

Editorial

Applications of Catalytic Nanomaterials in Energy and Environment

Hongda Li ^{1,*} , Shuai Jian ¹ and Mohammed Baalousha ^{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

² Center for Environmental Nanoscience and Risk, Department of Environmental Health Sciences, Arnold School of Public Health, University of South Carolina, 921 Assembly Street, Columbia, SC 29208, USA

* Correspondence: hdli@gxust.edu.cn (H.L.); mbaalous@mailbox.sc.edu (M.B.)

Nanotechnology is a crucial technology for the development of science and technology. Nanomaterials, constituting a key building block of nanotechnology, are solid objects with at least one dimension between 1 and 100 nm. Nanomaterials include nanoparticles, nanosheets, nanofibers (rods, tubes, etc.), nanodots, etc. Due to their small size, nanomaterials possess unique and novel properties and functions such as increased specific surface area and reactivity, and quantum confinement. Therefore, nanomaterials have a wide range of applications, including medical diagnosis, material modification, environmental remediation, biotechnology, catalysis and photocatalysis, etc.

Catalysts, substances that increase the rate of a reaction without undergoing permanent chemical changes, play important roles in the chemical industry and the environment. Catalysts have been used in the treatment of fuels such as oil, natural gas, and coal and in the purification of wastewater and industrial waste gases. Catalysts can be classified as homogeneous or heterogeneous catalysts. The former refers to catalysts that exist in the same phase (gas or liquid) as the reactants, whereas the latter refers to catalysts that are not in the same phase as the reactants. Heterogeneous catalysis occurs at the interface of two phases, usually with a porous solid catalyst and a liquid or gas reactant. For chemicals to react, their chemical bonds must be changed, and a certain amount of energy is needed to change or break these chemical bonds. The minimum energy threshold required to change chemical bonds is called activation free energy, and a catalyst affects a reaction rate by changing the activation free energy of the chemical reactants. Compared with homogeneous catalysts, heterogeneous catalysts possess higher selectivity and offer better yields. Therefore, heterogeneous catalysts are receiving much more attention than homogeneous catalysts. To improve the efficiency, yield, and purity of catalysts, it is very important to study new catalytic materials or optimize existing catalyst systems.

At present, the research in this field mainly focuses on nano-structured catalysts with special physical and chemical properties. Nanoscale catalysts possess higher surface area and surface energy compared with non-nanoscale catalysts, which ultimately results in higher catalytic activity. Nanocatalysts improve reaction selectivity by reducing the required activation energy and the occurrence of side reactions and improving the recovery of energy consumption. Therefore, nanocatalysts have been widely used in green chemistry, environmental remediation, the efficient conversion of biomass, renewable energy development, and other fields. This Special Issue focuses on the application of nanocatalysts in the field of energy and environment.

In addition to producing clean energy efficiently, nanocatalysts enable the recycling of wastewater, waste gas, and solid waste, which is crucial to solving energy and environmental problems. In recent years, great progress has been made in thermal catalysis, photocatalysis, and electrocatalysis for energy and environmental applications. In particular, pollutant degradation [1–7], green hydrogen production [8], indoor formaldehyde



Citation: Li, H.; Jian, S.; Baalousha, M. Applications of Catalytic Nanomaterials in Energy and Environment. *Molecules* **2023**, *28*, 4000. <https://doi.org/10.3390/molecules28104000>

Received: 25 April 2023

Revised: 28 April 2023

Accepted: 9 May 2023

Published: 10 May 2023



Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

purification [9], oxygen reduction [10], and other fields [11–13] have ushered in major developmental opportunities and important original breakthroughs.

The controllable preparation and structure–activity relationships of nanocatalysts are crucial aspects with respect to overcoming the bottleneck regarding nanocatalysts' application. The design of nanocatalysts has evolved from the initial macro-strategies, such as component regulation, size control, and morphology tailoring, to the precise regulation of the catalytic center coordination and electronic structures at the subatomic/atomic level. At the same time, the development of advanced nanocatalysts is inseparable from the bold innovations in preparation strategies, the technical innovations in characterization methods, the iterative renewal of the concept of catalysis, and the continuous exploration and re-evaluation of the objective law of the structure–activity relationship.

This Special Issue focuses on energy and the environment, including with respect to the latest research results, experiences, and prospects, and contains eleven original research papers. Most of the studies focus on the synthesis and related mechanisms of photocatalytic nanomaterials. Photocatalysis technology has great potential for solving energy shortages and environmental pollution. Improving the sunlight utilization efficiency and catalytic activity of photocatalytic nanomaterials constitutes the key problem restricting the large-scale application of photocatalytic technology. This Special Issue presents a detailed account of the internal mechanism whereby photocatalytic activity is enhanced via elemental doping [1–3], the construction of composite heterogeneous structures [4–6,10], the introduction of organic photosensitive materials [8], morphology control [9], and so on. These contributions provide various approaches to the design and establishment of efficient photocatalytic nanomaterials. This Special Issue also presents two works on the use of metal–organic frameworks (MOFs) for efficient ammonia capture [11,12]. Although these two works do not involve catalytically related applications, most of these MOFs have high porosity and good chemical stability. Due to their ability to control pore structure and their large surface area, MOFs have wider application prospects in the catalyst field than other porous materials. The unsaturated metal sites of MOF materials, acting as Lewis acid sites, can be used as a catalytic center. MOFs have been used in the cyanidation reaction, the oxidation reaction of hydrocarbons and alcohols, the esterification reaction, the Diels–Alder reaction, and in other catalytic applications. This Special Issue also includes two review articles summarizing the state of the art in the two important areas of the application of photocatalysis and sonocatalysis for the treatment of organic dye wastewater [7] and the preparation, passivation, and application of two-dimensional black phosphorus in lithium-ion batteries [13]. These review articles cover a wide range of topics, including the preparation methods, characterization techniques of energy and environmental catalytic materials, and practical applications of nanocatalysts in the field of photo/electrochemistry. It is hoped that the publication of this Special Issue will advance the field of “catalysis for energy and the environment” and provide the reader with a launch point into this highly innovative area of research.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Wang, F.; Zhou, X.; Li, J.; He, Q.; Zheng, L.; Liu, Q.; Chen, Y.; Zhang, G.; Liu, X.; Li, H. Rationally Designed $\text{Bi}_2\text{M}_2\text{O}_9$ ($\text{M} = \text{Mo}/\text{W}$) Photocatalysts with Significantly Enhanced Photocatalytic Activity. *Molecules* **2021**, *26*, 7334. [[CrossRef](#)] [[PubMed](#)]
2. Tang, L.; Jia, Y.; Zhu, Z.; Hua, Y.; Wu, J.; Zou, Z.; Zhou, Y. Effects of Co Doping on the Growth and Photocatalytic Properties of ZnO Particles. *Molecules* **2022**, *27*, 833. [[CrossRef](#)] [[PubMed](#)]

3. Li, Q.; Jiang, L.; Li, Y.; Wang, X.; Zhao, L.; Huang, P.; Chen, D.; Wang, J. Enhancement of Visible-Light Photocatalytic Degradation of Tetracycline by Co-Doped TiO₂ Templated by Waste Tobacco Stem Silk. *Molecules* **2023**, *28*, 386. [[CrossRef](#)] [[PubMed](#)]
4. Fan, H.; Ma, X.; Li, X.; Yang, L.; Bian, Y.; Li, W. Fabrication of Novel g-C₃N₄@Bi/Bi₂O₂CO₃ Z-Scheme Heterojunction with Meliorated Light Absorption and Efficient Charge Separation for Superior Photocatalytic Performance. *Molecules* **2022**, *27*, 8336. [[CrossRef](#)] [[PubMed](#)]
5. Wang, Y.; Yang, X.; Lou, J.; Huang, Y.; Peng, J.; Li, Y.; Liu, Y. Enhance ZnO Photocatalytic Performance via Radiation Modified g-C₃N₄. *Molecules* **2022**, *27*, 8476. [[CrossRef](#)] [[PubMed](#)]
6. Guo, X.; Pan, G.; Fang, L.; Liu, Y.; Rui, Z. Z-Scheme CuO_x/Ag/TiO₂ Heterojunction as Promising Photoinduced Anticorrosion and Antifouling Integrated Coating in Seawater. *Molecules* **2023**, *28*, 456. [[CrossRef](#)] [[PubMed](#)]
7. Wang, G.; Cheng, H. Application of Photocatalysis and Sonocatalysis for Treatment of Organic Dye Wastewater and the Synergistic Effect of Ultrasound and Light. *Molecules* **2023**, *28*, 3706. [[CrossRef](#)]
8. Kim, S.; Kim, H. Photocatalytic Hydrogen Production by the Sensitization of Sn(IV)-Porphyrin Embedded in a Nafion Matrix Coated on TiO₂. *Molecules* **2022**, *27*, 3770. [[CrossRef](#)] [[PubMed](#)]
9. Yin, R.; Sun, P.; Cheng, L.; Liu, T.; Zhou, B.; Dong, X. A Three-Dimensional Melamine Sponge Modified with MnO_x Mixed Graphitic Carbon Nitride for Photothermal Catalysis of Formaldehyde. *Molecules* **2022**, *27*, 5216. [[CrossRef](#)] [[PubMed](#)]
10. Wierzyńska, E.; Pisarek, M.; Łęcki, T.; Skompska, M. Comparative Studies of g-C₃N₄ and C₃N₃S₃ Organic Semiconductors-Synthesis, Properties, and Application in the Catalytic Oxygen Reduction. *Molecules* **2023**, *28*, 2469. [[CrossRef](#)] [[PubMed](#)]
11. Zhang, D.; Shen, Y.; Ding, J.; Zhou, H.; Zhang, Y.; Feng, Q.; Zhang, X.; Chen, K.; Xu, P.; Zhang, P. A Combined Experimental and Computational Study on the Adsorption Sites of Zinc-Based MOFs for Efficient Ammonia Capture. *Molecules* **2022**, *27*, 5615. [[CrossRef](#)] [[PubMed](#)]
12. Zhang, D.; Shen, Y.; Ding, J.; Zhou, H.; Zhang, Y.; Feng, Q.; Zhang, X.; Chen, K.; Wang, J.; Chen, Q.; et al. Tunable Ammonia Adsorption within Metal-Organic Frameworks with Different Unsaturated Metal Sites. *Molecules* **2022**, *27*, 7847. [[CrossRef](#)] [[PubMed](#)]
13. Li, H.; Li, C.; Zhao, H.; Tao, B.; Wang, G. Two-Dimensional Black Phosphorus: Preparation, Passivation and Lithium-Ion Battery Applications. *Molecules* **2022**, *27*, 5845. [[CrossRef](#)] [[PubMed](#)]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.