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Editorial

Catalysis in Energy and the Environment: Opportunities and Challenges

Xiong He [1,*], Yuhao Li [1] and Hongda Li [1,2]

[1] Liuzhou Key Laboratory for New Energy Vehicle Power Lithium Battery, School of Electronic Engineering, Guangxi University of Science and Technology, Liuzhou 545006, China; q2476166290@126.com (Y.L.); hdli@gxust.edu.cn (H.L.)
[2] Suzhou Institute for Advanced Research, University of Science and Technology of China, Suzhou 215123, China
* Correspondence: hexiong@gxust.edu.cn

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Energy and the environment are the foundations of modern human society. The demand for energy has rapidly increased with the acceleration of industrialization over the past decades. However, the consumption of fossil fuels as the dominant energy source has brought about serious environmental problems. Carbon dioxide emissions have to climate change as a result of the greenhouse effect. Under the constraints of the carbon peak and carbon neutralization, the development and application of renewable energy have been the focus in the energy field. Even though the transition towards renewable sources is ultimately inevitable, the consumption of renewable energy is still insufficient. The development and utilization of sustainable clean energy and environmental pollution control are still major challenges in the Multi-Energy Complementary Age.

Catalysis includes thermal catalysis, photocatalysis, electrocatalysis, and photoelectrochemical catalysis. It plays an important role in the development of advanced renewable energy technologies, such as green hydrogen, metal–air batteries, and fuel cells, among others. For instance, electrocatalytic water splitting is a green technology capable of producing clean hydrogen with zero carbon emissions. However, the efficiency of this technique has been constrained by its high overpotential and sluggish multi-electron kinetics. Catalysts, which accelerate the reaction rate while reducing activation energy, are a promising prospect in this field. Their performance can be evaluated in terms of their activity, selectivity, and stability—which is closely associated with their intrinsic activity—as well as in terms of the number of active catalyst sites. Unsatisfactory catalytic activity and selectivity limit the efficiency of industrial production, increase separation costs, and lead to environmental pollution. As catalysis is a new chemical process, low catalytic efficiency and high production costs directly hinder its large-scale application.

The intrinsic activity of catalysts can be substantially improved by modifying their electronic structures. An expanded specific surface area can be achieved through morphology and architecture design and engineering. Catalytic performance can be enhanced through many strategies, including element doping, crystal facets, heterostructures, co-catalysts, oxygen and metal vacancies, and lattice distortion. For example, doped elements could tailor the d-band center of the active metal to optimize binding strength during the catalytic process. The fundamentals that guide the catalytic process are still being explored. Some electrocatalytic mechanisms can be inspired by bionics. Inspired by the active center ($CaMn_4O_5$) of the PSII system in the chloroplast, the synergy regulation of bimetallic electrocatalysts in the formation and breaking of O-O bonds was reported for water oxidation. Although catalytic activity has been substantially enhanced, challenges remain, including catalyst migration in the electrocatalytic process and their operation in industrial conditions.

This Special Issue reports on the latest research results, past experiences, and prospects in the fields of energy and the environment. It contains twenty-three original research papers related to this topic. Here, we aim to briefly introduce and classify these works. The majority focus on the synthesis and mechanisms of photo-/electrocatalysts [1–9]. Photo-/electrocatalysis technology has great potential for energy conversion and storage. Improving the catalytic activity and stability of photo-/electrocatalysts under industrial conditions is a key problem that restricts their large-scale application. This Special Issue explores the promotion of photo-/electrocatalytic activity by means of morphology control [4], element doping [3], heterojunction construction [6–8], oxygen vacancy regulation [1], and optical properties [9], among others. Various approaches to the design and engineering of efficient photo-/electrocatalytic materials are presented. One review discusses research on solid-state hydrogen storage technology [10]. Meanwhile, photo-/electrocatalytic materials can be employed in other applications and devices. ZnO and Fe_2O_3 are traditional photocatalysts that are applied in memory cells for resistive switching behaviors [11,12]. Metal–organic frameworks (MOFs), as one of most promising catalyst materials, serves as a fluorescent probe in a visual sensor [13]. In addition, carbon-based composites are employed for lithium-ion batteries [14–16]. This Special Issue also includes investigations related to pollutant removal with sorption capability [17–23]. The preparation and adsorption performance of activated carbon are emphatically discussed [19,20]. Though some works do not directly discuss catalytic applications, they are still related to the scope of this Special Issue. We hope that this Special Issue will advance the field of "catalysis for energy and the environment" with its collection of insightful and meaningful articles.

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