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EDITORIAL

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Special issue on electrochemical energy storage and conversion

The escalating global consumption of fossil fuels has significantly elevated the levels of CO_2 in the atmosphere, leading to an undesirable global energy crisis and environmental degradation. Rapid deployment of renewable energy resources is crucial to mitigate these challenges. In recent years, there has been noteworthy progress in electrochemical energy storage and conversion techniques and devices, including hydrogen energy and fuel cells, advanced energy storage and power batteries, and CO_2 electrochemical conversion and utilization. Meanwhile, the artificial intelligence (AI) technology is gaining prominence in the energy sector, garnering significant attention and paving a promising path toward efficient energy conversion and utilization. Furthermore, energy material research and engineering verification play a pivotal role in advancing industrialization. Each of these technologies has yielded a series of encouraging advances. To showcase these recent advances, *Frontiers in Energy* is launching a special issue titled "electrochemical energy storage and conversion".

In this thematic issue, seven feature articles, either from invited or selected contributions, have been compiled to collectively illustrate the typical advancements in this field. Among these, the review papers provide invaluable insights into various aspects, including the photocatalytic conversion of CO_2, the design of platinum-based catalyst for oxygen reduction reaction (ORR), the improvement of platinum-based ORR catalyst through strain engineering, the electrochemical ammonia synthesis, the recent progress of Prussian blue (PB) electrodes and devices, the development of sodium transition metal oxide cathodes, and the application of machine learning (ML) in lithium-ion battery.

Semiconductor photocatalysts can harness solar energy and facilitate energy conversion due to their fascinating and tunable optoelectronic properties. In particular, metal oxide-based semiconductor photocatalysts play a crucial role in converting CO_2 into fuels, making a significant contribution to renewable energy. Prakash and coworkers (this issue) reviewed the latest developments based on metal oxide-based tailored semiconductor photocatalysts for photo-electrochemical carbon dioxide conversion. The review specifically explores the general mechanism of CO_2 photo-electrochemical conversion, delving into the design, performance optimization and specific applications of various metal oxide-based emerging hybrid photocatalysts. The review not only sheds light on the current state of the field but also offers valuable insights into the potential future directions for development in this area.

Proton exchange membrane fuel cells (PEMFCs) play a central role in the future sustainable energy system. However, its application is hindered by the sluggish ORR. Herein, Yuan and coworkers (this issue) reviewed single-atomic platinum (Pt)-based catalysts for driving the sluggish kinetics of cathodic ORR in PEMFCs, including the design concepts and synthesis methods. The findings presented in this review contribute significantly to the ongoing research and development of single-atomic Pt-based catalysts. Moreover, Wang and colleagues (this issue) elaborated in detail the improvement of Pt-based ORR catalysts through strain engineering, including the recent advances in the strain effects and strain engineering strategies for ORR

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catalysts. The review not only highlights the current challenges but also outlines future prospects for the modulation of Pt-based catalysts through strain engineering.

The Haber−Bosch process is an ammonia synthesis technology. However, this method is associated with substantial energy consumption and significant environmental pollution. Therefore, there is a pressing need to explore alternative, sustainable routes for ammonia synthesis. Electrochemical synthesis of ammonia emerges as a promising solution, as it allows for the use of solar, wind or hydroelectric power to directly convert nitrogen or nitrate into ammonia, while avoiding the emission of greenhouse gases and toxic gases. In light of this, Cao and coworkers (this issue) undertook a comprehensive review, examining the research progress and challenges in nitrogen/nitrate electrocatalytic reduction for ammonia synthesis. The review covers fundamental mechanisms, representative approaches, and major technologies, and highlights the main challenges and future development directions in this evolving field.

PB has garnered considerable attention as a promising electrocatalytic material among researchers. In their review, Zhang and coworkers (this issue) reviewed the recent progress in PB electrodes and devices, including preparation techniques, and the key strategies employed to enhance the electrochromic (EC) performance of PB electrodes. The review also discusses potential opportunities and obstacles relevant to the development of PB-based electrochromic devices (ECDs). This comprehensive review offers precious insights crucial for the design, fabrication, and practical application of PB-based ECDs.

The electrochemical properties of cathode materials in sodium-ion batteries exhibit more distinct advantages compared to lithium-ion batteries. Despite these advantages, the commercialization progress of sodium-ion batteries is still hampered by the inherent properties of these cathode materials. In a comprehensive review, Zhang and coworkers (this issue) discussed the fundamental principles and strategies for the development of sodium transition metal oxide cathodes. This review offers a new perspective that could facilitate innovative designs in sodium metal oxide cathodes.

Various AI methods have been used in battery modeling to improve the efficiency, stability and reliability of batteries. In their review, Qi and coworkers (this issue) assessed the value of AI methods in lithium-ion battery health management, with a specific focus on ML to lithium-ion battery state of health (SOH). The review also highlights the advantages and strengths of neural network (NN) methods. In anticipation, AI methods are poised to make substantial contributions to battery management.

We are grateful for the opportunity to edit this special issue and hope that this collection serves as a valuable resource for readers interested in electrochemical energy storage and conversion. Our sincere gratitude is extended to all the authors for their contributions and to the reviewers for their dedicated efforts in reviewing the manuscripts. Special thanks are also extended to the Editorial Office of *Frontiers in Energy* for their unwavering support and tireless efforts in bringing this special issue to fruition.

Editor’s Bio-Sketches:

Dr. Yun ZHENG is a full professor at the School of Materials Science and Engineering at Fuzhou University, China. He received his Ph.D degree in Chemical Engineering and Technology from Tsinghua University in China from 2015 to 2019, and did his postdoctoral training at the University of Waterloo in Canada from 2019 to 2022. In 2023, he was promoted to full professor at Fuzhou University. His research interest is the development of solid-state electrochemical energy materials, especially for solid-state lithium metal batteries, high-temperature proton exchange membrane fuel cells, and solid oxide cells. He has published more than 70 international journal papers and 2 books on electrochemical energy storage and conversion.

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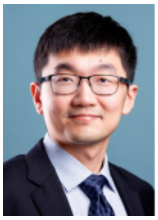

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Dr. Jiujun ZHANG is currently a professor at Fuzhou University. Dr. Zhang obtained his Ph.D degree in electrochemistry from Wuhan University in 1988 and has over 30 years of research experience. He has published over 750 journal papers and 28 books on electrochemical energy storage and conversion. His research interests span across materials science, electrochemistry, electroanalysis, electrocatalysis, batteries, lithium-ion batteries, fuel cells, supercapacitors, etc.