Enhanced photocatalytic activity of sputter-deposited nanoporous $BiVO_4$ thin films by controlling film thickness

Siavash Bakhtiarnia [a,b], Saeed Sheibani [a,*], Alain Billard [b], Hui Sun [c], Eric Aubry [b], Mohammad Arab Pour Yazdi [b]

[a]. School of Metallurgy and Materials Engineering, College of Engineering, University of Tehran, Tehran, Iran.
[b]. Institut FEMTO-ST, UMR 6174, CNRS, Univ. Bourgogne Franche-Comté, 15B, Avenue des Montboucons, 25030 Besançon, France[c].
[c] School of Space Science and Physics, Shandong University, Weihai 264209, China

Abstract

In this study, nanoporous $BiVO_4$ 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 $BiVO_4$ 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: $BiVO_4$; Thin film; Thickness; Sputtering; Photocatalyst

Journal of Alloys and Compounds 879 (2021) 160463

https://doi.org/10.1016/j.jallcom.2021.160463