 4.85 ± 0.60 GPa, respectively, compared to neat chitosan films with a tensile strength of 61.3 ± 8.7 MPa and Young's modulus of 2.16 ± 0.61 GPa. Moreover, the ChNFs created a tortuous diffusion pathway that effectively hindered the transport of water and oxygen molecules. This resulted in a significant reduction in water vapor permeability (WVP) and oxygen transmission rates (OTR). At 50 wt% ChNF loading, the WVP and OTR decreased by 16.2% and 41.1%, respectively. Although the WVP of the 50 wt% ChNF composite film remained higher than that of conventional plastics, its OTR was considerably lower than that of polypropylene and poly(ethylene terephthalate). Overall, this study demonstrates that ChNF-reinforced chitosan films provide a sustainable and high-performance alternative to petroleum-based materials for food packaging.

**Keywords:** Chitosan, Chitin nanofibers, Food packaging, Biodegradable material

# Modified screen-printed electrodes for heavy metal determination in environmental samples

Pattanun Ngaosri, Watchara Suphap, Johannes Philipp Mensing, Chanpen Karuwan*

[a] *Graphene Research Team (GRP), National Nanotechnology Center (NANOTEC), National Science and Technology Development Agency (NSTDA), Phahonyothin Road, Khlong Nueng, Khlong Luang, Pathum Thani, 12120, Thailand*

*Corresponding Author's E-mail: chanpen.kar@nanotec.or.th

**Abstract**

Heavy metal contamination in environmental waters and seafood remains a critical concern due to its persistence, bioaccumulation, and toxicity to human health. A disposable electrochemical sensor based on modified screen-printed electrodes (SPEs) was developed for the simultaneous detection of Cd(II), Pb(II), Cu(II), and Hg(II) using square-wave voltammetry (SWV). Screen-printed electrodes offer several advantages, including low cost, simple fabrication, and suitability for portable and on-site analysis. Carbon derived from biochar was employed as a functional carbon material due to its porous structure and favorable electrical conductivity. The biochar-derived carbon was mixed with carbon ink and screen-printed onto carbon electrodes to fabricate the sensing platform. The incorporation of biochar-derived carbon enhanced the electroactive surface area and facilitated electron transfer, resulting in improved electrochemical performance toward heavy metal ion detection. The modified electrode enabled simultaneous stripping responses with high sensitivity, wide linear response ranges, and low detection limits for all target ions. The sensor exhibited good repeatability and reproducibility with relative standard deviations (RSDs) below 5%. The analytical performance was further evaluated using environmental water and seafood samples. The developed disposable sensor provides a sustainable and cost-effective approach for heavy metal monitoring in environmental and food samples while promoting the utilization of biochar-based carbon materials.

**Keywords:** Screen-printed electrodes, Carbon-based materials, Heavy metal detection, Electrochemical Sensor, Simultaneous detection

# A portable electrochemical immunosensing of citrullinated histone H3 using screen-printed graphene electrodes

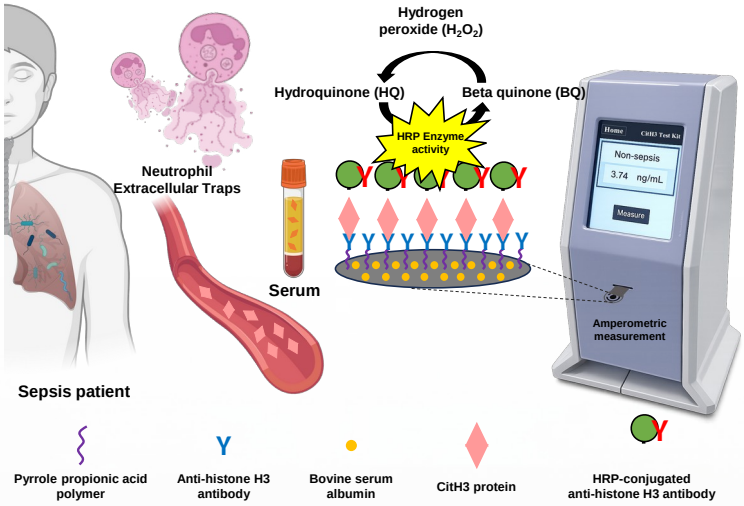
Vitsarut Primpray[a], Wichayaporn Kamsong[a], Assawapong Sappat[a], Anurat Wisitsoraat[a], Awirut Charoensappakit[b,c], Asada Leelahavanichkul[c], Chanpen Karuwan[a,*]

[a]*National Nanotechnology Center (NANOTEC), National Science and Technology Development Agency (NSTDA), Pathum Thani 12120, Thailand*
[b]*Department of Clinical Microscopy, Faculty of Allied Health Sciences, Chulalongkorn University, Bangkok 10330, Thailand*
[c]*Center of Excellence on Translational Research in Inflammation and Immunology (CETRII), Bangkok, Thailand*
*Department of Microbiology, Faculty of Medicine, Chulalongkorn University, Bangkok, 10330, Thailand*

*Corresponding Author's E-mail: chanpen.kar@nanotec.or.th

**Abstract**

Early and reliable detection of sepsis is critical for timely clinical intervention; however, currently available biomarkers often lack sufficient specificity and rapid response for effective point-of-care testing (POCT). Citrullinated histone H3 (CitH3), a neutrophil extracellular trap–associated biomarker, rises rapidly following infection and is a promising indicator for early sepsis diagnosis. This work reports the development of a portable graphene-based enzymatic electrochemical immunosensor for CitH3 detection in serum. The sensor was fabricated using a screen-printed graphene electrode (SPGE) on a polyethylene terephthalate substrate and functionalized with electrochemically polymerized poly(pyrrolepropionic acid) for stable covalent immobilization of anti-CitH3 capture antibodies. CitH3 detection was performed via a sandwich immunoassay employing a horseradish peroxidase–conjugated anti-histone H3 detection antibody, with amperometric signal transduction using a hydroquinone/hydrogen peroxide redox system. The immunosensor was integrated with a portable potentiostat, enabling on-site qualitative and quantitative signal readout. The developed device exhibited a linear detection range of 100–1000 pg/mL, with a limit of detection of 42.83 pg/mL and a limit of quantification of 100.89 pg/mL, demonstrating higher sensitivity than conventional ELISA. Validation using serum samples (n = 15) showed strong agreement with ELISA results, with a correlation coefficient of 0.9868. The proposed platform demonstrates potential for portable POCT applications in early sepsis assessment and monitoring of NETs-related inflammatory conditions.




**Keywords:** Citrullinated histone H3, Sepsis, Electrochemical immunosensor, Screen-printed electrode, Graphene

# Signal-off electrochemical detection of glutathione based on competitive chloride–thiol coordination at copper-functionalized MIL-100(Fe)

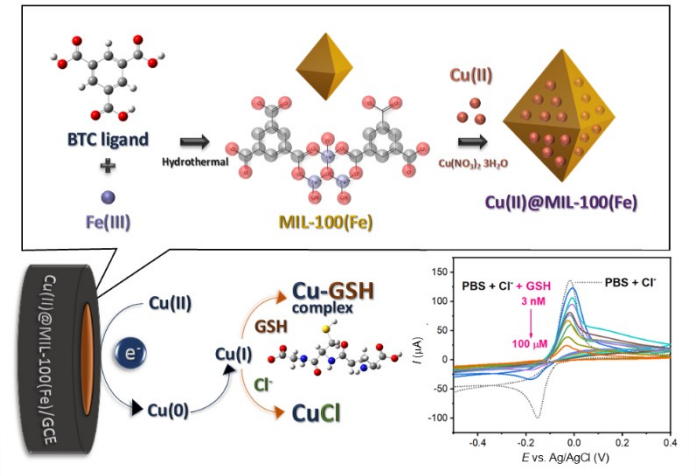
Chanida Jakkrawhad[a], Christopher Batchelor-McAuley[b], Supinya Nijpanich[c], Kamonwad Ngamchuea [a,*]

[a]*School of Chemistry, Institute of Science, Suranaree University of Technology, Muang, Nakhon Ratchasima, 30000, Thailand.*
[b]*School of Chemistry, University of Dublin, Trinity College Dublin, Dublin, Ireland.*
[c]*Synchrotron Light Research Institute, Suranaree, Muang, Nakhon Ratchasima 30000, Thailand.*

*Corresponding Author's E-mail: kamonwad@sut.ac.th

**Abstract**

L-Glutathione (GSH) is a vital antioxidant, and its concentration in biological fluids is a key indicator of oxidative stress and various pathological conditions. In this work, we report a novel "signal-off" electrochemical sensor for the detection of GSH based on a glassy carbon electrode (GCE) modified with a copper-functionalized iron-based metal-organic framework (Cu(II)@MIL-100(Fe)). The sensing material was synthesized and thoroughly characterized by SEM-EDS, PXRD, FTIR, and XPS, which confirmed the successful incorporation of copper into the MOF structure. The sensing mechanism relies on the competitive coordination between chloride ions and GSH with copper ions at the electrode surface. In a chloride-rich system (80 mM, in PBS buffer pH 6.5), the material exhibits a strong, stable electrochemical signal. The introduction of GSH leads to a measurable decrease in this signal, as the thiol group of GSH preferentially binds to the copper centers due to the formation of a highly stable Cu-GSH complex. This concentration-dependent signal suppression allows for the sensitive quantification of GSH. Under optimized conditions, the sensor demonstrated excellent analytical performance, exhibiting a wide linear detection range from 3 nM to 100 µM with a low limit of detection of 0.2 nM. The sensor also displayed high selectivity for GSH against a variety of common biological interferents. Furthermore, its practical utility was successfully validated through the analysis of supplementary products and human blood serum samples, yielding excellent recovery rates and demonstrating its potential as a robust platform for clinical diagnostics.




**Keywords:** L-Glutathione; Electrochemical Sensor; MOFs; Copper-based materials; GCE

# CuO and $CeO_2$ Functionalized PLA-Derived Polyurethane/MXene Networks for Flexible Non-Enzymatic Glucose Sensing Platforms

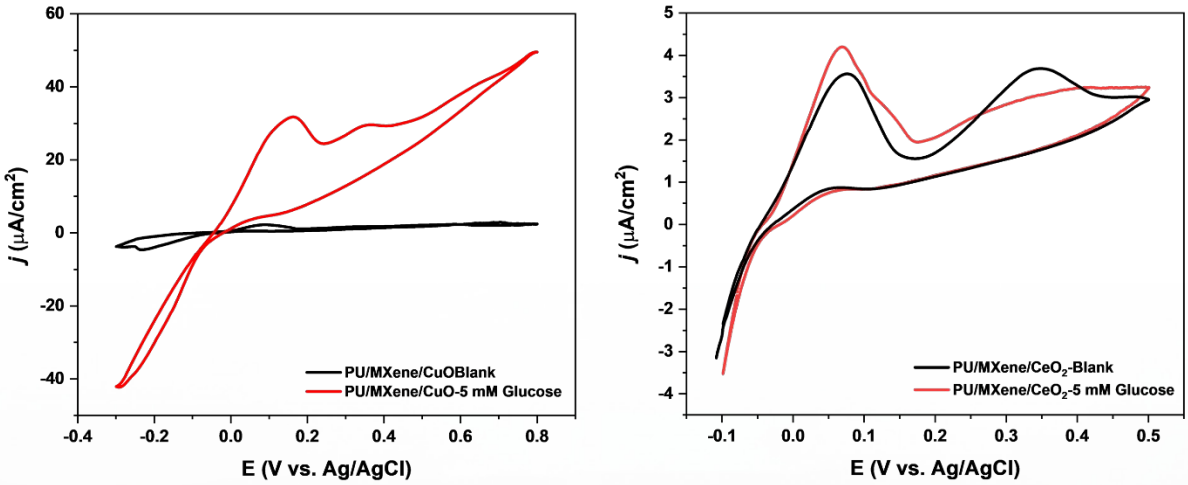
Oceu Dwi Putri[a,b], Atitsa Petchsuk[c], Pakorn Opaprakasit[b,*], Kazuaki Matsumura[a,*]

[a]*School of Materials Science, Japan Advanced Institute of Science and Technology (JAIST), Nomi-shi, Ishikawa 923-1292, Japan,*
[b]*School of Integrated Science and Innovation, Sirindhorn International Institute of Technology (SIIT), Thammasat University, Pathum Thani 12120, Thailand,*
[c]*National Metal and Materials Technology Center, Thailand Science Park, Pathum Thani 12120, Thailand*

*Corresponding Author's E-mail: pakorn@siit.tu.ac.th, mkazuaki@jaist.ac.jp

**Abstract**

The development of flexible, non-enzymatic wearable biosensors is often hindered by the poor mechanical durability of traditional conductive substrates and the severe environmental impact of sensor-derived e-waste. In this study, we present a sustainable electrochemical glucose sensor utilizing an upcycled polylactic acid (PLA)-derived polyurethane (PU) flexible substrate. A highly conductive MXene network was integrated into the PU matrix and functionalized with transition metal oxide nanoparticles (CuO and $CeO_2$) to evaluate and compare their catalytic performances. Initial cyclic voltammetry evaluations revealed distinct, advantageous electrochemical behaviors for both catalyst systems. Importantly, both composites showed a direct increase in peak current as glucose concentrations increased, proving their catalytic effectiveness across physiological blood glucose ranges. Notably, while the CuO-modified composite exhibited a strong current response at higher oxidation potentials, the $CeO_2$-modified composite demonstrated a highly sensitive low operating potential (<0.1 V). This low-potential activation is highly desirable for minimizing background interference in complex biological fluids, giving the $CeO_2$ system a distinct advantage in target selectivity. Further chronoamperometric analysis is utilized to quantify the precise sensitivity and limit of detection (LOD) for both composites. The mechanical robustness of the upcycled PLA-PU matrix is also assessed under static and cyclic bending strain to validate its suitability for wearable applications. Additionally, the sensors' practical reliability is evaluated through rigorous selectivity screening against common physiological interferents and recovery assessments in complex artificial biofluids. Ultimately, this work establishes a sustainable pathway for upcycling plastic waste into high-value, mechanically durable wearable diagnostic technologies.




**Keywords:** Upcycled polylactic acid, polyurethane, MXene, non-enzymatic glucose sensor, transition metal oxides

# Correlating structural properties with capacitive and faradaic responses in graphene screen-printed electrodes

Tharinda Kasemphong[a], Monchai Jitvisate[b], Chanida Jakkrawhad[a], Wichayaporn Kamsong[c], Chanpen Karuwan[c], Pachanuporn Sunon[d], Supinya Nijpanich[e], Phanawan Whangdee[f], Theranun Siritanon[a], Kamonwad Ngamchuea[a],*

[a]*School of Chemistry, Institute of Science, Suranaree University of Technology, 111 University Avenue, Muang Nakhon Ratchasima, 30000, Thailand*
[b]*School of Physics, Institute of Science, Suranaree University of Technology, 111 University Avenue, Suranaree, Muang, Nakhon Ratchasima 30000, Thailand*
[c]*National Nanotechnology Center (NANOTEC), National Science and Technology Development Agency (NSTDA), Pathum Thani 12120, Thailand*
[d]*Institute of Research and Development, Suranaree University of Technology, 111 University Avenue, Suranaree, Muang, Nakhon Ratchasima, 30000, Thailand*
[e]*Synchrotron Light Research Institute, Suranaree, Muang, Nakhon Ratchasima 30000, Thailand*
[f]*Department of Applied Physics, Faculty of Sciences and Liberal Arts, Rajamangala University of Technology Isan, Nakhon Ratchasima, 30000, Thailand*

*Corresponding Author's E-mail: kamonwad@sut.ac.th

**Abstract**

Although graphene is widely used in energy-related and electrochemical sensing applications, the influence of its origin on the interfacial behavior of screen-printed electrodes after ink formulation and printing remains unclear. In this work, four graphene screen-printed electrodes prepared from different graphene sources–commercial, combustion-derived, exfoliated, and chemical vapour deposition (CVD) were studied. All electrodes were fabricated using the same ink composition and printing conditions, allowing a direct and systematic comparison of both capacitive and Faradaic behaviour. The interfacial properties of the electrodes were investigated using conventional electrochemical techniques together with step-potential electrochemical spectroscopy, which allowed the evaluation of differential capacitance C(E) and the corresponding charging times (τ). All electrodes showed a characteristic U-shaped differential capacitance profile, with points of zero charge closely clustered in the range of 0.35–0.40 V versus Ag/AgCl. While the general trends were consistent across electrodes, clear differences in capacitance magnitude and charging dynamics were observed the, which can be attributed to variations in graphene structure, defect density, and surface chemistry. For the Faradaic behaviour, the partially inner-sphere redox couple $[Fe(CN)_6]^{4-/3-}$ was used to evaluate heterogeneous electron transfer kinetics. The obtained rate constants ranged from $(0.76–1.99)\times10^{-5}$ m $s^{-1}$ and were found to depend mainly on edge sites, defect density, and oxygen-containing functional groups rather than on the overall conductivity of the graphene films. Overall, the results demonstrate that both the type of graphene and the preparation method play a fundamental role in determining the interfacial electrochemical properties of screen-printed electrodes.

**Keywords:** Graphene, Screen-printed electrodes, Differential capacitance, Heterogeneous electron transfer, Interfacial wettability

# Molecularly imprinted polymer for electrochemical detection of nucleosides

Raputporn Kongjapo[a], Jinnapat Wijitsak[b], Kamonwad Ngamchuea[a],*

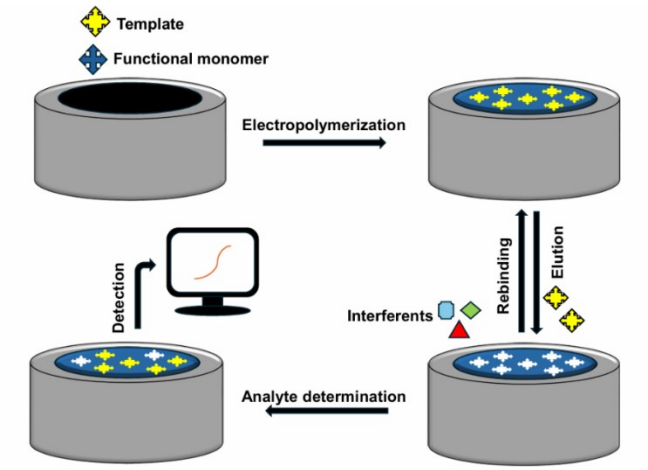
[a]*School of Chemistry, Institute of Science, Suranaree University of Technology, 111 University Avenue, Muang Nakhon Ratchasima, 30000, Thailand*

[b]*Institute of Research and Development, Suranaree University of Technology, 111 University Avenue, Suranaree, Muang, Nakhon Ratchasima, 30000, Thailand*

*Corresponding Author's E-mail: kamonwad@sut.ac.th

**Abstract**

The detection of guanosine and its structural analogs in biological samples is crucial for disease diagnosis and monitoring. However, because guanosine and common interfering substances exhibit similar electrochemical behaviors, achieving selective differentiation using conventional electrochemical techniques remains challenging. This project aims to develop Molecularly Imprinted Polymers (MIPs) to enhance the specificity and accuracy of guanosine detection. Using cyclic voltammetry, the project systematically optimizes MIP synthesis parameters, including functional monomers, cross-linker ratios, and polymerization conditions. The anticipated results will enable the clear differentiation of structurally similar derivatives while significantly improving the sensitivity of the electrochemical sensor. Ultimately, this work aims to facilitate the future application of the developed sensor for real-sample analysis, such as in blood, to reliably monitor relevant disease biomarkers.




**Keywords:** Guanosine, Molecularly Imprinted Polymer, Electrochemical Sensor, Cyclic Voltammetry, Biomarker

# Polypyrrole/$Ag_2S$ Quantum Dot-Based Nanocomposite for Gas Sensing Applications at Room Temperature

Supakit Chinpakdee[a], Tanatsaparn Tithito[a], Sarawut [K]ondee[a], Chatchawal Wongchoosuk[a,*]

[a]*Department of Physics, Faculty of Science, Kasetsart University, Chatuchak, Bangkok 10900, Thailand.*

*E-mail: chatchawal.w@ku.ac.th

**Abstract**

Polypyrrole (PPy) is a conducting polymer that has received considerable attention for gas sensing applications due to its good electrical conductivity, environmental stability, and ease of processing. Silver sulfide ($Ag_2S$), a semiconductor material with distinct optical and electrical properties, exhibits unique behavior at the nanoscale. Combining PPy with $Ag_2S$ quantum dots is expected to enhance gas sensing performance by taking advantage of the complementary properties of both materials. In this study, a PPy/$Ag_2S$ quantum dot nanocomposite was developed for environmental gas sensing. $Ag_2S$ quantum dots were incorporated into the PPy matrix with the aim of achieving a uniform distribution within the polymer structure. This design increases the available surface area and facilitates efficient charge transport, which are essential for improving gas sensing performance. The nanocomposite was synthesized using a simple and low-cost chemical method that allows reproducible fabrication without requiring complex equipment. Ethanol was selected as a representative volatile organic compounds to evaluate the sensing performance at room temperature. The results show that the PPy/$Ag_2S$ nanocomposite exhibits a stronger and more distinct response compared to pristine PPy. Furthermore, the material demonstrated faster response and recovery times, which are important for practical applications. The improved sensing behavior can be attributed to the synergistic interaction between PPy and $Ag_2S$ quantum dots. The quantum dots enhance gas adsorption and provide conductive pathways within the polymer, allowing efficient charge transfer and making the composite's electrical properties more responsive to gas exposure, particularly at low concentrations. Overall, the PPy/$Ag_2S$ nanocomposite shows strong potential as a low-cost, high-performance gas sensing material. This work offers a novel approach to designing nanocomposite-based sensors for environmental monitoring and may guide future research toward efficient, reliable, and cost-effective gas sensing technologies.

**Keywords:** $Ag_2S$ Quantum Dots, Polypyrrole, Gas Sensing, Volatile Organic Compounds

# Interface-Engineered Au Nanoclusters/zinc oxide–CQDs via Microwave-Assisted Synthesis for Ratiometric Fluorescence Sensing and Photocatalytic Degradation of Antibiotics

Linda Kumalayanti, [a] Supree Pinitsoontorn,[a],[b] Navadecho Chankhunthod, [a],[b]*

*[a] Materials Science and Nanotechnology Program, Department of Physics, Faculty of Science, Khon Kaen University, Khon Kaen, 40002, Thailand*

*[b] Institute of Nanomaterials Research and Innovation for Energy (IN-RIE), Khon Kaen University, Thailand*

E-mail: navach@kku.ac.th

**Abstract**

The development of reliable and sensitive platforms for antibiotic detection and removal remains a critical challenge in environmental and biomedical applications. In this work, an interface engineered nanocomposite consisting of Au nanoclusters (AuNCs), zinc oxide (ZnO), and carbon quantum dots (CQDs) was successfully constructed for dual-function ratiometric fluorescence sensing and photocatalytic degradation of antibiotics. The AuNCs/ZnO component was synthesized via a rapid microwave-assisted approach, followed by integration with CQDs to establish a dual-emission system.The resulting AuNCs/ZnO-CQDs exhibits distinct fluorescence emissions at 520 nm (CQDs) and 640 nm (AuNCs), enabling a ratiometric sensing strategy. Upon increasing concentrations of antibiotics, the emission intensity of AuNCs significantly decreased, while the CQDs emission remained relatively stable, leading to a monotonic increase in the fluorescence intensity ratio ($I_{520}/I_{640}$). A wide detection range from 0 to 200 µM was achieved with a sensitivity of 0.0646 $\mu M^{-1}$ and a limit of detection (LOD) of 3.5 µM. In contrast, the AuNCs/CQDs system without ZnO exhibited severe fluorescence quenching and unstable responses, highlighting the critical role of ZnO in regulating interfacial interactions. Comprehensive structural and spectroscopic analyses (UV–Vis, PL, TEM, and XPS) reveal the interfacial electronic modulation. Additionally, the nanocomposite exhibited effective photocatalytic degradation of oxytetracycline and ciprofloxacin at 10 ppm under light irradiation. This work provides a simple and efficient approach for designing interface-engineered nanomaterials with enhanced sensing and degradation performance for environmental remediation. This work provides a simple and efficient strategy for designing interface-engineered nanomaterials with enhanced ratiometric sensing performance and photocatalytic activity, offering promising potential for environmental monitoring and remediation.

**Keyword:** Antibiotic, Carbon Quantum Dots, Gold Nanocluster, Ratiometric, Zinc Oxide

# Development of a Sustainable Paper-based Analytical Device Using Natural Anthocyanin for Rapid Sweat Lactic Acid Detection as a Preliminary Health Indicator

Kanyarat Suksomjaisaman[a], Timpika Hormsombut[a], Nopchulee Cheeveewattanagul[a], Patsamon Rijiravanich[a, b*]

[a]*Sensor Technology Laboratory, Pilot Plant Development and Training Institute, King Mongkut's University of Technology Thonburi, Bang Khun Thian, Bangkok 10150, Thailand*
[b]*Industrial Sensor Technology Research Team, National Center for Genetic Engineering and Biotechnology, National Sciences and Technology Development Agency at King Mongkut's University of Technology Thonburi, Bang Khun Thian, Bangkok 10150, Thailand*

*Corresponding Author's E-mail: patsamon.rij@biotec.or.th, patsamon.rij@kumtt.ac.th

**Abstract**

This study presents a proof-of-concept paper-based colorimetric sensor for the detection of lactic acid in sweat, offering a low-cost, non-toxic, and user-friendly approach. Lactic acid is a key biomarker for physiological and health monitoring. The proposed paper-based analytical device (PAD) is designed for potential skin application, providing a convenient non-invasive alternative for preliminary health surveillance. The sensor utilizes natural anthocyanin extracted from the butterfly pea petals (*Clitoria ternatea*) as a colorimetric indicator. The extract is adjusted to an alkaline condition at pH 8.0, yielding a green solution that is coated onto paper. The sensing layer is integrated with a sweat-absorbing pad and a transparent waterproof film, enabling future on-skin deployment. In this laboratory validation, the device is tested with artificial sweat containing known lactic concentrations. Upon exposure to lactic acid, a proton exchange reaction induces a visible color change.

As lactic acid concentration increases, the sensor exhibits a clear transition: from green (0–20 mM, normal levels) to bluish purple (30–50 mM, physically active individuals), and finally to pinkish purple (60–100 mM, risk of shock). A major advantage is the naked-eye readout, allowing users to distinguish concentration ranges without instrumentation. The sensor also shows high selectivity against other acids present in sweat, as confirmed in an artificial sweat matrix.

This proof-of-concept platform demonstrates strong potential for non-invasive health monitoring, personal wellness tracking, and athlete physiological assessment, providing a solid foundation for future on-skin clinical validation studies.

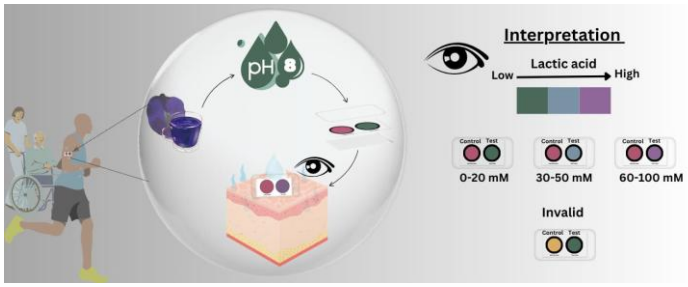



Figure 1. Schematic illustration of the colorimetric sensor enabling naked-eye detection, with color transitions corresponding to increasing lactic acid concentrations.

**Keywords:** Lactic Acid, Sweat Analysis, Paper-based Analytical Device (PAD), Anthocyanin, Colorimetric Detection.

# Design and Development of a Wearable Dual-Electrode Sweat-Harvesting Energy Device

You-Zeng, Wu[1†], Jennifer Marsha Susanto[4], Dhanaprabhu Pattappan[1], Yi-Ting Lai[1,2,3*]

[1] *Department of Materials Engineering, Ming Chi University of Technology , New Taipei City, 24301, Taiwan.*
[2] *Biochemical Technology R&D Center, New Taipei City, 24301, Taiwan*
[3] *Center For Plasma and Thin Film Technology, New Taipei City, 24301, Taiwan*
[4] *Department of Biotechnology, Indonesia International Institute for Life Sciences, DKI Jakarta, 13210, Indonesia*

*Corresponding Author's E-mail: *laieating@mail.mcut.edu.tw*

**Abstract**

With the rapid development of wearable electronic devices, the demand for sustainable and self-powered energy systems has significantly increased. In this study, the conductive polymer polypyrrole (PPy) and the two-dimensional material molybdenum disulfide ($MoS_2$) were investigated as photoactive electrode materials to explore the feasibility of converting light energy and bioenergy in a sweat environment.

PPy provides a conductive interface and exhibits photoresponsive behavior, while $MoS_2$ possesses a narrow semiconductor bandgap that enables strong light absorption in the visible region. In this work, PPy and $MoS_2$ were individually fabricated on flexible ITO/PET substrates, and artificial sweat was employed as the electrolyte to simulate the energy conversion conditions of wearable applications.

Photoelectrochemical measurements were conducted to systematically evaluate the effects of different illumination conditions, electrolyte compositions, and glucose-related reactions on the photocurrent response. The experimental results demonstrate that, in artificial sweat electrolyte, the system can generate stable and reproducible current responses under light illumination. These results indicate that sweat not only provides ionic transport but also supports light-assisted energy conversion mechanisms.

Overall, this study verifies the feasibility of sweat-driven photoelectrochemical systems for self-powered wearable applications and provides an experimental foundation and design strategy for future integration of light energy conversion, sensing, and wearable electronic devices.

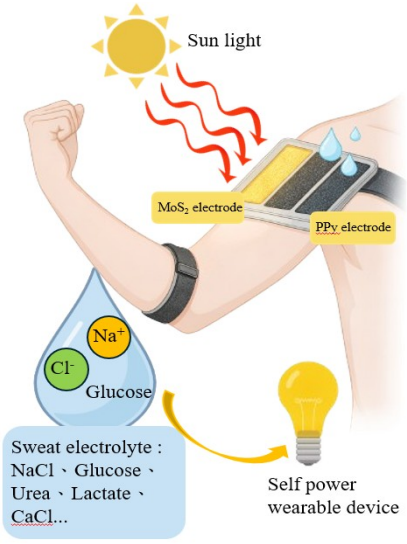



Figure 1. Sweat-Driven Photoelectrochemical Energy Harvesting for Self-Powered Wearable Devices

**Keywords:** PPy, $MoS_2$, photoelectrochemical energy harvesting, self-powered wearable devices

# A Versatile Colorimetric Assay for Rapid Environmental Lead Ion Screening and Detection Using DNAzyme-Functionalized Magnetic and Gold Nanoparticles

Nopchulee Cheeveewattanagul[a,*], Nutsara Mekjinda[b], Paskorn Muangphrom[a-a,c], Patsamon Rijiravanich [a,d]

[a] *Sensor Technology Laboratory, Pilot Plant Development and Training Institute, King Mongkut's University of Technology Thonburi, Bangkok, 10150, THAILAND*
[b] *Analytical Sciences And National Doping Test Institute, Mahidol university, 10400, THAILAND*
[c] *Nanoscience and Nanotechnology Graduate Program, Faculty of Science, King Mongkut's University of Technology Thonburi, Bangkok, 10140, THAILAND*
[d] *Industrial Sensor Technology Research Team, National Center for Genetic Engineering and Biotechnology, National Sciences and Technology Development Agency at King Mongkut's University of Technology Thonburi, Bang Khun Thian, Bangkok 10150, Thailand*[d]

*Corresponding Author's E-mail: nopchulee.che@kmutt.ac.th

**Abstract**

In many Thai industries, the extensive use of lead (Pb) has resulted in widespread environmental contamination and subsequent lead poisoning. Currently, conventional lead ion ($Pb^{2+}$) analysis is largely confined to laboratory settings due to the requirement for sophisticated instrumentation. To overcome this limitation, a rapid colorimetric biosensor was developed for the on-site detection of $Pb^{2+}$ using GR5 DNAzyme-functionalized magnetic particles (MPs) and gold nanoparticles (AuNPs). In this platform, $Pb^{2+}$ serves as a cofactor that catalyzes the cleavage of the ribonucleotide phosphodiester bond within the GR5 DNAzyme. The presence of MPs facilitates this catalytic process, allowing it to be completed within only one minute. Upon applying an external magnetic field, the newly formed cleaved-DNAzyme-MP-AuNP complexes are sequestered, reducing the concentration of free AuNPs and causing a visible fading of the solution's color. The system achieves a detection limit of 10 ppb and demonstrates high selectivity for $Pb^{2+}$ over other heavy metal ions. This visual transition enables efficient, instrument-free water quality monitoring in field settings.

**Keywords:** Colorimetric biosensor, DNAzyme, Gold nanoparticles, Lead ion detection, Magnetic particle

# All-in-one, multiplex paper microfluidic diagnostic kit for malarial pathogens quantification in remote populations

Natcha Siriyod[a],*, Nopchulee Cheeveewatanagula[a], Khajohnpong Manopwisedjaroen[c], Wang Nguitragool[c, d] and Patsamon Rijiravanich[a,b]

[a] *Sensor Technology Laboratory, Pilot Plant Development and Training Institute, King Mongkut's University of Technology Thonburi, Bang Khun Thian, Bangkok 10150, Thailand.*

[b] *Industrial Sensor Technology Research Team, National Center for Genetic Engineering and Biotechnology, National Sciences and Technology Development Agency at King Mongkut's University of Technology Thonburi, Bang Khun Thian, Bangkok 10150, Thailand*

[c] *Mahidol Vivax Research Unit, Faculty of Tropical Medicine, Mahidol University, Ratchathewi, Bangkok, 10400, Thailand*

[d] *Department of Molecular Tropical Medicine and Genetics, Faculty of Tropical Medicine, Mahidol University, Bangkok, Thailand*

*Corresponding Author's E-mail: natcha.sensorlab@gmail.com, patsamon.rij@biotec.or.th

**Abstract**

Globally, more than 40% of the world population resides in malaria-risk areas, leading to more than 300 million cases and 3 million fatalities each year. The burden of this tropical disease in Thailand is primarily driven by two species: *P. falciparum* and *P. vivax* [1] and transmission is primarily centered in displaced populations and migrant workers residing in forested and mountainous regions along Thailand's western and eastern borders, with Myanmar and Cambodia [2]. Rapid and accurate diagnosis is vital for spotting and treating cases early.

We previously developed a point of care (POC), wax-printed microfluidic paper-based analytical device (μPAD) capable of detecting *Plasmodium* specific-species DNA by integrating recombinase polymerase amplification (RPA) and amplicon quantification process in a simple device, for use in low-resource settings while having high sensitivity and short detection time [3]. This study aims to achieve multiplex detection of *Plasmodium* species and incorporate DNA extraction from blood samples to the POC diagnostic kit, providing a truly all-in-one diagnostic solution.

The resulting kit was highly sensitive and provides multiplex sample-to-result visual output within a single device. The limit of detection (LOD) was established using serial dilutions of synthetic dsDNA (gBlock). With naked eye, the LOD with a flatbed scanner was calculated to be 0.625 pg $\mu L^{-1}$ for the genus level Plasmodium detection, 0.989 pg $\mu L^{-1}$ for P. falciparum, and 1.135 pg $\mu L^{-1}$ for P. vivax, while 100 pg $\mu L^{-1}$ for all three targets observed by the naked eyes. Our diagnostic kit promises a reliable tool to identify asymptomatic infections and particularly useful for unprivileged remote populations.

**Keywords:** Microfluidic paper-based analytical device (μPAD), Recombinase polymerase amplification (RPA), Malaria diagnosis, *Plasmodium*

**Selected References:**

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# CNT/PDMS Nanocomposite In-Sensor Reservoir Computing Device for Real-Time Object Recognition

Kouki Kimizuka[a], Ahmet Karacali[b], Saman Azhari[ac], Yuki Usami[ab], Shuhei Ikemoto[ab], Hakaru Tamukoh[ab], Hirofumi Tanaka[ab*]

[a] *Research Center for Neuromorphic AI Hardware, Kyushu Institute of Technology, Fukuoka, Japan*
[b] *Graduate School of Life Science and Systems Engineering, Kyushu Institute of Technology, Fukuoka, Japan*
[c] *Graduate School of Information, Production and Systems (IPS), Waseda University, Fukuoka, Japan*

*Corresponding Author's E-mail: tanaka@brain.kyutech.ac.jp

**Abstract**

Real-time object recognition is a key capability for next-generation robotic and tactile sensing systems; however, conventional approaches rely on extensive signal preprocessing and external computing resources, leading to latency and increased system complexity. In this study, we present a real-time object recognition framework based on a carbon nanotube–polydimethylsiloxane (CNT/PDMS) nanocomposite pressure sensor that functions as an in-sensor reservoir computing device. CNT/PDMS nanocomposite was fabricated via a sacrificial template method using commercially available sugar, enabling the formation of a porous structure that exhibits nonlinear electromechanical responses due to deformation-induced changes in conductive pathways [1]. These intrinsic nonlinear and dynamic characteristics allow the sensor to operate as a physical reservoir by directly utilizing its voltage–time responses under mechanical interactions.

Object recognition was performed in real time during grasping of four objects (block, bottle, mandarin, and strawberry), with system control implemented via LabVIEW. The sensors were integrated onto PCB substrates using a silane coupling agent (1% APTES), and 15 output signals were acquired using Arduino Nano 1 and 2 (Fig. 1(a)). Experimental demonstrations of grasping tasks confirm that the proposed system enables stable and repeatable real-time object recognition performance (Fig. 1(b)).

This work highlights the potential of CNT/PDMS nanocomposites as multifunctional sensing and computing materials, providing a promising pathway toward compact, low-latency, and energy-efficient tactile intelligence for robotics and human–machine interfaces.

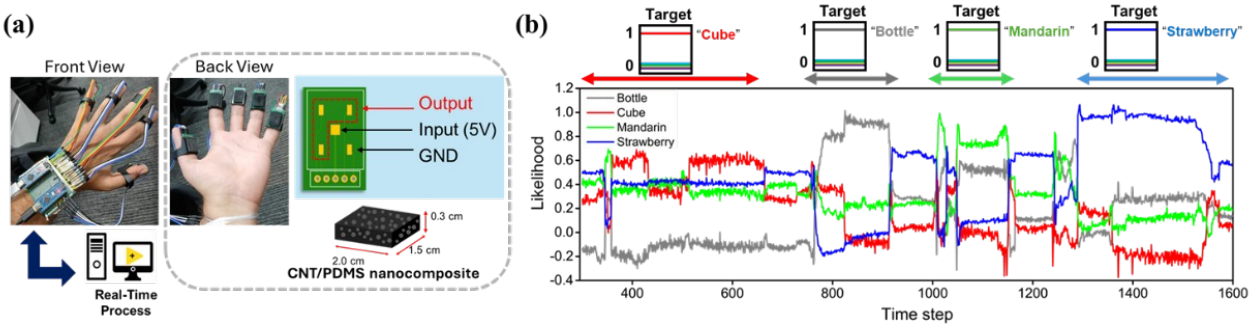



Fig. 1(a) Schematic and experimental setup of the real-time object recognition system. (b) Real-time classification results for four grasped objects (Block, Bottle, Mandarin, and Strawberry).

**Keywords:** haptic sensors, in-sensor computing, nanomaterials, reservoir computing, soft robotics

**Reference**

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# Surface-Modified Titanium Electrodes for In Situ Electrochemical Monitoring of Corrosion and Shelf-Life Degradation in Canned Food Packaging

Pornsak Srisungsitthisunti[a,*], Noparat Kanjanprayut[b]

[a]*Department of Production Engineering, Faculty of Engineering, King Mongkut's University of Technology North Bangkok, Bangkok 10800, Thailand*
[b]*Corrosion Technology Department, Thai-French Innovation Institute, King Mongkut's University of Technology North Bangkok, Bangkok 10800, Thailand,*

*Corresponding Author's E-mail: pornsak.s@eng.kmutnb.ac.th

**Abstract**

Metal cans are widely used in the food packaging industry because of their high mechanical strength, hermetic sealing capability, and long-term storage performance, typically providing a shelf life of 3–5 years. However, internal corrosion caused by aggressive food constituents remains a major concern, as it can accelerate package degradation and reduce the actual storage life below the manufacturer's predicted expiration period. Conventional shelf-life evaluation commonly relies on accelerated storage tests combined with destructive random can opening at different time intervals and temperatures. This approach requires 6–12 months of testing, consumes a large number of samples, and cannot provide continuous information on corrosion progression inside sealed packages. In this study, corrosion-resistant titanium-based sensor electrodes were developed for in situ real-time monitoring of corrosion evolution and shelf-life behavior in canned food packaging using Electrochemical Impedance Spectroscopy (EIS). Commercially pure Grade 1 titanium was selected as the substrate and modified by three surface engineering methods: gold coating, platinum coating, and anodization. The electrochemical corrosion resistance and interfacial stability of the fabricated electrodes were evaluated using potentiodynamic polarization and EIS. The developed electrodes were then integrated into actual canned food containers for continuous impedance monitoring under accelerated thermal storage at 35, 45, and 55 °C. Electrochemical responses were recorded after 1, 7, 10, 20, 30, and 50 days to investigate the relationship between impedance evolution, corrosion progression, and shelf-life degradation. The findings are expected to demonstrate that surface-engineered titanium electrodes provide high corrosion durability, stable electrochemical responses, and strong sensitivity for detecting progressive degradation inside canned food packages. This sensing platform offers a rapid, non-destructive, and reliable alternative to conventional shelf-life testing with strong potential for intelligent shelf-life prediction in advanced food packaging

**Keywords:** Titanium electrode; Surface modification; Electrochemical impedance spectroscopy; Canned food packaging; Shelf-life monitoring

# Rapid Determination of $H_2O_2$ in Exhaled Breath Condensate using a Laminated Paper-Based Chemiluminescence Device with Co-MOF as a Catalyst

Chonnatee Tinala[a,b], Wasin Somboot[a], Tippawan Prapamontol[d], Jaroon Jakmunee[a,c,e], Tinakorn Kanyanee[a,c,e,*]

[a] *Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[b] *The Graduate School, Chiang Mai University, Chiang Mai 50200, Thailand*
[c] *Center of Excellence in Materials Science and Technology, Chiang Mai University, Chiang Mai 50200, Thailand*
[d] *Research Institute for Health Sciences, Chiang Mai University, Chiang Mai 50200, Thailand*
[e] *Center of Excellence for Innovation in Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*

* Corresponding author's E-mail address: tinakorn.kanyanee@cmu.ac.th, tkanyanee2@gmail.com (T. Kanyanee).

**Abstract**

Hydrogen peroxide ($H_2O_2$) in exhaled breath condensate (EBC) serves as a critical biomarker for oxidative stress in respiratory diseases such as asthma, COPD, and post-COVID inflammation. However, current detection methods such as fluorescence spectroscopy and flow injection chemiluminescence (FI-CL) are limited by poor portability, high cost, and insufficient sensitivity in complex biological matrices. This study introduces a laminated paper-based chemiluminescence (CL) device enhanced by cobalt-based metal-organic framework (Co-MOF) as a catalyst for luminol-$H_2O_2$ reaction. The device was fabricated by synthesizing a Co metal–organic framework (Co-MOF) using 4,4′-bipyridine as the ligand, followed by deposition onto filter paper. Determination of $H_2O_2$ was achieved through a miniature PMT as CL detector. The Co-MOF catalyst enhanced the chemiluminescence (CL) intensity by approximately 5-fold compared to the $Co^{2}$ ion-based luminol system, achieving a limit of detection (LOD) of 11.7 nM and a linear range of 50–5000 nM for $H_2O_2$ ($R^2$ = [0.9919]). In real EBC samples (n = 30), the device showed results statistically consistent with the standard fluorometric method using 4-HPAA and HRP, as confirmed by a t-test ($t_{calc}$ = 0.47 < $t_{crit}$ = 2.00), indicating no significant difference. This laminated paper-based CL device with Co-MOF represents a breakthrough in disposable biosensing, offering rapid, and low-cost.

**Keywords:** Chemiluminescence, Metal-Organic Framework, Paper-based device, Exhaled breath condensate, $H_2O_2$ biosensor

# Facile Fabrication of Cost-effective Plasmonic SERS Substrates for Sensitive Paraquat Detection

Nopphamat Thepin, Asmar Sathukarn, Pitak Eiamchai, Mati Horprathum, Noppadon Nuntawong, Khwanchai Tantiwanichapan, Raju Botta*

*National Electronics and Computer Technology Center (NECTEC), NSTDA, Thailand Science Park, Khong Nueng, Khlong Luang, Pathum Thani-12120, Thailand.*

*Corresponding Author's E-mail: raju.botta@nectec.or.th (or) raazbotta@gmail.com

**Abstract**

Rapid and sensitive detection of hazardous agrochemicals is vital for environmental and food safety monitoring. While surface enhanced Raman spectroscopy is a powerful molecular fingerprinting tool, its widespread adoption is often hindered by high costs associated with sophisticated nanofabrication methods like lithography or physical vapor deposition. This study presents a cost-effective alternative utilizing a Tollen's reaction to grow densely packed silver nanoparticles (AgNPs) and nanoclusters (AgNCs) directly on glass slides.

Characterization via filed emission scanning electron microscopy (FESEM) reveals a uniform distribution of nanostructures, which creates interparticle separation "hotspots". These hotspots generate strong localized surface plasmon resonance (LSPR), significantly amplifying Raman scattering signals. The SERS performance was evaluated using Rhodamine 6G (R6G) as a probe molecule, demonstrating a signal enhancement of approximately 142 times compared to a bare glass slide. Characteristic Raman bands were clearly observed even at trace concentrations.

To demonstrate practical applicability, the developed substrate was employed for the detection of paraquat (PQ), a highly toxic herbicide. Distinct Raman lines of PQ at 1650, 1195, and 840 $cm^{-1}$ were successfully detected at a concentration of 10 µM. Furthermore, the substrate exhibited high reliability, with a signal reproducibility of 13% RSD across the surface. These results indicate that the controlled Tollen's reaction offers a simple, salable and cost-effective route for producing high-performance SERS substrates. This research provides a robust platform for the real-time detection of hazardous chemicals, ensuring a safer approach to agricultural and environmental management.

**Keywords:** Plasmonics, Silver nanoparticles, Sensor, SERS, Paraquat, Herbicides

# $Bi_2O_2Se$ /$PbHfO_3$ Heteroepitaxy for Antiferroelectric Field-Effect Transistor

Ping Li Huang[1], Yu Hao Tu[2], Yu Hsien Lee[3], Ying Hao Chu[1*]

[1]*Department of Materials Science & Engineering, National Tsing Hua University, Hsinchu, Taiwan*

*Corresponding Author's E-mail: yhchu@mx.nthu.edu.tw

**Abstract**

Silicon-based components have been the dominant material in the semiconductor industry in recent years. According to Moore's Law, "the number of transistors on a microchip doubles every two years while maintaining minimal cost increases." However, difficulties such as decreased carrier mobility and increased short-channel effects arise when minimizing silicon-based electronics. To overcome these obstacles, two-dimensional materials, which possess properties such as atomic-scale thickness and dangling-bond-free surfaces, are considered suitable for next-generation electronics. Among all the two-dimensional semiconductors, $Bi_2O_2Se$ (BOSe) exhibits exceptional properties, including high mobility, excellent stability, and a tunable bandgap. Excess electrons filling the vacancies in the Se layer render BOSe a naturally n-type material. As the amount of BOSe increases, its semiconducting nature gradually transitions toward metallic behavior, attributed to variations in carrier concentration. In this work, $PbHfO_3$ is used as the antiferroelectric (AFE) oxide layer with a high dielectric constant, enabling the same capacitance with a significantly reduced thickness, thereby mitigating current leakage in the oxide layer. The dipoles in the AFE layer switch in response to the external electric field. After removing the external field, the switched dipoles depolarize quickly. During switching, the capacitance varies, thereby influencing band bending in the BOSe layer at the top. Additionally, changes in BOSe content modulate carrier concentrations, thereby affecting the dynamic polarization response of the AFE layer. These phenomena impart this electronic component with nonlinear behavior and short-term memory, enabling it to serve as an analogy to an artificial neuron in describing the volatile behavior of neural signals. Compared to the traditional ferroelectric transistors, AFE transistors exhibit volatile polarization. Their spontaneous depolarization enables unipolar operation and results in a relatively narrow memory window, thereby reducing polarization-switching energy.

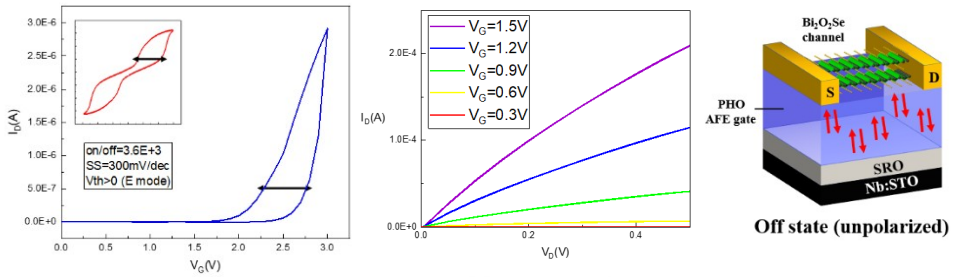



Fig.1 Transfer characteristics of the AFE transistor and the illustration of the device

**Keywords:** Antiferroelectric, Epitaxy, Transistor, Two-dimensional Semiconductor, $Bi_2O_2Se$

# Lead zirconate titanate ceramics with aligned crystallite grains

Jinglei Li[a,*], Shujun Zhang[b], Fei Li[a]

[a] *Electronic Materials Research Laboratory (Key Lab of Education Ministry), State Key La-boratory for Mechanical Behavior of Materials and School of Electronic and Information Engineering, Xi'an Jiaotong University, Xi'an, China*
[b] *A Department of Chemistry, City University of Hong Kong, Kowloon, Hong Kong, China*

*Corresponding Author's E-mail: lijinglei@xjtu.edu.cn

**Abstract**

The piezoelectric properties of lead zirconate titanate [$Pb(Zr,Ti)O_3$ or PZT] ceramics could be enhanced by fabricating textured ceramics that would align the crystal grains along specific orientations. We present a seed-passivated texturing process to fabricate textured PZT ceramics by using newly developed $Ba(Zr,Ti)O_3$ microplatelet templates. This process not only ensures the template-induced grain growth in titanium-rich PZT layers but also facilitates desired composition through interlayer diffusion of zirconium and titanium. We successfully prepared textured PZT ceramics with outstanding properties, including Curie temperatures of 360°C, piezoelectric coefficients $d_{33}$ of 760 picocoulombs per newton and $g_{33}$ of 100 millivolt meters per newton, and electromechanical couplings $k_{33}$ of 0.85. This study addresses the challenge of fabricating textured rhombohedral PZT ceramics by suppressing the otherwise severe chemical reaction between PZT powder and titanate templates.

**Keywords:** Ferroelectric Ceramics, Piezoelectric Ceramics, Textured Ceramics

# Preparation of Several Novel Ferroic Functional Oxides based on Lattice Strain Engineering

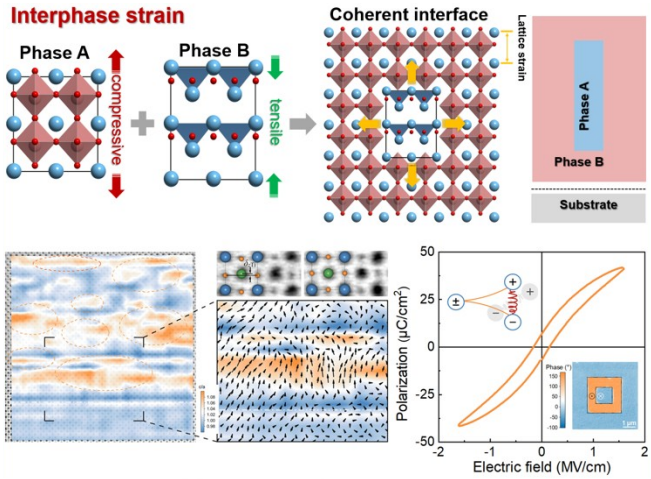
Tianyu Li[a,b*], Jun Chen[a,c]

[a]*School of Materials Science and Engineering, University of Science and Technology Beijing, Beijing 100083, China*
[b]*Department of Physics & Department of Chemistry, City University of Hong Kong, Hong Kong SAR, China*
[c]*State Key Laboratory of Tropic Ocean Engineering Materials and Materials Evolution, Hainan University, Haikou 570228, China*

*Corresponding Author's E-mail: tianyuli@ustb.edu.cn

## Abstract

Ferroic materials, including ferroelectric, ferromagnets, and multiferroics, are promising for high-density memory, energy harvesting, and precision electromechanical devices. Yet intrinsic ferroics are scarce because ferroic ordering requires non-centrosymmetric structures with broken space or time-reversal symmetry, whereas most compounds are paraelectric or non-magnetic. In this report, the speakers focused on these paraelectric and paramagnetic oxides and developed interphase lattice strain and triaxial lattice strain methods to activate hidden ferroic states (T. Li *et al*., *Chem. Rev*. 2024, *124*, 7045). In prototypical perovskite $SrTiO_3$-based epitaxial films, interphase lattice strain transforms an intrinsic non-polar symmetry into a robust polar structure, boosting strong room-temperature ferroelectricity and inducing high-temperature multiferroic glassy states for both polarization and spin (T. Li *et al*., *Adv. Mater*. 2021, *33*, 2008316; T. Li *et al*., *Phys. Rev. Lett.* 2023, *131*, 246801). In this basis, a synergistic strategy combining spatial charge confinement with local lattice strain further optimize charge states, greatly enhancing dielectric quality and enabling high energy-storage density with high efficiency (T. Li *et al*., *J. Am. Chem. Soc.* 2024, *146*, 1926; T. Li *et al*., *J. Am. Chem. Soc.* 2024, *146*, 20205). In paramagnetic $LaCoO_3$, three-dimensional lattice strain, by combining interphase strain with epitaxial strain, stabilizes room-temperature ferromagnetic insulating state (T. Li *et al*., *Phys. Rev. Lett.* 2025, *131*, 016702). Therefore, lattice strain engineering offers a route to design emergent ferroic properties and correlated functionalities.




**Keywords:** Interphase strain, Perovskite oxides, Ferroic materials, Lattice symmetry, Thin films

# Synthesis of Carbon Dots Derived from Coffee Grounds for Enhancing the Performance of Triboelectric Nanogenerator

Sulen Chann[a], Sikharinthan Chitthongkul[a], Viyada Harnchana[a,b,*]

[a] *Department of Physics, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand*
[b] *Institute of Nanomaterials Research and Innovation for Energy (IN-RIE), Khon Kaen University, Khon Kaen 40002, Thailand*

*Corresponding Author's E-mail: viyada@kku.ac.th

**Abstract**

Triboelectric nanogenerators (TENGs) convert mechanical energy into electricity via contact electrification (CE) and electrostatic induction (EI). Green materials are popular in TENGs because of their biodegradability and environmental sustainability, and they serve a crucial function in TENGs. Natural rubber (NR) is one of the green materials and is widely explored as an eco-friendly alternative; however, the relatively low electrical output of natural rubber (NR)-based TENGs limits their practical applications. The improvement of NR performance in TENGs can be achieved by introducing functional nanomaterials into the polymer matrix. This method enhances charge density and increases the electrical output of TENGs. In this study, a new biocomposite triboelectric nanogenerator (TENG) was fabricated by utilizing natural rubber (NR) incorporated with carbon dots (CDs) derived from coffee grounds (CDs). This NR/CDs was chosen to be the tribo-positive material. CGs were utilized as the source of carbon, and urea was used as a nitrogen dopant via microwave-assisted synthesis. To investigate the effect of nitrogen doping on TENGs output, various urea concentrations were prepared (1.5–3.0 M). The maximum output is 114 V of voltage, 10.6 μA of current, and 3.94 W/m² of power density. This result was achieved from the NR/CDs modified with 3.0 M of urea, which is 3.37-fold higher compared to pristine NR. This enhancement is attributed to improved charge trapping and increased surface electronegativity induced by nitrogen doping. These findings illustrate that nitrogen-doped carbon dots significantly enhance the TENGs performance. To sum up, the developed TENGs display excellent potential for energy harvesting and sensing, and they can be inexpensive, flexible, stable, and environmentally sustainable

**Keywords:** Carbon dots (CDs), Coffee grounds (CGs), Energy harvesting, Natural rubber (NR), Nitrogen doping, Self-powered sensing, Triboelectric nanogenerators (TENGs)

# Barrier-free near-zero-field switching in sliding ferroelectrics

Yuanda Liu[a,*], Jinghua Teng[a]

[a]*2Institute of Materials Research and Engineering (IMRE), Agency for Science, Technology and Research (A*STAR), Singapore 138643.*

*Corresponding Author's E-mail: yuanda_liu@a-star.edu.sg

**Abstract**

Sliding ferroelectricity in two-dimensional (2D) van der Waals materials offers a topology-conserving switching mechanism for fatigue-free, ultrafast electronics. However, polarization switching in pristine commensurate lattices is fundamentally bottlenecked by massive kinetic nucleation barriers, necessitating impractically high electric fields or stochastic native pinning centers. Here, we exploit nanoscale geometric constraints to demonstrate barrier-free sliding in 3R-$MoS_2$. By introducing site-controlled out-of-plane structural ripples, we show that local nanoscale curvature induces a deterministic shear strain gradient that functions as a permanent, barrier-free structural seed that initiates soliton-like domain wall propagation, bypassing the intrinsic nucleation bottleneck. This precise topological intervention enables polarization reversal at an unprecedented onset electric field of only 3.5 mV/nm. Operating at an ultralow coercive field of 0.035 V/nm, our device achieves robust non-volatile performance, including on/off ratios exceeding $10^8$, fatigue-free operation beyond $10^9$cycles, and stable retention exceeding $10^5$s. Our results prove that precise nanoscale structural morphology fundamentally dictates macroscopic sliding dynamics. This breakthrough not only transitions near-zero-field ferroelectric switching into a practical reality but also establishes geometric design as a universal platform for next-generation nanoelectronics.

**Keywords:** sliding ferroelectricity, 3R-MoS2, non-volatile.

# Enhanced Electromechanical Strain in A-site Modified Lead-Free Relaxor Ferroelectric Ceramics

Ketkaeo Bunpang[a,b], Puripat Kantha[c], Jialuo Wang[d], Pathit Premwichit[e], Sasipohn Prasertpalichat[e], Xiaoxu Zhao[d], and Natthaphon Raengthon[a,b,*]

*[a]Department of Materials Science, Faculty of Science, Chulalongkorn University, Bangkok 10330 Thailand [b]Center of Excellence on Advanced Materials for Energy Storage, Chulalongkorn University, Bangkok, Thailand [c]Division of Physics, Faculty of Science and Technology, Rajamangala University of Technology Thanyaburi, Pathum Thani, Thailand [d]School of Materials Science and Engieering, Peking University, Beijing 100871, China [e]Department of Physics, Faculty of Science, Naresuan University, Phitsanulok 65000, Thailand* *: Natthaphon.R@chula.ac.th

**Abstract**

High-performance piezoelectric ceramics requires precise and careful control of phase and defect chemistry of material. Dominance lead-based compounds such as $Pb(Zr,Ti)O_3$-based and $Pb(Mg,Nb)O_3$-based ceramics exhibits excellent piezoelectric performance for actuator and transducer applications. However, environmental concern of the use of Pb in the device have transitioned research interest toward development of lead-free ferroelectric materials. Promising lead-free piezoelectric includes $BaTiO_3$-based, $(Bi,Na)TiO_3$-based, and $(K,Na)NbO_3$-based compounds. This study investigates relaxor ferroelectric ceramic based on $BaTiO_3$-$Bi(Zn_{1/2}Ti_{1/2})O_3$ compounds, focusing on A-site modification via monovalent alkali ions ($Na^+$ and $K^+$) doping. Phase compositions revealed by X-ray diffraction consisting of tetragonal and cubic phases in which the tetragonal phase fraction increases while dopant increases. Formation of defect dipoles comprising monovalent A-site dopants coupled with oxygen vacancies is observed by room-temperature electron paramagnetic resonance spectroscopy. Dielectric characteristics show systematically shift in maximum permittivity temperature to higher values together with sharper phase transition behavior when increasing dopants. Composition-driven phase transition from relaxor to antiferroelectric-like to ferroelectric behavior are found when increasing concentration of dopants and increasing temperatures, which are observed by electric field-induced polarization, current and strain measurements. A large-signal piezoelectric coefficient $d_{33}^*$ or 1,073 pm/V measure at 30 kV/cm at room temperature is observed when doped with 0.04 mol of K. This finding is a competitive electromechanical response among lead-free piezoelectric systems that can be observed at low electric-field. The presence of defect dipoles in combination with phase composition play crucial role in enhancing electromechanical strain when compared with undoped relaxor ferroelectric compound.

**Keywords:** Lead-free piezoelectric, A-site doping, electromechanical strain

# Zn-Mg ZIF-Incorporated PVDF-HFP-based Nanofiber Films for Biomechanical Energy Harvesting

Venkata Siva Kavarthapu, Goutham Gatla, Jae Su Yu*

*Department of Electronic Engineering, Institute for Wearable Convergence Electronics, Kyung Hee University, 1732 Deogyeong-daero, Giheung-gu, Yongin-si, Gyeonggi-do, 446-701, South Korea*

**Corresponding author. Email address: jsyu@khu.ac.kr (J. S. Yu)*

**Abstract**

The popularity of portable and commercial electronics has raised the demand for energy harvesting. Several ways for generating or collecting electrical energy have been investigated to meet this demand. Among the many energy sources, mechanical energy stands out because it is abundant, renewable, and powered by everyday human activity. Hybrid nanogenerators (HNGs) use electrostatic and triboelectric induction to transform tiny amounts of biomechanical energy into electricity. In this presentation, a Zn-Mg zeolitic imidazolate framework (ZM-ZIF)-incorporated poly(vinylidene fluoride-co-hexafluoropropylene (PVDF-HFP)-based HNGs are developed to enhance electromechanical energy conversion performance. The ZM-ZIF was fabricated via sol-gel synthesis and further incorporated into the PVDF-HFP polymer matrix via an electrospinning process, enabling significant improvements in dielectric properties, interfacial polarization, surface modification, and electroactive phase content. The electrical output of the HNG was optimized by varying the ZM-ZIF concentrations in the composite films, resulting in increased electrical performance. The optimized HNG was further tested for long-term durability and stability across a range of mechanical frequencies and forces. Long-term cycling tests confirmed its reliability and sustainable operation. The hierarchical architecture of the ZM-ZIF provides a high surface area and abundant active sites, facilitating efficient charge trapping and transfer mechanisms. Moreover, the synergistic interaction between dual metal centers further enhances polarization and electrical conductivity within the composite, leading to superior hybrid energy harvesting performance. Furthermore, the electricity generated by the optimized HNG was used to harvest mechanical energy from daily human activities and power various portable electronic devices. The fabricated nanogenerator demonstrates excellent electrical output under low-frequency biomechanical motions, making it highly suitable for real-world wearable and sensing applications.

**Keywords:** Zn-Mg zeolitic imidazolate framework, Hybrid nanogenerator, electrospinning technique, mechanical energy harvesting.

# Liquid Metals in Liquid-Solid Nanogenerators for High-Performance Energy Conversion

Supakarn Worathat[a,f], Utchawadee Pharino[a,f], Kanokwan Chaithaweep[a,f], Sugato Hajra[b], Charalampos Pitsalidis[b], Noppawit Sukpan[c], Pongsakorn Kanjanaboos[c], Wanwilai Vittayakorn[d], Saichon Sriphan[a,e*] and Naratip Vittayakorn[a,f]

[a] *Advanced Materials Research Unit, School of Science, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand*
[b] *Department of Physics, Khalifa University of Science and Technology, Abu Dhabi, UAE Advanced Research and Innovation Center (ARIC), Khalifa University of Science and Technology, Abu Dhabi, UAE*
[c] *School of Materials Science and Innovation, Faculty of Science, Mahidol University, Nakhon Pathom, 73170 Thailand*
[d] *Department of Nanoscience and Nanotechnology, School of Integrated Innovative Technology, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand*
[e] *Faculty of Science, Energy and Environment, King Mongkut's University of Technology North Bangkok, Bangkok 10800, Thailand*
[f] *Department of Chemistry, School of Science, King Mongkut's Institute of Technology Ladkrabang, Bangkok, 10520, Thailand*

*Corresponding Author's E-mail: Saichon.s@sciee.kmutnb.ac.th and naratip.vi@kmitl.ac.th

**Abstract**

Triboelectric nanogenerators (TENGs) have emerged as a promising technology for harvesting ambient mechanical energy, with liquid-solid configurations (L-S TENGs) offering unique advantages in interface adaptability. However, conventional water-based systems are critically limited by inherent instability and low charge density, stemming from the weak electrical double layer governed by the Gouy-Chapman limit. Herein, we report a gallium liquid metal-solid triboelectric nanogenerator (Ga-LS TENG) that fundamentally overcomes these challenges. Unlike deionized (DI) water, gallium liquid metal (GLM) directly injects electrons into the triboelectric layer during contact electrification. This distinct mechanism enables exceptional output performance, yielding an open-circuit voltage ($V_{oc}$) of 384 V and a short-circuit current ($I_{sc}$) of 182 $\mu$A. Furthermore, the device demonstrates superior robustness and durability, a direct result of GLM unique properties, including its high metallic conductivity, non-volatility, and inherent freeze-resistance. This work establishes gallium liquid metal as a highly effective liquid phase for L-S TENGs, providing a clear pathway toward the development of high-performance and durable energy harvesting technologies suitable for demanding, real-world applications.

**Keywords:** Triboelectric nanogenerators (TENGs), Liquid-solid interface, Gallium liquid metal (GLM), Gouy-Chapman limit, Energy harvesting.

# Kinetic Analysis of Liquid–Solid Contact Electrification: Using Adsorption Models as Mechanistic Probes for Hybrid EDL Behavior

Kanokwan Chaithaweep[a,g], Utchawadee Pharino[a,g], Satana Pongampai[a,b], Saichon Sriphan[a,c], Thitirat Charoonsuk[d], Sugato Hajra[e], Wanwilai Vittayakorn[f], Tosapol Maluangnont[f] and Naratip Vittayakorn[a,g]*

[a]*Advanced Material Research Unit, School of Science, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand*
[b]*Department of Electronics Engineering, School of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok 1052 0, Thailand*
[c] *Faculty of Science, Energy and Environment, King Mongkut's University of Technology North Bangkok, Rayong Campus, Rayong 2112 0, Thailand*
[d]*Department of Materials Science, Faculty of Science, Srinakharinwirot University, Sukhumvit 23, Watthana, Bangkok 10110, Thai land*
[e]*Department of Physics, Khalifa University of Science and Technology, Abu Dhabi, UAE*
[f]*School of Integrated Innovative Technology, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand*
[g]*Department of Chemistry, School of Science, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand*

*Corresponding Author's E-mail: Naratip.vi@kmitl.ac.th

**Abstract**

Liquid–solid interfaces are central to technologies ranging from energy storage to triboelectric nanogenerators (TENGs). Whereas classical electric double layer (EDL) theory describes these interfaces mainly in terms of electrostatic ion adsorption, hybrid EDL concepts suggest that interfacial electron transfer may also contribute importantly to charge generation. However, the hybrid EDL model has so far been discussed primarily at a qualitative level or through complex theoretical and computational treatments, and a simple, experimentally accessible macroscopic kinetic handle that can discriminate, in operando, between adsorption-dominated and ET-influenced regimes remains lacking. By analyzing high-resolution charging dynamics over systematically varied $H_2SO_4$ and $HNO_3$ concentrations, a clear concentration-dependent kinetic transition is identified. At low ionic strengths, the charging process is described more effectively by pseudo-second-order (PSO) kinetics, consistent with a reaction-influenced interfacial step, whereas at higher concentrations the system becomes pseudo-first-order (PFO) dominated, consistent with transport- and ion-screening-controlled behavior. Although previous studies have provided compelling theoretical and spectroscopic evidence that interfacial electron transfer contributes to liquid–solid contact electrification in TENGs, these mechanisms have rarely been examined through such simple macroscopic kinetic formalisms. In this work, classical adsorption kinetic models are used as operational probes for distinguishing electron-transfer-influenced regimes from ion-transport-dominated regimes at PTFE/liquid interfaces. The PSO-to-PFO crossover reported here is interpreted within the hybrid EDL framework as a kinetic marker of a transition from an electron-transfer-influenced charging regime at low concentration to an ion-transport- and screening-dominated regime at high concentration, thereby demonstrating how adsorption kinetics can serve as a practical diagnostic language for liquid–solid triboelectric systems.

**Keywords:** liquid-solid contact electrification, liquid-solid interface, adsorption kinetic models, electron double layer (EDL), hybrid EDL model

# Liquid–Solid Interfacial Dynamics-Driven Performance Enhancement in Tube-Shaped Triboelectric Nanogenerators for Ocean Wave Energy Harvesting

Utchawadee Pharino[a], Yossaya Jaitam[a], Ananya Intharangsee[a], Sirinya Ukasi[a], Naratip Vittayakorn[a,*]

[a]*Advanced Materials Research Unit, School of Science, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand; Department of Chemistry, School of Science, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand*

*Corresponding Author's E-mail: naratip.vi@kmitl.ac.th

**Abstract**

Ocean waves represent a readily accessible source of renewable energy with high energy density; however, their low-frequency and irregular motion pose significant challenges for conventional energy-harvesting technologies. Liquid–solid tube-shaped triboelectric nanogenerators (L-S tube-TENGs) have emerged as promising candidates for harvesting low-frequency mechanical energy due to their high sensitivity to fluid motion. In this study, three distinct electrode configurations were systematically designed and investigated to enhance the electrical performance of tube-TENGs. A particular emphasis was placed on the examination of liquid motion behavior within the tubular structure, given the pivotal role that the dynamically changing L-S contact area plays in regulating the triboelectric charge transfer process. By correlating liquid dynamics with electrode arrangement, the influence of interfacial contact behavior on electrical output was elucidated, enabling optimization of the device structure for enhanced energy harvesting performance. The experimental results demonstrated that the optimized tube-TENG generated stable electrical output under low-frequency operation. At an operating frequency of 0.5 Hz, the device attained an instantaneous power density of 26 μW/cm$^2$. Furthermore, even at an ultra-low frequency of 0.25 Hz, the device exhibited a peak current of approximately 8.5 μA, thereby substantiating its capacity to harvest intermittent low-frequency mechanical energy. This work provides further insight into liquid–solid interfacial interactions in tubular TENG systems and offers an effective strategy for efficient ocean-wave energy harvesting.

**Keywords:** Liquid–solid triboelectrification, Triboelectric nanogenerator (TENG), Low-frequency mechanical energy, Ocean wave energy harvesting

# Complex formation of hybrid electron transport materials enabling high performance and photostability in organic photovoltaics

Patipan Sukpoonprom[a,b], William D.J. Tremlett[a], Zhuoran Qiao[a], Chitsanucha Chattakoonpaisarn[b], Eunyoung Hong[a], Beier Hu[a], Karen Forberich[c], Jianhua Han[d], Junyi Wang[a], Somlak Ittisanronnachai[e], Longren Li[a], Francesco Vanin[f], Pichaya Pattanasattayavong[b], Zonglong Zhu[f], Artem Bakulin[a], Christoph J. Brabec[c], Derya Baran[d], Nicholas J. Long[a,*], Nicola Gasparini[a,*]

[a]*Department of Chemistry and Centre for Processable Electronics, Imperial College London, London W12 0BZ, UK*
[b]*Department of Materials Science and Engineering, School of Molecular Science and Engineering, Vidyasirimedhi Institute of Science and Technology (VISTEC), Rayong 21210, Thailand*
[c]*Institute of Materials for Electronics and Energy Technology (I-MEET), Friedrich-Alexander-University Erlangen-Nuremberg, Erlangen 91058, Germany*
[d]*Materials Science and Engineering Program (MSE), Physical Sciences and Engineering Division (PSE), King Abdullah University of Science and Technology (KAUST), Thuwal 23955-6900, Saudi Arabia*
[e]*Frontier Research Center (FRC), Vidyasirimedhi Institute of Science and Technology (VISTEC), Rayong 21210, Thailand*
[f]*Department of Chemistry and Hong Kong Institute of Clean Energy, City University of Hong Kong, Kowloon 999077, Hong Kong, China*

*Corresponding Author's E-mail: n.long@imperial.ac.uk and n.gasparini@imperial.ac.uk.

**Abstract**

Nowadays, the development of organic photovoltaics (OPVs) has been focusing on rational molecular design for donors and acceptors (i.e., light absorption layer), resulting in the power conversion efficiency (PCE) exceeding 20%. To push the performance further, electron transport layers (ETLs) concurrently play a pivotal role in controlling both the efficiency and photo-thermal stability in OPVs. To fine-tune the properties of ETLs, ferrocene (Fc)-based molecules ($FcFk_2$ in Fig. 1) provide an effective route owing to their combination good electron mobility and versatile structures by metal or ligand tailoring. Herein, we explored hybrid organic-inorganic ETLs by forming complexes between typical electron transport materials and newly synthesized Fc derivatives. Experimental and theoretical investigations revealed strong interactions between the components, which allow for work function tuning to improve charge extraction properties and reduce trap-assisted recombination. This leads to significantly enhanced performance for various donor:acceptor blends and ETLs, with fill factor (FF) and PCE exceeding 80% and 19.7% (20.1% with an antireflective coating), respectively. Finally, we advanced towards real-world operation by showing improved photostability for the hybrid ETLs with OPV devices that retained 80% of their initial performance under operating conditions (ISOS-L-1I) up to 700 h. The enhancement of device efficiency and robustness via ferrocene-based hybrid ETLs provides a promising avenue to go beyond current state-of-the-art OPVs.

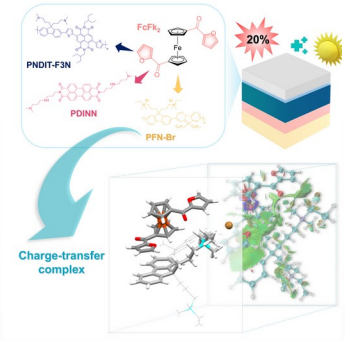



Fig.1 Graphical abstract shows the complex formation of ETLs with ferrocenyl-bis-furyl-2-ketone ($FcFk_2$), which is exploited in OPVs. (Ref. *Joule* **2025**, *9*, 102107)

**Keywords:** Organic photovoltaics, Electron transport layers, Ferrocene derivatives, Ferrocene-based solar cells

# Interfacial Charge Transfer toward Artificial Leaf Architectures Probed by Scanning Probe Techniques

He-Yun Du[a,b,c*], Kuei-Hsien Chen[d,e], Li-Chyong Chen[e,f,g]

[a]*Department of Chemical Engineering, Ming Chi University of Technology, New Taipei City, Taiwan*
[b]*Battery Research Center of Green Energy, Ming Chi University of Technology, New Taipei City, Taiwan*
[c]*R&D Centerof Biochemical Engineering Technology, Ming Chi University of Technology, New Taipei City, Taiwan*
[d]*Institute of Atomic and Molecular Sciences, Academia Sinica, Taipei, Taiwan*
[e]*Center for Condensed Matter Sciences, National Taiwan University, Taipei, Taiwan*
[f]*Department of Physics, National Taiwan University, Taipei, Taiwan*
[g]*Center of Atomic Initiative for New Materials, National Taiwan University, Taipei, Taiwan*

*Heyundu@mail.mcut.edu.tw

**Abstract**

Artificial leaf systems aim to integrate light absorption, charge separation, and catalytic conversion within compact material architectures. A central challenge in these systems is the control of interfacial charge transfer, which governs carrier separation efficiency and surface reaction kinetics. Understanding how local electronic structure and interfacial reconstruction influence charge-transfer behavior is therefore essential for rational material design.

In this study, we employ scanning probe techniques, including scanning electrochemical cell microscopy (SECCM) and related surface-sensitive methods, to investigate spatially resolved charge-transfer processes in layered semiconductor architectures designed for artificial leaf applications. Local current mapping reveals confined interfacial activity associated with band alignment and structural heterogeneity. Variations in layer thickness and stacking configuration lead to distinct charge-transfer pathways and reactivity patterns.

By directly correlating interfacial electronic behavior with functional performance, this work establishes a structure-interface-activity relationship relevant to artificial leaf design. The results demonstrate how advanced scanning probe approaches can provide mechanistic insight into charge separation processes, guiding the development of next-generation materials for solar-driven energy conversion.

**Keywords:** Artificial leaf, heterointerface, charge separation, scanning probe techniques

# Effect of Side Chain Modification on Performance of Organic Solar Cells

Amadou Barry*, Safakath Karuthedath

*Institute of Materials Research, Tsinghua Shenzhen International Graduate School, Tsinghua University 518055 China*

*Corresponding Author's E-mail: amdbl24@mails.tsinghua.edu cn

**Abstract:**

Side-chain engineering is an effective strategy to optimize voltage losses in non-fullerene acceptor (NFA) organic solar cells; however, the underlying mechanism linking side-chain modification to charge carrier dynamics remains insufficiently understood. Herein, we report systematic spectroscopic and morphological studies combined with device-physics investigations of three structurally related acceptors, Y6, Y6-2O, and Z19, blended with D18 to establish structure-property relationships and to elucidate key factors governing voltage-current balance in organic solar cells (OSCs). Through combined transient absorption spectroscopy, time-resolved photoluminescence, charge-transport analysis, and device-level characterization of D18-based blends, we systematically resolve how side chain-induced aggregation reshapes exciton formation, diffusion, and charge generation. While D18:Y6 systems deliver high performance, alkoxy substitution (Y6-2O) enhances the open-circuit voltage but simultaneously strengthens intermolecular aggregation, slows down charge generation, induces severe transport imbalance, and promotes trap-assisted recombination, resulting in drastic current drop and efficiency loss. In contrast, steric modulation in Z19 regulates aggregation dimensionality, restores favorable nanoscale intermixing and balanced carrier mobilities, and recovers high device efficiency approaching Y6-based cells while maintaining voltage gains. Our results reveal that performance losses in D18:Y6-2O systems arise predominantly from limitations in ultrafast charge generation rather than from bimolecular recombination at later timescales. We conclude that effective side-chain design must modulate energetics without inducing excessive aggregation, as observed in Y6-2O-based cells, while preserving efficient charge-transfer state dissociation and maintaining balanced transport pathways to suppress recombination, as demonstrated by Z19-based devices. This work establishes clear correlations between side-chain modification, charge-generation dynamics, and device performance in D18-based NFA systems, providing mechanistic insight into the voltage–current trade-off in high-performance organic solar cells.

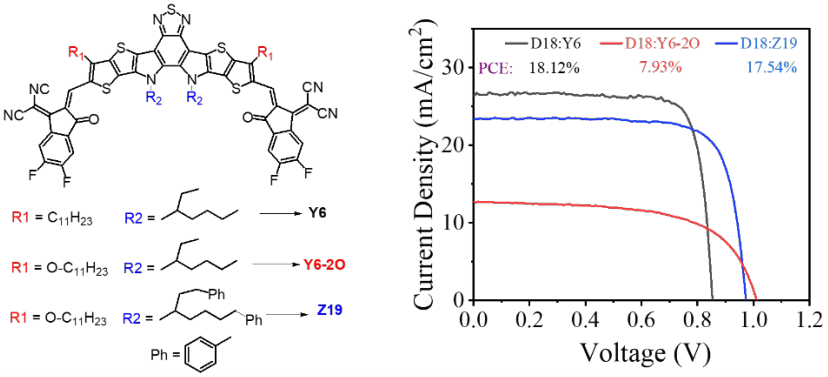



Fig.1: Chemical structures of the non-fullerene acceptors Y6, Y6-2O, and Z19 and the corresponding photovoltaic performance of D18:NFA blend solar cells.

**Keywords:** Organic solar cell, Side chain engineering, Charge generation, Transient absorption spectroscopy, Non-fullerene acceptors

# Short-wavelength infrared imaging with organic photodetectors based on non-fullerene acceptors with detection above 1200 nm

Zhuoran Qiao [a,*], Martin Heeney [b], Nicola Gasparini [a]

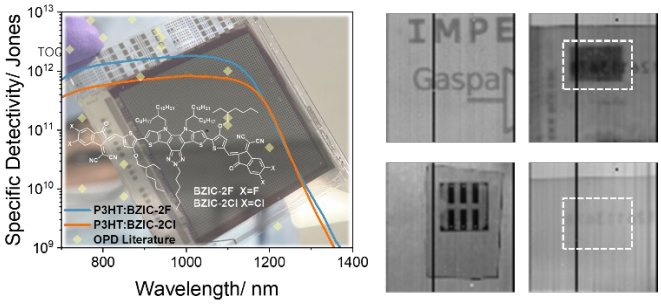
[a] *Department of Chemistry and Centre for Processable Electronics, Imperial College London, London, W12 0BZ, UK.*
[b] *King Abdullah University of Science and Technology (KAUST), Thuwal, 23955, Saudi Arabia.*

*Corresponding Author's E-mail: z.qiao20@imperial.com

**Abstract**

Solution-processable organic photodetectors (OPDs) have garnered significant interest due to their tunable optoelectronic properties, achieved by tailoring the chemical structures of photoactive materials[1]. Compared to donor-acceptor (D-A) conjugating polymers, which suffer from inherent high non-radiative losses and a high bandgap limit, non-fullerene acceptors (NFAs) can be the solution to these limitations via fine-tuning the frontier molecular orbitals. Among the light detection regions, short-wavelength infrared (SWIR, 1000-2500 nm) is crucial for health monitoring[2], night vision, biological imaging and invisible optical communication applications. However, to date, very few NFAs have been reported that can be incorporated into OPDs with a SWIR detection range.

In this work, we present two novel low-bandgap small-molecule NFAs, BZIC-2F and BZIC-2Cl. Designed with the aid of computer simulations, they exhibit remarkably low optical bandgap (1.2 and 1.1 eV, respectively) to be compatible with the scalable polymer donor P3HT, to obtain broadband photodetectors able to detect light in the 300-1200 nm region with record specific detectivity of $1.82\times10^{12}$ Jones at 1010 nm under -2V. The optimized SWIR OPDs based on these two NFAs, to our best knowledge, feature state-of-the-art performance, with exceptionally high EQE values of 60% at 1010 nm (surpassing commercially available Si detectors) and 37% at 1030 nm under -2V bias. Furthermore, OPDs with a blade-coated active layer exhibited superior stability over 3 million on/off cycles in ambient conditions and potential applications in health monitoring. Lastly, for the first time, we demonstrated a prototypical 64*64 active-matrix imager with SWIR detection range, which can be used for fast image reading (faint NIR/SWIR light detection, LiDAR signal visualization, Si wafer non-invasive detection), human vein recognition and banknote verification.




**Keywords:** organic photodetector, non-fullerene acceptor, short-wavelength infrared, active-matrix imager

1 Nodari, D. *et al.* Towards high and reliable specific detectivity in visible and infrared perovskite and organic photodiodes. *Nature Reviews Materials* (2025).
2 Jacoutot, P. *et al.* Enhanced sub-1 eV detection in organic photodetectors through tuning polymer energetics and microstructure. *Sci Adv* **9**, eadh2694 (2023).

# From Charge Collection Narrowing to Photomultiplication: Unconventional Strategies to Enhance NIR/SWIR Detection in Organic Photodetectors

Matilde Brunetta[a,b*], Bob C. Schroeder[b], Nicola Gasparini[c**]

[a]*Department of Materials, Molecular Science Research Hub, Imperial College, London W12 0BZ, UK* [b]*Department of Chemistry, University College London, 20 Gordon Street, London WC1H 0AJ, UK* [c]*Department of Chemistry and Centre for Processable Electronics, Imperial College London, W12 0BZ, UK* *Presenting author () **Corresponding author ()

**Abstract**

Charge collection narrowing (CCN) and photomultiplication (PM) are two promising strategies employed in organic photodetectors (OPDs) to assist near-infrared (NIR) and short-wave infrared (SWIR) detection. The two approaches are based on completely different processes, with CCN being imposed via thick bulk heterojunctions (BHJs) allowing only sub-bandgap photons to be extracted, resulting in spectrally selective OPDs without need for input filtering. PM effect, instead, is a method used to achieve external quantum efficiencies (EQEs) above unity by adopting unbalanced donor:acceptor ratios in the BHJ and exploiting trap-assisted charge tunnelling injection at higher reverse bias. Despite both being already established practices in literature, their mechanism is still under discussion leaving plenty of room for exploration. Here, we present a novel low bandgap random copolymer (ranDPP-2TBT) used as a donor material in OPDs. RanDPP-2TBT was blended with non-fullerene (NFA) acceptor IEICO-4F to obtain CCN OPDs with a specific detectivity of $10^{11}$ Jones at -2V at 916 nm and a spectral response window as narrow as 68 nm (full-width-at-half-maximum). This was achieved with an active layer thickness of only 1 µm, among the lowest in literature for CCN OPDs. Finally, we demonstrate the first application of a CCN-derived OPD as a real-time contactless heart rate monitoring device based on photoplethysmography (PPG). Secondly, we introduce PM-OPDs utilizing an equal donor:acceptor ratio in the BHJ, changing the common understanding of PM-OPDs. NIR polymer TQ-3T was used with NFA Y6. PM-OPDs with EQE of above 1100% at 840 nm and 31% at 1100 nm at -10 V, and fast response times of 73 µs were achieved. We also demonstrate ultrathin (<3 µm) flexible PM-OPDs with a stable dark current density after 1000 bending cycles. Finally, we demonstrate an application of the PM-OPD as a flexible and pulse oximeter and large-area image sensor for accurate vein recognition.

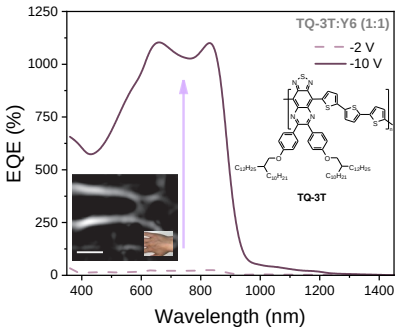



Fig. 1 EQE spectrum of PM-OPDs based on TQ-3T:Y6 BHJ, including TQ-3T chemical structure and imaging of veins from TQ-3T:Y6 based image sensor

**Keywords:** Charge collection narrowing, Photomultiplication, Organic Photodetector, IR detection, Biomedical sensor

# Light emitting materials based on oxygen-bridged triphenylamine polymers for optoelectronic applications

Patthira Sumsalee[a,b], Yusei Kaya[b], Chihaya Adachi[b,c], Lydia Sosa Vargas[a,*] Fabrice Mathevet[a,b,c,*]

[a]*Sorbonne Université, CNRS, Institut Parisien de Chimie Moléculaire, Paris 75005, France*
[b]*Center for Organic Photonics and Electronics Research (OPERA), Kyushu University, Fukuoka 819-0395, Japan*
[c]*Organic Photonics and Electronics International Laboratory (OPHELIA), CNRS-Kyushu University, IRL 2043, Fukuoka 819-0395, Japan*

*Corresponding Author's E-mail: fabrice.mathevet@sorbonne-universite.fr and Lydia.sosa-vargas@sorbonne-universite.fr

## Abstract

The partial functionalization of triphenylamine (TPA) scaffolds with oxo-bridges yields light-emitting quasi-planar structures with enhanced molecular rigidity and effectively restricts intramolecular rotational motion.[1] In this work, we designed and synthesized side-chain homopolymers based on a polymethyl methacrylate (PMMA) backbone incorporating these emissive, oxygen-bridged TPA scaffolds, which were previously decorated with linear or branched alkyl substituents to improve solubility. The chemical structures of the two obtained polymers, namely **TPA-L1** and **TPA-B1** respectively, were investigated, and the influence of the steric hindrance of the alkyl groups on polymerization behavior and the resulting material properties was evaluated. Notably, this variation significantly affected the degree of polymerization, emphasizing the important role of steric effects in chain growth. Photophysical studies reveal that the rigidified quasi-planar structure contributes to enhanced emission efficiency. Among the studied systems, **TPA-L1** exhibits photoluminescence quantum yields (PLQYs) of up to 40% in toluene solution and 39% in doped films. Furthermore, these oxygen-bridged triphenylamine polymers, which exhibit donor characteristics, were combined with an organoboron polycyclic aromatic hydrocarbon (PAH) acceptor, **BOCN**, to form thermally activated delayed fluorescence (TADF) exciplexes, and their intermolecular donor-acceptor interactions in the solid state were probed.[2,3] These results demonstrate the importance of structural design and side-chain engineering in tuning the polymerization and photophysical properties of quasi-planar TPA-based polymers. The polymeric exciplex emitters showed a PLQY of up to 29%, and their electroluminescence properties were investigated when employed as the emissive layer (EML) in solution-processed organic light-emitting diodes (OLEDs).

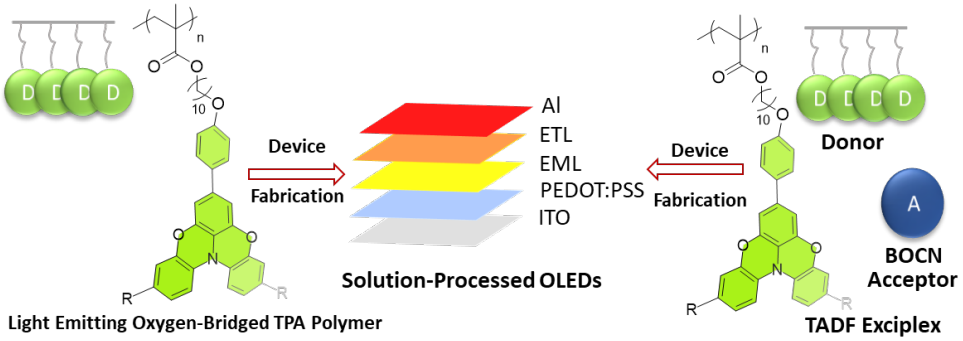



**Figure 1**. Chemical structures of the oxygen-bridged, triphenylamine-based homopolymers and an illustration of a solution-processed OLED device architecture.

[1] Wakamiya, A.; Nishimura, H.; Fukushima, T.; Suzuki, F.; Saeki, A.; Seki, S.; Osaka, I.; Sasamori, T.; Murata, M.; Murata, Y.; Kaji, H. *Angew. Chem. Int. Ed.* **2014**, *53,* 5800-5804.
[2] Uoyama, H.; Goushi, K.; Shizu, K.; Nomura, H.; Adachi, C. *Nature*, **2012**, *492*, 234-238.
[3] Li, J.; Nomura, H.; Miyazaki, H.; Adachi C. *Chem. Commun.*, **2014**, *50*, 6174-6176.

**Keywords:** Polymer, materials, exciplex, TADF, OLEDs

# Triplet–Charge Annihilation Governs Recoverable Thermal Degradation in Organic Solar Cells

Yexiao Huang [a], Safakath Karuthedath [a*]

[a] *Institute of Materials Research, Tsinghua Shenzhen International Graduate School, Tsinghua University, Shenzhen, 518055 China.*

*Corresponding Author's E-mail: safakath@sz.tsinghua.edu.cn

**Abstract**

Thermal degradation in organic solar cells (OSCs) leads to pronounced voltage losses that limit device stability and practical deployment. Understanding whether these losses arise from reversible or irreversible processes is therefore crucial. Here, we investigate a partially reversible thermal degradation pathway in both bilayer and bulk-heterojunction (BHJ) OSCs using PBQx-TF:eC9-2Cl as a model system. Transient absorption (TA) spectroscopy reveals that thermal aging (70 °C, 6 h) accelerates triplet exciton formation and enhances bimolecular recombination via triplet–charge annihilation. In contrast, subsequent exposure to ambient air (1 h) suppresses the triplet generation and reduces the recombination losses. Kelvin probe force microscopy (KPFM) shows a reversible shift in interfacial vacuum levels after aging and air exposure, consistent with the recovery of device performance, while atomic force microscopy–infrared spectroscopy (AFM-IR) confirms more stable nanoscale morphology in bilayer films. Importantly, similar recovery behavior is also observed in high-performance systems including PM6:Y6 and D18:BTP-eC9. These results identify triplet exciton dynamics and interfacial energetics as coupled mechanisms governing recoverable thermal degradation in OSCs. The recovery is not repeatable, as device performance declines monotonically after a second aging cycle. Controlled air exposure therefore mitigates thermally induced voltage losses and provides design insights for air-processable organic photovoltaics.

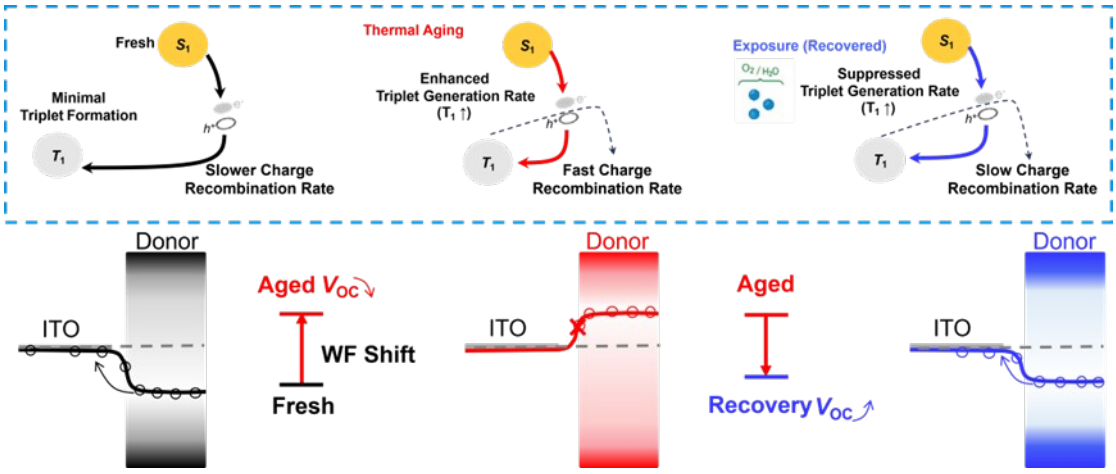



Fig 1. Schematic illustration of the excited-state processes and interfacial energy-level evolution in the fresh, thermally aged, and recovered conditions.

**Keywords:** Reversible degradation, Thermal degradation, Non-fullerene acceptors, Bilayer organic solar cells, Triplet-charge annihilation, Charge carrier dynamics

# Tailoring crystallization in hybrid metal organochalcogenide semiconductors: From large structures to nanocrystals

Watcharaphol Paritmongkol[a,*]

[a]*Department of Materials Science and Engineering, School of Molecular Science and Engineering, Vidyasirimedhi Institute of Science and Technology (VISTEC), Rayong, Thailand*

*Corresponding Author's E-mail: watcharaphol.p@vistec.ac.th

**Abstract**

Crystallization is fundamental to the development of semiconductors that underpin modern technologies. While traditional methods cater to purely inorganic or organic semiconductors, hybrid organic-inorganic materials often face challenges due to their low thermal stability and poor solvent compatibility. This talk highlights our advancements in tailoring crystallization in metal chalcogenide semiconductors, focusing on large-scale structures and nanocrystals.

In one study, we address the long-standing solubility challenge of metal organochalcogenides (MOCs), a promising class of hybrid semiconductors. By leveraging poly-dentate amine solutions, we achieve solution-based single-crystal growth of 15 MOC species, including eight novel compounds with diverse structures and substituents. Single-crystal X-ray diffraction reveals a structural correlation with substituent positions, and spectroscopic studies elucidate the dissolution mechanism, involving fragmentation into polymeric units driven by nitrogen-lone pair interactions. This work enables a pathway for crystallizing previously insoluble MOCs, expanding their structural and functional applications.

Complementing this, our second study pioneers a rapid, scalable synthesis of MOC nanocrystals. Using a hot-injection method, we produce silver phenylselenide nanocrystals in with a ~70% yield, demonstrating tunable sizes from 50 nm to 10 μm. These nanocrystals exhibit long-term colloidal stability, high thermal resilience, and ease of film fabrication for device integration. Optical and electronic studies reveal bandgap tunability, strong p-type behavior, and a hole mobility of $4.48 \times 10^{-2}$ $cm^2 \cdot V^{-1} \cdot s^{-1}$, rivaling top-performing inorganic hole-transporting materials.

These findings underscore the transformative potential of MOCs, from designing large single crystals to engineering nanoscale materials for advanced electronics.

**Keywords:** Hybrid organic-inorganic semiconductors, crystallization, single crystals, nanocrystals, hole mobility

# Efficient Non-Doped Deep Red to Near-Infrared (NIR) Fluorescent OLEDs Using *o*-Hydroxyphenylphenanthroimidazole-Indandione Derivatives *via* ESIPT Mechanism

Pongsupradit Y.[a], Wongkaew P.[a], Saenubol P.[a], Rueantong K.[a], Sudyodsuk T.[a], Promarak V.[a,*]

[a]*School of Molecular Science and Engineering, Vidyasirimedhi Institute of Science and Technology (VISTEC), Wangchan, Rayong 21210, Thailand*

Presenter's E-mail: yanisa.p_s23@vistec.ac.th
Corresponding Author's E-mail: vinich.p@vistec.ac.th

**Abstract**

Long-wavelength organic light-emitting diodes (OLEDs) emitting in the deep red and near-infrared (NIR) regions are critical for bio-imaging, phototherapy, and optical telecommunications. Achieving efficient non-doped devices at these wavelengths remains challenging due to the energy gap law and aggregation-caused quenching (ACQ). This work presents a novel series of deep red to near-infrared (NIR) fluorophores that overcome these barriers through excited-state intramolecular proton transfer (ESIPT). The ESIPT with unique photophysical features of large Stokes-shifted fluorescence emission as non-doped emitters for fluorescent OLEDs would make a perfect counterpart since the non-self-absorbing fluorescent emission, unlike most organic fluorophores, can help to avoid unwanted self-reabsorption of the emitted light, leading to improved efficiency. By coupling a series of *o*-hydroxyphenyl phenanthroimidazole (*o*-HPI) as ESIPT and proton-donor cores with a 1,3-indandione electron-withdrawing moiety, a strong intramolecular charge-transfer (ICT) character is achieved, driving significant bathochromic emission shifts. We demonstrate that ortho-substitution geometry plays a decisive role as it simultaneously modulates ICT extent and suppresses detrimental intermolecular π–π stacking in thin films, effectively mitigating ACQ without requiring a host matrix. Photophysical characterization and DFT calculations confirm the ESIPT mechanism, and material characterizations reveal emission color and quantum yield. The optimized non-doped devices exhibit tunable electroluminescence across the deep red and NIR regions. The NIR device achieves peak emission at 706 nm with a maximum external quantum efficiency ($EQE_{max}$) of 2.06% and a low turn-on voltage of 2.8 V. The deep red device delivers high color purity emission at 656 nm (CIE: 0.673, 0.324) with an $EQE_{max}$ of 4.61%. These findings establish *o*-HPI-based ESIPT emitters as a versatile platform for long-wavelength OLEDs. The dual function of ortho-substitution in enabling deep red/NIR emission while suppressing ACQ offers a clear and transferable molecular design principle for next-generation non-doped electronic materials.

**Keywords:** OLEDs, NIR emission, ESIPT, o-hydroxyphenylphenanthroimidazole, non-doped devices

# Development of Photocatalytic Platforms via Integration of Plasmonic Nanoparticles with Double-Network Hydrogels

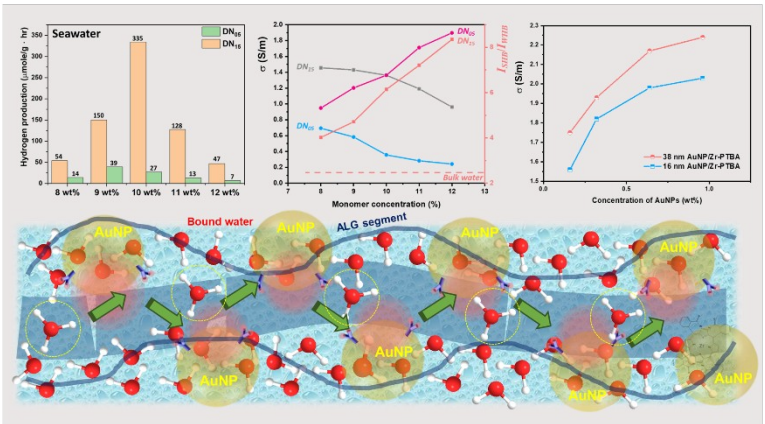
Jrjeng Ruan*, Chen-Yi Hsueh

*Department of Materials Science and Engineering, National Cheng Kung University, Tainan,701, Taiwan*

*jrjeng@mail.ncku.edu.tw

**Abstract**

While contemporary research on photocatalytic water splitting predominantly focuses on catalyst designs, critical environmental impacts, specifically water status, and ionic transportation, remain largely unnoticed. Beyond the conventional "catalyst-centric" approach, this research investigates the critical impacts of water statuses on the efficiency of photocatalytic water splitting and engineers an alginate/polyacrylamide double-network (DN) hydrogel with the dispersion of plasmonic nanoparticles as a functional platform for photocatalytic seawater splitting. Within the polyacrylamide covalent network, the ionic alginate networks act not merely as a passive scaffold for water inclusion, but also an active regulator of water thermodynamic statuses. The hydrogel densification via adopted structural engineering is found able to efficiently enhance the ratio of strongly hydrogen-bonded (SHB) water, which has been newly unveiled as a facile proton source However, the achieved hydrogel densification unavoidably promotes steric hindrance for proton transportation in the form of hydronium ions. Unveiled as the rate-determining step for hydrogen production within hydrogels, the efficient proton supply to catalytically active sites is needed together with the abundance of proton-generating SHB waters. Therefore, a dilemma related to hydrogel confinement emerges. Surprisingly, the spread of local surface plasmon resonance-induced electric fields of dispersed plasmonic nanoparticles has been newly unveiled to evolve "proton-transportation highways" within hydrogels. As restricted proton transportation is successfully decoupled from efficient proton generation via hydrogel densification, a remarkable hydrogen evolution rate of 604 μmol $g^{-1}$ $h^{-1}$ has been achieved upon the splitting of seawaters confined within hydrogel platforms with dispersed catalysts, superior to that via the splitting of non-confined seawaters.




**Keywords:** photocatalytic water splitting, plasmonic nanoparticles, double-network hydrogels, water status, ionic conductivity.

# $SiO_2$ Interfacial Layer For The Improved Photodiode Properties of Silicon Schottky Diodes.

M.M. Ntobeng[a],[*], J. O. Bodunrin[a], S. J. Moloi[a]

[a]*Department of Physics, College of Science, Engineering and Technology, University of South Africa, Private Bag X6, Florida, 1 710, South Africa.*

*Corresponding Author's E-mail: moloisj@unisa.ac.za (S.J. Moloi)

**Abstract**

This study explores the use of a $SiO_2$ interfacial layer in a Schottky diode to suppress unfavourable properties of the formed interface states. The deposition of the $SiO_2$ layer improves the electrical properties of the device by reducing the interface state density. Before device fabrication, the following material characterisations, Raman, scanning electron microscopy (SEM), and energy-dispersive X-ray spectroscopy (EDS) were used, to measure the layer thickness, and investigate the elemental composition, and molecular structure of the deposited layer. Electrical characterizations were performed through current–voltage (I–V) and capacitance–voltage–frequency (C–V–f) measurements under both forward and reverse bias conditions after fabrication. The obtained results showed a reduction in interface state density ($N_{SS}$) leading to improved device performance. Overall, the results are an indication that $SiO_2$ serves as an effective interfacial layer for suppressing interface states, thereby enhancing the performance and reliability of Ni/n-Si Schottky diodes.

**Keywords:** Silicon, $SiO_2$, Capacitance – Voltage – Frequency , Current– Voltage

# Secondary Ammonium-Mediated 2D/3D Heterointerface Reconstruction for Stable Perovskite Solar Cells

Chukwuebuka Emmanuel Usulor[1,2], * Woraprom Passatorntaschakorn[2,3], Sukhanidhan Singh[2,3], Warunee Khampa[3], Wongsathon Musikpan[3], Isaac Chinaza Ogbuagu[2], Nattawut Kamjam[5], Athipong Ngamjarurojana[2], Pisist Kumnorkaew[4], Anusit Kaewprajak[4], Pongsakorn Kanjanaboos[5], Pipat Ruankham[2,3,6], Duangmanee Wongratanaphisan[2,3,6 , *]

[1]*Graduate Ph.D. Degree Program in Physics, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[2]*Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[3]*Materials Science Research Center, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[4]*National Nanotechnology Center (NANOTEC), National Science and Technology Development Agency (NSTDA), 111 Thailand Science Park, Pathum Thani 12120, Thailand*
[5]*School of Materials Science and Innovation, Faculty of Science, Mahidol University, Nakhon Pathom 73170, Thailand*
[6]*Thailand Center of Excellence in Physics (ThEP Center), Ministry of Higher Education, Science, Research and Innovation, Bangkok 10400, Thailand*

*Email: duangmanee.wong@cmu.ac.th

**Abstract**

Metal-halide perovskites are highly promising materials for next-generation photovoltaic devices. The performance and stability of perovskite solar cells (PSCs) depend critically on the crystalline quality of the perovskite layer and its interfaces with charge transport layers. Surface defects often degrade interfacial quality, reducing both efficiency and stability, and are typically mitigated through surface passivation. Here, post-surface treatment of 3D perovskites with the secondary amine dibutylammonium bromide (DBABr) induces the formation of a 2D Ruddlesden-Popper perovskite phase, enabling dimensional engineering. The optimized DBABr concentration produced a defect-suppressed morphology with enhanced crystallinity, reduced ion migration, and improved energy level alignment. Photovoltaic devices showed a notable increase in power conversion efficiency, from 13.82% to 15.52%, under standard 1 sun illumination (AM1.5G, 100 mW $cm^{-2}$). Similarly, under indoor illumination (6500 K LED), efficiency improved. The combined protection of the hydrophobic carbon electrode and the 2D perovskite layer allowed devices to retain 91% of their initial PCE after 1000 hours under ambient conditions (30-35% RH). This approach provides a simple and effective strategy to enhance both the performance and long-term stability of PSCs.

Keywords: dibutylammonium bromide, perovskite solar cells, dimensional engineering, indoor photovoltaics.

# Bridging Small-Molecule Adducts and Macromolecular Topology to Engineer Stable Perovskite Halide under Ambient Conditions

Rongrong Cheacharoen[a,*], Chinnatip Harnmanasvate[b], Rico Meitzner[c], Rungroj Chanajaree[a], Eva Unger[c], Nopporn Rujisamphan[d], Yuxin Liu[e], Yaoguang Rong[f]

[a]*Metallurgy and Materials Science Research Institute, Chulalongkorn University, Bangkok 10330, Thailand*
[b]*International Graduate Program of Nanoscience & Technology, Chulalongkorn University, Bangkok 10330, Thailand*
[c]*Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin 14109, Germany*
[d]*Faculty of Science, King Mongkut's University of Technology Thonburi, Bangkok 10140, Thailand*
[e]*Institut für Chemie & IRIS Adlershof Humboldt-Universität zu Berlin, Berlin 12489, Germany*
[f]*School of Chemistry, Chemical Engineering and Life Sciences, Wuhan University of Technology, Wuhan 430070, China*

*Corresponding Author's E-mail: Rongrong.C@chula.ac.th

**Abstract**

To overcome the commercial barriers imposed by inert-atmosphere fabrication, advancing robust ambient processing techniques for perovskite photovoltaics is essential. Herein, we present a sequential materials engineering approach, beginning with the use of urea to resolve precursor instability. Supported by Density Functional Theory (DFT), we show that carbonyl-lead halide coordination generates a thermodynamically stable intermediate adduct. This mechanism effectively suppresses premature turbidity and promotes the formation of large, dense crystalline grains exceeding 1 μm. Building upon this foundation, we explored the influence of macromolecular topology on crystallization kinetics by comparing linear amylose and branched amylopectin additives. Real-time tracking via in-situ photoluminescence (PL) revealed that the linear architecture of amylose selectively dictates vertically oriented crystal growth while simultaneously passivating interfacial defects to minimize non-radiative losses. Integrating these strategies enabled the ambient, high-humidity fabrication of all-solution-processed carbon-based perovskite devices, achieving peak efficiencies of 16.2% alongside a twofold enhancement in T80 operational lifetime. To thoroughly validate this enhanced durability, we will also present our recently customized in-house stability testing apparatus, which is engineered to execute standard ISOS protocols and elucidate the underlying mechanisms of device degradation under operational conditions. Ultimately, this research provides a scalable framework for the green manufacturing of advanced photovoltaics. Paired with our ongoing innovations in eco-friendly rechargeable batteries, this work advances our broader commitment to developing safe, sustainable energy technologies in alignment with multiple UN Sustainable Development Goals.

**Keywords:** Perovskite Solar Cells; Ambient Fabrication; Bio-inspired Additives; Macromolecular Templating; Operational Stability

# $Cu_2O$-MIL-53(Al) Metal–Organic Framework Nanocomposite Surface Passivation for Stable Perovskite Solar Cells

Sorrawit Meeklinhom[a], Madsakorn Towannang[b], Chalita Ratanatawanate[a], Kitiphat Sinthiptharakoon [a], Anusit Kaewprajak[a], Pisist Kumnorkaew[a,*]

[a] *National Nanotechnology Center (NANOTEC), National Science and Technology Development Agency (NSTDA), 111 Thailand Science Park, Pathum Thani, 12120, Thailand*

[b] *Thailand Center of Excellence in Physics (ThEP center), Ministry of Higher Education, Science, Research and Innovation, Bangkok, 10400, Thailand*

*Corresponding Author's E-mail: pisist@nanotec.or.th

**Abstract**

Perovskite solar cells offer strong potential for next-generation photovoltaics, but interfacial defects, residual $PbI_2$, and non-radiative recombination still limit their efficiency and stability. Here, we introduce $Cu_2O$MIL-53(Al) metal–organic framework nanocomposites (CuM) as a simple surface passivation layer for n-i-p perovskite solar cells. The CuM layer, deposited by spin coating onto the perovskite surface, improves film quality, reduced the relative $PbI_2$ defects, and enhances interfacial charge transport at the perovskite/hole-transport-layer interface. Photoluminescence, time-resolved photoluminescence, electrochemical impedance spectroscopy and IMPS analyses confirm reduced recombination and faster carrier transport. The optimized device using 0.075 mg/mL CuM achieved a power conversion efficiency of 20.25% and negligible hysteresis. Moreover, the unencapsulated device retained over 96% of its initial efficiency after 1000 h under ambient humidity. These results demonstrate CuM surface passivation as a facile and scalable strategy for developing efficient and stable perovskite solar cells.

**Keywords:** Perovskite solar cells, Metal-organic frameworks, $Cu_2O$-MIL-53(Al) nanocomposite, Surface passivation

# $CsPbBr_3$ Quantum Dots for Efficient and Stable Carbon-Based Perovskite Solar

Isaac Chinaza Ogbuagu[a], Woraprom Passatorntaschakorn[b], Chukwuebuka Emmanuel Usulor[a], Warunee Khampa[b], Wongsathon Musikpan[b], Athipong Ngamjarojana[a], Pipat Ruankham[a], and Duangmanee Wongratanaphisan[a,b,c,*]

[a] *Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[b] *Materials Science Research Center, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[c] *Thailand Center of Excellence in Physics (ThEP Center), Ministry of Higher Education, Science, Research and Innovation, Bangkok 10400, Thailand*

*Email: duangmanee.wong@cmu.ac.th

**Abstract**

Carbon-electrode perovskite solar cells (C-PSCs) are promising for low-cost and stable photovoltaic applications, but their performance is often limited by interfacial defects and inefficient charge extraction at the perovskite/hole transport layer interface. In this work, $CsPbBr_3$ quantum dots were synthesized through a simple one-step ligand-assisted method and introduced as interfacial modifiers to improve the performance of C-PSCs. The $CsPbBr_3$ quantum dots effectively modulate the perovskite surface, promote charge extraction, and suppress interfacial recombination, leading to enhanced device efficiency and stability. Compared with the control devices, the modified C-PSCs show improved photovoltaic performance, including higher power conversion efficiency, better charge transport behavior, and more stable device operation. The improvement is attributed to the favorable interfacial interaction between $CsPbBr_3$ quantum dots and the perovskite absorber, which helps reduce defect-assisted losses and strengthen the charge extraction pathway toward the carbon electrode. These results demonstrate that $CsPbBr_3$ quantum dots provide a simple and effective strategy for improving carbon-based perovskite solar cells and offer a practical route toward stable, low-cost photovoltaic devices.

**Keywords:** $CsPbBr_3$ quantum dots; one-step ligand synthesis; carbon-based perovskite solar cells, interfacial modification.

# Effect of activation strategy on the electrochemical performance of silk cocoon derived carbon for supercapacitor applications

Suritno Fayanto[a], Wassana Wannabut[b], Pawinee Klangtakai[b,c*]

[a]*Material Science & Nanotechnology Program, Department of Physics, Khon Kaen University, Khon Kaen, 40002, Thailand*
[b]*Department of Physics, Faculty of Science, Khon Kaen University, Khon Kaen, 40002, Thailand*
[c]*Institute of Nanomaterials Research and Innovation for Energy (IN-RIE), Khon Kaen University, 40002, Thailand*

*Corresponding Author's E-mail: pawinee@kku.ac.th

**Abstract**

The development of sustainable electrode materials is essential to enhance the electrochemical performance of supercapacitors while reducing dependence on fossil-based carbon sources. This study investigates the effect of activation strategy on the electrochemical performance of carbon derived from silk cocoon (Bombyx mori L.) biomass. The precursor was cleaned, dried, and carbonized at 500–1000 °C under a nitrogen atmosphere. Two activation approaches were employed: self-activation without chemical additives and chemical activation using NaCl as a mild activating agent prior to heat treatment. The obtained carbons were ground and directly used as working electrodes. Structural characterization by X-ray diffraction (XRD) revealed broad diffraction peaks at $2\theta \approx 20–30°$, corresponding to the (002) and (100) planes, indicating predominantly amorphous carbon with improved structural ordering at elevated temperatures (700–900 °C). Electrochemical performance was evaluated in 6 M KOH using a three-electrode configuration through cyclic voltammetry (CV) and galvanostatic charge–discharge (GCD) measurements. The self-activated sample at 900 °C exhibited optimal and stable behavior at 1 A $g^{-1}$, delivering a specific capacitance of 76.83 F $g^{-1}$. In contrast, the NaCl-activated carbon at 700 °C demonstrated good performance, achieving 101.58 F $g^{-1}$ at 0.5 A $g^{-1}$ and retaining 43.33 F $g^{-1}$ at 20 A $g^{-1}$. CV analysis revealed a maximum specific capacitance of 101.74 F $g^{-1}$ at 5 mV $s^{-1}$. These results confirm that activation strategy and carbonization temperature critically govern the electrochemical behavior of silk cocoon-derived carbon, with NaCl activation offering enhanced capacitive performance and rate capability

**Keywords:** NaCl, activated carbon, silk cocoon, supercapacitor

# Investigation of the charge storage mechanism of hydrothermally synthesized cobalt sulfides in supercapacitors

Jiraphong Sararat[a], Pawinee Klangtakai[b,*]

[a]*Department of Physics, Faculty of Science, Khon Kaen University, Khon Kaen, 40002, Thailand*
[b]*Institute of Nanomaterials Research and Innovation for Energy (IN-RIE), Khon Kaen University, Khon Kaen 40002, Thailand*

*Corresponding Author's E-mail: *pawinee@kku.ac.th (Pawinee Klangtakai)

**Abstract**

Cobalt sulfides have attracted significant attention as electrode materials for supercapacitors due to their multiple oxidation states, which enable redox reactions and high theoretical specific capacitance (2356 F $g^{-1}$). In this study, cobalt sulfides were hydrothermally synthesized at 200 °C for 24 h using deionized water (DI), ethanol (ET), and a mixed solvent of DI and ET (DIET). All obtained powders were subsequently ball-milled and denoted as CS_DI, CS_ET, and CS_DIET according to the solvent used. X-ray diffraction analysis revealed that CS_DI, CS_ET, and CS_DIET consisted of mixed $CoS/CoS_2$ phases, mixed $CoS/Co_9S_8$ phases, and pure CoS phases, respectively. CS_ET exhibited the smallest particle sizes (0.83 ± 0.46 µm) and the highest specific surface areas (16.51 $m^2$ $g^{-1}$). Electrochemical measurements demonstrated specific capacitances of 1086.92 F $g^{-1}$ (CS_DI), 1866.75 F $g^{-1}$ (CS_ET), and 1513.17 F $g^{-1}$ (CS_DIET). To clarify the charge-storage mechanism, surface and chemical-state analyses were performed. Energy-dispersive X-ray spectroscopy and X-ray photoelectron spectroscopy indicate that charge storage is dominated by a reversible Faradaic redox process. During charging, $OH^-$ ions penetrate the $CoS/Co_9S_8$ structure and oxidize $Co^{2+}$ to $Co^{3+}$. During discharge, the reverse process occurs: $OH^-$ ions are released, and $Co^{3+}$ is reduced back to $Co^{2+}$. The mixed-phase structure of $CoS/Co_9S_8$ facilitates this redox transition by providing multiple electroactive sites and improved ion diffusion pathways. These findings clarify the relationship between phase composition and charge storage behavior in hydrothermally synthesized cobalt sulfides.

**Keywords:** cobalt sulfides; charge storage mechanism; hydrothermal synthesis; mixed phases; supercapacitors

# Effect of cobalt incorporation on the structural evolution and electrochemical performance of $Ni(OH)_2$ for high-performance supercapacitor electrodes

Phatcharin Phumuen[a], Pisist Kumnorkaew[b], Ekkaphan Sawatsitang[a], Pawinee Klangtakai[a,c,*], Samuk Pimanpang[d], Vittaya Amornkitbamrung[a,c]

[a]*Department of Physics, Faculty of Science, Khon Kaen University, Khon Kaen, 40002, Thailand,*
[b]*National Nanotechnology Center (NANOTEC), National Science and Technology Development Agency (NSTDA), 111 Thailand Science Park, Pathum Thani 12120, Thailand,*
[c]*Institute of Nanomaterials Research and Innovation for Energy (IN-RIE), Khon Kaen University, Khon Kaen 40002, Thailand,*
[d]*Department of Physics, Faculty of Science, Srinakharinwirot University, Bangkok, 10110, Thailand*

*Corresponding Author's E-mail: pawinee@kku.ac.th

**Abstract**

Supercapacitors are attractive energy storage devices owing to their high-power density and rapid charge–discharge capability. $Ni(OH)_2$ is a well-known pseudocapacitive material with high theoretical capacitance; however, its poor electrical conductivity and structural instability during cycling limit its performance. In this work, the effect of cobalt incorporation on the structural and electrochemical properties of $Ni(OH)_2$ was systematically investigated. Cobalt-modified $Ni(OH)_2$ samples were synthesized via a hydrothermal method at 150 °C for 24 h with various Ni:Co molar ratios (1:1-7:0). X-ray diffraction analysis showed that the sample with a Ni: Co ratio of 2:1 to 6:1 contained mixed phases of α-$Ni(OH)_2$ and $Ni_{2/3}Co_{1/3}(CO_3)_{1/2}(OH)\cdot 0.11H_2O$, whereas the 1:1 and 7:0 displayed single-phase structures. Field-emission scanning electron microscopy revealed rod-like morphologies for cobalt-containing samples, with reduced rod dimension at higher Ni content, while pure $Ni(OH)_2$ exhibited plate-like particles. Among all compositions, the Ni:Co_6:1 powder exhibited the highest specific surface area (291.63 $m^2\ g^{-1}$) and delivered an outstanding specific capacitance of 892.66 F $g^{-1}$ at 3 A $g^{-1}$. A high capacitance of 825.18 F $g^{-1}$ was retained at 20 A $g^{-1}$, indicating excellent rate capability. Moreover, the Ni:Co_6:1 electrode retained 49.97% of its initial capacitance after 10,000 cycles, outperforming pure $Ni(OH)_2$ (31.64%). The improved performance is attributed to the synergistic effects of cobalt incorporation, which enhance the structural integrity, charge transport, and electrochemical performance of $Ni(OH)_2$, highlighting the Ni:Co_6:1 composition as a promising electrode material for high-performance supercapacitors.

**Keywords:** $Ni(OH)_2$, cobalt incorporation, supercapacitors, pseudocapacitive behavior

# Enhanced performance of gel polymer electrolyte with hydroquinone for supercapacitors

Nannaphat Kiatkaiwansiri[a], Pawinee Klangtakai[b,c*], Samuk Pimanpang[d]

[a]*Materials Science and Nanotechnology Program, Faculty of Science, Khon Kaen, 40002, Thailand.*
[b]*2Department of Physics, Faculty of Science, Khon Kaen University, Khon Kaen, 40002, Thailand.*
[c]*Institute of Nanomaterials Research and Innovation for Energy (IN-RIE), Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand.*
[d]*Department of Physics, Faculty of Science, Srinakharinwirot University, Bangkok, 10110, Thailand.*

* Corresponding Author' E-mail: pawinee@kku.ac.th,

**Abstract**

Electric double-layer capacitors (EDLCs) are widely recognized for their excellent cycling stability; however, their charge storage capability can be further improved by introducing redox-active additives into the electrolyte. In this study, a gel polymer electrolyte (GPE) based on poly(vinyl alcohol) (PVA) and poly(vinylpyrrolidone) (PVP) was developed with hydroquinone (HQ) as a redox additive to enhance electrochemical performance while maintaining improved safety compared to liquid electrolytes. The GPE was prepared by dissolving PVA (1 g) and PVP (0.5 g) in 15 mL of deionized water, followed by the addition of HQ at concentrations of 0, 0.1, 0.3, 0.5, and 0.7 M. The obtained gels were dried and soaked in 6 M KOH, and assembled with activated carbon electrodes in a Swagelok cell. The specific capacitance of the GPE-based devices increased significantly with HQ concentration, reaching 55.54, 84.01, 160.88, 174.24, and 216.29 F g-1 at a current density of 1 A g-1 for 0, 0.1, 0.3, 0.5, and 0.7 M HQ, respectively. In comparison, the device using liquid 6 M KOH electrolyte delivered a specific capacitance of 65.57 F g-1 under the same conditions. The ionic conductivity of the GPEs also increased with HQ content (0.008-0.558 S cm-1), approaching that of the liquid electrolyte (0.685 S cm-1). The enhanced capacitance is attributed to the reversible redox reaction of HQ in addition to the electric double-layer mechanism. These results demonstrate that PVA/PVP/HQ GPEs are promising alternatives to conventional liquid electrolytes for high-performance, safer supercapacitors.

**Keywords:** gel polymer electrolytes; hydroquinone; redox additive; ionic conductivity; electric double-layer capacitors

# Real-Time UV–Vis Monitoring of $I^-/I_2/I_3^-$ Traveling in Electrolyte of an $Fe_2O_3$//Activated Carbon Aqueous Energy Storage System

Wassana Wannabut[a,*], Pawinee Klangtakai[b,†], Samuk Pimanpang[c]

[a]*Department of Physics, Faculty of Science, Khon Kaen University, Khon Kaen, 40002, Thailand*
[b]*Institute of Nanomaterials Research and Innovation for Energy (IN-RIE), Khon Kaen University, Khon Kaen, 40002, Thailand,*
[c]*Department of Physics, Faculty of Science, Srinakharinwirot University, Bangkok, 10110, Thailand*

*Corresponding Author's E-mail: **w.wassana@kkumail.com (Wassana Wannabut), †pawinee@kku.ac.th (Pawinee Klangtakai)*

**Abstract**

Nanostructured $Fe_2O_3$ and activated carbon (AC) were developed for assembling an aqueous electrochemical system. $Fe_2O_3$ nanoparticles synthesized by a solvothermal method exhibited spherical nanostructures. Highly porous AC prepared from *Cyclea barbata* Miers leaves via carbonization at 500 °C followed by KOH activation at 800 °C under an Ar atmosphere, resulting in a high specific surface area of 3,750.73 $m^2\ g^{-1}$. Electrochemical of nanostructured $Fe_2O_3$ and activated carbon (AC) electrodes were conducted in 0.5 M KI electrolyte based on both three-electrode and two-electrode configurations. In the three-electrode system, iodide ions ($I^-$) strongly interact with the AC surface through adsorption within the porous structure, accompanied by electron transfer. The oxidation of $I^-$ to $I_2$ and $I_3$ occurred without distinct oxidation peaks on the CV curve, while the reduction process appeared at 0.41 V, corresponding to the conversion of $I_2$ and $I_3^-$ back to $I^-$. As a result, AC delivered a high specific capacitance of 1,652.87 $F\ g^{-1}$ at 1 $A\ g^{-1}$ within a potential window of 0 - 0.5 V. The $Fe_2O_3$ electrode exhibited a specific capacitance of 230.5 $F\ g^{-1}$ under negative potential (-1.0 – 0 V). It is the multiple oxidation peaks at -0.37, -0.20, and -0.05 V and reduction peaks at -0.75 and -0.89 V detected on the $Fe_2O_3$ electrode. In the two-electrode system, in situ UV–Vis spectroscopy was employed to directly track the change on the electrolyte along with the charge-discharge cycling. The symmetric AC//AC cell delivered a specific capacitance of 73.5 $F\ g^{-1}$ with a redox feature near 0.1 V, while the asymmetric $Fe_2O_3$//AC cell provided 110.6 $F\ g^{-1}$ with reduction peaks at 0.86 V ($I_2$), 0.74 V ($I_3^-$), and 0.52 V ($I^-$), confirming an iodide-mediated hybrid charge-storage mechanism.

**Keywords:** Iodide redox electrolyte, activated carbon, $Fe_2O_3$, asymmetric supercapacitor

# Effect of Slow Heating Rate on the Synthesis of Hard Carbon Derived from Macadamia Shell for Use as an Anode Electrode in Sodium-Ion Batteries

Ukrit Sahapatsombut*, Panpanat Tesatchabut, Yaowamarn Chuminjak, Naruemon Apinyakul, and Pimpa Limthongkul

*Energy Innovation Research Group, National Energy Technology Center (ENTEC), Pathum thani, Thailand*

*ukrit.sah@entec.or.th

**Abstract**

Since their commercial debut in 1991, lithium-ion batteries (LIBs) have become the dominant rechargeable energy source for portable electronics and electric vehicles, owing to their affordability, high energy density, and versatile applicability. However, the European Commission's 2020 critical raw materials report highlighted growing shortages of lithium, cobalt, and natural graphite, driven by surging demand for lithium-based energy storage. This has prompted researchers to explore sodium-ion batteries (SIBs) as a cost-effective and sustainable alternative, with hard carbon (HC) emerging as a promising anode material. A key challenge remains developing high-performance anodes capable of overcoming graphite's narrow interlayer spacing limitation. This study investigates the synthesis and characterization of hard carbon derived from macadamia shell, an underutilized agricultural by-product, as an anode material for SIBs. The central hypothesis is that employing a slow heating rate of 1 °C/min during carbonization at 1400 °C produces hard carbon with reduced defect density, lower surface area, and a higher closed-to-open micropore ratio compared to a conventional rate of 5 °C/min — structural attributes expected to improve Initial Coulombic Efficiency (ICE) by minimizing irreversible sodium-ion trapping during the first electrochemical cycle. The results demonstrate that macadamia-derived hard carbon synthesized at 1 °C/min achieved an ICE of 70.52%, surpassing the sample prepared at 5 °C/min and comparable to commercial hard carbon (ICE = 70.54%). Furthermore, the discharge capacity reached 504.566 mAh/g, exceeding that of commercial hard carbon in anode half-cell testing as shown in Figure 1. These findings highlight macadamia shell-derived hard carbon as a competitive, sustainable, and high-performance anode candidate for next-generation sodium-ion batteries.

**Keywords:** Hard carbon, Sodium-ion battery, Macadamia shell, Half-cell, Heating rate.

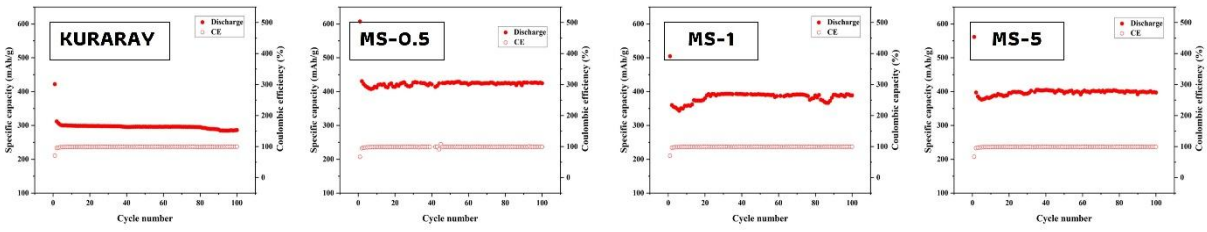



**Figure 1.** The cycling capacity with coulombic efficiency of various synthesized hard carbon at different heating rate compared to commercial one.

# Solvent-Controlled β-Phase in PVDF for Stable Sodium Deposition and Enhancing Cycle Life in Anode-Free Sodium Metal Batteries

Narisara Inarn[a], Mussatorn Promachan[a], Parita Jumpaburee[a], Phonchita Thahong[a], Jiraphat Prakopphon[a], Kanokwan Duchthuyawat[a], Ratchataphan Thammawat[a], Nonglak Meethong[a],[b], Orapa Thamwattana[a],[b*]

[a]*Department of Physics, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand,*
[b]*The Institute of Nanomaterials Research and Innovation for Energy (IN-RIE), Materials Science and Nanotechnology Program, Department of Physics, Faculty of Science, Khon Kaen University, Muang Khon Kaen 40002, Thailand*

*E-mail: Orapata@kku.ac.th

**Abstract**

Anode-free sodium metal batteries have attracted significant attention as a promising next-generation energy storage system due to their high theoretical energy density and low material cost. However, their practical implementation is hindered by non-uniform sodium deposition during cycling, which leads to dendrite formation, poor coulombic efficiency, and limited cycle life. In this work, we demonstrate that the β-phase content in PVDF-based artificial interphases plays a critical role in governing sodium deposition behavior. PVDF coatings prepared using different solvent environments exhibit distinct β-phase distributions, resulting in notable differences in interfacial properties and electrochemical performance. Electrochemical impedance spectroscopy (EIS) reveals that β-phase-rich PVDF significantly reduces charge-transfer resistance, facilitating more uniform ion transport and sodium flux at the interface. As a result, the β-phase-enhanced interphase enables smooth and homogeneous sodium deposition, leading to a prolonged cycling stability of up to 1000 cycles at 2 mA $cm^{-2}$ with a fixed deposition capacity of 3 mAh $cm^{-2}$. In contrast, PVDF films with lower β-phase content exhibit higher interfacial resistance and irregular sodium plating, which accelerates performance degradation. These findings highlight that β-phase engineering in PVDF is a key strategy for controlling sodium deposition and improving the stability of anode-free sodium metal batteries. This work provides new insights into the design of functional polymer interphases for advanced sodium-based energy storage systems.

**Keywords:** anode-free, sodium metal battery, PVDF coating, artificial SEI layer

# Impact of Carbon Incorporation Strategies on the Electrochemical Performance of $FeNbO_4$ Anodes for Lithium-Ion Batteries

Napassorn Kietisirirojana [a, b], Kamonpan Pengpat [c], Uraiwan Intatha [d], Sukum Eitssayeam [c, *]

[a] *Doctoral Degree Program in Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*

[b] *Graduate school, Chiang Mai University, Chiang Mai, Thailand*

[c] *Department of Physics and Materials Science, Chiang Mai University, Chiang Mai 50200, Thailand*

[d] *Center of Innovative Materials for Sustainability, School of Science Mae Fah Luang University, Chiang Rai 57100, Thailand*

*Corresponding Author's E-mail: sukum99@yahoo.com

**Abstract**

The development of high-performance anode materials is crucial for advancing lithium-ion batteries (LIBs) to meet increasing energy storage demands. However, transition metal oxides such as $FeNbO_4$ are limited by poor electrical conductivity and volume expansion during cycling. In this study, $FeNbO_4$ was synthesized via a ball-milling method followed by calcination at temperatures ranging from 1000 to 1200 °C to achieve a well-defined crystalline structure. Structural analysis confirmed the formation of monoclinic $FeNbO_4$ at 1200 °C with enhanced crystallinity. To improve electrochemical performance, $FeNbO_4$/carbon composites were prepared using different mechanical mixing approaches, aiming to combine the high lithium storage capability of $FeNbO_4$ with the excellent electrical conductivity of carbon materials. The electrochemical performance was evaluated using CR2032 coin cells. The results show that the composite electrodes exhibit improved lithium storage properties compared to pristine $FeNbO_4$, including higher specific capacity and enhanced cycling stability. The incorporation of carbon effectively facilitates electron transport and reduces internal resistance during charge–discharge processes. This study demonstrates the critical role of carbon incorporation in enhancing the electrochemical performance of $FeNbO_4$-based anodes and provides useful insights for the design of advanced composite materials for next-generation lithium-ion batteries.

**Keywords:** Energy storage device, Li-ion battery, Anode, Composite materials, $FeNbO_4$

# Stabilizing P2-Type $Na_{0.67}Ni_{0.22}Fe_{0.22}Mn_{0.56}O_2$ Layered Oxide Cathodes via Calcium Doping for Sodium-Ion Batteries

Awatsada Buraned[a], Asst. Prof. Dr. Songyoot Kaewmala[ab], Asst. Prof. Dr. Natthawan Prasongthum[ab], Assoc. Prof. Dr. Nonglak Meethong[ab] and Dr. Panya Thanwisai[ab,*]

[a]*Battery and New Energy Science Program, Department of Physics, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand*
[b]*The Institute of Nanomaterials Research and Innovation for Energy (IN-RIE), Materials Science and Nanotechnology Program, Department of Physics, Faculty of Science, Khon Kaen University, Muang Khon Kaen 40002, Thailand*

*Corresponding Author's E-mail: panyth@kku.ac.th

**Abstract**

Ni/Mn-based P2-type layered oxides are promising cathode materials for sodium-ion batteries (SIBs) because of their high energy density, fast Na+ diffusion kinetics, and ease of synthesis. To make these batteries more cost-effective, partially replacing expensive nickel (Ni) with earth-abundant iron (Fe) in the Na-Ni-Fe-Mn-O system is a practical strategy. However, these cathode materials often face severe capacity fading and slow kinetics during long-term cycling. This structural degradation is mainly caused by the Jahn-Teller distortion of $Mn^{3+}$ ions and irreversible P2-O2 phase changes at high voltages accompanied by anionic O redox. To solve these instability issues, this study improves the P2-type structure by doping with cost-effective and earth-abundant calcium (Ca). The large $Ca^{2+}$ ions preferably located in Na site due to identical ionic radius act as "structural pillars" that expand the space between layers (d-spacing) and prevent the structure from collapsing during $Na^+$ charging and discharging. The optimization of Ca concentrations of 1 mol%, 3 mol% and 5 mol% was also investigated. It was found that the cathode doped with 3 mol% Ca (CCa3) shows significantly greater electrochemical properties compared to other samples. At 0.01C, CCa3 delivers a high specific discharge capacity of 131.14 mAh/g, and 115.1 mAh/g for the undoped material (PR). Furthermore, the CCa3 sample shows excellent structural stability, maintaining a capacity of over 60 mAh/g even at a high rate of 10C. The cycling stability of CCa3 yield 74.25% for 230 cycles which is much greater than 51.94% of PR. Based on the findings, we further utilized bio-waste-derived eggshells as a sustainable and eco-friendly Ca source. The eggshell doped (ECa3) also exhibits greater cycling stability (78.11% for 230 cycles) than the pristine sample. This work highlights the potential of employing low-cost and sustainable dopants to stabilize the layered oxide cathodes for high performance sodium-ion batteries.

**Keywords:** Sodium-ion batteries, P2-type layered oxides, Calcium doping, Jahn-Teller distortion, Biowaste precursor, Structural stability

# Graphitic carbon nitride: a gamma radiation-tolerant dielectric insulator

Tosapol Maluangnont[a,*]

[a]*School of Integrated Innovative Technology, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand*

*Corresponding Author's E-mail: tosapol.ma@kmitl.ac.th

**Abstract**

Graphitic carbon nitride is subjected to gamma irradiation up to 400 kGy at room temperature. The resulting materials are characterized by X-ray diffraction, IR spectroscopy, and combined $^{13}C$, $^{15}N$, and $^{1}H$ solid state nuclear magnetic resonance spectroscopy. It is found that all samples remains highly insulating with resistivity remains extremely high at ~$10^9$ Ω·cm. This is nearly independent of irradiation dose (0−400 kGy), temperature (RT–350 °C), and frequency ($10^4$−$10^6$ Hz). The dielectric permittivity decreases slightly from ~7.2 to ~4.7–5.2, while the dielectric loss tangent remains low (~0.02). Accordingly, g-$C_3N_4$ retains robust insulating and dielectric behavior even after substantial radiation-induced defect redistribution.

**Keywords:** graphitic carbon nitride, insulator, dielectric

# A Comprehensive Study of CoO and CoO@GO/$SiO_2$ for Enhancement of Anode Materials in Lithium Ion Battery

M. D. Tadesse[a,*], S. T. Dibaba [b], A. Lass-Seyoum [c]

[ab] *Adama Science and Technology University, Adama 1888, Ethiopia*
[b] *University of Applied Sciences (HTW) Berlin, Wilhelminenhofstraße 75A, 12459 Berlin, Germany.,*

*Corresponding Author's E-mail: meti.desalegn7@gmail.com

**Abstract**

The advancement of next-generation lithium-ion batteries (LIBs) is hindered by rapid capacity decay and structural instability in transition metal oxide anodes. To address challenges, this study reports the design and synthesis of a ternary CoO@rGO/$SiO_2$ nanocomposite via a scalable chemical-hydrothermal approach. The architecture is engineered to encapsulate ultrafine CoO nanoparticles within a dual-matrix of reduced graphene oxide (rGO) and silica ($SiO_2$). The physical and chemical properties of the prepared materials were characterized by powder X-ray diffraction, FTIR, scanning electron microscopy, TEM, TGA, and Brunauer–Emmett–Teller (BET) techniques; the analysis confirms a unique morphology in which insulating $SiO_2$ acts as a mechanical buffer to mitigate volume expansion, while the rGO network ensures continuous, long-range electronic conductivity. This integrated framework maximizes the electrode-electrolyte interface and preserves structural integrity during aggressive lithiation/delithiation cycles. Electrochemical evaluations demonstrate that the ternary composite significantly outperforms pristine CoO, delivering a high specific capacity of 1450mAh $g^{-1}$ at 0.1C. Notably, the material exhibits exceptional kinetic stability, maintaining 78% capacity retention at an elevated rate of 2C. Long-term durability tests show a capacity retention of 89% after 200 cycles at 1C, with a Coulombic efficiency consistently exceeding 95%. These results suggest that the synergistic interaction between the conductive rGO and the buffering $SiO_2$ effectively suppresses the inherent limitations of conversational-type materials. By surpassing the performance of many conventional $SnO_2$-based anodes and approaching commercial viability, this work provides a robust strategy for developing high-energy density anodes. The findings offer significant implications for optimizing durable energy storage solutions in electric mobility and grid-scale applications.

**Keywords:** Lithium-ion batteries, Transitions metal oxides, Anode materials, rGO/$SiO_2$ nanocomposite, Synergistic effect

# Engineered Macadamia Nut Shell–Derived Biochar as a Sustainable Zincophilic Current Collector for High-Performance Zinc–Air Batteries: Operando Synchrotron Insights

Ramin Khezri[a,*], Soorathep Kheawhom[b], Wanwisa Limphirat[c], Shiva Rezaeimotlagh[d]

[a] *Metallurgy and Materials Science Research Institute, Chulalongkorn University, Soi Chula 12, Phayathai Road, Patumwan, Bangkok 10330, Thailand,*
[b]*Department of Chemical Engineering, Faculty of engineering, Chulalongkorn university,*
[c]*Synchrotron Research and Applications Division, Synchrotron Light Research Institute, Nakhon Ratchasima 30000, Thailand,*
[d] *Research Unit on Sustainable Algal Cultivation and Applications, Faculty of Engineering, Chulalongkorn University, Bangkok 10330, Thailand,*

*Corresponding Author's E-mail: ramin.k@chula.ac.th

**Abstract**

Macadamia nut shell–derived biochar is engineered and surface-modified to function as a sustainable high-performance current collector for zinc anodes in zinc–air batteries. Controlled pyrolysis, chemical activation, and heteroatom/metal functionalization are employed to tailor pore architecture, surface chemistry, electrical conductivity, and zincophilicity. The optimized biochar exhibits a high specific surface area of approximately 1050 $m^2\ g^{-1}$ and a hierarchical porous structure, providing favourable conditions for uniform zinc nucleation, efficient ion transport, and improved electrode stability. Structural and physicochemical properties are characterized using BET analysis, electron microscopy, Raman spectroscopy, X-ray diffraction, X-ray photoelectron spectroscopy, and four-probe conductivity measurements. Electrochemical testing shows a reduction in zinc nucleation overpotential by ~45 mV, improved Coulombic efficiency to ~98% compared to ~90% for the baseline, and extended galvanostatic cycling stability to ~450 hours. Hydrogen evolution and ZnO formation are effectively suppressed. Operando and in-situ synchrotron-based X-ray techniques are implemented to directly probe zinc nucleation and interfacial reactions under realistic operating conditions. Time-resolved X-ray absorption spectroscopy and X-ray imaging capture the dynamic evolution of zinc speciation, nucleation pathways, and surface phase transformations during plating and stripping. These real-time observations reveal more homogeneous nucleation behaviour, stabilized zincate species, and reduced passivation, providing mechanistic insight that connects material design with electrochemical performance and guides the development of sustainable carbon-based current collectors for advanced zinc–air battery systems.

**Keywords**: Biochar; Zinc–air batteries; Zinc deposition; Sustainable current collector; Operando synchrotron characterization

# Graphene-based fiber cathode fabrication from recycled graphite for zinc ion batteries

Nakarin Subjalearndee[a*], Jirada Chanpriang[b], Phrutsakorn Thongkrairat[a], Panpanat Tesatchabut[c], Priew Eiamlamaic, Panida Muangkasem[c], Zezhao Lid, Nattanai Kunanusont[c], Xiangwu Zhang[d], Theeranun Siritanon[b], and Pimpa Limthongkul[c*]

[a]*National Nanotechnology Center (NANOTEC), Advanced Composite and Nanotextiles Research Team, 111 Thailand Science Park, Phahonyothin Rd., Klong Nueng, Klong Luang, Pathumthani 12120, Thailand.*

[b]*Suranaree University of Technology, 111 Maha Witthayalai Rd, Suranari, Mueang Nakhon Ratchasima District, Nakhon Ratchasima 30000, Thailand.*

[c]*National Energy Technology Center (ENTEC), 114 Thailand Science Park, Phahonyothin Rd., Klong Nueng, Klong Luang, Pathum Thani 12120, Thailand.*

[d]*Fiber and Polymer Science Program, Department of Textile Engineering, Chemistry and Science, Wilson College of Textiles, North Carolina State University, Raleigh, NC 27695, USA.*

*Corresponding Author's E-mail: Nakarin@nanotec.or.th

**Abstract**

Due to the increasing amount of electronic waste being discarded daily, these materials need to be recycled and disposed of. Among the processes, there are often materials considered useless, such as black mass derived from distorted graphite. This study is interested in using recycled graphite from waste to develop a flexible cathode made from fibers by combining recycled graphite obtained from reduced graphene oxide (RGO) with commercial graphene oxide (GO), followed by coating with $MnO_2$ for use in zinc-ion batteries. The graphene oxide fibers were created through wet spinning at different GO:RGO ratios, with a 50:50 ratio found to be the most suitable, balancing surface area and mechanical integrity. The fibers were coated with α- and β-$MnO_2$ using a dip-coating method to enhance electrochemical performance. Structural analysis confirmed that the recycled graphite retained its crystalline structure after processing, while the incorporation of RGO increased surface roughness and porosity. Electrochemical evaluation revealed that the cathode using β-$MnO_2$ exhibited superior performance compared to α-$MnO_2$, providing a maximum specific capacity of approximately 140 mAh $g^{-1}$ and maintaining a capacity of about 80 mAh $g^{-1}$ after 100 cycles with stable coulombic efficiency. These research findings demonstrate that recycled graphite can be upcycled into high-performance and flexible cathode materials, offering a sustainable and scalable approach for next-generation zinc-ion batteries.

**Keywords:** Recycled graphite, Graphene oxide, Fiber cathode, $MnO_2$

# Electrospun Ni-Mg Selenide Electrocatalysts Toward Water Splitting and Zinc-air Batteries

Ramakrishna Reddy Ayyaluri, Manoj Pathala, Jae Su Yu*

*Department of Electronics and Information Convergence Engineering, Institute for Wearable Convergence Electronics, Kyung Hee University, Yongin-si, Gyeonggi-do 17104, Republic of Korea*

**Abstract**

The rapid growth of modern livelihood energy consumption requires the development of sustainable and innovative energy storage and conversion technologies that are cost-effective and environmental-friendly. In this context, highly active and stable electrocatalysts are essential for advanced energy systems such as water-splitting devices and zinc-air batteries. A simple electrospun and pyrolysis approach is employed in this work to design the nickel-magnesium (Ni-Mg) selenide electrocatalyst material with good electrochemical performance. Electrospinning can enhance the specific surface area of the Ni-Mg selenide and improve electron transport while the resulting nanofibers alter the electronic structure of active sites, increasing exposure and promoting electron transfer and mass diffusion, which improves electrocatalytic performance. The Ni-Mg selenide electrocatalyst material has excellent electrocatalytic activity for oxygen reduction reaction (ORR), oxygen evolution reaction (OER), and hydrogen evolution reaction (HER). As a result, the Ni-Mg selenide electrocatalyst material requires modest overpotentials to attain a current density of 10 mA $cm^{-2}$ and an excellent ORR activity. The optimized electrocatalyst demonstrated excellent stability in during the chronopotentiometry test, suggesting its suitability for long-term water-splitting applications involving both OER and HER. These results demonstrate an effective approach to designing Ni-Mg selenide-based multifunctional electrocatalysts and provide a pathway for the development of robust transition metal-based material systems for large-scale water-splitting and zinc-air battery applications.

**Keywords:** Electrospinning, Ni-Mg selenide, Multifunctional electrocatalysts, Water splitting, Zinc-air battery

# Biomass (Durian Peel)-Derived Carbon and Metal Chalcogenide Composites for Energy Storage Electrodes

Murali Krishna Sreeramareddygari [a,*], Jinatcha Arunrat [b], Natchanon Songpracha [b], Boonsita Wigath [b]

[a] *Pilot Plant Development and Training Institute (PDTI), King Mongkut's University of Technology Thonburi, Bangkok, Thailand*
[b] *Engineering-Science Classroom (Darunsikkhalai School), King Mongkut's University of Technology Thonburi, Bangkok, Thailand*

*Corresponding Author's E-mail: sreerama.mur@kmutt.ac.th

**Abstract**

Biomass-derived carbon materials (BDCMs) are materials usually derived from agricultural waste that offer a cost-effective and environmentally friendly alternative to traditional carbon materials. Besides these characteristics, BDCMs are ideal candidates for energy generation and storage applications due to their large specific surface areas, tailorable porous texture, and excellent electrical conductivity. As the demand for renewable-energy technologies continues to grow, BDCMs and their composites with metal oxides or metal dichalcogenides are being widely explored for applications in supercapacitors and batteries. In this study, durian peel waste (generated in large quantities annually in Thailand) was utilized as a precursor to synthesize graphene-like carbon material and its composite with $MoS_2$. The peels, which possess a naturally fibrous structure and are rich in cellulose and lignin, were first converted into biochar through pyrolysis at 550 °C, then chemically activated with KOH, and a secondary pyrolysis at 800 °C, followed by mechanical exfoliation to obtain graphene-like carbon with micro- and mesoporous features. The resulting material was used to produce composite material with solvothermal synthesized $MoS_2$ gel by sonication assisted method. Subsequently, both graphene-like carbon and $MoS_2$-durian peel derived carbon ($MoS_2$/D-carbon) composites were employed as an active component for fabricating capacitor electrodes. Finally, the capacitor electrodes was assembled by either graphene-like carbon or its composite with $MoS_2$ coated carbon paper as cathode and anode, and lithium chloride-Polyvinyl Alcohol (PVA) gel coated chromatographic paper as dielectric. Chronoamperometry (CA) and cyclic voltammetry (CV) techniques were used for the electrochemical characterization process. The preliminary results obtained from CV studies reveal that the electrodes fabricated from these materials exhibit specific capacitance ranges from 1.1 to 15.35 F/g depending upon $MoS_2$ and D-carbon ratio, suggesting that these materials are promising candidates for energy storage devices.

**Keywords:** Biomass-derived carbon materials (BDCMs), Durian peel waste, Graphene-like carbon, $MoS_2$-carbon composite, Capacitor electrodes

# Colorimetric Coordination–Acid–Base Coupling Additive Enables Local pH Stabilization for Durable Aqueous Zn Metal Batteries**Error! Bookmark not defined.**

Mingwu Luo [a], Mengyao Li [a*], Feiyu Kang [a*]

[a] *Institute of Materials Research, Tsinghua Shenzhen International Graduate School, Tsinghua University, Shenzhen, 518055 China .*

*Corresponding Author's E-mail: mengyaoli@sz.tsinghua.edu.cn; fykang@sz.tsinghua.edu.cn

**Abstract**

Aqueous zinc-based energy storage systems are promising for safe and low-cost large-scale energy storage, but their wide-temperature operation is limited by electrolyte freezing at low temperatures and aggravated Zn/electrolyte interfacial instability at elevated temperatures. Herein, we propose a bio-inspired electrolyte regulation strategy based on the balanced facial amphiphilicity of bile salt molecules. Sodium cholate, sodium taurocholate, and sodium taurodeoxycholate were selected as model additives to clarify the relationship between molecular structure and Zn anode stabilization. Among them, sodium taurocholate integrates a rigid hydrophobic steroid skeleton, three hydrogen-bond-regulating hydroxyl groups, and a taurine-conjugated sulfonate/amide terminal group, enabling simultaneous modulation of water structure and the Zn/electrolyte interface.

The sodium taurocholate-containing electrolyte effectively suppresses ice formation and lowers the freezing point of the aqueous electrolyte to below −40 °C, as confirmed by differential scanning calorimetry. Meanwhile, its facially amphiphilic structure modulates $Zn^{2+}$ solvation and interfacial water activity, thereby reducing hydrogen evolution, Zn corrosion, and dendritic deposition. Consequently, Zn//Zn symmetric cells deliver stable Zn plating/stripping for over 5000 h at −40 °C and over 2500 h at 40 °C under 1 mA $cm^{-2}$/0.5 mAh $cm^{-2}$. Furthermore, AC//Zn hybrid capacitors exhibit stable cycling for over 10000 cycles at 1 A $g^{-1}$, demonstrating the broad applicability of this strategy. This work highlights balanced facial amphiphilicity as a molecular design principle for multifunctional electrolyte additives toward wide-temperature aqueous zinc energy storage.

**Keywords:** Aqueous zinc energy storage, Wide-temperature operation, Bile salt additives, Facial amphiphilicity, Zinc anode

# Spinel Ferrites Enabling Synergistic Photocatalysis and Piezocatalysis for Organic Compound Degradation

Tso-Fu Mark Chang[a,b,*], Xinyu Jin[a], Yu-Hao Chen[a], Shota Kitaoka[a], Tomoyuki Kurioka[a,b], Chun-Yi Chen[a,b], Yung-Jung Hsu[a,b,c], Masato Sone[a,b], Satoshi Okamoto[a,b]

[a]*Institute of Integrated Research, Institute of Science Tokyo, Yokohama, 2268501, Japan*
[b]*Sumitomo Chemical Next-Generation Eco-Friendly Devices Collaborative Research Cluster, Institute of Science Tokyo, Yokohama, 2268501, Japan*
[c]*Department of Materials Science and Engineering, National Yang Ming Chiao Tung University, Hsinchu, 30010, Taiwan*

*Corresponding Author's E-mail: chang.m.aa@m.titech.ac.jp

**Abstract**

Organic compounds such as methylene blue (MB), rhodamine B (RhB), malachite green (MG), and indigo are environmentally persistent compounds that can accumulate in ecosystems and pose risks to human health, including potential carcinogenicity. Developing efficient strategies to decompose these molecules in aqueous environments is therefore of increasing importance. Photocatalysis is a promising approach because photoexcited catalysts can generate reactive species that mineralize organic molecules into benign products such as $CO_2$ and $H_2O$. Spinel ferrites have attracted attention owing to their multiple-band electronic structures that enable light harvesting from the visible to near-infrared regions. Many ferrites, including $NiFe_2O_4$ and $CoFe_2O_4$, also exhibit strong magnetism, allowing facile recovery from solution using an external magnet and thereby reducing catalyst loss and unintended release.

Recent studies have further improved catalytic performance by introducing piezocatalytic activity into spinel ferrites through lattice-symmetry breaking induced by dopant incorporation. Piezocatalysis enables decomposition even in the absence of light via mechanically driven polarization and charge generation. When combined, photocatalytic and piezocatalytic effects can act synergistically to significantly enhance degradation efficiency (Fig. 1).

In this presentation, we discuss the degradation of aqueous solutions containing MB, RhB, MG, and indigo using spinel ferrite-based catalysts, with emphasis on the synergy between photocatalytic and piezocatalytic processes.

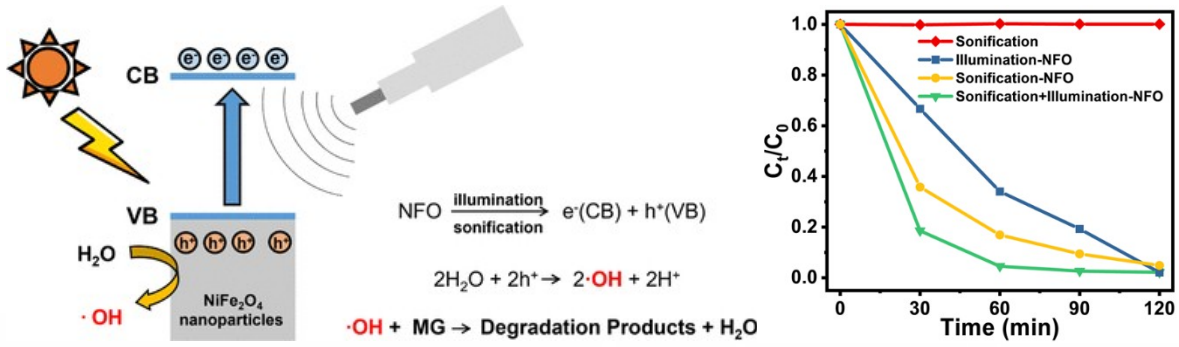



Fig.1 Synergistic photocatalytic and piezocatalytic degradation of malachite green

**Keywords:** Spinel ferrites, Photocatalysis, Piezocatalysis, Organic compound degradation

# Electro-Assisted Fabrication of Silane-Bridged Graphene Electrodes for Efficient Electrochemical Heavy Metal Removal

Chen-Cheih Liao[1], Dhanaprabhu Pattappan[1], Tse-yang Wang[1], Yi-Ting Lai[1,2,3]

[1]*Department of Materials Engineering, Ming Chi University of Technology, New Taipei City, 24301, Taiwan*
[2]*Biochemical Technology R&D Center, Ming Chi University of Technology, New Taipei City, 24301, Taiwan*
[3]*Center for Plasma and Thin Film Technologies, Ming Chi University of Technology, New Taipei City, 24301, Taiwan*

*Corresponding Author's E-mail: laieating@mail.mcut.edu.tw

**Abstract**

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This study develops an electro-assisted silane-bridged graphene electrode and evaluates its practical performance for heavy metal removal. Graphene oxide (GO) was deposited onto conductive substrates via cyclic voltammetry, followed by chronoamperometric grafting of ethylenediamine-based silane to construct a three-dimensional functionalized graphene electrode.
Material characterization results indicate that silane modification significantly enhanced surface properties. The water contact angle decreased from 40.4° to 17.14°, while the electrochemical active surface area (ECSA) increased to approximately 31.0 $cm^2$, demonstrating improved surface accessibility and charge transfer capability. For heavy metal removal, $Cu^{2+}$ was selected as a representative contaminant. Under electro-assisted conditions, the silane-bridged graphene electrode effectively reduced $Cu^{2+}$ concentration in solution, achieving a removal efficiency exceeding 80% under optimal operating conditions. In addition, stable removal performance was maintained over repeated adsorption–desorption cycles, indicating good reusability and structural stability.
Overall, the electro-assisted silane-bridged graphene electrode exhibits effective heavy metal adsorption performance through the synergistic effects of surface functional groups and electrochemical mechanisms, demonstrating strong potential for practical remediation of heavy metal–contaminated water and soil systems.
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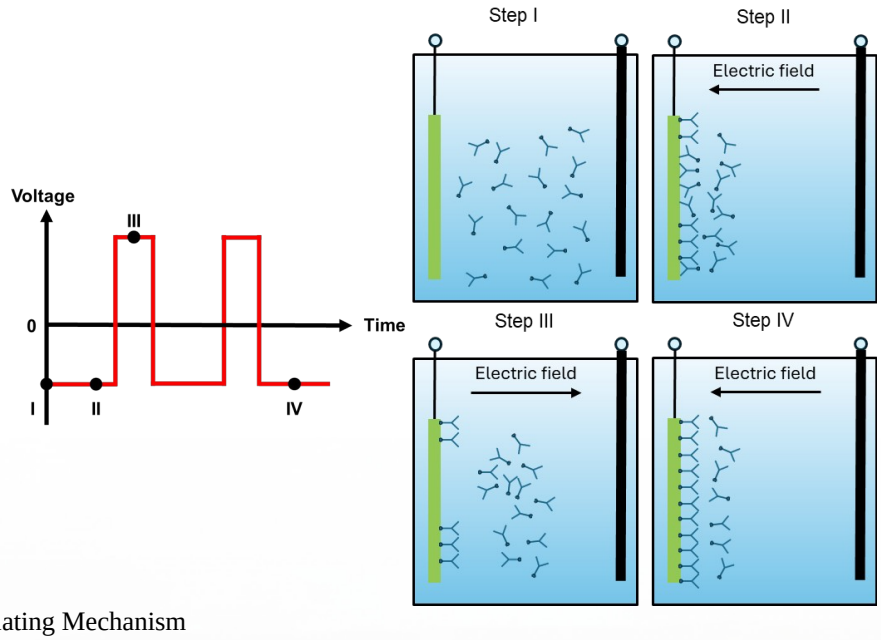



Fig 1. Electroplating Mechanism

**Keywords:** graphene electrode, EDA, electrochemical modification, electrochemical remediation, pollutant degradation

# Metal-Modified Buckypaper for Enhanced Wettability and Thermal Transport in Liquid Metal Interfaces

Yao-Tien Tseng[a,*], Jui-En Chang[a], Sammy Lap Ip Chan[a, b *]

[a] *Department of Chemical and Materials Engineering, National Central University, Taiwan*
[b] *School of Materials Science and Engineering, University of New South Wales, Sydney, NSW, 2052, Australia*

*Corresponding Authors' E-mail addresses: ytt0025@ncu.edu.tw; sli.chan@unsw.edu.au

**Abstract**

Efficient thermal management is increasingly critical for next-generation high-power electronic devices, particularly in artificial intelligence hardware, advanced packaging, and high-heat-flux power modules. Liquid metals are attractive thermal interface materials because of their intrinsically high thermal conductivity; however, their practical integration with carbon-based materials is often limited by poor wettability and high interfacial thermal resistance. In this study, a metal-modified buckypaper platform is developed to improve the interfacial compatibility between liquid metals and carbon nanostructured films. The metal-modified buckypaper exhibits markedly improved wetting behavior toward liquid metals compared with pristine buckypaper. The contact angle of liquid metal on the untreated carbon surface is approximately 135°, whereas after metal modification it decreases to 5–37°, depending on the selected metal species, indicating substantially enhanced interfacial affinity and spreading. In addition to the wettability improvement, the modified buckypaper shows an enhanced thermal transport performance. The in-plane thermal conductivity increases from approximately 50 W/m·K for the untreated film to above 70 W/m·K after the modification, while the overall thermal conductivity of the liquid metal/carbon composite system exceeding 80 W/m·K. These improvements result in a thermal conductivity reaching more than 140% of that of the untreated counterpart in the composite thermal interface structure. The improved performance is attributed to the introduction of a metallic interfacial layer, which promotes stronger interfacial coupling, facilitates phonon bridging and electron transport, and reduces thermal boundary resistance across the heterogeneous liquid metal/carbon interface. This work demonstrates that metal-modified buckypaper provides a promising route toward high-performance liquid metal thermal interface materials with potential applications in advanced electronics, AI computing, and thermal management systems.

**Keywords:** Buckypaper; liquid metal; interfacial engineering; thermal conductivity; heat dissipation; thermal management

# Revisiting High-Temperature Activation in La–Ca–Mg–Ni-Based $AB_3$ Hydrogen Storage Alloys: Advantage of Room-Temperature Activation for Fuel Cell Applications

Min-Wei Lee[a], Yu-Chen Kuo[a], Yun-Lin Liao[a], Meng-Cheng Chou[a], Ruiran Guo[b], Yifan Zhou[b], Sammy Lap Ip Chan[a, b, *]

[a] *Department of Chemical and Materials Engineering, National Central University, Taiwan*
[b] *School of Materials Science and Engineering, University of New South Wales, Sydney, NSW, 2052, Australia*

*Corresponding Author's E-mail: sli.chan@unsw.edu.au

**Abstract**

$AB_3$-type intermetallic alloys exhibit a theoretical hydrogen storage capacity of 1.3–1.7 wt.% while reducing rare-earth usage, making them promising candidates for solid-state hydrogen storage. However, their gas–solid hydrogen reactions are highly sensitive to activation conditions, which strongly influence the hydrogen absorption/desorption plateau pressures and reversible hydrogen storage capacity; and a consistent activation protocol remains unclear. In this work, a La–Ca–Mg–Ni-based $AB_3$ alloy was investigated to clarify the influence of activation parameters on the hydrogen storage performance and cycling stability. Samples were activated under vacuum at different temperatures from 25–450 °C, followed by hydrogenation under pressures up to 7.5 MPa, and subsequently subjected to 500 hydrogen absorption–desorption cycles. The results show that after 175 °C vacuum treatment, the alloy can be fully activated at room temperature under 5.8 MPa hydrogen pressure within 10 min, exhibiting the best hydrogen storage performance. In contrast, excessive high-temperature activation (e.g., 450 °C vacuum / 300 °C hydrogenation) leads to an increase in plateau pressure and a reduction in saturated hydrogen capacity. Particle size analysis reveals that low-temperature activation results in an average particle size of ~21.1 μm, whereas high-temperature activation produces larger particles (~33.8 μm), indicating reduced hydrogen-induced pulverization and incomplete activation. ICP results confirm that elemental compositions remain stable with only ±1–3 wt.% variation. Consequently, excessive activation temperatures decrease the cumulative usable hydrogen over 500 cycles and may undermine alloy performance. By increasing Mg content while reducing La and Ca ratios, the desorption plateau pressure was tuned to approximately 9 bar, which is well suited for hydrogen supply to fuel cells – a promising hydrogen storage medium for stationary power generation in remote areas.

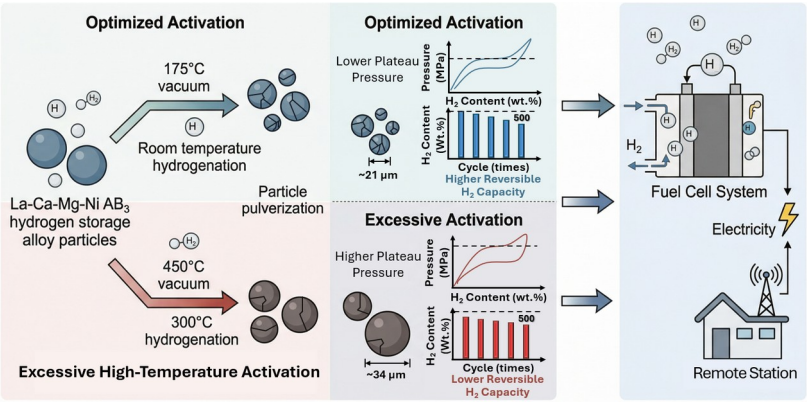



Fig. 1. Effect of activation conditions on hydrogen storage performance of La–Ca–Mg–Ni $AB_3$ alloys and their application in fuel cell hydrogen supply.

**Keywords:** La–Ca–Mg–Ni intermetallic alloys, $AB_3$ hydrogen storage materials, Activation temperature effects, Hydrogen storage thermodynamics, Stationary fuel cell applications

# Microstructure and Electrochemical Properties of Al-Sn and Al-Sn-In Alloys Produced by Friction Stir Processing for Anode Applications

Pornpan Wanna[1], Jesada Punyafu[2], Suphitcha Moonngam[3], and Chaiyasit Banjongprasert[1,2*]

[1]*Department of Physics and Materials Science,*
*Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[2]*Materials Science Research Center*
*Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[3]*Office of Research Administration*
*Chiang Mai University, Chiang Mai, 50200, Thailand*

*Email: chaiyasit.b@cmu.ac.th

**Abstract**

This study investigates the synergistic effects of alloying elements and microstructural refinement on the performance of aluminum–air battery anodes. Aluminum–air batteries are promising energy storage systems due to their high theoretical energy density (~8.1 kWh/kg); however, their practical application is limited by severe self-corrosion and hydrogen evolution. To address these challenges, Al–Sn and Al–Sn–In alloys (Al–0.1Sn, Al–0.1Sn–0.05In, and Al–0.1Sn–0.1In, composition in wt%) were cast and followed by homogenization treatment in which the samples were heated at 550 °C at a rate of 20 °C/min, held for 180 min, and subsequently water-quenched to room temperature. Friction Stir Processing (FSP), a severe plastic deformation technique, was used to simultaneously refine the microstructure and enhance electrochemical activation. The rotating tool in FSP induces dynamic recrystallization, transforming coarse grains into fine grains, promoting a more uniform distribution of intermetallic and (Sn,In), which act as activators to disrupt the passive oxide film. Microstructural evolution is characterized using Optical Microscopy, SEM/EDS, and EBSD, while electrochemical properties, including open-circuit potential (OCP) and corrosion current density ($I_{(corr)}$), are evaluated through potentiodynamic polarization. The discharge performance and energy output are further assessed in a prototype Al–air battery cell. This approach provides a promising strategy for improving electrochemical efficiency and mitigating parasitic reactions, contributing to the development of high-performance, cost-effective, and environmentally friendly anodes for next-generation energy storage systems.

**Keywords:** Aluminum–air battery, Friction Stir Process, Anode, Microstructural Refinement, Electrochemical properties

# Exfoliation-Free Solvothermal Synthesis of ink-like $MoS_2$ gel for Printable Water Purification Filters

Muralikrishna Sreeramareddygari[a,*], Chatuporn Phanthon[ga],[b], Mithran Somasundrum [a,b], Patsamon Rijiravanich[a,b], Werasak Surareungchai[c], Jyothi Mannekote Shivanna [d,*]

[a] *Sensor Technology Laboratory, Pilot Plant Development and Training Institute (PDTI), King Mongkut's University of Technology Thonburi, Bangkok, Thailand*

[b] *Industrial Sensor Technology Research Team, National Center for Genetic Engineering and Biotechnology, National Science and Technology Development Agency at KMUTT (Bangkhuntien Campus), Bangkok, 10150, Thailand*

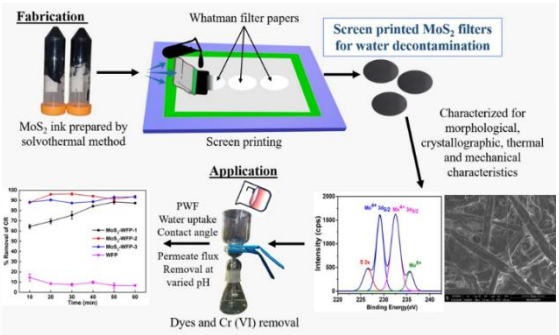
[c] *Nanoscience & Nanotechnology Graduate Programme, Faculty of Science, King Mongkut's University of Technology Thonburi, Bangkhuntien-chaitalay Road, Thakam, Bangkok, 10150, Thailand*

[d] *Department of Chemistry, Nitte Meenakshi Institute of Technology (NMIT), Nitte (Deemed to be University), Bengaluru, India 560064*

*Corresponding Author's E-mail: sreerama.mur@kmutt.ac.th, jyothi0901@gmail.com

**Abstract**

A novel screen-printing approach was employed to fabricate molybdenum disulfide ($MoS_2$) based membranes using exfoliation-free solvothermally synthesized ink-like $MoS_2$ gel and Whatman filter paper (WFP). Three membranes, $MoS_2$-WFP-1, $MoS_2$-WFP-2, and $MoS_2$-WFP-3, were fabricated by varying the number of print coatings to tailor the hydrophobicity and mechanical integrity. Structural and morphological investigations were performed by X-ray Diffraction (XRD), X-ray Photoelectron Spectroscopy (XPS) and Field Emission Scanning Electron Microscopy (FE-SEM) analysis. The XPS results confirmed a well-adhered $MoS_2$ layer with mixed 1T/2H phases that enhanced mechanical and thermal stability. The $MoS_2$ incorporated membranes exhibited increased tensile strain, moderate water uptake (53–55%), and contact angles (104–118°) which increased with increasing coat number, demonstrating tunable surface wettability. In spite of reduced pure water flux, compared to bare filter paper, all coated membranes sustained consistent permeability. The membranes efficiently removed the Congo red (~90%), methylene blue (~55%) and Cr (VI) (~72%) under pH-dependent conditions. The pH-dependent removal arises from electrostatic interactions between the $MoS_2$ surface and charged species, where protonation of the negatively charged $MoS_2$ surface at acidic pH enhances the attraction of anionic contaminants (Congo red and Cr anions such as such as $HCrO_4^-$ and $Cr_2O_7^{2-}$ ), while deprotonation at basic pH favors adsorption of cationic MB. The investigations confirm a simple, scalable and low-cost route for the fabrication of printable $MoS_2$ membrane filters suitable for wastewater purification.




**Keywords:** Screen printing, Ink-like $MoS_2$ gel, Membrane separation, Filtration, Water purification.

# Development of Co–W and Co–W–Cu Coatings on AISI 430 Stainless Steel via Electrodeposition for SOFC Interconnects

Grid Suparapinyopapkul, Thanasak Nilsonthi, Thammaporn Thublaor*

*High Temperature Corrosion Research Centre, Department of Materials and Production Engineering, Faculty of Engineering, King Mongkut's University of Technology North Bangkok, 1518, Pracharat 1 Road, Wongsawang, Bangsue, Bangkok 10800, Thailand*

*Corresponding Author's E-mail: thammaporn.t@eng.kmutnb.ac.th

**Abstract**

Ferritic stainless steel interconnects are widely used in solid oxide fuel cells (SOFCs); however, protective coatings are necessary to improve their long-term performance. In this study, Co-W and Co-W-Cu oxide coatings were developed on AISI 430 stainless steel via electrodeposition. The effects of key deposition parameters, including time, voltage, and current density, were systematically investigated. A uniform coating layer was achieved at a current density of 1.5 A $dm^{-2}$ with a deposition time of 30 min. Oxidation behavior was evaluated in air at 800 °C for 96 h. Among the tested conditions, Co-W and Co-W-Cu coatings deposited at 1.3 A $dm^{-2}$ for 30 min exhibited the best oxidation resistance. The corresponding mass gains were 15.94 µg $mm^{-2}$ and 15.07 µg $mm^{-2}$, respectively. X-ray diffraction (XRD) analysis indicated that the oxide scales formed on the coated samples consisted primarily of $Co_3O_4$, $CoWO_4$, and $WO_3$ phases. The Co-W-Cu electroplated coating demonstrated improved protective performance by effectively suppressing chromium volatilization and limiting inward oxygen diffusion, thereby enhancing the oxidation resistance of AISI 430 stainless steel for SOFC interconnect applications.

**Keywords:** SOFC Interconnect, Electrodeposition, Coating

# Development of a Two-Color Ultrafast Pump-Probe Experimental Station at Chiang Mai University

Nuttawat Khammata[a,b], Nattanon Chaidet[a] and Sakhorn Rimjaem[a,c,*]

[a]*PBP-CMU Electron Linac Laboratory, Plasma and Beam Physics Research Facility, Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[b]*Master Degree Program in Physics, Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[c]*Particle Accelerators and Laser Technology Research Group, Chiang Mai University, Chiang Mai, 50200, Thailand*

*Corresponding Author's E-mail: sakhorn.rimjaem@cmu.ac.th

**Abstract**

We report on the development and commissioning of a two-color ultrafast pump-probe experimental station at Chiang Mai University for advanced materials characterization. The system is designed to support both optical pump-optical probe and optical pump-terahertz (THz) probe spectroscopy, enabling the investigation of transient carrier and low-energy excitation dynamics with high temporal resolution. Compared with conventional one-color pump-probe systems, the two-color configuration improves measurement reliability by reducing pump leakage, minimizing crosstalk, and enhancing the signal-to-noise ratio. The experimental station is also designed to integrate a cryogenic sample environment for temperature-dependent studies down to approximately 7 K. The pump source is based on a non-collinear optical parametric amplifier (NOPA) driven by a femtosecond titanium–sapphire laser system. This source delivers tunable visible pulses in the 400-700 nm range with a pulse duration of about 100 fs and pulse energy of 5-10 μJ. The optical probe path employs broadband white-light generation for spectrally resolved transient measurements, while the terahertz probe path, based on time-domain spectroscopy (TDS). This part uses difference-frequency generation (DFG) and electro-optic sampling (EOS) to provide probe pulses in the 0.1-3 THz range with a pulse duration near 1 ps, pulse energy of 5-10 nJ, and a time resolution of about 100 fs. The optical delay system provides fine temporal control with a delay precision of approximately 1.67 fs, and the optical probe detection system achieves a spectral resolution of 2 nm. In addition, the tunable pump wavelength can be adjusted in 10 nm steps. Commissioning of the station includes optimization of the pump, white-light probe, and THz probe beam paths, verification of temporal and spatial overlap, and stabilization of synchronized detection using lock-in-based measurements. The experimental geometry is designed with sufficient working distance to accommodate a cryogenic chamber while preserving optical access for both optical and THz probe configurations. This instrument provides a flexible in-house platform for ultrafast studies of semiconductors, perovskites, metal oxides, superconductors, and other quantum and functional materials, and represents an important step in strengthening advanced spectroscopy infrastructure at Chiang Mai University.

**Keywords**: Ultrafast pump-probe spectroscopy, Optical pump-optical probe, Optical pump-terahertz probe, Terahertz time-domain spectroscopy, Cryogenic system.

# Investigation of Factors Affecting Reliability of Real-Time Color Monitoring System in Sugar Production Lines

Nichakarn Termsaithong[a], Kamonchanok Duangkanya[a], Nantarat Srisuai[a], Patharakorn Rattanawan[a], Jia-Yi Chia[a], Paramin Sangwongngam[a], Rungroj Jintamethasawat[a], Noppadon Nuntawong[a,*]

[a]*National Electronics and Computer Technology Center, National Science and Development Agency, Pathum Thani, Thailand 12120*

*Corresponding Author's E-mail: noppadon.nuntawong@nectec.or.th

**Abstract**

Spectroscopy method has been widely used as a standard colorimetric method for measuring color raw sugar samples, which is a crucial factor for sugar production to achieve the desired quality. However, this technique requires well-defined procedures involving sample preparation and data acquisition within a controlled experimental environment. In circumstances where raw sugar samples are measured directly within the production line, the received spectral signals show considerable variances and instability, thus compromising color prediction accuracy. To address this issue, two studies were investigated on two raw sugar samples: syrup and molasses. For the first study, spectra of undiluted and diluted raw sugar samples, prepared according to the factory's standard protocol, were recorded continuously for 35-minutes. Then, the degree of spectral variance and drift were evaluated for both undiluted and diluted sugar samples. For the second study, spectra of undiluted raw sugar samples were also recorded and evaluated over the same duration as the previous study, but the acquisition was repeated for different light sources whose emission wavelength was close to the target wavelength specified in the standard colorimetric method (420 nm). Results show that direct measurements on undiluted samples lead to a noticeable increase in the spectral variance. Nonetheless, by carefully choosing the light source so that its wavelength aligns with that used in the standard colorimetric method, as well as applying corresponding acquisition settings appropriately, both spectral variance and drift can be reduced further. Furthermore, we will demonstrate measurement configurations capable of reducing the standard deviation to four decimal places, which is a necessary condition for achieving acceptable accuracy in sugar color prediction. These findings provide a practical basis for improving the accuracy and reliability of the inline sugar color monitoring system deployed in industrial production.

**Keywords:** spectroscopy, in-line, sugar, colorimetric method

# Associative Memory Operation in a Spintronic Oscillator via a Virtual Oscillator Network

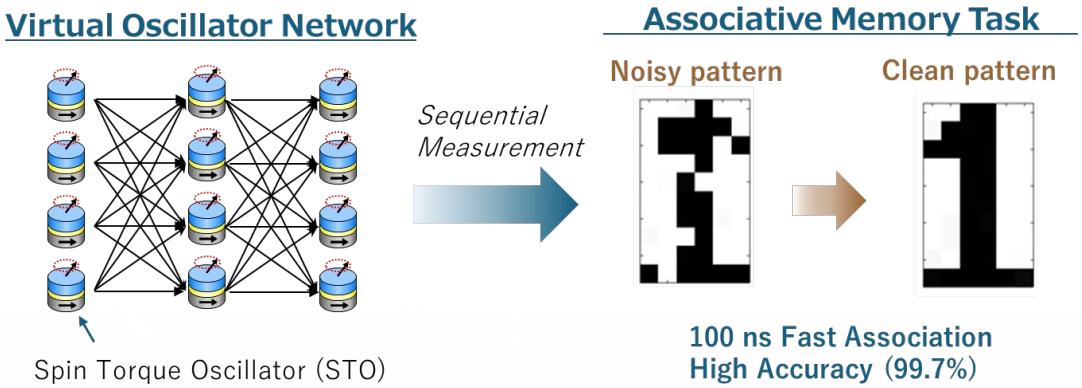
Sumito Tsunegi [a,b*], Kay Yakushiji [b], Shinji Yuasa [b], and Hitoshi Kubota [b]

[a] *Kyushu Institute of Technology, Kitakyushu, Fukuoka 808-0196, Japan*
[b] *National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki 305-8568, Japan*

*Corresponding Author's E-mail: s_tsunegi@brain.kyutech.ac.jp

**Abstract**

We experimentally demonstrate associative memory operation [1] using a spintronic oscillator based on a virtual oscillator network. Oscillator neural networks have attracted considerable attention as a platform for efficient neuromorphic computing. However, their experimental implementation remains challenging due to the difficulty in integrating large numbers of coupled oscillators [2].
To overcome this limitation, we developed a virtual oscillator network, in which the behavior of multiple coupled oscillators is emulated by sequential measurements of a single spintronic oscillator. This approach enables scalable implementation without complex circuit integration.
Using this platform, we performed an associative memory task with 60-pixel patterns. The system successfully retrieved stored patterns from noisy inputs with high accuracy within 100 ns, demonstrating fast and reliable operation. Furthermore, we quantitatively evaluated the impact of device variability by artificially introducing frequency variations in the oscillator. The results reveal that synchronization-based computation is robust against moderate variations and can be further improved by increasing the input amplitude.
In addition, we investigated the input–output characteristics of the spintronic oscillator and clarified that its nonlinear phase response plays a role analogous to the activation function in conventional neural networks. These findings provide insight into the physical mechanism underlying oscillator-based computation.
This work demonstrates that spintronic oscillators can serve as a practical hardware platform for associative memory and suggests a pathway toward scalable oscillator-based computing systems using nanoscale devices.
This work was supported by JSPS KAKENHI (Grant Numbers 24K01336 and 26K03000).
[1] J. J. Hopfield, Proc. Natl. Acad. Sci. U.S.A. 79, 2554 (1982).
[2] S. Dutta et al., Nat. Electron. 4, 502 (2021).




**Keywords:** Spintronic oscillator, Associative memory, Oscillator neural network, Neuromorphic computing, Device variability

# Valorization Of Platinum Smelter Slag Into High Performance Geopolymer Pavers For Sustainable Mining Infrastructure

Nomagugu Ncube[a], Nyasha C Kadenge[b] ,Munashe Felix Mudhindi[c]

[a]*Department of Civil and Water Engineering, National university of Science and Technology, No1 George Avenue King George VI Centre Bulawayo, Zimbabwe*
[b]*Department of Civil and Water Engineering, National university of Science and Technology, No. 21 Inglewood Road Woodlands Bulawayo , Zimbabwe*
[c]*Department of Civil and Water Engineering, National university of Science and Technology, No.467 Bulawayo Drive Manningdale Bulawayo, Zimbabwe*

Corresponding Author's E-mail: felix.mudhindi@nust.ac.zw

**Abstract**

The platinum industry in Zimbabwe produces significant amounts of smelter slag, creating long-term environmental and land management challenges. Meanwhile, Ordinary Portland Cement (OPC) is highly carbon-intensive and a major contributor to global $CO_2$ emissions. Although interest in circular economy strategies within the mining sector is growing, research on using locally available platinum slag to produce high-performance construction materials for infrastructure is limited. This study investigates the potential to convert platinum smelter slag into cement-free geopolymer pavers for sustainable mining and urban development. The methodology involves physical and chemical tests of the slag, including X-ray fluorescence (XRF) for oxide analysis, particle size distribution for fineness assessment, and pH tests to effectively evaluate the alkalinity of the slag. The XRF and grading analyses indicate the presence of reactive $SiO_2$, $Al_2O_3$, and CaO phases, with appropriate fineness for Geopolymerization. Mechanical testing, such as compressive and flexural strength, water absorption, and leachability, is ongoing. Preliminary results show potential for achieving strength suitable for heavy-duty paving with adequate durability, although results are pending. The study also evaluates environmental advantages, including reducing OPC consumption and slag disposal. These findings aim to support sustainable mining infrastructure, waste valorisation, and eco-friendly construction aligned with ESG standards in Zimbabwe.

**Keywords:** *platinum smelter slag, geopolymer pavers, waste valorization, sustainable mining infrastructure, low-carbon construction.*

# Development of Green Roof Tile by Utilization of Mine Slag and Plastic Waste from A Local Mine

Bongiwe Ndebele[a], Nyasha C Kadenge[b], Munashe Felix Mudhindi[c]

[a]*Department of Civil and Water Engineering, National university of Science and Technology, No.24058 Pumula South, Bulawayo, Zimbabwe*
[b]*Department of Civil and Water Engineering, National university of Science and Technology, No. 21 Inglewood Road Woodlands Bul awayo , Zimbabwe*
[c]*Department of Civil and Water Engineering, National university of Science and Technology, No.467 Bulawayo Drive Manningdale Bulawayo,Zimbabwe*

Corresponding Author's E-mail: nyasha.kadenge@nust.ac.zw

**Abstract**

The construction industry is under increasing pressure to adopt sustainable materials that improve resource efficiency while minimizing environmental impacts. At the same time, the mining sector generates significant quantities of slag and plastic waste from daily operations, creating persistent disposal challenges. Despite growing interest in waste valorization, there is limited research on the combined utilization of platinum slag and plastic waste in composite roofing materials within the Zimbabwean context. Therefore, this study addresses this gap by exploring how these wastes can be engineered into a high-performance construction material. The research aims to characterize the physical and chemical properties of platinum slag through sieve analysis, pH analysis, loss on ignition, and XRF testing. The composite roof tiles will incorporate 30% recycled plastic waste bottles, while the remaining 70% will consist of river sand partially substituted with slag at varying replacement levels to determine optimal performance. The plastic bottles are first shredded and cleaned to remove contaminants. The raw materials are then processed through controlled heating, mixing, and molding to ensure uniform distribution and adequate bonding. The produced tiles are evaluated for flexural strength (ASTM C1167), impact resistance (ASTM D5420), density (DIN EN standards for bulk density determination), and water absorption (ASTM D570). Preliminary observations indicate potential for producing lightweight, water-resistant composite roof tiles with promising structural integrity and thermal performance. Full mechanical and durability testing is currently underway to establish compliance with relevant roofing material standards. The Green Tile concept presents a practical circular economy approach for local mines by converting industrial waste into a value-added construction material while contributing to sustainable engineering solutions in Zimbabwe.

**Keywords:** platinum slag, structural integrity, waste valorization

# Investigating the use of coconut fibres reinforcement, polyester resin, and macadamia shell filler materials in bio composites to promote sustainability

Mbatha Abednigo Jabu

*Vaal University of Technology, Department of Mechanical Engineering, Industrial Engineering and Operation Management*

*Private Bag X021, Vanderbijlpark, 1900, South Africa*

abednigom@vut.ac.za

**Abstract**

Synthetic fibres are very difficult to recycle and are not biodegradable, making their disposal extremely difficult. Natural fibres and agricultural waste are gaining momentum in engineering applications due to their mechanical strength, which is comparable to that of synthetic fibres currently in use. Composites made from natural fibres and agricultural waste have been used in a variety of engineering applications because of their biodegradable properties, acceptable mechanical strength, and durability. The main objective of the study was to investigate the use of coconut fibres and macadamia filler materials to fabricate composites that promote sustainability in the automotive industry. The macadamia shells were crushed and sieved. The coconut fibres were extracted from the coconut husk and soaked in water for 24 hours. The composite was fabricated using the hand lay-up method, with a volume ratio ranging from 2% to 6% for coconut fibres and 10% to 15% for macadamia filler materials. The mechanical property tests conducted on the composite included tensile strength, Leeb hardness, and flexural strength. Natural fibers are hydrophilic, and further studies are needed to improve both the water absorption of natural fibers and the durability of the resulting composites. Researchers should explore the use of different natural reinforcement fibers or matrix materials to enhance the performance characteristics of these composites. By addressing the hydrophilicity issue, it may be possible to develop more resilient materials suitable for a wide range of applications.

**Key words:** Composites, Coconut Fibres, Mechanical properties, and sustainability

# Artificial Intelligence for Deciphering Mobility and Trap Dynamics in OLED Transient Responses

Al Amin[a], Rino Choi[a], Jeong-Hwan Lee[a,b,*]

[a] *Dept. of Materials Science and Engineering, Inha University, Incheon 22180, Republic of Korea*
[b] *Progam in Semiconductor Convergence, Inha University, Incheon 22180, Republic of Korea*

*Corresponding Author's E-mail: jeong-hwan.lee@inha.ac.kr

**Abstract**

Understanding charge trapping and polaron dynamics in organic light-emitting diodes (OLEDs) is essential for improving device efficiency, operational stability, and rational material design. However, these internal charge processes are difficult to extract directly from experiments because transient electroluminescence (Tr-EL) signals reflect multiple coupled physical phenomena. In this work, we propose a physics-guided convolutional neural network (CNN) framework to decode charge-dynamic information from Tr-EL responses in phosphorescent OLEDs. A large simulation-derived dataset was generated using an electrical device model covering wide ranges of charge transport, trapping, and recombination parameters. CNN was trained to learn the relationship between transient EL features and hidden internal states, particularly trapped hole density and polaron-related behavior associated with overshoot characteristics.

To enable comparison with experiments, measured EL signals were preprocessed into photon-density-proportional transients, ensuring consistency with the simulation-trained model. The trained CNN successfully predicted trap-related trends across different Ir-based phosphorescent dopants and distinguished materials showing severe initial overshoot from those with weaker or negligible overshoot. [1] The extracted polaron/trap information was further correlated with external quantum efficiency (EQE) roll-off through an analytical fitting model incorporating triplet-triplet annihilation and triplet-polaron quenching. SCLC/C-V characteristics induced injection properties and trap dynamics unifies the AI+experimental evaluation verification. This approach demonstrates that Tr-EL can be transformed from a qualitative diagnostic tool into a quantitative inverse probe of internal OLED charge dynamics. The proposed framework provides a practical route toward rapid interpretation of transient signals and data-driven optimization of OLED materials and device structures.

**Keywords:** OLEDs, transient electroluminescence, mobility, charge trapping, convolutional neural network

**References**

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**Acknowledgement**

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# Lead-Free Perovskite $RbYbI_3$ as an Efficient Electron Injection Layer for High-Performance OLEDs

Amarja S. Katware[a], Jinho Ahn[b], Jeong-Hwan Lee[a,c*]

[a] *Department of Materials Science and Engineering, Inha University, Incheon 22212, Republic of Korea*
[b] *Materials Science and Engineering, Hanyang University*
[c] *Program in Semiconductor Convergence, Inha University, Incheon 22212, Republic of Korea*

*Corresponding Author's E-mail: jeong-hwan.lee@inha.ac.kr

**Abstract**

Balanced charge injection is essential for efficient organic light-emitting diodes (OLEDs), yet electron injection is often limited by interfacial energy barriers at the cathode/organic contact. Conventional electron-injection layers (EILs), such as LiF, Liq, Mg, and Yb, can lower this barrier but frequently suffer from stability limitations and electrode-dependent performance [1]. Here, we report a vacuum-deposited lead-free perovskite, $RbYbI_3$, as an efficient EIL for OLEDs. A 5nm $RbYbI_3$ interlayer induces a 630 mV surface potential shift at the cathode/ETL interface, strengthening the interfacial dipole and reducing the effective electron-injection barrier without additional surface treatment or device redesign. First-principles density functional theory calculations support the formation of a termination-dependent dipole in $RbYbI_3$, explaining its stronger barrier-lowering effect relative to LiF. Consequently, $RbYbI_3$ enables efficient electron injection across different organic semiconductors and is compatible with both aluminum and silver cathodes. In blue OLEDs, it lowers the turn-on voltage by 0.4 V and improves EQE from 17.7% to 19.5%. In green OLEDs, it delivers a maximum EQE of 23.0% and retains 20.7% at 10,000 cd $m^{-2}$, outperforming LiF-based controls. Overall, $RbYbI_3$ based devices show 2-4% higher EQE and about 10% higher power efficiency while preserving compatibility with standard multilayer vacuum processing. These findings identify $RbYbI_3$ as a promising perovskite EIL for high-performance OLEDs.

**Keywords:** Organic Light-Emitting Diodes, Inorganic Perovskites, Electron injection layer, Polarization.

**References:**

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# Enhanced Luminescence and Optical Properties of $Dy^{3+}$-Doped Rice Husk Ash Glasses for Photonic Devices Application

N. Mahingsa[a],[b], N. Srisittipokakun[a,b], J. Kaewkhao[a,b], K. Kirdsiri[a,b*]

[a] *Physics Program, Faculty of Science and Technology, Nakhon Pathom Rajabhat University, Nakhon Pathom, 73000, Thailand*
[b] *Center of Excellence in Glass Technology and Material Science (CEGM), Nakhon Pathom Rajabhat University, Nakhon Pathom, 73000, Thailand*

*Corresponding Author's E-mail: nanonymous@webmail.npru.ac.th

**Abstract**

In this investigation, a series of rice husk ash-derived glasses with the composition $SiO_2$: $B_2O_3$: $Li_2O$: BaO: $Al_2O_3$: $Gd_2O_3$: $Dy_2O_3$ were synthesized via the conventional melt-quenching method to study their structural, physical, optical, and luminescence properties. $Dy^{3+}$ ions led to increases in density, molar volume, and refractive index with increasing $Dy_2O_3$ concentration. X-ray diffraction (XRD) confirmed the amorphous nature structure of the samples, while Fourier transform infrared (FTIR) spectroscopy revealed the characteristic structural absorption bands of the glasses. The highest emission intensity of $Dy^{3+}$ doped glasses was found to be at 0.5 mol% (by 275 nm excitation of $Gd^{3+}$ ion) and 0.5 mol% (by 350 nm excitation of $Dy^{3+}$ ion) of $Dy_2O_3$ concentration. The absorption spectra exhibit bands at 384, 424, 451, 469, 802, 894, 1090, 1268, and 1662 nm, corresponding to transitions of $Dy^{3+}$ ions from the ground state $^6H_{15/2}$ to the excited states $^4M_{21/2}$, $^4G_{11/2}$, $^4I_{15/2}$, $^4F_{9/2}$, $^6F_{5/2}$, $^6F_{9/2}$, $^6H_{7/2}$, $^6F_{7/2}$ and $^6H_{11/2}$, respectively. Various radiative parameters such as branch ratio ($\beta_R$), transition probability ($A_R$), radiative lifetime ($\tau_R$), effective bandwidth ($\Delta\lambda_p$), and stimulated emission cross-section ($\sigma_{se}$) have been calculated. The excitation spectra of $Dy^{3+}$-doped glasses monitored at an emission wavelength of 575 nm, exhibit several sharp peaks, with the most intense peak observed at 350 nm, corresponding to the $^6H_{15/2}$ $^6P_{7/2}$ transition. Under 350 nm excitation, the glasses show distinct emission bands in the blue and yellow regions with the 0.5 mol% concentration showing the highest emission intensity. The CIE 1931 chromaticity coordinates and correlated color temperature (CCT) values, derived from the emission spectra of $Dy^{3+}$-doped glasses under 350 nm excitation, fall within the cool yellowish-white region, indicating that the as-prepared glass series is a promising candidate for photonic device applications.

**Keywords:** Rice husk ash, dysprosium, energy transfer, photonic

# Structural, Optical and Photoluminescence Properties of Samarium-Doped Sugarcane Leaf Ash Glasses for Display Devices Applications

P. Saengka[a,b], N. Srisittipokakun[a,b]*, J. Kaewkhao[a,b]

*1 Physics program. Faculty of Science and Technology, Nakhon Pathom Rajahat University, Nakhon Pathom 73000 Thailand.*

*2 Center of Excellence in Glass Technology and Material Science (CEGM), Nakhon Pathom Rajabhat University, Nakhon Pathom, 73000, Thailand.*

*Corresponding Author's E-mail: Nattapon2004@gmail.com

**Abstract**

Glass samples prepared from samarium-doped sugarcane leaf ash were systematically investigated. The structural, physical, optical and luminesces properties of the prepared glasses were characterized in order to evaluate key parameters, including absorption spectra, photoluminescence behaviour, emission characteristics, and decay times. X-ray diffraction (XRD) analysis confirmed the amorphous nature of the glass samples, while Fourier transform infrared (FTIR) spectroscopy identified the structural functional groups within the glass network. The density, molar volume and refractive index tended to increase with increasing of $Sm_2O_3$ concentration. The absorption spectra revealed electronic transitions from the ground state ($^6H_{5/2}$) to various excited states of $Sm^{3+}$ ions. The Judd-Ofelt (JO) intensity parameters were determined from the absorption data. Photoluminescence spectra were investigated in the wavelength range of 200-900 nm, using an excitation wavelength of 403 nm, exhibiting a prominent emission peak at 601 nm. The CIE chlorinate 1931 fall in orange region. The decay times was found to decrease with increasing $Sm_2O_3$ concentration, indicating enhanced non-radiative processes at higher dopant levels. The obtained fluorescence properties highlight the significant potential of these materials for applications in laser materials and display devices.

**Keywords:** Sugarcane leaf, Glass, Samarium, Luminescence, Judd-Ofelt

# Luminescent Behavior of $Eu^{3+}$ ion-Doped Boro-Tellurite Glass for Reddish orange Light Emission Applications

S. Khondara[a,b], K. Boonin[a,b,*], P. Yasaka[a,b], N. Intachai[c], S. Kothan[c], H.J. Kim[d], and J. Kaewkhao[a,b]

[a]*Physics Program, Faculty of Science and Technology, Nakhon Pathom Rajabhat University, Nakhon Pathom 73000, Thailand,*
[b]*Center of Excellence in Glass Technology and Materials Science (CEGM), Nakhon Pathom Rajabhat University, Nakhon Pathom 73000, Thailand,*
[c]*Center of Radiation Research and Medical Imaging, Department of Radiologic Technology, Faculty of Associated Medical Sciences, Chiang Mai University, Chiang Mai, 50200, Thailand,*
[d]*Department of Physics, Kyungpook National University, Daegu, 41566, South Korea*

*Corresponding Author's E-mail: kboonin@hotmail.com, kboonin@webmail.npru.ac.th

**Abstract**

Rare-earth-ion-doped glasses have attracted considerable attention due to their ability to enhance the optical performance of host materials through unique intra-4f electronic transitions. Among various rare-earth ions, terbium ($Eu^{3+}$) is particularly notable for its intense reddish orange emission, making it highly promising for photonic and reddish orange light-emitting applications. In this study, $Eu^{3+}$-doped boro-tellurite glasses were successfully fabricated using a conventional melt-quenching technique. The influence of $Eu^{3+}$ ions on the structural, optical, and luminescent properties of the glasses was systematically investigated. X-ray diffraction (XRD) analysis confirmed the amorphous nature of all prepared samples. Optical absorption spectra were recorded to determine the Judd-Ofelt (J-O) intensity parameters, providing insight into the local environment of $Eu^{3+}$ ions. Photoluminescence (PL) measurements, including excitation and emission spectra, revealed strong reddish orange emission attributed to the $^5D_0 \rightarrow {}^7F_2$ transition of $Eu^{3+}$ ions. The chromaticity coordinates were evaluated using the Commission Internationale de l'Éclairage (CIE) 1931 diagram, confirming the suitability of the glasses for reddish orange emission applications. Furthermore, luminescence decay curves were analyzed using the Inokuti-Hirayama model with S = 6. The obtained results demonstrate that $Eu^{3+}$-doped boro-tellurite glasses exhibit favorable optical and luminescent characteristics, highlighting their strong potential for applications in photonic devices and reddish orange light-emitting technologies.

**Keywords:** Boro-tellurite glass, Terbium oxide, Photoluminescence, Judd-Ofelt analysis, Inokuti-Hirayama model

# Integrated Approach to Plasma-Activated Hydrogel Design: From Factorial Optimization to Veterinary Application

Kochakon Moonsub[a], Phisit Seesuriyachan[ab], Wassanai Wattanutchariya[a,*]

[a]*Advanced Technology and Innovation Management for Creative Economy Research Group (AIMCE), Department of Industrial Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai 50200, Thailand; Kochakon.mm@gmail.com* [b]*Division of Biotechnology, Faculty of Agro-Industry, Chiang Mai University, Chiang Mai 50100, Thailand; phisit.seesuriyachan@gmail.com* *: wassanai@eng.cmu.ac.th

**Abstract**

This study optimized the synthesis and stability of plasma-activated hydrogel (PAH) as a chemical-free antimicrobial formulation targeting *Staphylococcus aureus* infections on animal skin, addressing the challenge of antibiotic resistance and chronic wounds. Plasma-activated water (PAW), rich in reactive oxygen and nitrogen species (RONS), served as the active antimicrobial component, while hydrogel incorporation enhanced the stability and applicability of PAW on irregular wound surfaces. A factorial design was employed to examine the effects of PAW treatment duration (0–20 min) and hydrogel ratio (1:5–3:5) on physicochemical properties, including oxidation–reduction potential (ORP), electrical conductivity (EC), pH, and hydrogen peroxide ($H_2O_2$) concentration, with triplicate testing. Extended PAW exposure lowered ORP (385.97 to 278.90 mV) and pH (to 5.17), while increasing EC (up to 263.75 µS/cm), reflecting progressive RONS formation and non-linear ORP–EC behavior. Optimal conditions were identified at a 3:5 hydrogel ratio and 20-min PAW treatment, yielding ORP 278.90 mV, EC 263.75 µS/cm, pH 5.325, and $H_2O_2$ 29.38 ppm. Kinetic analysis revealed slower $H_2O_2$ decay in PAH compared to PAW, maintaining ~10.6 ppm after four weeks at refrigeration temperature. The optimized PAH achieved an approximate 9.5 $\log_{10}$ CFU/mL reduction of *S. aureus*, underscoring its potential as a safe and effective antimicrobial agent for veterinary wound management.

**Keywords:** Plasma-activated hydrogel, Plasma-activated water, Reactive oxygen species (ROS), Staphylococcus aureus inhibition, Antimicrobial wound treatment

# Structural Insights into Sustainable Biomass-Derived Si–$SiO_2$ Nanocomposites Anchored with Sn–$SnO_2$ Nanoparticles within a Carbon Protective Buffer for High-Energy Lithium-Ion Battery Anodes

Orapim Namsar[a,b], Chawin Yodbunork[a,b,c], Waewwow Yodying[a], Kittiputh Kunniyom[a,d], Thanapat Autthawong[b,d,e], Jiayi Wu[f], Mitsutaka Haruta[f] and Thapanee Sarakonsri[a,b,d,*]

[a]*Department of Chemistry, Faculty of Science, Chiang Mai University, Muang, Chiang Mai 50200, Thailand*
[b]*Materials Science Research Center, Faculty of Science, Chiang Mai University, Muang, Chiang Mai 50200, Thailand*
[c]*Office of Research Administration, Office of the University, Chiang Mai University, Muang, Chiang Mai 50200, Thailand*
[d]*Center of Excellence for Innovation in Chemistry (PERCH-CIC), Faculty of Science, Chiang Mai University, Muang, Chiang Mai 50200, Thailand*
[e]*Department of Industrial Chemistry, Faculty of Science, Chiang Mai University, Muang, Chiang Mai 50200, Thailand*
[f]*Institute for Chemical Research, Kyoto University, Uji, Kyoto 611-0011, Japan*

*Corresponding Author's E-mail: thapanee.s@cmu.ac.th

**Abstract**

The development of high-energy and sustainable anode materials is critical for next-generation lithium-ion batteries (LIBs), particularly in the context of increasing demand for environmentally benign energy storage systems. Herein, a biomass-derived Si–$SiO_2$ nanocomposite anchored with Sn–$SnO_2$ nanoparticles and encapsulated within a flexible carbon protective buffer is rationally designed and synthesized. The utilization of a renewable precursor not only reduces environmental impact but also offers a cost-effective and scalable pathway for advanced material fabrication. The synergistic integration of Si-based and Sn-based phases provides enhanced lithium storage capacity through complementary alloying and conversion reactions. Detailed structural and morphological characterization reveals the formation of a well-dispersed heterostructure, in which Sn–$SnO_2$ nanoparticles are uniformly anchored onto the Si–$SiO_2$ matrix and effectively confined within the flexible carbon framework. This unique architecture accommodates the severe volume expansion typically associated with Si- and Sn-based phases during lithiation-delithiation processes, thereby alleviating mechanical degradation. In addition, the carbon protective buffer stabilizes the electrode–electrolyte interface by suppressing continuous solid electrolyte interphase (SEI) formation during cycling. Electrochemical evaluation demonstrates that the developed nanocomposite electrode delivers a high specific capacity, good rate capability, and long-term cycling stability compared to conventional Si-based anodes. The protective carbon plays a crucial role in maintaining structural integrity and buffering mechanical stress, while the incorporation of Sn–$SnO_2$ nanoparticles facilitates improved reaction kinetics and provides additional lithium storage pathways. This research offers important structural insights into the rational design of biomass-derived hybrid nanocomposites and highlights their significant potential as high-performance, sustainable anode materials for next-generation LIB applications.

**Keywords:** Lithium-ion anodes, Si-based materials, Sn-based materials, Biomass, Sustainability

# Development of high-performance aluminum-air batteries for future energy storage systems

Jesada Punyafu[a,*], Suphitcha Moonngam[b], Chaiyasit Banjongprasert[a,c]

[a]*Materials Science Research Center, Faculty of Science, Chiang Mai University, 239 Huaykaew Road, Suthep, Chiang Mai 50200, Thailand*
[b]*Research Administration Center, Office of the University, Chiang Mai University, 239 Huaykaew Road, Suthep, Chiang Mai 50200, Thailand*
[c]*Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, 239 Huaykaew Road, Suthep, Chiang Mai 50200, Thailand*

*Corresponding Author's E-mail: jesada.punyafu@gmail.com

**Abstract**

The rapid expansion of renewable energy technologies has intensified the demand for high-energy-density alternatives to conventional battery systems. Aluminum–air batteries have emerged as a promising candidate owing to their exceptionally high theoretical energy density, low cost, and the abundance and environmental compatibility of aluminum. However, their practical implementation is severely limited by parasitic corrosion of the aluminum anode, which significantly reduces utilization efficiency and shortens battery lifespan. To address this challenge, this study investigates the enhancement of anode electrochemical performance through microstructural refinement achieved via severe plastic deformation. Friction stir processing (FSP) was employed to refine the aluminum anode microstructure, resulting in an average grain size of less than 10 μm. This refinement led to approximately a 2-time increase in anodic utilization efficiency. The improvement is attributed to a transition in the corrosion mechanism from localized pitting in the coarse-grained microstructure to a more uniform intergranular corrosion behavior in the refined structure. FSP also demonstrated scalability for fabricating large-area fine-grained aluminum anodes suitable for high-power-density applications. Moreover, prototype aluminum–air battery cells and systems were developed and demonstrated stable operation while powering small electronic devices, including LEDs, motors, and water pumps. These results highlight the potential of microstructure engineering via friction stir processing as an effective strategy for enhancing anode performance and advancing the practical deployment of aluminum–air batteries for sustainable energy storage applications.

**Keywords:** Aluminum-air batteries, Severe plastic deformation, Microstructural engineering, Anodic efficiency, Energy storage materials

# Catalytically amplified nickel metal–organic framework–based electrochemical immunosensor for competitive insulin detection

Siriporn Anuthum[a], Jaroon Jakmunee[a,b], Kontad Ounnunkad[a,b,*]

[a]*Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[b]*Center of Excellence for Innovation in Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*

*Corresponding Author's E-mail: kontad.ounnunkad@cmu.ac.th, suriyacmu@yahoo.com

## Abstract

Type 2 diabetes mellitus, prediabetes, and insulin resistance represent a growing silent epidemic, yet often remain undetected in early stages due to the lack of sensitive and accessible diagnostic tools. Accurate insulin quantification is therefore critical for early intervention and disease management. Herein, we report a competitive electrochemical immunosensor for ultrasensitive insulin detection that exploits an electrocatalytic signal-amplification strategy. A composite of graphene oxide (GO) and new two-dimensional bimetallic molybdenum tungsten disulfide (2D $MoWS_2$) was deposited onto a screen-printed carbon electrode (SPCE) to enhance the electroactive surface area and support biomolecule immobilization. Insulin antigen was subsequently immobilized on the modified electrode, followed by blocking with bovine serum albumin (BSA) to minimize non-specific binding, forming the bioelectrode. A nickel metal-organic framework, $Ni_3(HITP)_2$ (nickel 2,3,6,7,10,11-hexaiminotriphenylene), conjugated with an anti-insulin antibody, served as both a capture probe and a signal-amplifying nanotag, exploiting its electrocatalytic activity toward hydrogen peroxide oxidation monitored using the chronoamperometric signal. In the competitive format, free insulin in the sample was mixed with anti-insulin/$Ni_3(HITP)_2$ nanotags to form immunocomplexes in solution. The mixture was then incubated on the bioelectrode surface, where only unbound nanotags attach to the immobilized insulin antigen, generating an electrocatalytic signal. As insulin target concentration increases, more nanotags are consumed in solution, resulting in fewer surface-bound nanotags and a proportional decrease in chronoamperometric current. The immunosensor exhibited a wide linear detection range of 10-50,000 pg $mL^{-1}$ with an ultralow limit of detection of 2.95 pg $mL^{-1}$, along with good selectivity, stability, and reproducibility, and was successfully validated in human serum samples. These results highlight the potential of $Ni_3(HITP)_2$-based catalytic signal amplification integrated with a 2D nanocomposite sensing platform for clinical insulin monitoring and early screening for metabolic diseases.

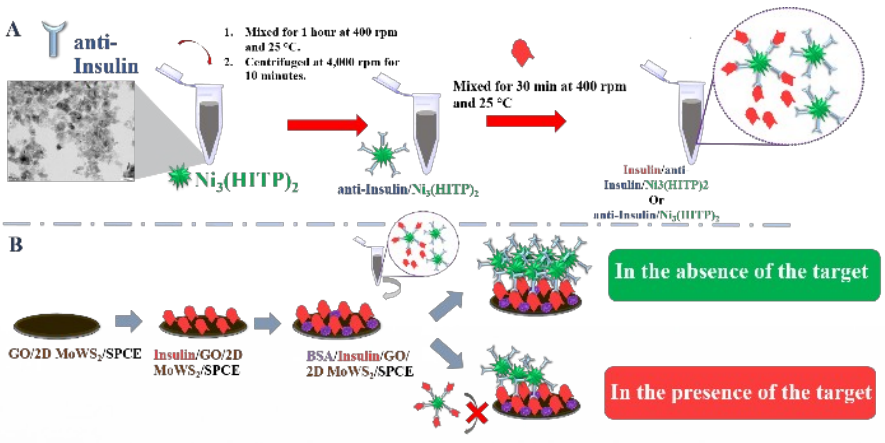



Fig. 1. Competitive immunosensor for insulin detection: (a) binding of anti-insulin/ $Ni_3(HITP)_2$ nanotag and insulin target, (b) binding of free anti-insulin/ $Ni_3(HITP)_2$ nanotag and insulin on a BSA/insulin/GO/2D $MoWS_2$/SPCE.

**Keywords:** Competitive Immunosensor, Diabetes, Insulin, Nickel metal-organic framework, Catalytic signal amplification

# Electrostatic PVC Film-Enabled Vacuum Heat-Transfer Engineering for Flexible Carbon-based Perovskite Solar Modules

Woraprom Passatorntaschakorn[a,b], Warunee Khampa[a], Wongsathon Musikpan[a], Athipong Ngamjarurojana[b], Anusit Kaewprajak[c], Pisist Kumnorkaew[c], Pipat Ruankham[a,b], Duangmanee Wongratanaphisan[a,b,d,*]

[a]*Materials Science Research Center, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[b]*Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai, 50200 Thailand*
[c]*National Nanotechnology Center (NANOTEC), National Science and Technology Development Agency (NSTDA), 111 Thailand Science Park, Pathum Thani 12120, Thailand*
[d]*Thailand Center of Excellence in Physics (ThEP Center), Ministry of Higher Education, Science, Research and Innovation, Bangkok 10400, Thailand*

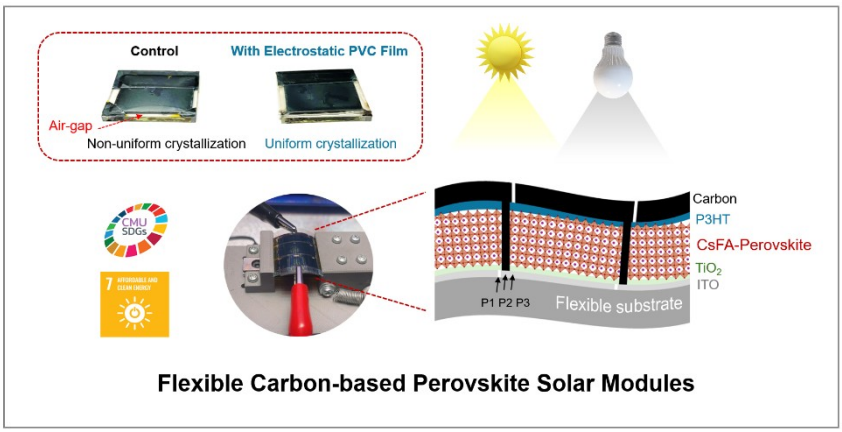
*Corresponding Author's E-mail: duangmanee.wong@cmu.ac.th

## Abstract

Flexible carbon-based perovskite solar modules (f-CPSMs) offer a promising pathway toward low-cost, lightweight, and scalable photovoltaic technologies; however, achieving uniform perovskite crystallization under all-low-temperature processing remains a critical bottleneck. In this work, we report an electrostatic polyvinyl chloride (PVC) film-enabled vacuum heat-transfer engineering strategy for the fabrication of flexible carbon-based perovskite modules. The proposed architecture (glass/electrostatic PVC film/PEN/ITO/$TiO_2$/CsFA-perovskite/P3HT/Carbon) employs a commercially available, adhesive-free PVC film as a vacuum-assisted support layer, enabling improved interfacial contact without introducing additional soft interlayers.

The combination of electrostatic PVC and vacuum pressing effectively suppresses interfacial air gaps and promotes more homogeneous heat transfer during annealing, leading to enhanced perovskite crystallinity and improved film uniformity under low-temperature conditions. This simple, low-cost, and scalable approach minimizes contamination risks and simplifies the fabrication process, making it highly compatible with industrial manufacturing. As a result, the fabricated flexible carbon-based modules exhibit improved performance uniformity and mechanical durability. This work highlights the potential of utilizing commercially available materials and vacuum-assisted processing to enable high-quality perovskite films for next-generation flexible photovoltaic applications, thereby contributing to the advancement of sustainable energy technologies aligned with Sustainable Development Goal 7 (Affordable and Clean Energy).

**Keywords:** Carbon electrode, Electrostatic PVC, Flexible perovskite, Vacuum processing, Solar modules



# Engineering PHEMA-Based Porous Scaffolds and Compact Hydrogel Sheets Using Functionalized Silk Sericin as a Multifunctional Crosslinker

Pattaraporn Suttaphakdee[a], Nantaprapa Tuancharoensri [a], Sudarat Promkrainit[a], Medta Boupan[a], Preeyawass Phimnuan [b], Anuphan Sittichokechaiwut [c], Jirapas Jongjitwimol [d,e], Sararat Mahasaranon [a,e], Pensri Charoensit[b], Gareth M. Ross [a,e],Jarupa Viyoch [b], Sukunya Ross [a,e*]

[a] *Biopolymer Group, Department of Chemistry, Faculty of Science, Naresuan University, Phitsanulok 65000, Thailand*
[b] *Department of Pharmaceutical Technology, Faculty of Pharmaceutical Sciences and Center of Excellence for Innovation in Chemistry, Naresuan University, Phitsanulok 65000, Thailand*
[c] *Department of Periodontology, Faculty of Dentistry, Naresuan University, Phitsanulok 65000, Thailand*
[d] *Biomedical Sciences Program, Department of Medical Technology, Faculty of Allied Health Sciences, Naresuan University, Phitsanulok 65000, Thailand*
[e] *Center of Excellence in Biomaterials, Faculty of Science, Naresuan University, Phitsanulok 65000, Thailand,*

*Corresponding Author's E-mail: sukunyaj@nu.ac.th

**Abstract**

Hydrogels with tunable structural, mechanical, and biological properties are highly attractive for biomedical applications, particularly in wound healing and tissue engineering. In this study, poly(2-hydroxyethyl methacrylate) (PHEMA)-based hydrogels were developed in both porous scaffold and compact sheet forms by incorporating vinyl-functionalized silk sericin (SSC) as a multifunctional crosslinking component. Chemical modification introduced polymerizable vinyl groups onto silk sericin, enabling its co-polymerization with N,N′-methylene bisacrylamide (MBAAm) in a conventional redox-initiated system. Porous scaffolds were fabricated by lyophilization, while compact hydrogel sheets were prepared by molding. The effect of SSC concentration (1.25, 2.50, and 5.00% w/v) on hydrogel properties was systematically investigated. Compared with SSC-free C-PHEMA, C-PHEMA/SSC scaffolds exhibited smaller and more open pore structures, with pore sizes decreasing from 60–220 µm to 10–60 µm. SSC incorporation also increased the swelling ratio to approximately 160% and prolonged gelation time, indicating its significant influence on network formation and water uptake behavior. FTIR analysis confirmed successful hydrogel formation and suggested intermolecular hydrogen-bonding interactions between carbonyl and amine groups, supporting the formation of an integrated polymer network. Cytocompatibility evaluation using normal human dermal fibroblast (NHDF) cells revealed that C-PHEMA/1.25SSC was non-cytotoxic, maintaining cell viability above 70% and supporting cell attachment and growth, whereas higher SSC concentrations showed cytotoxic effects. Based on these findings, C-PHEMA/1.25SSC was selected for compact sheet fabrication and exhibited balanced viscoelastic properties with an improved tan delta. Overall, C-PHEMA/1.25SSC shows strong potential as a hydrogel platform for advanced biomedical applications.

**Keywords:** Poly(2-hydroxyethyl methacrylate) (PHEMA), silk sericin, hydrogel, porous scaffold, cytocompatibility, tissue engineering

# Tailoring Mechanical Performance and Printability of PLA-Based Filaments via ATEC Plasticization and TMC-200 Nucleation

Manasanan Namhongsa[a,b], Tanyaluck Mekpothi[a,c,d], Tawan Chiwan[a,c,d], Kulrachart dung-u-kos[e], Apirat chaitan[e], Gareth M. Ross[f], Sukunya Ross[f], Winita Punyodom[a,d*]

[a]*Bioplastics Production Laboratory for Medical Applications, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[b]*Center of Excellence in Materials Science and Technology, Chiang Mai University, Chiang Mai 50200, Thailand*
[c]*Office of Research Administration, Chiang Mai University, Chiang Mai 50200, Thailand*
[d]*Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[e]*IRPC Public Company Limited, Mueang District, Rayong 10900, Thailand*
[f]*Center of Excellence in Biomaterials, Department of Chemistry, Faculty of Science, Naresuan University, Phitsanulok 65000, Thailand*

*Corresponding Author's E-mail: winita.punyodom@cmu.ac.th

**Abstract**

Poly(L-lactide) (PLA) is a promising biodegradable and biocompatible polymer for biomedical applications; however, its intrinsic brittleness limits its use in fused deposition modeling (FDM). In this work, flexible and high-performance PLA monofilaments were developed via melt blending using acetyl triethyl citrate (ATEC, 1.0–5.0 wt%) as a plasticizer and zinc phenyl phosphonate (TMC-200, 0.3 wt%) as a nucleating agent. PLA containing 3.0 wt% ATEC exhibited the highest flexibility, while the incorporation of TMC-200 further enhanced tensile strength and ductility. Notably, the ternary blend (PLA/TMC-200/ATEC) demonstrated a synergistic effect, achieving a tensile strength of 35.0 MPa and elongation at break of 232.0% (compared to 12.1% for neat PLA), along with a significant increase in crystallinity from 4.7% to 45.0%. The resulting monofilaments (1.70 ± 0.05 mm) showed smooth surface morphology, balanced mechanical properties, and excellent cytocompatibility (>99% cell viability in L929 fibroblasts). Furthermore, FDM-printed specimens retained their mechanical and thermal performance, indicating good process stability. These findings highlight a synergistic plasticization–nucleation strategy for producing high-performance, medical-grade PLA filaments with improved toughness, printability, and biocompatibility for biomedical 3D printing applications.

**Keywords:** poly(L-lactide) monofilament, fused deposition modeling, nucleating agent, plasticizer, biodegradable polymers

# Effect of PEG Molecular Weight on the Synthesis of Zinc Oxide Nanoparticles and Their Integration into PLA/PBAT Films for Enhanced Antibacterial Active Packaging

Gopinath Kasi[a], Sarinthip Thanakkasaranee[a,b], Kittisak Jantanasakulwonga[a,b], Pornchai Rachtanapun[a,b*]

[a] *Division of Packaging Technology, Faculty of Agro-Industry, Chiang Mai University, 50100, Thailand.*
[b] *Center of Excellence in Agro Bio-Circular-Green Industry (Agro BCG), Chiang Mai University, Chiang Mai 50100, Thailand.*

*E-mail: pornchai.r@cmu.ac.th (P.R.); +66-635-492-556 (P.R.)

**Abstract**

The present work investigates the effect of polyethylene glycol (PEG; Mn = 400, 4000, 8000) molecular weight on the physicochemical properties of zinc oxide nanoparticles (ZnO NPs) synthesized via a hydrothermal method. The work focuses on optimizing thermal, structural, morphological, optical and stability characteristics for scalable production. Despite extensive studies on ZnO NPs, the role of PEG molecular weight in controlling nucleation, growth, and stability remains insufficiently explored. Thermogravimetric analysis (TGA) confirmed ZnO formation at 500 °C after 3 hours of calcination. X-ray diffraction (XRD) patterns revealed the crystallinity of ZnO in a hexagonal wurtzite structure. Transmission electron microscopy (TEM) results showed a nano-flower morphology of ZnO NPs. Energy-dispersive X-ray spectroscopy (EDS) mapping confirmed stoichiometric purity and particle uniformity. The zeta potential analysis demonstrated that PEG-8000 provided superior colloidal stability. The antibacterial activity of all the ZnO NPs was initially evaluated against *Staphylococcus aureus* (*S. aureus*) and *Escherichia coli* (*E. coli*) using the agar well diffusion method, where PEG-8000-ZnO NPs exhibited superior antibacterial performance. Subsequently, PEG-8000-ZnO NPs were surface-functionalized with 3-(glycidyloxypropyl)trimethoxysilane (SF-ZnO NPs) and incorporated into polylactic acid/polybutylene adipate terephthalate (PLA/PBAT) composite films at loadings of 0.5-3 wt.% via the solvent casting method. The fabricated composite films were characterized for their functional, structural, and morphological properties. Fourier transform infrared spectroscopy (FTIR) and XRD analyses confirmed successful incorporation of SF-ZnO NPs into the PLA/PBAT matrix, enhancing interfacial interactions and increasing crystallinity by acting as effective nucleating agents. Scanning electron microscope (SEM) analysis revealed that 1 wt.% SF-ZnO NPs achieved optimal dispersion. The composite films exhibited strong antibacterial activity, with films containing 1 and 3 wt.% SF-ZnO NPs achieving complete inhibition of *E. coli* and enhanced reduction of *S. aureus*, highlighting their potential for active food packaging applications.

**Keywords:** Hexagonal wurtzite, Hydrothermal method, Interfacial interaction, Nano-flower, Nucleating agent

# Anion-Dependent Redox Pathways Governing Water Splitting in Superconcentrated Lithium Electrolytes

Sagar Ingavale, Pawin Iamprasertkun*

*School of Bio-Chemical Engineering and Technology,*
*Sirindhorn International Institute of Technology and Research Unit in Sustainable Electrochemical Intelligent,*
*Thammasat University, Klong Luang, Pathum*
*Thani 12120, Thailand*

*Corresponding Author's E-mail: pawin@siit.tu.ac.th

**Abstract**

Electrochemistry involving super-concentrated electrolytes has rapidly gained attention as a transformative approach in electrochemical processes. Super-concentrated electrolytes have emerged as a groundbreaking solution in electrochemical applications, recognized for their non-flammable nature, eco-friendly composition, and expanded electrochemical stability window compared to conventional dilute aqueous electrolytes. The electrochemical hydrogen evolution reaction (HER) and oxygen evolution reaction (OER) are fundamental processes in energy conversion and storage technologies. This study investigates the electrochemical activity of platinum electrodes in lithium-based electrolytes for understanding the electrochemical characteristic from low to high concentration. The HER and OER kinetics in a super-concentrated electrolytes performed to address challenges related to stability and efficiency in high-concentration ionic environments. Highly concentrated electrolytes characterized by their unique solvation structure and extended electrochemical stability potential window, offer promising avenues for enhancing energy storage and conversion applications. Through cyclic voltammetry and linear sweep voltammetry, we analyze key parameters such as redox reactions, overpotentials, and kinetic reactions. This study explores the interaction between platinum and highly concentrated aqueous electrolytes to elucidate its influence on catalytic performance. The results provide insights into optimizing platinum-based electrocatalysis for next-generation sustainable energy solutions, highlighting the role of electrolyte composition in dictating reaction kinetics, potential window and overall electrochemical performance.
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**Keywords:** "water-in-salt", Oxygen evolution reaction, Hydrogen evolution reaction, Platinum, Voltage window

# Impact of Oxygen Pressure during Rapid Thermal Annealing on ALD ZnO TFTs

Jihun Ha[a], Seung-Hun Lee[a], Ahyun Park[a], Jae Woong Lee[a], Jeong Hwan Kim[a,*]

[a]*Department of Materials Science and Engineering, Hanbat National University, Daejeon 34158, Republic of Korea*

*Corresponding Author's E-mail: jkim@hanbat.ac.kr (J. H. Kim)

**Abstract**

Oxide thin-film transistors (TFTs) have attracted attention for next-generation transparent and low-temperature electronic applications because of their high optical transparency and favorable electrical properties. Among oxide semiconductors, ZnO is a promising channel material owing to its wide bandgap, simple composition, and high electron mobility. Atomic layer deposition (ALD) is advantageous for ZnO growth because it enables thickness control, uniformity, and low-temperature processing. However, ALD ZnO thin films contain oxygen-vacancy-related defects and residual impurities, which deteriorate the structural uniformity and electrical performance of TFT devices. To address these issues, post-deposition annealing has been employed to improve film quality, and $O_2$ rapid thermal annealing (RTA) is particularly effective because it suppresses defect-related states, reduces residual impurities, and stabilizes Zn-O bonding. In this process, oxygen pressure is a critical parameter because it directly determines the oxygen supply during annealing and thereby influences the structural, chemical, optical, and electrical properties of ZnO thin films.

In this work, we investigated the effects of oxygen-pressure-controlled $O_2$ RTA on ALD ZnO TFTs. ZnO thin films were annealed at 200 and 400 °C under oxygen pressures from vacuum to 400 Torr, and their structural, chemical, optical, and electrical properties were analyzed. As the oxygen pressure increased, the films became denser and smoother, while residual carbon impurities and oxygen-vacancy-related defects decreased. In contrast, the grain size decreased at high oxygen pressures, indicating suppressed grain growth. The optical bandgap remained nearly unchanged, whereas the threshold voltage shifted toward 0 V, the subthreshold swing improved, and the on/off ratio increased. The best device performance was obtained at 100 Torr, 400 °C, with a saturation mobility of 4.0 $cm^2/V \cdot s$, a subthreshold swing of 0.6 V/dec, and an on/off current ratio of $5.5 \times 10^8$. These results show that oxygen-pressure-controlled $O_2$ RTA is an effective post-treatment method for optimizing ALD ZnO TFTs.

**Keywords:** ZnO, Thin-film transistor, Atomic layer deposition, Rapid thermal annealing, Oxygen pressure

# Effect of Double Oxidation on ALD-Grown ZnO Thin Films and TFT performance

[A]hyun Park[a], Seung-Hun Lee[a], Jihun Ha[a], Jae Woong Lee[a], Jeong Hwan Kim[a,*]

[a]*Department of Applied Materials Engineering, Hanbat National University, Daejeon 34158, Republic of Korea*

*Corresponding Author's E-mail: jkim@hanbat.ac.kr

**Abstract**

Zinc oxide (ZnO) is a promising n-type channel material for transparent thin film transistors (TFTs) owing to its wide bandgap (3.37 eV), high optical transparency, and compatibility with low-temperature processing. However, the electrical performance and operational stability of ZnO TFTs are closely related to defect states in the channel layer, particularly oxygen-vacancy ($O_V$) defects and impurity levels formed during film growth. In this regard, atomic layer deposition (ALD) is a highly suitable technique for ZnO channel layer deposition because its self-limiting surface reactions enable precise control over film properties. In ALD-grown ZnO, the oxidant is a key process parameter because it determines the surface reaction pathway during deposition and thereby influences the resulting film characteristics. In this study, ZnO thin films were deposited using double oxidation processes consisting of two sequential oxidant pulses, within a single ALD cycle. In contrast to the conventional oxidation process using only one oxidant, this approach allows the distinct characteristics of each oxidant to complement each other during film growth. In addition, the second oxidant pulse facilitates the removal of DEZ-derived ethyl ligands ($-C_2H_5$) remaining after the first oxidation step. To verify these effects, ZnO films and TFTs were fabricated by thermal ALD using conventional oxidation ($H_2O$ or $O_3$) and double oxidation ($H_2O/O_3$ and $O_3/H_2O$) processes, followed by structural, chemical, and electrical characterization. Overall, double oxidation improved the densification and crystallinity of ZnO films and was effective in controlling $O_V$ defects and carbon-related impurities. In particular, the ZnO film deposited using the $H_2O/O_3$ oxidation process exhibited improved TFT performance, with higher mobility, lower subthreshold swing, and reduced hysteresis. These results indicate that both oxidant selection and pulse sequence are important parameters in determining the properties of ALD-grown ZnO films, and that double oxidation is an effective process for achieving high-performance ZnO TFTs.

**Keywords:** Atomic layer deposition, ZnO, Thin film transistor, Double oxidation

# Enhanced Dielectric Properties of W and In co-doped $TiO_2$ ceramics

Theeranuch Nachaithong[a,*], Suphanut Sotonsak[b], Prasit Thongbai[b], Ken Kurosaki[a]

[a]*Institute for Integrated Radiation and Nuclear Science, Kyoto University, Osaka 590-0494, Japan*
[b]*Giant Dielectric and Computational Design Research Group (GD–CDR), Department of Physics, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand,*

*Corresponding Author's E-mail: nachaithong.theeranuch.3s@kyoto-u.ac.jp

**Abstract**

Titanium dioxide ($TiO_2$) is an important oxide semiconductor with a stable rutile structure and potential for use in electronic and capacitor applications. However, pure $TiO_2$ typically exhibits a moderate dielectric constant, which limits its performance in high-permittivity devices. In this work, $W^{6+}$ and $In^{3+}$ co-doping was employed to modify the defect chemistry and enhance the dielectric response of $TiO_2$ ceramics.

($W^{6+}$+$In^{3+}$) co-doped $TiO_2$ ceramics were synthesized using a conventional solid-state reaction route and sintered to achieve dense microstructures. Phase structure and grain morphology were examined by X-ray diffraction and scanning electron microscopy, respectively. Dielectric properties were measured over a broad frequency range at room temperature.

The co-doped ceramics show a significant increase in dielectric constant compared with undoped $TiO_2$, accompanied by relatively low dielectric loss at high frequency. Enhanced dielectric behavior is attributed to the formation of electrically heterogeneous microstructures consisting of semiconducting grains and insulating grain boundaries, which is consistent with an internal barrier layer capacitor (IBLC) mechanism. The simultaneous incorporation of donor-type W and acceptor-type In dopants promote charge compensation and defect dipole formation, contributing to interfacial polarization and improved dielectric performance.

These results demonstrate that defect engineering through ($W^{6+}$+$In^{3+}$) co-doping is an effective strategy to develop high-dielectric $TiO_2$-based ceramics and provides insight into the relationship between dopant chemistry, microstructure, and dielectric response in oxide semiconductors.

**Keywords:** $TiO_2$, Co-Doping, Dielectric Ceramics, Internal Barrier Layer Capacitor

# Enhanced Thermoelectric Performance of Screen-Printed $Ag_2Se$ Nanowire Films through Tellurium Compositing and Post-Treatment

Peeranut Kitthonbancha[a,b], Wei-Di Liu[b], Zhi-Gang Chen[b], Supree Pinitsoontorn[a,c,*]

[a] *Materials Science and Nanotechnology Program, Department of Physics, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand,*
[b] *School of Chemistry and Physics, ARC Research Hub in Zero-emission Power Generation for Carbon Neutrality, and Centre for Materials Science, Queensland University of Technology, Brisbane, QLD 4000, Australia,*
[c] *Institute of Nanomaterials Research and Innovation for Energy (IN-RIE), Department of Physics, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand.*

*Corresponding Author's E-mail: psupree@kku.ac.th

**Abstract**

Scalable fabrication to high-performance thermoelectrics remains a critical challenge for practical energy harvesting. Here, we report screen-printed $Ag_2Se$ nanowire films using ethyl cellulose (EC) as a binder, followed by controlled post-treatment and tellurium (Te) compositing to tune transport near room temperature. Cold pressing markedly increases electrical conductivity ($\sigma$) to 214 S $cm^{-1}$ by densifying the film and reducing thickness from 35 to 3.7 μm, thereby improving carrier transport pathways. In contrast, annealing increases the magnitude of the Seebeck coefficient ($S$) (up to −141 μV $K^{-1}$) due to reduced carrier concentration, leading to a trade-off between $\sigma$ and $S$. Te compositing combined with pressing and annealing enables enhancement of $\sigma$ and $S$, resulting in a substantial increase in power factor from 0.24 to 5.05 μW $cm^{-1}$ $K^{-2}$. Hall measurements indicate that the improvement is primarily mobility-driven, with carrier mobility reaching 518 $cm^2$ $V^{-1}$ $s^{-1}$ despite a decrease in carrier concentration. Water contact angle values of 98–112° confirm the hydrophobic character of EC-based films, which supports uniform deposition and film stability during processing. These results provide a practical approach to enhance the performance of printed $Ag_2Se$ thermoelectrics.

**Keywords:** $Ag_2Se$ nanowire, flexible thermoelectric, screen printing, tellurium composite

# Solid-State Synthesis and Thermoelectric Properties of $Ag^2Se$

Thunchanok Kongpiriyakorn[a,b], Wisanart Teangchangrum[a,b], Weerawat Toaran[a,b], Santi Maensiri[a,b,*]

[a]*School of Physics, Institute of Science, Suranaree University of Technology, Nakhon Ratchasima 30000, Thailand*
[b]*Center of Excellence on Advanced Functional Materials, Suranaree University of Technology, Nakhon Ratchasima, 30000, Thailand*

*Corresponding Author's E-mail: santimaensiri@sut.ac.th

**Abstract**

Silver selenide ($Ag_2Se$) is a narrow-bandgap chalcogenide that has attracted increasing attention as a promising thermoelectric material due to its high electrical conductivity and favorable carrier transport properties. In this work, $Ag_2Se$ was synthesized via a simple solid-state reaction using elemental silver and selenium powders as starting materials. The mixed powders were pelletized and sealed in evacuated quartz ampoules before heat treatment at 400 °C to promote solid-state diffusion and phase formation. The crystal structure and phase purity of the synthesized samples were characterized by X-ray diffraction (XRD), while the microstructure was examined using scanning electron microscopy (SEM). Basic thermoelectric properties, including electrical conductivity, Seebeck coefficient, and power factor, were also evaluated to assess the potential of the prepared materials for thermoelectric applications. The solid-state route provides a straightforward and scalable method for producing crystalline $Ag_2Se$, serving as a reference system for understanding the structure–property relationships in $Ag_2Se$-based thermoelectric materials

**Keywords:** Silver selenide, Solid-State Reaction, Thermoelectric, Seebeck coefficient, Characterization.

# Hydrothermal Synthesis of PVP-Assisted $Ag_2Se$ and Its Thermoelectric Properties

Wisanart Teangchangrum[a,b] , Thunchanok kongpiriyakorn[a,b] , Weerawat Toaran[a,b] , Santi Maensiri[a,b,*]

[a]*School of Physics, Institute of Science, Suranaree University of Technology, Nakhon Ratchasima 30000, Thailan* [d]

[b]*Center of Excellence on Advanced Functional Materials, Suranaree University of Technology, Nakhon Ratchasima, 30000, Thailand*

*Corresponding Author's E-mail: santimaensiri@sut.ac.th

**Abstract**

Silver selenide ($Ag_2Se$) nanostructures have attracted considerable interest for thermoelectric applications owing to their tunable microstructure and transport properties. In this study, $Ag_2Se$ nanostructures were synthesized via a hydrothermal method using polyvinylpyrrolidone (PVP) as a structure-directing agent. Silver ions were gradually introduced into a selenium-containing solution under controlled dropwise conditions to regulate nucleation and growth processes. The reaction mixture was subsequently subjected to hydrothermal treatment to form $Ag_2Se$ nanostructures. The influence of PVP concentration on particle morphology and agglomeration behavior was systematically investigated. The phase composition of the products was analyzed by X-ray diffraction (XRD), while the microstructure and morphology were examined using scanning electron microscopy (SEM). In addition, the basic thermoelectric properties, including electrical conductivity and Seebeck coefficient, were measured to evaluate the effect of synthesis conditions on the transport behavior of the materials. The results provide insights into the relationship between synthesis parameters, microstructure, and thermoelectric performance of $Ag_2Se$ prepared by solution-based methods.

**Keywords:** Silver selenide, Hydrothermal Synthesis, Thermoelectric, Seebeck coefficient , Characterization

# Advanced Thermal and Charge Management Systems for Thermally Chargeable Supercapacitor Modules in Energy Harvesting Applications

Shohei Horike[a,b,c,d*], Ryoko Nakae[b], Yasuko Koshiba[a,c], Azumi Akiyama[a,c], Masahiro Funahashi[a,c] Qingshuo Wei[d,e]

[a]*Department of Chemical Science and Engineering, Graduate School of Engineering, Kobe University, 1-1 Rokkodai-cho, Kobe 657-8501, Japan*
[b]*Center for Environmental Management, Kobe University, 1-1 Rokkodai-cho, Kobe 657-8501, Japan*
[c]*Research Center for Membrane and Film Technology, Kobe University, 1-1 Rokkodai-cho, Kobe 657-8501, Japan*
[d]*Research Institute of Core Technology for Materials Innovation, National Institute of Advanced Industrial Science and Technology (AIST), 1-1-1 Higashi, Tsukuba 305-8656, Japan*
[e] *Graduate School of Pure and Applied Science, University of Tsukuba, 1-1-1 Tennodai, Tsukuba 305-8577, Japan*

*Corresponding Author's E-mail: horike@crystal.kobe-u.ac.jp

**Abstract**

As wireless sensors in the Internet of Things (IoT) become ubiquitous, energy harvesting technologies are essential for realizing independent power supplies. Thermally chargeable supercapacitors (TCSs), a novel class of thermoelectric devices utilizing redox-free electrolytes, have garnered attention. Their giant thermoelectromotive force significantly simplifies module fabrication compared to conventional electron-transporting materials. In this presentation, we will report our recent advancements in the device engineering and thermal management of TCSs for practical IoT applications.

First, we developed a TCS module comprising 1-ethyl-3-methylimidazolium chloride and poly(vinyl alcohol) hydrogels. By electrically connecting multiple elements in series, we successfully generated an open-circuit voltage exceeding 4 V without using a DC-to-DC converter. This large output is sufficient for the cold-start activation of commercial wireless sensors.

Second, unlike conventional thermoelectric generators, the voltage of a TCS decays under a continuous electrical load. To address this, we integrated an ultralow-energy-consumption voltage detector integrated circuit (IC) into the module. This charge management circuit automatically controls the intermittent charging and discharging cycles, successfully driving a versatile IoT sensor.

Finally, practical thermoelectric generation requires maintaining a temperature difference under natural convection. We will demonstrate a compactly designed TCS module equipped with a heat transporting and dissipation system combining a heat pipe and heat sinks (Fig. 1). This configuration efficiently transfers thermal energy from spatially separated heat sources to the device while dissipating heat into the air, enabling intermittent sensor operation solely through natural cooling. These device designs and thermal engineering strategies offer a sustainable solution for recovering low-grade waste heat to power future IoT networks.

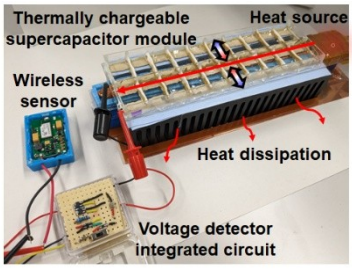



**Fig. 1** Photo of TCS module with developed thermal and charge management systems (Reproduced from Horike *et al.*, *Chem. Eng. J.* 2025, 516, 164119 under a CC-BY license).

**Keywords:** thermoelectric, electrolyte, wireless sensor, charge management, thermal management

# Size-Controlled Synthesis of Metal Organic Chalcogenide Nanocrystals Through Antisolvent Reprecipitation Method

Achawee Dangkongko[a,*], Pimpan Leangtanom[a], Watcharaphol Paritmongkol[a]

[a]*Department of Materials Science and Engineering, School of Molecular Science and Engineering, Vidyasirimedhi Institute of Science and Technology (VISTEC), Rayong, 21210, Thailand.*

[*]Corresponding Author's E-mail*: Achawee.d_s23@vistec.ac.th*

**Abstract**

Metal organic chalcogenides (MOCs) are an emerging class of hybrid semiconductor materials with distinctive optoelectronic properties, including tunable photoluminescence emission, strong exciton binding energy, and non-toxic composition. Among these, silver- and copper-based MOCs have attracted particular interest due to their promising optical characteristics and potential as hole transport materials, making them attractive candidates for photovoltaic and light-emitting devices. Despite these promising attributes, current synthesis strategies for MOC nanocrystals remain limited, particularly regarding precise control over particle size and morphology, which are critical parameters governing optical and electronic performance. In this work, we propose the antisolvent reprecipitation method as a novel and efficient approach for synthesizing MOC nanocrystals. This technique exploits the differential solubility of the material between two immiscible solvents, whereby rapid injection of a precursor solution into a poor solvent induces immediate supersaturation and triggers fast nucleation, yielding well-defined nanocrystals. The method offers significant advantages in terms of simplicity, speed, and reproducibility compared to conventional synthetic routes. Crucially, nanocrystal size can be systematically tuned by adjusting key parameters, including the choice of antisolvent and precursor concentration, providing a straightforward handle for tailoring material properties. Furthermore, this approach demonstrates compositional versatility through systematic chalcogen substitution across sulfur, selenium, and tellurium, enabling fine-tuning of the optical bandgap and photoluminescence properties of the resulting MOC nanocrystals. Collectively, this work establishes the antisolvent reprecipitation method as a powerful and accessible platform for the controlled synthesis and compositional engineering of silver- and copper-based MOC materials toward optoelectronic applications.

**Keywords:** Metal organic chalcogenides, antisolvent reprecipitation, nanocrystals, photoluminescence

# Effects of Fe and Sn Co-doping on the Densification and Thermoelectric Properties of ZnO Ceramics

Poonnisar Maneechai[a], Benjarath Waytathum[c] and Anucha Watcharapasorn[a],[b],[c]

[a]*Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*

[b]*Center of Excellence in Materials Science and Technology, Materials Science Research Center, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*

[c]*Advanced Electronic Materials Research Laboratory, Department of Physics and Materials Science, Faculty of science, Chiang Mai University, Chiang Mai, 50200, Thailand*

*Corresponding Author's E-mail: poonnisar.man@gmail.com

**Abstract**

ZnO is a promising n-type thermoelectric material due to its relatively high-temperature stability and high figure of merit. However, its performance is limited by low electrical conductivity and high thermal conductivity. To address these limitations, this study has systematically investigated the dopant effects and found a possible combination of doping elements which may enhance thermoelectric performance of ZnO. The co-doping of Fe and Sn in ZnO ceramic having compositions of $Zn_{1-x}Fe_xO$ and $Zn_{1-x-y}Fe_xSn_yO$ Sn were therefore investigated for their densification behaviour and thermoelectric properties. All samples were compacted into cylindrical pellets and subjected to a multi-step sintering process at temperatures ranging from 900 °C to 1100 °C. All samples were characterized for their crystal structure and phase using X-ray diffraction technique. The microstructure and elemental composition studies were conducted using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS). X-ray Photoelectron Spectroscopy (XPS) was used to provide the chemical state, oxidation state, and bonding analysis. Thermoelectric properties at various temperatures of these co-doped ZnO ceramics were also investigated and discussed in relation to their physical and chemical characteristics.

**Keywords:** ZnO, Co-doping, Thermoelectric properties, X-ray Photoelectron Spectroscopy, Solid-state reaction

# Study on the Thermoelectricity of CCFN based on High-Entropy Alloys Thin Film as prepared by RF Magnetron Sputtering

Wutthikrai Udomlap[a], Mekhala Insawang[b], Saksorn Limwichean[c], Mati Horprathum[c], Tosawat Seetawan[a,b], Athorn Vora-ud[a,b*],

[a]*Program of Physics, Faculty of Science and Technology, Sakon Nakhon Rajabhat University, 680 Nittayo Road, Mueang District, Sakon Nakhon, 47000, Thailand*
[b]*Center of Excellence on Alternative Energy, Research and Development Institute, Sakon Nakhon Rajabhat University, 680 Nittayo Road, Mueang District, Sakon Nakhon, 47000, Thailand*
[c]*National Electronics and Computer Technology Center, 114 Thailand Science Park, Paholyothin Road, Klong 1, Klong Luang, Pathumthani 12120, Thailand*

*Corresponding Author's E-mail: athornvora-ud@snru.ac.th

**Abstract**

In this work, CoCrFeNi (CCFN) high-entropy alloy (HEA) thin films were prepared by radio-frequency (RF) magnetron sputtering for thermoelectricity studies. The $SiO_2$/Si wafer substrates were used to support thin-film sample deposition. The substrates were placed in the sample holder in the sputtering chamber with a base pressure set below $2.3 \times 10^{-3}$ Pa and a working pressure of 1.3 Pa under an Ar atmosphere with a flow rate of 40 sccm. The thin film deposition conditions were fixed at a sputtering power of 100 watts and maintained for 5 minutes. After thin film deposition, the crystal structure, morphology, film thickness, and atomic composition of the CCFN thin film were characterized using X-ray diffraction (XRD), field-emission scanning electron microscopy (FE-SEM), and energy-dispersive X-ray spectroscopy (EDS) techniques, respectively. The thermoelectric properties (electrical resistivity; ρ and Seebeck coefficient; S) were measured by the ZEM-3 method to calculate the power factor (PF) value. The crystalline characterized results showed that the CCFN thin films are amorphous. The thermoelectricity studied illustrated the power factor is 3.0 mW $m^{-1}$ $K^{-2}$ ($\rho = 1.14 \times 10^{-5}$ Ω m and S = 185 μV $K^{-1}$) at ambient temperature measurement.

**Keywords:** Thermoelectricity, high-entropy alloys thin film, CoCrFeNi material, magnetron sputtering

# Tunable visible and NIR emission characteristics of $Ho^{3+}$ and $Ho^{3+}$ /$Yb^{3+}$ co-doped zinc tellurite glasses for solid-state lightning and 2 µm laser applications

Suresh Keenatampalle[a], C.R. Kesavulu[b], A. Madhu[c], C.K. Jayasankar[d,b], Kanokthip Boonyarattanakalin[a], Thanaphon Kansaard[a], Wanichaya Mekprasart[a]* and Wisanu Pecharapa[a*]

[a]*School of Integrated Innovative Technology, King Mongkut's Institute of Technology Ladkrabang, Bangkok, 10520, Thailand.*
[b]*Department of Physics, School of Engineering, Amrita Vishwa Vidyapeetham, Amaravati Campus, Guntur-522 503, A.P., India.*
[c]*Department of Physics, Dayananda Sagar College of Engineering, Kumaraswamy Layout, Bangalore-560 078, India*
[d]*Department of Physics, Sri Venkateswara University, Tirupati-517 502, A.P., India*

**Corresponding author E-mail address: wanichaya.me@kmitl.ac.th and kpewisan@gmail.com*

**Abstract**

$Ho^{3+}$ and $Ho^{3+}$/$Yb^{3+}$ co-doped tellurite glasses based on zinc were prepared by deploying the melt and rapid quenching technique. Judd–Ofelt analysis was employed to assess the intensity and fluorescent parameters of $Ho^{3+}$ in this glassy matrix. The emission cross-section ($\sigma_{em}$) of the dominant emission peaks observed around 547, 658, 754, 1193 and 2006 nm are calculated by using the Fuchtbauer–Ladenburg equation and found to be 1.61, 1.23, 0.02, 0.87 and 1.1, x 10-20 $cm^2$, respectively. The color coordinates of the glass doped with 0.5 mol % $Ho^{3+}$ falls in the exact green region with color purity of 96 %. Also, substantial enhancement in the emission intensities of $Ho^{3+}$: $^5I_7 \rightarrow {}^5I_8$ (2.0 µm) transition was observed through the sensitization of $Yb^{3+}$: $^2F_{5/2} \rightarrow {}^2F_{7/2}$ transition when excited at 980 nm. The potential energy transfer mechanism from $Yb^{3+}$ to $Ho^{3+}$ is investigated by analyzing photoluminescence excitation spectra, de-excitation spectra, and decay dynamics. Furthermore, the McCumber theory was employed to validate the absorption cross-section and $\sigma_{em}$ of $Ho^{3+}$: $^5I_7 \rightarrow {}^5I_8$ transition (2 µm emission). The obtained $\sigma_{em}$ of 1.41x10-20 $cm^2$ aligns well with the value of $1.2x10^{-20}$ $cm^2$ calculated via Fuchtbauer–Ladenburg equation. These results suggest that $Ho^{3+}$ and $Ho^{3+}$/$Yb^{3+}$ co-doped zinc tellurite glasses are promising candidates for solid state lightning and infrared solid-state lasers and optical amplifier applications around 2.0 µm.

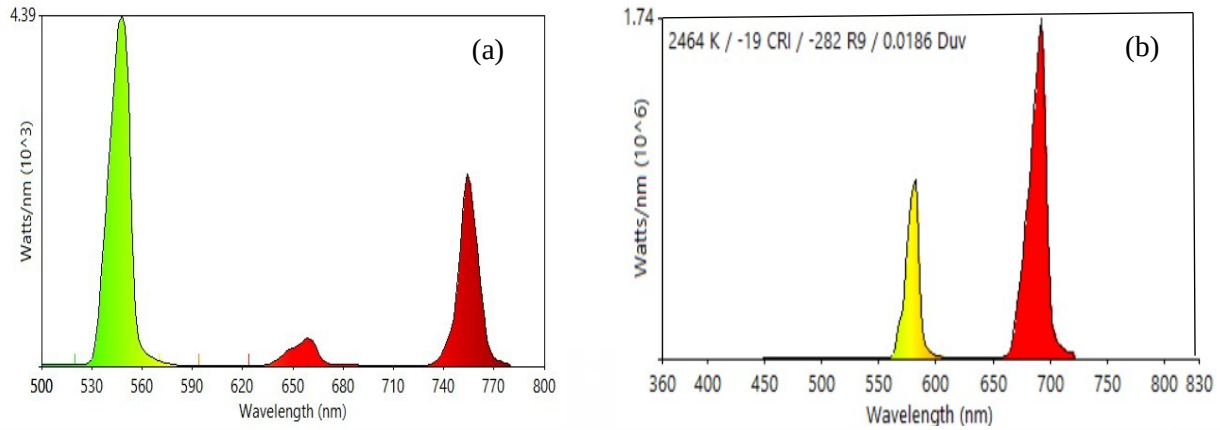



Fig. Emission spectra of (a)$Ho_{0.5}$ glass and (b) $Ho_{0.5}Yb_{1.0}$ glass under 453 and 980 nm excitation, respectively

**Keywords:** $Ho^{3+}$/$Yb^{3+}$ tellurite glasses, Judd-Ofelt theory, Energy transfer, McCumber theory, Decay analysis

# Engineering ZnO/Carbon Quantum Dot Heterojunctions for Enhanced Charge Transfer and Visible-Light Photoresponse

Maneerat Songpanit[a], Thanaphon Kansaard[a], Kanokthip Boonyarattanakalin[a], Hideyuki Okumura[b], Keiichi N. Ishihara[c], Wisanu Pecharapa[a], Wanichaya Mekprasart [a,*]

[a] *Department of Nanoscience and Nanotechnology, School of Integrated Innovative Technology, King Mongkut's Institute of Technology Ladkrabang, Bangkok, 10520, Thailand*
[b] *Graduate School of Energy Science, Kyoto University, Yoshida Honmachi, Sakyo, Kyoto, 606-8501, Japan*
[c] *Open Innovation Institute, Kyoto University, Yoshida Honmachi, Sakyo, Kyoto, 606-8501, Japan*

*Corresponding Author's E-mail*: wanichaya.me@kmitl.ac.th*

**Abstract**

Mild-hydrothermal synthesis of ZnO, as a wide bandgap semiconductor, followed by surface modification with biomass-derived carbon quantum dots (CQDs) from cassava pulp via a wet-impregnation approach, is presented to improve interfacial charge transfer properties. ZnO/CQDs composites with varying CQDs loadings (1, 3, 5, 7, 9 and 10 mL) were fabricated to investigate their structural, electronic, and photoresponsive characteristics. X-ray diffraction and FTIR analyses confirmed that all samples retained the hexagonal wurtzite structure of ZnO with characteristic Zn-O bonding after CQDs incorporation, indicating structural stability. Meanwhile, field-emission scanning electron microscopy (FE-SEM) revealed that ZnO powders maintained a plated-like and fluffy morphologies with increasing CQDs impregnation time. X-ray photoelectron spectroscopy verified successful CQDs integration and strong interfacial coupling between ZnO and CQDs, which modulates surface electronic states and facilitates charge transfer. Electrochemical measurement revealed the improvement of photocurrent response under light irradiation owing to the influence of charge transfer resistance. Photoresponse performance of the samples was evaluated by Rhodamine B degradation under Xenon lamp irradiation as a simulated visible-light source. The ZnO/CQDs composites exhibited significantly enhanced photoresponse, with an optimal CQDs loading observed at 5 mL, while higher CQDs loadings (7–10 mL) resulted in a slight decline due to excessive surface coverage and light-shielding effects. The enhanced performance is attributed to heterojunction formation of ZnO–CQDs interface, where CQDs act as electron acceptors and charge-transfer pathways, promoting charge separation and suppressing electron–hole recombination. The results demonstrate a sustainable strategy for the electronic and photoresponse properties of ZnO semiconductor through integration with biomass-derived carbon nanomaterials, offering potential applications in photoactive semiconductor devices and light-driven technologies.

**Keywords:** ZnO, CQDs, Charge transfer, Photoresponse

# Current Induced Magnetic Switching of $WTe_2/Fe_3GaTe_2$ Two-Dimensional Heterostructure

Pradeep Raj Sharma, Bogeun Jang, and Jongill Hong*

*Department of Materials Science and Engineering, Yonsei University, Seoul 03722, South Korea*

*Corresponding Author's E-mail: hong.jongill@yonsei.ac.kr

**Abstract**

Among the materials and structural designs, two-dimensional (2D) van-der Waals (vdW) materials and their heterostructures have proven to be highly scalable and promising structures for studying spin-orbit torque (SOT). Particularly, 2D-vdW material $Fe_3GaTe_2$ (FGaT) exhibiting strong perpendicular magnetic anisotropy at room temperature and a topological-semimetal WTe2 with an asymmetric crystallographic structure are catching eminence attention as an innovative structure controlling zero-field magnetization switching via SOT due to its high scalability and low energy consumption. Here, we present the SOT effect in the Hall cross-bar-designed devices by analyzing the anomalous Hall effect (AHE) modulated by pulse current and second harmonic measurements.

We demonstrate field-free SOT switching, revealing an ultra-low threshold switching current density of about $6.5\times10^9$ A/m² and a giant SOT efficiency of 8.5. Furthermore, the second harmonic-modulated non-linear signal results in similar SOT efficiency approaching nearly double digits. These values exceed the SOT performance of heavy-metal/FM-based systems by two orders of magnitude and surpass values reported for fully vdW material-based systems. This work marks a milestone toward advancing the SOT application, particularly in developing energy-efficient and compatible cutting-edge memory technologies.

**Keywords:** $Fe_3GaTe_2$, van-der Waals materials, Ferromagnetism, Current Induced Magnetic Switching

# Development of Nanocellulose-Based Spray Coatings for Enhanced Mechanical Strength and Water Resistance of Medical Protective Fabrics

Kittiya Plermjai1 [a*], Parida Jampeeruang [a], Phee Limpitheep [b]

[a]*Department of Science Service, 5/7 Rama VI Road, Ratchathewi, Bangkok 10400, Thailand*
[b] *Innovation Center, Thai Cane Board Co., Ltd., 147/235 Borommaratchachonnani Rd., Arun Amarin, Bangkok Noi, Bangkok 10700, Thailand*

*Corresponding Author's E-mail: bbewplermjai@gmail.com

**Abstract**

The development of sustainable functional coatings for medical protective textiles has attracted increasing attention due to the growing demand for environmentally friendly and high-performance materials. This study investigates the optimal formulation of nanocellulose-based coatings to enhance the mechanical strength and water resistance of fabrics intended for medical personal protective equipment (PPE). Nanocellulose was combined with inorganic nanoparticles, including silicon dioxide ($SiO_2$) and titanium dioxide ($TiO_2$), to form hybrid coating systems. These coatings were applied onto polyester fabrics using a spray-coating technique. The coated fabrics were characterized in terms of surface morphology, water resistance, and mechanical performance. The results showed that the nanocellulose/$TiO_2$ coating exhibited the best performance among all formulations. The coated fabric demonstrated a significantly improved breaking strength of 327.46 N, compared with 83.19 N for the untreated fabric. In addition, the hybrid coating containing 2.5 wt% nanocellulose provided the highest water resistance, with the lowest water penetration of 6.95 g and a maximum hydrostatic pressure resistance of 229.50 mm$H_2O$. These results indicate that nanocellulose-based hybrid coatings offer a promising and sustainable approach for developing high-performance medical protective textiles with enhanced mechanical durability and liquid barrier properties.

**Keywords:** Spray coating agent, Nanocellulose, Fabric surface coating material, Textile coating agent

# Glucose-Sensitive and 3D-Printable Dynamic Chitosan Hydrogels from Boronic Acid-Functionalized Chitosan and Gallol-Functionalized Chitosan

Ting-Yu Chang , Tsai-Yu Chen , Qian-Pu Cheng , Shan-hui Hsu*

*Institute of Polymer Science and Engineering, National Taiwan University, Taipei, Taiwan, ROC*

*Corresponding Author's E-mail: shhsu@ntu.edu.tw

**Abstract**

Chitosan-based hydrogels are widely recognized for their biocompatibility; however, achieving high structural fidelity in 3D printing at low polymer concentrations remains a significant challenge. This study introduces a novel self-healing hydrogel ink (CGB) based on the dynamic covalent chemistry between gallol-functionalized chitosan (CG) and boronic acid-functionalized chitosan (CB). Notably, this system enables robust 3D printability at an exceptionally low solid content of only 2 wt%. Advanced structural characterization through rheological measurements and small-angle X-ray scattering (SAXS) reveals that CG and CB independently form rod-shaped self-assembled clusters. Upon mixing, the formation of dynamic boronate ester linkages induces a highly compact, fractal-like network with superior short-range organization. This unique hierarchical architecture imparts the CGB hydrogel with pronounced shear-thinning properties and rapid recovery, allowing for the extrusion through 160 μm nozzles and the construction of high-aspect-ratio structures up to 60 layers without collapse.Beyond its excellent printability, the CGB hydrogel exhibits versatile responsiveness, demonstrated through its application as a customizable visual redox sensor and a glucose-sensitive sacrificial template for creating complex 90°-rotated H-shaped microchannels. Furthermore, the hydrogel maintains potent antimicrobial activity and supports high cell viability (>90%). These findings demonstrate that the CGB system serves as a sophisticated ink platform for fabricating intricate 3D constructs in tissue engineering.

**Keywords:** Self-healing hydrogel, Boronic acid chitosan, Gallol chitosan, 3D printing, Stackability

# Development of Natural Rubber and High-Density Polyethylene Blends: A Sustainable Alternative to Commercial Thermoplastic Elastomer

Athapon Simpraditpan, Anothai Pholsuwan, Varistha Chobpattana, Kawita Chattrakul, Chuntip Skumnuantip*

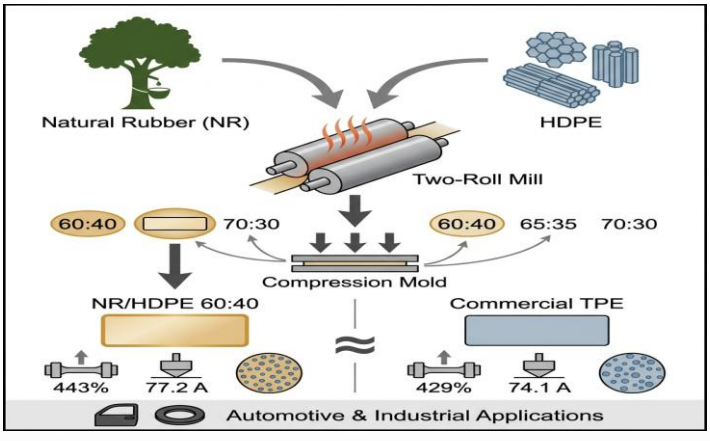
*Department of Materials and Metallurgical Engineering, Faculty of Engineering, Rajamangala University of Technology Thanyaburi, Thailand*

*Corresponding Author's E-mail: chuntip.s@en.rmutt.ac.th

**Abstract**

This study investigates the development of a thermoplastic elastomer (TPE)-like polymer blend using natural rubber (NR, STR 5L) and high-density polyethylene (HDPE R1760) as an alternative to commercial TPE materials. Three blend formulations were prepared at NR:HDPE ratios of 60:40, 65:35, and 70:30 (phr) by melt mixing on a two-roll mill at 180–200°C, followed by compression molding. The blends were characterized for density, Shore A hardness, melt flow index (MFI), tensile properties (100% modulus, tensile strength, elongation at break), tear strength, and morphological compatibility via scanning electron microscopy (SEM), with all values benchmarked against a commercial TPE reference. Results demonstrated that the NR:HDPE blend at a 60:40 ratio yielded the closest approximation to the commercial TPE across all properties. This formulation achieved a density of 0.918 g/cm³, Shore A hardness of 77.2 (vs. TPE: 74.1), MFI of 4.14 g/10 min, tensile strength of 6.94 MPa (vs. TPE: 7.76 MPa), elongation at break of 443.1% (vs. TPE: 428.7%), and tear strength of 40.5 N/mm. Mechanical performance increased consistently with higher HDPE content, attributed to HDPE's linear crystalline microstructure enhancing rigidity and reinforcement of the amorphous NR matrix. SEM analysis confirmed that the 60:40 blend exhibited the most uniform phase dispersion, resulting from optimal shear conditions during two-roll milling—a key factor governing interfacial compatibility and final mechanical performance. These findings demonstrate that NR/HDPE melt blends can serve as viable, cost-effective TPE substitutes, particularly at a 60:40 ratio, with potential applications in automotive sealing and industrial rubber goods sectors. Future work should explore the incorporation of compatibilizers and vulcanization systems to further close the performance gap with commercial TPE grades.

**Keywords:** Polymer blend, Natural rubber, Polyethylene, Thermoplastic elastomer, Mechanical properties



# Polymer-Free Fabrication of Fibrinogen-Based Decellularized ECM Sheets with Enhanced Functionality via Ascorbic Acid

Youngdoo Chung[a], Hee Seok Yang[a, b, *]

[a]*Department of Nanobiomedical Science & BK21 FOUR NBM Global Research Center for Regenerative Medicine, Dankook University, Cheonan, 31116, Republic of Korea,*
[b]*Department of Biomedical Sciences & Biosystems, Dankook University, Cheonan, 31116, Republic of Korea*

*Corresponding Author's E-mail: hsyang@dankook.ac.kr

**Abstract**

Decellularized tissue and cell-derived extracellular matrix (ECM) play critical roles in tissue engineering by providing structural support and biochemical cues for cell adhesion, proliferation, and differentiation. However, conventional decellularized matrices often exhibit limited functionality and inconsistent mechanical properties. In this study, fibroblasts were cultured in growth medium supplemented with ascorbic acid (AA-GM) to enhance ECM synthesis via activation of sodium-dependent ascorbate transporters (SVCT2) and subsequent collagen and glycoprotein production. Enhanced ECM deposition was confirmed through immunocytochemical staining of fibronectin and scanning electron microscopy, revealing a dense and interconnected fibrillar network. Quantitative analysis showed that AA-GM 50 (50 μg/mL AA) increased ECM content by approximately 91% compared to the control group without AA. Cell sheets were fabricated by simply dispensing fibrinogen solution in growth medium, without the use of synthetic polymers or chemical crosslinkers, enabling a biomimetic and cytocompatible platform. Decellularization was achieved using a mild Triton X-100 surfactant treatment, effectively removing cellular components while preserving ECM integrity without additional chemical enzyme. The resulting sheets exhibited significantly reduced DNA content, indicating minimal immune reaction after transplantation. Furthermore, stacking of the sheets enabled the formation of a stable multilayered three-dimensional structure through robust fibrin gel integration. Lyophilization of the ECM sheets imparted muco-adhesive properties, facilitating their application to a mouse skin wound healing model. Histological analyses demonstrated that multilayer ECM sheets significantly enhanced tissue regeneration compared to single-layer constructs, showing improved re-epithelialization and matrix remodeling. These findings suggest that fibrinogen-based decellularized ECM sheets represent a promising, scalable, and polymer-free therapeutic platform for advanced wound healing applications.

**Keywords:** Ascorbic acid, Decellularization, Fibrinogen-based sheet, Skin wound healing

# Fibrinogen-Based 3D Spheroid Sheets Enhance Functional Regeneration of Full-Thickness Rotator Cuff Tears in a Rat Model

Jin Hee Park[a], Myung Seo Kim[c], Hee Seok Yang[a, b, *]

[a]*Department of Nanobiomedical Science & BK21 FOUR NBM Global Research Center for Regenerative Medicine, Dankook University, Cheonan, 31116, Republic of Korea,*
[b]*Department of Biomedical Sciences & Biosystems, Dankook University, Cheonan, 31116, Republic of Korea,*
[c]*Department of Orthopaedic Surgery, Kyung Hee University College of Medicine, Kyung Hee University Hospital at Gangdong, Seoul, 05278, Republic of Korea*

*Corresponding Author's E-mail: hsyang@dankook.ac.kr

**Abstract**

The clinical translation of stem cell–based strategies for rotator cuff tendon regeneration remain limited due to poor cell retention, reduced viability, and insufficient understanding of the native tendon–bone microenvironment. Conventional single-cell delivery results in rapid cell loss in the synovial milieu, whereas bulk scaffold or hydrogel encapsulation disrupts cell-to-cell communication and restricts dynamic interactions with host tissues. To overcome these limitations, this study examines a fibrinogen-based three-dimensional stem cell spheroid sheet (FSP) that preserves spheroid architecture while enabling direct biological crosstalk with the injured microenvironment. FSPs are fabricated through a simple and clinically adaptable process by introducing a fibrinogen solution directly into a standard cell culture medium. A bioactive degradable matrix is generated that anchors intact spheroids while maintaining an open interface for cell–matrix and cell–tissue interactions. In a rat model of full-thickness rotator cuff tendon defects, FSP transplantation significantly enhances macrophage recruitment and promotes pro-regenerative M2 polarization compared with fibrinogen-based single-cell sheets. This immunomodulatory effect induces accelerated regeneration of the tendon–bone interface, improves collagen fiber organization, and promotes tenogenic differentiation. Collectively, FSP functions as an advanced stem cell delivery platform that synergistically integrates three-dimensional cellular organization with a fibrinogen-mediated matrix, resulting in superior functional tendon regeneration.

**Keywords:** Cell delivery platform, Fibrinogen-based cell sheet, Rotator cuff regeneration, Three-dimensional cell spheroid

# Engineering Radially Oriented Fibrous Scaffolds with Sustained Growth Factor Release for Improved Bone Regeneration

Jungeun Ha[a], Hee Seok Yang[a], [b], *

[a]*Department of Nanobiomedical Science & BK21 FOUR NBM Global Research Center for Regenerative Medicine, Dankook University, Cheonan, 31116, Republic of Korea,*
[b]*Department of Biomedical Sciences & Biosystems, Dankook University, Cheonan, 31116, Republic of Korea*

*Corresponding Author's E-mail: hsyang@dankook.ac.kr

**Abstract**

Electrospun nanofibrous scaffolds have been extensively utilized in bone tissue engineering, yet their disorganized fiber orientation and compact structure often hinder effective cell infiltration and migration. To address these limitations, we fabricated a radially oriented fibrous scaffold that provides topographical guidance to direct cells toward the center of a defect site. In addition, a thermosensitive hydrogel system incorporating platelet-derived growth factor (PDGF) was introduced into the central region to achieve localized and sustained delivery. *In vitro* analysis demonstrated that the radially aligned architecture significantly enhanced guided cell migration compared to conventional random fiber scaffolds. The presence of PDGF further stimulated cellular motility and osteogenic responses, including elevated alkaline phosphatase activity and increased mineralization. The regenerative efficacy was further evaluated using a mouse calvarial defect model. Administration of bone morphogenetic protein-2 (BMP-2) promoted new bone formation relative to untreated controls. Importantly, the combined delivery of PDGF and BMP-2 resulted in the most pronounced regenerative effect. Substantial defect closure and dense bone formation were observed. These effects were especially evident at the defect. Overall, these results show that combining directional structural cues with controlled growth factor release is effective. This approach enhances cell movement, osteogenic differentiation, and bone regeneration. This approach presents a promising strategy for improving the therapeutic performance of scaffolds in calvarial bone regeneration.

**Keywords:** Bone regeneration, Electrospinning, Growth factors Radial scaffold

# Macromolecular Crowding–derived ECM Nanovesicles as Bioinstructive Materials for Angiogenic Biomaterials

Eunchae Kim[a], Hee Seok Yang[a, b, *]

[a]*Department of Nanobiomedical Science & BK21 FOUR NBM Global Research Center for Regenerative Medicine, Dankook University, Cheonan, 31116, Republic of Korea,*
[b]*Department of Biomedical Sciences & Biosystems, Dankook University, Cheonan, 31116, Republic of Korea*

*Corresponding Author's E-mail: hsyang@dankook.ac.kr

**Abstract**

Stem cell–based approaches for ischemic tissue regeneration have been widely explored; however, their therapeutic efficacy is often limited by poor cell retention, low viability, and insufficient paracrine signaling. To address these challenges, we present a bioinspired nanomaterial strategy based on extracellular matrix (ECM)–enriched nanovesicles engineered via macromolecular crowding (MMC). NIH-3T3 fibroblasts were cultured under MMC conditions using Ficoll to enhance matrix assembly, while ascorbic acid was supplemented independently to promote collagen synthesis and extracellular matrix (ECM) production, resulting in dense ECM deposition. This environment promoted the formation of a collagen and fibronectin-rich matrix, which was subsequently processed into ECM-rich nanovesicles (ECM-NVs) via extrusion process. The prepared ECM-NVs effectively preserve essential ECM components and structural cues, enabling their function as bioactive, matrix-mimetic nanomaterials. *In vitro* assays demonstrated that ECM-NVs significantly enhanced cell migration and endothelial tube formation, confirming their potent angiogenic bioactivity. To evaluate therapeutic efficacy *in vivo*, ECM-NVs were administered to a mouse model of hindlimb ischemia, which resulted in markedly improved perfusion recovery and acerated functional repair of the ischemic tissue. The ECM-NVs act as supportive, biofunctional interfaces that enhance cell–matrix interactions and improve the microenvironment for regenerative processes. Overall, this work highlights the design and fabrication of ECM-based nanostructured biomaterials that recapitulate key matrix components and bioactivity, demonstrating their potential as a biomimetic platform for promoting angiogenesis in ischemic tissue. These results show that the potential of MMC-engineered ECM nanovesicles as advanced biofunctional materials for angiogenesis and ischemic tissue regeneration.

**Keywords:** ECM-Enriched Nanovesicles, Ischemic Tissue Regeneration, Macromolecular Crowding

# Bioconjugation Approaches for Nisin-Conjugated Liposomes as a Drug Delivery System for Breast Cancer Therapy

Ubaid Ahmad[1,2], Yanisa Panporm[1,2], Piyathida Wuthinonchai[2], Malinee Pradain[2], Chanida Phetdee[2], Panchika Prangkio[2,3,*]

[1]*Graduate Program in Biotechnology, Multidisciplinary and Interdisciplinary School, Chiang Mai University, Chiang Mai 50200, Thailand*
[2]*Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200 Thailand*
[3]*Center of Excellence in Materials Science and Technology, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*

**Corresponding Author's E-mail: panchika.p@cmu.ac.th*

## Abstract

Breast cancer remains a major global health challenge, necessitating more effective targeted therapies. While liposomal drug delivery systems offer improved pharmacokinetics and reduced systemic toxicity, their efficacy is often limited by passive targeting. Peptide-based surface functionalization has emerged as a promising strategy to enhance targeting specificity. Nisin, a cationic antimicrobial peptide with reported anticancer activity, can interact with negatively charged cancer cell membranes and influence cellular processes such as membrane integrity and apoptosis. These properties make nisin a plausible candidate for improving liposomal targeting and cellular uptake. In this study, we present a comparative evaluation of two bioconjugation strategies, carbodiimide coupling and thiol–maleimide chemistry, for the development of nisin-functionalized liposomes to enhance targeted delivery in breast cancer therapy.

Physicochemical characterization showed that nisin-conjugated liposomes from both methods-maintained nanoscale size (114–122 nm), low polydispersity (PDI < 0.3), and moderate surface charge, indicating acceptable stability and uniformity. Transmission electron microscopy confirmed spherical morphology, while FT-IR analysis suggested successful nisin conjugation, with thiol–maleimide chemistry showing relatively higher conjugation efficiency. In vitro drug release studies indicated pH-responsive behavior, with higher release observed under acidic conditions (pH 5.5) compared to physiological pH 7.4. Nisin-conjugated liposomes exhibited relatively more controlled and sustained release profiles, particularly in the thiol–maleimide system.

Cytotoxicity studies in MCF-7 breast cancer cells and L929 fibroblast cells showed that doxorubicin-loaded liposomes enhanced anticancer activity while maintaining comparatively lower toxicity toward normal cells. Nisin-functionalized liposomes further improved cytotoxic effects in cancer cells, suggesting enhanced cellular interaction and uptake. Overall, these findings indicate that bioconjugation strategy influences liposomal performance, with thiol–maleimide functionalization showing potential advantages.

**Keywords:** Liposomal drug delivery, Nisin functionalization, Breast cancer, Bioconjugation chemistry, Doxorubicin delivery

# Mechanical properties of natural rubber latex sheets with edible mushrooms

Sitthi Duangphet[a,b,*], Uraiwan Intatha[a,b], Somwan Chumphongphan [a,b]

[a]*School of Science, Mae Fah Luang University, Chiang Rai, 57100 Thailand*
[b]*Center of Innovative Materials for Sustainability (iMatS), Mae Fah Luang University, Chiang Rai, 57100 Thailand.*

*Corresponding Author's E-mail: sitthi.dua@mfu.ac.th

**Abstract**

Tensile properties and hardness (shore A) of sheets produced from mixture of natural rubber latex and edible mushroom were investigated. Four edible mushrooms including *Hypsizygus tessulatus* (bunapi-shimeji & buna-shimeji), *Flammulina filiformis* (enoki), and *Pleurotus eryngii* (king oyster) were combined with pre-vulcanized natural rubber latex using 1:1, 1:2, 1:3 and 1:4 (w/w) mushroom-latex ratios. Natural rubber sheet without mushroom showed elastic behavior with the lowest modulus (1.15±0.31 MPa) and hardness (29.42±1.05) but maximum elongation at break (881.93±58.88 %). Adding mushroom to latex altered stress-strain behaviors by reduce ductility and finally become brittle material at 1:1 (w/w) mushroom-latex ratios. Comparison between type of mushroom, *Hypsizygus tessulatus* (both bunapi-shimeji & buna-shimeji) and *Flammulina filiformis* did not presented different reinforcement effect between species. However, king oyster mushroom provided significantly better mechanical strength among them. At 1:1 (w/w) mushroom-latex ratios, natural rubber sheet with king oyster gave highest modulus (20.62±0.70 MPa), tensile strength (3.14±0.023 MPa) and hardness (61.50±1.29).

**Keywords:** Natural rubber latex, Mushroom, Biocomposite, Hardness, Tensile

# Enhancing Molecular and Thermal Properties of PCL via TNPP-Assisted Chain Extension in Ring-Opening Polymerization

Tanyaluck Mekpothi[a,b,c], Manasanan Namhongsa[b,d], Tawan Chaiwon[a,b,c], Donraporn Daranarong[b,e], Winita Punyodom[b,c*]

[a]*Office of Research Administration, Chiang Mai University, Chiang Mai 50200 Thailand*
[b]*Bioplastics Production Laboratory for Medical Applications, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[c]*Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[d]*Center of Excellence in Materials Science and Technology, Chiang Mai University, Chiang Mai 50200, Thailand*
[e]*Multidisciplinary Research Institute, Chiang Mai University, Chiang Mai 50200, Thailand*

*Corresponding Author's E-mail: winita.punyodom@cmu.ac.th

**Abstract**

Poly(ε-caprolactone) (PCL) is a biodegradable and biocompatible polymer widely used in biomedical applications; however, its inherently low thermal resistance limits its broader functional performance. This work investigated a strategy to improve the molecular weights and thermal properties of PCL through reactive chain extension. PCL was synthesized by bulk ring-opening polymerization (ROP) of *ε*-caprolactone using tris(nonylphenyl) phosphite (TNPP) as a chain extender at concentrations of 0.25, 0.50, and 0.75 % w/w, with tin(II) *n*-butoxide (Sn(*On*Bu)$_2$) as the initiator. The results showed that adding TNPP into the PCL matrix significantly affected the polymerization behavior and molecular characteristics of the resulting polymers. Structural verification with $^1$H-NMR and FT-IR confirmed successful polymer formation and the presence of expected functional groups. The findings revealed that the PCL-TNPP polymers had high molecular weights (Mw = 1.4-2.0 × 10$^5$ g/mol) with moderate dispersity (Đ ≈ 1.6) compared to pure PCL. Notably, PCL containing 0.50% w/w TNPP achieved a high molecular weight of approximately 2.0 × 10$^5$ g/mol. Additionally, thermal analysis showed melting temperatures between 48 and 58 °C and excellent thermal stability, with decomposition temperatures up to 440 °C relative to other conditions. These results demonstrate that TNPP functions effectively as a chain extender, allowing control over the molecular weight and thermal properties of PCL without losing its inherent biodegradability. This approach offers a promising way to tailor PCL-based materials for advanced biomedical applications that demand improved thermal performance and structural stability.

**Keywords:** Poly(ε-caprolactone) (PCL), Ring-opening polymerization (ROP), Tris(nonylphenyl) phosphite (TNPP),
Chain extension, Biodegradable polymers

# PLG–LL-37 Microparticle for Controlled Peptide Delivery in Bone Regeneration

Thannaphat Jenvoraphot [a,b], Chayarop Supanchart [b,c], Winita Punyodom [b,d], Donraporn Daranarong [b,e,*]

[a] *Office of Research Administration, Chiang Mai University, Chiang Mai 50200, Thailand*
[b] *Center of Excellence in Materials Science and Technology, Chiang Mai University, Chiang Mai 50200, Thailand*
[c] *Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chiang Mai University, Chiang Mai 50200, Thailand*
[d] *Department of Chemistry, Faculty of Science, Chiang Mai University 50200, Thailand*
[e] *Multidisciplinary Research Institute, Chiang Mai University, Chiang Mai 50200, Thailand*

* Corresponding: donraporn.d@cmu.ac.th

**Abstract**

Localized and sustained delivery of bioactive peptides is essential for enhancing bone regeneration while minimizing systemic exposure. This study reports the development of poly(L-lactide-*co*-glycolide) (PLG) microparticles as a biodegradable carrier system for the antimicrobial peptide LL-37 for guided bone regeneration (GBR) applications. Microparticles were fabricated with controlled morphology and structural parameters to enable tunable peptide encapsulation and release. Incorporation of LL-37 altered particle physicochemical properties, including size distribution, crystallinity, and internal porosity, suggesting interactions between the peptide and polymer matrix. High encapsulation efficiency was maintained across different loading levels. *In vitro* release analysis demonstrated sustained LL-37 delivery for up to 60 days, with release kinetics governed by initial peptide concentration. Collectively, these findings indicate that PLG microparticles function as a long-acting peptide delivery platform with potential utility in GBR strategies.

**Keywords:** poly(L-lactide-co-glycolide), LL-37, microparticles, Bone Regeneration

# PMMA-Based Polymeric Blend Nanocarriers for Controlled Drug Delivery

Montira Sriyai[a,b,c], Nuttawut Khammata[d], Robert Molloy[c], Puttinan Meepowpan[c,d], Winita Punyodom[c,d,*]

[a]*Office of Research Administration, Chiang Mai University, Chiang Mai 50200, Thailand*
[b]*Bioplastics Production Laboratory for Medical Applications, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[c]*Center of Excellence in Materials Science and Technology, Chiang Mai University, Chiang Mai 50200, Thailand*
[d]*Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*

*Corresponding Author's E-mail: winitacmu@gmail.com

**Abstract**

PM2.5 air pollution is strongly associated with lung cancer, underscoring the need for advanced drug delivery systems. This study reports polymeric blend nanocarriers based on poly(methyl methacrylate) (PMMA) combined with poly(ε-caprolactone) (PCL) and poly(ethylene glycol) (PEG), prepared via miniemulsion–ultrasonication method. Optimal formulations (70/30 PMMA/PCL and 60/40 PMMA/PEG blends) exhibited particle sizes of 120–220 nm, low dispersity ($Đ < 0.20$), and good stability. PMMA/PCL systems are expected to enhance drug (i.e., paclitaxel (PTX) and curcumin (CUR)) encapsulation and sustained release for further investigation, while PMMA/PEG systems improve colloidal stability and circulation properties. These nanocarriers exhibit tunable physicochemical properties that enable enhanced permeability and retention (EPR)-mediated tumor targeting, highlighting their potential for PM2.5-related cancer therapy.

**Keywords:** Type your keywords here, separated by comma, maximum of five keywords

# Dimensionally Stable PNIPAM/PLGA-PEG-PLGA Thermoresponsive Blended Hydrogels for Biomedical applications

Nuttawut Khammata[a,b], Jutamas Kongsuk[a,b], Kiattikhun Manokruang[a,c] , Chawan Manaspon[c,d] and Winita Punyodom[a,b],[c,d,*]

[a] *Department of Chemistry Faculty of Science Chiang Mai University, Chiang Mai 50200, Thailand*
[b]*Bioplastics Production Laboratory for Medical Applications, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[c]*Center of Excellence in Materials Science and Technology, Chiang Mai University, Chiang Mai 50200, Thailand*
[d] *Biomedical Engineering Institute, Chiang Mai University, Chiang Mai 50200, Thailand*

*Corresponding Author's E-mail: winita.punyodom@cmu.ac.th

**Abstract**

Thermoresponsive hydrogels, particularly poly(*N*-isopropylacrylamide) (PNIPAM), hold significant potential as structural scaffolds for cell encapsulation and therapeutic delivery. However, their clinical application is frequently hindered by severe syneresis and macroscopic volume shrinkage above their lower critical solution temperature (LCST), which compromises mechanical stability and restricts critical nutrient exchange. To address these material limitations, this study presents a novel blended hydrogel system comprising PNIPAM and a biodegradable poly(lactide-*co*-glycolide)-*b*-poly(ethylene glycol)-*b*-poly(lactide-*co*-glycolide) (PLGA-PEG-PLGA) triblock copolymer. The PLGA-PEG-PLGA copolymer was synthesized via ring-opening polymerization using a highly effective liquid tin(II) *n*-butoxide catalyst. The physical incorporation of PLGA-PEG-PLGA into the PNIPAM matrix successfully suppressed water expulsion and prevented the dimensional shrinkage typically observed during the sol-gel phase transition. Morphological characterization revealed that the optimized blended hydrogel exhibited a highly interconnected porous structure with a maximum average pore size of 29.11 µm, providing an ideal microenvironment for mass transfer. Furthermore, the blended system demonstrated an LCST of 28-31 °C, making it perfectly suited for physiological applications. In addition to dimensional stability, the blended hydrogel exhibited enhanced biodegradability, achieving a 46.49% weight loss after 120 hours of hydrolysis. In vitro cytotoxicity assays confirmed excellent biocompatibility, maintaining approximately 99% cell viability for L929 mouse fibroblast cells. These findings indicate that blending PNIPAM with PLGA-PEG-PLGA effectively resolves the structural instability of pure PNIPAM hydrogels, yielding a highly promising, dimensionally stable, and biocompatible material for advanced cell encapsulation technologies.

**Keywords:** Thermoresponsive hydrogel, PNIPAM, PLGA-PEG-PLGA, Syneresis, Dimensional stability

# Fabrication of Bile Duct Tubular Prototype from Poly(L-lactide-*co*-ε-caprolactone) Monofilament utilizing 3D-Printing Technology

Tawan Chaiwon[a,b,c], Manasanan Namhongsa[b,d], Tanyaluck Mekpothi[a,b,c], Winita Punyodom[b,c*]

[a]*Office of Research Administration, Chiang Mai University, Chiang Mai 50200 Thailand*
[b]*Bioplastics Production Laboratory for Medical Applications, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[c]*Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[d]*Center of Excellence in Materials Science and Technology, Chiang Mai University, Chiang Mai 50200, Thailand*

*Corresponding Author's E-mail: winita.punyodom@cmu.ac.th

**Abstract**

This research focuses on the development of a medical-grade, biodegradable bile duct tubular prototype using poly(L-lactide-*co*-ε-caprolactone) (PLC) monofilaments and 3D-printing technology. A PLC copolymer with a 70:30 molar ratio was synthesized *via* bulk ring-opening polymerization (ROP) in accordance with ASTM F1925-17 and ISO 13485 standards. Characterization using $^{1}$H-NMR and Differential Scanning Calorimetry (DSC) confirmed copolymer composition and thermal properties, providing a suitable thermal profile for Fused Deposition Modeling (FDM). To optimize mechanical performance, various extrusion conditions, such as temperature and screw speed, were adjusted to establish an effective process for filament production. Biocompatibility assessments *via* MTT assays on L929 fibroblast cells indicated low cytotoxicity, with cell viability remaining near 100%. While a bile duct tubular (BDT) prototype was successfully fabricated, initial results showed that the PLC monofilaments require further enhancement of flow ability to prevent nozzle clogging and ensure printing continuity. This study establishes a foundation for the domestic production of high-quality, customized surgical implants in Thailand, potentially reducing reliance on expensive imported medical materials.

**Keywords:** Poly(L-lactide-co-ε-caprolactone) (PLC), Bile duct tubular, 3D-printing technology

# Synthesis and Characterization of Amorphous Hydrogel Composed of P(Na-AMPS) and CMC for Use as Wound Dressing

Waewploy Sukmongkolwongs[a], Peerakan Aewprasert[a], Pharaporn Yodkrum[a], Amlika Roungrod[b] and Runglawan Somsunan[a],[c,*]

[a]*Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[b]*Laboratory of Organic Synthesis, Chulabhorn Research Institute, Bangkok, 10210, Thailand*
[c]*Center of Excellence in Materials Science and Technology, Chiang Mai University, Chiang Mai, 50200, Thailand*

**E-mail: runglawan.s@cmu.ac.th*

**Abstract**

This study aimed to synthesize and characterize amorphous hydrogels for wound dressing applications. The hydrogels were prepared from sodium 2-acrylamido-2-methyl propane sulfonate (Na-AMPS) and carboxymethyl cellulose (CMC) via free-radical polymerization using a thermal initiator. CMC was incorporated to enhance adhesion and viscosity, with concentrations ranging from 0 to 5% w/v. Poly(ethylene glycol) diacrylate and potassium persulfate were employed as the crosslinker and initiator, respectively. The resulting hydrogels exhibited a turbid appearance, with increasing CMC concentrations leading to darker coloration and higher viscosity. Mechanical testing indicated that migration time increased with higher CMC content, reflecting enhanced viscosity, which was consistent with rheological analysis showing increased viscosity at higher shear rates. In contrast, water content decreased as CMC concentration increased. Fluid absorption behavior, evaluated according to BS EN 13726, demonstrated that the hydrogels were more suitable for low-exudate wounds than for high-exudate conditions. Cytotoxicity assessment using L929 fibroblast cells revealed cell viability above 70% for all formulations, indicating non-toxicity and good biocompatibility. In conclusion, the incorporation of CMC effectively improved the mechanical properties of the hydrogels by increasing viscosity. These results suggest that the synthesized amorphous hydrogels have strong potential for application as wound dressing materials.

**Keywords:** Amorphous hydrogels, Poly(sodium 2-acrylamido-2-methylpropane sulfonate), Carboxymethyl cellulose, Wound dressing

# Dual-Responsive Sprayable Hydrogel for Controlled Neem Delivery in Wound Dressing Applications

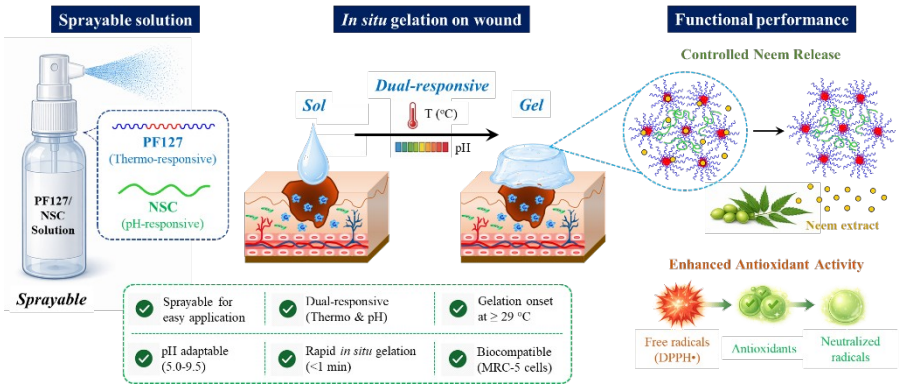
Amlika Rungrod[a], Arthit Makarasen[a], Suwicha Patnin[a], Supanna Techasakul[a,*], Runglawan Somsunan[b,c,*]

[a]*Laboratory of Organic Synthesis, Chulabhorn Research Institute, Bangkok, Thailand,*
[b]*Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand,*
[c]*Center of Excellence in Materials Science and Technology, Chiang Mai University, Chiang Mai, Thailand*

*Corresponding Author's E-mail: supanna@cri.or.th; runglawan.s@cmu.ac.th

## Abstract

Sprayable hydrogels with rapid *in situ* gelation provide a practical approach for wound dressing due to their ease of application and ability to conform to irregular surfaces. A dual-responsive hydrogel system based on thermo-responsive Pluronic F127 (PF127) and pH-responsive *N*-succinyl chitosan (NSC) was developed as a carrier for natural bioactive delivery. A formulation containing 20% (w/v) PF127 and 0.25% (w/v) NSC, exhibiting sol - gel transition at approximately 29 °C and rapid gelation within 55 s at 37 °C. The system also demonstrated pH-responsive behavior, forming gels across a pH range of 5.0 - 9.5, which covers the dynamic pH variations in wound environments. These properties are suitable for in situ application under physiological conditions, with gelation time below 1 min minimizing formulation loss after application. The hydrogel also demonstrated good sprayability and stable gel formation. Cytotoxicity evaluation using MRC-5 fibroblast cells confirmed that the hydrogel was non-cytotoxic, supporting its biocompatibility for topical use. *Azadirachta indica* (neem) extract was incorporated at concentrations of 0.05 - 0.30 g/mL. The neem-loaded hydrogel exhibited controlled and dose-dependent release behavior, with increasing release corresponding to higher neem loading. In addition, the neem incorporation significantly enhanced antioxidant activity, showing a concentration-dependent increase in radical scavenging capacity which may contribute to reducing oxidative stress at the wound site. Overall, the developed dual-responsive PF127/NSC sprayable hydrogel demonstrates suitable gelation properties, pH adaptability, biocompatibility, controlled bioactive release, and enhanced antioxidant activity, highlighting its potential as a multifunctional wound dressing for topical applications.




**Keywords:** wound dressing, sprayable hydrogel, dual-responsive, Azadirachta indica (neem)

# Multifunctional Electrospun Nanofibrous Membrane for Quercetin Release in Advanced Wound Dressing Applications

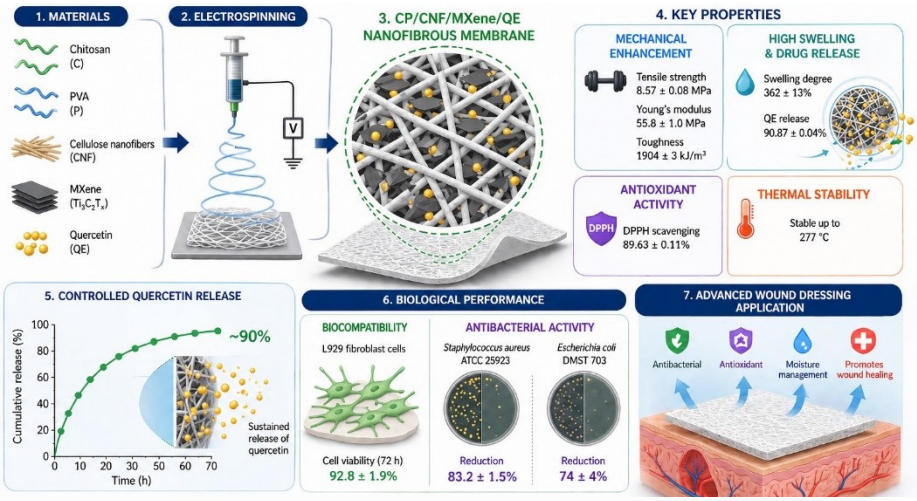
Thanaphorn Rakkan[a,b], Winita Punyodom[a,b,c], Puttinan Meepowpan[a,b,c], Yottha Srithep[e], Sarinthip Thanakkasaranee[c,f,g], Pornchai Rachtanapun[c,f,g], Kittisak Jantanasakulwong[c,f,g] Patnarin Worajittiphon[b, c,d,*]

[a] *Office of Research Administration, Chiang Mai University, Chiang Mai 50200, Thailand*
[b] *Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[c] *Center of Excellence in Materials Science and Technology, Chiang Mai University, Chiang Mai 50200, Thailand*
[d] *Center of Excellence for Innovation in Chemistry (PERCH-CIC), Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[e] *Department of Manufacturing Engineering, Faculty of Engineering, Mahasarakham University, Mahasarakham 44150, Thailand*
[f] *Division of Packaging Technology, Faculty of Agro-Industry, Chiang Mai University, Chiang Mai 50100, Thailand*
[g] *Center of Excellence in Agro Bio-Circular-Green Industry (Agro BCG), Chiang Mai University, Chiang Mai 50100, Thailand*

*Corresponding Author's E-mail: patnarin.w@cmu.ac.th

**Abstract**

The design of advanced wound dressings within the scope of polymer-based biomaterials and medical devices requires multifunctional systems that integrate mechanical robustness, biocompatibility, bioactivity, and controlled therapeutic delivery. In this study, a novel electrospun nanofibrous membrane was developed using a chitosan/poly(vinyl alcohol) (CP) polymeric matrix reinforced with cellulose nanofibers (CNF) and functionalized with MXene ($Ti_3C_2T_x$) as a bioactive nanomaterial, for the release of quercetin (QE, 0.3 phr). The incorporation of CNF (1.5 phr) significantly enhanced the structural integrity of the polymer network, while MXene (2.0 phr) further improved the mechanical performance, achieving tensile strength, Young's modulus, and toughness of 8.57 ± 0.08 MPa, 55.8 ± 1.0 MPa, and 1904 ± 3 kJ/m$^3$, respectively. The resulting composite membrane exhibited a high swelling capacity (362 ± 13%), enabling efficient QE release up to 90.87 ± 0.04%, indicating its suitability as a drug-eluting wound dressing. From a biomaterial's perspective, the membrane demonstrated excellent antioxidant activity, with DPPH radical scavenging efficiency of 89.63 ± 0.11%, and high thermal stability up to 277 °C. *In vitro* biocompatibility assessment using L929 mouse fibroblast cells confirmed high cell viability (92.8 ± 1.9%) after 72 h, supporting its cytocompatibility for biomedical applications. Moreover, the membrane exhibited significant antibacterial performance against *S. aureus* and *E. coli*, with bacterial reduction rates of 83.2 ± 1.5% and 74 ± 4%, respectively. Overall, this study highlights the potential of CP/CNF/MXene/QE electrospun membranes as multifunctional polymeric biomaterials with integrated therapeutic and protective functions, offering a promising platform for next-generation wound dressing medical devices.




**Keywords:**
Electrospun nanofibrous membrane, Polymeric biomaterials, Drug release, MXene, Wound dressing

# Thermochemical Evolution and Surface Chemical States of Biogenic Biphasic Calcium Phosphate Ceramics: Correlation with Mechanical Properties and In Vitro Bioactivity

Theerachai Bongkarn[1), 2)], Nutkamon Sonchaopri[1)], Sununta Yimsabai[1)], Surirat Yotthuan[3)], Nuttawan Sawangboon[3)], Usanee Pantulap[3)], Naratip Vittayakorn[4)], Chittakorn Kornphom[5)*]

[1)]*Department of Physics, Faculty of Science, Naresuan University, Phitsanulok, 65000, Thailand*
[2)]*Research Center for Academic Excellence in Applied Physics, Faculty of Science, Naresuan University, Phitsanulok, 65000, Thailand*
[3)] *Division of Engineering Materials, Department of Science Service, Ratchathewi, Bangkok 10400, Thailand*
[4)] *Advanced Material Research Unit, Faculty of Science, King Mongkut's Institute of Technology Ladkrabang, Bangkok, 10520, Thailand*
[5)]*Department of Physics and General Science, Faculty of Science and Technology, Chiang Mai Rajabhat University, Chiang Mai, 50300, Thailand*

*Corresponding Author's E-mail: chittakorn_kor@g.cmru.ac.th

**Abstract**

Biogenic biphasic calcium phosphate (BCP) ceramics derived from natural bone are promising for biomedical applications due to their chemical similarity to human hard tissues. In this study, nanocrystalline BCP powders were synthesized from salmon bone via a solid-state combustion technique using glycine as a fuel, followed by sintering at 1200-1400°C to investigate thermochemical evolution, surface chemical states, and their correlation with mechanical properties and in vitro bioactivity. X-ray diffraction (XRD) and Rietveld refinement confirmed the formation of a stable biphasic structure consisting of hydroxyapatite (HAp) and β-tricalcium phosphate (β-TCP). Fourier transform infrared (FTIR) analysis revealed the persistence of phosphate groups, along with progressive attenuation of hydroxyl ($OH^-$) and carbonate ($CO_3^{2-}$) species, indicating thermally induced dehydroxylation and decarbonation. X-ray photoelectron spectroscopy (XPS) further demonstrated the evolution of surface chemical states, particularly the emergence of defect-related oxygen at elevated temperature. Microstructural analysis showed enhanced densification and grain growth with increasing sintering temperature, which directly influenced the mechanical response. The ceramic sintered at 1300°C exhibited the most balanced combination of density and hardness. In vitro bioactivity, evaluated using simulated body fluid (SBF), confirmed apatite formation on the ceramic surface, indicating favorable bioactive behavior. These results demonstrate that the properties of BCP ceramics are governed by coupled thermochemical and surface chemical evolution, linking phase stability, defect formation, and microstructural development.

**Keywords:** Biogenic BCP ceramics; Combustion synthesis; Nanocrystalline powders; Surface chemical states; Bioactivity

# Water-Resistant Paper with Improved Dry and Wet Mechanical Strength via Chemical Vapor Deposition

Patcharawarin Sathapornwajana[a], Kuntinee Suvarnakich[a,b], Kamonwan Pacaphol[a,b,c*]

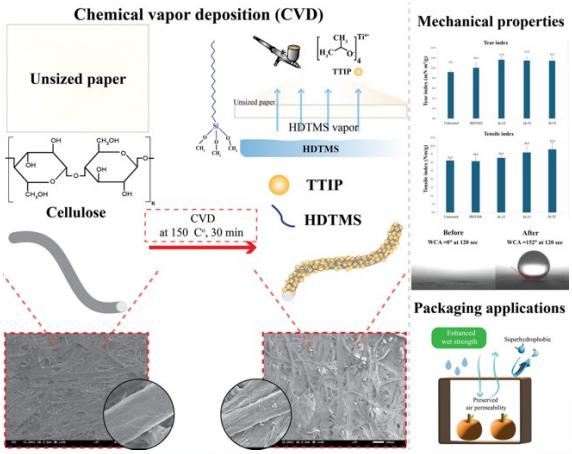
[a] *Pulp, Paper and Packaging Technology Program, Faculty of Science, Chulalongkorn University, Bangkok, Thailand.*
[b] *Department of Imaging and Printing Technology, Faculty of Science, Chulalongkorn University, Bangkok, Thailand.*
[c] *Center of Excellence in Responsive Wearable Materials, Chulalongkorn University, Bangkok, Thailand.*

*Corresponding Author's E-mail: kamonwan.p.@chula.ac.th

**Abstract**

Paper is a promising sustainable packaging material because of its biodegradability and recyclability. However, its moisture sensitivity limits broader application, as water absorption causes cellulose fiber swelling, weakens interfiber bonding, and reduces mechanical strength. In addition, conventional liquid-based coating and drying may further deteriorate paper strength through bond disruption and hornification. In this study, cellulose fibers within the paper structure were chemically modified to improve both dry and wet mechanical strength while preserving air permeability. Hexadecyltrimethoxysilane (HDTMS) was applied by chemical vapor deposition (CVD), based on conditions established in our previous work, as an alternative to conventional surface coating. The selected CVD condition was employed at 150°C for 30 min under atmospheric pressure in a closed 600 cm³ stainless steel container. HDTMS dosages of 0.2, 1.0, and 1.6 mL/m² of paper were investigated in combination with titanium(IV) isopropoxide (TTIP) as a catalytic primer, pre-applied on paper by spraying at concentrations of 1, 3, and 5% v/v. Among the HDTMS-only treatments, 1.0 mL/m² produced a remarkable increase in water contact angle (125°); however, the mechanical properties showed no improvement and remained comparable to those of the untreated sample. In contrast, the combination of HDTMS with 3% v/v TTIP significantly improved mechanical properties under both dry and wet conditions. The average burst index, tear index, bending stiffness, and tensile index increased by approximately 5, 17, 46, and 23%, respectively. The treated papers retained air permeability, as measured by a Gurley air resistance tester, which is important for packing processes requiring rapid air release to prevent package swelling. Moreover, they exhibited superhydrophobicity on both sides, with an average water contact angle of 152°. These findings demonstrate that vapor deposition using HDTMS with TTIP is an effective approach to modifying paper for potential use in breathable, water-resistant paper packaging with improved wet mechanical strength.

**Keywords:** paper packaging, superhydrophobicity, wet mechanical strength, chemical vapor deposition, silane



# Synergistic effects of copper and iron co-doping on the multifunctional properties of hydroxyapatite for bone tissue engineering

Tanawut Rittidach[a,b], Kueakoon Poonthong[a], Atipong Bootchanont[a,b,*]

[a] *Division of Physics, Faculty of Science and Technology, Rajamangala University of Technology Thanyaburi (RMUTT), Pathumthani, 12110, Thailand*

[b] *Smart Materials Research Unit, Rajamagala University of Technology Thanyaburi, Pathumthani, 12110, Thailand*

*Corresponding Author's E-mail: atipong_b@rmutt.ac.th

**Abstract**

This study examines the combined influence of copper (Cu) and iron (Fe) co-doping on the multifunctional properties of hydroxyapatite (HAp) for potential use in bone tissue engineering. A series of HAp samples was synthesized with a constant Fe content of 1 mol% and varying Cu concentrations of 0, 1, and 3 mol%. Their structural and morphological properties were characterized by X-ray diffraction (XRD), X-ray absorption spectroscopy (XAS), and scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM-EDX). The XRD results indicate that the undoped sample exhibits a single-phase hydroxyapatite structure. For the doped samples, the intensity of the CaO phase increases with increasing Cu content. XAS analysis reveals the formation of $Ca_2Fe_2O_5$ and $Ca_5(CuO_2)_6$ clusters within HAp structure. Bioactivity was assessed through immersion in Simulated Body Fluid (SBF), and the results showed that the sample co-doped with 1 mol% Cu and 1 mol% Fe (1CuFe-HAp) produced the most pronounced flower-like apatite layer formation. In addition, this composition exhibited the highest dielectric constant, indicating improved electrical polarization that may support bone regeneration. Antibacterial testing further demonstrated that 1CuFe-HAp and 3CuFe-HAp provided the strong inhibitory activity against pathogenic microorganisms. Overall, the results suggest that controlled co-doping with Cu and Fe can markedly enhance both the biological performance and physicochemical characteristics of HAp, making 1CuFe-HAp a promising candidate for advanced orthopedic implant applications.

**Keywords**: hydroxyapatite, copper, iron, bone tissue engineering

# Differential miRNA Signatures of MSC-Derived Exosomes and Their Potential Regulatory Roles in Dermal Papilla Cells

Hyun Jae Kim[a], Seokhwan Yun[a,*]

[a]*Turinax Inc. Research Institute, 82, Baegot 2-ro, Siheung-si, Gyeonggi-do, Republic of Korea*

*Corresponding Author's E-mail: yuntobi@turinax.com

**Abstract**

Mesenchymal stem cells (MSCs) are well-recognized for their superior regenerative potential and multi-lineage differentiation capacity. MSC-derived exosomes, which retain the functional properties of their parental cells, have emerged as promising therapeutic biomaterials for various pathologies. In the context of alopecia, the activation of dermal papilla cells (DPCs) is a fundamental determinant of hair follicle cycling. While exosome-based interventions to modulate DPC activity have gained significant attention, research on the regulatory roles of exosomal miRNAs remains in its nascent stages.In this study, we isolated exosomes from two distinct MSC sources: adipose-derived MSCs (AD-MSCs) and umbilical cord-derived MSCs (UC-MSCs). The miRNA expression profiles of these exosomes were characterized using Next-Generation Sequencing (NGS), followed by comprehensive bioinformatic analysis. Our comparative analysis revealed both shared and distinct miRNA expression patterns between AD-MSC and UC-MSC-derived exosomes. These findings suggest that exosomes from different sources may exert their biological effects on DPCs through divergent intracellular signaling pathways. Consequently, this study demonstrates that the selection of an exosome source should be strategically tailored based on the specific therapeutic objective for DPC activation. These results provide a foundational framework for developing personalized, exosome-based therapeutic strategies for hair loss.

**Keywords:** adipose-derived MSC, umbilical-cord-derived MSC, exosome, dermal papilla cells, miRNA

# Anomalous Sensing Behavior in 2D Gas Sensing Materials: Black Phosphorus and $Ti_3C_2T_x$

Lei Miao, Qiuyu Jin, Shu Yin*

*Institute of Multidisciplinary Research for Advanced Materials, Tohoku University, 2-1-1, Katahira, Aoba-Ku, Sendai 980-8577, Japan.*

*Corresponding Author's E-mail: yin.shu.b5@tohoku.ac.jp

**Abstract**

Anomalous gas sensing behavior forms the basis for the Response-Behavior Selectivity (RBS). This study reports on the anomalous sensing behavior of two 2D materials during gas sensing process. Black phosphorus (BP) exhibits a resistance increase (positive, -p) gas sensing behavior in response to target gases in air. However, as the concentration of the target gas increases, the magnitude of the resistance change in BP gradually decreases, and the response intensity shows a negative correlation with the gas concentration. In contrast to BP, the response of $Ti_3C_2T_x$ in air maintains a positive correlation with concentration. Meanwhile, $Ti_3C_2T_x$ exhibits a unique resistance-decreasing (negative, -n) behavior towards $NH_3$ while $Ti_3C_2T_x$ maintains -p sensing behavior towards other reducing gases. The anomalous sensing characteristics of both materials can be attributed to the changes in the work function before and after gas adsorption as well as the formation of Schottky barrier. As the number of adsorbed gas molecules increases, the work function of BP gradually decreases, causing the difference between the work function of BP and that of the electrode to satisfy the conditions for the formation of Schottky barrier. However, the reverse current induced by the formed Schottky barrier is insufficient to inverse the sensing behavior, and it results in the suppression of the response intensity of the target gas. As the number of adsorbed gas molecules increases, this suppression effect becomes increasingly pronounced. This concentration-response suppression mechanism of BP also applies to all gases under investigation. In contrast, $Ti_3C_2T_x$ fails to satisfy the conditions for the formation of a Schottky barrier only upon $NH_3$ adsorption only, thereby enabling $NH_3$ to exhibit unique -p behavior than other detected gases (-n) and demonstrate RBS among all gases studied. This study lays the experimental foundation for research into RBS.

**Keywords:** Black phosphorus, $Ti_3C_2T_x$, gas sensing, anomalous sensing behavior, Response-Behavior Selectivity

# Enzyme-Free Glucose Sensor Based on Cobalt Hydroxycarbonate Nanostructures

Zh.K. Kalkozova[a,c], L.V. Gritsenko[a,b], R.R. Nemkayeva[a,c], Kh.A. Abdullin[c]

[a] *Institute of Applied Science & Information Technology, Shashkin Str. 40-48, Almaty 050040, Kazakhstan,*
[b] *General Physics Department, Institute of Energy and Mechanical Engineering, Satbayev University, Satpayev Str., 22, Almaty 050013, Kazakhstan,*
[c] *National Nanotechnology Laboratory of Open Type (NNLOT), Al-Farabi Kazakh National University, Al-Farabi Ave., 71, Almaty 050040, Kazakhstan*

*Corresponding Zh.K. Kalkozova E-mail: zhanar.kalkozova@kaznu.edu.kz

**Abstract**

Highly sensitive non-enzymatic glucose sensors are in great demand for the diagnosis and monitoring of diabetes mellitus. Diabetes mellitus is one of the most common chronic diseases worldwide. Consequently, the development of highly sensitive sensors for the timely monitoring of blood glucose levels represents an important scientific and practical challenge.

Non-enzymatic glucose sensors do not require the use of enzymes, are resistant to temperature and chemical influences, and are capable of operating over a wide pH range. Their principle of operation is based on the direct electrochemical oxidation of the analyte on the electrode surface, with the electrode acting as a catalyst to facilitate the electrochemical reaction.

In this study, a cobalt hydroxycarbonate nanostructure was synthesized using a simple hydrothermal method. Morphological analysis showed that the material possesses a high specific surface area. X-ray phase analysis confirmed the layered crystalline structure of the sample: all major peaks are in good agreement with reference data, indicating the absence of impurity phases.

Electrochemical measurements revealed that the material is highly sensitive to glucose: in the range of 0–3 mM, the sensor sensitivity was approximately 1950 $\mu A \cdot mM^{-1} \cdot cm^{-2}$, and the detection limit was 30 μM. Excellent stability was also observed during storage under normal conditions. It has been shown that even a small amount of zinc precursors during synthesis leads to a change in the growth mechanism of the $Co_6(CO_3)_2(OH)_8 \cdot H_2O$ phase and the formation of a highly dispersed nanocrystalline phase with a high specific surface area. This, in turn, due to increased dispersion and reduced nanoparticle size, leads to a significant increase in the sensor's catalytic activity: sensitivity reaches 6745 $\mu A \cdot cm^{-2} \cdot mM^{-1}$, and the detection limit is reduced to 16 μM. The material demonstrates high stability, with a change in sensitivity over 12 weeks not exceeding 0.5%.

**Keywords**: non-enzymatic glucose sensor, cobalt hydroxycarbonate, hydrothermal synthesis, electrochemical sensor.

# Green Synthesis of Gold Nanoparticles for Gas Sensing Application

Natnicha Chanvithidkul[a], Witsanu Kunket[a], Kanokrak Boonmee[a], Alisa Saengsonachai[a], Jenjira Chaimanan[a], and Chatchawal Wongchoosuk[a,*]

[a]*Department of Physics, Faculty of Science, Kasetsart University, Chatuchak, Bangkok 10900, Thailand*

*Corresponding Author's E-mail: chatchawal.w@ku.ac.th

**Abstract**

Gold nanoparticles (AuNPs) are highly significant materials in the field of nanotechnology due to their remarkable optical and electrical properties. These properties exhibit high sensitivity to changes in the molecular-level environment, making AuNPs superior to many other materials. As a result, they are considered excellent candidates for the development of highly accurate gas sensors, offering enhanced chemical stability compared to other metals. This study focuses on the synthesis of gold nanoparticles using extracts derived from agricultural and food waste, such as mangosteen peels, orange peels, and green tea residues. This approach aims to add value to otherwise discarded materials through a green synthesis method, which is safe and environmentally friendly. In this work, the synthesis of AuNPs is demonstrated, and their properties are characterized using transmission electron microscopy (TEM) and X-ray photoelectron spectroscopy (XPS). The results indicate that the synthesized AuNPs are spherical in shape, homogeneous, and possess an average diameter of approximately 20–30 nm, along with good long-term stability. The findings of this study demonstrate the effectiveness of AuNPs for gas sensing applications at room temperature, particularly for detecting methanol, ethanol, toluene, acetone, propanol, formaldehyde, and ammonia.

**Keywords:** Gold nanoparticles; AuNPs; Green synthesis; Gas Sensing.

# Flexible sensor based on MXene Quantum Dots/Graphene for gas sensor

Nathan Jamulitrath[a], Yossapat Phattarawuttinun[a], Nobpon Seniwong-Na-Ayuttaya[a], Supakit Chinpakdee[a], Usanee Pantulap[b], Nuttawan Sawangboon[b], Chatchawal Wongchoosuk[a,*]

[a]*Department of Physics, Faculty of Science, Kasetsart University, Chatuchak, Bangkok 10900, Thailand*
[b]*Physical Reference Laboratory Center (PRLC), National Institute of Reference Laboratories (NIRL), Department of Science Service, Ratchathewi, Bangkok 10400, Thailand*

*Corresponding Author's E-mail: chatchawal.w@ku.ac.th

**Abstract**

MXene quantum dots (MXene QDs) have emerged as promising candidates for gas sensing applications due to their outstanding electrical conductivity, which enables low-noise operation at room temperature. Furthermore, their nanoscale size (approximately 1–10 nm) provides a high specific surface area, facilitating efficient gas adsorption. However, the tendency of MXene layers to undergo restacking can reduce the accessible surface area and limit effective interaction with gas-phase molecules. To enhance these properties, the integration of MXene with graphene-based materials has been extensively investigated. Graphene, known for its high electrical conductivity and exceptional surface area, can be incorporated to improve both the structural and electronic characteristics of MXene. In such hybrid systems, graphene acts as an interlayer spacer, effectively suppressing restacking and preserving an expanded interlayer spacing. This structural configuration enhances gas diffusion pathways and increases the availability of active sites, thereby improving gas sensing performance. In this study, MXene QDs were synthesized using an oil bath system, while graphene was prepared via chemical reduction. The resulting MXene QDs/graphene composite is expected to exhibit high sensitivity, stable performance, and long-term durability, owing to the synergistic interaction between MXene QDs and graphene. The gas sensing performance of the fabricated sensors will be evaluated at room temperature toward various volatile organic compounds (VOCs), including methanol, ethanol, toluene, acetone, propanol, formaldehyde, and ammonia.

**Keywords:** MXene Quantum Dots, Graphene, Nanoparticles, Gas Sensor

# Biodegradable Waterborne Polyurethane-Reinforced Gelatin Eutectogels with Enhanced Mechanical and Ionic Performance

Yen-Fei Lu, Chan-Yi Chu, Ting-Yu Chang and Shan-hui Hsu*

*Institute of Polymer Science and Engineering, National Taiwan University, Taipei 10617, Taiwan, ROC*

*Corresponding Author's E-mail: shhsu@ntu.edu.tw

**Abstract**

Eutectogels have recently attracted significant interest as soft materials due to their intrinsic anti-freezing capability, ionic conductivity, and mechanical compliance. Among them, gelatin-based eutectogels are particularly appealing because of their biocompatibility and biodegradability. However, their limited mechanical robustness and structural stability restrict their practical applications. To address these limitations, incorporating reinforcement is a common strategy to enhance the mechanical integrity of polymer networks, but conventional fillers often compromise flexibility or ionic transport. Various nanoparticles have emerged as promising fillers that reinforce polymer networks while minimizing their impact on ionic conductivity. Among these, waterborne polyurethane (WPU) nanoparticles possess good flexibility and tunable mechanical properties, offering superior mechanical reinforcement and network stability compared to other nanoparticles. In addition, WPU demonstrates versatility and adaptability to various hydrogel systems. Eutectogels represent a promising class of hydrogels with improved stability and ionic transport, but their mechanical reinforcement with WPU is largely unexplored. Herein, we report a reversible reinforcement strategy by incorporating a novel functionalized WPU (FPU) into a gelatin eutectogel network. The FPU introduces interactions within the gelatin matrix, forming a hybrid network that enhance mechanical properties without compromising ionic conductivity. As a result, the FPU-reinforced gelatin eutectogel (FPUG) exhibits an enhanced compressive modulus of 35.8 kPa compared to 30.3 kPa for the pristine gelatin eutectogel. Both values closely match the mechanical properties of human skin. FPUG exhibits an ionic conductivity of 2.23 mS $cm^{-1}$. This approach overcomes the mechanical limitations of gelatin eutectogels and retains their functional performance. It provides a platform for resilient, ionically conductive and biodegradable soft materials suitable for flexible bioelectronics and wearable ionic devices.

**Keywords:** eutectogels, biodegradable, ionic conductivity, flexible bioelectronics

# Preparation and Structural Characterization of Ru-Loaded rGO/$SnO_2$ Nanocomposites for $SO_2$ Gas Sensing

Siwakorn [B]unna[ka], Pimpan Leangtanom[c], Sirorat Moollor[a], Chatchawan Sammana[a], Salintip Jongpongsa[a], Narong Chanlek[d], Viruntachar Kruefu[a,b,*]

[a] *Applied Physics Program, Faculty of Science, Maejo University, Chiang Mai, 50290 Thailand*
[b] *Program in Nanoscience and Nanotechnology, Faculty of Science, Maejo University, Chiang Mai 50290, Thailand*
[c] *Department of Materials Science and Engineering, School of Molecular Science and Engineering, Vidyasirimedhi Institute of Science and Technology (VISTEC), Rayong 21210, Thailand*
[d] *Synchrotron Light Research Institute, Nakhon Ratchasima 30000, Thailand*

** Corresponding author email address: v_viruntachar@hotmail.com*

**Abstract**

Ru-loaded reduced graphene oxide/tin oxide (Ru-rGO/$SnO_2$) nanocomposites with Ru contents ranging from 0 to 0.75 wt% were synthesized via a combined reflux hydrothermal impregnation strategy. Structural and morphological characterizations performed using X-ray diffraction (XRD), field-emission scanning electron microscopy (FE-SEM), and high-resolution transmission electron microscopy (HR-TEM) confirmed the successful formation of the composite structure. Surface and optical properties were further examined using Brunauer-Emmett-Teller (BET) surface area analysis. The results verified the successful decoration of Ru nanoparticles onto few-layer reduced graphene oxide sheets integrated within the $SnO_2$ matrix, forming a hierarchical nanocomposite architecture. Notably, the 0.25 wt% Ru-rGO/$SnO_2$ sample exhibited the largest specific surface area among all compositions, which is expected to provide more active sites for gas adsorption and thereby enhance sensing performance.

**Keywords**: Ru-loading rGO/$SnO_2$ nanocomposites, Hydrothermal synthesis, Structural characterization

# Facile Synthesis of $CeO_2$ Nanofiber/F-MXene Nanocomposites with Enhanced Structural Integration for Gas Sensor Applications

Sirorat Moollor[a], Pimpan Leangtanom[c], Salintip Jongpongsa[a], Siwakorn [B]unna[ka], Chatchawan Sammana[a], Viruntachar Kruefu[a],[b],*

[a] *Applied Physics Program, Faculty of Science, Maejo University, Chiang Mai, 50290 Thailand*
[b] *Nanoscience and Nanotechnology Program, Faculty of Science, Maejo University, Chiang Mai 50290, Thailand*
[c] *Department of Materials Science and Engineering, School of Molecular Science and Engineering, Vidyasirimedhi Institute of Science and Technology (VISTEC), Rayong 21210, Thailand*

*Corresponding Author's E-mail: v_viruntachar@hotmail.com

**Abstract**

Cerium oxide ($CeO_2$) nanostructures have attracted considerable attention due to their outstanding physicochemical properties, including high chemical stability and large specific surface area. In this study, a $CeO_2$ nanofiber/F-MXene nanocomposite was successfully synthesized through a combination of electrospinning, acid etching, and hydrothermal methods. $CeO_2$ nanofibers were first fabricated via electrospinning and subsequently calcined at 500°C for 2 h to obtain crystalline $CeO_2$ nanofibers. Meanwhile, F-MXene was prepared by selectively etching the aluminum (Al) layer from the $Ti_3AlC_2$MAX phase using hydrofluoric acid (HF), resulting in $Ti_3C_2T_x$ MXene with surface functional groups. The $CeO_2$ nanofibers were then integrated with F-MXene sheets through a hydrothermal process to enhance interfacial interaction and structural adhesion between the components. The crystalline structure, surface morphology, and chemical bonding characteristics of the synthesized materials were systematically characterized using X-ray diffraction (XRD), scanning electron microscopy (SEM), Raman spectroscopy, and Fourier transform infrared spectroscopy (FTIR). The results confirm the successful formation of $CeO_2$ nanofibers and their effective incorporation with F-MXene within the composite structure. This work provides a feasible strategy for the fabrication of $CeO_2$/MXene nanocomposites and offers fundamental insights into their structural properties for potential applications in gas sensing materials.

**Keywords**: $CeO_2$ nanofiber, F-MXene, Nanocomposite, Electrospinning, Hydrothermal synthesis

# Microwave-Assisted One-Pot Synthesis of CeO2-Decorated NiO Nanoflower p–n Heterojunctions for Enhanced Ethanol Gas Sensing

Viruntachar Kruefu[a,b],*, Pimpan Leangtanom[c], Montawat Wiboon[a], Siwakorn [B]unna[kb], Chatchawan Sammana[b], Salintip Jongpongsa[b], Sirorat Moollor[b], Patcharee Kongpark[b], Sakchai Satienperakul[d], Anurat Wisitsoraat[e], Narong Chanlek[f], Yingyot Poo-arporn[f], Kata Jaruwongrungsee[g]

[a] *Program in Nanoscience and Nanotechnology, Faculty of Science, Maejo University, Chiang Mai 50290, Thailand*
[b] *Applied Physics Program, Faculty of Science, Maejo University, Chiang Mai, 50290 Thailand*
[c] *Department of Materials Science and Engineering, School of Molecular Science and Engineering, Vidyasirimedhi Institute of Science and Technology (VISTEC), Rayong 21210, Thailand*
[d] *Applied Chemistry Program, Faculty of Science, Maejo University, Chiang Mai, 50290 Thailand*
[e] *National Nanotechnology Center, National Science and Technology Development Agency, Klong Luang, Pathumthani 12120, Thailand*
[f] *Synchrotron Light Research Institute, Nakhon Ratchasima 30000, Thailand*
[g] *Opto-Electrochemical Sensing Research Team, National Electronics and Computer Technology Center, Pathumthani 12120, Thailand*

** Corresponding author email address: v_viruntachar@hotmail.com*

**Abstract**

Highly selective and sensitive ethanol detection is essential for environmental monitoring, industrial safety, and healthcare-related applications. Herein, $CeO_2$-decorated p-type NiO nanoflowers were successfully synthesized via a one-pot microwave-assisted hydrothermal strategy to enhance ethanol sensing performance through heterojunction interface engineering and surface catalytic modulation. Structural and morphological characterizations confirmed that $CeO_2$ submicrospheres were uniformly anchored onto hierarchical NiO nanoflowers, leading to enlarged specific surface area and the formation of well-defined NiO/$CeO_2$ p-n heterojunction interfaces that facilitate charge carrier modulation. Gas-sensing measurements revealed that $CeO_2$ decoration significantly improves ethanol sensing performance compared with pristine NiO, providing enhanced sensitivity and excellent selectivity toward ethanol against various interfering gases including methanol, propanol, acetone, ammonia, hydrogen sulfide, and nitrogen dioxide. The sensor with an optimal Ni:Ce molar ratio of 95:5 exhibited the highest response at an operating temperature of 250°C, together with rapid response-recovery characteristics and a low detection limit. Moreover, the sensor demonstrated low humidity interference, outstanding repeatability, and stable sensing performance over 48 days of operation. The enhanced sensing behaviour is attributed to the synergistic effects of the NiO/$CeO_2$ p-n heterojunction interface, improved charge transfer efficiency, and the hierarchical nanoflower architecture generated by microwave-assisted synthesis. These findings highlight the strong potential of $CeO_2$-decorated NiO nanoflowers as promising sensing materials for reliable and practical ethanol monitoring under varying environmental conditions.

**Keywords**: $CeO_2$-decorated NiO, p-n heterojunction, Ethanol sensing, Nanoflower morphology, Microwave-assisted hydrothermal synthesis, Metal oxide gas sensor

# Capturing the Shift in Defect Compensation Near the Universal Acceptor Concentration in $BaTiO_3$ through Trace-Level La Control via Liquid-Phase Ultrasonic Doping

Won Yeong Chung[a], Young Soo Lim[a,b,*], Seok-Hyun Yoon[c]

[a] *Department of Smart Green Technology Engineering, Pukyong National University, Busan 48513, Republic of Korea*
[b] *Department of Materials System Engineering, Pukyong National University, Busan 48513, Republic of Korea*
[c] *Component Division, Samsung Electro-Mechanics Co. Ltd., Suwon 16674, Republic of Korea*

*Corresponding Author's E-mail: yslim@pknu.ac.kr

**Abstract**

Barium titanate ($BaTiO_3$) serves as the foundational dielectric in multilayer ceramic capacitors (MLCCs), which underpin modern electronic systems. The rapid expansion of advanced technologies—including AI servers, physical-AI platforms, automotive electronics, and high-frequency communication systems—has led to increasing demands for MLCCs with higher capacitance density, improved microstructural uniformity, and enhanced long-term electrical reliability. Achieving such performance requires precise control over defect chemistry and microstructural evolution, both of which are highly sensitive to trace-level doping in $BaTiO_3$-based systems.

However, realizing this precise control through conventional solid-state doping via ball milling is hindered by fundamental physical limitations. Prolonged mechanical attrition introduces unintended zirconium contamination from the milling media, while conventional solid-state mixing fundamentally restricts the uniform dispersion of trace solid-state dopants. Beyond these processing challenges, inevitable background impurities inherent in the raw $BaTiO_3$ powders act as acceptors, establishing the universal acceptor concentration (UAC), which is widely recognized to be approximately 100 ppm. This intrinsic material characteristic cannot be ignored when controlling trace-level dopants, as its interplay with the added dopants complicates the interpretation of defect equilibria, making systematic analysis highly challenging.

In this study, we overcome these limitations using a liquid-phase ultrasonic doping route that eliminates zirconium contamination and enables homogeneous adsorption of $La^{3+}$ across a rigorously controlled 30–1000 ppm range. Combining complementary structural, microstructural, dielectric, ferroelectric, and electrical characterizations within this unique experimental window reveals a distinct compensation-mechanism crossover near the ~100 ppm threshold, corresponding to the UAC. Below this level, the observed trends are consistent with oxygen-vacancy suppression and donor–acceptor association, whereas above it, the responses indicate a transition to a Ti-vacancy-related compensation regime. The results establish a rigorous and industrially relevant framework for understanding and controlling trace-level doping in $BaTiO_3$-based MLCC dielectrics.

**Keywords:** La added $BaTiO_3$, trace-level doping, universal acceptor concentration, compensation crossover

# Control of Ca Site Occupancy in $BaTiO_3$ Ceramics via Sonochemical Processing with a Liquid Precursor

Jin Uk Kim[a], Hyo Min Kim[b], Gil-Geun Lee[b], Young Soo Lim[a,*]

[a]*Department of Smart Green Technology Engineering, Pukyong National University, Busan 48513, Republic of Korea*
[b]*Department of Materials System Engineering, Pukyong National University, Busan 48513, Republic of Korea*

*Corresponding Author's E-mail: yslim@pknu.ac.kr

**Abstract**

$BaTiO_3$ has been widely investigated with various dopants to tailor its dielectric and ferroelectric properties. Among them, Ca is recognized as an amphoteric dopant that can occupy both the A- and B-sites of the perovskite lattice. Ca incorporated at the A-site has been reported to induce off-centering, stabilize ferroelectricity, and increase the Curie temperature, whereas Ca at the B-site is generally associated with reduced tetragonality and altered phase-transition behavior. However, the site occupancy of Ca is highly sensitive to processing conditions and stoichiometry, and selective A-site incorporation often requires B-site excess, making it difficult to realize the nominal composition as designed. Conventional processing of doped $BaTiO_3$ has largely relied on ball milling of solid raw materials. Recently, however, sonochemical processing has attracted increasing attention because of its shorter processing time, lower impurity incorporation, and superior dispersion and pulverization of starting materials. These characteristics make it advantageous for achieving homogeneous mixing prior to sintering.

In this study, $Ba_{1-x}Ca_xTiO_3$ ($x$ = 0–0.04) ceramics were fabricated by sonochemical mixing of $BaTiO_3$ and $TiO_2$ powders with a liquid $Ca(C_2H_3O_2)_2$ precursor in deionized water, followed by sintering. For comparison, specimens with the same compositions were also prepared by conventional ball milling using solid-state raw materials including $CaCO_3$. Structural and dielectric properties were systematically investigated. The sonochemically processed specimens exhibited higher Curie temperatures, indicating more effective A-site incorporation of Ca, whereas the ball-milled specimens showed larger lattice volumes and lower Curie temperatures because of Zr contamination from the $ZrO_2$ milling media. These results demonstrate that the combination of sonochemical processing and a liquid precursor enables more homogeneous Ca incorporation, thereby providing an effective strategy for controlling Ca site occupancy and more reliably realizing the nominal composition in Ca-doped $BaTiO_3$ ceramics, while also suggesting a viable processing route for other amphoteric-dopant systems.

**Keywords:** Ca-doped $BaTiO_3$, amphoteric dopant, site occupancy, sonochemical processing

# Defect-compensation in trace-level La-doped $SrTiO_3$ ceramics

Soon Jong Eom[a], Won Yeong Chung[a], Young Soo Lim [a,b*], Seok-Hyun Yoon[c]

[a]*Department of Smart Green Technology Engineering, Pukyong National University, Busan 48513, Republic of Korea*
[b]*Department of Materials System Engineering, Pukyong National University, Busan 48513, Republic of Korea*
[c]*Component Division, Samsung Electro-Mechanics Co. Ltd., Suwon 16674, Republic of Korea*

*Corresponding Author's E-mail: yslim@pknu.ac.kr

**Abstract**

$SrTiO_3$ (STO) is a versatile perovskite oxide used in a wide range of applications, including high-frequency tunable devices, thermoelectric devices, and solid oxide fuel cells, owing to its controllable electrical properties from semiconducting to insulating behavior, and thermal stability. Its electrical properties can be tailored by donor doping such as La substitution on the Sr-site. While La-doped STO has been extensively investigated, most studies have mainly focused on relatively high doping.

Meanwhile, in $BaTiO_3$, an isostructural perovskite oxide, universal acceptor concentration has been well established as a defect-chemical framework in which background acceptor states trap donor electrons and strongly influence charge compensation, defect equilibria, and electrical behavior. A similar situation is expected in STO because unavoidable impurity species can form a background acceptor population. These background acceptors may compensate donor electrons introduced by La doping and also affect the initial concentration of oxygen vacancies through charge neutrality. This effect is expected to be especially significant in the trace-doping regime, where the intentional dopant level can be comparable to the impurity level. Nevertheless, the role of background acceptors in trace-level La-doped STO has not been sufficiently considered.

In this study, La was introduced into STO by a liquid-phase ultrasonic doping method to achieve homogeneous dopant incorporation at the trace level. Dielectric and impedance measurements revealed different electrical/defect-compensation behaviors in the low- and high-doping regimes. In the lower concentration range, donor electrons are considered to be largely compensated by background acceptor states while maintaining oxygen vacancy-related defect. At higher concentrations, Fermi-level shift reduces the oxygen-vacancy concentration, resulting in suppressed dielectric relaxation and altered electrical behavior. These results suggest that defect interactions among donor dopants, background acceptors, and oxygen vacancies are closely related to the electrical response of trace La-doped STO.

**Keywords:** defect-compensation, trace-level doping, La-doped $SrTiO_3$, universal acceptor concentration

# Relaxor behavior and high-temperature dielectric properties of $(1-x)BaTiO_3–x(Bi_{0.5}Li_{0.5})SnO_3$ ceramics

Seung Wan Yu[a], Yean Joo Kim[b], Gil-Geun Lee[b], Young Soo Lim[a,*]

[a]*Department of Smart Green Technology Engineering, Pukyong National University, Busan 48513, Republic of Korea*
[b]*Department of Material System Engineering, Pukyong National University, Busan 48513, Republic of Korea*

*Corresponding Author's E-mail: yslim@pknu.ac.kr

**Abstract**

The essential properties of lead-free dielectrics for high-temperature electronic applications are high dielectric constant, low dielectric loss, and stable dielectric response across a wide temperature range. To achieve these properties, $BaTiO_3–(Bi_{0.5}Na_{0.5})TiO_3$ (BT–BNT) dielectrics, in which $Bi^{3+}$ and $Na^+$ possessing a lone pair similar to $Pb^{2+}$ are partially substituted at the A-site, have attracted attention. However, although improved high-temperature dielectric properties have been observed in BT–BNT systems, unusual relaxor behavior accompanied by increased tetragonality with increasing BNT content has also been reported, leading to degradation of DC characteristics.

To address this issue, recent studies have reported partial substitution of Sn at the B-site in BT–BNT systems. The isovalent substitution of $Sn^{4+}$ at the B-site suppresses the first-order ferroelectric phase transition and transforms the dielectric response into a diffuse phase transition, thereby stabilizing relaxor behavior. As a result, improved dielectric permittivity at high temperatures, reduced dielectric loss, and enhanced insulation properties have been reported. However, the stabilization of relaxor behavior in Sn-modified high-temperature lead-free dielectrics is still at an early stage, and the introduction of monovalent cations other than $Na^+$ has been rarely studied.

In this study, $(1-x)BaTiO_3–x(Bi_{0.5}Li_{0.5})SnO_3$ (x = 0.1–0.5) (BT–BLS) solid solutions were synthesized for the first time via a solid-state reaction method, where $Bi^{3+}$ and $Li^+$ were partially substituted at the A-site and $Sn^{4+}$ at the B-site. The crystal structure, microstructure, relaxor behavior, and high-temperature dielectric properties of the sintered ceramics were investigated. With increasing x, the relaxor behavior became more pronounced, and the relaxor characteristics were evaluated using the Vogel–Fulcher relation. In addition, a stable dielectric response was observed over a wide temperature range. These results suggest that the BT–BLS system is a promising dielectric candidate for MLCC applications.

**Keywords:** BT-BLS system, Lead-free dielectric, Relaxor behavior, Temperature stable dielectric

# A Triboelectric Nanogenerator with Micropits on PMMA Dielectric Surface for Improved Output Voltages

Tomotaka Kaneya [a], Takuma Kudo [a], Nitipon Puttaraksa [b,c], Hironori Seki [d], Hiroyuki Nishikawa [c,*]

[a] *Graduate School of Engineering and Science, Shibaura Institute of Technology, Japan*
[b] *Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Thailand*
[c] *College of Engineering, Shibaura Institute of Technology, Japan*
[d] *SIT Research Laboratories, Shibaura Institute of Technology, Japan*

*Corresponding Author's E-mail: nishi@shibaura-it.ac.jp

**Abstract**

A triboelectric nanogenerator (TENG) is a technology to convert mechanical energy into electricity through contact electrification and electrostatic induction between dielectric materials. The TENG technology has been employed in, for instance, energy-harvesting and self-powered sensing applications. One of the key developments of TENG devices is to enhance the output performance by modifying the dielectric surfaces with microstructures. While other studies have mainly focused on structures, such as pyramids [1], our work [2] has proposed a micropit structure.

The micropit structures were fabricated by Proton Beam Writing in a poly(methyl methacrylate)/PMMA layer of a 3 µm thickness spin-coated on a ~5 mm × ~5 mm Cu tape with a 50 µm thickness. The micropit PMMA on the Cu tape was controlled to move in contact and separation with a polytetrafluoroethylene/PTFE of a thickness of 90 µm on another Cu tape to perform a contact-separation mode TENG device. In our previous study [2], the number of micropits of 20 µm diameter was produced in several tens to hundreds for examining the effect of the micropit number on the TENG output voltage. The previous results suggested that the output voltage increased with increasing the micropit number and saturated at several hundred micropits. To further understand the mechanism of the involvement of micropits in the output voltage enhancement, several micropit parameters, e.g., pit size, spacing, and contact area, are investigated, which will be presented at this conference.

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**Keywords:** Triboelectric nanogenerator, Micropit structure, Proton Beam Writing, Output enhancement

# Simultaneous enhancement of high energy density and efficiency in high-entropy BNBSCT ceramics via $Bi(Mg_{2/3}Ta_{1/3})O_3$ modification

Pathit Premwichit[a], Sununta Yimsabai[a], Chen Deqin[b], Jia Yi Chia[c], Noppadon Nuntawong[c], Nengneng Luo[b] & Sasipohn Prasertpalichat[a], [d*]

[a]*Department of Physics, Faculty of Science, Naresuan University, Phitsanulok 65000, Thailand*
[b]*Guangxi Key Laboratory of Processing for Non-ferrous Metals and Featured Materials, MOE Key Laboratory of New Processing Technology for Non-ferrous Metals and Materials, School of Resources, Environment and Materials, Guangxi University, Nanning 530004, China*
[c]*National Electronics and Computer Technology Center (NECTEC), National Science and Technology Development Agency (NSTDA), Pathum Thani 12120, Thailand*
[d]*Research Centre for Academic Excellence in Applied Physics, Faculty of Science, Naresuan University, Phitsanulok 65000, Thailand*

*Corresponding Author's E-mail: sasipohnp@nu.ac.th

**Abstract**

High-entropy design has emerged as an effective strategy for tailoring dielectric properties and improving energy storage performance in perovskite ceramics. In this work, a series of high-entropy $(1–x)(Bi_{0.2}Na_{0.2}Ba_{0.2}Sr_{0.2}Ca_{0.2})TiO_3–xBi(Mg_{2/3}Ta_{1/3})O_3$ ($x$ = 0–0.30)ceramics were fabricated using a conventional solid-state reaction method. The incorporation of $Bi(Mg_{2/3}Ta_{1/3})O_3$ effectively enhances the dielectric response and contributes to the optimization of polarization behavior, leading to improved energy storage characteristics. Meanwhile, refined microstructure, increased electrical resistivity, and an enlarged bandgap are observed, which collectively contribute to a remarkable enhancement in breakdown electric field ($E_b$). As a result, the optimized composition at $x$ = 0.20 exhibits an ultrahigh $E_b$ of 577 kV/cm, achieving a high recoverable energy density ($W_{rec}$) of 6.96 J/cm$^3$ and an excellent energy storage efficiency (η) of 91%. In addition, the optimized ceramic demonstrates outstanding thermal stability over a wide temperature range (~29–140 °C), with only slight variations in $W_{rec}$ (~8%) and η (~3%). The superior energy storage performance, together with good thermal stability, indicates that high-entropy $(Bi_{0.2}Na_{0.2}Ba_{0.2}Sr_{0.2}Ca_{0.2})TiO_3$-based ceramics modified by $Bi(Mg_{2/3}Ta_{1/3})O_3$ are promising candidates for advanced dielectric capacitors.

**Keywords:** High-entropy ceramics, Energy storage, Breakdown electric field, Relaxor behavior

# Enhanced Strain and Magnetoelectric properties in $MnO_2$-Doped KNLNTS-BCTZ Ceramics Synthesized via Solid-State Combustion Method

Wiwat Pattanakasem[a], Sununta Yimsabai[a], Manlika Sriondee[a], Pawarin Tharamas[b], Pawinee Pakkharawat[b], Naratip Vittayakorn[c], Supree Pinitsoontorn[d], Aurawan Rittidech[e], Truong-Tho Pham[f,g], and Theerachai Bongkarn[a,*]

[a]*Department of Physics, Faculty of Science, Naresuan University, Phitsanulok, 65000, Thailand,*
[b]*National Science and Technology Development Agency (NSTDA), 111 Thailand Science Park, Phahonyothin Road, Khlong Nueng, Khlong Luang, Phathum Thani, 12120, Thailand,*
[c]*Advanced Material Research Unit, Faculty of Science, King Mongkut's Institute of Technology Ladkrabang, Bangkok, 10520, Thailand,*
[d]*Institute of Nanomaterials Research and Innovation for Energy (IN-RIE), Khon Kaen University, Khon Kaen, 40002, Thailand,*
[e]*Department of Physics, Faculty of Science, Mahasarakham University, Mahasarakham, 44150, Thailand,*
[f]*Laboratory of Magnetism and Magnetic Materials, Science and Technology Advanced Institute, Van Lang University, Ho Chi Minh City, Vietnam,*
[g]*Faculty of Applied Technology, Van Lang School of Technology, Van Lang University, Ho Chi Minh City, Vietnam*

*Corresponding Author's E-mail: researchcmu@yahoo.com

**Abstract**

In this work, the effect of $MnO_2$ doping ($x$=0-0.8 wt%) on the phase formation, microstructure, electrical, and magnetic properties of $0.985[(K_{0.44}Na_{0.52}Li_{0.04})(Nb_{0.84}Ta_{0.10}Sb_{0.06})O_3]$-$0.015[(Ba_{0.85}Ca_{0.15})(Ti_{0.90}Zr_{0.10})O_3]$ (abbreviate to KNLNTS-BCTZ+$x$$MnO_2$) ceramics was investigated. These ceramics were fabricated by the solid-state combustion method using glycine as fuel. KNLNTS and BCTZ powders were calcined at 850°C and 1050 °C for 2 hours, respectively. The KNLNTS-BCTZ ceramics doping with $MnO_2$ were sintered at 1100 °C for 2 h. X-ray diffraction (XRD) analysis revealed that ceramics doped with 0-0.6 wt% $MnO_2$ exhibited a pure perovskite phase with coexisting orthorhombic and tetragonal phases. However, upon increasing the doping to 0.8 wt%, a secondary phase of $MnNb_2O_6$ was detected. The doping of $MnO_2$ also led to an increasing trend in the average grain size of ceramics. Regarding the dielectric properties measured at 1 kHz, the dielectric loss (tan δ) exhibited a significant decrease in the $MnO_2$-doped sample. In terms of ferroelectric properties, when the $MnO_2$ content increased from 0 to 0.8 wt%, the remanent polarization ($P_r$) decreased from 20.0 to 10.7 μC/cm$^2$, and the coercive field ($E_c$) decreased from 14.5 to 9.3 kV/cm. The ceramics exhibited diamagnetic behavior at $MnO_2$ concentrations of 0 to 0.4 wt%, transitioned to paramagnetic behavior at 0.6 wt%, and displayed antiferromagnetic properties at 0.8 wt%. Interestingly, $MnO_2$ doping remarkably enhanced the strain response, achieving a high effective piezoelectric coefficient ($d^*_{33}$) of ~304.1 pC/N. For $x$ = 0.6 wt%, the maximum magnetoelectric coefficient (~0.97 mV/cm·Oe) was obtained. These results suggest that $MnO_2$ doping can be effectively used to improve electrical properties, induce magnetism and enhance magnetoelectricity in KNLNTS-BCTZ ceramics that are promising candidates for multiferroic material applications.

**Keywords:** phase formation, microstructure, dielectric, magnetic, solid state combustion method

# An Advanced Biomimetic Biomimetic Stevia–PVA Hydrogel Triboelectric Nanogenerator with Machine Learning-Enhanced Motion Recognition

Kyungwho Choi[a,*], Changbum Ryan Ahn[b], Hojin Lee[c]

[a]*School of Mechanical Engineering, Sungkyunkwan University, 2066 Seobu-ro, Jangan-gu, Suwon, Gyeonggi 16419, SouthKorea*
[b]*Department of Architecture and Architectural Engineering, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul, 08826, South Korea*
*cSchool of Electronic Engineering, Soongsil University,* ***369,*** *Sangdo-ro, Dongjak-gu, Seoul, South Korea*

*Corresponding Author's E-mail*: *kw.choi@skku.edu*

**Abstract**

The demand for flexible, portable, and self-powered sensor devices has increased due to the rapid advancements in AI and the Internet of Things. The development of biocompatible, mechanically tunable, environmentally adaptable, and highly conductive hydrogels for use as flexible sensors in triboelectric nanogenerators is an ingenious idea. TENG application is limited by the paucity of suitable biomaterials and the need for highly conductive fillers such 2D materials, which trade off transparency, output, and sensing. To get around this problem, researchers are looking at a novel triboelectric nanogenerator (S-TENG) that mimics the properties of stevia and PVA hydrogels: it's very transparent, highly stretchable, and has a high output performance. Adding biomimetic stevia to polyvinyl alcohol (PVA) increases hydrogel cross-linking and crystalline domains, and it's cost-effective because of its abundant dynamic hydrogen bonding. The S-hydrogel outperforms 2D-, bio-, and transparent-material-based TENGs in terms of mechanical strength and electrical output, while still being transparent, thanks to these structural improvements. The voltage output of the S-hydrogel can be preserved during recycling and recovery through water-assisted dissolution and re-gelation. A self-powered sensor for a variety of human actions, the upgraded S-TENG has a 13 ms reaction time and exceptional sensitivity. A promising future for self-powered sensors is seen in the XGBoost approach, which achieved the highest classification accuracy of 95.29% out of eleven machine learning models.

**Graphical abstract:**




**Keywords:** hydroge, machine learning, Stevia, triboelectric nanogenerator

**Acknowledgments**

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# Flexible hybrid piezoelectric-triboelectric nanogenerator using lead-free BNBT-LS ceramics via the solid-state combustion technique

Anupong Luangpangai[a], Nattapong Apirattanon[a], Manlika Sriondee[a], Rattiphorn Sumang[b], Aurawan Rittidech[c], Naratip Vittayakorn[d], Theerachai Bongkarn[a,*]

[a]*Department of Physics, Faculty of Science, Naresuan University, Phitsanulok 65000, Thailand*
[b]*Program of Physics, Faculty of Science and Technology, Pibulsongkram Rajabhat University, Phitsanulok 65000, Thailand*
[c]*Department of Physics, Faculty of Science, Mahasarakham University, Mahasarakham 44150, Thailand*
[d]*Advanced Materials Research Unit, Faculty of Science, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand*

*Corresponding Author's E-mail: researchcmu@yahoo.com

**Abstract**

In this study, lead-free (1-x)$Bi_{0.47}Na_{0.47}Ba_{0.06}TiO_3$-x$LiSbO_3$ (BNBT-xLS, where x=0-0.05) ceramics were synthesized via the solid-state combustion technique to investigate the effect of $LiSbO_3$ doping on their phase formation, microstructure and electrical properties. X-ray diffraction (XRD) patterns revealed that all samples exhibited a pure perovskite structure with the coexistence of rhombohedral and tetragonal phases. The concentration of oxygen vacancies increased with increasing $LiSbO_3$ content as determined by X-ray photoelectron spectroscopy (XPS). The optimal electrical properties were achieved at x=0.01, showing a maximum dielectric constant ($\varepsilon_m$) of 5069, a maximum polarization ($P_{max}$) of 36.87 μC/cm², a maximum strain ($S_{max}$) of 0.29% and a normalized strain ($d_{33}^*$) of 584 pm/V. To evaluate their energy harvesting performance, BNBT-0.01LS ceramic powders were incorporated into a polydimethylsiloxane (PDMS) matrix at varying weight fractions (0-30 wt%) to fabricate composite films. Increasing the ceramic powder loading enhanced the electrical output of the hybrid piezoelectric-triboelectric nanogenerator (PENG/TENG), reaching a maximum voltage of 88 V at a filler content of 25 wt% BNBT-0.01LS. This research provides an effective approach for fabricating high-performance flexible ceramic-polymer composite films for energy harvesting applications. The developed composites show promising applicability in self-powered systems, such as autonomous IoT sensors and wearable electronics.

**Keywords:** electrical properties, hybrid PENG/TENG, composite films, BNBT-xLS/PDMS

# Enhancement of electrical properties in BNT-ST ceramics modified by MnO doping for energy storage applications

Piewpan Parjansri[a,d,*], Sukum Eittsayeam[b,d], Uraiwan Inthata[c,d], Kamonpan Pengpat[b,d],

[a]*Physics Division, Faculty of Science and Technology, Rajamangala University of Technology Krungthep, Bangkok 10120, Thailand*
[b]*Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[c]*Materials for Energy and Environment Research Group (MEE), School of Science, Mae Fah Luang University, Chiang Rai 57100, Thailand,*
[d]*Hub of Advanced Ceramics, Faculty of Science, Chiang Mai University, 239 Huay Kaew Road, Suthep, Mueang Chiang Mai, Chiang Mai, Thailand, 50200*

*Corresponding Author's E-mail: piewpan.p@mail.rmutk.ac.th

**Abstract**

This research focuses on developing dielectric materials in the lead-free group. Modifying chemical structures to have properties suitable for energy storage applications, including improving various properties and applying prepared ceramics in recent working conditions. The preparation of lead-free ceramics in BNT-based systems was carried out according to the $Bi_{0.5}Na_{0.5}TiO_3$-$SrTiO_3$ (BNT-STs) and $Bi_{0.5}Na_{0.5}TiO_3$-$SrTiO_3$-Mn (BNT-STs-Mn) formula by conventional mixed-oxide method and seed-induced method, as well as studying the effect of MnO doping. The results showed that the ceramics exhibited the perovskite phase for all preparation conditions. The density value of the MnO-doped samples was in the range of 5.15-5.48 g/cm$^3$. The MnO-doped materials had density values between 5.15 and 5.48 g/cm3. The sample with MnO=1.0 mol% had the highest density value. With the appropriate STs and MnO content, the dielectric constant rises. MnO-doped ceramics have a maximum dielectric value of 784 (1 kHz) found in the sample of MnO = 0.02. While the dielectric loss exhibited insignificant changes with varying amounts of STs and MnO, maintaining values within the range of 0.032–0.047.

**Keywords**: BNT, lead-free ceramics, dielectric properties, energy storage

# Effects of $Eu^{3+}$ Doping Concentration and Cooling Rate on Structural and Electrical Properties of $(K_{0.47}Na_{0.47}Li_{0.06})_{1-x}Eu_xNbO_3$ Ceramics

Sriwan Kaewsit[a], Khanisorn Sompong[a], Worapong Pairindra[b], Kamonpan Pengpat[c], Ploypailin Yongsiri[a,*]

[a] *Department of Manufacturing System Technology, School of Integrated Innovative Technology, KMITL, Bangkok, 10520, Thailand*
[b] *Department of Engineering Education, School of Industrial Education and Technology, KMITL, Bangkok, 10520, Thailand*
[c] *Department of Physics, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*

*Corresponding Author's E-mail: ploypailin.yo@kmitl.ac.th

**Abstract**

Rare earth doping and post-sintering thermal treatment represent two underexplored yet interdependent processing variables governing the structural integrity and functional electrical performance of lead-free potassium sodium niobate (KNN)-based ceramics. This study investigates the combined effects of $Eu^{3+}$ substitution ($x = 0.01, 0.03$) and cooling protocol by controlled slow cooling (5°C/min) versus rapid quenching, on the phase structure, microstructure, dielectric, and ferroelectric properties of $(K_{0.47}Na_{0.47}Li_{0.06})_{1-x}Eu_xNbO_3$ ceramics synthesized via conventional solid-state reaction and sintered at 1100°C for 3 h. X-ray diffraction confirms phase-pure perovskite formation in an orthorhombic structure across all compositions, with no detectable secondary phases. Microstructural analysis by FESEM reveals that $Eu^{3+}$ incorporation progressively refines grain size, consistent with dopant-induced lattice site competition and unit cell contraction arising from the smaller ionic radius of $Eu^{3+}$ relative to host A-site cations. Slow-cooled samples consistently exhibit smaller average grain sizes than their quenched counterparts, attributed to extended thermally activated grain boundary diffusion during gradual cooling, a process kinetically suppressed under rapid quenching, which additionally preserves elevated oxygen vacancy populations and metastable defect configurations. Dielectric characterization demonstrates frequency-dependent permittivity reduction across all samples, with slow-cooled specimens at $x = 0.01$ achieving the highest dielectric constant ($\varepsilon_r = 1058$ at 100 Hz), reflecting the combined contribution of rhombohedral-symmetry enhancement and reduced point-defect density. Ferroelectric P–E measurements reveal that the $x = 0.01$ slow-cooled sample attains the highest remanent polarization ($P_r = 20.3\ \mu C/cm^2$), demonstrating that optimal $Eu^{3+}$ content and controlled cooling synergistically promote domain switching efficiency. These findings establish that $Eu^{3+}$ doping concentration and post-sintering cooling rate act as coupled processing levers governing defect chemistry, microstructural evolution, and macroscopic electrical response in lead-free KNLN-based ceramics, providing quantitative design criteria for tailoring functional performance in next-generation piezoelectric and ferroelectric applications.

**Keywords:** Potassium sodium niobate, Europium Oxide, Cooling rate, Quenching, Electrical properties

# Synergistic Piezo-Photocatalytic Performance of Multiferroic $BiFeO^3$ Nanoparticles for Enhanced Rhodamine B Degradation

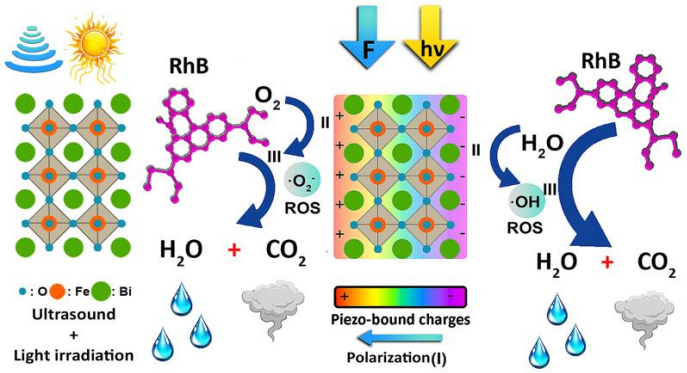
Kokkiligadda Jhansi[a*] and Parasuraman Swaminathan[a]

[a]*Electronic Materials and Thin Films Lab, Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras, Chennai, 600036, India*

*Corresponding Author's E-mail: jhansimme732@gmail.com

**Abstract**

Multiferroic materials possessing coupled ferroic functionalities have emerged as promising candidates for harvesting multiple forms of energy and enabling advanced catalytic processes. Among them, bismuth ferrite ($BiFeO_3$, BFO) combines ferroelectric, piezoelectric, and photoactive properties, making it an attractive material for multi-stimuli-driven catalysis. In the present work, BFO nanoparticles (NPs) were investigated as multifunctional catalysts for the degradation of Rhodamine B (RhB) under the simultaneous application of light irradiation and ultrasonic stimulation. The combination of photocatalysis and piezo-catalysis facilitates efficient charge separation and enhances the generation of reactive oxygen species, resulting in superior catalytic performance compared with individual stimulation modes. The piezo-photocatalytic activity of BFO NPs was evaluated using RhB at an initial concentration of 20 mg $L^{-1}$, which is significantly higher than the concentrations commonly reported in previous photo and piezo-catalytic studies. The synergistic coupling of optical and mechanical energy inputs accelerated the degradation kinetics and improved pollutant removal efficiency. The enhanced performance is attributed to the piezoelectric polarization generated under ultrasonic excitation, which promotes the separation and migration of photogenerated charge carriers while suppressing their recombination. This synergistic effect enables more effective utilization of the harvested energy and increases the availability of reactive species for pollutant degradation. The results demonstrate the potential of multiferroic BFO NPs as efficient catalysts for multi-stimuli-assisted environmental remediation. More importantly, this study highlights the broader applicability of ferroelectric and piezoelectric materials in advanced catalytic systems that can simultaneously exploit multiple energy sources. Such multifunctional materials offer a promising pathway toward sustainable and energy-efficient technologies for wastewater treatment and environmental remediation.




Graphical abstract showing synergistic piezo-photocatalysis using $BiFeO_3$

**Keywords:** Multiferroic, Ferroelectric, Piezoelectric, **Piezo-Photocatalysis**, Bismuth ferrite

# Synthesis of Unsymmetric Diketopyrrolopyrrole-Based Copolymers with Controlled Regioregularity and Their Photovoltaic Characteristics

Ryosuke Kamimura[a], Fumitaka Ishiwari[a,b], Akinori Saeki[a,*]

[a]*Graduate School of Engeenering, The Univ. of Osaka, 2-1 Yamadaoka, Suita, Osaka, Japan*
[b]*Graduate School of Urban Environmental Sciences, Tokyo Metropolitan Univ., 1-1 Minami-Osawa, Hachioji, Tokyo, Japan*

*Corresponding Author's E-mail: saeki@chem.eng.osaka-u.ac.jp

**Abstract**

Organic photovoltaics (OPVs) are anticipated as a key next-generation solar cell for a carbon neutral society. As a design guideline of p-type semiconductors, combination of electron-donor (D) and electron-acceptor (A) is a general approach to yield narrow bandgap copolymers (NBPs). Diketopyrrolopyrrole (DPP) is an authentic π-conjugated skeleton with strong electron-withdrawing properties, and has been extensively studied as a building block for NBP (e.g. R. Kamimura et al., *ACS Omega* **2025**, *10*, 56511). π-Conjugated polymers with DPP as the central backbone generally exhibit a symmetric structure with the same aromatic rings, such as thiophene, on both sides of the central backbone. However, unsymmetric structures (uDPP) with different aromatic rings on either side of the DPP core have been reported only in limited cases. While uDPP is expected to exhibit high solubility due to its unsymmetry, simple synthetic routes yield regiorandom copolymers (Fig. 1a), where the orientation of the unsymmetric skeleton is uncontrolled, leading to low crystallinity. Therefore, our research group synthesized a regioregular Type I polymer that cancels out the dipole arising from unsymmetry (Fig. 1b), but the power conversion efficiency (PCE) was only 2.5%. There are two types of design that control the regioregularity of uDPP polymers: Type I and Type II (Fig. 1c), the latter of which does not cancel the dipole in the main chain direction. In this study, we designed and synthesized two Type II polymers with different alkyl chains, RR-P1 and RR-P2, which achieve both high crystallinity and high solubility (P1: 2-hexyl decyl, P2: 2-octyl dodecyl). For a comparison, we synthesized the regiorandom copolymers of Ran-P1 and Ran-P2 with the same alkyl chains and compared the OPV characteristics when blended with the non-fullerene acceptor Y6.

**Fig. 1** Schematic of regiorandom and two types regioregular copolymers, and their chemical structures.

**Keywords:** Organic semiconductor, Organic photovoltaics, Polymer, Regioregular, Unsymmetry

# Effect of $NiI_2$ Quantum Dots as Additive and Interface Passivation on Performance of NiO-Based Perovskite Solar Cells

Wakul Bumrungsan[a,b], Vasan Yarangsi[a] , Kritsada Hongsith[a,b], Suparoek Yarin[a], Prapasiri Phimsarn[a], Siripatsorn Thanasanvorakun[a] Sukrit Sucharitakul[a], Surachet Phaduangdhitidhata[a], Supab Choopun[a,*]

[a]*Department of Physics and Materials Science, Faculty of Science, Chiangmai, 50200, Thailand*
[b]*Office of Research Administration, Chiangmai University, Chiangmai,50200, Thailand*

*Corresponding Author's E-mail: supab99@gmail.com

**Abstract**

Nickel oxide (NiO) is a promising hole transport layer for p-i-n perovskite solar cells (PSCs) due to its stability and transparency. However, its performance is often hindered by low conductivity and surface defects, leading to charge recombination. To overcome these limitations, nickel iodide ($NiI_2$) quantum dots (QDs) have emerged as a candidate for both bulk and interface engineering. In this work, $NiI_2$ quantum dots synthesized via electrochemical process are applied as a dopant in nickel precursor and used as a passivator on NiO for perovskite solar cell enhancement. Effects of $NiI_2$ quantum dots additive and interface passivation on NiO thin films are intensively investigated by various techniques such as scanning electron microscopy for morphological properties, X-rays photoelectron spectroscopy for chemical surface properties, contact angle measurement for wettability properties, photoluminescence spectroscopy and UV-visible spectroscopy for optical properties. In addition, the modified-NiO by $NiI_2$ QDs are used as a hole transport layer in p-i-n PSCs. The p-i-n PSCs performance is study via *J-V* characteristic curve, electrochemical spectroscopy. The solar cell devices show maximum power conversion efficiency (PCE) values of more than 14% for the modified-NiO thin film compared to 12% of the reference device. Therefore, it can be concluded that $NiI_2$ QDs can be used for NiO thin film modification in p-i-n PSC applications.

**Keywords:** p-i-n perovskite solar cells, $NiI_2$ quantum dots, Nickel oxide, doping and passivation,

# Enhanced Performance of Perovskite Solar Cells via $SnO_x$ Quantum Dot Additives in $SnO_2$ Electron Transport Layers

Suparoek Yarin[a], Vasan Yarangsi[a], Kritsada Hongsith[a,b], Wakul Bumrungsan[a,b], Prapasiri Phimsarn[a], Siripatsorn Thanasanvorakun[a], Sukrit Sucharitakul[a], Surachet Phadungdhitidhada[a], Supab Choopun[a,*]

[a]*Department of Physics and Materials Science, Faculty of Science, Chiangmai, 50200, Thailand*
[b]*Office of Research Administration, Chiangmai University, Chiangmai, 50200, Thailand*

*Corresponding Author's E-mail: supab99@gmail.com

**Abstract**

$SnO_2$ electron transport layers (ETLs) are widely utilized in perovskite solar cells (PSCs) due to their low-temperature processing, cost-effectiveness, and simple film fabrication. However, the $SnO_2$ films suffer low electrical conductivity, non-uniform coverage, and high interfacial trap densities, which limit charge transport and increase charge recombination in PSC devices. To address these limitations, this study aims to improve PSC performance by employing $SnO_x$ quantum dots (QDs) as additives into $SnO_2$ ETLs. The $SnO_x$ QDs were synthesized via an electrochemical method using a 0.1 M citric acid (CA) electrolyte solution and tin foil electrodes at 6 V for 24 h. Then, the synthesized quantum dots were introduced as additives into the ETL precursor (sol–gel $SnO_2$, SG) at concentrations of 2.5, 5, and 7.5 vol% to fabricate ETL in planar PSCs with the structure FTO/$SnO_2$/Perovskite/Spiro-OMeTAD/Ag. The results show that the utilization of $SnO_x$ QD additives significantly improves the performance of PSC devices. The optimal modification condition with 2.5 vol% $SnO_x$ QDs achieves an average power conversion efficiency (PCE) of 18.85%, outperforming the reference PSC devices (average PCE of 15.94%). This enhancement is attributed to improved charge extraction, enhanced interfacial contact, and reduced defect density at the ETL/perovskite interface. Overall, $SnO_x$ QD additives provide a promising, scalable strategy to overcome the intrinsic limitations of conventional $SnO_2$ ETLs and enhance PSC performance.

**V (V)**

Fig.1 J-V characteristics of perovskite solar cells of pristine sol-gel $SnO_2$ (SG), citric acid (CA), and 2.5% $SnO_x$ quantum dots modified ETLs

**Keywords:** Perovskite solar cells, Electron transporting layer, $SnO_x$ Quantum dots, Electrochemical synthesis

# Selective halide passivation enhances hole mobility in metal organochalcogenides

Pimpan Leangtanom[a], Rattapon Khamlue[a], Siriporn Jungsut[t]iwong[b], Achawee Dangkongko[a], Nuttapon Kongsip[a], Somlak Ittisanronnachai[c], Watcharaphol Paritmongkol[a,*]

[a]*Department of Materials Science and Engineering, School of Molecular Science and Engineering, Vidyasirimedhi Institute of Science and Technology (VISTEC), Rayong 21210, Thailand*
[b]*Department of Chemistry and Center of Excellence for Innovation in Chemistry, Ubon Ratchathani University, Ubon Ratchathani, 34190, Thailand*
[c]*Frontier Research Center (FRC), Vidyasirimedhi Institute of Science and Technology (VISTEC), Wangchan Valley, 555 Moo 1 Payupnai, Wangchan, Rayong, 21210, Thailand*

*Corresponding Author's E-mail: watcharaphol.p@vistec.ac.th

**Abstract**

Two-dimensional metal organochalcogenides (MOCs) are emerging hybrid organic–inorganic semiconductors with exciting properties, including strong exciton binding energy, polarized luminescence, in-plane anisotropy, and record-high exciton–polariton coupling. Among them, AgSePh exhibits a hole mobility of $4.88\times10^{-2}$ $cm^2 \cdot v^{-1} \cdot s^{-1}$, outperforming many organic and hybrid semiconductors and rivaling commonly used inorganic hole-transporting materials such as CuSCN and $NiO_x$ in thin-film electronics. However, defect-induced trap states, particularly vacancy defects, remain a key limitation to further improving charge transport. Here, we report a simple yet effective strategy to modulate defect chemistry in AgSePh via selective halide passivation using alkali halide salts (NaX, X = Cl, Br, I) in methanol. Despite negligible changes in crystal structure and surface ligands, halide treatment leads to a pronounced and selective enhancement in hole transport, with mobility following the trend NaI < pristine < NaCl < NaBr. Notably, NaCl and NaBr treatments increase the hole mobility by approximately one order of magnitude. Low-temperature photoluminescence measurements reveal the suppression of trap-state emission for all halide-treated samples, indicating effective defect passivation. X-ray photoelectron spectroscopy confirms the formation of Ag–Cl and Ag–Br bonds. Density functional theory calculations further identify Se–Ph vacancies as the dominant defect species and support their passivation by halide ions. These findings demonstrate that strong and stable halide–metal interactionsdictate hole transport in AgSePh, providing a general strategy for tuning charge transport in MOCs via selective halide chemistry.

**Keywords:** Metal organochalcogenides, Hybrid semiconductors, Surface passivation, Defect healing, Hole-transporting materials

# Thiadiazole[3,4-c]pyridine Derivative as NIR Luminophore for Electroluminescent Device and Luminescence Solar Concentrator

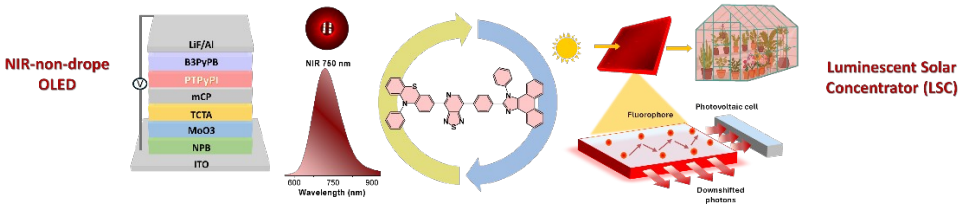
Rattanasiri Wanapakdee[a,*], Praweena Wongkaew[b], Taweesak Sudyoadsuk[b], Vinich Promarak[c]

[a]*Author1's Department of Materials Science and Engineering, School of Molecular Science and Engineering, Vidyasirimedhi Institute of Science and Technology, Wangchan, Rayong 21210, Thailand*
[b]*Author2's Department of Materials Science and Engineering, School of Molecular Science and Engineering, Vidyasirimedhi Institute of Science and Technology, Wangchan, Rayong 21210, Thailand*
[c]*Author3's Department of Materials Science and Engineering, School of Molecular Science and Engineering, Vidyasirimedhi Institute of Science and Technology, Wangchan, Rayong 21210, Thailand*

*Corresponding Author's E-mail: *vinich.p@vistec.ac.th*

**Abstract**

Near-infrared organic light-emitting diodes (NIR-OLEDs) have attracted significant attention for various applications; however, achieving long-wavelength emission together with high efficiency remains challenging. Recently, NIR OLEDs based on hybridized local and charge-transfer (HLCT) excited states have emerged as an effective strategy to enhance efficiency by combining the strong radiative nature of local excited (LE) states with the charge separation of charge-transfer (CT) states, enabling hot exciton utilization and potentially up to 100% internal quantum efficiency. Here, a novel D–A–D* type NIR emitter (PP-TPI) is designed and synthesized, incorporating thiadiazole[3,4-c]pyridine as the acceptor (A) and phenothiazine (PT) and phenanthroimidazole (PI) as donor units (D). Experimental results and density functional theory (DFT) calculations confirm its HLCT characteristics with mixed LE and CT contributions. The material exhibits strong near-infrared photoluminescence with a peak at 725 nm and balanced charge transport properties. When applied as a non-doped emissive layer in OLED devices, it produces intense NIR electroluminescence with a peak at 750 nm. The optimized device achieves an external quantum efficiency (EQE) of 2.58%, a power efficiency (PE) of 0.48 lm $W^{-1}$, and a maximum radiance of 8919 mW $sr^{-1}$ $m^{-2}$, demonstrating promising performance in a non-doped configuration. Beyond OLED applications, PP-TPI also functions as an active medium in a luminescent solar concentrator (LSC) designed for greenhouse applications, achieving a power conversion efficiency (PCE) of 1.69% with an average visible transmittance (AVT) of approximately 60%. These results highlight the versatility of HLCT-based molecular design and demonstrate the potential of PP-TPI as a multifunctional material for both optoelectronic devices and semi-transparent solar energy harvesting systems.




**Keywords:** Hybridized local and charge-transfer; Near-infrared emitter; Organic light emitting diode; Thiadiazole[3,4-c]pyridine

# Regulating Zn Deposition Using Chelation-Buffer Electrolyte Additives for High-Rate Zn-$Br_2$ Hybrid Flow Batteries

Phonnapha Tangthuam[a], Pongpon Pipattanachaiyanana[a], Wathanyu Kao-ian[b], Suttipong Wannapaiboon[c], Phakkhananan Pakawanit[c], Ying Wang[d], Yuki Nagao[b,e], Manaswee Suttipong[a,*], Soorathep Kheawhom[b,f]

[a] *Department of Chemical Technology, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand*
[b] *Department of Chemical Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok 10330, Thailand*
[c] *Synchrotron Light Research Institute, 111 University Avenue, Muang District, Nakhon Ratchasima 30000, Thailand*
[d] *Department of Macromolecular Science, State Key Laboratory of Molecular Engineering of Polymers, Fudan University, Shanghai 200438, China*
[e] *School of Materials Science, Japan Advanced Institute of Science and Technology, Ishikawa 923-1211, Japan*
[f] *Center of Excellence on Advanced Materials for Energy Storage, Chulalongkorn University, Bangkok 10330, Thailand*

*Corresponding Author's E-mail: *Manaswee.S@chula.ac.th*

**Abstract**

Zinc-bromine (Zn-$Br_2$) hybrid flow batteries are promising for large-scale energy storage due to their use of nonflammable aqueous electrolytes and earth-abundant materials. However, their performance is often limited by irregular Zn deposition, interfacial parasitic reactions, and efficiency losses at high operating rates. In this work, a dual-additive electrolyte strategy is developed to regulate Zn electrodeposition by combining a chelating ligand ($EDTA^{2-}$) with a buffering species derived from ammonium acetate ($NH_4OAc$). The synergistic interaction of these additives modifies $Zn^{2+}$ solvation while stabilizing the local acidity near the electrode surface. Synchrotron-based Zn K-edge X-ray absorption spectroscopy (XAS) reveals changes in the primary Zn-O coordination environment during Zn plating, including variations in coordination number and bond distance. X-ray tomographic microscopy (XTM) further shows the formation of dense and laterally connected Zn networks throughout the three-dimensional carbon felt (CF) electrode. These morphological and structural changes lead to lower iR-corrected overpotentials and high coulombic efficiencies (CE ≥ 95%) during rate testing up to 200 mA $cm^{-2}$. When operated at an areal capacity of 35 mAh $cm^{-2}$, the electrolyte containing both additives maintains improved capacity retention for more than 300 cycles compared with electrolytes containing a single additive or no additive. Overall, the results highlight how cooperative chelation and buffering effects can regulate Zn deposition and interfacial chemistry, offering mechanistic insights for electrolyte engineering in mildly acidic Zn-$Br_2$ hybrid flow battery systems.

**Keywords:** Zinc-bromine, Flow battery, chelating agent, X-ray absorption, Tomographic microscopy

# Mechanism-guided design of UiO-66-$SO_3H$ ASEI for enhanced cycling stability of zinc-metal anodes in aqueous batteries

Vipada Aupama[a,*], Manaswee Suttipong[a], Soorathep Kheawhom[b]

[a]*Department of Chemical Technology, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand.*
[b]*Department of Chemical Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok 10330, Thailand*

*Corresponding Author's E-mail: Vipada.A@chula.ac.th

**Abstract**

Aqueous zinc batteries are critically limited by dendrite formation and parasitic interfacial reactions. Here, we report a mechanism-guided artificial solid-electrolyte interface (ASEI) based on a sulfonated zirconium metal–organic framework (UiO-66-$SO_3H$) that transforms a nominal surface coating into an ion-coordination–active interphase for zinc metal anodes in 2 M $ZnSO_4$. Operando optical microscopy confirms suppressed dendritic protrusions and stabilized plating/stripping fronts. *In situ* Raman spectroscopy reveals that sulfonate oxygen sites can transiently coordinate with $Zn^{2+}$, promoting partial desolvation. Density-functional theory (DFT) calculations indicate stronger Zn adsorption at sulfonate sites compared to pristine UiO-66, consistent with the reduced nucleation overpotential and lowered charge-transfer resistance observed by electrochemical impedance spectroscopy. As a result, symmetric Zn||Zn cells exhibit stable cycling for over 1000 h at 0.5 mA $cm^{-2}$ (0.5 mAh $cm^{-2}$) and over 800 h at 3 mA $cm^{-2}$ (3 mAh $cm^{-2}$), while Zn||Cu cells deliver an average Coulombic efficiency of ~99.6% for more than 500 cycles. Full cells paired with a NaVO cathode maintain stable cycling for over 1000 cycles at 6C with improved rate capability. These results establish sulfonate-directed $Zn^{2+}$ coordination and interfacial desolvation as key design principles for engineering molecularly active MOF-based ASEIs. Such interfaces homogenize ion flux, suppress parasitic reactions, and effectively extend the lifetime of zinc-metal anodes in aqueous Zn batteries.

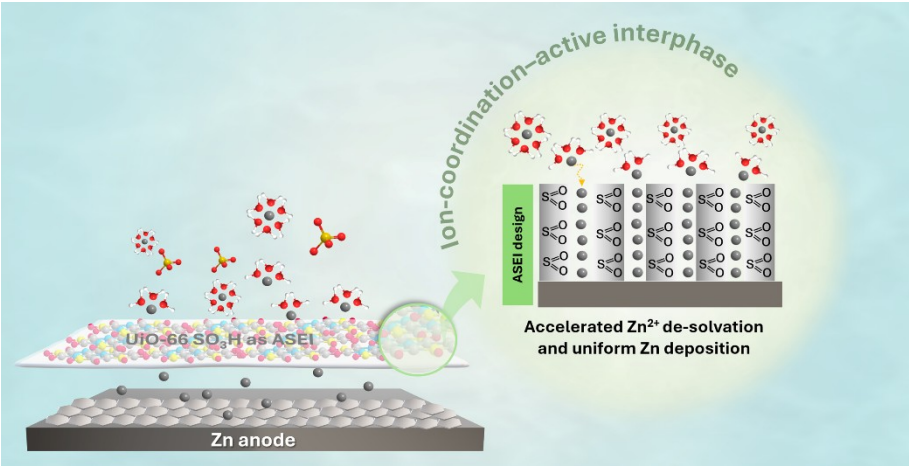



**Fig.1** Design concept of a UiO-66-$SO_3H$ ASEI for coordination-regulated $Zn^{2+}$desolvation and dendrite-free Zn deposition.

**Keywords:** Aqueous zinc batteries; Sulfonated MOF; $Zn^{2+}$ coordination; Desolvation; Dendrite suppression

# In situ surface transformation of $Ni_3S_2$/NF electrodes into $Ni(OH)_2/Ni_3S_2$ heterostructures for enhanced electrochemical energy storage

Markhabayeva A.A. [a,*], Abdullin Kh. A.[a], Zh. K. Kalkozova[a], L.V. Gritsenko[b], Zh. S. Kanatov[a], D. Zhapargali[a]

[a] *National Nanotechnology Laboratory of Open Type of Al-Farabi Kazakh National University, al-Farabi ave., 71, Almaty, 050040, Kazakhstan*
[b] *Satbayev University, Satpayev str., 22, Almaty, 050013, Kazakhstan*

*Corresponding Author's E-mail: ayymkul@kaznu.kz

**Abstract**

Nickel sulfide–based electrodes have attracted significant attention for electrochemical energy storage due to their high electrical conductivity and theoretical capacity. In this work, $Ni_3S_2$ layers were directly synthesized on nickel foam (NF) via a one-step hydrothermal method, resulting in a binder-free and highly conductive electrode architecture. Structural characterization confirmed the formation of phase-pure $Ni_3S_2$ with a porous nanosheet morphology.

Electrochemical investigations in alkaline electrolyte revealed a pronounced evolution of the electrode surface during cycling. Raman spectroscopy demonstrated the rapid disappearance of $Ni_3S_2$ vibrational modes and the emergence of Ni–O related features after initial electrochemical activation, indicating the formation of an oxidized surface layer. Prolonged cycling led to the development of a nanocrystalline $Ni(OH)_2$ phase, forming a $Ni(OH)_2/Ni_3S_2$/NF heterostructure.

The electrode exhibited high areal capacitance of up to 4.1 C $cm^{-2}$ at 20 mA $cm^{-2}$ and demonstrated unusual cycling behavior, including partial capacitance recovery after electrochemical activation. This behavior is attributed to the synergistic effect between the highly conductive $Ni_3S_2$ backbone and the electrochemically active $Ni(OH)_2$ layer formed in situ during cycling.

The results highlight that the electrochemical performance of $Ni_3S_2$-based electrodes is governed not only by the initial sulfide phase but also by dynamic surface transformations under operating conditions. Understanding this in situ mechanism provides new insights into the design of advanced electrode materials for high-performance supercapacitors [1].

**Keywords:** $Ni_3S_2$, $Ni(OH)_2$, in situ transformation, supercapacitor, electrochemical energy storage, nanostructured electrodes.

Literature

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# Effect of Cu substitution on the structure and enhanced electrochemical performance of $Bi_{12}Ni_{1-x}Cu_xO_{19}$ nanostructures for high-performance supercapacitor applications

Jessada Khajonrit[a,*], Wittawat Saenrang[b], Kittiya Salangsing[a], Kittima Salangsing[a], Suchunya Wongprasert[b] , Nantawat Tanapongpisit[b], Santi Maensiri[b]

[a]*Department of Science and Mathematics, Faculty of Science and Health Technology, Kalasin University, Kalasin, 46000, Thailand*
[b]*School of Physics, Institute of Science, Suranaree University of Technology, Nakhon Ratchasima, 30000, Thailand*

*Corresponding Author's E-mail: Ex_phys@hotmail.com

**Abstract**

The development of advanced electrode materials with high electrochemical performance is essential for next-generation energy storage systems. In this study, Cu-doped bismuth nickel oxide, $Bi_{12}Ni_{1-x}Cu_xO_{19}$ (x = 0-0.3), was synthesized via a sol–gel method followed by calcination at 600 °C to obtain nanostructured materials. The structural characteristics of the synthesized materials were analyzed using X-ray diffraction (XRD), confirming the formation of a single-phase structure without detectable impurities. Morphological observations revealed agglomerated nanoparticle structures, facilitating ion transport and charge storage. $N_2$ adsorption analysis indicated a relatively high specific surface area, contributing to improved electrochemical performance. Electrochemical properties were investigated using cyclic voltammetry (CV), galvanostatic charge–discharge (GCD), and electrochemical impedance spectroscopy (EIS) in an alkaline electrolyte. The optimized composition exhibited a high specific capacitance of 792.7 F $g^{-1}$ at a scan rate of 5 mV $s^{-1}$, demonstrating excellent charge storage capability. The enhanced performance is attributed to the synergistic effect of Ni and Cu redox-active sites, which improve electrical conductivity and facilitate fast Faradaic reactions. These findings suggest that $Bi_{12}Ni_{1-x}Cu_xO_{19}$ nanostructures are promising candidates for high-performance supercapacitor electrodes and provide a viable strategy for tuning the electrochemical properties of bismuth-based metal oxides for energy storage applications.

**Keywords:** $Bi_{12}Ni_{1-x}Cu_xO_{19}$ nanostructures, Cu substitution, supercapacitors, specific capacitance, electrochemical performance

# Artificial Solid Electrolyte Interface Derived from Fluorinated Cyclic Phosphate for Enhancing Lithium Metal Anode Performance

Yune Shingaki[a],, Yota Okuno[b,c*], Yukiko Matsui[c], Minako Deguchi[c],

Masashi Ishikawa[b,c], Yasuhiko Iwasaki[b,c]

[a]*Graduate School of Science and Engineering, Kansai University, Suita, Osaka 564-8680, Japan.*
[b]*Dept. of Chemistry and Materials Engineering, Kansai University, Suita, Osaka 564-8680, Japan.*
[c]*Organization for Research and Development of Innovative Science and Technology, Kansai University, Suita, Osaka 564-8680, Japan.*

*Corresponding Author's E-mail: y_okuno@kansai-u.ac.jp

**Abstract**

Lithium metal anodes (LMAs) are considered key materials for enhancing the energy density of lithium-based secondary batteries, owing to their high theoretical capacity (3,860 mAh $g^{-1}$) and low electrochemical potential (−3.04 V vs. SHE). However, the uncontrolled growth of lithium dendrites and the formation of "dead lithium" during charge-discharge processes remain significant challenges. Since the properties of the solid electrolyte interphase (SEI) regulate lithium dissolution and deposition behavior, constructing a robust artificial SEI is crucial to addressing these issues. In this study, 2-fluoro-1,3,2-dioxaphospholane 2-oxide (FOP) was synthesized as an agent for creating an artificial SEI (**Fig.1a**). FOP was prepared via a two-step reaction, and its high purity (> 99 mol%) was confirmed by NMR spectroscopy and titration. The LMA was modified by immersion in an FOP solution, resulting in the formation of a thin surface layer. XPS analysis revealed that this artificial SEI consists of lithium fluoride (LiF) and phosphoester-based organic components. Li||Li symmetric cells employing the modified LMA exhibited stable cycling for over 1,500 hours at 0.5 mA $cm^{-2}$ and 1 mAh $cm^{-2}$, significantly outperforming the unmodified LMA (**Fig.1b**). This enhanced performance is attributed to the hybrid layer, in which the flexible phosphoester groups and LiF play a synergistic role. Furthermore, full-cell evaluations using LFP||Li and S||Li configurations demonstrated extended cycle life and improved stability.

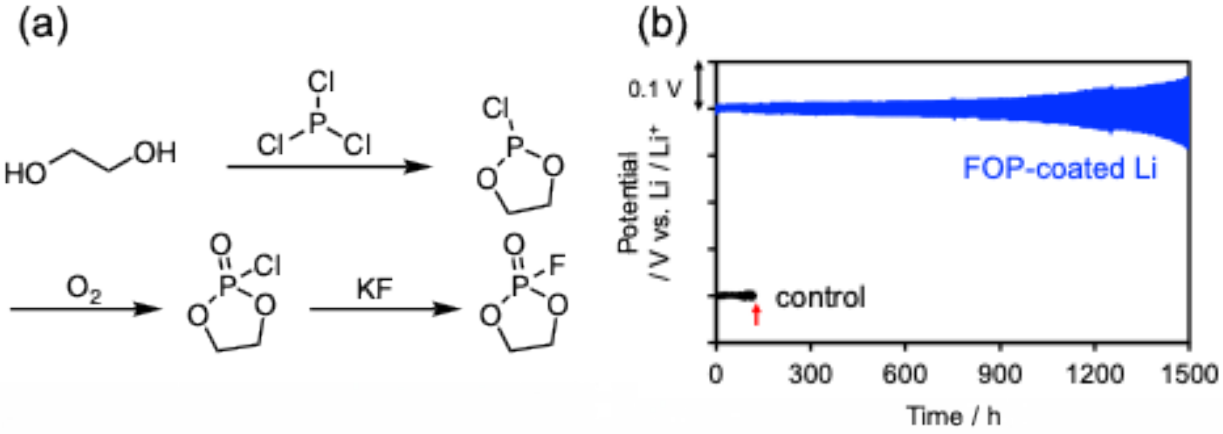



**Fig 1.** (a) Synthetic scheme for 2-fluoro-1,3,2-dioxaphospholane 2-oxide (FOP), and (b) time-course overpotential profiles of Li||Li symmetric cells during galvanostatic stripping/plating (0.5 mA $cm^{-2}$, 1 mAh $cm^{-2}$). The red arrow indicates the short circuit.

**Keywords:** Lithium metal anode, Artificial solid electrolyte interface, Lithium-sulfur battery, Surface modification, Fluorinated phosphoester

# The Role of Current Collector Guiding Sodium Deposition and Cycling Stability of Anode-Free Sodium Metal Batteries

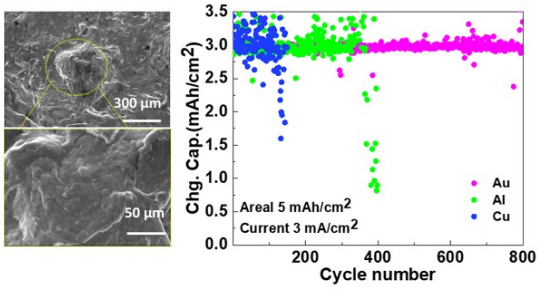
Kanokwan Duchthuyawat[a,1], Parita Jumpaburee[a], Mussatorn Promachan[a], Ratchataphan Thammawat[a], Narisara Inarn[a] ,Phonchita Thahong[a], Jiraphat Prakopphon[a], Orapa Thamwattana[b,*]

[a] *Department of Physics, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand*
[b] *The Institute of Nanomaterials Research and Innovation for Energy (IN-RIE), Materials Science and Nanotechnology Program, Department of Physics, Faculty of Science, Khon Kaen University, Muang Khon Kaen 40002, Thailand*

*Corresponding Author's E-mail: Orapata@kku.ac.th

**Abstract**

Anode-free sodium metal batteries (AFSMBs) are promising next-generation energy-storage systems because they provide high energy density while eliminating excess sodium metal. However, unstable sodium nucleation and dendritic growth on the current collector surface remain critical challenges that cause rapid capacity decay and poor cycling stability. This study systematically compares three metallic current collectors, Au, Cu, and Al, to clarify how their interfacial affinity toward sodium influences sodium deposition behavior and electrochemical performance in AFSMBs. The interaction between sodium and each current collector was evaluated through nucleation overpotential, contact-angle measurement, and post-deposition morphology. Electrochemical performance was investigated by galvanostatic cycling, coulombic efficiency measurement, and electrochemical impedance spectroscopy. Surface and cross-sectional analyses were further performed after cycling to examine sodium deposition and dendrite formation. Among the investigated current collectors, Au exhibited the strongest sodiophilic behavior, resulting in the lowest nucleation overpotential and the most uniform sodium deposition. In contrast, Cu and Al showed weaker interfacial affinity, leading to localized sodium growth and severe dendritic morphology. Cells using Au demonstrated superior cycling stability and lower impedance increase after prolonged cycling, whereas Cu- and Al-based cells suffered from rapid interfacial resistance growth and accelerated degradation. The results demonstrate that current collector chemistry strongly governs sodium nucleation and dendrite evolution in AFSMBs. The Au current collector effectively stabilizes the sodium/electrolyte interface and suppresses dendrite formation, providing a practical strategy for designing stable and high-energy anode-free sodium metal batteries.




**Keywords:** Anode-free sodium metal battery; Current collector; Sodium dendrite; Sodiophilicity; Interfacial engineering

# Defect-Engineered Mo-Doped $NiCo_2O_4$ Nanowires with Abundant Oxygen Vacancies for High-Rate Vanadium Redox Flow Batteries

Zih-Jhong Huang, Chen-Hao Wang*

*Department of Materials Science and Engineering, National Taiwan University of Science and Technology*

*Corresponding author's e-mail: chwang@mail.ntust.edu.tw

**Abstract**

Vanadium redox flow batteries (VRFBs) hold immense potential for grid-scale energy storage, yet their high-rate performance is often limited by severe polarization and sluggish electrode kinetics. To address these challenges, this study introduces a robust defect-engineering approach by decorating graphite felt (GF) electrodes with molybdenum-doped nickel-cobalt oxide (NCO-Mo) nanowires. Prepared via a facile hydrothermal process, the NCO-Mo nanowires form a uniform coating on the GF fibers, significantly expanding the electrochemically active surface area. Detailed characterizations, including X-ray photoelectron spectroscopy (XPS) and electron paramagnetic resonance (EPR), confirm that Mo incorporation induces abundant oxygen vacancies and optimizes the electronic structure, notably altering the $Co^{3+}/Co^{2+}$ ratio. These oxygen-vacancy-driven defects act as highly active catalytic sites, effectively reducing the activation barrier for the $VO^{2+}/VO_2^+$ redox couple.

Electrochemical analyses reveal that the optimal NCO-Mo3 electrode delivers exceptional catalytic performance, as evidenced by enhanced redox reversibility, diminished charge-transfer resistance, and a narrower peak-to-peak voltage separation. During cell testing, the NCO-Mo3-modified electrode yielded an impressive energy efficiency (EE) of 86.96% at 80 mA $cm^{-2}$. More importantly, it maintained stable operation at an ultra-high current density of 260 mA $cm^{-2}$—a level at which conventional electrodes typically fail—achieving a functional EE of 63.46%. The electrode also exhibited remarkable long-term cycling stability, enduring 250 charge-discharge cycles with virtually no performance degradation. Ultimately, this work demonstrates that regulating oxygen vacancies through Mo doping is a highly scalable and effective strategy for advancing high-power, long-lifespan VRFB systems.

**Keywords:** Grid-scale energy storage; All-vanadium redox flow batteries (VRFBs); Defect chemistry; Oxygen-deficient sites; Heteroatom doping (Mo); Modified carbon electrodes.

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# Optimizing Carbon-Free $LiFePO_4$ Cathodes via Temperature-Controlled Hydrothermal Synthesis

Taegu Han[a], Yangdo Kim[a], Chang Sik Son[b] ,Donghyun Hwang[b,*]

[a] *School of Materials Science and Engineering, Pusan National University, Busan 46241, Republic of Korea*
[b] *Department of Materials Science and Engineering, Silla University, Busan 46958, Republic of Korea*

*Corresponding Author's E-mail: dhhwang@silla.ac.kr

**Abstract**

Lithium iron phosphate ($LiFePO_4$, LFP) is a widely studied cathode material for lithium-ion batteries because of its excellent safety, structural stability, and low cost. However, the poor intrinsic electronic conductivity of pristine LFP generally requires carbon coating or post-treatment to achieve acceptable electrochemical performance. Herein, carbon-coating-free LFP powders were synthesized through a one-pot hydrothermal route, and the effect of hydrothermal temperature on the structure–property relationship was systematically examined. LFP samples were prepared at 190, 200, 210, and 220 °C under otherwise identical synthesis conditions to isolate the role of temperature in crystallization and particle growth. All samples exhibited a phase-pure olivine structure without detectable secondary phases. The sample synthesized at 200 °C showed the most favorable crystallographic characteristics, including the narrowest (121) diffraction peak, the largest apparent crystallite size, and the lowest microstrain. SEM and TEM observations revealed that this condition produced well-dispersed sub-micron particles with improved faceting, whereas the 190 °C sample showed insufficient crystallization and the 210–220 °C samples exhibited particle coarsening and aggregation. XPS analysis confirmed an $Fe^{2+}$-dominant surface chemistry and a surface composition closest to the ideal LFP stoichiometry for the 200 °C sample. Consequently, the 200 °C electrode delivered the highest initial discharge capacity of 130.4 mAh $g^{-1}$ at 0.1 C, approximately 99% capacity retention over 30 cycles, about 90 mAh $g^{-1}$ at 1.0 C, and the lowest charge-transfer resistance. These results indicate that hydrothermal temperature is a decisive parameter for optimizing carbon-coating-free LFP and that 200 °C provides the best balance between crystallographic development and controlled particle growth.

**Keywords:** Lithium iron phosphate; Hydrothermal synthesis; Carbon-free cathode; Temperature control; Structure-property relationship

# Improving the Low-Temperature and Fast-Charging Properties of MoOx@$TiO_2$-Based Li-Ion Battery Anodes

Hsien-Chun Tseng[1], Horng-Hwa Lu [1], Sheng-Chang Wang[2], Ching-Huan Lee[1] ,
Yu-Min Shen[3*]

*1 Department of Mechanical Engineering, National Chin-Yi University of Technology,Taichung, Taiwan*
*2 Department of Mechanical Engineering,Southern Taiwan University of Science and Technology,Tainan,Taiwan*
*3 Department of Materials Science and Engineering, National Dong Hwa University, Hualien,Taiwan*
*Presenter:Hsien-Chun Tseng*

[*]Corresponding author: Yu-Min Shen Corresponding author e-mail: ymshen@gms.ndhu.edu.tw

**Abstract**

Titanium dioxide ($TiO_2$) is considered a promising anode material for lithium-ion batteries due to its excellent chemical stability, safety, and environmental friendliness. However, its intrinsically low electronic conductivity and sluggish lithium-ion diffusion kinetics lead to significant capacity degradation under low-temperature conditions. To overcome these limitations, this study introduces the transition metal molybdenum (Mo) in oxide or suboxide form (MoOx), deposited or doped into the $TiO_2$ lattice and surface. The incorporation of MoOx is expected to generate oxygen vacancies and locally reduced $Ti^{3+}$ species, thereby improving electronic conductivity and $Li^+$ diffusion capability.

In this work, $TiO_2$ precursors were synthesized via a hydrothermal process, followed by the addition of a molybdenum source ($(NH_4)_6Mo_7O_{24}$). The resulting powders were dried and then subjected to short-term (3 h) heat treatment at 700°C and 750°C under a reducing atmosphere ($H_2$/Ar) to control the reduction degree and oxygen vacancy concentration. The structural and electronic states were characterized mainly by X-ray photoelectron spectroscopy (XPS) to quantify the $Ti^{4+}/Ti^{3+}$ ratio, oxygen vacancy level, and Mo oxidation states ($Mo^{6+}/Mo^{5+}/Mo^{4+}$), while TEM/SAED analyses were performed to observe crystal structure and possible secondary phases. Electrochemical performance was evaluated at low (0°C), ambient (25°C), temperatures through galvanostatic charge–discharge cycling (rate 0.2, 0.5, 1, 2, 5, and 10 C, 5 cycles each), long-term cycling tests (0.2 C, 1 C, 5 C, ≥500 cycles), and electrochemical impedance spectroscopy (EIS) and cyclic voltammetry (CV) analyses. The results showed that MoOx@$TiO_2$ annealed at 750°C exhibited a first-cycle discharge capacity of 910 mAh $g^{-1}$, maintaining 880 mAh $g^{-1}$ after five cycles with only 3.3% capacity decay, along with stable charge–discharge voltage plateaus.

Overall, moderate reduction under $H_2$/Ar atmosphere effectively enhanced the low-temperature discharge capacity, reduced charge-transfer resistance (EIS), and improved the reversibility observed in CV and rate-performance tests. These findings establish a clear correlation between the structural defects and electrochemical behavior of MoOx@$TiO_2$, providing a valuable guideline for designing high-stability anode materials capable of operating over a wide temperature range.

**Keywords:** Titanium dioxide, MoOx@$TiO_2$, Low-Temperature

# Hydrothermal Synthesis and Electrochemical Performance of Se Incorporated Zinc Cobalt Oxide for Energy Storage Applications

Jae Su Yu*, Obula Reddy Ankinapalli, Ramakrishna Reddy Ayyaluri

*Department of Electronics and Information Convergence Engineering, Institute for Wearable Convergence Electronics, Kyung Hee University, Yongin-si, Gyeonggi-do 17104, Republic of Korea*

*Corresponding Author's E-mail: jsyu@khu.ac.kr

**Abstract**

Supercapacitors require electrode materials that are inexpensive and abundantly available, exhibiting outstanding electrochemical performance with well-defined morphological structures. In this presentation, we synthesized the zinc cobalt oxide (ZCO) electrode materials using a simple hydrothermal approach. Doping of selenium (Se) source in the same experiment at the same temperature to obtain the Se incorporated ZCO material. Various characterization techniques were employed to confirm the formation of nanoparticles. Among the materials, the Se-doped ZCO electrode material demonstrated superior electrochemical performance for supercapacitors, resulting in high specific capacitance/specific capacity values in KOH electrolyte. The addition of Se enhances the electrical conductivity and structural stability of the electrode material, which is beneficial for effective battery-type electrodes of supercapacitors. Due to the synergistic impact of Se, zinc, and cobalt ions, Se doping improves the conductivity of the material's active sites, facilitating faster charge transfer. Moreover, the increased number of active sites promotes improved cycling stability with superior rate capability and capacity retention. The assemble supercapacitor device was fabricated by using a Se-doped ZCO material as the positive electrode and activated carbon as the negative electrode. The fabricated device demonstrated significantly enhanced energy and power densities along with excellent device cycling stability and high Coulombic efficiency. These exceptional results suggest Se-doped ZCO material as a promising material, offering a robust doping strategy for future energy conversion and storage technologies.

**Keywords:** Se doping, Electrochemical performance, Specific capacity, Cycling stability, Supercapacitors

# Butterfly Pea Flower (*Clitoria ternatea L.*)-Assisted Synthesis of $MnO_2$ Nanoparticles via Comparative Hydrothermal and Green Route for Enhanced Oxygen Reduction Reaction in Zinc-Air Batteries

Wanrudee Kaewmesri[1], Sankum Nusen[2], Chaiyasit Banjongprase[rt3,4],

Manat Jaimasith[1,*]

[1]*Division of Chemistry, School of Science, University of Phayao,*
*19 Moo.2, Mae-ka, Muang, Phayao, 56000, Thailand*
[2]*Department of Industrial Chemistry, Faculty of Science, Chiang Mai University,*
*239 Huay Keaw Road, Suthep, Muang, Chiang Mai, 50200, Thailand.*
[3]*Department of Physics and Materials Science, Chiang Mai University,*
*239 Huay Keaw Road, Suthep, Muang, Chiang Mai, 50200, Thailand.*
[4]*Materials Science Research Center, Faculty of Science, Chiang Mai University,*
*239 Huay Keaw Road, Suthep, Muang, Chiang Mai, 50200, Thailand.*

*Corresponding Author's E-mail: manat.ja@up.ac.th

**Abstract**

Zinc-air batteries (ZABs) have considerable attention as promising energy storage devices due to their high theoretical energy density and environmental friendliness. However, the oxygen reduction reaction (ORR) at the air cathode is a critical challenge limiting their performance. In this study, manganese dioxide ($MnO_2$) nanoparticles were synthesized using butterfly pea flower (*Clitoria ternatea L.*) extract as a natural reducing agent via two approaches: hydrothermal synthesis and green synthesis, and their electrocatalytic performances were comparatively evaluated for zinc-air battery applications. For the hydrothermal synthesis, the reaction was conducted over 4 hours at temperatures (120 °C and 180 °C). The electrochemical performance of synthesized $MnO_2$ nanoparticles was evaluated as an air cathode electrocatalyst in a demonstrative solid-state zinc-air battery. The results showed that the $MnO_2$ nanoparticles synthesized at 180 °C improved charge-discharge cycling stability of 13 cycles, compared to the hydrothermally synthesized at 120 °C. The cycling performance was approximately improved 85%. While the synthesized $MnO_2$ using the butterfly pea flower extract via a green chemistry approach (0.10 M potassium permanganate stirred in the natural extract 5 mL at 120 rpm under the ambient), effectively controlling the size and morphology of the electrocatalyst were achieved due to ternatin anthocyanin functioned as both reducing agent and a surface capping agent. Consequently, the synthesized $MnO_2$ exhibited significantly superior long-term operational stability compared to the commercial platinum carbon (Pt/C) catalyst. This resulting green-synthesized $MnO_2$ maintained a coulombic efficiency of 100% throughout the first 20 cycles and retained a coulombic efficiency of more than 75% up to the 50th cycle. This results confirmed the successful formation of ∝-$MnO_2$/ carbon-based nano-electrocatalyst. Utilizing the green approach not only enhanced the performance and characteristics of the synthesized $MnO_2$ nanoparticles but also demonstrated an optimized pathway for sustainable clean energy storage applications in solid-state zinc-air battery systems.

**Keywords:** butterfly pea flower, green synthesis, hydrothermal, $MnO_2$ electrocatalyst, zinc-air battery

# Surface Functionalization of Carbon Nanotubes with 2-aminothiazoline-derived molecules for High-Performance Pt Electrocatalysts toward Methanol Oxidation

Siripon Wattanasing[a,b], Surin Saipanya[a,b], Wong Phakhodee[a], Suwaphid Themsirimongkon[a,b,d], Jaroon Jakmunee[a,] and Paralee Waenkaew[a, b*]

[a]*Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200 Thailand*
[b]*Laboratory of Vantage Electromaterials (LOVEs), Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200 Thailand*
[c]*Materials Science Research Center, Chiang Mai University, Chiang Mai 50200 Thailand*
[d]*Office of Research Administration, Chiang Mai University, Chiang Mai, 50200, Thailand*

*Corresponding Author's E-mail: paralee.w@cmu.ac.th

**Abstract**

Carbon nanotubes (CNTs) were successfully modified with 2-aminothiazoline-derived (O-121) molecules and subsequently used as supports for platinum nanoparticle electrodeposition to develop an efficient electrocatalyst for methanol oxidation. Transmission electron microscopy (TEM) analysis revealed a high dispersion of electrodeposited Pt nanoparticles on the O-121-modified CNT surface. Energy-dispersive X-ray spectroscopy (EDX) confirmed the presence of Pt, S, N, C, and O elements on the catalyst surface, verifying the successful functionalization and Pt deposition, while Fourier transform infrared spectroscopy (FTIR) confirmed the presence of functional groups associated with the modified 2Pt/CNT-1%O-121 structure. Furthermore, the electrochemical performance of the prepared catalysts was evaluated by cyclic voltammetry (CV) and chronoamperometry (CA) in a solution containing 0.5 M $CH_3OH$ and 0.5 M KOH. The 2Pt/CNT-1%O-121 catalyst exhibited a significantly higher current density of approximately 12.10 mA/cm², representing the best performance among the catalysts with varying O-121 contents and indicating enhanced electrocatalytic activity toward methanol oxidation, compared with the 2Pt/CNT catalyst, which showed a current intensity of approximately 3.42 mA/cm². In addition, the catalyst demonstrated superior long-term stability during 3600 s CA measurements. The improved catalytic performance is attributed to the presence of O-121 molecules, likely related to steric effects from the ortho-hydroxyl substituent, which promote better Pt nanoparticle distribution and stronger catalyst–support interactions. Therefore, the 2Pt/CNT-1%O-121 catalyst shows strong potential as a promising anodic electrocatalyst for direct methanol fuel cell applications.

**Keywords:** Carbon nanotubes (CNTs); Platinum nanoparticles; Methanol oxidation reaction (MOR); Electrocatalyst; 2-Aminothiazoline-derived

# Platinum Nanoparticles on Cu–Ni/Polypyrrole Functionalized CNTs for Enhanced Methanol Oxidation Reaction

Parisa Klanarong[a,b], Paralee Waenkaew[a,b,c], Suwaphid Themsirimongkon[a,b,d],

*Napapha Promsawan[a,b,c], Jaroon Jakmunee[a,c], Surin Saipanya[a,b*]*

[a] *Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200 Thailand*

[b] *Laboratory of Vantage Electromaterials (LOVEs), Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200 Thailand*

[c] *Materials Science Research Center, Chiang Mai University, Chiang Mai 50200 Thailand*

[d] *Office of Research Administration, Chiang Mai University, Chiang Mai, 50200 Thailand*

**Corresponding Author's E-mail address: surin_saipanya@hotmail.co.uk*

**Abstract**

A novel trimetallic electrocatalyst based on platinum electrodeposited onto carbon nanotube-supported Cu–Ni/polypyrrole composites (CNT/Cu-Ni-PPy/Pt) was successfully prepared for methanol oxidation applications. In this study, carbon nanotubes (CNTs) were modified with polypyrrole (PPy) and decorated with copper and nickel species to serve as a conductive and active support for Pt electrodeposition. The electrocatalytic performance of the prepared catalyst was evaluated by cyclic voltammetry (CV), linear sweep voltammetry (LSV), and chronoamperometry (CA) in a solution containing 0.5 M $CH_3OH$ and 0.5 M KOH. The CNT/Cu-Ni-PPy/Pt catalyst exhibited significantly higher current intensity and improved long-term stability compared with the conventional CNT/Pt catalyst, indicating superior catalytic activity toward methanol oxidation. Transmission electron microscopy (TEM) revealed a high dispersion of Pt nanoparticles on the CNT/Cu-Ni-PPy support surface. Energy-dispersive X-ray spectroscopy (EDX) confirmed the presence of Pt, Cu, Ni, C, and O elements, verifying the successful fabrication of the trimetallic catalyst system. The enhanced electrocatalytic performance is attributed to the synergistic effects of Cu and Ni species, the conductive PPy matrix, and the uniform dispersion of Pt nanoparticles on the CNT support. Therefore, the CNT/Cu-Ni-PPy/Pt catalyst is a promising anodic electrocatalyst for direct methanol fuel cell applications.

**Keywords:** Carbon nanotubes (CNTs), Polypyrrole (PPy), Trimetallic catalyst, Methanol oxidation reaction (MOR), Direct methanol fuel cell (DMFC)

# Pt Nanoparticles Supported on aza-BODIPY-Modified Graphene Oxide for High-Performance Methanol Oxidation

Natnicha Ingongngam[a,b], Surin Saipanya[a,b,c], Kullapa Chanawanno[a], Paralee Waenkaew[a,b,c], Jaroon Jakmunee[a,c], Suwaphid Themsirimongkon[a,b,d*]

[a]*Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200 Thailand*
[b]*Laboratory of Vantage Electromaterials (LOVEs), Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200 Thailand*
[c]*Materials Science Research Center, Chiang Mai University, Chiang Mai 50200 Thailand*
[d]*Office of Research Administration, Chiang Mai University, Chiang Mai, 50200 Thailand*

*Corresponding Author's E-mail: suwaphid.ochin@gmail.com

**Abstract**

Platinum nanoparticles were successfully electrodeposited onto aza-BODIPY-modified graphene oxide carbon composites to produce Pt/aza-BODIPY/GO electrocatalysts for methanol oxidation applications. The aza-BODIPY functionalized support provided abundant binding sites for Pt nanoparticle deposition, promoting uniform dispersion and enhanced accessibility of catalytically active sites. Transmission electron microscopy (TEM) revealed well-dispersed Pt nanoparticles on the aza-BODIPY/GO surface, while energy-dispersive X-ray spectroscopy (EDX) confirmed the presence of Pt, B, N, O, F, and C elements, verifying the successful preparation of the composite catalyst. Electrochemical performance was evaluated by cyclic voltammetry (CV) and chronoamperometry (CA) in 0.5 M $CH_3OH$ and 0.5 M KOH solution. The Pt/aza-BODIPY/GO catalyst exhibited high current density, low methanol oxidation onset potential, and excellent long-term stability, demonstrating superior electrocatalytic activity compared with conventional Pt-based catalysts. The enhanced performance is attributed to the strong interaction between Pt nanoparticles and the aza-BODIPY-modified carbon support, which improves electrical conductivity, increases electrochemically active surface area, and stabilizes Pt nanoparticles during operation. These results indicate that aza-BODIPY-modified carbon composites are highly promising catalyst supports for direct methanol fuel cells and other alcohol electrooxidation energy systems.

**Keywords:** Platinum nanoparticles, aza-BODIPY, Graphene oxide (GO), Methanol oxidation reaction (MOR), Direct methanol fuel cell (DMFC)

# Bifunctional ORR/OER Electrocatalysts Based on Ni, Co MOF-Derived N-Doped Porous Carbon Nanoparticles

Kamonpan Manowilaikun[a,b], Nagahiro Saito [a,b,c], Rojana Pornprasertsuk[a,b,c*], Prasit Pattananuwat[a,b,c,d*]

[a]*International Collaborative Program in Sustainable Materials and Technology for Industries between Nagoya University and Chulalongkorn University, Faculty of Science, Chulalongkorn University, Bangkok, Thailand*
[b]*International Collaborative Program in Sustainable Materials and Technology for Industries between Nagoya University and Chulalongkorn University, Graduate School of Engineering, Nagoya University, Nagoya, Japan*
[c]*Department of Chemical System Engineering, Nagoya University, Japan*
[d]*Department of Materials Science and Bioengineering, Nagaoka University of Technology, Japan*

*Corresponding Author: rojana.p@chula.ac.th, prasit.pat@chula.ac.th

**Abstract**

In this study, we report porous bimetallic Ni, Co-Embedded MOF-Derived N-Doped Bimetallic Porous Carbon nanoparticles (Co/Ni@N-C NPs) as highly efficient bifunctional electrocatalysts for oxygen reduction and evolution reactions (ORR/OER). This catalyst is derived from a two-dimensional (2D) metalloporphyrin-based metal–organic framework (PMOF) precursor composed of 5,10,15,20-tetrakis(4-carboxyphenyl) porphyrin nickel linkers coordinated with $Co^{2+}/Co^{3+}$ metal nodes, followed by controlled pyrolytic treatment. The carbon scaffold effectively confines and uniformly disperses the Co and Ni species, with no observable aggregation. XPS confirms the coexistence of Ni–$N_4$ single-atom configurations and Ni/Co nanoparticles. This integration induces a synergistic electronic coupling that promotes electron transfer between Co, Ni, and N-C. Electrochemical measurements reveal that the Co/Ni-doped carbon nanocomposites possess outstanding bifunctional electrocatalytic performance toward both ORR and OER in alkaline media. Co/Ni@C NPs can deliver a half-wave potential ($E_{1/2}$) of 0.8633 V for ORR and requires an overpotential of only 603 mV to achieve a current density of 10 mA $cm^{-2}$ for OER, significantly outperforming their monometallic carbon counterparts. Overall, the rational design of this 2D MOF-derived bimetallic system offers a robust strategy for engineering high-density active sites for advanced Zn–air battery applications.

**Keywords:** metal–organic framework (MOF), carbon nanocomposites, oxygen reduction reaction (ORR), oxygen evolution reaction (OER)

# Harnessing Positional Isomerism and In Situ Synthesis to Optimize Lithium Azobenzenedicarboxylate for High-Performance Lithium-Storage

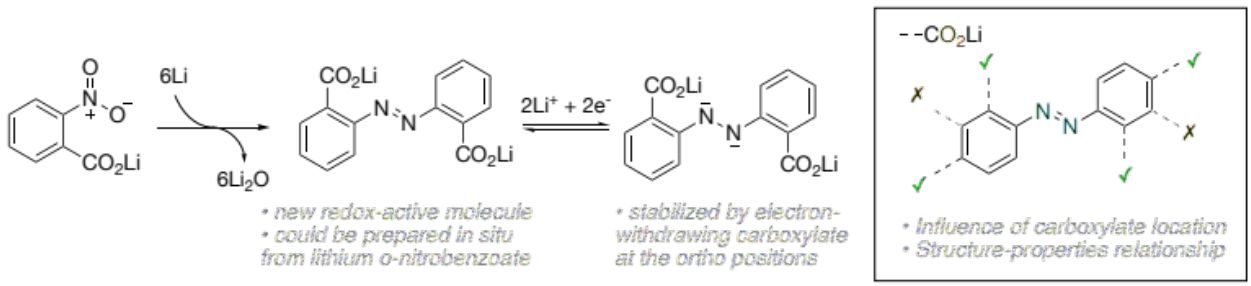
Natthawat Semakul[a,*], Sirakorn Wiratchan[a], Wittawat Punyaarthansakun[a], Anon Tabthong[a], Wipada Lomkaew[a], Pubet Yodaoi[a], Thapanee Sarakonsri[a], Apinpus Rujiwatra[a], Dieter Baurecht[b]

[a] *Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand*
[b] *Institute of Physical Chemistry, University of Vienna, Währingerstraße 42, 1090 Wien, Austria*

*Corresponding Author's E-mail: natthawat.semakul@cmu.ac.th

**Abstract**

Azobenzene dicarboxylates (ABDC) have emerged as promising organic electrode materials for alkali-ion batteries due to the rapid, reversible redox kinetics of the azo functional group. While the para-isomer of $Li_2$ 4,4´-ABDC has been extensively studied, the broader impact of molecular architecture on electrochemical behavior remains largely unexplored. This study systematically investigates the role of positional isomerism by comparing ortho- (2,2´-), meta- (3,3´-), and para- (4,4´-) substitution patterns to establish structure-performance relationships. We identify lithium azobenzene-2,2´-dicarboxylate as a promising contender, delivering a high specific capacity of 210 mAh $g^{-1}$, superior rate capability, and cycling stability comparable to the conventional para-isomer. Additionally, we introduce an efficient synthetic strategy that utilizes lithium 2-nitrobenzoate (Li 2-NB) to generate the $Li_2$ 2,2´-ABDC in situ during the electrode charge/discharge process. Successful chemical transformation is verified through post-mortem Raman and X-ray photoelectron spectroscopy of the electrode. By bridging fundamental structural insights with streamlined manufacturing, this work provides a robust framework for the rational design of high-efficiency organic energy storage systems.




**Keywords:** Organic electrode materials, Lithium azobenzene dicarboxylate, Positional isomerism, Lithium-ion batteries, In situ synthesis

# Layered Vanadium Phosphates with Large Plate-like Morphology: Novel Substrate-Free Colored Pearlescent Pigments

Qiuyu Cheng[a], Ayahisa Okawa[a], Takuya Hasegawa[a], Shu Yin[a,b,*]

[a]*Institute of Multidisciplinary Research for Advanced Material (IMRAM), Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai, 980-8577, Japan*
[b]*Advanced Institute for Materials Research (WPI-AIMR), Tohoku University, Katahira 2-1-1, Aoba-ku, Sendai, 980-8577, Japan*

*Corresponding Author's E-mail: yin.shu.b5@tohoku.ac.jp

**Abstract**

To reproduce the optical effect of natural pearlescence, pearlescent pigments are typically composed of plate-like particles (platelets) that generate interference-induced iridescence. These pigments are generally classified into two categories: substrate-based and substrate-free. Conventional substrate-based pearlescent pigments usually consist of mica platelets coated with metal oxides, most commonly $TiO_2$. Although such materials have been widely commercialized, their preparation often involves complex multistep processes, high production costs, and specialized equipment, and impurity phases may also be introduced during fabrication. In contrast, substrate-free pearlescent pigments are composed of single-component platelets without any supporting substrate, offering advantages such as lower cost, simpler preparation, and potentially higher compositional uniformity. In this study, novel colored substrate-free pearlescent pigments based on layered vanadium phosphates, $VOPO_4 \cdot 2H_2O$ (VOP) and $H_{0.6}(VO)_3(PO_4)_3(H_2O)_3 \cdot 4H_2O$ (HVP), were synthesized by solution processing (SP) and hydrothermal treatment (HT). Four samples were successfully obtained: SP-VOP, HT-O-VOP (produced by oxidation of HT-HVP), SP-HVP (produced by reduction of SP-VOP), and HT-HVP. As shown in **Fig. 1**a, VOP exhibits a yellow-green color, while HVP shows a deeper green appearance, demonstrating the tunability of color within this vanadium phosphate system. Notably, as shown in the inset of **Fig. 1**a, the HT-HVP dispersion displays a distinct pearlescent luster that dynamically changes along the flow of the solution, indicating strong light reflection and interference effects. Furthermore, the optical microscope image of HT-HVP ( **Fig. 1**b) reveals a well-developed, large plate-like morphology with an average particle diameter of approximately 147 μm, which is expected to be favorable for the development of pronounced pearlescent optical properties.

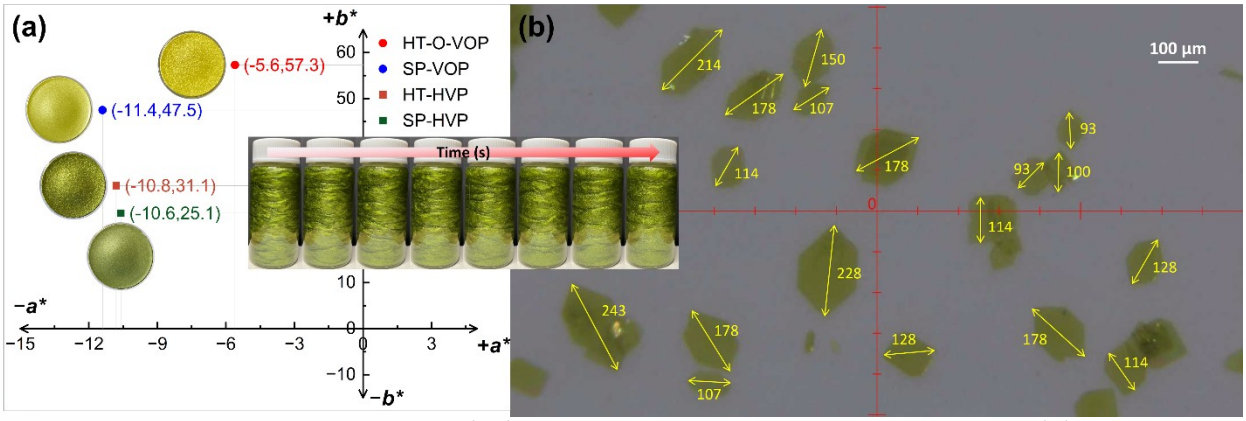



**Fig. 1** (a) Photographs and corresponding ($a^*$, $b^*$) color-coordinate data of VOP and HVP in the $a^*b^*$ color space (inset: a series of photographs of the HT-HVP solutions taken at 1 s intervals); (b) Optical microscope image of HT-HVP.

**Keywords:** Pearlescent pigment; Substrate-free; Layered structure; Plate-like morphology; Hydrothermal synthesis

# Solvothermal Synthesis of Inorganic Nanomaterials with Excellent Infrared Light Response Performance

Shu Yin[a,b,*] ,Yibei Xue[a], Lei Miao[a], Qiuyu Cheng[a], Ayahisa Okawa[a], Takuya Hasegawa[a]

[a]*Institute of Multidisciplinary Research for Advanced Material (IMRAM), Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai, 980-8577, Japan*

[b]*Advanced Institute for Materials Research (WPI-AIMR), Tohoku University, Katahira 2-1-1, Aoba-ku, Sendai, 980-8577, Japan*

*Corresponding Author's E-mail: yin.shu.b5@tohoku.ac.jp

## Abstract

It is accepted that the physical properties of inorganic materials strongly depend on their chemical composition, particle size, specific surface area, morphology, crystal planes, etc. Solvothermal synthesis is a suitable process to control the number of crystal nuclei and their growth rate by controlling the solvent's dielectric constant, resulting in precisely controlled particle size and morphology. In this research, some environmentally friendly synthesis processes, including solvothermal, microwave-assisted solvothermal, and water molecular controlled release solvothermal process (WCRSP), are utilized to synthesize infrared light responsive inorganic functional particle materials. Some novel applications, such as infrared responsive photocatalyst systems, infrared light shielding, infrared hyperthermia, and multifunctional photocatalyst system, will be introduced in detail. By combining weak visible light induced high-sensitivity photocatalysts with up-conversion phosphors, we successfully realized the full-spectra photocatalysis functions. We successfully produce a series of bronze structure of $M_xWO_3$ (M=Cs, K, Na, Rb) materials with homogeneous nanoparticle size. The $M_xWO_3$ possessed a mixed valence state and showed excellent visible light transparency and infrared shielding ability. The uniform $M_xWO_3$ nanoparticles could be easily incorporated into cancer cells also and showed potential application as hyperthermia materials because they can achieve a remarkable temperature rise (infrared-temperature conversion) effect by external ray irradiation. It was also found that ion-doped $VO_2$ nanoparticles synthesized by the solvothermal process possessed excellent thermochromic properties, indicating their potential application as a smart window material. Furthermore, combining IR shielding materials with a photocatalytic ZnO in a thin film makes it possible to realize a multifunctional photocatalyst system consisting of infrared shielding and photocatalytic functionalities (**Fig.1**).

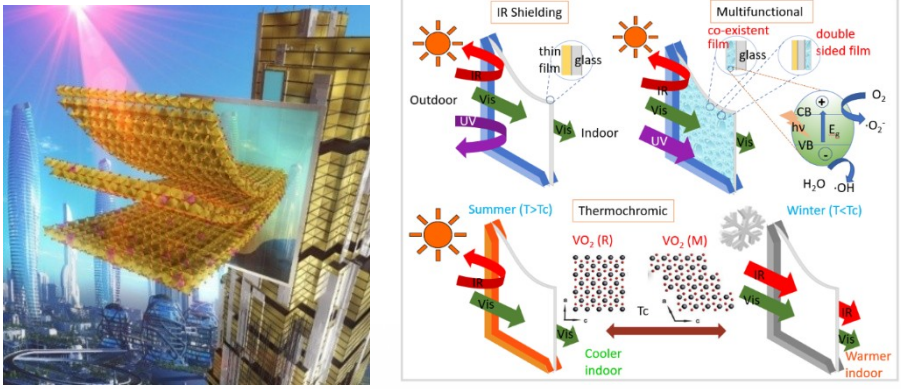



**Fig. 1** Application image(left) and mechanism(right) of multifunctional smart windows

**Keywords:** Solvothermal synthesis, Multifunctionality, Infrared light shielding, Photocatalysis.

# Mechanical and Physical Aspects of $ZrO^2$ in Lithium Disilicate Glass Ceramics for Dental Applications

Chonlathit Pitipoomsuksan[1],Jetsada Ruangsuriya[2], Anuthida Uranjit[3],

Arnon Kraipok[4], Wilaiwan Leenakul[3,5],*

[1]*Department of Industrial Engineering, Faculty of Industrial Education, Rajamangala University of Technology Phra Nakhon, Bangkok 10300*
[2]*Department of Biochemistry, Faculty of Medicine, Chiang Mai University, Chiang Mai 50200, Thailand*
[3]*Division of Industrial Materials Science, Faculty of Science and Technology, Rajamangala University of Technology Phra Nakhon, Bangkok 10800, Thailand*
[4]*Budget Bureau, The Prime Minister's Office, Bangkok, 10400, Thailand*
[5]*Hub of Advanced Ceramics, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
*2Division of Industrial Materials Science, Faculty of Science and Technology, Rajamangala University of Technology Phra Nakhon, Bangkok, 10800, Thailand*

*Corresponding Author's E-mail: wilaiwan.l@rmutp.ac.th

**Abstract**

Lithium disilicate (LD) glass ceramic, one of the most popular dental material, has recently been attractive to many scientists for improvement of its properties for extended applications. Thermal treatment was employed to produce LD glass ceramics with enhanced properties by altering their compositions. The objective of this study was to examine the impact of $ZrO_2$ additive oxides on the mechanical properties and phase formation of the LD glass ceramics prepared by the conventional technique. It was found that the presence of $ZrO_2$ at 0.5 – 1 wt% in LD caused a little elevation in crystallization temperature. The cultivation of crystals at 650°C resulted in the glass demonstrating higher mechanical properties due to the increased formation of lithium disilicate and lithium metasilicate crystals. In vitro culture of MG63 cells with LDZ0.5 confirmed its biocompatibility without promotion of bone formation.

**Keywords:** Lithium disilicate, Mechanical properties, Zirconium dioxide

# Thermoluminescence Response of Eu, Cu Co-doped $K_2Ca_2(SO_4)_3$ Nanostructures Under $O^{6+}$ Ion Beam Irradiation

Hohyeong Kim[a], Jae Young[b,*]

[a]*Korea Institute of Industrial Technology, Industrial Components R&D Department, 156 Gaetbeol-ro, Yeonsu-gu, Incheon 21999, Republic of Korea*

[b]*Korea Institute of Industrial Technology, Regional Industry Innovation Department, 156 Gaetbeol-ro, Yeonsu-gu, Incheon 21999, Republic of Korea*

*Corresponding Author's E-mail: redolpin@kitech.re.kr

**Abstract**

Ion beams such as protons and heavier ions (He, C, O) have emerged as effective alternatives to conventional gamma- and X-rays in radiotherapy, owing to their well-defined Bragg peak, reduced range straggling, lower multiple scattering, and favorable depth–dose profile, which together minimize damage to surrounding healthy tissue. Reliable clinical use of these beams requires accurate, real-time dosimetry, motivating the search for sensitive thermoluminescence (TL) dosimeter materials. Among the candidates, $K_2Ca_2(SO_4)_3$ doped with Ce, Eu, or Cu has been widely recognized for its high TL sensitivity. However, the TL response of Eu and Cu co-doped $K_2Ca_2(SO_4)_3$ nanostructures under $O^{6+}$ ion irradiation has not yet been reported.

In this work, Eu, Cu:$K_2Ca_2(SO_4)_3$ nanostructures were synthesized and irradiated with $O^{6+}$ ions at multiple beam energies and fluences. The TL glow curves, dose response, and sensitivity were systematically analyzed to evaluate the role of incident energy and fluence on trap-level activation and defect formation. The results demonstrate the potential of Eu, Cu co-doped $K_2Ca_2(SO_4)_3$ nanostructures as a high-sensitivity TL dosimeter material for heavy-ion radiotherapy and ion beam research.

**Keywords:** Thermoluminescence dosimetry; $K_2Ca_2(SO_4)_3$; Eu/Cu co-doping; $O^{6+}$ ion irradiation; nanostructures; heavy-ion radiotherapy

# Metallization of Silicone Rubber Using a Sol–Gel-Derived Pd–$SiO_2$ Catalyst Layer

Hohyeong Kim[a], Jae Young Park[b,*]

[a]*Korea Institute of Industrial Technology, Industrial Components R&D Department, 156 Gaetbeol-ro, Yeonsu-gu, Incheon 21999, Republic of Korea*

[b]*Korea Institute of Industrial Technology, Regional Industry Innovation Department, 156 Gaetbeol-ro, Yeonsu-gu, Incheon 21999, Republic of Korea*

*Corresponding Author's E-mail: redolpin@kitech.re.kr

**Abstract**

The metallization of silicone rubber is a critical yet unresolved challenge in electronic packaging applications due to its intrinsically low surface energy (~20 mN/m) and chemically inert backbone. In this work, a catalyst-assisted surface engineering approach is proposed to enable reliable metal–elastomer integration using a sol–gel-derived Pd–$SiO_2$ interfacial layer. Palladium nanoparticles (5–10 nm) were uniformly nucleated and immobilized within a silica sol matrix through a sonochemical process, ensuring high catalytic activity and coating stability. The Pd–$SiO_2$ catalyst layer was conformally deposited onto alkali-activated silicone rubber via dip-coating, followed by thermal curing at 120 ℃ to induce covalent Si–O–Si bonding across the interface.
Based on this engineered interlayer, a multilayer metallization sequence consisting of electroless Ni, electroplated Cu, and electroless Sn was successfully achieved, forming uniform metal coatings with thicknesses of approximately 840 nm, 3.3 μm, and 490 nm, respectively. Cross-sectional focused ion beam analysis revealed a defect-free multilayer architecture with strong interfacial adhesion and no observable delamination at the polymer–ceramic–metal interfaces. The metallized silicone rubber exhibited the highest adhesion performance (ISO 2409, Grade 0) and a solder joint strength of 0.79 kgf, demonstrating mechanical and thermal robustness relevant to electronic assembly processes.
The results highlight the role of sol–gel catalyst layer design in overcoming interfacial incompatibility between elastomers and metals and demonstrate the feasibility of conductive silicone rubber as a ground gasket material for advanced electronic packaging and EMI grounding applications.

**Keywords:** Silicone rubber metallization, Sol–gel process, Pd–$SiO_2$ interfacial layer, Electroless plating, Surface modification

# Deep Blue Vitreous Enamel from Chanthaburi Quartz as a Local Alternative for Domestic Enamel Production for Jewelry Applications

Surapong Panyata [a,b], Pathra Srisukho[a], Pattarabordee Pimki[a] and Narumon Lertcumfu [la,*]

[a] *Creative Design Program, Faculty of Industrial Technology, Rambhai Barni Rajabhat University, Chanthaburi 22000 Thailand*
[b] *Hub of Advanced Ceramics, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*

*Corresponding Author's E-mail: narumon.l@rbru.ac.th

**Abstract**

Deep-blue vitreous enamels are highly regarded in jewelry however are inadequately represented in Thailand's domestic supply chain, which predominantly depends on imports. To rectify this deficiency, we formulated a locally sourced method to saturated deep-blue enamel utilizing a high-lead silicate glass (75PbO-25$SiO_2$-0$Al_2O_3$, wt%) tinted with CoO. Silica obtained from high-purity Chanthaburi quartz was processed, melted at 1,100 ˚C, ground and flame-fused onto copper substrates. The colorimetric assessment in the CIELab space of five formulations revealed an ideal composition (Formulation 2, 74.65PbO-24.30$SiO_2$-0.2$Fe_2O_3$-0.85CoO) that yielded a homogeneous, defect-free gloss coating with intense blue chromaticity on copper (L* = 13.85, a* = 7.33, b* = -18.95). Buoyancy measurements produced a bulk density of 7.443 ± 0.006 g $cm^{-3}$, aligning with PbO-rich glasses. Thermal study revealed a glass-transition temperature ($T_g$) of around 498 ˚C, a softening temperature ($T_f$) of approximately 550 ˚C, and an initial stage of melting at approximately 736 ˚C, indicating low-temperature processing that is compatible with copper without causing substrate distortion. Collectively, these composition, processing, and color relationships clarify the role of cobalt loading (0.55-0.85 wt%) and MnO exclusion in achieving high-chroma blue while preserving coating integrity. They also offer evidence-based formulations and practical parameters for domestic production that are in accordance with the local materials and jewelry manufacturing sectors of Thailand.

**Keywords:** vitreous enamel, glass melting, jewelry, glaze, coating

# Hybrid 3D-Printed PLA–Electrospun PVA/HPMC Nanofiber Wound Dressings with $TiO_2$ Antimicrobial Activity and Ibuprofen Delivery

Benjaporn Inseemeesak[1], Pratiharn Namsirivivat[2], Gasidit Panomsuwan[1], Ratchatee Techapiesancharoenkilj[1], Jun Ohta[3], Prakit Sukyai[4], Chatchawal Wongchoosuk[5], Kiadtisak Saenboonruang[6], Oratai Jongprateep[1*]

[1]*Department of Materials Engineering, Faculty of Engineering, Kasetsart University, 50 Ngamwongwan Road, Chatuchak, Bangkok, 1 0900, Thailand*

[2]*Shrewsbury International School Bangkok, 1922 Charoen Krung Road, Wat Praya Krai, Bang Kholaem, Bangkok 10120, Thailand*

[3]*Institute for Research Initiatives, Nara Institute of Science and Technology, Ikoma, Nara 630-0192, Japan*

[4]*Department of Biotechnology, Faculty of Agroindustry, Kasetsart University, 50 Ngamwongwan Road, Chatuchak, Bangkok, 10900, Thailand*

[5]*Department of Physics, Faculty of Science, KasetsartUniversity50 Ngamwongwan Road, Chatuchak, Bangkok, 10900, Thailand*

[6]*Department of Applied Radiation and Isotope, Faculty of Science, Kasetsart University, 50 Ngamwongwan Road, Chatuchak, Bangko k, 10900, Thailand*

[*]*Corresponding author e-mail: fengotj@ku.ac.th, Phone: +66 (0) 846452900*

**Abstract**

The integration of mechanical strength, fluid management, and controlled drug delivery in wound dressings remains a significant challenge. In this study, a novel hybrid wound dressing system was developed by combining a 3D-printed polylactic acid (PLA) scaffold with electrospun polyvinyl alcohol (PVA)/hydroxypropyl methylcellulose (HPMC) nanofibers incorporating $TiO_2$ and ibuprofen. The 3D-printed PLA provides structural support and macroporosity, while the nanofibrous layer offers a tunable interface for fluid interaction and therapeutic functionality. The electrospun fibers exhibited tunable diameters (221–695 nm) and porosity (63–85%), governed by solution composition. The addition of $TiO_2$ resulted in finer fibers and higher porosity (~85%), while HPMC increased fiber diameter and reduced pore size due to increased solution viscosity. All systems showed hydrophilic behavior (contact angle ~17–40°) and composition-dependent swelling, demonstrating that fluid interaction is controlled by both surface chemistry and pore architecture. Mechanical testing revealed that $TiO_2$ significantly enhanced tensile strength (2.02 ± 0.15 MPa) and Young's modulus (68.40 ± 4.01 MPa), whereas ibuprofen improved flexibility (elongation at break up to 10.85 ± 1.40%). The scaffolds maintained stable pH values (7.15–7.35) in simulated body fluid, indicating good physiological compatibility. The ibuprofen-loaded systems exhibited a biphasic release behavior, characterized by an initial rapid release followed by sustained drug delivery over time. The incorporation of HPMC and $TiO_2$ was observed to moderate the release profile compared to the base system. Overall, this work demonstrates a novel and scalable hybrid strategy integrating 3D printing and electrospinning, enabling simultaneous control of structure, mechanical properties, wettability, and drug release, with strong potential for advanced wound dressing applications.

**Keywords:** 3D printing, Electrospinning, Wound dressing, $TiO_2$ nanoparticle, Ibuprofen

# Synergistic Effects of Hybrid Nanolubricants on Surface Integrity and Friction Behavior in Immersion Milling of Tool Steel

Titiwat Ariyacharoendamrong[a], Peerapong Kasuriya[a], Nutthanun Moolsradoo[a,*]

[a]*Department of Production Technology Education, Faculty of Industrial Education and Technology, King Mongkut's University of Technology Thonburi, Bangkok, Thailand*

*Corresponding Author's E-mail: nutthanun.moo@kmutt.ac.th

**Abstract**

This study investigates the synergistic effects of hybrid nanolubricants composed of $SiO_2$ and $Al_2O_3$ nanoparticles dispersed in base oil on the machining performance of SKD61 tool steel under immersion milling conditions. This work explores a fully flooded lubrication regime to evaluate the tribological and surface modification mechanisms induced by nano-additives.

Three concentrations were prepared for both mono and hybrid nanoparticle systems. Milling experiments were conducted under controlled cutting parameters, and the resulting surface integrity was evaluated in terms of surface roughness (Ra, Rz) and surface morphology using optical profilometry and microscopy. Friction behavior was indirectly assessed through cutting force analysis.

The results indicate that hybrid nanolubricants significantly improve surface quality compared to mono nanoparticle systems. The combination of $SiO_2$ and $Al_2O_3$ promotes a dual mechanism involving rolling effect and protective tribofilm formation, leading to reduced tool–workpiece interaction. The optimal concentration was found at 1.0 wt%, where surface roughness decreased by up to 28% compared to base oil.

This study provides new insights into the role of hybrid nanoparticles in immersion milling and highlights their potential for enhancing surface integrity in tool steel machining applications.

**Keywords:** Hybrid nanolubricant, SKD61, Surface integrity

# Influence of Coolant Jet Orientation on Surface Integrity and Tribological Performance of Reamed Holes in AISI 1045 Steel

Chayapol Srideeiam[a], Peerapong Kasuriya[a], Nutthanun Moolsradoo[a,*]

[a]*Department of Production Technology Education, Faculty of Industrial Education and Technology, King Mongkut's University of Technology Thonburi, Bangkok, Thailand*

*Corresponding Author's E-mail: nutthanun.moo@kmutt.ac.th

**Abstract**

Surface integrity in precision hole finishing is critically influenced by coolant delivery conditions, yet the combined effects of coolant jet orientation and pressure during reaming remain insufficiently understood. This study investigates the internal surface quality of AISI 1045 steel holes (Ø6 mm) produced by drilling followed by a reaming process under controlled coolant application strategies.

Three coolant jet angles and multiple pressure levels were systematically varied to evaluate their influence on surface roughness, dimensional accuracy, and tribological behavior of the internal hole surface. The experiments were conducted using HSS tools under consistent cutting conditions to isolate coolant effects. Surface roughness (Ra), roundness error, and friction coefficient (via post-process tribological testing) were analyzed.

Results reveal that coolant jet orientation significantly affects chip evacuation and lubrication regime within the confined hole geometry. A moderate jet angle (22.5°) combined with elevated pressure improves lubricant penetration, leading to reduced surface roughness and enhanced tribological performance. In contrast, direct (0°) and steep (45°) angles show less effective fluid distribution due to flow stagnation and deflection.

This study provides new insights into optimizing coolant delivery in internal finishing operations and highlights the importance of fluid dynamics in achieving superior surface integrity in reamed components.

**Keywords:** Reaming, Coolant Jet Angle, Surface Integrity

# Effect of Nanoparticle-Enhanced Lubrication on Surface Integrity and Tribological Performance in Aluminum Milling

Totsapol Junwadee[a], Peerapong Kasuriya[a], Nutthanun Moolsradoo[a,*]

[a]*Department of Production Technology Education, Faculty of Industrial Education and Technology, King Mongkut's University of Technology Thonburi, Bangkok, Thailand*

*Corresponding Author's E-mail: nutthanun.moo@kmutt.ac.th

**Abstract**

This study investigates the influence of hybrid nanoparticle-enhanced lubrication on surface integrity and tribological performance during the milling of aluminum alloys. Nanoparticles were dispersed in a base oil to formulate nano-lubricants with varying concentrations.

The experimental design considered multiple nanoparticle types and concentrations to assess their effects on cutting performance. Surface roughness parameters (Ra, Rz, Rt) and surface morphology were analyzed using a non-contact optical profilometer and microscopy techniques. In addition, friction behavior during machining was correlated with the lubrication mechanisms of nanoparticles, including rolling effect, tribofilm formation, and mending effect.

Results indicate that nanoparticle significantly improved surface finish and reduced friction compared to conventional lubrication and mono nanoparticle formulations. The optimal concentration range was identified, beyond which agglomeration negatively affected performance. The findings demonstrate that nano-lubrication can effectively enhance machining performance and surface quality in aluminum milling processes.

This work contributes to the development of sustainable and high-performance lubrication strategies for advanced manufacturing.

**Keywords:** Nanoparticle lubrication, Aluminum milling, Surface roughness, Tribology

# Engineered Surface Resistance via Fiber Laser Texturing for Controlled Heat Localization in Resistance Spot Welding of SUS304

Nattawut Srikong[a], Prachya Peasura[a], Nutthanun Moolsradoo[a,*]

[a]*Department of Production Technology Education, Faculty of Industrial Education and Technology, King Mongkut's University of Technology Thonburi, Bangkok, Thailand*

*Corresponding Author's E-mail: nutthanun.moo@kmutt.ac.th

**Abstract**

Surface condition plays a critical role in resistance spot welding (RSW) by governing contact resistance and heat generation at the faying interface. This study proposes a surface engineering approach using fiber laser texturing to systematically control heat localization during RSW of SUS304 sheets (1.0 mm thickness). Linear laser patterns with two energy density levels were applied to modify surface roughness and contact characteristics. A baseline welding condition (10 kA, 10 cycles, 4 kN) was first established through experimental optimization to ensure process stability. Subsequently, the effects of surface modification—including as-received, acid-etched, sanded, and laser-textured surfaces—on weld quality were investigated. Mechanical performance was evaluated using lap shear testing, while nugget formation and failure modes were examined through metallographic analysis. The results demonstrate that laser-induced surface textures significantly alter the contact resistance, leading to controlled heat concentration and improved nugget consistency. Compared with conventional surface treatments, laser texturing exhibits a superior ability to tailor weld performance without altering global welding parameters. This work provides a mechanistic framework linking surface engineering to weld quality, offering a novel pathway for process optimization in resistance spot welding.

**Keywords:** Resistance spot welding, Fiber laser texturing, Contact resistance

# Load–Speed Interaction and Counter-Body Effects on the Tribological Behavior of SKH51 Tool Steel under Dry Sliding

Worakorn Neamthong[a], Nutthanun Moolsradoo[a,*]

[a]*Department of Production Technology Education, Faculty of Industrial Education and Technology, King Mongkut's University of Technology Thonburi, Bangkok, Thailand*

*Corresponding Author's E-mail: nutthanun.moo@kmutt.ac.th

**Abstract**

This study investigates the tribological behavior of SKH51 tool steel under dry sliding conditions, focusing on the combined effects of sliding speed, normal load, and counter-body materials. Ball-on-disk experiments were conducted using WC–Co as a metallic reference and $Al_2O_3$ as a representative ceramic counter-body. A full factorial design was first applied to the WC–Co/ SKH51 pair across three sliding speeds (3.14, 10, and 15 cm/s) and three normal loads (5, 10, and 15 N) to establish baseline load–speed interactions.

The results reveal a strong dependence of friction behavior on both load and sliding speed, with distinct transitions from adhesive-dominated to more stable sliding regimes. Increasing load generally intensified contact severity, while sliding speed influenced friction stability and thermal effects. The ceramic counter-body ($Al_2O_3$) exhibited lower friction fluctuations and more stable steady-state behavior compared to WC–Co, indicating reduced adhesion and improved contact stability.

Wear track observations further confirmed that WC–Co interactions promoted severe adhesive wear and material transfer, whereas $Al_2O_3$ resulted in more uniform wear characteristics. The findings demonstrate that both load–speed interaction and counter-body selection play critical roles in controlling friction stability and wear mechanisms of SKH51.

This work provides insight into material pairing strategies for dry sliding applications involving tool steels.

**Keywords:** SKH51 tool steel, Tribological behavior, Load–speed interaction

# Geometry Effects on Friction in Ring Compression of Al6061

Nattaphat Boonthuam[a], Phichada Chongcharoen[a], Nutthanun Moolsradoo[a,*]

[a]*Department of Production Technology Education, Faculty of Industrial Education and Technology, King Mongkut's University of Technology Thonburi, Bangkok, Thailand*

*Corresponding Author's E-mail: nutthanun.moo@kmutt.ac.th

**Abstract**

This study investigates the influence of specimen geometry and interface conditions on frictional behavior during ring compression of Al6061. Two ring geometries, including a conventional design and a profiled configuration, were evaluated to determine their roles in modifying material flow and friction sensitivity. Compression tests were conducted under displacement-controlled conditions at a fixed height reduction of 40%.

Three interface conditions were considered: dry contact, polymer interlayer, and liquid lubrication, representing high, intermediate, and low friction regimes, respectively. In addition, a fully annealed condition (O-temper) was selectively applied to the profiled geometry to assess the robustness of geometry-induced friction effects under reduced flow stress.

The results demonstrate that specimen geometry significantly affects friction sensitivity, with the profiled geometry exhibiting enhanced responsiveness to interface changes. The use of polymer interlayers and lubricants effectively reduced the apparent friction, although their effectiveness varied depending on the geometry. Despite the reduction in flow stress after annealing, the relative friction hierarchy among interface conditions remained consistent.
The findings highlight that geometry is not merely a passive parameter but plays an active role in amplifying or moderating frictional behavior. This work provides insights into the interaction between geometry, interface conditions, and material state, with implications for metal forming process design.

**Keywords:** Ring compression, friction behavior, specimen geometry

# Velocity-Dependent Friction Stabilization of Silicon Wafer under Dry Ceramic Sliding Contact

Tanison Lekthong[a], Nutthanun Moolsradoo[a,*]

[a]*Department of Production Technology Education, Faculty of Industrial Education and Technology, King Mongkut's University of Technology Thonburi, Bangkok, Thailand*

*Corresponding Author's E-mail: nutthanun.moo@kmutt.ac.th

**Abstract**

This study investigates the influence of sliding velocity on the friction behavior of silicon wafers under dry ceramic contact conditions. Ball-on-disk experiments were conducted using $Al_2O_3$ and $Si_3N_4$ counter bodies at sliding speeds of 5 and 10 cm/s under a constant normal load of 1 N. The friction coefficient evolution was analyzed in terms of running-in behavior, steady-state friction, and friction stability. Results reveal that sliding speed significantly affects the transition from unstable to stable friction regimes. At higher speeds, the running-in period becomes shorter and the friction response stabilizes more rapidly. $Si_3N_4$ exhibits more stable friction behavior compared to $Al_2O_3$, which shows greater fluctuation due to abrasive interaction and debris formation. Friction stability analysis, including standard deviation and peak-to-peak variation, indicates that material-dependent contact mechanisms play a critical role in governing tribological performance. The findings highlight that stable ceramic contact does not necessarily correspond to lower friction but rather to reduced fluctuation and more predictable behavior. This work provides insight into friction control of silicon wafer surfaces under dry sliding conditions relevant to precision manufacturing environments.

**Keywords:** friction behavior, silicon wafer, sliding velocity

# Load-Induced Surface Damage Evolution of Silicon Wafer under Ceramic and Metallic Contact

Satakun Sriassadorn[a], Nutthanun Moolsradoo[a,*]

[a]*Department of Production Technology Education, Faculty of Industrial Education and Technology, King Mongkut's University of Technology Thonburi, Bangkok, Thailand*

*Corresponding Author's E-mail: nutthanun.moo@kmutt.ac.th

**Abstract**

This research examines the effect of normal load on surface damage mechanisms of silicon wafers under dry sliding conditions using ceramic ($Al_2O_3$) and metallic (SUS440) counter materials. Ball-on-disk tests were performed at a constant sliding speed of 7 cm/s with applied loads of 1 and 2 N. Surface damage was characterized through wear track morphology, wear volume, and wear rate of both disk and ball. The results demonstrate that increasing load significantly intensifies surface damage, including micro-cracking, material removal, and debris generation. Metallic contact (SUS440) leads to more severe damage and higher wear rates compared to ceramic contact, attributed to adhesion and unstable friction behavior. In contrast, ceramic contact produces relatively smoother wear tracks but can still induce brittle fracture under higher loads. A strong correlation is observed between friction instability and wear volume, indicating that fluctuating friction promotes damage progression. The study reveals that friction coefficient alone is insufficient to describe tribological performance, as low friction conditions may still result in severe surface degradation. These findings provide a deeper understanding of failure mechanisms in silicon wafer processing under different contact conditions.

**Keywords:** surface damage, wear mechanism, contact material

# Interfacial engineering of ohmic-like type-I $SnO_2$/BiOCl heterostructure for efficient charge carrier separation and phenol photodegradation

Theeranun Siritanon[a,*], Boonyaporn Tiwthong[b], Anurak Waehayee[c]

[a]*Theeranun Siritanon, School of Chemistry, Institute of Science Muang Nakhon Ratchasima 30000, Thailand*
[b]*Boonyaporn Tiwthong, School of Chemistry, Institute of Science Muang Nakhon Ratchasima 30000, Thailand*
[c]*Anurak Wahayee, School of Chemistry, Institute of Science Muang Nakhon Ratchasima 30000, Thailand*

*Corresponding Author's E-mail: theeranun@sut.ac.th

**Abstract**

Photocatalytic materials have been widely investigated for environmental applications, particularly for the removal of organic contaminants in water. However, their efficiency is often hindered by the rapid recombination of photogenerated carriers. To address this, a $SnO_2$/BiOCl composite was synthesized via a hydrothermal method. Physical characterization revealed that SnO2 particles formed agglomerated clusters dispersed on the surface of plate-like BiOCl, establishing a robust heterostructure. Detailed investigation of the electronic band structure indicates that the two semiconductors form an ohmic-like type-I heterojunction. This specific configuration, characterized by the energy gaps of 3.53 eV (BiOCl) and 2.86 eV ($SnO_2$), facilitates an efficient transfer of photogenerated electrons from the conduction band of BiOCl to that of SnO2. This ohmic-like charge transfer mechanism leverages Internal Electric Field (IEF) effects, which significantly boost charge separation efficiency and suppress carrier recombination, as confirmed by photoluminescence analysis. Consequently, the 50%$SnO_2$/BiOCl composite demonstrated superior photocatalytic activity, achieving 76.2% degradation of phenol within 5 hours, whereas pure $SnO_2$ and BiOCl exhibited only 17.1% and 44.9% degradation, respectively. These findings suggest that engineering an ohmic-like heterojunction with IEF effects is a highly effective strategy for enhancing photocatalytic performance in wastewater remediation.

**Keywords:** $SnO_2$/BiOCl, Type-I heterostructure, Charge carrier separation, Phenol photodegradation.

# Effect of cations and anions composition on photocatalytic properties of single-halogen layered Sillén oxyhalide: a case study on $ABi_3O_4X_2$ (A = Li and Na; X = Cl and Br)

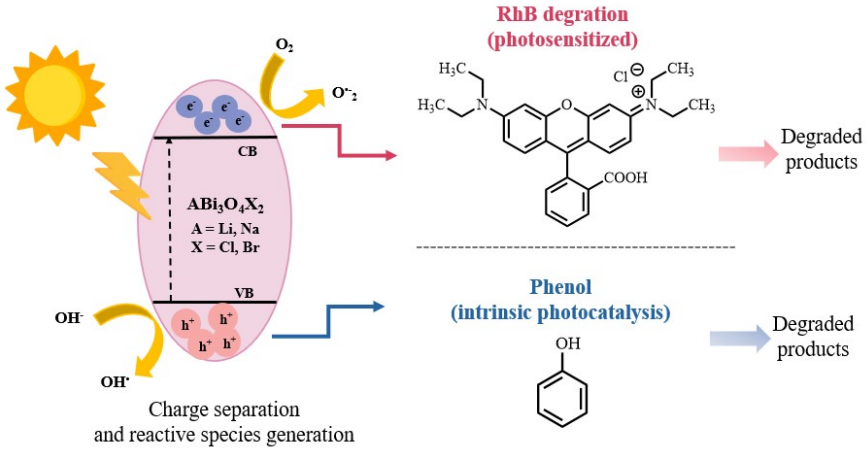
Theeranun Siritanon[a,*], Arraya Kapkham[b], Anurak Waehayee[c]

*[a]Theeranun Siritanon,[b] Arraya Kaphamk,[C]Anurak Wahayee, School of Chemistry, Institute of Science,Suranaree University of Techology 111 Maha Witthayalai Rd. .Suranari,Muang Nakhon Ratchasima Distric, Nakhon Ratchasima 30000, Thailand*

**Corresponding Author's E-mail:* theeranun@sut.ac.th

**Abstract**

The removal of dye and phenolic pollutants from industrial wastewater remains a critical challenge due to their environmental persistence and associated health risks. One of the promising technologies for such applications is photocatalysis, whose efficiencies depend greatly on photocatalysts. Herein, we report a systematic study on the effects of cation ($Li^+$, $Na^+$) and anion ($Cl^-$, $Br^-$) in $ABi_3O_4X_2$ on their structural characteristics and photocatalytic performance. Phase purity was confirmed by X-ray diffraction, while morphological analysis revealed distinct variations in particle size and surface features. Raman spectroscopy identified characteristic Bi–O and Bi–X vibrational modes, confirming successful ion substitution. The photocatalytic activities were evaluated via the degradation of Rhodamine B (RhB) and phenol under simulated solar irradiation. $LiBi_3O_4Cl_2$ exhibited the highest activity toward RhB degradation, whereas $LiBi_3O_4Br_2$ demonstrated superior performance for phenol removal. The enhanced RhB degradation is attributed to a photosensitization effect, which facilitates charge transfer and promotes photocatalytic reactions. In contrast, phenol degradation is governed primarily by intrinsic photocatalytic activity, leading to a different performance trend. These findings demonstrate that cation and anion substitution effectively modulates the structure–property–performance relationship in $ABi_3O_4X_2$ and highlight the critical role of photosensitization in dye-involved photocatalytic systems.




**Keywords:** Semiconductors, Layered structure, Photocatalysis, Azo dye, Phenol

# Study on PLA/NR TPV fabricate via dynamic vulcanization and its printability using Portable 3D printing.

Chayanon Yaprakhon [a], Chanchai Thongpin [a,*]

[a] *Department of Material Science and Engineering, Faculty of Engineering and Industrial Technology, Silpakorn University, Sanamchandra Palace Campus, Nakhon Pathom, 73000, Thailand*

** Corresponding author. Tel.: +6634219363; fax: +6634219363. E-mail address:* Chanchai@su.ac.th

**Abstract**

3D printability of thermoplastic vulcanizate (TPV) prepared from dynamic vulcanization of NR compound during melt mixing with poly (lactic acid) (PLA) in an internal mixer was investigated in this research. PLA/NR TPV with the ratio of 80/20 was extruded using twin screw extruder at temperature of 100-175°C, while the screw speed was set to 60 rpm. The extrudate diameter was controlled carefully to maintain its diameter at1.75 ± 0.10 mm. The extrudate was then applied to the build plate in order to attach to the Bambu lab A1 mini 3D printer. The Bambu studio software is used for model printing. The model was sliced into 75 layers with a thickness of 0.2 mm, and the diameter of model was 15x15x15 mm (Fig. 1). The printing speed was set to 20 mm/s, while the bed temperature was set to 60 °C while the fan speed was set to 70% while the infill pattern was set to 15% and grid, Which the nozzle was 0.4 mm. The nozzle temperature varied to 220,230,240,250 and 260 °C to investigate print quality. The results showed that PLA/NR TPV with the ratio of 80/20 being printed at nozzle temperature of 250 °C was the optimal temperature to result good printed qualified product. The dimensional expansion was observed at 2.23 % compared with the others nozzle temperature (Fig. 1). Lower nozzle temperature caused discontinuous and increased stringing during printing. Meanwhile, higher temperatures caused uncontrolled melt flow resulted in filament deposition during printing difficulty.

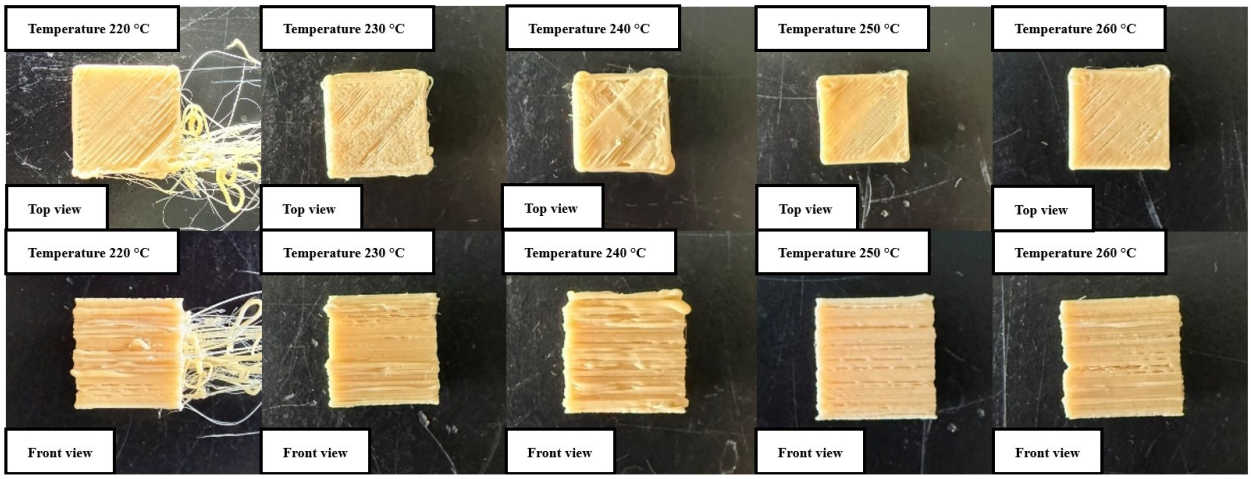



Fig. 1 illustrates the prototype specimens produced from PLA/NR 80/20 filament.

**Keywords:** Thermoplastic vulcanizate, Dynamic vulcanization, 3D printing, Natural rubber, Polylactic acid

# Revisiting the Color Physics of Amethyst: New Evidence Overturning the Classic Fe-Related Defect Model

Nuatawan Thamrongsiripak[a,b], Wutthikrai Busayaporn[c], Nongnuch Jangsawang[b],

*Tirapat Wechprasit[d], Wutthigrai Sailuam[e], Atipong Bootchanont[a*]*

*[a] Division of Physics, Faculty of Science and Technology, Rajamangala University of Technology Thanyaburi, Pathum Thani 12110, Thailand*

*[b] Electron Accelerator Section, Nuclear Engineering and Technology Center, Thailand Institute of Nuclear Technology (Public Organization), Nakhon Nayok 26120, Thailand*

*[c] Synchrotron Light Research Institute (Public Organization), 111 University Avenue, Mueang, Nakhon Ratchasima 30000, Thailand*

*[d] Division of Physics, Faculty of Science and Technology, Thammasat University, Pathum Thani 12120, Thailand*

*[e] Department of Applied Physics, Faculty of Engineering, Rajamangala University of Technology Isan, Khon Kaen Campus, Khon Kaen 40000, Thailand*

**E-mail: atipong_b@rmutt.ac.th*

**Abstract**

Amethyst, a single-crystal gemstone in the quartz family, remains highly popular in jewellery, particularly when it displays a deep violet to purple colour. Natural amethyst has been examined to understand the role of Fe-related defects in heat-induced colour changes. Changes in quartz structure and optical absorption were evaluated using X-ray diffraction and ultraviolet–visible diffuse reflectance spectroscopy, while the local environment of iron was examined through Fe K-edge X-ray absorption spectroscopy. Calculated XANES spectra based on density functional theory-derived defect models were compared with the experimental spectra. The untreated sample showed the characteristic visible absorption of purple amethyst. Heating at 380 °C removed the purple colour and reduced the main visible absorption band. At 520 °C, yellowing was observed, accompanied by an obvious increase in absorption in the violet–blue region. Fe K-edge XANES indicates that iron in all investigated conditions is better described as mixed-valence $Fe^{2+}/Fe^{3+}$ rather than as a single oxidation state. The calculated spectra for substitutional and interstitial Fe defect models did not match the experimental XANES spectra. This mismatch indicates that the colour behaviour of amethyst cannot be explained by the substitution of Fe for Si. From the optical and XANES results, the colour change during heating appears to involve Fe compounds in $SiO_2$ with intervalence charge transfer. This study provides new evidence for revisiting the classic Fe-related defect model of amethyst colouration and supports a clearer scientific basis for understanding heat-induced colour modification in natural purple quartz gemstones.

**Keywords:** Amethyst, Fe K-edge XANES, Heat treatment, Coloration mechanism, Fe-related defects

# Effect of Heat Treatment on Microstructure and Mechanical Properties of Aluminum Alloys for Battery Components

J. H. Kim[1,*], D. Y. Kim[1], D. S. Han[1], D. N. Kim[1]

[1]*Gyeongbuk Institute of IT Convergence Industry Technology ICT Research Division*

*Corresponding Author's E-mail: jhkim@gitc.or.kr

**Abstract**

Lightweighting has emerged as a key strategy in the automotive, shipbuilding, and aerospace industries to improve fuel efficiency and reduce emissions, thereby enhancing both environmental sustainability and performance. Aluminum alloys, as representative lightweight materials, are widely used across various industrial applications.
In this study, a forged aluminum alloy for battery fastening components was investigated to analyze the effects of heat treatment conditions on its microstructure and mechanical properties. Heat treatment was conducted from room temperature (RT) to 400 °C at intervals of 100 °C, followed by 1 hour of holding and subsequent air cooling.
Microstructural characterization was performed using field emission scanning electron microscopy (FE-SEM) and electron backscatter diffraction (EBSD). Mechanical properties were evaluated through tensile, compression, and bending tests using a universal testing machine (UTM).
The results revealed a clear correlation between microstructural evolution and mechanical properties. Furthermore, this study provides a database of heat treatment-dependent properties for forged aluminum alloys applicable to automotive components.

**Keywords:** Aluminum, Lightweighting, Heat Treatment

This work was supported by the Technology Innovation Program for SMEs funded by the Ministry of SMEs and Startups (MSS), Republic of Korea, in 2025 (No. 02304778).

# Linking Colorimetric Change and Technical Imaging in the Assessment of Pigment/Binder Degradation under Accelerated Aging

Krittin Assawaphom[a], Pichayada Katemake[a,b*],

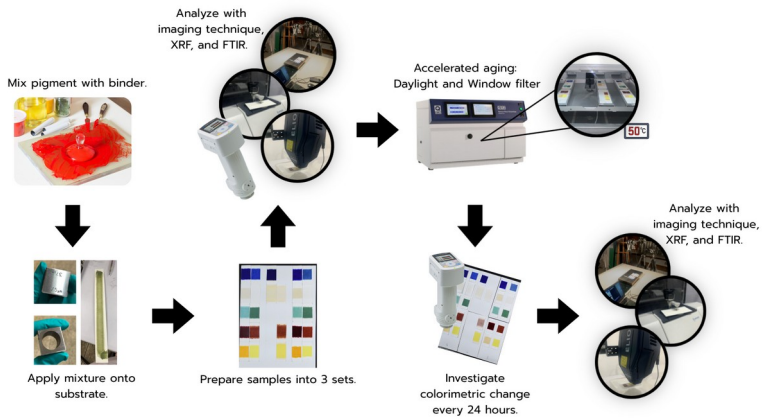
[a]*Department of Imaging and Printing Technology, Faculty of Science, Chulalongkorn University, Bangkok, Thailand.*
[b]*Science Conservation Centre for Art (SCICCA), Faculty of Science, Chulalongkorn University, Bangkok, Thailand.*

*Corresponding Author's E-mail: pichayada.k@chula.ac.th

**Abstract**

This study investigates the stability of organic and inorganic pigments combined with different binders under light and thermal exposure, reflecting conditions typical of museum environments. Such conditions can significantly influence pigment degradation, depending on their chemical composition. Ten pigments were examined: Ultramarine Blue, Han Blue, Chalk from Champagne, Lithopone, Copper Blue, Malachite, Carmine Naccarat, Madder Lake Coral, Turmeric powder, and Cadmium Yellow. These were mixed with three binders: gum acacia (gac), egg tempera (et), and linseed oil (lo). Due to compatibility constraints, linseed oil was applied to only five pigments, resulting in 25 samples. Initial characterization included CIE L*a*b* color measurements, technical photography, elemental analysis, and chemical composition analysis. Samples were then divided into three sets: Set 1 (control) stored in sealed dark conditions; Set 2 exposed to accelerated aging under combined light and heat using xenon light simulating outdoor daylight (DL); and Set 3 exposed to xenon light simulating daylight through window glass (WD). Micro-fading was monitored every 24 hours over 240 hours. Post-exposure analyses were conducted using the same characterization methods. Technical images (visible, UV reflectance (UVR), UV-induced fluorescence (UVF), and infrared false color (IRFC)) were analyzed via RGB pixel averaging. Results show that Set 2 (DL) exhibited the greatest deviation from the control, with higher color differences (ΔE*ab) than Set 3 (WD). Among binders, linseed oil produced the largest color changes, followed by egg tempera and gum acacia. For pigment/binder interactions, turmeric/et showed the highest color difference, followed by turmeric/gac. Other notable combinations included Carmine Naccarat/et, Han Blue/et, and Copper Blue/et. Technical imaging effectively revealed pre- and post-aging differences, particularly for turmeric/et, turmeric/gac, and madder lake coral/lo. It can be used to detect early degradation or micro-fading, while ΔE*ab reflects visible perceptual change

**Keywords:** pigment stability, accelerated aging, technical photography, micro-fading



# Real-Time Monitoring of Crystal Structure Evolution under Thermal Treatments by in-situ Synchrotron XRD at BL1.1W, SLRI

Krongthong Kamonsuangkasem[a,*], Miskawan Sripakdee[a], Suttipong Wannapaiboon[a], Chatree Saiyasombat[a], Prae Chirawatkul[a]

[a]*Synchrotron Light Research Institute (Public Organization), 111 University Avenue, Muang District, Nakhon Ratchasima, 30000, Thailand*

*Corresponding Author's E-mail: krongthong@slri.or.th

**Abstract**

Beamline BL1.1W of the Synchrotron Light Research Institute (SLRI) in Nakhon Ratchasima, Thailand has developed and implemented an advanced in-situ synchrotron X-ray diffraction (XRD) technique to support research in material science by enabling real-time investigation of crystal structure transformations under thermal treatments. The experimental system integrates a controlled high-temperature heating stage capable of reaching temperatures up to 1100°C, combined with high-flux synchrotron radiation and fast data acquisition. This setup enables continuous monitoring of phase transitions, lattice parameter evolution and microstructural changes under controlled thermal conditions and sample environments. The in-situ XRD capability at BL1.1W has been designed to accommodate diverse material classes and experimental requirements relevant to materials research. Its performance has been demonstrated through investigations of metallic solder alloys, where alloying effects on phase stability, anisotropic lattice behaviour, and thermally driven microstructural evolution were resolved. The instrumentation has also been applied to functional ceramics and advanced oxide material. It has been used to study thermally induced structural behaviour in CaO-doped ZrO nanocrystals, high-temperature polymorphism and band-gap evolution in $BaZrS_3$, and temperature-dependent structural changes in lead-free piezoceramics such as (1−x)BZT–(x)BCT. Additionally, the flexible experimental geometry allows integration with complementary techniques, such as synchrotron-based X-ray absorption spectroscopy (XAS), for investigating oxidation and thermal conversion processes in mixed-metal cobaltite spinel oxides ($ZnCo_2O_4$ and $NiCo_2O_4$), enabling correlated structural and chemical analysis during thermal treatments. The development of this in-situ synchrotron XRD instrumentation at BL1.1W provides a powerful and versatile platform for advanced materials characterization, supporting comprehensive structure–property correlation studies under realistic thermal conditions, thereby advancing synchrotron-based materials research in Thailand and the ASEAN region.

**Keywords:** in-situ synchrotron XRD, BL1.1W, high-temperature diffraction, crystal structure evolution, phase transformation

# Role of As-Cast Grain Boundary Network in Internal Oxidation of Al–Mg Alloys with Minor La and Zr Additions

Seong-Ho Ha[a,*], Tae-Yeong So[a], Young-Chul Shin[a]

[a]*Korea Institute of Industrial Technology, 156 Gaetbeol-ro, Yeonsu-gu, Incheon, Republic of Korea*

*Corresponding Author's E-mail: seonghoha1999@gmail.com

**Abstract**

Al–Mg alloys are widely used not only as lightweight structural materials but also in electronic and functional applications due to their excellent corrosion resistance, formability, and thermal stability. In such applications, oxidation behavior at elevated temperatures is a critical factor affecting long-term reliability. This study investigates the effects of minor La and Zr additions on the oxidation behavior and microstructural evolution of Al–Mg alloys, with particular emphasis on the role of as-cast microstructures and grain boundary characteristics in controlling internal oxidation. SEM and EBSD analyses of the as-cast alloys revealed that La addition significantly modifies the solidification structure, producing a refined cellular/dendritic substructure in which conventional grain size determination is ambiguous. Therefore, grain size was defined based on EBSD using high-angle grain boundaries (HAGBs, >15°), while the microstructural length scale was separately quantified using dendritic or cellular spacing. The as-cast EBSD results indicate that La addition alters the connectivity and density of HAGB networks, potentially reducing surface-connected diffusion paths for oxygen ingress during the early stages of oxidation. After prolonged oxidation at 500 °C for 30 h, both La-containing and La-free alloys exhibited equiaxed grain structures due to recovery and recrystallization, and the initial differences in HAGB fraction became less pronounced. However, significant differences in internal oxidation behavior persisted. Cross-sectional SEM analyses revealed that La addition effectively reduced the depth and continuity of internal oxidation. Combined SEM–EBSD overlay analysis demonstrated that internal oxides preferentially form along grain boundaries, but their connectivity is disrupted in La-containing alloys. These results suggest that suppression of internal oxidation by La addition is governed by early-stage diffusion path modification and grain boundary-mediated oxidation behavior, rather than the final grain structure after long-term thermal exposure.

**Keywords:** Al–Mg alloys, Internal oxidation, Grain boundary network, SEM–EBSD analysis

# Common Mistakes and Errors from Materials Characterization Techniques: Practical Experience and Suggestions

Jindaporn Chaison[a,*], Yupawadee Kumoon[a] and Chaiyasit Banjongprasert[a]

[a]*Materials Science Research Center, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*

*Corresponding Author's E-mail*:* Jindaporn.chaison@cmu.ac.th, *yupawadee.k@cmu.ac.th*

**Abstract**

Materials characterization is a fundamental component of materials science, providing critical insight into the internal structure, composition, and properties of materials. Through various analytical and testing techniques, researchers can evaluate how materials perform under different conditions and understand the relationships between structure and properties. Accurate characterization is therefore essential for reliable scientific research, quality control, and technological development. However, errors and mistakes frequently occur during the characterization process, which can significantly affect the accuracy, reliability, and interpretation of results.

These errors commonly arise from improper sample preparation, misunderstanding or insufficient knowledge of characterization techniques, and human operational mistakes. Sample preparation is often a crucial source of error, as contamination, incorrect dimensions, poor surface quality, or inappropriate handling can compromise results before testing even begins. In addition, researchers may misuse or misinterpret characterization techniques due to inadequate understanding of machine principles, operational parameters, or data analysis methods. Human errors, including incorrect machine settings, procedural mistakes, or carelessness during operation, also contribute significantly to unreliable data.

This presentation discusses common mistakes observed in several key characterization and testing instruments used at the Materials Science Research Center, Chiang Mai University. The focus includes widely used techniques such as X-ray diffraction (XRD), Differential scanning calorimetry (DSC), Simultaneous thermal analyzer (STA), nanoscale characterization instruments, and hardness testing. In the case of X-ray Diffraction (XRD), a widely utilized technique for crystallographic structure analysis, sample preparation is a critical factor that directly influences peak positions, intensities, and profiles. Sample preparation errors, such as preferred orientation and sample displacement, can lead to significant data inaccuracies and, consequently, the misidentification of material phases. Similarly, in Differential Scanning Calorimetry (DSC), the precision of thermal analysis is highly dependent on sample preparation. Factors such as the mass of the sample, the thermal contact between the sample and the crucible, and the uniformity of the specimen can substantially affect the sensitivity and resolution of the resulting thermograms, potentially leading to errors in determining transition temperatures. Regarding hardness testing, this technique evaluates a material's resistance to localized plastic deformation induced by indentation. Hardness values serve as a fundamental indicator of mechanical properties, primarily utilized in quality control for metallic components. However, results are highly sensitive to specimen preparation and environmental variables. Discrepancies often arise from inadequate surface finish, excessive roughness, or specimen misalignment (tilting). Furthermore, the selection of improper indentation loads and dwell time significantly compromises data integrity. Consequently, precise control over surface preparation, dwell time, loading rates, and ambient conditions is imperative to ensure the accuracy of hardness measurements.

By examining practical examples from these machines, the presentation identifies recurring issues and categorizes them into three major contributing factors: (1) sample preparation errors, (2) misunderstanding or lack of technical knowledge, and (3) human operational errors.

Furthermore, the presentation provides practical recommendations and preventive strategies to minimize these mistakes. By improving preparation procedures, enhancing technical understanding, and promoting careful machine operation, researchers can significantly increase the accuracy and reliability of characterization outcomes.

**Keywords:** Materials characterization, X-ray diffraction, Differential scanning calorimetry, Hardness testing, Sample preparation

# In-Materio Physical Reservoir Computing Device using SWNT/{$Mo_{154/152}$}-ring Composite Networks

Muhammad Syahmi Hazim Bin Mohd Nizar[a], Tomoki Mi[sakac], Yuki Usami[ab] , Takuya Matsumoto[c], Hirofumi Tanaka[ab*]

[a] *Graduate School of Life Science and Systems Engineering, Kyushu Institute of Technology, Fukuoka, Japan*
[b] *Research Center for Neuromorphic AI Hardware, Kyushu Institute of Technology, Fukuoka, Japan*
[c] *Graduate School of Science, The University of Osaka, 1-1 Machikaneyama, Toyonaka, Osaka, 560-0043 Japan*

*Corresponding Author's E-mail: tanaka@brain.kyutech.ac.jp

**Abstract**

In-materio reservoir computing (MRC) utilizes intrinsic nonlinear electrical responses and material dynamics for temporal information processing. Building on previous SWNT/porphyrin-POM systems, this study introduces a ring-shaped polyoxometalate **{**$Mo_{154/152}$**}**-ring that posses high nuclearity and rich redox activity to enhance charge transport dynamics. Two different SWNTs synthesized via the High-Pressure Carbon Monoxide (HiPco) and Super-Growth (SG) are used to make SWNT/**{**$Mo_{154/152}$**}**-ring composite. The SWNTs are dispersed in 0.01% Sodium Dodecyl Benzene Sulfonate (SDBS) and mixed with 0.5 g/L of **{**$Mo_{154/152}$**}**-ring in DI water. Afterwards, the synthesised sample are drop casted onto the 16-electrode substrate (Gap size: 100 µm). Raman analysis reveals HiPco SWNTs have smaller diameters (~0.93 nm, RBM ~267 $cm^{-1}$) while SG SWNTs have larger diameters (~1.47 nm, RBM ~169 cm). By referencing the Kataura plot, HiPco SWNTs are identified to be more metallic while SG SWNTs are more semiconducting [4]. Also supported by G-band analysis and electrical measurements further confirm that SG-based devices exhibit higher conductance. Performance evaluation using waveform generation tasks shows that both devices demonstrate nonlinear and dynamic responses essential for reservoir computing, with SG-based devices achieving higher accuracy than HiPco-based devices. The improved RC performance of SG devices is attributed to their semiconducting nature, which provides richer nonlinear dynamics and enhanced conductance. Overall, these hybrid networks highlight the potential of SWNT/**{**$Mo_{154/152}$**}**-ring composites for low-power MRC applications.

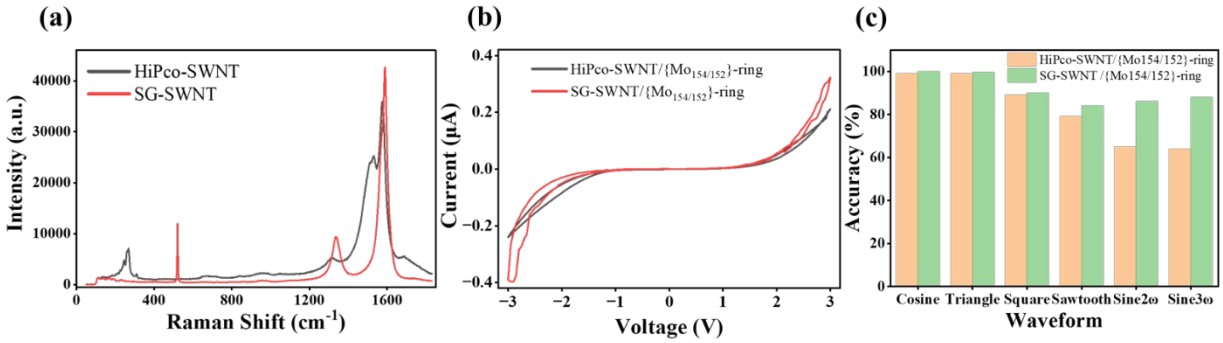



Figure 1. (a) Raman spectroscopy of both Hipco-SWNT and SG-SWNT. (b) Voltage-Current curve of SWNT/{$Mo_{154/152}$}-ring device comparison of both SWNT. (c) Comparison of waveform generation task accuracies.

**Keywords:** Physical reservoir computing, Polyoxometalate, Neuromorphic device, Nonlinear dynamics,

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# Low-Cost IoT Flight Logger for Bang Fai Rocket Analysis and Safety Monitoring

Anupon Suwannatrai[a,*], Sayan Kaennakham[a,b], Wiwat Nuansing[a,c,d]

[a]*Department of Interdisciplinary Science and Internationalization, Institute of Science, Suranaree University of Technology , Thailand*
[b]*School of Mathematics and Geoinformatics, Institute of Science, Suranaree University of Technology, Thailand*
[c]*School of Physics, Institute of Science, Suranaree University of Technology, Nakhon Ratchasima, 30000, Thailand*
[d]*Center of Excellence on Advanced Functional Materials (CoE-AFM), Suranaree University of Technology, Thailand*

*Corresponding Author's E-mail: jo.anupon@gmail.com

**Abstract**

Bang Fai and Bang Fai Talai are traditional Thai handmade rockets with difficult-to-predict flight behavior due to variations in structure, materials, fuel packing, and launch conditions. Previous studies reported low-cost rocket sensor packages [1], IMU calibration with Kalman-filter-based interpretation [2], and LoRa-based rocket telemetry using inertial sensors [3]. This study develops a low-cost IoT flight logger for Bang Fai rocket analysis and safety monitoring. The system integrates an inertial measurement unit, pressure/altitude sensing, GNSS positioning, LoRa telemetry, and onboard microSD logging. Acceleration, angular velocity, pressure, altitude, position, ground speed, flight state, and telemetry quality were recorded and visualized through a real-time ground-station dashboard (Figure 1). Data were processed using cleaning, time alignment, GNSS-IMU interpretation, and Kalman-filter-based noise reduction. Field tests were conducted on Bang Fai Talai, Bang Fai Hang, Bang Fai San, and Bang Fai Laan rockets. The recovered datasets showed that the logger can distinguish static records from actual flights and identify launch, ascent, apogee, descent, recovery, and telemetry interruption. A representative Bang Fai Talai flight showed a GNSS flight duration of 242.2 s, relative apogee of 737.5 m, maximum GNSS speed of 204.9 km/h, and estimated recovery distance of 1.05 km. Larger datasets captured high-altitude behavior with relative apogees of approximately 4.0–6.9 km, while LoRa relay data extended descent information when onboard logging was interrupted. These results demonstrate that low-cost edge-IoT telemetry can convert Bang Fai activities into analyzable flight datasets for safety monitoring and future risk assessment.




**Figure 1.** Ground station dashboard for real-time visualization of Bang Fai rocket telemetry.

**Keywords:** Bang Fai rocket, Flight logger, Edge-IoT sensing, GNSS-IMU data acquisition, LoRa telemetry

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# Design of dynamic covalent networks with repeatable healing property via reversible phosphonate linkages

Kazuho Maeda[a], Yota Okuno[a], Yasuhiko Iwasaki[a,*]

[a]*Faculty of Chemistry, Materials and Bioengineering, Kansai University, Yamate-cho, Suita-shi, Osaka 564-8680, Japan*

*Corresponding Author's E-mail: yasu.bmt@kansai-u.ac.jp

**Abstract**

Dynamic covalent networks (DCNs) with healing properties have attracted significant attention regarding the sustainability and recycling of polymer material resources. However, many healing processes require high temperatures, leading to the deterioration of physical properties due to thermal degradation of the polymers. In this study, it was prepared crosslinked polymer films that maintain their properties even after repeated healing by designing a network structure that produces no elimination during bond exchange reaction (Fig. 1). Mixed solutions of poly(2-hydroxyethyl methacrylate) (PHEMA) and 2-methoxy-2-oxo-1,3,2-dioxaphosphoran (MP) or 2-methyl-2-oxo-1,3,2-dioxaphosphoran (MeP) with different ratio in N,N-dimethylformamide were prepared. The solutions were poured into Teflon mold and heated to form crosslinked structure in films. Subsequently, the films were immersed in 2-propanol to remove unreacted substances and then dried under vacuum. The molar ratio (X) of phosphate units or phosphonate units to HEMA units in the film was determined by the molybdenum blue method. The films were selected that X value of 0.21, and they prepared using MP or MeP were labeled $PHPO_{0.21}$ or $PHPC_{0.21}$, respectively. Repeating healing property of the films was characterized by thermal treatment at 120°C for 2 hours. While PHEMA and $PHPO_{0.21}$ did not demonstrate healing ability, $PHPC_{0.21}$ showed repeated healing every 2 hours. Structural and physical property changes in films before and after the healing test were investigated using Fourier transform infrared (FTIR) spectroscopy and stress relaxation measurements. No significant changes were observed in the FTIR spectra of either $PHPO_{0.21}$ or $PHPC_{0.21}$. However, in the stress relaxation measurements, the relaxation behavior after heating was slower in $PHPO_{0.21}$, while it was not changed in $PHPC_{0.21}$. These indicate that, although the structure of the network did not change significantly due to heat treatment in either case, the absence of elimination due to bond exchange reactions in $PHPC_{0.21}$ confirmed to maintain its physical properties.

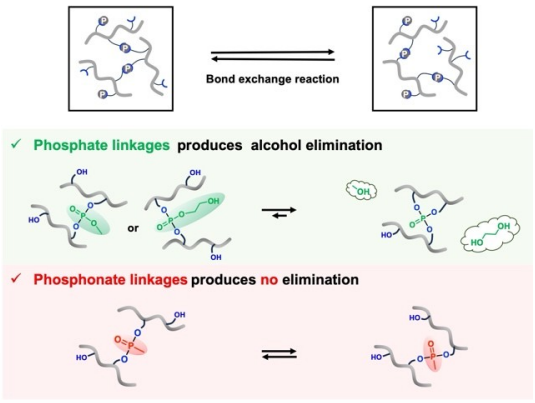



Fig. 1 The comparison of bond exchange mechanisms between phosphate and phosphonate linkages.

**Keywords:** Cyclic phosphonate, Transesterification, Dynamic covalent network (DCN), Self-healability, Degradability

# Effect of Polymeric Binders on Mechanical and Physical Properties of Compression-Molded Rice Straw and Coconut Fiber Composite Panels

Athapon Simpraditpan, Chuntip Skumnuantip, Varistha Chobpattana, Kawita Chattrakul, Anothai Pholsuwan*

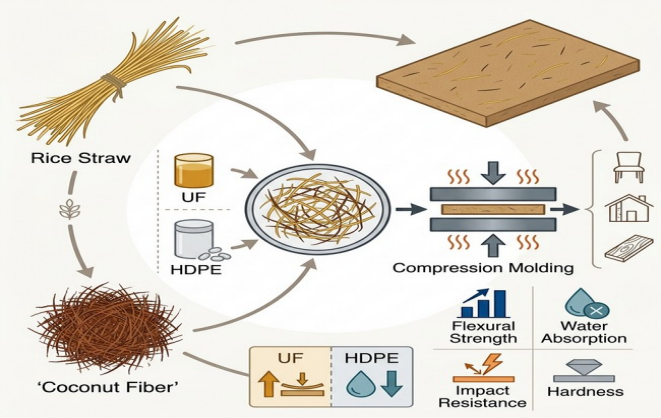
*Department of Materials and Metallurgical Engineering, Faculty of Engineering, Rajamangala University of Technology Thanyaburi, Thailand*

*Corresponding Author's E-mail: anothai.p@en.rmutt.ac.th

**Abstract**

The increasing volume of agricultural residues has created opportunities for developing sustainable composite materials derived from natural fibers. This study investigates the fabrication and properties of compressed composite sheets produced from rice straw and coconut fiber using polymeric binders through a compression molding technique. The research aims to evaluate the effect of binder type and content on the mechanical and physical properties of the resulting bio-based panels, with the goal of creating value-added materials from agricultural waste resources. Rice straw and coconut fibers were selected as reinforcing materials due to their abundance and lignocellulosic structure, which offers potential for reinforcing composite systems. Two types of polymeric binders were employed: urea–formaldehyde (UF) adhesive, representing a thermosetting resin widely used in wood-based composites, and high-density polyethylene (HDPE) as a thermoplastic binder. Composite sheets were prepared by mixing the fibers with varying binder contents and subsequently forming them under heat and pressure using a compression molding process. The fabricated panels were evaluated for their mechanical properties, including flexural strength, flexural modulus, impact resistance, and hardness, as well as their physical properties such as water absorption and dimensional stability. The results demonstrate that the type and proportion of binder significantly influence composite performance. Increasing binder content generally improves mechanical strength due to enhanced interfacial bonding between the fibers and the polymer matrix. Panels bonded with urea–formaldehyde exhibited higher mechanical strength, while those produced with HDPE showed lower water absorption and better moisture resistance. Differences in fiber characteristics between rice straw and coconut fiber also contributed to variations in the overall performance of the composite sheets. These findings indicate that rice straw and coconut fiber can be effectively utilized to produce environmentally friendly composite panels with potential applications in furniture, interior construction materials, and wood substitutes.

**Keywords:** Rice straw, Coconut fiber, Natural fiber composites, Compression molding, Polymeric binders, Mechanical properties



# Low-Cost Fabrication of Hydrophobic Candle Soot/$CaCO_3$ Composite Coated Stainless-Steel Mesh for Oil-Water Separation

Natda Wetchakun[a,*], Khatcharin Wetchakun[b], Sumet Sakulsermsuk[a]

[a]*Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[b]*Faculty of Science, Ubon Ratchathani Rajabhat University, Ubon Ratchathani 34000, Thailand*

*Corresponding Author's E-mail: natda.we@cmu.ac.th

**Abstract**

Oil spill accidents from industry cause serious and long-term damage to natural resources. The design of hydrophobic filters is a key issue for oily wastewater treatment. However, the preparation of such materials requires costly reagents and complex steps. Thus, developing a low-cost filter for oil-water separation is desired. In this study, bio-waste chicken eggshell-derived calcium carbonate ($CaCO_3$) and candle soot (CS) coated stainless steel meshes (SSMs) were prepared via a combination of spray coating and brushing process. The candle soot dispersed solution was sprayed with 1, 3, and 5 cycles on $CaCO_3$@SSMs. Results of characterization by XRD, SEM, and EDX showed that the CS/$CaCO_3$ was coated on SSMs to roughen the surface. The hydrophobicity of the samples was determined through water contact angles measurement. From the experiments to evaluate separation efficiency, it was found that the CS/$CaCO_3$@SSMs can separate the toluene-water mixture and the hexane-mixture with a separation efficiency of over 98.00%.

**Keywords:** $CaCO_3$, Candle soot, Composites, Hydrophobic, Oil-water separation

# Development of Biodegradable Porous Cryogels for Effective Microplastic Remediation in Environmental Water Sources

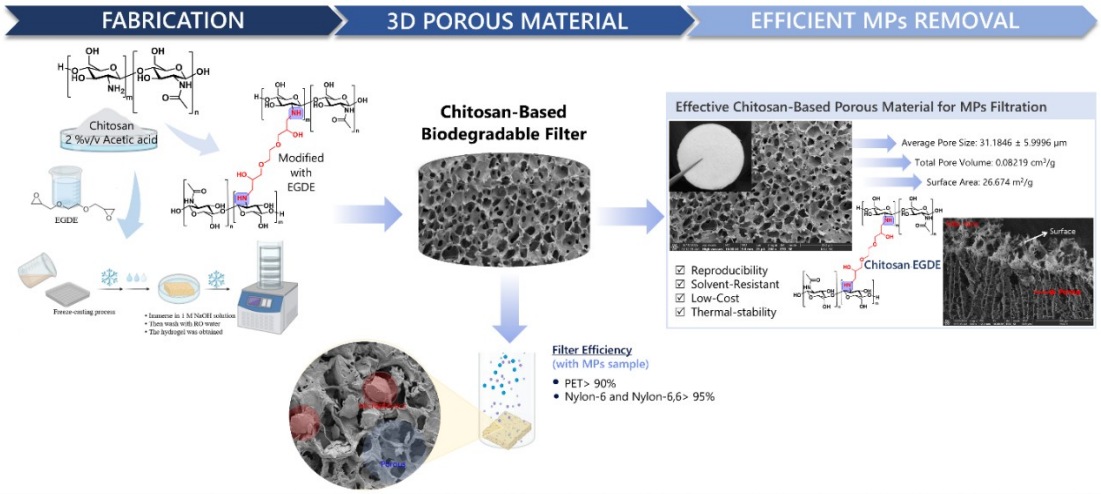
Sarocha Duangdesh[a], Puracheth Rithchumpon[b], Nathaporn Cheechana[a,c], Wanich Limwanich[d], Winita Punyodom[a,e], Patnarin Worajittiphon[a,e], Puttinan Meepowpan[a,e,*]

[a]*Department of Chemistry, Faculty of Science, Chiang Mai University, 239 Huay Kaew Road, Chiang Mai 50200, Thailand*
[b]*Department of Chemistry, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand*
[c]*Office of Research Administration, Chiang Mai University, Chiang Mai, 50200, Thailand*
[d]*Faculty of Science and Agricultural Technology, Rajamangala University of Technology Lanna, 128 Huay Kaew Road, Chiang Mai 50300, Thailand*
[e]*Center of Excellence in Materials Science and Technology, Chiang Mai University, 239 Huay Kaew Road, Chiang Mai 50200, Thailand*

*Corresponding Author's E-mail: puttinan.m@cmu.ac.th

## Abstract

Microplastics (MPs) are a widespread pollutant contaminating Thailand's water sources, particularly rivers and estuaries, significantly affecting ecosystems and water quality. To address these issues, this research aims to develop filter materials from biodegradable polymers to promote sustainable water treatment and minimize reliance on synthetic filters, which could potentially act as a source of microplastics in the future. Chitosan-based porous materials were fabricated through a cryogelation process, yielding a three-dimensional polymeric structure with a continuous and interconnected multilevel pore network and a high surface area. Furthermore, cross-linking chitosan with ethylene glycol diglycidyl ether (EGDE) at a 1:2 ratio reduced the pore size to 31.2 ± 6.0 µm. This modification enhanced the mechanical strength of porous material, allowing the material to maintain its structural integrity under aqueous conditions. Filtration efficiency tests using microplastic (MP) particles (MPs size: PET: 268.0 ± 173.3 µm Nylon-6: 179.7 ± 147.4 µm and Nylon-6,6: 135.2 ± 78.4 µm) demonstrated removal rates exceeding 90% for PET and 95% for both Nylon-6 and Nylon-6,6 from their respective aqueous solutions. These results demonstrate the potential of chitosan as a sustainable filter material attributed to its unique surface and internal porosity. This research highlights the feasibility of using these materials for the remediation of microplastic contamination from natural water sources and provides a framework for developing environmentally friendly water treatment systems for future applications.




**Keywords:** Chitosan-based cryogels, Microplastics, Microplastic filter, Biodegradable polymers, Cryogelation

# Sustainable Recovery of Precious Metals from Electronic Waste via Hybrid Organic–Inorganic Materials

Nichayanan Manyuan[a], Rattapon Khamlue[a], Natcha Deechakawan[b], Paphitchaya Chaowalit[b], Watcharaphol Paritmongkol[a,*]

[a]*Department of Materials Science and Engineering, School of Molecular Science and Engineering, Vidyasirimedhi Institute of Science and Technology (VISTEC), Rayong 21210, Thailand*
[b]*Kamnoetvidya Science Academy (KVIS), 999 Moo 1 Payupnai, Wangchan, Rayong, 21210, Thailand*

*Corresponding Author's E-mail: watcharaphol.p@vistec.ac.th

**Abstract**

Electronic devices such as smartphones, computers, and printed circuit boards contain precious metals including silver (Ag), gold (Au), and platinum (Pt). Recovering these metals is essential due to their limited natural availability and increasing demand. Current recycling techniques, including pyrometallurgy and hydrometallurgy, rely on extreme temperatures (1,000–1,600 °C), corrosive chemical reagents, and substantial energy input. These processes generate significant $CO_2$ emissions and hazardous byproducts, while their limited selectivity results in material losses and processing costs. Here, we introduce a mild chemical process using metal organochalcogenides (MOCs), a class of hybrid organic–inorganic materials that exhibit strong potential for selective metal binding and reduction. This work applies concepts of bonding and atomic interactions to design MOC materials, enabling efficient and low-energy metal regeneration. These MOCs form intermediates that can be thermally decomposed at relatively low temperatures (200–300 °C) to regenerate pure metals. Using this approach, we demonstrate that silver can be recovered with over 98% purity, as confirmed by PXRD and XRF analysis, after controlled decomposition at 250 °C. This represents a significant reduction in thermal demand compared to conventional metallurgical processes. Additionally, the reaction medium can be recycled, highlighting the reusability of the system. Overall, this study presents an environmentally friendly pathway for precious metal recovery, offering a promising alternative for sustainable resource recovery and circular materials processing, with potential for industrial deployment.

**Keywords:** Metal organochalcogenides, metal recovery, electronic waste, hybrid organic-inorganic materials

# Fe-Doped $TiO_2$/Hard Carbon Coated PLA 3D-Printed Structures for Synergistic Adsorption–Photocatalytic Removal of Methylene Blue in Water

Pornpailin Saengkla[1], Chanakan Permmit[1], Sirinda Chalermthiralert[2], Tyme Hetrakul[3], Benjaporn Inseemeesak[1], Angsuthorn Ngamprasit[1], Natthaphong Thanawatchaimongkol[1], Gasidit Panomsuwan[1], Ratchatee Techapiesancharoenkij[1], Oratai Jongprateep[1*]

[1]*Department of Materials Engineering, Faculty of Engineering, Kasetsart University, 50 Ngamwongwan Road, Chatuchak, Bangkok, 1 0900, Thailand*

[2] *International School Bangkok, 39/7 Soi Nichada Thani, Samakee Road, Amphur Pakkret, Nonthaburi 11120 Thailand*

[3]*Harrow International Bangkok, 45 Soi Kosumruamchai 14, Kosumruamchai Road, Don Mueang Subdistrict, Don Mueang District, Bangkok, 10210 Thailand*

*Corresponding author e-mail: fengotj@ku.ac.th Phone: +66 (0)846452900

**Abstract**

This study presents a sustainable waste-to-resource approach for water treatment through the development of an immobilized adsorption–photocatalytic system based on Fe-doped $TiO_2$ and biomass-derived hard carbon. Hard carbon was synthesized from durian peel via a hydrothermal– carbonization process, transforming agricultural waste into a high-value adsorbent with a high specific surface area (~279 $m^2 g^{-1}$) and hierarchical pore structure. Fe-doped $TiO_2$ nanoparticles (3 and 5 mol%) were prepared using a solution combustion method with titanium isopropoxide (TTIP) and glycine, resulting in porous anatase-dominant structures.

The Fe-doped $TiO_2$/hard carbon composite was subsequently coated onto 3D-printed polylactic acid (PLA) scaffolds to form an immobilized catalytic system. Structural and physicochemical characterization (XRD, Rietveld refinement, SEM/TEM, BET, UV–Vis DRS, and FTIR) confirmed that Fe doping effectively reduced the bandgap (from 3.02 to ~2.89 eV) and introduced defect states that enhance charge separation. The 3 mol% Fe-doped $TiO_2$ exhibited the most optimal structural and textural properties, including the highest surface area (~123 $m^2 g^{-1}$) among $TiO_2$-based samples.

Photocatalytic performance was evaluated using methylene blue (MB) as a model organic pollutant. The Fe-doped $TiO_2$/hard carbon-coated PLA structures demonstrated enhanced removal efficiency compared to pristine $TiO_2$, attributed to a synergistic mechanism combining pollutant adsorption and photocatalytic degradation. The hard carbon component facilitates pollutant pre-concentration, while Fe doping improves light absorption and suppresses charge carrier recombination. The 3 mol% Fe-doped $TiO_2$/hard carbon system exhibited the best performance, consistent with its optimized structural, optical, and surface properties.

Importantly, the use of biomass-derived carbon and 3D-printed biodegradable PLA substrates highlights the environmental and practical advantages of the developed system, including resource recovery, catalyst stability, and ease of reuse. This work demonstrates a promising pathway for integrating waste valorization with advanced water treatment technologies, contributing to sustainable and circular approaches for environmental remediation.

**Keywords**: Biomass-derived hard carbon, Fe-doped $TiO_2$, 3D-printed PLA scaffold, Adsorption–photocatalysis, Methylene blue removal

# Influence of Clear Glass Cullet and Lithium Contents on the Physical and Mechanical Properties of Low-Temperature Fired Clay Tiles

Chonlathit Pitipoomsuksan[a] and Wilaiwan Leenakul[b,c,*]

[a] *Department of Industrial Engineering, Faculty of Industrial Education, Rajamangala University of Technology Phra Nakhon, Bangkok 10300*
[b]*Division of Industrial Materials Science, Faculty of Science and Technology, Rajamangala University of Technology Phra Nakhon, Bangkok 10800, Thailand*
[c]*Hub of Advanced Ceramics, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*

*Corresponding Author's E-mail: wilaiwan.l@rmutp.ac.th

**Abstract**

This study aimed to develop low-temperature fired clay tiles using clear glass cullet mixed with Sisaket volcanic soil. The clear glass cullet was added at 60, 65, 70, 75, 80, and 85 wt%, while the Sisaket volcanic soil was used at 40, 35, 30, 25, 20, and 15 wt%, respectively. Lithium oxide was added as an additive at 0, 1, and 2 wt%. The test specimens were formed by uniaxial pressing at a pressure of 100 bar into rectangular bars with dimensions of 50 × 100 × 7 mm. The specimens were then fired at 800 and 850 °C with a heating rate of 120 °C/h and a soaking time of 1 h. The physical and mechanical properties of the fired specimens were evaluated, including flexural strength, weight loss after firing, linear firing shrinkage, water absorption, and bulk density. Microstructural and phase analyses were also carried out using SEM and XRD. The results were compared with the Thai Industrial Standard TIS 2508-2555. The experimental results showed that increasing the amounts of clear glass cullet and lithium improved the flexural strength of the specimens. At the same time, the linear firing shrinkage also increased. The higher shrinkage indicated better densification of the fired body and a reduction in porosity, which contributed to greater strength. In addition, water absorption and weight loss after firing tended to decrease with increasing glass cullet and lithium contents. These results suggest that the fired specimens became denser with fewer pores, leading to improved strength and overall properties.

**Keywords:** Glass cullet, Clay, Flexural strength, Lithium oxide, Volcanic soil

# Enzymatic Hydrolysis Pretreatment of Hemp Fibers for Size Reduction in Cellulose Nanofiber Production: Effects of Cellulase-to-Xylanase Ratio and Total Enzyme Loading

Wiranchana Srichanachaichok[a], Wichanee Bankeeree[c], Kamonwan Pacaphol[a],[b,d*],

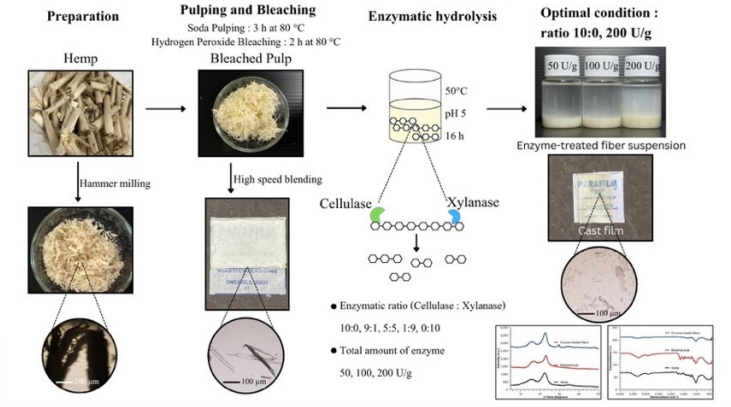
[a]*Pulp, Paper and Packaging Technology Program, Faculty of Science, Chulalongkorn University, Bangkok, Thailand.*
[b]*Department of Imaging and Printing Technology, Faculty of Science, Chulalongkorn University, Bangkok, Thailand.*
[c]*Plant Biomass Utilization Research Unit, Department of Botany, Faculty of Science, Chulalongkorn University, Bangkok, Thailand*
[d]*Center of Excellence in Responsive Wearable Materials, Chulalongkorn University, Bangkok, Thailand.*

* Corresponding Author E-mail: kamonwan.p@chula.ac.th

**Abstract**

The production of cellulose nanofibers remains challenging due to the strong and entangled structure of cellulose, which limits effective fiber size reduction. Conventional approaches typically combine chemical treatments and mechanical defibrillation. However, these approaches require high energy input and may raise environmental concerns regarding wastewater treatment. Enzymatic pretreatment is a sustainable alternative because it is environmentally friendly and selectively breaks polymer chains. Common enzymes, cellulase and xylanase, are widely used to degrade cellulose and hemicellulose. This study aims to improve the size reduction of purified hemp fibers derived from agricultural residues after delignification. Two enzymes, cellulase and xylanase, were applied at varying ratios, 10:0, 9:1, 5:5, 1:9, and 0:10 w/w. After selecting the optimal ratio, total enzyme loadings of 50, 100, and 200 U/g were studied. All treatments were conducted at 50°C and pH 5 for 16 h according to our previous study. The results indicate that the optimal condition for size reduction was achieved at ratio 10:0 with a total enzyme loading of 200 U/g. The fibers were most defibrillated and showed the greatest size reduction, as observed by SEM and OM. Average fiber diameters were reduced from approximately 400 μm to 25-35 μm, and fines content increased from 20% to 39% as analyzed using a Fiber Quality Analyzer. These results were consistent with the reducing sugar content and suspension stability, its cast film showed the highest light transmittance compared to other treatments. A moderate yield of 50.2 ± 1.4 was achieved. Additionally, the characteristics of treated fibers were investigated by XRD and FTIR to examine the change in crystallinity and chemical structure. These findings demonstrate that enzymatic treatment, particularly cellulase under appropriate conditions, can effectively reduce hemp fiber size and has strong potential as a pretreatment method to reduce energy consumption and chemical usage in nanocellulose production.

**Keywords:** hemp fibers, cellulase, xylanase, enzymatic hydrolysis, fiber size reduction.



# Valorization of Industrial Mirror Waste as a Fluxing Agent for Low-Temperature Porcelain Synthesis

Phumipat Chokimsuwan, Sittha Kuntik, Thatpicha Meewong, Siritorn Thongboonsong, Thammapat Totaen, Niti Yongvanich*

*Department of Materials Science and Engineering, Faculty of Engineering and Industrial Technology*
*Silpakorn University, Muang, Nakornpathom, Thailand*

*Corresponding Author's E-mail: niti.yongvanich@gmail.com

**Abstract**

Conventional porcelain production is energy-intensive, requiring firing temperatures around 1200°C, which significantly contributes to high manufacturing costs. This research investigates the feasibility of utilizing mirror powder, derived from industrial cullet waste, as a high-efficiency fluxing agent to enhance the vitrification of porcelain clay. Mirror waste was added to clay slips in amounts ranging from 0 to 100 w/v%. The results demonstrate that the addition of mirror waste significantly enhances the maturation degree of the clay mixture. Characterization through Scanning Electron Microscopy (SEM) observations revealed a denser microstructure with diminished porosity, leading to a substantial decrease in water absorption. X-ray Diffraction (XRD) analysis identified the development of quartz, mullite, and anorthite phases within an intensified glassy matrix. While increasing mirror waste content improved surface smoothness and glossiness, a critical threshold was identified; additions exceeding 60 w/v% led to pyroplastic deformation (warping) when fired at 1100°C. The study concludes that mirror waste can effectively lower the maturation point by 100°C without compromising essential material properties. This shift offers substantial energy savings and demonstrates a viable pathway for the ceramic industry to adopt circular economy principles. By utilizing industrial waste as a functional additive, this research contributes to both economic competitiveness and environmental sustainability in material manufacturing.

**Keywords:** Porcelain, Mirror Waste, Energy Reduction, Waste Valorization, Circular Economy

# Noble Metal-Based Intermetallic Compounds for Energy Catalysis

Qipeng Lu[a,*]

[a] *School of Materials Science and Engineering, University of Science and Technology Beijing, Beijing 100083, China*

*qipeng@ustb.edu.cn

**Abstract**

Catalytic materials are the core for the conversion and utilization of renewable energy. Addressing the global demand for highly efficient and stable catalytic materials, we focus on three fundamental scientific challenges: the design of active site structures, the precise construction of catalytic surfaces and interfaces, and the operational lifespan of low-dimensional noble metal catalysts under practical conditions. Starting from the structural optimization of high-performance catalytic materials, we have precisely prepared a series of noble metal-based intermetallic compounds with well-defined structures, controllable compositions, and excellent performance. This presentation highlights recent achievements from our research group: by introducing a selective etching reagent during the co-reduction of metal ions, the differences in metal deposition rates caused by varying redox potentials can be balanced, thus enhancing the diffusion rate of different atoms within the particles. Based on this mechanism, we have achieved the customized preparation of various noble metal-based intermetallic compounds under mild conditions. Additionally, we synthesized a series of bcc-structured noble metal-gallium-based intermetallic compounds using a support anchoring method, revealing the temperature-driven atomic ordering mechanism. By systematically comparing the catalytic performance of these materials in reactions such as electrocatalytic water splitting and NO reduction, we clarified the relationship among crystal structure, atomic coordination environment, and catalytic performance.

**Keywords:** intermetallic compounds; electrocatalysis; catalytic materials; energy conversion

# Generic skyrmion phase diagram in ferrimagnetic films

Moditha Viraj Wijethunga[1,*], Xiangrong Wang[2]

[1]*Physics Department, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, China.*
[2]*School of Science and Engineering, Chinese University of Hong Kong (Shenzhen), Shenzhen 51817, China.*

*Corresponding Author's E-mail: mvwijethunga@connect.ust.hk

**Abstract**

Ferrimagnetic skyrmions offer enhanced tunability compared to ferromagnetic systems due to the presence of antiferromagnetically coupled sublattices and reduced net magnetization. In chiral magnetic films at zero magnetic field, skyrmion stability is commonly characterized by a dimensionless parameter $\kappa$, measuring relative interaction strengths preferring curling and collinear structures, yet its applicability to ferrimagnetic systems remains unclear, as most studies assume a fixed, strong antiferromagnetic inter-sublattice coupling $J$. Here we investigate how variations in $J$ govern relaxed stable and metastable ferrimagnetic skyrmion configurations and introduce a dimensionless parameter $\zeta_{eff}$ to characterize the crossover between strong and weak inter-sublattice locking. In the strong coupling regime, where the two sublattices of thicknesses $t_1$ and $t_2$ share the same skyrmion texture described by an effective parameter $\kappa_{eff}$, the condition $\kappa_{eff}=1$ separates isolated ($\kappa_{eff}<1$) and condensed ($\kappa_{eff}>1$) skyrmion phases. This condition further enables the construction of a phase diagram in the $\kappa_{1_{eff}}\kappa_{2_{eff}}$-plane, where $\kappa_{1_{eff}}$ and $\kappa_{2_{eff}}$ are the effective $\kappa$ parameters of sublattices 1 and 2, in which isolated skyrmions are (meta)stable when $\left(1/\kappa_{1eff}+1/\kappa_{2eff}\right)>1$, whereas condensed skyrmions are (meta)stable when $\left(1/\kappa_{1eff}+1/\kappa_{2eff}\right)<1$. As $J$ decreases, this locking breaks down, leading to independent sublattice behavior in the weak coupling regime, where the intrinsic criterion $\kappa_l=1$ for each sublattice $S_l$ ($l=1,\ 2$) separates isolated ($\kappa_l<1$) from condensed ($\kappa_l>1$) skyrmion phases, leading to the breakdown of the effective $\kappa$-based description. Notably, in the strong coupling regime, exchange locking between the two sublattices enables stabilization of skyrmions even when one sublattice is Dzyaloshinskii–Moriya interaction (DMI)-free, provided that the other sublattice has finite DMI. As the coupling weakens, this mechanism breaks down and the DMI-free sublattice can no longer sustain a skyrmion. These findings provide a unified framework linking inter-sublattice exchange to skyrmion phase stability and offer practical design principles for coupling-engineered spintronic devices based on ferrimagnetic systems.

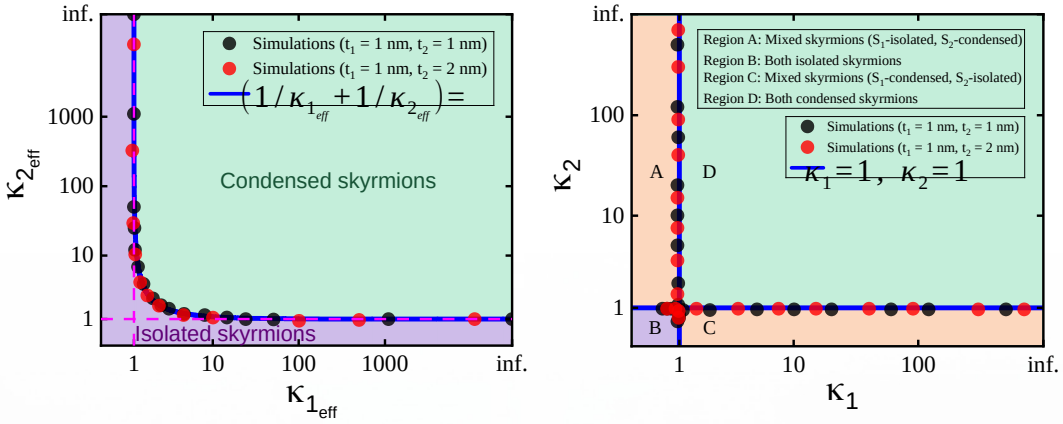



Figure 1. Phase diagram of isolated and condensed skyrmions: $\kappa_{1eff}\kappa_{2eff}$-plane for strong coupling (left) and $\kappa_1\kappa_2$-plane for weak coupling (right).

**Keywords:** Nano magnetism, ferrimagnetic skyrmions, antiferromagnetic coupling, phase diagram, skyrmion stability

# The impact of residual copper on oxide scale adhesion in recycled hot-rolled steels: a novel macro-tensile approach for assessing industrial process waste

Thanasak Nilsonthi*, Somrerk Chandra-ambhorn

*High Temperature Corrosion Research Centre and Department of Materials and Production Technology Engineering, Faculty of Engineering, King Mongkut's University of Technology North Bangkok, 1518, Pracharat 1 Road, Wongsawang, Bangsue, Bangkok 10800, Thailand*

*Corresponding Author's E-mail: thanasak.n@eng.kmutnb.ac.th

**Abstract**

The circular transition in the steel industry has led to the increased use of recycled scrap, resulting in the inevitable accumulation of residual copper (Cu) in hot-rolled products. This study introduces a novel macro-tensile approach as a quantitative for assessing industrial process waste by evaluating the adhesion of oxide scales on as-received hot-rolled steel strips. The research identifies the mechanical failure of industrial scales containing varying residual Cu levels (0.098 to 0.283 wt.%).

The investigation used a tensile testing machine integrated with real-time CCD monitoring to capture the precise strain-to-spallation of the industrial scale, applying fracture mechanics to determine the mechanical adhesion energy ($J/m^2$) as a direct metric for assessing the characteristics of scale waste generated during production. Microstructural analyses revealed that higher copper concentrations (0.283 wt.%) trigger the segregation of a Cu-rich phase at the steel/scale interface, which significantly weakens the interfacial bond compared to lower Cu levels.

Innovatively, this macro-tensile framework establishes a direct correlation between adhesion strength and process waste, while lower Cu content results in higher adhesion and minimal scale loss, higher residual Cu leads to significantly lower adhesion energy, thereby generating a greater volume of scale waste during the manufacturing process. This approach serves as a reliable quantitative metric for assessing oxide scale waste generation, driving industrial sustainability through environmentally-friendly processing.

**Keywords:** Recycled steel, copper enrichment, oxide scale adhesion, macro-tensile testing, process waste assessment

# Evaluation of Microstructure and Mechanical Properties of Non-Quenched and Tempered Steel According to Coating Treatment and Multi-stage Forging Process

D. Y. Kim[1*], D. N. Kim[1], D. S. Han[1], J. H. Kim[1#]

[1]*Gyeongbuk Institute of IT Convergence Industry Technology ICT Research Division*

[#]Corresponding Author's E-mail: jhkim@gitc.or.kr

**Abstract**

Non-quenched and tempered (NQT) steels have emerged as vital materials in modern manufacturing, offering superior mechanical properties while eliminating energy-intensive quenching and tempering cycles. This process simplification significantly reduces production costs and enhances productivity. However, optimizing their industrial application requires a detailed investigation of microstructural evolution and mechanical behavior under specific processing conditions.

This study evaluates the impact of coating treatments and multi-stage forging on NQT steel bars fabricated through extrusion and drawing. Two distinct coating methods were employed to assess surface performance. Microstructural analysis was performed using high-resolution Field Emission Scanning Electron Microscopy (FE-SEM) and Electron Backscatter Diffraction (EBSD) to observe grain characteristics and phase distribution. Concurrently, the mechanical response and deformation behavior were characterized through tensile, compression, and bending tests using a Universal Testing Machine (UTM) to account for various geometric and process variables. The findings establish a critical link between processing parameters and final material performance, providing a technical basis for optimizing NQT steel fabrication for high-stress industrial applications. This research contributes to the development of more efficient and sustainable material processing strategies.

**Keywords:** NQT steel, Multi-stage forging, Coating, EBSD, Mechanical properties

Acknowledgements

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# Opportunities for rare-earth and critical-element analysis using X-ray spectroscopic beamlines at the synchrotron Light Research Institute

W. Busayaporna[a,*], W. Klysubuna, W. Limpirata, K. Kamonsuangkasema, C. Saiyasombata, S. Wannapaiboona, S. Tancharakorna, R. Supruangneta, W. Tanthanucha, N. Jearanaikoona, C. Songsiriritthigula, O. Hasdina, S. Mahakota, C. Cholsuka, W. Wongtepaa, S. Ratanasuporana, J. Pradabsria, N. Mothonga,

[a]*Synchrotron Light Research Institute (Public organization), Nakhon Ratchasima, 30000, THAILAND*

*Corresponding Author's E-mail: wutthikrai@slri.or.th

**Abstract**

Rare-earth and related critical elements are central to emerging technologies, including permanent magnets, phosphors, catalysts, energy-storage materials, opto-electronics, radiation-detection media, and functional ceramics. Their performance is governed not only by bulk composition, but also by oxidation state, local coordination, dopant distribution, phase purity, and spatial chemical heterogeneity. This article highlights opportunities for studying rare-earth and critical-element-containing materials using X-ray spectroscopic beamlines at the Synchrotron Light Research Institute (SLRI), Thailand. Selected beamlines, including Beamlines 1.1W, 2.2, 5.1W, 5.2, 7.2W, and 8, provide complementary X-ray-based capabilities such as X-ray Absorption Spectroscopy (XAS), X-ray Fluorescence (XRF), microbeam analysis, and related structural characterization. Together, these techniques enable multi-scale investigation of elemental composition, chemical speciation, local atomic structure, and spatial distribution in complex materials. Potential applications cover rare-earth-doped glasses and ceramics, luminescent materials, catalysts, environmental and geological samples, recycled resources, advanced energy materials, and functional materials for electronics and sensing. In addition, XANES and EXAFS measurements can clarify valence state, coordination geometry, and local disorder around selected absorbing atoms, while XRF-based approaches support elemental screening and mapping of trace and minor constituents. The combined use of multiple SLRI beamlines therefore offers a practical analytical platform for connecting processing, structure, composition, and functional properties of rare-earth and critical materials. This work aims to promote wider utilization of synchrotron X-ray spectroscopy for rare-earth research and to strengthen Thailand's research capability in the characterization and development of critical materials across the value chain.

**Keywords:** Rare earth elements, Critical materials, X-ray absorption spectroscopy, X-ray fluorescence, Synchrotron radiation

# Redox-Active Copper Metal-Organic Frameworks for Electrochemical Immunosensing of Hepatitis B Surface Antigen

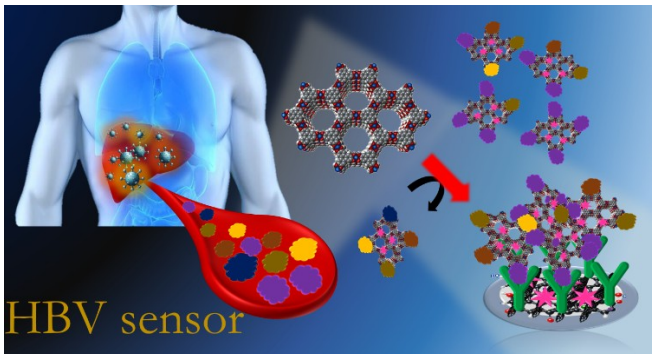
Supakeit Chanarsa[a], Patnarin Worajittiphon[a], Jaroon Jakmunee[a,b], Kontad Ounnunkad[a,b,*]

[a] *Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[b] *Center of Excellence for Innovation in Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*

*Corresponding Author's E-mail: kontad.ounnunkad@cmu.ac.th, suriyacmu@yahoo.com

**Abstract**

Copper metal-organic frameworks (Cu-MOFs) have attracted considerable interest as redox-active materials for electrochemical biosensing owing to their high porosity, numerous coordination sites, and inherent electrochemical activity. In this study, we developed a redox-amplified electrochemical immunosensor for the detection of hepatitis B surface antigen (HBsAg) by integrating a helical carbon nanotube/graphene oxide (HCNT/GO) nanocomposite as the electrode-modifying platform with Cu-MOFs as redox-active capture probes. The HCNT/GO composite offers a conductive and large-surface-area interface that promotes efficient antibody immobilization and improves interfacial electron transfer. Meanwhile, the Cu-MOFs provide enhanced faradaic responses from copper redox centers, resulting in effective signal amplification after antigen recognition. Differential pulse voltammetry (DPV) was employed to measure HBsAg following incubation. The proposed immunosensor displayed a concentration-dependent DPV response over the range of 0.05 to 50 ng $mL^{-1}$ and achieved a low detection limit of 0.0015 ng $mL^{-1}$. Furthermore, the sensor exhibited satisfactory stability, reproducibility, repeatability, and selectivity, with negligible interference from non-target substances. These results demonstrate an effective approach for ultrasensitive HBsAg detection and suggest the strong potential of Cu-MOF-based redox probes combined with carbon nanocomposites for clinical screening and point-of-care diagnostic applications.




**Keywords:** Copper metal-organic frameworks (Cu MOFs); Electrochemical immunosensor; Hepatitis B surface antigen (HBsAg); HCNT/GO nanocomposite, Differential pulse voltammetry (DPV)

# Oxygen-vacancy-rich $TiO_2$-based metal oxide nanocomposites synthesized by spark discharge for visible-light photocatalytic hydrogen evolution

Nirinphat Pooseekheaw[a], Winai Thongpan[b], Arisara Panthawan[c], Pisith Singjai[d,e], Wattikon Sroila[d], Ekkapong Kantarak[d], Natthawikan Yodsungnoen[e], Wiradej Thongsuwan [a,d,e,*]

[a] *Materials Science Research Center (MSRC) Faculty of Science, Chiang Mai University*
[b] *Department of Physics, Faculty of Science and Technology, Thammasat University, Lampang, 52190, Thailand*
[c] *Office of Research Administration, Chiang Mai University (ORA), Thailand*
[d] *Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Thailand*
[e] *Center of Excellence in Materials Science and Technology, Chiang Mai University, Thailand*

*Corresponding Author's E-mail: wiradej.t@cmu.ac.th

**Abstract**

The escalating global energy demand and the urgent need for carbon neutrality have positioned hydrogen ($H_2$) as a critical clean energy carrier for a sustainable future. While hydrogen can be produced through various methods such as steam methane reforming and water electrolysis, photocatalytic water splitting has emerged as a particularly transformative approach. This process enables the direct conversion of abundant solar energy into chemical fuel using only water and a semiconductor catalyst, offering a green, low-cost, and carbon-free production pathway. Among various materials, titanium dioxide ($TiO_2$) remains a benchmark photocatalyst. However, photocatalytic hydrogen evolution using $TiO_2$ is limited by its wide bandgap and rapid charge recombination, resulting in poor visible-light activity. This study presents the synthesis of oxygen-vacancy-rich $TiO_2$-based metal oxide nanocomposites via a spark discharge method to address these limitations. The introduction of oxygen vacancies ($V_O$) and formation of heterojunctions with secondary metal oxides are expected to enhance visible-light absorption and improve charge separation efficiency. The spark discharge technique offers a rapid, solvent-free, and scalable route for producing defect-engineered nanomaterials with controlled properties. The transient high-temperature plasma and subsequent rapid quenching inherent in spark discharge facilitate the in-situ generation of high-density, stable oxygen vacancies ($V_O$) within the $TiO_2$ crystalline lattice. These $V_O$ defects introduce essential mid-gap states, effectively narrowing the optical bandgap and extending the photocatalytic response into the visible-light region. Furthermore, the integration of secondary metal oxide phases creates tailored heterojunction interfaces that promote efficient spatial separation of electron-hole pairs. The as-synthesized nanocomposites are anticipated to exhibit improved photocatalytic hydrogen evolution performance under visible-light irradiation due to synergistic effects between defect states and interfacial charge transfer. This work provides a promising strategy for designing efficient, cost-effective photocatalysts and contributes to the development of sustainable hydrogen production technologies.

**Keywords:** Photocatalytic hydrogen evolution, Sparking method, $TiO_2$, Oxygen vacancies, Visible-light activity

# Mesoporous K- and Ca-Promoted Ni/Al2O3 Catalysts Derived from MIL-53(Al) for Microwave Plasma-Assisted Dry Reforming of Methane into Syngas

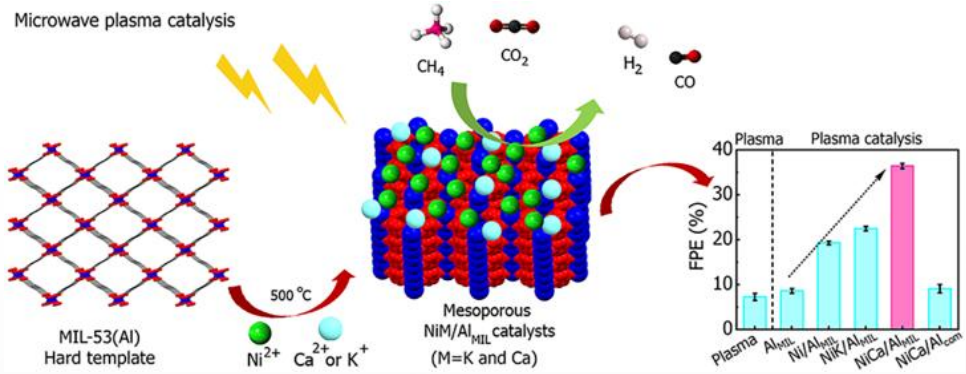
Supaphorn Thammakan[a], Dheerawan Boonyawan[d*], Yothin Chimupala[e], Saranphong Yimklan[f], Arlee Tamman[g], Pimchanok Tapangpan[a], Mudtorlep Nisoa[h], Choncharoen Sawangrat[a, b, c*]

[a] *Department of Industrial Engineering, Faculty of Engineering, Chiang Mai University, Thailand*
[b] *Agriculture and Bio Plasma Technology Center, Science and Technology Park, Chiang Mai University, Thailand*
[c] *Research Center of Plasma Innovation for Sustainable Quality of Life, Chiang Mai University, Thailand*
[d] *Department of Physics and Material Science, Faculty of Science, Chiang Mai University, Thailand*
[e] *Department of Industrial Chemistry, Faculty of Science, Chiang Mai University, Thailand*
[f] *Department of Chemistry, Faculty of Science, Chiang Mai University, Thailand*
[g] *Thailand Institute of Nuclear Technology (Public Organization), Nakhon Nayok, Thailand*
[h] *School of Science, Walailak University, Nakhonsrithammarat, Thailand*

*Corresponding Author's E-mail: *Choncharoen@step.cmu.ac.th and dheerawan.b@cmu.ac.th*

**Abstract**

Microwave plasma-catalyzed dry reforming of methane (DRM) offers an innovative strategy for the conversion of $CO_2$ and $CH_4$ into syngas, highlighting the necessity for the development of novel catalysts. This study investigates the comparative efficacy of alkaline (e.g., K) and alkaline earth (e.g., Ca) promoters in enhancing the catalytic performance. The $Ni_5M_{2.5}/AlMIL$ (M = K, Ca) catalysts derived from MIL-53(Al) were synthesized and employed in the plasma-assisted DRM process. Among the catalysts evaluated, $Ni_5Ca_{2.5}/Al_{MIL}$ exhibited exceptional activity and synergy with plasma, achieving a fuel production efficiency (FPE) of about 36%. This catalyst demonstrated a $CO_2$ conversion of 53.5%, a $CH_4$ conversion of 43.4%, a CO selectivity of 56.5%, and a $H_2$ selectivity of 86.7%, resulting in CO and $H_2$ yields of 25.9 and 39.1%, respectively. The significant enhancement in catalytic efficiency can be attributed to several factors: improved reducibility, stronger metal-support interactions (MSI), increased basicity, facilitated the formation of oxygen vacancies, and diminished carbon deposition. These attributes collectively facilitate the enhanced adsorption and activation of reactive species, thereby optimizing the synergy between plasma and catalysts in the DRM process. Moreover, the mesoporous AlMIL support contributes to a larger surface area and improved dispersion of active metals, effectively mitigating the limitations typically associated with conventional supports. Notably, the variation of the $H_2/CO$ ratio from 4.0 to 1.9 can be linked to the modulation of CO selectivity influenced by the MSI and basicity of the catalysts. This study underscores the potential of tailored catalysts in enhancing the efficiency of the microwave plasma-catalyzed DRM process.




**Keywords:** MOFs-derived porous $Al_2O_3$, Ni-based catalyst, Calcium loading, dry reforming of methane (DRM), microwave plasma catalysis

# Frictional behavior of carbon coatings in extreme temperature environments

Park Hyunjun[a,*], Kim Jin-Young[b], Lee HanChan[c]

[a]*Korea Institutie of Industrial Technology, Seohaean-ro 113-58, South Korea,*
[b]*Korea Institutie of Industrial Technology, Seohaean-ro 113-58, South Korea,*
[c]*Author3's EMS Inc., Gojan-dong 695, South Korea*

*Corresponding Author's E-mail: jun79s@kitech.re.kr

**Abstract**

Carbon coatings such as DLC are widely used in semiconductors, drive components, and tools that require low friction characteristics. Above the conventional semiconductor parts such as the electrostatic chuck, wafer carrier etc. are coated with Diamond-Like Carbon (DLC) as the process temperature remains below 200°C. However, with the rise in process temperatures beyond 200°C due to increasing integration density, the carbon coating like DLC tend to degrade, revealing limitations in thermal durability. As a result, a coating that retains the mechanical properties of the carbon coating while offering enhanced thermal resistance is required. In this study, the carbon coatings were deposited using Plasma-Enhanced Chemical Vapor Deposition (PECVD) at a temperature of 450°C to achieve both the inherent properties of DLC and improved thermal resistance. The coating thickness was controlled to be below 3 μm, and uniformity was ensured throughout the film. Consequently, the coating demonstrated thermal stability up to 400°C. Also, the coating has shown low friction in subzero temperature.

**Keywords:** Semiconductor, Carbon coating, Low friction, Thermal resistance, PECVD

# High-reliability real-time $CO_2$ quantitative monitoring system using infrared sensor cluster and pre-treatment module

Jin-Young Kim[a], Hyunjun Park[a,*]

[a]*Korea Institute of Industrial Technology, 113-58, Seohaean-ro, Siheung-si, Gyeonggi-do, 15014 Republic of Korea.*

*Corresponding Author's E-mail: jun79s@kitech.re.kr

**Abstract**

As global carbon neutrality policies accelerate in response to the climate crisis, the importance of technologies that precisely monitor and quantify greenhouse gas emissions in industrial process equipment is growing rapidly. In particular, since process exhaust gases are often characterized by high temperature, humidity, and irregular flow rates, conventional monitoring methods suffer from significant measurement errors due to environmental variables. To effectively comply with industrial emission regulations, it is essential to establish high-reliability gas analysis systems that integrate sample pre-treatment and pressure correction algorithms.

In this study, a real-time carbon dioxide ($CO_2$) monitoring system was designed and implemented to maximize measurement precision. To ensure accurate data acquisition, a cluster of three different NDIR sensors with varying detection ranges and sensitivities was configured. Furthermore, a pre-treatment module consisting of a cooler, a compressor, and a pressure sensor was integrated to optimize the state of the incoming sample gas.

The developed system minimizes sensor drift by removing moisture and maintaining constant pressure through cooling and compression stages. In particular, by applying a correction algorithm based on real-time data from the pressure sensor, the system enables the quantitative calculation of actual gas generation rates in mass units beyond simple concentration (ppm) measurements. Experimental results demonstrated higher reliability compared to single-sensor configurations through cross-verification of multi-sensor data. The findings suggest that this system serves as a cost-effective and high-efficiency solution for real-time gas emission management in industrial environments.

**Keywords:** Carbon dioxide ($CO_2$), Carbon neutrality, Infrared sensors, Real-time monitoring, Quantitative gas analysis

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เพื่อให้ลูกค้าของบริษัทฯได้รับความพึงพอใจสูงสุด บริษัทฯได้มีการพัฒนาประสิทธิภาพในการให้บริการแก่ลูกค้า โดยได้มีการนำระบบ **คุณภาพมาตรฐาน ISO 9001:2015** มาใช้ในการบริหารงาน และบริษัทฯ ยังสามารถให้ **บริการสอบเทียบเครื่องมือตามมาตรฐาน ISO/IEC 17025 :2005** สำหรับเครื่อง UV-VIS Spectrophotometer และเครื่อง Universal Testing Machine และจะขยายขอบเขตเพื่อให้ ครอบคลุมการสอบเทียบเครื่องมือชนิดอื่นๆต่อไป

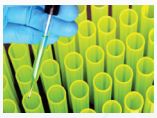
และการที่ บริษัท พาราไซแอนติฟิค จำกัด เป็นบริษัทใน **กลุ่มบริษัท พาราวินเชอร์ จำกัด** ซึ่งเป็นองค์กรขนาดใหญ่ชั้นนำของประเทศ ทำให้บริษัทฯ มีศักยภาพสูง สามารถให้บริการลูกค้าได้ทุกระดับ ซึ่งรวมถึงการจัดซื้อ ที่เป็นโครงการขนาดใหญ่

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# Enhance your materials analysis with Auto Cross Section Software for Thermo Scientific FIB-SEMs


## Author

Bartlomiej Winiarski


Focused ion beam scanning electron microscopes (FIB-SEMs), such as the Thermo Scientific™ Scios™ 3 FIB-SEM, are frequently used for the preparation of cross-sections; the FIB is used to remove bulk material while the SEM can visualize the process and the resulting cross-sectioned surfaces. This reveals features that are otherwise hidden under the surface of the sample, helping to unravel critical characteristics of materials.

Thermo Scientific Auto Cross Section (AXS) Software is a dedicated solution for automated FIB cross-sectioning and site imaging with SEM at multiple scales and resolutions. It can be used to define multiple sites on multiple specimens, to perform the subsequent automated cross-sectioning/imaging, and it will save the recorded SEM images produced during the process.

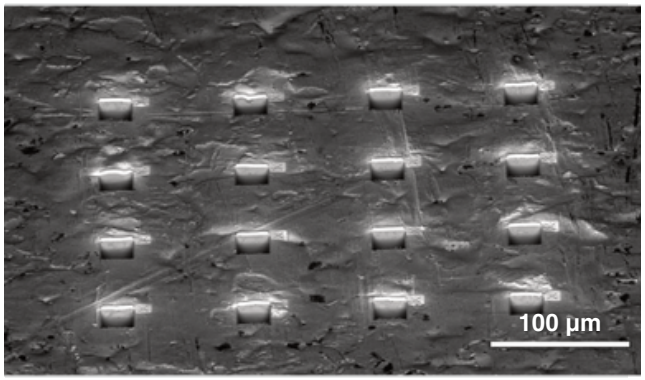



Figure 1. Scanning electron microscopy image of a cross-section array created on a Zn-Mg-Al-coated low-carbon steel. Cross-sections were generated automatically with AXS Software in a Scios 3 FIB-SEM.

In this way, AXS Software provides significant time-saving and efficiency improvements, enabling industrial and academic users to complete their tasks more quickly in order to focus on the critical analysis that follows. It also removes the complexity of operating a FIB-SEM instrument, allowing even users with minimal experience to acquire high-quality data.

Automation routines guarantee reproducibility and consistency, helping to ensure that each cross-section is prepared
accurately for reliable and consistent results. Additionally, automation can reduce user bias and error while also improving safety, making the entire cross-sectioning workflow more dependable and secure, especially in industrial environments.

## Zinc-based automotive coating

Zinc-based coatings are extensively utilized in the automotive industry to enhance corrosion resistance and to extend the durability of steel components that are exposed to harsh atmospheric conditions. These coatings act as protective layers, preventing the oxidation of the underlying steel, and are applied through methods such as hot-dip galvanization
and electroplating.

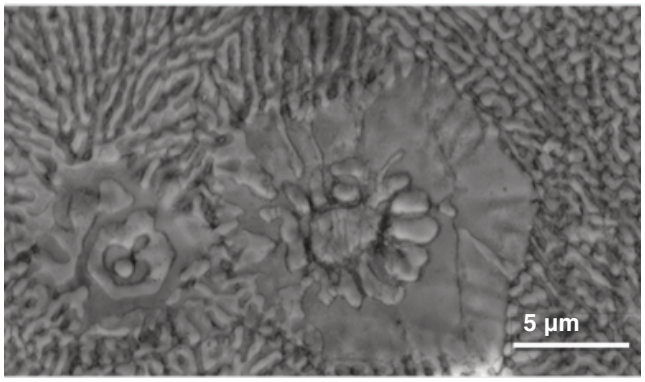



Figure 2. SEM imaging showing the surface features of a Zn-Mg-Al automotive coating.

Microstructural analysis of Zn-Al-Mg coatings is often challenging due to the complexity and varying scales of the developed structures. For instance, primary zinc dendrites can be large, with diameters exceeding 100 µm, while the eutectic phase structures can be significantly smaller, with diameters around 100 nm. Therefore, it is essential to have access to an array of large cross-section SEM images (Figure 1 and 3) at multiple magnifications and at high resolution (Figure 4).

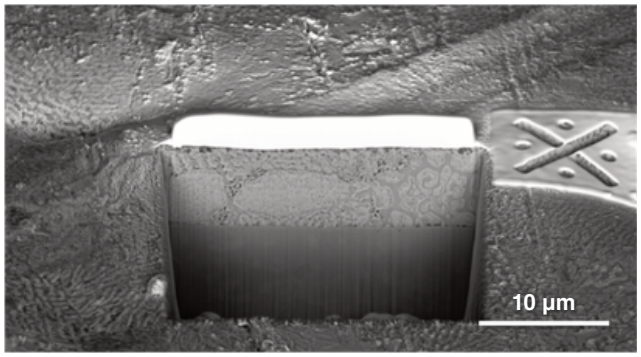



Figure 3. SEM image showing a cross-section automatically created by AXS Software on a Zn-Mg-Al-coated low-carbon steel.

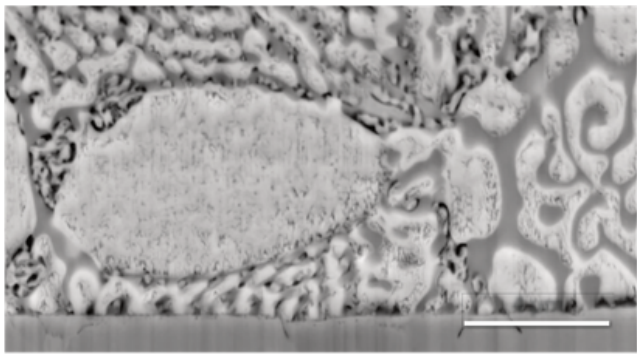


Figure 4. SEM tilt-corrected image showing microstructural features of the Zn-Mg-Al coating on the low-carbon steel substrate.

## Conclusions

Thermo Scientific Auto Cross Section Software, powered by the outstanding performance of the Scios 3 FIB-SEM, provides a precise and efficient solution for the analysis of zinc-based coatings. By enabling detailed cross-sectional imaging and analysis, the software aids in the assessment of coating thickness and uniformity, the evaluation of adhesion quality, and the detection of defects and inconsistencies. This method can help ensure the reliability and longevity of zinc-coated steel components in the automotive industry, facilitating proactive quality control and maintenance.

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