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Effects of transition metals (Fe, Co) on the physical and photoelectrochemical hydrogen generation properties of copper oxide nanoparticulate films

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ABSTRACT

The composites of some transition metal oxides are currently attracting interesting roles in various fields of technology and industry. The present work attempts to tune the properties of copper oxide (CuO) for hydrogen energy generation. Iron (Fe) and cobalt (Co) were intentionally doped at precise contents into CuO thin films. X-ray diffraction (XRD) indicated that the successful substitution of Fe and Co on the Cu sites created induces pressure (tensile) stress in the lattice. Fe doping deteriorated the films' crystallinity and increased the dislocation density from 1.82×10^{-3} to 4.36×10^{-3} nm^{-2}, while Co codoping displayed unsystematic behavior. The scanning electron microscope (SEM) images showed that the films have smooth surfaces comprising a huge number of particles/unit area with a narrow size distribution. The energy-dispersive X-ray (EDX) analysis confirmed the presence of both Fe and Co with almost the pre-calculated ratios. The optical measurement showed that increasing the Fe contents increases the absorption coefficient of CuO and narrows its optical band gap from 1.7 to 1.55 eV. The photoluminescence (PL) intensity increases for Fe-doped CuO films whereas quenched when doped with Co. A series of photoelectrochemical (PEC) measurements were conducted to evaluate the performance of the prepared films in the production of solar hydrogen. The CuO–6%Fe film showed high photocatalytic performance for H_2 generation from H_2O splitting over a wide wavelength range of sunlight with long-term photostability. The photocurrent density of CuO–6%Fe film is about 155 times more than those obtained from pure CuO film. The incident photon-to-current efficiency (IPCE) and the solar-to-hydrogen efficiency (η_{STH}) of CuO–6%Fe film were 5.98 % at 307 nm and 0.94 % under Xenon illumination, respectively. Hence, this work proposed an efficient and reasonable technique to enhance the performance of a CuO-based photoelectrode for solar hydrogen production.

1. Introduction

The composites based on transition metal oxide (TMO) grabbing increased attention worldwide. This is owing to the numerous technological uses such as in gas sensing, energy-saving applications, optoelectronic devices, and hydrogen generation [1–8]. Among the TMOs, CuO is an interesting material due to its abundance in nature and environmentally friendly. Its direct optical energy bandgap of 1.2–2.2 eV enables the material to absorb all wavelengths in the visible region. This encourages the use of CuO in photoelectrochemical (PEC) cells, Li-ion batteries, and infrared photodetectors [6–9]. It is well-known that the properties and application of nano-sized materials depend mainly on the route and preparation conditions, morphology, composition, and type of dopants. Lee et al. [3] improved the CuO photostability by post-annealing treatment at 500–600 °C. Sahu et al. [4] fabricated CuO films by DC magnetron sputtering, at different substrate temperatures, with improved activity to degrade methyl orange (MO) and methyl blue (MB) dyes which are useful in wastewater treatment. Ashour et al. [7]

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