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Editorial

Editorial: Noble Metal-Based Nanomaterials for Heterogeneous Catalysis

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As is well known, precious metal catalysts can be widely used in fields such as environmental protection, energy conversion, food processing, petrochemicals, and fine chemicals due to their unique intrinsic properties and irreplaceable catalytic activities [1]. Although their scarcity and high cost mean they are often quickly excluded, nanostructure engineering, especially designing (sub)-nano structures, provides another opportunity to industrial application of precious metal catalysts, which can maximize the use of their atomic surfaces [2].

Heterogeneous catalysis, in which the rate of a specific reaction is accelerated by a catalyst, plays a key role in the quest for reliable and sustainable energy. Various noble metal-based nanomaterials have been developed for electrocatalysis, photocatalysis, thermal catalysis, etc., based on controlled synthesis and rational structural regulations [3–6]. In particular, nanocatalysts have been proven to be very promising for use in storage devices such as fuel cells, and for achieving sustainable energy conversion, water splitting, and high-value-added compound synthesis from CO_2, N_2, and available feedstock [7–9]. In this case, the rational design of new noble metal-based catalysts has aroused global interest in academic research and product pilot deployment.

This Special Issue titled "*Noble Metal-Based Nanomaterials for Heterogeneous Catalysis*" aims to provide a scientific overview of the current advances in the field of noble metal-related nanocatalysts. Original research papers and short reviews were invited for submission, and four reviews and one research article are included, focusing on very recent progress covering the main topics of platinum (Pt)- and ruthenium (Ru)-based fuel cells and water splitting catalysts. We believe that this Special Issue will offer important viewpoints for promoting collaborations between experts in catalysis, materials science, chemical engineering, and environmental sciences. The topics presented herein will be valuable and meaningful for a very wide range of groups regarding the exploration of advanced noble metal catalysts.

Engineering the dimensions of catalysts is very important for achieving efficient heterogeneous catalysis that is highly active, stable, and selective. In contribution 1, Zhao et al. systematically summarized innovative approaches for regulating the size and morphology of nano-noble metal catalysts with different dimensions. They also showed the potential application of these advanced nanostructures in exhaust gas purification, battery manufacturing, water splitting, and selective hydrogenation. This detailed review is of significance for promoting the development of heterogeneous catalysts.

The advancement of green hydrogen energy is of great consequence for building a low-carbon energy system. Water electrolysis has become one of the most important hydrogen production methods due to its simple operation, limited number of side reactions, and contribution to the green economy. In order to reduce reaction energy consumption, it is necessary to develop highly active and stable cathodic hydrogen evolution (HER) catalysts. In this regard, Ru-based catalysts have gained extensive attention as a promising candidate

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for achieving high-performance water electrolysis. In contribution 2, Yu et al. discussed the recent progress on the modification of Ru-based electrocatalysts for HER catalysis, especially highlighting the catalytic mechanism for the adsorption of intermediates on the Ru-based electrocatalyst surface and the adsorption–activation of interface water molecules. Through understanding the interface water molecule structures, this topic may be helpful for designing high-performance Ru-based catalysts in the future.

In addition to hydrogen production technology, in the hydrogen energy industry chain the utilization of hydrogen is also an important research direction. A proton exchange membrane fuel cell (PEMFC) is an efficient and clean energy conversion device that can convert chemical energy stored in H_2 and O_2 into electrical energy through electrochemical means. The oxygen reduction reaction (ORR) is a key half reaction for PEMFCs, challenged by the sluggish kinetics and high cost of conventional Pt-based catalysts. To address this issue, in contribution 3, Li et al. developed non-spherical Pt nanoparticles on Ketjen Black carbon via a surfactant-free one-pot method. The as-optimized Pt/KB-N (Pt nanoparticles supported on nitrogen-doped carbon) showed a high mass activity and specific activity of 115 A g^{-1} and 4.7 A m^{-2}, respectively. Although excellent catalytic activity has been achieved by engineering the surface electronic structure of advanced Pt-based materials, the durability is still seriously limited due to the corrosion of carbon supports, the preferential leaching of active metal elements, the instability of low-coordinated surface atoms, and the sintering/agglomeration of nanocrystals. To this end, in contribution 4, Chen et al. summarized the advanced regulation strategies for enhancing the durability of recently reported Pt-based catalysts. The typical strategies include the optimization of supports, metal-doped alloys, core/shell structures, intermetallics and high-entropy alloys, etc. By designing ultradurable Pt-based ORR catalysts, we anticipate that more advanced catalysts can be applied in PEMFCs under long-term operation conditions.

By replacing anodic H_2 fuel with liquid alcohol fuels, direct alcohol fuel cells (DAFCs) can be developed, and they have become highly promising energy conversion devices. Beyond cathodic ORR catalysis, Pt-based anodic alcohol oxidation reaction (AOR) catalysts still experience the issues of carbon monoxide (CO) poisoning and unsatisfactory long-term stability. In contribution 5, Xia et al. reviewed typical dimension-based designs of Pt-based alloy methanol oxidation reaction (MOR) catalysts, involving anisotropic nanowires, metallene, nanoframes, and corresponding rationales for performance enhancements. In addition, several advanced regulation strategies were further proposed, such as intermetallics, interface engineering, surface engineering, and high-entropy alloys.

This Special Issue in *Catalysts* affords an international platform to share the impressive research progress on emerging noble metal-based catalysts for heterogeneous catalysis. The in-depth discussion herein is expected to inspire a new family of technology that will accelerate the development of heterogeneous catalysis. Finally, we would like to express our gratitude to MDPI Editorial and the *Catalysts* journal for the opportunity to serve as Guest Editors, contributing to the current state in noble metal-based nanomaterials for heterogeneous catalysis. In addition, we also sincerely appreciate the Assistant Editors, Ms. Jamila Zhang and Mr. Ives Liu, for co-initiating this Special Issue and handling all the papers. We would particularly like to thank all the authors, reviewers, editors, and readers for their great contributions to make this high-quality issue possible. Any comments, suggestions, and feedback are always welcome.

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