Applied Catalysis A: General 425–426 (2012) 74–78

Contents lists available at SciVerse ScienceDirect

Applied Catalysis A: General

journal homepage: www.elsevier.com/locate/apcata

Novel photocatalyst, $Bi_2Sn_2O_7$, for photooxidation of As(III) under visible-light irradiation

Qinfen Tian [a,b], Jiandong Zhuang [c], Jixin Wang [a], liyan Xie [a], Ping Liu [a,*]

[a] Research Institute of Photocatalysis, State Key Laboratory Breeding Base of Photocatalysis, Fuzhou University, Fuzhou, 350002, PR China
[b] Xi'an Catalyst Chemical Co., LTD., Northwest Institute for Nonferrous Metal Research, Xi'an, 710016, PR China
[c] State Key Laboratory of High Performance Ceramics and Superfine Microstructure, Shanghai Institute of Ceramics, Chinese Academy of Sciences, Shanghai, 200050, PR China

ARTICLE INFO

Article history:
Received 17 November 2011
Received in revised form 29 February 2012
Accepted 1 March 2012
Available online 10 March 2012

Keywords:
$Bi_2Sn_2O_7$
Visible-light photocatalyst
As(III) removal
Hydrothermal process

ABSTRACT

Nanocrystalline $Bi_2Sn_2O_7$, a visible-light photocatalyst synthesized via a facile hydrothermal route, is used to remove arsenite from aqueous solution for the first time. The as-synthesized $Bi_2Sn_2O_7$ product is characterized by X-ray diffraction, N_2 sorption–desorption, UV–vis diffuse reflectance spectroscopy, transmission electron microscopy, electron spin resonance, X-ray photoelectron spectra, and electrochemistry technology. The results reveal that the sample has an average particle size of approximately 10 nm, a specific surface area of 51.3 m^2/g, and a band gap of 2.88 eV. Moreover, the $Bi_2Sn_2O_7$ nanoparticles exhibit a high photocatalytic activity in the oxidation of As(III) (up to 96.8%) under visible-light irradiation. $^{\bullet}O_2^-$ and h^+ are recognized as the primary active species responsible for As(III) oxidation. Meanwhile, a possible mechanism for the photo-oxidation of As(III) over $Bi_2Sn_2O_7$ is also proposed.

1. Introduction

Arsenic contamination in natural water is posing a great threat to millions of people in many regions of the world [1]. Being a widely distributed element in nature, arsenic can be mobilized into groundwater from soils and ores through both natural process and anthropogenic activities [2,3]. Chronic arsenic poisoning can cause a lot of human health problems through contaminated drinking and agricultural irrigation water. In natural water, most arsenic pollution exists mainly as the As(III) and As(V) oxyanions, arsenite $(AsO_2)^-$ and arsenate $(AsO_4)^{3-}$. In comparison with arsenate, arsenite is much more toxic and mobile in natural waters, and less efficiently removed in adsorption/coagulation processes [4–6]. Therefore, the oxidation of As(III) to As(V) is highly desirable for enhancing the immobilization of arsenic and is required for most arsenic removal technologies [7–9]. Ever since the first report by Rajeshwar in 1999 [8], many efforts have been made on the photocatalytic oxidation of As(III) with TiO_2 under UV light illumination [5,10–14]. However, TiO_2 is active only under UV irradiation ($\lambda < 387$ nm) because of its wide band gap (~3.2 eV), which hinders its further application in the visible light region ($\lambda > 400$ nm).

To improve the efficiency of utilizing solar energy, considerable attentions have been focus on designing the visible-light-driven photocatalysts. TiO_2-based photocatalysts that are sensitive to visible-light have been widely investigated by various strategies, such as doping with metal or non-metal impurities [15–17], coupling with narrow band-gap semiconductors [18] and so on. Nevertheless, through exploitation of new materials, some non-titania-based catalysts have also been synthesized; for example, $BiVO_4$ [19], $Bi_2Si_2O_5$ [20] and some sulfides [21,22] have been found to possess visible-light-driven photocatalytic activity. As a kind of pyrochlore-type stannate, $Bi_2Sn_2O_7$ has received considerable attention due to its wide applications in catalysis and gas sensors [23,24]. The crystal structure of $Bi_2Sn_2O_7$ is constructed of octahedral SnO_6, and these octahedra connect to each other by sharing vertexes. A network of corner-shared octahedra can facilitate the mobility of the charged carriers [25], which may make $Bi_2Sn_2O_7$ a novel material for photocatalysis [26].

In this paper, the nanocrystalline $Bi_2Sn_2O_7$, which synthesized through a facile hydrothermal route, is used for photocatalytic removal of arsenic from aqueous solution. Under visible light irradiation, the $Bi_2Sn_2O_7$ nanoparticles exhibit high photocatalytic activity in the oxidization of arsenite $(AsO_3)^{3-}$ to arsenate $(AsO_4)^{3-}$. The role of the active species during the photocatalytic oxidation of As(III) is also investigated in detail. It is expected that the as-synthesized $Bi_2Sn_2O_7$ nanocrystallite can be used as a promising visible-light photocatalyst for the oxidation and removal of As(III).

2. Experimental

2.1. Catalyst preparation

$Bi(NO_3)_3{\cdot}5H_2O$ and $K_2SnO_3{\cdot}3H_2O$ were used as the starting materials for the syntheses. All reagents are A.R. grade and

* Corresponding author. Fax: +86 591 83779239.
E-mail address: liuping@fzu.edu.cn (P. Liu).

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doi:10.1016/j.apcata.2012.03.005