Nanoporous $BiVO_4$ Thin Film Deposition by Reactive Magnetron Sputtering

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Abstract

Bismuth vanadate ($BiVO_4$) is amongst the hottest semiconductor materials in the photocatalysis field owing to features like visible light absorption, stability, and photoactivity. $BiVO_4$ photocatalysts in the form of thin film could also solve the recyclability and reusability issue with which the powder photocatalysts have been struggling. In this research, nanoporous $BiVO_4$ thin films have been deposited on fused silica substrates through reactive magnetron sputtering of metallic bismuth and vanadium targets. The amount of power, applied to each target, adjusted to control the chemical composition of the films, which were measured by the energy dispersive spectroscopy (EDS) method. The films were annealed at 300 and 450 ˚C to obtain the photoactive monoclinic scheelite crystal structure, as well as to make a comparative investigation of the annealing temperature effect on the microstructure and optical properties. The samples were characterized by X-ray diffraction (XRD), field emission scanning electron microscopy (FESEM), and ultraviolet-visible-infrared spectroscopy (UV-Vis-IR). XRD results showed that the as-deposited films were amorphous while the pure monoclinic scheelite $BiVO_4$ crystal structure was obtained after both 300 and 450 ˚C post-annealing treatment with a slight difference in average crystallite size (45 and 48 nm, respectively). FESEM images showed a uniform surface with no observable domains or grain boundaries for the as-deposited film, whereas the films annealed at 300 and 450 ˚C showed cracks and separate domains probably due to the crystallization and difference in linear thermal expansion coefficients between $BiVO_4$ (the film) and fused silica (the substrate). Nanometric voids and pores are also observable in the film annealed at 450 ˚C as opposed to the film annealed at 300 ˚C with dense surface morphology, which could be associated with the high annealing temperature compared to the bismuth's melting point causing fast diffusion of vanadium and oxygen atoms into the molten area resulting in nanopores formation based on the Kirkendall effect. UV-Vis-IR spectroscopy technique was utilized to measure the transmittance and reflectance, and to calculate absorbance and optical bandgaps of the films. A reduction in the films' transparency was observed, as well as the bandgap values (2.82, 2.69, 2.51 eV, respectively) by the rise in the annealing temperature. These results established the influence of the annealing temperature, which is optimum at 450 ˚C to gain the most amount of porosity, and the narrowest bandgap enabling the films to harvest visible light more effectively in photocatalysis applications.

Keywords: Sputtering; $BiVO_4$; Thin Film; Photocatalysis; Spectroscopy

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