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Facile fabrication of binary g-C_3N_4/NH_2-MIL-125(Ti) MOF nanocomposite with Z-scheme heterojunction for efficient photocatalytic H_2 production and CO_2 reduction under visible light

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ABSTRACT

A binary g-C_3N_4/NH_2-MIL-125(Ti) MOF nanocomposite was fabricated through a facile sonochemical-assisted thermal approach for enhanced photocatalytic H_2 production and CO_2 reduction under visible light. Compared to pure g-C_3N_4, the g-C_3N_4/MOF photocatalyst showed enhanced visible light absorption with promoted charge carrier separation which increased the H_2 production rate and the CO_2 reduction into CH_4 and CO. This enhancement was attributed to the successfully constructed Z-scheme heterojunction in addition to the visible-active, large surface area and highly CO_2 adsorbable NH_2-MIL-125(Ti) MOF. The highest H_2 production of 480 μmol g^{-1} was exhibited over the g-C_3N_4/NH_2-MIL-125(Ti) nanocomposite with 20 wt% MOF. Similarly, the highest CO production rate of 338 μmol g^{-1} was achieved with 20 wt% MOF composite. However, for the CH_4 product gas, it was observed that the highest production rate was attained with pure g-C_3N_4 which reveals the NH_2-MIL-125(Ti) MOF selectivity towards CO production instead of CH_4. Among all the investigated sacrificial agents for H_2 production, methanol was the best. The performance of CO_2 reduction process was found to be increasing with the pressure increase. Furthermore, the stability investigations revealed continuous productions of H_2, CO and CH_4 over the C_3N_4/MOF photocatalyst in multiple cyclic runs without any significant photocatalyst deactivation. This study provides new ideas for the fabrication of cheap, efficient and easy-synthesized nanomaterials for energy production and environmental remediation applications.

1. Introduction

Nowadays, fossil fuels depletion and greenhouse gas emissions produced from burning these fuels are regarded as the main global issues to humanity [1,2,84]. Fossil fuels represent almost 80 % of our energy sources and the demand on these fuels is expected to rise up to 56 % by 2040 which will lead to a severe shortage in fulfilling the energy requirements [3,4]. Thus, looking for sustainable and renewable technologies for energy production and environmental remediation is essential in the future. Hydrogen-based energy is one of the strongest competitors in this field, as it is considered a clean alternative since hydrogen combustion generates no pollutants or greenhouse gases, moreover, hydrogen has a high energy yield of 122 kJ/g which is about three times greater than the hydrocarbon fuels [5,6]. However, 95 % of hydrogen is currently produced by energy-intensive and complex reforming processes of fossil fuels (mainly methane), in which high pressures and temperatures are required to conduct these processes [7,8]. Recently, a new clean and sustainable technology known as photocatalysis has attracted researcher's attention for hydrogen production and CO_2 reduction through solar light-assisted reaction in the presence of a semiconductor material known as photocatalyst. The photocatalyst plays a key role in this process, therefore, numerous studies and investigations have been reported for designing semiconductor photocatalysts with high photocatalytic performance.

Among all other semiconductor materials, graphitic carbon nitride (g-C_3N_4) has attracted great attention in the field of photocatalysis due

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