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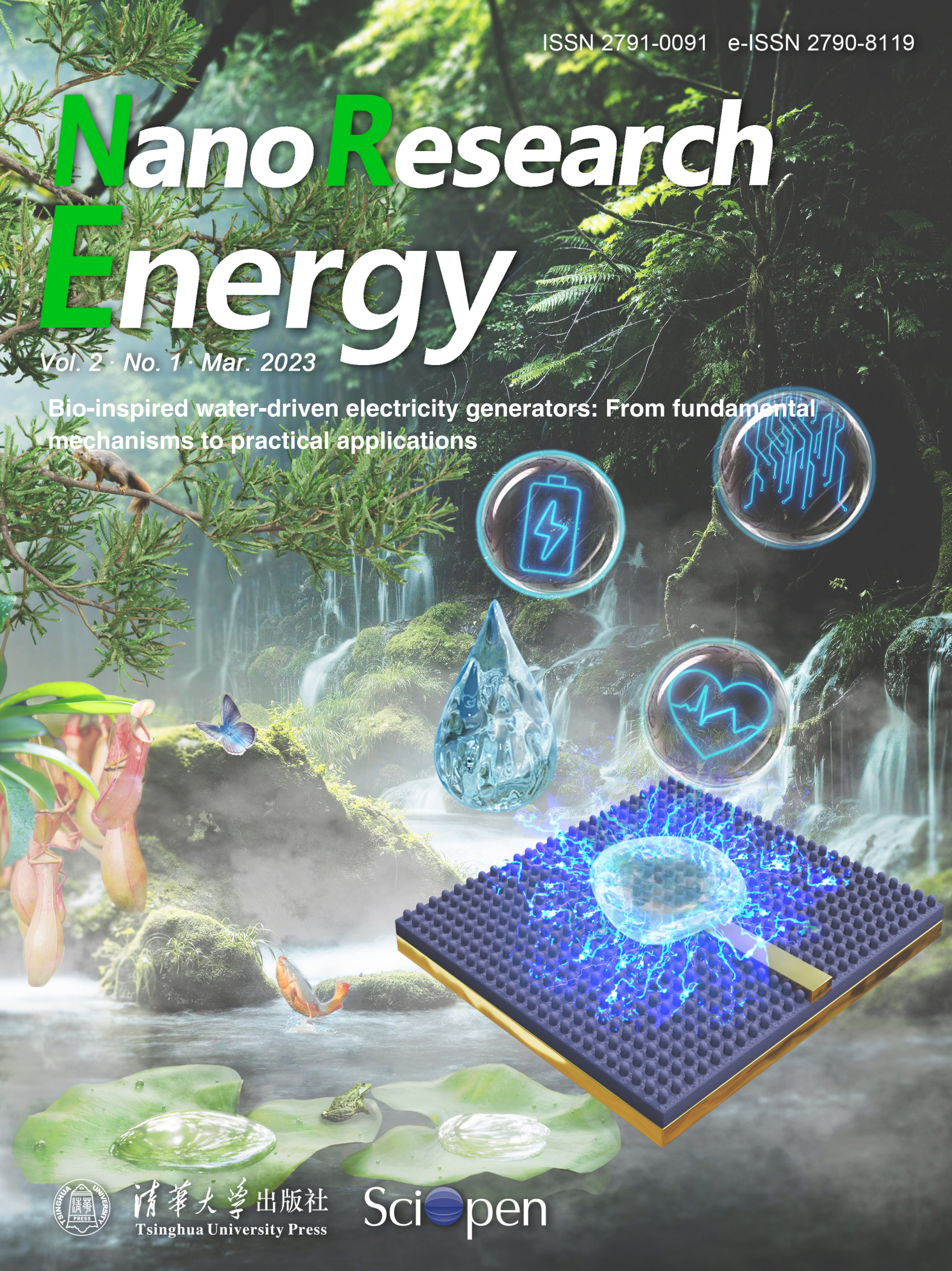
Bio-inspired water-driven electricity generators: From fundamental mechanisms to practical applications



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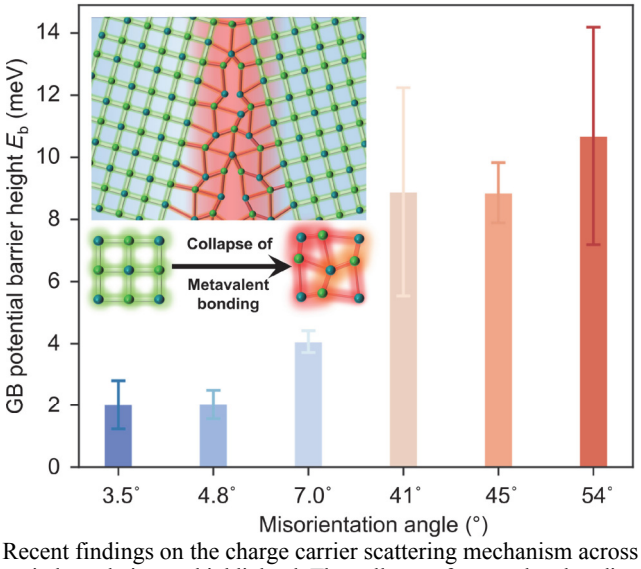
Highlights



Recent findings on the charge carrier scattering mechanism across grain boundaries are highlighted. The collapse of metavalent bonding is responsible for the increased potential barrier height at grain boundaries.

Review Articles

Recent advances and perspectives for Zn-based batteries: Zn anode and electrolyte

Huaiyun Ge, Xilan Feng, Dapeng Liu*, and Yu Zhang*

Beihang University, China

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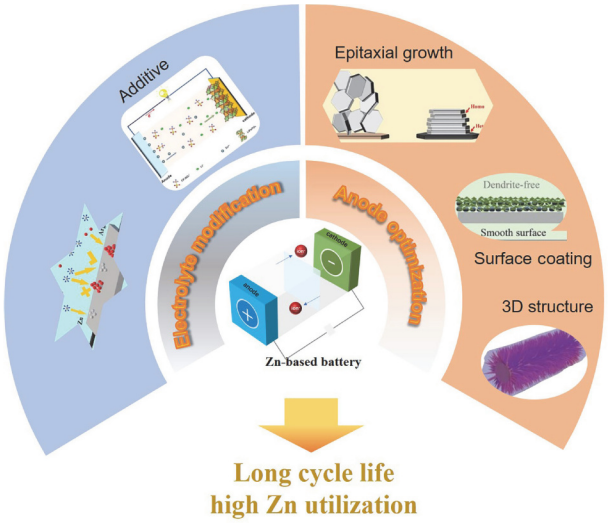

Zn-based batteries have attracted extensive attention due to their high theoretical energy density, safety, abundant resources, environmental friendliness, and low cost. They are a new energy storage and conversion technology with significant development potential and have been widely used in renewable energy and portable electronic devices. Considerable attempts have been devoted to improving the performance of Zn-based batteries. Specifically, battery cycle life and energy efficiency can be improved by electrolyte modification and the construction of highly efficient rechargeable Zn anodes. This review compiles the progress of the research related to Zn anodes and electrolytes, especially in the last five years. This review will introduce fundamental concepts, summarize recent development, and inspire further systematic research for high-performance Zn-based batteries in the future.

Bio-inspired water-driven electricity generators: From fundamental mechanisms to practical applications

Kaiqiang Wang[1,2], Wanghuai Xu[1], Wei Zhang[1], Xiong Wang[1], Xiao Yang[1,4], Jianfeng Li[2], Hanli Zhang[2], Jinjin Li[2], and Zuankai Wang[1,3,4,*]

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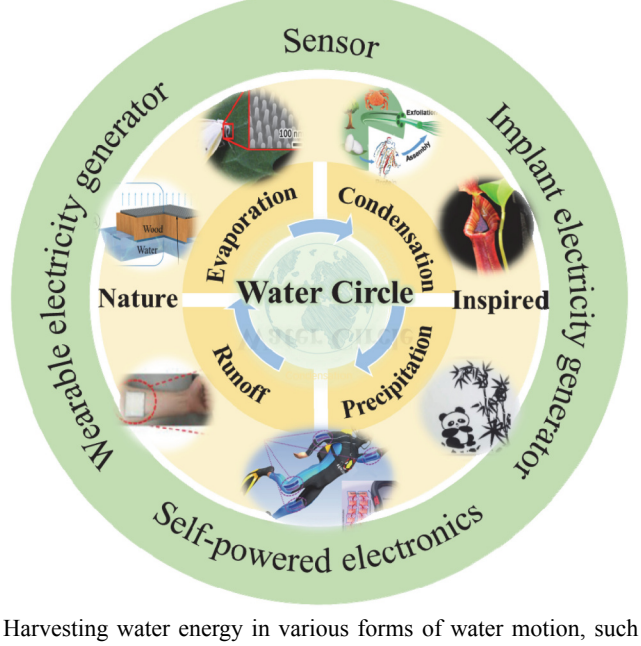
[2] Tsinghua University, China
[3] Centre for Nautre-Inspired Engineering, China
[4] Hong Kong Centre for Cerebro-Caradiovasular Health Engineering (COCHE), China



Harvesting water energy in various forms of water motion, such as evaporation, raindrops, river flows, ocean waves, and other, is promising to relieve the global energy crisis and reach the aim of carbon neutrality. However, this highly decentralized and distributed

water energy poses a challenge on conventional electromagnetic hydropower technologies that feature centralization and scalization. Recently, this problem has been gradually addressed by the emergence of a myriad of electricity generators that take inspiration from natural living organisms, which have the capability to efficiently process and manage water and energy for survival in the natural competition. Imitating the liquid–solid behaviors manifested in ubiquitous biological processes, these generators allow for the efficient energy conversion from water–solid interaction into the charge transfer or electrical output under natural driving, such as gravity and solar power. However, in spite of the rapid development of the field, a fundamental understanding of these generators and their ability to bridge the gap between the fundamentals and the practical applications remains elusive. In this review, we first introduce the latest progress in the fundamental understanding in bio-inspired electricity generators that allow for efficient harvesting water energy in various forms, ranging from water evaporation, droplet to wave or flow, and then summarize the development of the engineering design of the various bio-inspired electricity generator in the practical applications, including self-powered sensor and wearable electronics. Finally, the prospects and urgent problems, such as how to achieve large-scale electricity generation, are presented.

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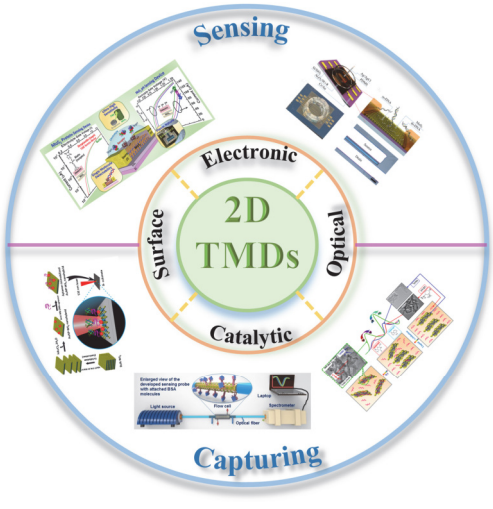
Biomolecule capturing and sensing on 2D transition metal dichalcogenide canvas

Yichao Bai, Linxuan Sun, Qiangmin Yu, Yu Lei*, and Bilu Liu*

Tsinghua University, China



Since the isolation of graphene in 2004, two-dimensional (2D) materials such as transition metal dichalcogenide (TMD) have attracted numerous interests due to their unique van der Waals structure, atomically thin body, and thickness-dependent properties. In recent years, the applications of TMD in public health have emerged due to their large surface area and high surface sensitivities, as well as their unique electrical, optical, and electrochemical properties. In this review, we focus on state-of-the-art methods to modulate the properties of 2D TMD and their applications in biosensing. Particularly, this review provides methods for designing and modulating 2D TMD via defect engineering and morphology control to achieve multi-functional surfaces for molecule capturing and sensing. Furthermore, we compare the 2D TMD-based biosensors with the traditional sensing systems, deepening our understanding of their action mechanism. Finally, we point out the challenges and opportunities of 2D TMD in this emerging area.

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Reviewing the impact of halides on electrochemical CO_2 reduction

Zebi Zhao[1], Jiguang Zhang[2], Ming Lei[1,*], and Yanwei Lum[2,*]

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[2] Agency for Science, Technology and Research (A*STAR), Singapore

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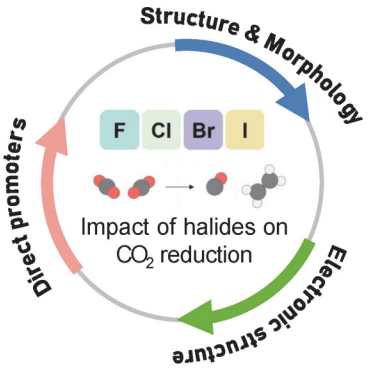

Electrochemical CO_2 reduction reaction (CO_2RR) is a promising technology for mitigating global warming and storing renewable energy. Designing low-cost and efficient electrocatalysts with high selectivity is a priority to facilitate CO_2 conversion. Halide ion (F^-, Cl^-, Br^-, I^-) modified electrocatalysts is a potential strategy to promote CO_2 reduction and suppress the competitive hydrogen evolution reaction (HER). Therefore, a comprehensive review of the role and mechanism of halide ions in the CO_2RR process can help better guide the future design of efficient electrocatalysts. In this review, we first discuss the role of halide ions on the structure and morphology of electrocatalysts. Secondly, the relationship between the halide ions and the valence states of the active sites on the catalyst surface is further elaborated on. Thirdly, the mechanisms of halide in enhancing CO_2 conversion efficiency are also summarized, including the involvement of halide ions in electron transfer and their influence on the reaction pathway. Finally, we conclude with a summary and future outlook.

Towards high power density aqueous redox flow batteries

Mengqi Gao[1], Zhiyu Wang[1], Dao Gen Lek[1], and Qing Wang[1,2,*]

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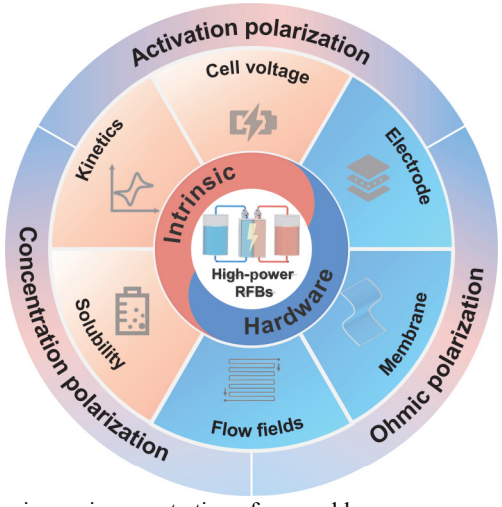

With the increasing penetration of renewable energy sources in the past decades, stationary energy storage technologies are critically desired for storing electricity generated by non-dispatchable energy sources to mitigate its impact on power grids. Redox flow batteries (RFBs) stand out among these technologies due to their salient features for large-scale energy storage. The primary obstacle to the successful industrialization and broad deployment of RFBs is now their high capital costs. A feasible route to cost reduction is to develop high-power RFBs, since the increase in power performance has a pronounced impact on the cost of RFB systems. In this review, an in-depth inspection of the power performance of RFBs is presented. Perspectives for the future development of high-power RFBs along with implementable strategies addressing both the intrinsic and extrinsic limiting factors are summarized, which are expected to provide useful references steering the further improvement in the power density of RFBs.

Mechanism, quantitative characterization, and inhibition of corrosion in lithium batteries

Yang-Yang Wang[1], Xue-Qiang Zhang[1,*], Ming-Yue Zhou[2], and Jia-Qi Huang[1,*]

[1] Beijing Institute of Technology, China
[2] Tsinghua University, China

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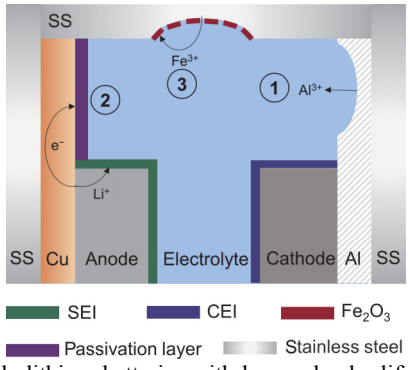

Rechargeable lithium batteries with long calendar life are pivotal in the pursuit of non-fossil and wireless society as energy storage devices. However, corrosion has severely plagued the calendar life of lithium batteries. The corrosion in batteries mainly occurs between electrode materials and electrolytes, which results in constant consumption of active materials and electrolytes and finally premature failure of batteries. Therefore, understanding the mechanism of corrosion and developing strategies to inhibit corrosion are imperative for lithium batteries with long calendar life. In this review, different types of corrosion in batteries are summarized and the corresponding corrosion mechanisms are firstly clarified. Secondly, quantitative studies of the loss of lithium in corrosion are reviewed for an in-depth understanding of the mechanism. Thirdly, the recent progress in inhibiting corrosion is demonstrated. Finally, perspectives to further investigate corrosion mechanism and inhibit corrosion are put forward to promote the development of stable lithium batteries.

Present and future of functionalized Cu current collectors for stabilizing lithium metal anodes

Yuhang Liu[1], Yifan Li[1], Jinmeng Sun[1], Zhuzhu Du[1], Xiaoqi Hu[1], Jingxuan Bi[1], Chuntai Liu[4], Wei Ai[1,*], and Qingyu Yan[2,3,*]

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[3] A*STAR, Singapore
[4] Zhengzhou University, China

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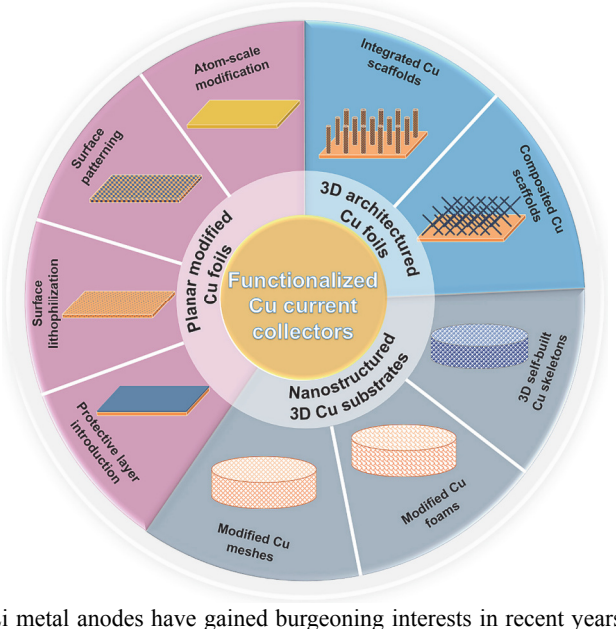

Li metal anodes have gained burgeoning interests in recent years due to its lowest redox overpotential and ultrahigh theoretical capacity. In pursuit of the practical implementation of Li metal batteries, fucntionalized Cu current collectors have been proposed to regulate the Li plating/stripping behaviors. In this review, we provides a comprehensive insight into the advances in functionalized Cu current collectors for stabilizing Li metal anodes. The corresponding design principles and strategies of functionalized Cu current collectors associated with their functionalities in optimizing Li plating/stripping behaviors are discussed. This review may shed light on the critical understanding of current collector engineering for high-energy-density Li metal batteries.

Research Articles

Autocatalytic reduction-assisted synthesis of segmented porous PtTe nanochains for enhancing methanol oxidation reaction

Qiqi Zhang[1], Tianyu Xia[2,*], He Huang[3], Jialong Liu[4,*], Mengyuan Zhu[3], Hao Yu[3], Weifeng Xu[3], Yuping Huo[1], Congli He[1], Shipeng Shen[1], Cong Lu[5], Rongming Wang[3], and Shouguo Wang[1,3,6,*]

[1] Beijing Normal University, China
[2] Zhengzhou University, China
[3] University of Science and Technology Beijing, China
[4] Beijing University of Chemical Technology, China
[5] Hyogo Science and Technology Association, Japan
[6] Anhui University, China

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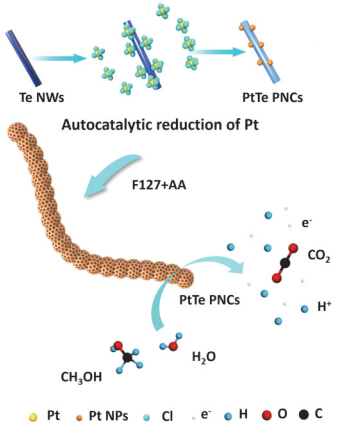

Morphology engineering has been developed as one of the most widely used strategies for improving the performance of electrocatalysts. However, the harsh reaction conditions and cumbersome reaction steps during the nanomaterials synthesis still limit their industrial applications. Herein, one-dimensional (1D) novel-segmented PtTe porous nanochains (PNCs) were successfully synthesized by the template methods assisted by Pt autocatalytic reduction. The PtTe PNCs consist of consecutive mesoporous architectures that provide a large electrochemical surface area (ECSA) and abundant active sites to enhance methanol oxidation reaction (MOR). Furthermore, 1D nanostructure as a robust sustaining frame can maintain a high mass/charge transfer rate in a long-term durability test. After 2,000 cyclic voltammetry (CV) cycles, the ECSA value of PtTe PNCs remained as high as 44.47 $m^2 \cdot g_{Pt}^{-1}$, which was much larger than that of commercial Pt/C (3.95 $m^2 \cdot g_{Pt}^{-1}$). The high catalytic activity and durability of PtTe PNCs are also supported by CO stripping test and density functional theory calculation. This autocatalytic reduction-assisted synthesis provides new insights for designing efficient low-dimensional nanocatalysts.

High sulfur loading and shuttle inhibition of advanced sulfur cathode enabled by graphene network skin and N, P, F-doped mesoporous carbon interfaces for ultra-stable lithium sulfur battery

Haotian Liu[1,2], Fan Liu[1], Zehua Qu[3], Jieling Chen[1], Hui Liu[1], Yiqing Tan[1], Jiabao Guo[1], Yan Yan[1,3,*], Shuang Zhao[1], Xinsheng Zhao[1], Xinming Nie[1,*], Xin Ma[4,*], Zengxia Pei[5], and Mingkai Liu[1,3,*]

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[2] Sun Yat-sen University, China
[3] Fudan University, China
[4] Nanjing University of Information Science and Technology, China
[5] The University of Sydney, Australia

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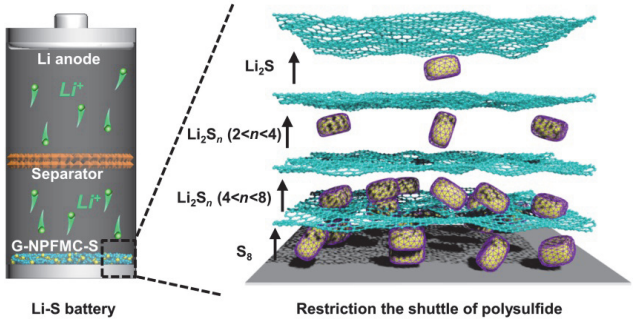

A free-standing graphene-N,P,F doped mesoporous carbon-sulfur (G-NPFMC-S) film with high sulfur content of 86 wt.% was rationally designed and further used as a binder free cathode in lithium-sulfur battery, in which the shuttle effect of polysulfide was dually restricted by chemical adsorption from the polar interfaces and physical barriers from the graphene networks.

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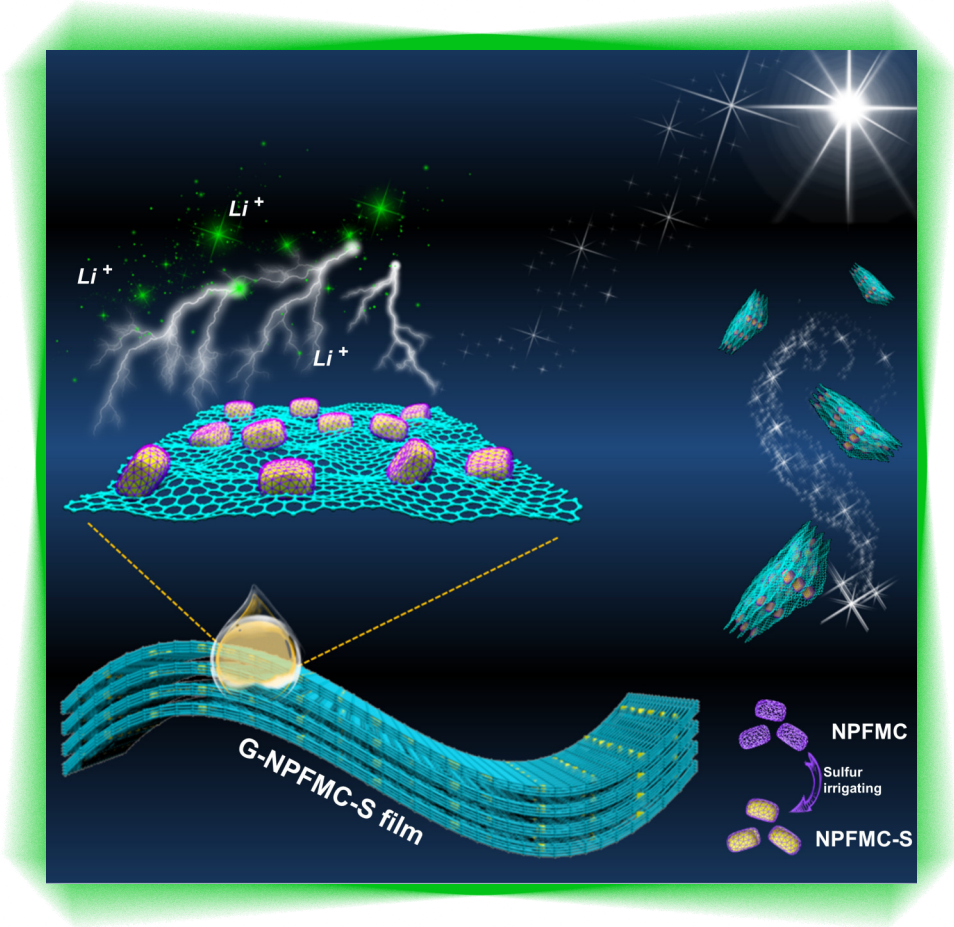

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