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Praseodymium orthovanadate-waste PET bottle derived sulfur doped carbon for efficient Z-scheme photocatalytic CO_2 reduction

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ABSTRACT

Escalating amounts of carbon dioxide (CO_2) in the Earth's atmosphere are a major cause of climate change and its negative consequences, making it a global concern. The present work highlights the intersection of waste management, resource utilization, and climate change mitigation, showcasing the potential for an additional sustainable and circular economy. Synthesizing carbon from waste polyethylene terephthalate (PET) bottles is an eco-friendly approach. X-ray diffraction, Raman spectroscopic, scanning electron microscopic, tunnelling electron microscopic, infrared fourier transform spectroscopy (FTIR) and X-ray photoelectron spectroscopic results indicate the effective extraction of carbon doped with sulfur (S@C) and the successive formation of nanocomposite with $PrVO_4$ (PrV/S@C). Superior photocatalytic activity was observed under visible light compared to UV light. PrV/S@C showed enhanced light-driven CO_2 reduction compared to pristine materials and was found to evolve 39, 56, and 98 μmol h^{-1} g^{-1} of H_2, CH_4 and CO, respectively. The effect of reaction temperature was examined and optimized at 100 °C. The enhanced activity in PrV/S@C compared to PrV and S@C probably due to the increased surface area, conductivity and synergy. In-Situ Diffused reflectance (DRIFT-IR) and liquid chromatography mass spectroscopy (LC-MS) confirm the evolution of CO and CH_4. The optical, photo/electrochemical, Scavenger studies, Electron spin resonance (ESR) and Mott-Schottky studies suggest the formation of a direct Z-scheme photoredox reaction in the presence of PrV/S@C and sacrificial gent. The reusability studies for 5 cycles indicate good stability with a slight deviation in structure and morphology of PrV/S@C, as observed in XRD and SEM. Tackling plastic pollution and generating value-added carbonaceous products through CO_2 reduction is the twin application of the present work that has piqued the interest of several researchers in environmental remediation.

1. Introduction

Carbon dioxide (CO_2) emissions from the increased use of fossil fuels over the past few decades have resulted in an increase in environmental issues. As human activities continue to emit enormous amounts of CO_2 into the atmosphere, there is an urgent need for new and long-term solutions to lessen the environmental impact [1,2]. Rapid increases in atmospheric CO_2 concentrations have unintended repercussions, including global warming, with temperatures rising at a rate (0.18 °C/decade) that is more than double (0.08 °C/decade) over the previous 100 years [3–5]. The United Nations has pledged to achieve "net zero" emissions by 2050, which means removing as much CO_2 from the atmosphere each year as is emitted due to human activity [6,7]. Attaining this aim will necessitate a global collaboration of scientists, policymakers, and industries. The development of innovative materials on industrial scales to selectively remove CO_2 from gas mixtures allows for a multifaceted strategy for reducing CO_2 emissions [8,9]. CO_2 can be captured in the atmosphere utilizing materials and processes for biological, chemical, and geological technology, reducing our dependency on fossil fuel supply. Many strategies for turning CO_2 into hydrocarbon

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