

Microenvironment Engineering of Catalysts Using Organic Molecules

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Abstract

Electrocatalysis plays a pivotal role in numerous energy conversion and storage technologies, including fuel cells, electrolyzers, and batteries. Achieving high electrocatalytic activity is crucial for improving the efficiency of these devices. In this article, we delve into the fascinating world of surface chemical microenvironment engineering of catalysts using organic molecules. We explore how organic molecules can be strategically employed to enhance the electrocatalytic performance of catalyst materials and contribute to the advancement of sustainable energy technologies. Electrocatalysis is a fundamental process in which catalysts facilitate the conversion of electrical energy into chemical energy and vice versa.

Keywords: Microenvironment • Catalysts • Molecules • Cells

Introduction

This phenomenon has far-reaching implications, spanning applications such as fuel cells, water electrolyzers, and metal-air batteries. The efficiency and performance of these electrochemical devices rely heavily on the electrocatalysts used. The quest for more efficient electrocatalysts has led to a burgeoning field focused on the surface engineering of catalyst materials. Surface chemical microenvironment engineering, which involves the deliberate manipulation of a catalyst's surface using organic molecules, has emerged as a powerful strategy to enhance electrocatalytic activity. This article explores the principles, techniques, and recent developments in the field of surface chemical microenvironment engineering for boosting electrocatalytic reactions. Electrocatalysis involves the reduction or oxidation of species at the electrode-catalyst interface. Key electrocatalytic reactions include the oxygen reduction reaction, hydrogen evolution reaction, and oxygen evolution reaction. Efficient electrocatalysts are essential for these reactions, as they lower the activation energy barriers and facilitate faster kinetics. Surface chemical microenvironment engineering refers to the tailored modification of a catalyst's surface to create a microenvironment conducive to the desired electrocatalytic reaction. Organic molecules serve as versatile tools in this context due to their tunable chemical properties and ability to interact with catalyst surfaces [1].

Literature Review

Choosing organic molecules with functional groups that can interact with the catalyst's active sites or modify its electronic structure. Depositing or binding the selected organic molecules onto the catalyst's surface, creating a controlled microenvironment. Thorough characterization techniques, such as spectroscopy and microscopy, to understand the changes in the catalyst's surface chemistry and structure. Evaluating the electrocatalytic performance of the modified catalyst using cyclic voltammetry, chronoamperometry and other electrochemical techniques. Organic molecules can act as ligands that bind to catalyst surfaces. The choice of ligands and their coordination with the catalytic

sites can significantly influence catalytic activity. For example, pyridine-based ligands have been used to enhance the performance of platinum catalysts in the ORR. Organic molecules can serve as passivating agents, preventing unwanted side reactions on the catalyst surface. This approach is particularly valuable in stabilizing catalyst materials, such as metal nanoparticles. Through interdisciplinary collaboration and innovative research, scientists are making significant strides in harnessing the potential of surface chemical microenvironment engineering to revolutionize electrocatalysis [2].

Discussion

Organic molecules can donate or withdraw electrons from the catalyst's active sites, modulating their electronic structure. This electronic tuning can optimize catalytic performance. For example, the introduction of nitrogen-containing groups can enhance the HER activity of transition metal catalysts. Organic molecules can stabilize reactive intermediates during electrocatalytic reactions. This stabilization reduces the energy barriers for reaction steps, thereby improving catalytic kinetics. The ORR is a critical reaction in fuel cells and metal-air batteries. Surface chemical microenvironment engineering has been used to enhance the ORR activity of catalysts, such as platinum and its alloys, by modifying their surface with organic molecules like porphyrins. The HER is essential for green hydrogen production. Organic molecules have been employed to improve the HER activity of catalysts, including transition metal dichalcogenides and metal phosphides. The OER is a key reaction in water electrolysis. Surface engineering with organic molecules has been explored to enhance the OER activity of catalysts, such as metal oxides and perovskite materials. The long-term stability of organic molecule-modified catalysts is a concern, as organic layers can degrade under harsh electrochemical conditions. Scaling up the synthesis and deposition of organic molecule-modified catalysts for practical applications remains a challenge [3].

A deeper understanding of the interactions between organic molecules and catalyst surfaces is needed to design more effective modifications. The development of advanced in situ and operando characterization techniques to monitor catalyst surface changes during electrocatalysis. The designs of multifunctional organic molecules that can simultaneously stabilize catalysts, improve electronic structure, and enhance reaction kinetics. Combining surface chemical microenvironment engineering with other strategies, such as alloying, doping, and support materials, to create synergistic effects. Surface chemical microenvironment engineering using organic molecules offers an exciting avenue for boosting the electrocatalytic activity of catalysts. This approach leverages the versatility of organic molecules to modify catalyst surfaces, resulting in improved catalytic performance. As the demand for sustainable energy technologies continues to grow, the development of efficient electrocatalysts through surface engineering will play a crucial role

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Received: 02 October, 2023, Manuscript No. MBL-23-117095; **Editor assigned:** 03 October, 2023, PreQC No. P-117095; **Reviewed:** 16 October, 2023, QC No. Q-117095; **Revised:** 21 October, 2023, Manuscript No. R-117095; **Published:** 30 October, 2023, DOI: 10.37421/2168-9547.2023.12.400

in advancing the field of electrochemistry and realizing a more sustainable energy future. The performance of electrocatalysts depends on their surface properties, including chemical composition, structure, and electronic configuration. Surface chemical microenvironment engineering aims to manipulate these properties by introducing organic molecules into the catalytic system [4].

Electrocatalysis, the process of accelerating electrochemical reactions at the electrode surface, plays a pivotal role in various applications, including energy conversion and storage technologies. By tailoring the surface chemistry and electronic properties of catalysts, researchers can achieve remarkable improvements in electrocatalytic reactions, paving the way for more efficient and sustainable energy solutions. Electrocatalysis has emerged as a critical area of research with profound implications for energy conversion, storage, and environmental sustainability. Electrochemical reactions, such as the oxygen reduction reaction in fuel cells and the hydrogen evolution reaction in electrolyzers, underpin technologies ranging from clean energy production to green transportation. To optimize these processes, researchers have turned to the concept of surface chemical microenvironment engineering, using organic molecules as a versatile toolkit to modify the catalytic activity of materials. This article delves into the world of electrocatalysis and explores how the strategic integration of organic molecules can tailor the microenvironment around catalysts, thereby enhancing their electrocatalytic performance. Electrochemical devices that convert chemical energy into electrical energy through the ORR, making them a promising clean energy source for transportation and stationary power [5].

Organic molecules can adsorb onto the catalyst's surface, forming a monolayer that modifies its chemical and electronic properties. Covalent attachment of organic moieties to the catalyst's surface can lead to tailored catalytic sites with enhanced reactivity. Organic molecules can be used to functionalize support materials that interact with the catalyst, influencing its performance indirectly. Organic molecules can be used to create or modify active sites on the catalyst's surface, providing additional binding sites for reactants and intermediates. This increases the catalytic efficiency of electrochemical reactions. Organic modifiers can enhance the diffusion of reactants and products to and from the catalyst surface, reducing mass transport limitations that often hinder electrocatalytic reactions. By altering the electronic environment of the catalyst, organic molecules can influence the binding energies of reaction intermediates, thereby promoting or inhibiting specific reaction pathways. Organic molecules can also serve as protective layers, preventing corrosion or degradation of the catalyst under harsh electrochemical conditions, thereby extending its lifespan. Researchers have employed organic molecules, such as pyridine-based compounds, to modify platinum catalysts for the ORR. These organic layers enhance the ORR kinetics and improve catalyst durability [6].

Conclusion

Organic precursors are often used to introduce nitrogen functionalities into carbon-based catalysts, significantly enhancing their HER activity by creating favorable binding sites for hydrogen adsorption. MOFs, consisting of metal nodes interconnected by organic ligands, have shown promise as

electrocatalysts due to their tunable structure and composition. Organic linkers can be strategically chosen to influence the catalytic properties of MOF-based catalysts. Organic molecules, such as cobaloximes and porphyrins, have been employed as co-catalysts in photoelectrochemical cells, driving water splitting reactions and enhancing solar-to-hydrogen conversion efficiency. Surface chemical microenvironment engineering of electrocatalysts using organic molecules is a promising avenue for boosting the efficiency and sustainability of energy conversion and storage technologies. By tailoring the surface chemistry, electronic properties, and reactivity of catalysts, researchers can overcome limitations and accelerate the transition to cleaner and more efficient energy solutions. As the field of electrocatalysis continues to advance, the integration of organic molecules into the design of electrocatalytic materials will likely play a pivotal role in achieving the ambitious goals of a sustainable and carbon-neutral energy future.

Acknowledgement

None.

Conflict of Interest

None.

References

1. Fallerini, Chiara, Margherita Baldassarri, Eva Trevisson and Valeria Morbidoni, et al. "Alport syndrome: impact of digenic inheritance in patients management." *Clin Genet* 92 (2017): 34-44.
2. Savige, Judy, Beata S. Lipska-Zietkiewicz, Elizabeth Watson and Jens Michael Hertz, et al. "Guidelines for genetic testing and management of Alport syndrome." *Clin J Am Soc Nephrol* 17 (2022): 143-154.
3. Webb, Nicholas JA, Shahnaz Shahinfar, Thomas G. Wells and Rachid Massaad, et al. "Losartan and enalapril are comparable in reducing proteinuria in children with Alport syndrome." *Pediatr Nephrol* 28 (2013): 737-743.
4. Gomez, Ivan G., Deidre A. MacKenna, Bryce G. Johnson and Vivek Kaimal, et al. "Anti-microRNA-21 oligonucleotides prevent Alport nephropathy progression by stimulating metabolic pathways." *J Clin Invest* 125 (2015): 141-156.
5. Zeisberg, Michael, Cindy Bottigligio, Navin Kumar and Yohei Maeshima, et al. "Bone morphogenic protein-7 inhibits progression of chronic renal fibrosis associated with two genetic mouse models." *Am J Physiol Ren Physiol* 285 (2003): F1060-F1067.
6. Ninichuk, Volha, Oliver Gross, Christoph Reichel and Andrej Khandoga, et al. "Delayed chemokine receptor 1 blockade prolongs survival in collagen 4A3-deficient mice with Alport disease." *J Am Soc Nephrol* 16 (2005): 977-985.

How to cite this article: Broadbelt, Linda. "Microenvironment Engineering of Catalysts Using Organic Molecules." *Mol Bio* 12 (2023): 400.