Characterization, Facile Fabrication of novel binary $ZnO/Bi_7O_9I_3$ (30%) anocomposite effective visible-light-indused for environmental remediation

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Abstract

over the past few years, visible-light-driven photocatalysts have attracted much intensive research attachment worldwide because photocatalytic processes could be intensively applied in various fields, such as environmental pollution control, and synthesis of different nanomaterials. In this Work, we construct the novel binary $ZnO/Bi_7O_9I_3$ (30%) nanocomposite by a facile sol-gel method as novel visible-light-illumination photocatalysts. The properties of these photocatalysts were characterized by various techniques such as XRD, FESEM, FT-IR .The photocatalytic ability of the $ZnO/Bi_7O_9I_3$ (30%) sample was examined by degradation of Rhodamine B (RhB) dye as water contamination under visible light irradiation. The results showed that the $ZnO/Bi_7O_9I_3$ (30%) nanocomposite highest photocatalytic performance, which was 15 times as high as that of pure ZnO. This result, could be attributed to the increment of the visible light absorption by narrow band gap $Bi_7O_9I_3$ semiconductor and structure of the heterojunction between ZnO and $Bi_7O_9I_3$, which is favorable for swift separation of the photoinduced charge carriers. Finaly, This paper may provide some intelligence into the design of novel visible-light photocatalysts.

Introduction

Since the 21st century, environmental pollution become serious with the significant growth of population and global industrialization. These widely used organic dyes are resistant and arduous to eliminate from wastewater. Nowadays, Different strategies have been proposed to address this concern. Among them, the advanced oxidation processes (AOPs) has been attracted much attention due to their potential applications in treatment of contaminants. Therefore, the photocatalytic degradation treatment of wastewater is an easy and simple technique, and cost-effective[1]. Zinc oxide (ZnO) is a well-known and well investigated semiconductor due to its amazing advantages like good chemical stability, biocompatibility, distinct electronic structure, and low production cost and the wide band gap of 3.2 eV and the fast recombination of charge carriers [2]. Bismuth oxyiodides ($Bi_7O_9I_3$) due to features such as suitable band gap, stability, and as highly efficient visible light driven photocatalysts for treatment of wastewater due to its narrow bandgap (2.4 eV) [3]. In this article, these results reveal that as-prepared ZnO/ $Bi_7O_9I_3$ (30%) nanocomposite is an efficient and promising advanced oxidation technology for the waste waters.

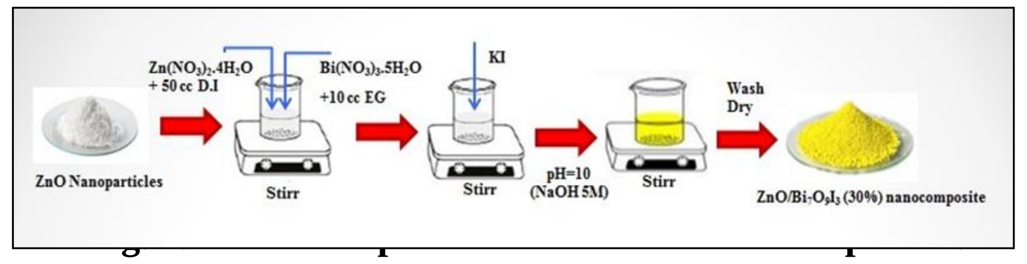
Methods & Materials

Materials

Zinc nitrate pentahydrate ($Zn(NO_3)_2.4H_2O$, 99%), Bismuth nitrate pentahydrate ($Bi(NO_3)_3.5H_2O$, 99%), Potassium iodide (KI, 99%), Ethylen glycol (EG, 99.5%), sodium hydroxide (99%), and RhB with high quality were employed without further purification. Deionized water was used for the experiments.

Preparation of the nanocomposites

From Fig. 1, The ZnO was prepared by ultrasonic method from Zn(NO3)2.4H2O as precursor [14]. For preparation of $ZnO/Bi_7O_9I_3$(30%), 0.21 g of ZnO powder was dispersed into 50 mL of water ultrasonically for 5 min. Then, 0. 25 g of $Bi(NO_3)_3.5H_2O$ was appended to the above suspension and stirred for 15 min at room temperature. Afterwards, 10 ml Ethylene glycol (EG) as gelling agent was added and stirred for another 30 min. then, an aqueous solution of KI (0.03 g in 10 mL water) was drop by drop added to the suspension. The mixture under stirring at room temperature for 60 min. the pH of the system was adjusted to 10 using 5 M NaOH. Then, the formed yellow suspension was stirred for 120 min. Finally, the resultant product was collected, washed three times with deionized water and absolute ethanol and dried in an oven at 75 °C for 24 h.



Experimental details for nanocomposite activity

From Fig. 2, For photocatalytic degradation experiments, rhodamine B (RhB), was tested as model organic dye pollutants. Photocatalysis experiments were done in a cylindrical Pyrex reactor with about 400 mL volume. Typically,The suspension containing 100 mg of the photocatalyst and 100 mL of RhB solution (5ppm) was mixed and The mixtures were stirred for 60 min in the dark to achieve equilibrium and continuously irradiated by a LED lamp of 50 W, as visible-light source, and aerated by a pump to provide oxygen. Temperature of the system was maintained at 25 °C using a water circulation. During the irradiation, at certain time intervals, 3 mL of the samples were taken out from the reactor at regular intervals and the photocatalyst separated before analysis by the spectrophotometer at 553 nm corresponding to the maximum absorption wavelength of RhB.

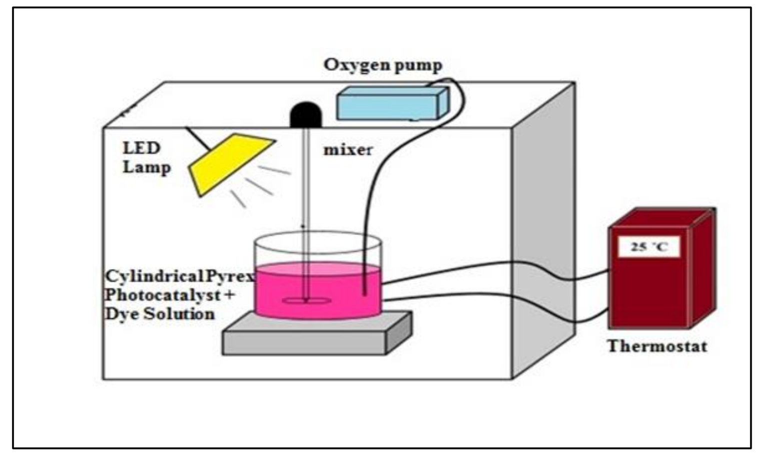


Fig. 2. Schematic of the photocatalytic experimental.

Results & Discussion

Structural and morphological studies

XRD analysis

From Fig. 3, XRD instrument was applied to investigate the phase composition and crystal structure of the ZnO/ $Bi_7O_9I_3$ (30%) nanocomposite.The XRD spectrum of the novel binary ZnO/ $Bi_7O_9I_3$ (30%) nanocomposite revealed other additional diffraction peaks, which corresponded to tetragonal phase of $Bi_7O_9I_3$ (JCPDS: 73-2026)[15]. For the ZnO sample, the diffraction peaks correspond to (100), (002), (101), (102), (110), (103), (200), (112), (201), (004) and (202) planes of wurtzite hexagonal crystalline phase (JCPDS file no. 36-1451)[16].In the ZnO/Bi7O9I3 (30%) nanocomposite , distinct peaks corresponding to $Bi_7O_9I_3$ as well as ZnO counterparts are observed, indicating formation of the binary nanocomposite and No impurity was detected in the samples.

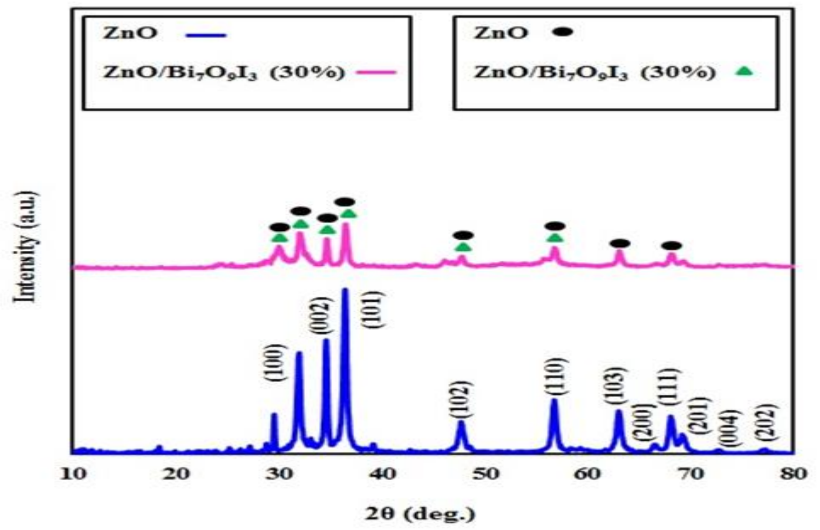


Fig. 3. The XRD patterns of the obtained photocatalysts.

FESEM analyses

Figure 4, shows FESEM images of $ZnO/Bi_7O_9I_3$ (30%) nanocomposite .From Fig. 3, it is evident that the ZnO sample exhibits rice-like nanoparticles through aggregation of smaller particles. It is clear that the irregularly shaped nanosheets of the $Bi_7O_9I_3$ are located beside the rice-like ZnO

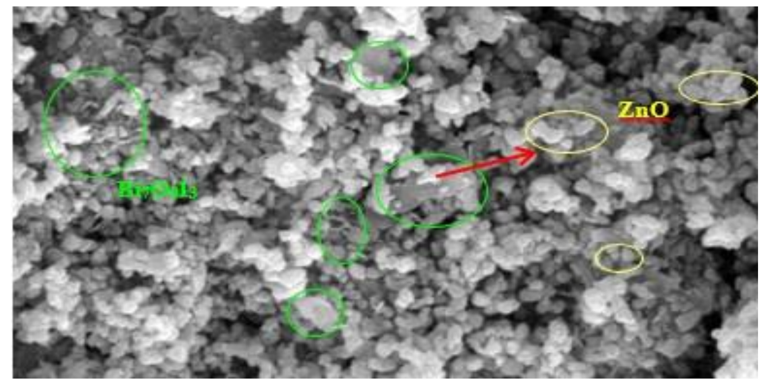


Fig. 4. The FESEM image of the $ZnO/Bi_7O_9I_3$ (30%) sample.

FTIR analyses

To characterize structural properties of the resultant samples, FT-IR spectra of ZnO, $ZnO/Bi_7O_9I_3$ (30%) nanocomposite were performed in the wavenumbers between 400 and 4000 cm^{-1}. From Fig. 5, The Zn-O peak is seen at 570 cm^{-1}[17]. For the all samples, the broadabsorption bands around 3450 cm^{-1} are ascribed to the O-H stretching vibration of adsorbed water molecules. The $ZnO/Bi_7O_9I_3$ (30%) nanocomposite another peak was observed at 507 cm^{-1} which is ascribed to Bi-O bond[18]. These results more confirmed that the synthesis of the $ZnO/Bi_7O_9I_3$ (30%) nanocomposite has been successfully carried out.

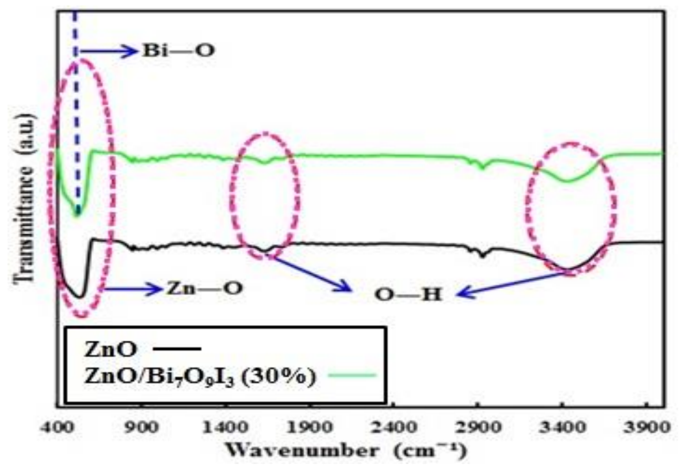


Fig. 5. FT-IR spectra of the ZnO and $ZnO/Bi_7O_9I_3$ (30%) photocataysts.

Photocatalytic performance

Fig. 6, displays a comparison of RhB degradation on the bare ZnO, $ZnO/Bi_7O_9I_3$ (30%) nanocomposite photocatalyst. The degradation rate constant on the $ZnO/Bi_7O_9I_3$ (30%) is about 15 times premier than the ZnO. Kinetic results proved that the construction of binary $ZnO/Bi_7O_9I_3$ (30%) nanocomposite could obviously boost the photocatalytic ability of bare ZnO under visible-light irradition.

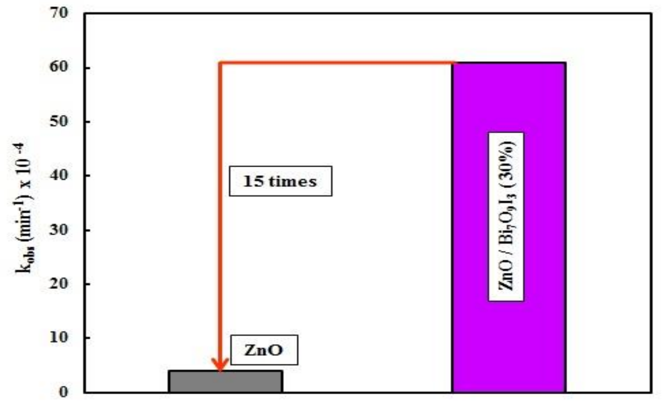


Fig.6 . The degradation rate constants of RhB over the ZnO and $ZnO/Bi_7O_9I_3$ (30%) sample.

CONCLUSIONS

The superior photocatalytic activity of the nanocomposites was mainly attributed to more absorption in visible range and effectual separation of the charge carriers. As seen in Fig. 6, the $ZnO/Bi_7O_9I_3$ (30%) nanocomposite displays the higher rate constant of 0.0061 min^{-1}, that is almost 15 times as high as that of the ZnO (0.00037 min^{-1}). As a result, Kinetic results demonstrated that the construction of novel binary $ZnO/Bi_7O_9I_3$ (30%) nanocomposite could obviously enhance the photocatalytic ability of bare ZnO under visible-light illumination.

Reference

[1]. K. Iqbal, A. Iqbal, A.M. Kirillov, W. Liu, Y. Tang, Hybrid metal-organic-framework/ inorganic nanocatalyst toward highly efficient discoloration of organic dyes in aqueous medium, Inorg. Chem. 57 (2018) 13270–13278. [2]. M.S. Nasrollahzadeh, M. Hadavifar, S.S. Ghasemi, M. Arab Chamjangali Synthesis of ZnO nanostructure using activated carbon for photocatalytic degradation of methyl orange from aqueous solutions Appl Water Sci, 8 (2018), p. 104, 10.1007/s13201-018-0750-6. [12]. T. Jiang, T. Xie, L. Chen, Z. Fu, D. Wang, Carrier concentration-dependent electron transfer in Cu_2O/ZnO nanorod arrays and their photocatalytic performance, Nanoscale 5 (2013) 2938–2944. [14]. M. Pirhashemi, A. Habibi-Yangjeh, Fabrication of novel $ZnO/MnWO_4$ nanocomposites with pn heterojunction: visible- light-induced photocatalysts with substantially improved activity and durability. J. Mater. Sci. Technol. 34, 1891–1901 (2018)

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