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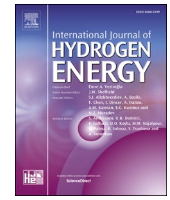

Challenges in photocatalytic hydrogen evolution: Importance of photocatalysts and photocatalytic reactors

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ABSTRACT

Photocatalytic hydrogen evolution has attracted tremendous interest as it offers a process for generation of green hydrogen based on solar radiation. But the process is extremely complex as many factors influence photocatalytic hydrogen evolution. While novel photocatalysts such as MOFs, perovskites, conjugated polymers, carbon-based materials, quantum dots, and others face challenges such as stability and scalability, semiconductor photocatalysts and cocatalysts such as TiO_2/Pt, Ni–CdS, CdS/ZnO, CdS/ZnS have the advantages of simplicity in synthesis, stability, and scalability. Despite decades of research, challenges such as charge separation, spectrum usage, low hydrogen generation efficiency, photocatalyst stability and scalability persist. This review discusses what has been achieved so far in the domain of photocatalytic hydrogen evolution and presents a critical analysis of challenges to be addressed in developing a robust and practical photocatalytic hydrogen generation system based on efficiency of photocatalysts and their stability and the extreme importance of efficient reactor designs.

1. Introduction

Hydrogen (H_2) is a green energy fuel with many advantages over traditional fuels like petroleum and coal, including the ability to be stored for several months and transported between sites, making it an attractive option to address current and future energy demands. Unlike petroleum and coal, hydrogen is ecologically pure, emitting no harmful gases during combustion, and has an ample energy density 2.6 times greater than petrol [1,2]. However, external energy is needed to produce hydrogen through water-splitting. Hence, hydrogen fuel cells (HFCs), considered to be an important green energy option of the future, would be sustainable if green hydrogen can be produced economically from renewable sources like solar energy [3]. The current energy problem has become acute with the current fossil fuel consumption which generated 33890.8 million tonnes of carbon dioxide in 2018 and accounted for 65% of global energy production [4]. On the other hand, hydrogen is a clean energy source as it only reacts with oxygen (O_2) to form water. Thus, the best long-term solution to the global environmental issues due to fossil fuels is hydrogen-based future energy infrastructure.

Hydrogen may be produced by a variety of processes, including photocatalysis, thermochemistry, and electrolysis. The most practical clean and renewable energy source that can successfully meet the world's energy needs is solar energy. Consequently, there is great interest in employing semiconductor catalysts and solar energy for photocatalytic hydrogen evolution via water splitting to generate hydrogen [5]. This is an important method to address the dual challenges of meeting energy demands and lowering ecological risks related to continuing dependency on fossil fuels [6]. This approach offers a viable means of reducing carbon dioxide emissions, bolstering the endeavour worldwide to tackle climate change. One benefit of photocatalytic hydrogen production using solar radiation and water is that it does not generate hazardous pollutants. One major challenge, however, is the

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