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Nonthermal plasma-assisted catalysis NH_3 decomposition for CO_x-free H_2 production: A review

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A R T I C L E I N F O

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A B S T R A C T

Hydrogen (H_2) is recognized as a viable and environmentally friendly energy source, utilized across various domains, from large-scale chemical energy exports to small-scale power generation in remote areas. However, the storage and distribution costs of H_2 present significant challenges. Ammonia (NH_3) emerges as a carbon-free hydrogen carrier, backed by a robust international transport and storage infrastructure. On-site hydrogen production can be efficiently achieved through NH_3 decomposition, predominantly via thermal catalysis. One innovative approach involves plasma technology, which utilizes NH_3, alcohols, or hydrocarbons to produce pure hydrogen in plasma reactors. Nonthermal plasma (NTP) in particular, for NH_3 decomposition and H_2 production, has garnered considerable interest owing to its higher energy efficiency than thermal plasma systems. Furthermore, integrating NTP with catalysis, termed plasma-assisted catalysis, creates a synergistic effect, enhancing NH_3 decomposition efficiency for H_2 production through improved plasma-catalyst interactions. Consequently, NTP-catalysis holds the potential to revolutionize NH_3 conversion and utilisation in the future. To date, there have been limited studies on NTP-assisted catalytic NH_3 decomposition. This review article compiles the latest NTP-assisted catalytic NH_3 decomposition methodologies for H_2 production. It delves into the basics of plasma-assisted NH_3 decomposition, including adsorption, desorption, and the synergistic processes during plasma catalysis. Additionally, it examines the impact of NTP on the chemical states and properties of various catalysts and provides a comprehensive analysis of the factors influencing NH_3-plasma decomposition.

1. Introduction

Hydrogen (H_2) gas is increasingly employed as an alternative energy source in industrial operations. Therefore, large-scale H_2 generation is required. H_2 energy systems are an effective, eco-friendly, and sustainable solution for decarbonising a range of sectors where substantial reductions in carbon emissions are challenging. H_2 may be synthesized from water, fossil fuels biomass, or a combination of these three. The H_2 production techniques have been summarised in several review articles [1–6]. Most of the H_2 produced worldwide is from the methane steam reforming process. Also, H_2 produced using renewable energy sources, known as low-carbon H_2, is a clean energy vector. H_2 contains 2.5 times the energy by weight of any other standard fuel; therefore, it could be considered the energy vector for the future. However, the disadvantage of using methane steam reforming is that CO_2, a greenhouse gas, is emitted as a co-product. Moreover, H_2 storage and distribution of H_2 is difficult, which considered a challenge. Therefore, H_2 must be produced on-site for various industrial applications [7–9]. Owing to the storage and distribution challenges of H_2 fuel, NH_3 is a carbon-free H_2 carrier that allows cost-effective storage and distribution.

NH_3 decomposition is an attractive H_2 supply strategy as NH_3 is a liquefiable fuel with a high density of H_2 [10–14]. NH_3 is simple to transport and store for the production of COx-free H_2, making it an appealing option for on-site H2 production. It is a term that defines H_2 generated without the accompanying emission of carbon oxides like carbon monoxide (CO) and carbon dioxide (CO_2). Most of the literature on NH_3 decomposition for H_2 production focuses on catalytic-assisted cracking (decomposition) using noble (Pt, Pd, Ru, etc.) and cost-efficient metal (Fe, Fi, etc.) catalysts. However, catalytic NH_3

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