



One pot synthesis of bismuth–bismuth oxybromide composites with enhanced visible-light photocatalytic activity



ZhangSheng Liu ^{a,*}, BianTao Wu ^b

^a School of Material Science and Engineering, China University of Mining and Technology, Xuzhou 221116, China

^b School of Information and Electrical Engineering, China University of Mining and Technology, Xuzhou 221116, China

ARTICLE INFO

Available online 5 December 2014

Keywords:

Chemical preparation

Bi/BiOBr

Photocatalytic property

ABSTRACT

Bismuth/bismuth oxybromide (Bi/BiOBr) composites were synthesized by a facile one-step solvothermal method with the help of dimethyl sulfoxide (DMSO). The products were characterized by X-ray diffraction (XRD), field emission scanning electron microscopy (FE-SEM), X-ray photoelectron spectroscopy (XPS), N₂ sorption, UV–visible diffuse reflectance spectra (DRS) and photoluminescence spectroscopy (PL). The photocatalytic activity of the products was evaluated by the photocatalytic degradation of methyl orange (MO) under the visible-light irradiation. The results showed that Bi/BiOBr composites with the different Bi contents could be obtained by adjusting the amount of dimethyl sulfoxide (DMSO), all of which exhibited enhanced photocatalytic activity in comparison with pure BiOBr. Among them, Bi/BiOBr composites prepared with 5 ml of DMSO presented the highest photocatalytic activity. The enhanced photocatalytic activity could be attributed to an increased amount of photo-induced charge carriers and effective separation of photo-generated electron–hole pairs. The trapping experiments confirmed that the photogenerated holes and $\cdot\text{O}_2^-$ radicals were the main active species responsible for the photodegradation of MO.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

In the past few decades, semiconductor photocatalysts have received considerable attention due to their potential applications in decomposing organic compounds for environmental remediation. Among them, TiO₂ has been mostly developed owing to its low cost, strong oxidizing power and nontoxic nature [1]. However, due to its wide band gap (~3.2 eV), only a small fraction of solar energy can be effectively absorbed and used for photo-degradation processes [2]. In order to utilize solar energy more efficiently, great efforts have been made to develop visible-light-induced photocatalysts.

As a typical p-type main group V–VI–VII ternary semiconductor, BiOBr has recently drawn considerable attention for its potential applications as a visible-light photocatalyst due to its high photocatalytic activity and stability under visible light irradiation [3–7]. BiOBr crystallizes in a tetragonal matlockite structure and has layered structure characterized by [Bi₂O₂] slabs interleaved by double slabs of bromine atoms. The strong internal static electric fields formed between the Br negative layer and [Bi₂O₂] positive layer endows BiOBr with excellent mobility and a prolonged transfer path for photo-generated electrons [8], and at the same time the hybridization between O 2p and Bi 6s states in BiOBr narrows the band gap of BiOBr and enables BiOBr to make full use of visible light, both of which favor the photocatalytic activity [9]. However, the photocatalytic activity of BiOBr is still far from efficient for practical applications. To enhance its photocatalytic performance, a variety of strategies, such as impurity doping [10–12], formation of semiconductor heterojunctions

* Corresponding author. Tel.: +86 516 83591979; fax: +86 51683591870.
E-mail address: lzslu2008@hotmail.com (Z. Liu).

[13–15] and surface metallization [16], have been employed. Semiconductor heterojunctions require specific band edge positions of the dual semiconductors, and impurity doping is highly sensitive to both the doping level and homogeneity [17], in contrast, surface metallization is more flexible and effective, which can greatly restrain recombination of photo-generated electron–hole pairs due to the surface plasmonic resonance effect of metal nanoparticles. So far, some noble metal/BiOBr composites, such as Pd/BiOBr [16] and Ag/BiOBr [18,19], have been proved as efficient photocatalysts under visible-light irradiation. Very recently, Toudert et al. reported that, as a base metal, Bi also displays surface plasmonic resonance property in the near UV and visible spectral range if the particle size of metallic Bi is larger than 100 nm [20]. Chang et al. and Yu et al. have respectively synthesized Bi/BiOI [21] and Bi/BiOCl [22] heterojunctions by adjusting the pH values of precursor solutions, both of which exhibit extraordinary high photocatalytic activity. The above studies inspire us to think that Bi/BiOBr may also be an efficient photocatalyst under visible-light irradiation.

In this paper, Bi/BiOBr composites were prepared by a facile one-step solvothermal method with the help of dimethyl sulfoxide (DMSO). The structural and optical properties of the products were characterized. The photocatalytic activities were also evaluated by photocatalytic degradation of methyl orange (MO) under the visible light irradiation. The results show that Bi/BiOBr composites exhibit a markedly enhanced photocatalytic performance, whose mechanism is investigated and discussed in detail.

2. Experimental

2.1. Preparation of photocatalysts

All of the reagents were provided by Sinopharm Chemical Reagent Co., Ltd. (China), which were used as received without further purification. Bi/BiOBr composites were synthesized via the facile solvothermal method. In a typical process, 1 mmol of $\text{Bi}(\text{NO}_3)_3 \cdot 5\text{H}_2\text{O}$ was dissolved into 20 ml of ethylene glycol (EG) mixed with dimethyl sulfoxide (DMSO), in which the volumes of DMSO were 0, 1, 3, 5 and 8 ml. Then, another 20 ml EG solution containing 1 mmol of cetyltriethylammonium bromide (CTAB) was dropped into the above solution and stirred until a transparent solution was obtained. The resultant precursor solution was transferred into a 50 ml Teflon-lined stainless steel autoclave after 30 min of stirring. Finally, the autoclave was sealed and maintained at 160 °C for 16 h and allowed to cool down to room temperature naturally. The precipitate was washed with absolute ethanol and distilled water thrice, respectively, and dried at 80 °C in air. The as-prepared samples were denoted as S0, S1, S3, S5 and S8 based on the volume of DMSO.

2.2. Characterization

The composition and structure of the as-prepared samples were examined by means of X-ray diffraction (XRD, Bruker D8 Advance with Cu $\text{K}\alpha_1$ radiation at 40 kV and 30 mA). The sizes and morphologies of the samples were determined using field emission scanning electron

microscopy (FE-SEM, Hitachi S-4800) equipped with an energy dispersive X-ray spectrometer (EDS). The surface properties of the samples were examined by X-ray photoelectron spectroscopy (XPS: Thermo ESCALAB250, USA) with Al $\text{K}\alpha$ X-rays ($h\nu=1486.6$ eV) irradiation operating at 150 W. The Brunauer–Emmett–Teller (BET) surface area was determined by N_2 adsorption–desorption isotherm measurement at 77 K using a Quantachrome NOVA-4200E system. The optical property was analyzed by both UV–vis diffuse reflectance spectra (DRS, Varian Cary 300) and photoluminescence spectra (PL, Varian Cary–Eclipse 500).

2.3. Measurements of photocatalytic performances

The photocatalytic activity of the samples was determined by the degradation of MO under visible light irradiation. The visible light source was a 150 W tungsten–halogen lamp (Beijing Institute of Opto-Electronic Technology, light intensity = 200 mW/cm^2). The short-wavelength components ($\lambda < 400$ nm) of the light were cut off using a cutoff glass filter. Experiments were carried out at 20 ± 3 °C as follows: 0.1 g of photocatalyst was added into 100 mL of 10 mg/L MO solution. The distance between the bottom of the lamp and the top of the solution was 10 cm. Before irradiation, the suspension was stirred for 20 min in the dark in order to reach the adsorption–desorption equilibrium. At given irradiation time intervals, about 3 ml suspensions were taken and centrifuged to remove the catalyst particles. The concentration of remnant MO was determined by UV–vis spectroscopy at its characteristic wavelength of 464 nm.

3. Results and discussion

3.1. XRD analysis

The crystallinity and crystal phase of the products are investigated by XRD. Fig. 1 shows the XRD patterns acquired from as-prepared catalysts. In the absence of DMSO, all the diffraction peaks of S0 sample can be easily indexed to tetragonal phase BiOBr (JCPDS Card no.73-2061), and the

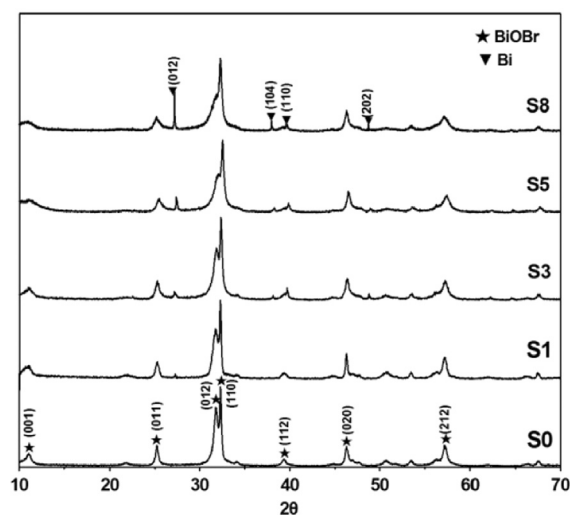


Fig. 1. XRD patterns of as-synthesized samples.

Download English Version:

<https://daneshyari.com/en/article/728035>

Download Persian Version:

<https://daneshyari.com/article/728035>

[Daneshyari.com](https://daneshyari.com)