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Photoelectrochemical and Structural Analysis of Electrodeposited CeO_2 Photoanodes

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Introduction

The growing demand for renewable energy solutions has led to the development of various photoelectrochemical systems that can harness solar energy for applications such as water splitting and energy conversion. Among the key components of these systems, photoanodes play a critical role in facilitating the photocatalytic processes that drive reactions like water oxidation. Metal oxide semiconductors, particularly Cerium Oxide (CeO_2), have gained attention as promising materials for PEC photoanodes due to their unique electronic and chemical properties, such as high oxygen evolution reaction activity, stability, and the ability to undergo reversible redox processes. CeO_2 is a wide bandgap material, which can be tuned for photoelectrochemical applications, offering not only good charge transport properties but also excellent surface chemistry for electron and hole generation. The combination of these characteristics makes CeO_2 an ideal candidate for use as a photoanode material in solar-driven PEC systems. The electrodeposition technique, which involves the deposition of CeO_2 films onto conductive substrates, offers an effective and cost-efficient method for preparing these photoanodes. By manipulating parameters such as deposition time, temperature, and electrolyte composition, the structure and performance of CeO_2 photoanodes can be fine-tuned for optimal PEC performance. This research explores the photoelectrochemical behavior and structural characteristics of electrodeposited CeO_2 photoanodes, aiming to provide insights into how the deposition process influences their efficiency and stability in PEC applications.

Description

Electrodeposition of CeO_2 thin films involves the application of an electric current to a solution containing cerium salts, which leads to the reduction of cerium ions onto a substrate, forming a thin oxide film. This method is widely used because it is simple, low-cost, and capable of producing uniform coatings with controlled thickness. The structure of the electrodeposited CeO_2 films is influenced by various factors, such as the composition of the electrolyte, the deposition potential, and the temperature during the deposition process. By adjusting these parameters, researchers can manipulate the crystallinity, morphology, and surface area of the CeO_2 films, which, in turn, affect their performance as photoanodes. For instance, higher deposition potentials tend to promote the formation of CeO2 films with larger crystallites, which can improve charge transport but may reduce the surface area available for photocatalytic reactions. On the other hand, lower deposition potentials often yield more amorphous films, which may enhance the surface area but reduce the electrical conductivity of the films. These structural changes are closely related to the photoelectrochemical performance of the CeO_2 photoanodes. A key factor in their performance is the ability of the material to efficiently separate and transport charge carriers generated under illumination. In CeO_2, the oxygen vacancy defects and Ce3+/Ce4+ redox couples contribute significantly to charge transfer processes, which influence the overall PEC activity.

The photoelectrochemical properties of CeO_2 photoanodes are primarily determined by their ability to drive the oxygen evolution reaction, a key step in solar-driven water splitting. Under illumination, the CeO_2 photoanode generates electron-hole pairs, with the photogenerated holes driving the oxidation of water to oxygen at the surface of the material. The efficiency of this process depends on several factors, including the electronic properties of the CeO_2 film, the concentration of oxygen vacancies, and the surface characteristics. The band gap of CeO_2, typically around 3.1 eV, makes it capable of absorbing UV light, though the material's ability to harness visible light is limited. Recent studies have shown that modifying the CeO_2 films, for example, by doping with metal ions or by controlling the size and distribution of oxygen vacancies, can extend the light absorption range into the visible spectrum, thus improving the overall PEC performance. Furthermore, the structural properties of the electrodeposited films play a significant role in their photoelectrochemical behavior. The morphology, surface roughness, and crystallinity of the CeO_2 films affect the density of active sites for the oxygen evolution reaction, as well as the charge transport pathways. Films with a higher surface area, for example, are likely to exhibit enhanced OER activity because they provide more active sites for the reaction. Similarly, well-aligned crystalline structures can facilitate better charge transport, reducing the recombination of charge carriers and improving the overall efficiency of the photoanode.

A critical aspect of photoelectrochemical performance is the stability of the photoanode material under operational conditions. For practical applications in solar energy conversion, a photoanode must not only be efficient but also durable under prolonged exposure to electrochemical conditions. The stability of CeO_2 photoanodes is influenced by factors such as the rate of surface degradation, the formation of undesirable surface states, and the susceptibility to corrosion or phase transformation. In the case of CeO_2, its ability to undergo reversible Ce3+/Ce4+ redox cycling is beneficial for its long-term stability, as it allows the material to recover from surface oxidation during PEC operation. However, high rates of water oxidation can lead to the formation of surface defects, which can negatively impact the material's performance. This challenge can be mitigated by optimizing the electrodeposition conditions to create films with a more robust structure, which can better withstand the electrochemical environment. Additionally, post-deposition treatments, such as annealing, can improve the crystallinity and stability of the films, enhancing their photoelectrochemical performance over time [1-5].

Conclusion

In conclusion, electrodeposited CeO2 photoanodes exhibit promising photoelectrochemical and structural properties that make them suitable for use in solar-driven water splitting and other PEC applications. The electrodeposition method provides an efficient way to prepare CeO2 films

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with tunable structural characteristics, which can be optimized for improved PEC performance. Key factors such as the morphology, crystallinity, and surface area of the films influence their ability to support efficient charge transfer and oxygen evolution reactions. Furthermore, the ability of CeO_2 to undergo reversible redox reactions contributes to its long-term stability under operational conditions, making it a promising candidate for sustainable energy applications. While there is significant progress in understanding the photoelectrochemical behavior of CeO_2 photoanodes, further research is needed to refine the electrodeposition process and improve the material's performance, particularly in enhancing its visible light absorption and reducing charge carrier recombination. With continued advancements in material design and deposition techniques, CeO2-based photoanodes have the potential to play a crucial role in the development of efficient and cost-effective renewable energy systems.

Acknowledgment

None.

Conflict of Interest

None.

References

1. Ankita, Ankita, Surjeet Chahal, Saurabh Singh and Sandeep Kumar, et al. "Europium-doped cerium oxide nanoparticles: Investigating oxygen vacancies and their role in enhanced photocatalytic and magnetic properties." *Environ Sci Pollut Res Int* 31 (2024): 1276-1287.
2. Lu, Yuzheng, Youquan Mi, Junjiao Li and Fenghua Qi, et al. "Recent progress in semiconductor-ionic conductor nanomaterial as a membrane for low-temperature solid oxide fuel cells." *Nanomaterials* 11 (2021): 2290.
3. Shi, Le, Sifei Zhuo, Mutalifu Abulikemu and Gangaiah Mettela, et al. "Annealing temperature effects on photoelectrochemical performance of bismuth vanadate thin film photoelectrodes." *RSC Adv* 8 (2018): 29179-29188.
4. Pelli Cresi, Jacopo Stefano, Lorenzo Di Mario, Daniele Catone and Faustino Martelli, et al. "Ultrafast formation of small polarons and the optical gap in CeO_2." *J Phys Chem Lett* 11 (2020): 5686-5691.
5. Luo, Yuting, Juan Li, Jie Zhu and Ye Zhao, et al. "Fabrication of condensate microdrop self-propelling porous films of cerium oxide nanoparticles on copper surfaces." *Angew Chem Int Ed* 54 (2015): 4876-4879.

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