



Novel pyrochlore type europium stannate – tungsten disulfide heterostructure for light driven carbon dioxide reduction and nitrogen fixation

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ABSTRACT

The reduction of carbon dioxide (CO₂) and nitrogen (N₂) to value-added products is a substantial area of research in the fields of sustainable chemistry and renewable energy that aims at reducing greenhouse gas emissions and the production of alternative fuels and chemicals. The current work deals with the synthesis of pyrochlore-type europium stannate (Eu₂Sn₂O₇: EuSnO), tungsten disulfide (WS₂/WS), and novel EuSnO/WS heterostructure by a simple and facile co-precipitation-aided hydrothermal method. Using different methods, the morphological and structural analyses of the prepared samples were characterized. It was confirmed that a heterostructure was formed between the cubic EuSnO and the layered WS. Synthesized materials were used for photocatalytic CO₂ and N₂ reduction under UV and visible light. The amount of CO and CH₄ evolved due to CO₂ reduction is high in EuSnO/WS (CO = 104, CH₄ = 64 μmol h⁻¹ g⁻¹) compared to pure EuSnO (CO = 36, CH₄ = 70 μmol h⁻¹ g⁻¹) and WS (CO = 22, CH₄ = 1.8 μmol h⁻¹ g⁻¹) under visible light. The same trend was observed even in the N₂ fixation reaction under visible light, and the amount of NH₄⁺ produced was found to be 13, 26, and 41 μmol h⁻¹ g⁻¹ in the presence of WS, EuSnO and EuSnO/WS, respectively. Enhanced light-driven activity towards CO₂ and N₂ reduction reactions in EuSnO/WS is due to the efficient charge separation through the formation of type-II heterostructure, which is in part associated with photocurrent response, photoluminescence, and electrochemical impedance spectroscopic (EIS) results. The EuSnO/WS heterostructure's exceptional stability and reusability may pique the attention of pyrochlore-based composite materials in photocatalytic energy and environmental applications.

1. Introduction

Because of the speed at which industrialization is progressing, the current generation is increasingly facing a major threat from CO₂ emissions. However, excessive reliance on fossil fuels is regarded as a critical concern for a carbon-dependent society (Liu and Li, 2022; Chen et al., 2020a; You et al., 2024). The main cause of ongoing global warming is the overuse of fossil fuels. In order to achieve a sustainable future, one should consider the most environmentally friendly way to

reduce and ultimately eliminate CO₂ (Yogesh Kumar et al., 2023a,b; Hepburn et al., 2019). As a result, photoinduced CO₂ reduction is deliberated as a practical and safe method of achieving a society free of carbon (Sreedhar et al., 2021; Wang et al., 2021). The carbonaceous products of the photocatalytic CO₂ reduction reaction (CRR) have a lot of industrial applications, like chemical feedstock for the synthesis of plastics, synthetic fuels, fuel for energy production, and fuel for transportation, heating, and the production of electricity (Bao et al., 2023; Ubaidullah et al., 2023). On the other hand, ammonia (NH₃) finds

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