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UNIVERSIDADE DE MACAU
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應用物理及材料工程研究院
INSTITUTO DE FÍSICA APLICADA E ENGENHARIA DE MATERIAIS
INSTITUTE OF APPLIED PHYSICS AND MATERIALS ENGINEERING

IAPME Newsletter

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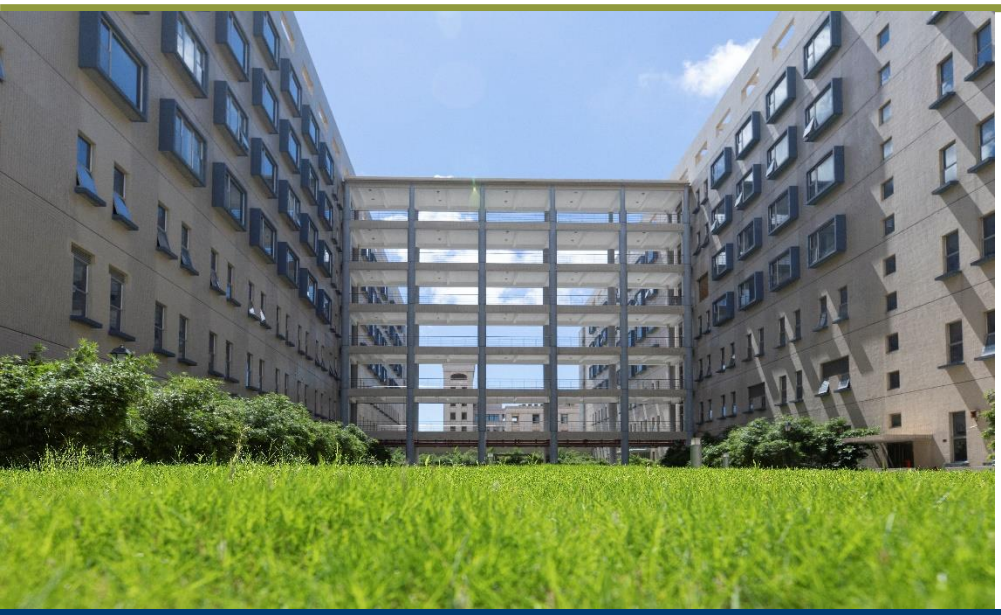

ISSUE 18

22 January 2025

✧ Content

❖ Publications (IF≥8; *corresponding author)

1. **Shengyang Dong**, Ruiqi Ren, Jingyuan Zhang, Xiaozhi Bao*, Xin Liu, Qiuwei Shi, Zhijie Chen*, and **Huaiyu Shao***. High-entropy oxides: Emergent materials for electrochemical energy storage and conversion. *Journal of Materials Science & Technology* (2024). DOI: 10.1016/j.jmst.2024.11.065 [2023 IF=11.2]

2. **Qian Zhao**, Kaitong Sun, Si Wu, and **Hai-Feng Li***. Crystal, ferromagnetism, and magnetoresistance with sign reversal in a EuAgP semiconductor. *Journal of Materiomics* **11(1)**, 100853 (2025). DOI: 10.1016/j.jmat.2024.02.012. [2024 IF=8.4]

Journal Pre-proof

High-entropy oxides: Emergent materials for electrochemical energy storage and conversion

Shengyang Dong , Ruiqi Ren , Jingyuan Zhang , Xiaozhi Bao , Xin Liu , Qiuwei Shi , Zhijie Chen , Huaiyu Shao

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Research paper

Crystal, ferromagnetism, and magnetoresistance with sign reversal in a EuAgP semiconductor

Check for updates

Qian Zhao [a], Kaitong Sun [a], Si Wu [b], Hai-Feng Li [a, *]

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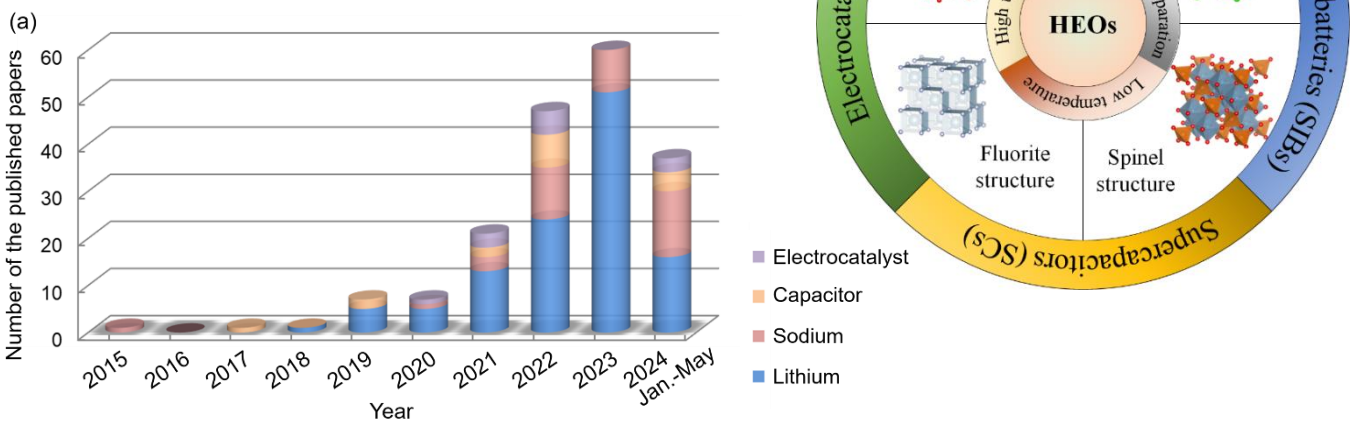
❖ Research Stories

UM research team reviewed high-entropy oxides for electrochemical energy storage and conversion

- High-entropy materials (HEMs), especially high-entropy oxides (HEOs), have gained significant interest over the years due to their unique structural characteristics and correlated possibilities for tailoring of functional properties. HEOs emerged as a field of research in 2015, when the first research on entropy-stabilized oxides was published. Over the past ten years, various advanced HEO materials have been developed to improve the performance for energy storage and conversion applications.
- The team reviewed the recent achievements, challenges, and opportunities of HEOs in electrochemical energy storage and conversion applications including lithium-ion batteries (LIBs), sodium-ion batteries (SIBs), electrochemical capacitors (ECs) and electrocatalysis, etc. This review highlights the fundamental understanding and preparation methods of HEOs. The fundamental science behind the challenges and potential solutions are also discussed in detail.

(From left) Dr. Shengyang Dong and (middle) Prof. Huaiyu Shao



Shengyang Dong, Ruiqi Ren, Jingyuan Zhang, Xiaozhi Bao*, Xin Liu, Qiuwei Shi, Zhijie Chen*, and **Huaiyu Shao***. High-entropy oxides: Emergent materials for electrochemical energy storage and conversion. *Journal of Materials Science & Technology* (2024). DOI: 10.1016/j.jmst.2024.11.065 [2023 IF=11.2]

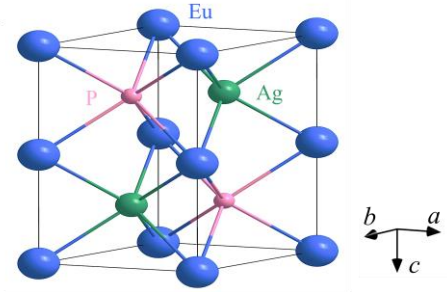
Prof. Huaiyu Shao, Dr. ZhiJie Chen and Dr. Xiaozhi Bao are the corresponding authors of this study. The first author is Dr. Shengyang Dong, who is a Macao Young Scholar in IAPME from 2023. This work was supported by the Macau Science and Technology Development Fund (FDCT) for funding (FDCT-MOST joint project No. 0026/2022/AMJ, project No. 0098/2020/A2, and No. 006/2022/ALC of the Macao Centre for Research and Development in Advanced Materials (2022-2024)), Natural Science Foundation of Guangdong Province. (No. 2023A1515010765), the Shenzhen-Hong Kong-Macau Science and Technology Plan Project (Category C) (Grant No. SGDX20220530111004028), Science and Technology Program of Guangdong Province of China (No. 2023A0505030001), the National Natural Science Foundation of China (No. 52102264), Leading Edge Technology of Jiangsu Province (BK20220009), and the Macao Young Scholars Program (No. AM2022009).

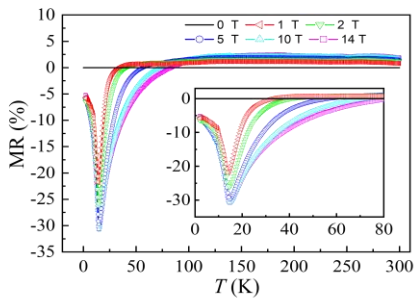
❖ Research Stories

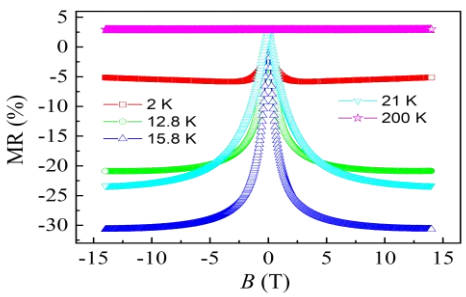
UM Research Team Unveils Advanced Properties of EuAgP Semiconductor

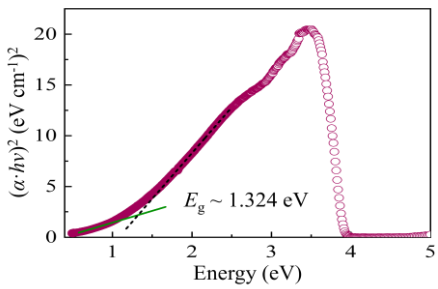
(From left) Dr. Qian Zhao and Prof. Hai-Feng Li

- Innovative Synthesis and Analysis: The research team at the Institute of Applied Physics and Materials Engineering (IAPME) at the University of Macau has synthesized and thoroughly analysed the ferromagnetic semiconductor EuAgP. This study marks a significant advancement in understanding the material's crystalline structure, magnetic behaviour, heat capacity, band gap, and magnetoresistance properties.
- EuAgP adopts a hexagonal structure with the P63/mmc space group.
- The material transitions from high-temperature paramagnetism to low-temperature ferromagnetism with a Curie temperature (T_C) of 16.45(1) K.
- Analysis revealed an electronic heat capacity coefficient (γ) of 0.03 J/(mol·K^2), indicative of its semiconducting nature.
- An intriguing shift from positive to negative magnetoresistance was observed as temperature decreases.
- Significance for Spintronics: The observed behaviours in EuAgP suggest its potential applications in spintronics, a field where the spin of electrons, rather than their charge, is used to create new electronic devices.









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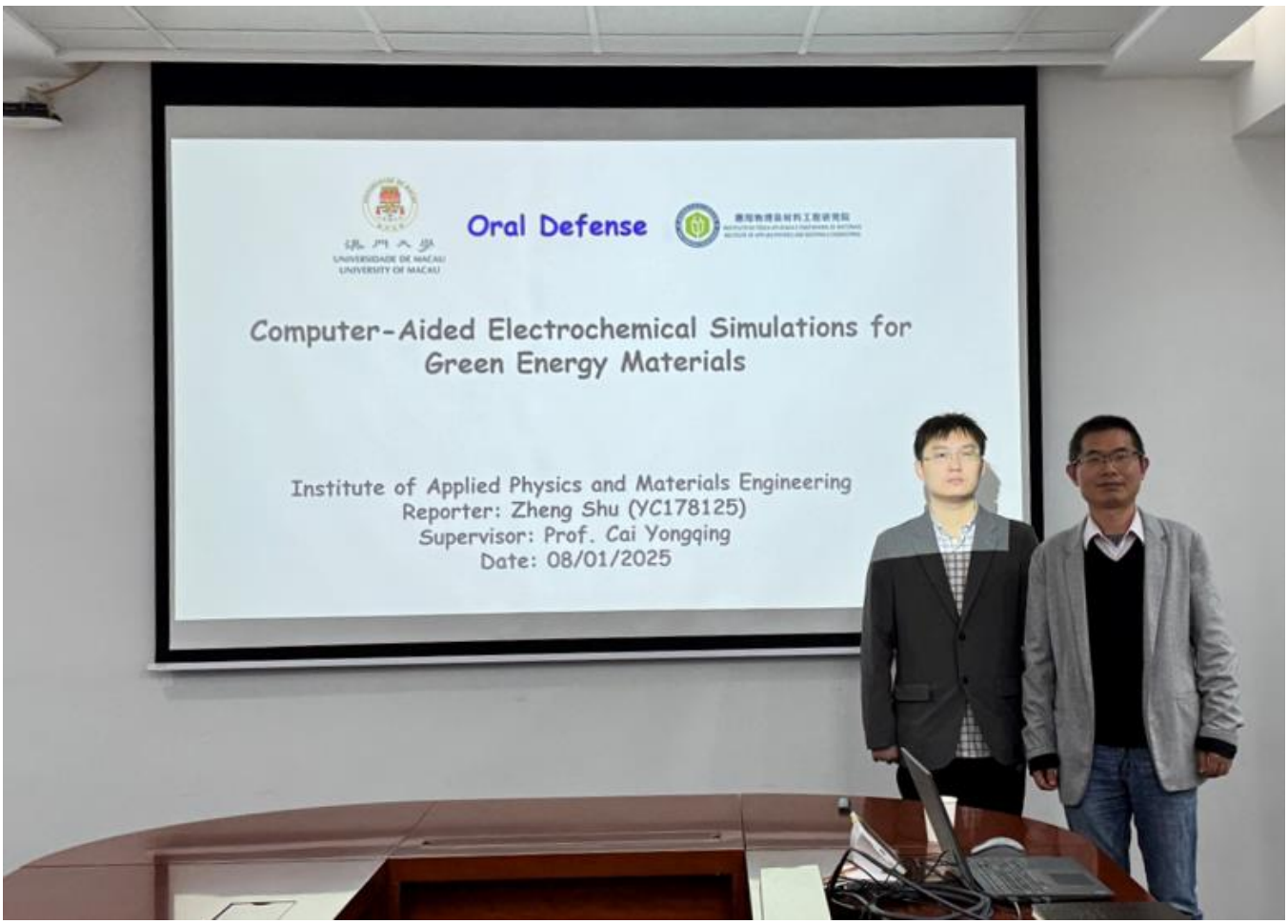
Prof. Hai-Feng Li served as the corresponding author, guiding the research with his expertise in materials science. Dr. Qian Zhao, who was a Ph.D. student from IAPME, led the experimental work and data analysis. This work was supported by the Science and Technology Development Fund, Macao SAR (File Nos. 0090/2021/A2 and 0049/2021/AGJ), University of Macau (MYRG2020-00278-IAPME), and the Guangdong-Hong Kong-Macao Joint Laboratory for Neutron Scattering Science and Technology (Grant No. 2019B121205003).

❖ Ph.D. Student Thesis Oral Defenses

Zheng Shu of Prof. Yongqing Cai's group presented "Computer-Aided Electrochemical Simulations for Green Energy Materials" in his oral defense on January 8, 2025.

Congratulations to Dr. Zheng Shu!



(from left) Dr. Zheng Shu and Prof. Yongqing Cai

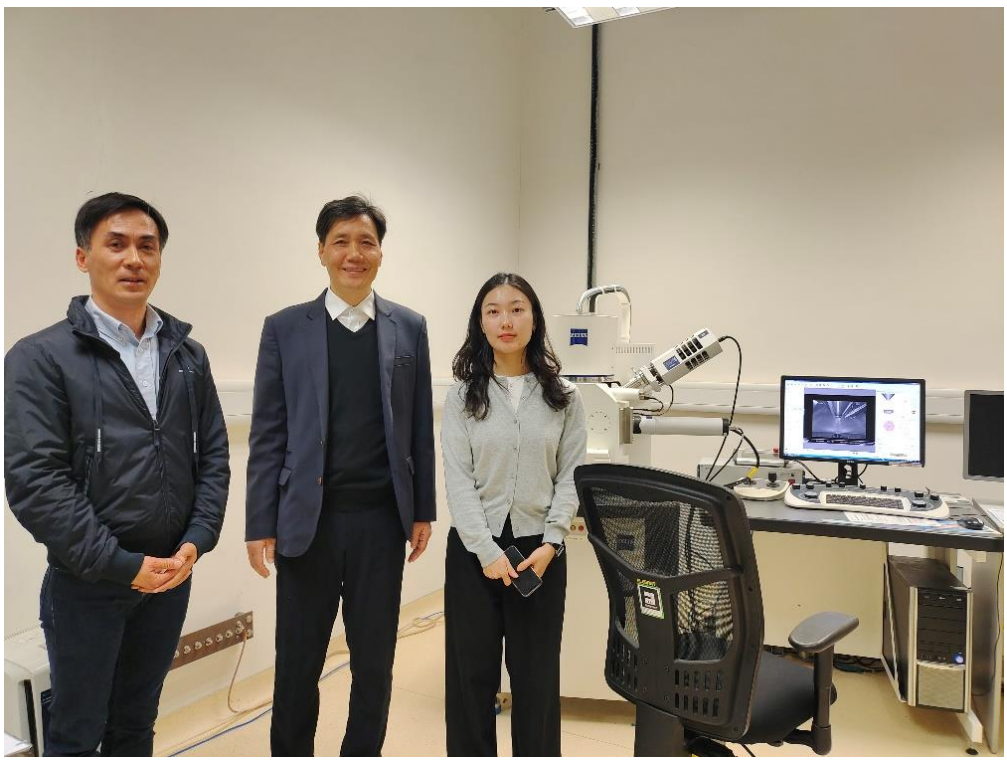
❖ Seminars

Prof. Hyun-Seog Roh, Director of the BK 21 FOUR project and Full Professor of the Department of Environmental and Energy Engineering at Yonsei University in Wonju, South Korea, visited IAPME on January 9, 2025. During his visiting, IAPME research team and him had a fruitful discussion for the collaboration between two groups, especially on new and renewable energies, such as green hydrogen production. Prof. Roh gave a talk on "Current research trends for target-oriented WGS reactions dealing with diverse types of resources".

Prof. Hyun-Seog Roh received his Ph.D. in Chemical Engineering from Yonsei University in Seoul, South Korea, in 2001. He began his career at Yonsei University in 2008, after a research career at the Korea Research Institute of Chemical Technology, Pacific Northwest National Lab. In Richland, and the Korea Institute of Energy Research. Prof. Roh serves on the editorial boards of Journal of CO2 Utilization, Catalysts, and Applied Sciences. His achievements include the publication of more than 237 papers in scientific literature and 29 patents. For the fourth consecutive year, he has been named in the world's top 2 percent of scientists list selected by Professor John Ioannidis from Stanford University published in PLOS Biology. His research interests are primarily in environmental catalysis, including catalyst design, manufacture, characterization, and application, as well as reactor design for hydrogen production through reforming and the water-gas shift reaction.

During the talk, Prof. Roh mentioned that green hydrogen is receiving special attention, and research on upcycling energy resources, including natural gas, coal, waste, and biomass, is in the spotlight. Catalytic reactions are often essential for producing high-value chemicals from these resources. The water–gas shift (WGS, CO + H2O → CO2 + H2) reaction is one of the most useful catalytic pathways for upcycling various types of synthesis gas. Currently, the application range of WGS reactions has further expanded to the upcycling of waste, biomass, and coal-derived synthesis gas. However, the reaction conditions and catalysts should be carefully customized for each resource by considering their characteristics. Prof. Roh presented his research on the reaction conditions and catalysts for the WGS reactions that have dealt with various types of feed gases over the last 10 years to understand the development progress. Based on the categorization (by the type of feed gas), the tested catalysts, capacity, temperature, feed gas composition, steam-to-carbon ratio, and catalyst performance were systematically discussed. The current research trends and perspectives for target-oriented WGS reactions in each type of feed gas source, which can give clues for customization were given at the end of his talk.

Moreover, a fruitful discussion was conducted between IAPME members and Prof. Roh, covering the possibility of strengthening the connection between the University of Macau and Yonsei University in the future. After the discussion, Prof. Roh had lab and campus tours.



❖ Upcoming Events

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IAPME Seminar

Design and synthesis of functional molecular materials and their application in high-efficiency perovskite solar cells

24 January 2025

Prof. Xingzhu WANG
University of South China
Venue: N23-3022
Time: 10:00 - 11:00
Hosted by: Prof. Shi CHEN

Abstract

Commercialized perovskite solar cells not only need to have high PCE, but also need to have long time stability, low cost, and can be prepared by green and scalable processes. Rational composition design and interface modulation are the effective approaches to achieve these goals, and I will present several recent works of our research group in these aspects. Through introducing GABr into the perovskite material to suppress the oxidation of Sn^{2+} ions, we have prepared the ideal-bandgap Sn/Pb (1.35eV) perovskite solar cells with PCE of 20.6% and Voc loss of 0.33V, which is the lowest Voc loss reported so far. Then we combined the ideal-bandgap perovskite layer with DTBTI organic absorb layer, we prepared the integrated ideal-bandgap perovskite/bulk-heterojunction solar cell with PCE of 24.3%, which is the record efficiency for bulk-heterojunction solar cells. We also developed the CTAC/IPA based green anti-solvent method and prepared the solar cells with PCE of 23.4% and with excellent environmental, light, and thermal stabilities. Further, we added perovskite micro-crystals into the precursor solution to induce and control the crystallization process, we can obtain perovskite solar cells with PCE of 23.06% without using any anti-solvents. In addition, we doped p-type semiconducting material Cu(Tu)Cl into perovskite to modify its energy band, we got solar cells with PCE of 22% without using hole transport layer, which greatly simplified the device structure and thus lower down the cost. Finally, through using an SAM material to effectively modify the interface between perovskite and HTL, we obtained the solar cells with the best PCE of 26.5% and the certified PCE of 26%.

Biography

Prof. Xingzhu Wang works at the University of South China as a Chair Professor and obtained his Ph.D. degree from the Hong Kong Baptist University in 2009. After postdoctoral work at the University of Cambridge and Nanyang Technological University, he joined the National University of Singapore from 2013 to 2017 as a senior research fellow. He joined SUSTech in 2018 as an Associate Professor and was promoted to Full Professor in 2020. His current research interests relate to organic-inorganic synthesis, organic-inorganic semiconductors, and optoelectronic devices. He obtained 30 financial projects and had published 170 SCI scientific papers in high-quality and high-impact international journals including Science., Nat. Mater., Joule, J. Am. Chem. Soc., Angew. Chem., Adv. Mater., Adv. Energy Mater., Adv. Funct. Mater. The published papers had been cited by more than 5,000 times. He has 30 authorized patents. He has won more than 6 national and provincial science and technology awards.

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