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ABSTRACT:

Photoelectrochemical Ammonia Synthesis: Advancements, Challenges, and Future Prospects

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This work provides a comprehensive overview of photoelectrochemical (PEC) ammonia synthesis, focusing on the use of photocatalysts and PEC reactors as sustainable alternatives to the traditional Haber-Bosch process. PEC ammonia synthesis leverages solar energy for the reduction of nitrogen (N_2) to ammonia (NH_3), offering a cleaner and more energy-efficient approach to ammonia production [1]. This work aims to explore various catalytic materials, reactor designs, and advancements in PEC technology, highlighting both their advantages and limitations.

Recent research has demonstrated the potential of different materials as photocatalysts for PEC ammonia synthesis, showcasing their ability to enhance reaction efficiency under ambient conditions. These materials effectively promote charge carrier dynamics and facilitate the nitrogen reduction reaction (NRR), achieving higher catalytic activity and stability compared to traditional methods. Additionally, innovations in reactor designs have optimized mass transfer, light absorption, and charge utilization, further improving the performance of PEC ammonia production. Despite significant progress, several challenges remain, particularly regarding faradaic efficiency, selectivity, and reaction stability. Competition with undesired reactions, such as hydrogen evolution and the formation of by-products like nitrites. Furthermore, the optimization of material properties and reactor configurations is crucial for scaling up PEC systems for industrial applications. Therefore, while the use of solar energy in PEC ammonia synthesis presents a promising opportunity to reduce environmental impact, further research is essential to address the existing technological limitations and ensure the economic viability of these systems.

[1] O. A. Ojelade, S. F. Zaman, B. Ni, J. Environ. Manage., 342 118348 (2023).