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Article

New Insights into Cu/Cu_2O/CuO Nanocomposite Heterojunction Facilitating Photocatalytic Generation of Green Fuel and Detoxification of Organic Pollutants

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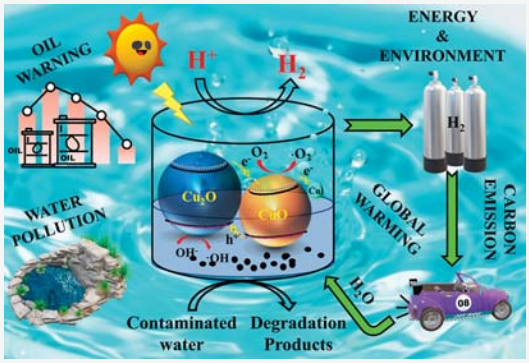
ABSTRACT: Cu/Cu_2O/CuO nanocomposites were synthesized using the simple wet chemical approach for the production of dihydrogen as a potential fuel source and for the detoxification of dyes. The formation of Cu/Cu_2O/CuO nanocomposites is confirmed by powder X-ray diffraction, whereas the W-H plot revealed the average particle size of nanocomposite approximately 17 nm, which is in good agreement with the Scherrer method and transmission electron microscopy analysis. The uniform distribution of Cu and O elements was supported by the elemental mapping of the nanocomposite. Band gaps of CuO and Cu_2O were found to be 1.71 and 1.92 eV, respectively, using diffuse reflectance spectroscopy spectra and Kubelka−Munk functions. The oxygen vacancies in the nanocomposite are confirmed by various analytical spectroscopic techniques, such as electron paramagnetic resonance, Raman, photoluminescence, and X-ray photoelectron spectroscopy (XPS) spectra. The significant boost in the performance of the fabricated nanocomposite was observed and is attributed to the formation of a heterojunction and existence of oxygen vacancy. The nanocomposite demonstrated proficiency in the photocatalytic splitting of water for the production of hydrogen. The maximum hydrogen generation yield (68 μmol g^{-1}) was observed for Cu/Cu_2O/CuO nanocomposites along with NiO (co-catalyst) and methanol as a hole scavenger as well as an electron donor. Moreover, the degradation of congo red (CR) and malachite green (MG) dyes was also investigated and the efficiency of the nanocomposite was found to be 80 and 60%, respectively, after 120 min of light irradiation. The stability of nanocomposites after photocatalysis was investigated by the XPS spectrum of the nanocomposite. Explicitly, the area and broadening of the O 1s XPS spectrum demonstrated higher degradation of CR dye as compared to MG dye.



1. INTRODUCTION

The exhaustion of fossil fuels triggered an energy crisis and caused significant environmental harm in one manner or another. The majority of energy is still derived from finite nonrenewable fossil fuels. In addition, burning of fossil fuels has a significant detrimental effect on the environment, resulting in air and water pollution, global warming, and many other problems. So, we must search for clean and environmentally benign fuels. Environmental restoration and energy conservation have sparked immense interest in photocatalytic water splitting. Hydrogen gas is produced by photocatalytic means, which is energy efficient and environmentally benign. Due to high calorific value, natural availability, and lack of harmful byproducts, hydrogen is a desirable fuel source.[1] Being omnipresent, it adapts to a low-carbon future and reduces reliance on fossil fuels in everyday routines.[2,3] It can take on diverse roles, such as energy storage and transport (analogous to electricity), seen in the case of hydrogen fuel cells and also for energy production in the case of hydrogen-driven vehicles.[4] Hydrogen gas generation via photocatalytic water splitting necessitates the photogeneration of photons. When photocatalysis is employed to split water to generate hydrogen gas, the electrons of conduction band (CB) play a significant role in the reduction of protons to generate hydrogen gas. The CB level for hydrogen generation must be lower than the level for hydrogen evolution (E_{H_2/H_2O}). The narrow band gap of single-phase particles exhibits weak photocatalytic activity. Therefore, mixing two or more phases with varying band gaps increases the photocatalytic activity. This is brought on by the ability for charge separation and the broad energy range for photoexcitation. Under light irradiation, the mixed phases of CuO and Cu_2O exhibit better photocatalytic performance.[5,6] The

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