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Enhanced photocatalytic activity of sputter-deposited nanoporous BiVO₄ thin films by controlling film thickness

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Abstract

In this study, nanoporous BiVO₄ thin films were deposited using reactive direct-current (DC) magnetron sputtering. The effects of thickness on the film morphology, crystal structure, microstructure, composition, optical and photocatalytic properties under visible light were investigated. The film porosity and refractive index were also determined via the UV-Vis spectrophotometric technique using transmittance and reflectance spectra and Cauchy dispersion law as the fitting model. The nanoporous morphology was observed using field-emission scanning electron microscopy (FESEM) with average pore sizes in the 20 - 40 nm range. The X-ray diffraction (XRD) results showed different texture grades corresponding to the (040) crystallographic plane, establishing the film thickness influence on the preferential orientation. The X-ray photoelectron spectroscopy (XPS) was also implemented to investigate the chemical state of the film surface, as well as to determine the valence band position. The film 715 nm in thickness showed the highest porosity (52 %), narrowest bandgap (2.44 eV), highest exposed (040) crystallographic plane and highest visible-light-driven photodegradation towards Rhodamine-B (RhB) solution. The pH of the solution also impacted the RhB photodegradation which was optimum at pH = 3 with chromophore cleavage pathway dominance, whereas at neutral pH it had distinctively slow kinetics probably due to poor electrostatic interactions and the N-deethylation kinetics bottleneck. The photocatalytic cycle experiments exhibited high stability and recyclability of BiVO₄ thin-film photocatalysts after four cycles (4 x 7 h) of exploitation. The photocatalytic mechanism was determined using scavengers and the significance of hydroxyl radicals and photogenerated holes were established. The photocatalytic activity reached 97 % after 7 h of illumination with a 400 W light source.

Keywords: BiVO₄; Thin film; Thickness; Sputtering; Photocatalyst

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