Materials Advances

EDITORIAL

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Cite this: *Mater. Adv.*, 2025, **6**, 8207

Advances in energy generation and conversion technologies

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DOI: 10.1039/d5ma90079d

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We are delighted to introduce this themed collection of *Materials Advances*, entitled "Advances in Energy Generation and Conversion Technologies." This curated collection highlights contemporary research addressing global energy challenges through innovations in materials science, electrochemistry, nanotechnology, and environmental engineering. As the world seeks to transition toward more sustainable energy systems, the development of new materials and conversion technologies remains at the heart of scientific and technological progress. This themed collection features ten high-quality research papers that exemplify the multifaceted nature of modern energy research. These contributions span a wide array of methodologies, materials systems, and application areas, from photocatalytic hydrogen production

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Shiv Singh

Dr Shiv Singh is currently working as a Sr. Scientist and Assistant Professor in the CSIR-Advanced Materials and Processes Research Institute, India. He has received his PhD degree from Indian Institute of Technology Kanpur, India in Chemical Engineering. He has expertise in the synthesis of novel carbon-based nanomaterials (CNFs/CNTs/CNPs/Graphene/C-dots) for biochemical and energy applications. He has done post-doctoral research at the Korea Institute of Materials Science, South Korea. Currently, he is working on electrode materials for bio/electrochemical reduction of CO_2 *to value-added products and bio-energy, overall water splitting and chemical vapor deposition processes. Dr Singh also received Seal of Excellence certificates from Marie Skłodowska-Curie actions call H2020-MSCA-IF of the European Commission and the DST INSPIRE faculty award. Additionally, Dr Singh is a Community Board Member of RSC Materials Horizons, an Early Career Board Member of Springer Nano-Micro Letters and Wiley's Energy & Environmental Materials, and serves as an Editor for Scientific Reports.*

Bo Weng

Dr Bo Weng is currently a Professor at the Institute of Urban Environment, Chinese Academy of Sciences. He earned his PhD in Physical Chemistry from Fuzhou University, China, in 2018. Following his doctorate, he pursued postdoctoral research at Xiamen University and KU Leuven, supported by the European Union's Horizon 2020 program under the Marie Skłodowska-Curie Actions (Individual Fellowships) and the Research Foundation – Flanders (FWO) Postdoctoral Fellowships. His research primarily focuses on photo-assisted AOPs for environmental remediation. He has published 90 papers, achieving an h-index of 39 and 6300 citations (Google Scholar). As the first author or corresponding author, he has published 44 papers including in Nat. Rev. Clean Technol., Angew. Chem., Adv. Mater., and Nat. Commun. He has been invited to serve as a (Young) Editorial Board Member of NPJ Clean Water (IF 10.4), Chem (IF 19.1), Carbon Energy (IF 19.5), EcoMat (IF 10.4), Nexus, EcoEnergy, etc. He also serves as a reviewer of Nat. Water, Nat. Commun., J. Am. Chem. Soc., Angew. Chem., Adv. Mater., etc.

and electrocatalysis to flexible photovoltaics, sodium-ion batteries, and sustainable materials engineering. Collectively, these papers offer new insights into overcoming long-standing challenges, namely efficient, scalable, and environmentally responsible energy generation.

For instance, Srivastava *et al.* explore the use of magnetic separation and catalytic degradation strategies for the removal of microplastics from both aquatic and terrestrial environments. This dual-function approach not only enhances separation efficiency but also mitigates the long-term environmental persistence of plastic waste (**https://doi.org/10.1039/D4MA01242A**). Kwati *et al.* develop a scalable tape-casting method to fabricate durable protonic electrolysis half-cells for hydrogen production at moderate temperatures. Cells with impressive volume, featuring dense $BaZr_{0.44}Ce_{0.36}Y_{0.2}O_{3-\delta}$ electrolytes and NiO–$SrZr_{0.5}Ce_{0.4}Y_{0.1}O_{3-\delta}$ fuel electrodes, achieve stable performance with minimal defects. This research advances cost-effective manufacturing of efficient proton-conducting electrolysis cells (**https://doi.org/10.1039/D5MA00028A**). Another study by Dhanka *et al.* investigates the electrocatalytic performance of Ag/CeO_2 nanocomposites, where the deliberate introduction of oxygen vacancies is shown to reduce overpotentials significantly during both the oxygen evolution reaction (OER) and hydrogen evolution reaction (HER) (**https://doi.org/10.1039/D5MA00321K**). These findings contribute to the growing field of bifunctional electrocatalysts aimed at improving the efficiency of water-splitting systems.

The work done by Dhanasekar *et al.* for advancements in photovoltaics is also featured. The work presents the low-temperature atmospheric pressure plasma jet (APPJ) printing of Kesterite (Cu_2ZnSnS_4) on flexible substrates, representing a leap forward in the fabrication of lightweight and flexible heterojunction solar cells (**https://doi.org/10.1039/D5MA00207A**). The combination of low-cost materials with adaptable processing techniques promises new pathways toward sustainable, roll-to-roll solar-panel production.

In the realm of photocatalysis, Jaksani *et al.* report a bimetallic Ni and Co system embedded in a CuBTC metal–organic framework (MOF) that demonstrates superior hydrogen generation under light irradiation. The synergistic interaction between the two metals and the MOF architecture enhances charge separation and redox kinetics, offering a scalable method for green hydrogen production (**https://doi.org/10.1039/D4MA01243G**). This collection also includes a comprehensive study by Yadav *et al.* for making a promising low-cost cathode for Li-ion batteries using $Li_{0.44}Mn_{0.89}Ti_{0.11}O_2$. It enhances its electrochemical performance by improving Li^+ diffusivity and rate kinetics. Structural analyses

Pradip Kumar

Dr Pradip Kumar is a Principal Scientist at CSIR-AMPRI, and an Assistant Professor at AcSIR, Bhopal, India. He received his PhD degree from the School of Physical Sciences, Jawaharlal Nehru University, New Delhi, India. After postdoctoral research at KAIST and KIST, Seoul, South Korea, he joined BARC, Mumbai and Central University of Rajasthan, Ajmer, India, as DST Inspire Faculty. His research interests focus on 2D materials and composites for hydrogen energy storage, thermal management and EMI shielding applications.

Neeraj Dwivedi

Dr Neeraj Dwivedi is presently a Principal Scientist at the CSIR-Advanced Materials and Processes Research Institute, and an Associate Professor at AcSIR, Bhopal, India. He obtained his PhD in 2013 from the Department of Physics, Indian Institute of Technology Delhi, India. He then worked as a postdoctoral fellow between 2013 and 2019 at the National University of Singapore, Singapore. His research interests include interface engineering, carbon nanocoatings, 2D materials such as graphene-based materials, MXenes, metal oxides and nitrides, and polymer composites for electronic, optoelectronic, energy, sensing and mechanical applications.

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Dr Akshay Modi is an Assistant Professor in the Department of Chemical Engineering at the Indian Institute of Science Education and Research (IISER) Bhopal, Madhya Pradesh, India. His academic journey includes earning a BTech degree in Chemical Engineering from the National Institute of Technology Srinagar, India, in 2013, followed by an MTech degree from the Indian Institute of Technology Kanpur, India, in 2015, and a PhD in Chemical Engineering from the Indian Institute of Technology Bombay, India, in 2020. With a broad spectrum of research interests, Dr Modi specializes in membrane science and technology, nanostructured materials, energy devices, water reclamation, gas separations, and biomedical engineering. Dr Modi has received several awards for his outstanding contributions to research.

confirm successful Ti incorporation without disrupting the original framework, enabling a solid-solution redox mechanism (https://doi.org/10.1039/D5MA00455A).

Another innovative approach by Husaain *et al.* involves the modification of rutile TiO_2 using Pd cocatalysts and the formation of Schottky junctions to direct charge flow, thereby enhancing photocatalytic hydrogen production. The integration of noble metals and heterojunction interfaces offers an effective strategy for tuning surface energetics and catalytic activity (https://doi.org/10.1039/D4MA01288G).

The field of electrocatalysis is further enriched by Kumar *et al.*, focusing on 2D monolayer molybdenum(IV) telluride, a transition metal dichalcogenide (TMD) that exhibits high catalytic activity for the hydrogen evolution reaction. The monolayer structure ensures a high surface area-to-volume ratio and favorable electronic properties, making it a strong candidate for future electrochemical energy devices (https://doi.org/10.1039/D4MA00892H).

Expanding into computational approaches, the paper by Na *et al.* demonstrates how large language model (LLM)-driven data mining techniques can be applied to layered cathode materials for sodium-ion batteries. This integration of artificial intelligence with materials discovery accelerates the identification of promising electrode chemistries, offering a paradigm shift in battery research (https://doi.org/10.1039/D5MA00004A).

The collection concludes with a contribution by Prajapat *et al.* that examines the use of anthocyanin-sensitized, Cu-doped TiO_2 nanoparticles in dye-sensitized solar cells (DSSCs). These natural dye-based systems not only reduce environmental impact but also provide cost-effective alternatives to traditional solar harvesting materials (https://doi.org/10.1039/D4MA01297F).

The broader scope of this themed collection also encompasses emerging research areas such as microbial fuel cells, carbon-based electrocatalysts derived from waste, and the use of sustainable, bio-derived materials in energy systems. The scientific community is increasingly interested in microbial fuel cell designs that enable simultaneous energy production and wastewater treatment. Similarly, converting agricultural residues, food waste, and vehicular soot into functional carbon-based electrocatalysts offers a dual benefit of waste valorisation and sustainable energy conversion. Next-generation technologies are also critically examined, including innovations in solid-state batteries, lithium-sulfur and aluminum-ion batteries, hydrogen fuel cells, as well as perovskite and tandem solar cells. The integration of nanomaterials such as graphene, MXenes, and metamaterials continues to revolutionize the efficiency, scalability, and adaptability of energy systems. Overall, this themed collection is prepared to cover a wide research audience in the area of energy materials, including nanomaterials, energy generation, and conversion.

We also extend our sincere thanks to Dr Zifei Lu, Assistant Editor at the Royal Society of Chemistry, for her contributions in the editorial process.

Together, these contributions reflect the dynamism, depth, and interdisciplinary nature of research at the intersection of materials science and sustainable energy. We hope this collection inspires future collaborations and accelerates the development of next-generation solutions for a cleaner, more energy-secure world.

On behalf of the Guest Editors and the editorial board of *Materials Advances*, we thank all authors, reviewers, and readers for their dedication and support in bringing out this themed collection.