A simple solvent-free method for the synthesis of $BiOIO_3$ nanoplates as a multifunctional photocatalyst

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Abstract: The $BiOIO_3$ nanoplate was first synthesized via a simple solid-state chemical reaction followed the principles of green chemistry, it exhibited superior UV light photocatalytic activity and good stability for degrading pollutants with different electrical properties, such as anionic dyes (methyl orange), cationic dyes (rhodamine B and methylene blue) and neutral pollutants (phenol, 2,4-dichlorophenol, bisphenol A and tetracycline hydrochloride). The study may not only open up a new simple approach to synthesize $BiOIO_3$ nanomaterials, but also provide a candidate with high photocatalytic activity for environmental purification.

Keywords: Bi-based nanomaterials, Solid-state synthesis, Photocatalysis.

1. Introduction

Bi-based photocatalysts such as BiOX (X=Cl, Br, I), $BiVO_4$, Bi_2WO_6 and $BiOIO_3$ have become hotspot research in recent years due to the excellent photocatalytic performance they possessed[1,2]. Among them, $BiOIO_3$ as a novel photocatalyst, its nonbonding layered structure, providing the space large enough to polarize the related atoms and orbitals, and then promote the e^-/h^+ separation, finally exhibit better photocatalytic activity than P25 (TiO_2)[3,4].

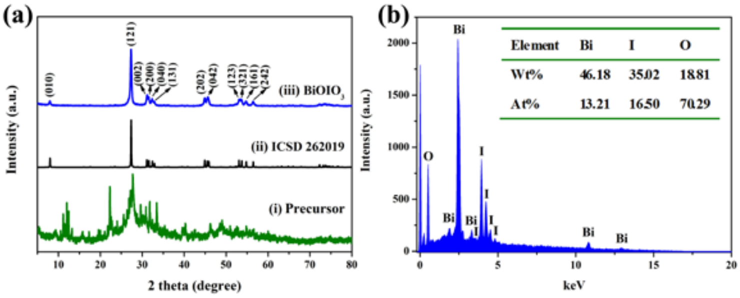
However, the synthetic methods of $BiOIO_3$ usually need high temperature, pressure or long time, which restricted large-scale preparation and practical application of such catalyst. Herein, a facile and environmental solvent-free method was for the first time used to synthesize $BiOIO_3$ nanoplates. The photocatalytic performance of the $BiOIO_3$ nanoplates was evaluated by the decomposition of various kinds of organic contaminants under UV light irradiation.

2. Experimental

All the chemicals used in this work are of analytical pure and used without further purification. The $BiOIO_3$ nanoplate was synthesized by a two-step solid-state chemical reaction. Firstly, a precursor was synthesized by grinding $Bi(NO_3)_3{\cdot}5H_2O$ and KIO_3 in solid phase, and then the $BiOIO_3$ nanoplate was obtained by calcining the precursors in 300°C for two hours at the rate of 2 °C/min under air atmosphere.

X-ray diffraction (XRD) was served to analysize the crystalline phase by a Bruker D8 using filtered Cu Kα radiation. Energy dispersive X-ray spectrometer (EDX) was obtained on an Oxford 2000 and the accelerating voltage is 200 kV. Field emission scanning electronic microscopy (FESEM, Hitachi, SU8010 at 5 kV) was performed to obtain the morphology of the samples. The photocatalytic experiments were carried out in an XPA-1 photochemical reactor (Xujiang Electromechanical Plant, Nanjing, China).

3. Results and discussion



Element	Bi	I	O
Wt%	46.18	35.02	18.81
At%	13.21	16.50	70.29

Figure 1. XRD patterns of the precursor and $BiOIO_3$ (a), EDS pattern of the $BiOIO_3$ (b).

Fig. 1a showed the XRD patterns of complex precursor and the as-prepared samples. Although the XRD pattern of complex precursor can’t be indexed in data base, it does not affect the preparation of $BiOIO_3$ photocatalysts. As shown in Fig. 1(aⅲ), the as-prepared $BiOIO_3$ shows sharp diffraction peaks, which can be indexed into the orthorhombic $BiOIO_3$ (ICSD 262019), indicating the good crystallinity of the sample. In addition, the EDX spectrum pattern further proved the Bi, I and O elements with atomic ratio of 13.21:16.50:70.29, which is basically consistent with the composition of the $BiOIO_3$ product.

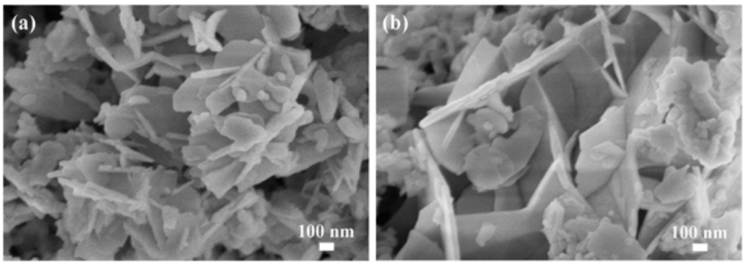


Figure 2. FESEM images of the $BiOIO_3$.

The morphology of $BiOIO_3$ was characterized by FESEM. The SEM images prove that the plate-like 2D structure of the synthesized $BiOIO_3$ with size ranging from tens of nanometers to sub-micrometers hundreds of nanometers (Fig. 2). The typical 2D structure of $BiOIO_3$ is ascribed to the layers of $(Bi_2O_2)^{2+}$ cations that are connected to $(IO_3)^-$ anions, and the thickness of $BiOIO_3$ nanoplates were examined about 30 nm.

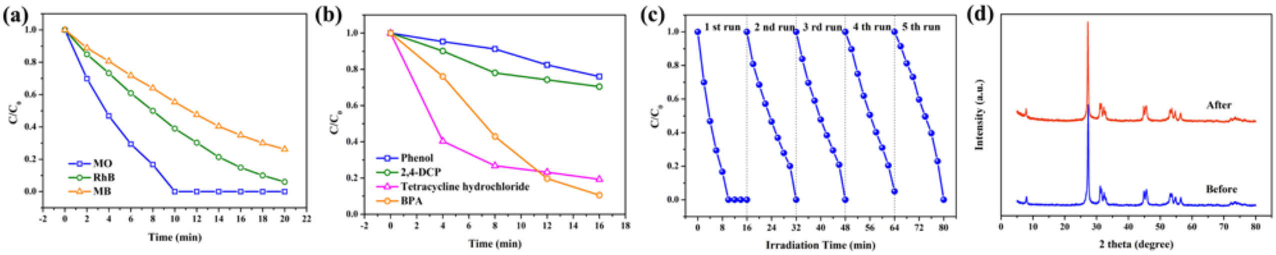


Figure 3. Degradation efficiencies of MO, RhB and MB (a), phenol, 2,4-dichlorophenol, bisphenol A and tetracycline hydrochloride (b) over $BiOIO_3$ nanoplates under UV light irriadation, recycling experiments was conducted on the UV photocatalytic degradation of MO by $BiOIO_3$ nanoplates (c) and XRD pattern of before and after photocatalysis for $BiOIO_3$ nanoplates (d).

The degradation of pollutants with different electrical properties were employed to evaluate the photocatalytic performance of $BiOIO_3$ nanoplates. As seen in Fig. 3a and b, after irradiation for 16 min under UV light, the photodegradation efficiency of MO, RhB, MB, phenol, 2,4-dichlorophenol, bisphenol A and tetracycline hydrochloride is 100%, 85.2%, 65.2%, 24.0%, 29.6%, 80.7% and 89.4%, respectively, illustrating the good photocatalytic performance of $BiOIO_3$ nanoplates. In order to evaluate the repeatability and stability of the photocatalyst, recycling experiment was conducted on the UV photocatalytic degradation of MO. Fig. 3b and c shows the photocatalytic activity and XRD pattern of $BiOIO_3$ almost no noticeable change after five cycles, indicating the $BiOIO_3$ nanopates is a stable catalyst during the photocatalytic reaction.

4. Conclusions

In this work, a solid-state chemical route was first applied on the synthesis of the $BiOIO_3$ nanoplates. The $BiOIO_3$ nanoplates exhibits superior photocatalytic activity and durability for the degradation of MO. Moreover, the $BiOIO_3$ nanoplates also can effectively degraded diverse pollutants, including RhB, MB, phenol, 2,4-dichlorophenol, bisphenol A and tetracycline hydrochloride under UV light. These findings open up a new avenue for manufacturing high-activity UV light photocatalysts.

References

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