

Hydrothermal Synthesis of ZnO/SnO₂ Nanoparticles with High Photocatalytic Activity

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Abstract—The paper reports the preparation and photocatalytic activity of ZnO/SnO₂ and SnO₂ nanoparticles. These nanoparticles were synthesized by hydrothermal method. The products were characterized by X-ray diffraction (XRD) and scanning electron microscopy (SEM). Their grain sizes are about 50-100 nm. The photocatalytic activities of these materials were investigated for congo red removal from aqueous solution under UV light irradiation. It was shown that the use of ZnO/SnO₂ as photocatalyst have better photocatalytic activity for degradation of congo red than SnO₂ or TiO₂ (anatase, particle size: 30nm) alone.

Keywords—ZnO/SnO₂ nanoparticle, hydrothermal, photocatalysis

I. INTRODUCTION

IN recent years, heterogenous photocatalysis has received increasing attention for environmental applications such as air purification, water disinfection, hazardous remediation and water purification [1-3]. However, the high photocatalytic degradation of semiconductors, such as TiO₂ and ZnO has attracted extensive attention of many researchers [4, 5]. In such semiconductors, photogenerated carriers (electrons and holes) could tunnel to a reaction medium and participate in chemical reactions. The high degree of recombination of these carriers decreased greatly their photocatalytic efficiency. Clearly, a wider separation of the electron and the holes increases the efficiency of photocatalyst [6]. Fortunately, utilize of coupled oxide semiconductors could increase the charge separation and extend the energy range of photooxidation. By far, many research groups have carried out the photocatalytic activity experiments of various coupled semiconductors [7-10]. However, the preparation of the coupled ZnO/SnO₂ often carried out by co-preparation method [11,12]. In this research, we synthesize ZnO/SnO₂ nanoparticles by hydrothermal method. The products were characterized by X-ray diffraction (XRD) and scanning electron microscopy (SEM). Also, the photocatalytic activities were evaluated using congo red as a model organic compounds.

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II. EXPERIMENTAL

ZnO/SnO₂ nanoparticles were synthesized by hydrothermal method. In typical experiments, 0.05 g of ZnO (zincite >99.9 Wt% rdh) and 1 g of Na₂SO₄ salt were added to 40 ml of distilled water. Then, 0.25 g of SnCl₂ · 2H₂O (Merck >97 %) was added the above mixture. To acidify the above solid-solution mixture, 1 ml of 4 M HNO₃ solution was used. The mixture was then transferred to a Teflon-lined stainless steel autoclave and placed inside an oil bath at 120°C for two days. After the reactions, the oil bath cooled naturally at room temperature, the solid products were separated from the liquid phase via centrifugation and washed with deionized water and pure ethanol. Then, the final products were dried in vacuum desiccators at room temperature overnight for material characterization. Also, SnO₂ nanoparticles were synthesized with the same method without using ZnO.

III. RESULTS

Fig. 1a and 1b showed the SEM images of the as-synthesized SnO₂ and ZnO/SnO₂ respectively, indicating products consist of nanoparticles structures. Statistical analysis of different SEM images showed that the average diameter of these nanoparticles was in the range of 50 -100 nm.

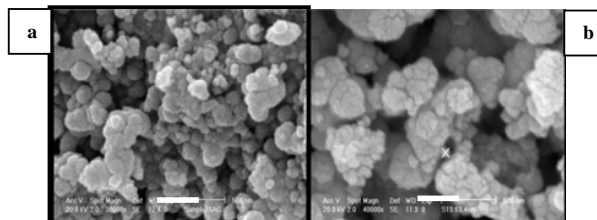


Fig. 1 (a) SEM image of SnO₂ (b) ZnO/SnO₂ nanoparticles prepared by hydrothermal

The structure and crystalline state of the powders were characterized by X-ray diffraction. Fig. 2a and 2b showed a representative XRD pattern of the ZnO/SnO₂ and SnO₂ nanoparticles respectively. All the diffraction lines are assigned to tetragonal rutile crystalline phases of tin oxide which is consistent with the standard data file 21-1445. No characteristic peaks of impurities, such as Zinc oxide or other tin oxides, were observed.

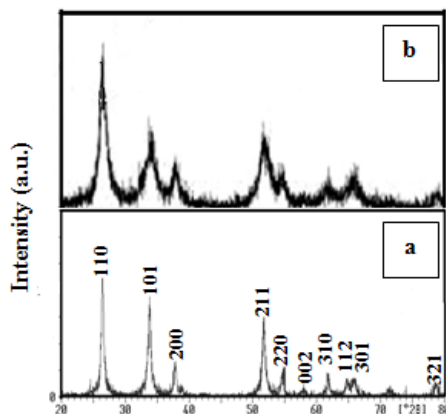


Fig.2 XRD patterns of a) ZnO/SnO₂ nanoparticles b) SnO₂ nanoparticles

The time-dependent UV-Vis Spectra of congo red during the irradiation are demonstrated in Fig. 3. It can be seen that the maximum absorbance of 497nm almost disappear after irradiation for 100 min.

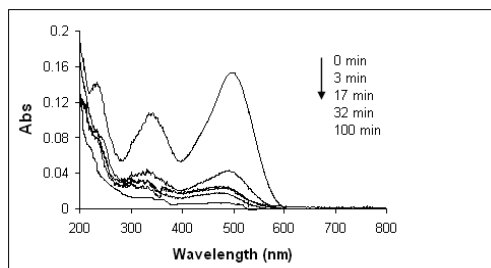


Fig.3 Absorbance spectral changes of congo red solution in the presence of ZnO/SnO₂

Fig. 4 shows comparison of the activities of ZnO/SnO₂, SnO₂ and TiO₂ at $\lambda = 497\text{nm}$. The experimental results showed that the ZnO/SnO₂ had high photocatalytic activity and its photocatalytic efficiency was higher than the pure SnO₂ and anatase TiO₂.

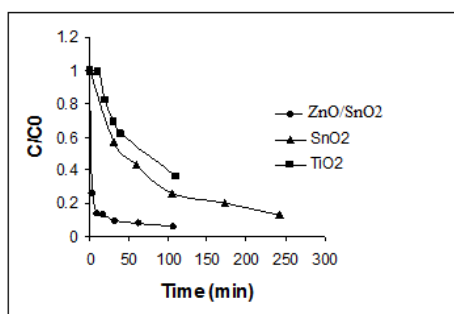


Fig. 4 Comparison of the activities of ZnO/SnO₂, SnO₂ and TiO₂ at $\lambda = 497\text{nm}$, Condition: amount of catalyst= 0.05 g/l

A mechanistic scheme of the charge separation and photocatalytic reaction for ZnO/SnO₂ photocatalyst is shown in Fig. 5

This scheme shows the conduction band (CB) position of SnO₂ is lower than that of ZnO, so that the former can act as a sink for the photogenerated electrons in the coupled oxides [13, 14]. Since the holes move in the opposite direction from the electrons, the photogenerated holes in SnO₂ might be trapped within the ZnO particle, making charge separation more efficient; then the recombination of electrons and holes in ZnO/SnO₂ is greatly suppressed. This is reason that the nanometer ZnO/SnO₂ possessed both higher photocatalytic oxidation and reduction activities than those of single TiO₂ or SnO₂.

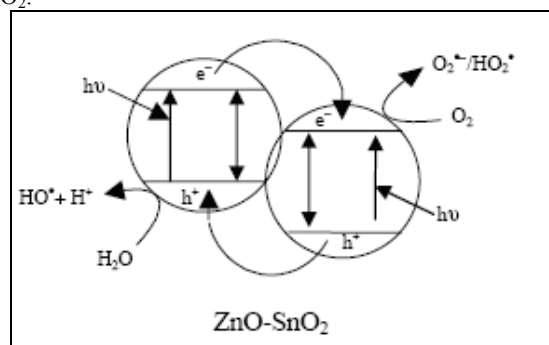


Fig. 5 A diagram illustrating the principle of charge separation and photocatalytic activity

IV. CONCLUSION

In the present experiment, we synthesize ZnO/SnO₂ and SnO₂ nanoparticles via hydrothermal method as a photocatalyst. The products were characterized by X-ray diffraction (XRD) and scanning electron microscopy (SEM). Also, the photocatalytic activities were evaluated using congo red as a model organic compounds. The experimental results showed that the ZnO/SnO₂ had high photocatalytic activity and its photocatalytic efficiency was higher than the pure SnO₂ and anatase TiO₂.

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