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Preparation and characterization of magnetic core–shell $ZnFe_2O_4$@ZnO nanoparticles and their application for the photodegradation of methylene blue

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HIGHLIGHTS

- A novel $ZnFe_2O_4$@ZnO core–shell photocatalyst was successfully prepared.
- The photocatalyst exhibited higher photocatalytic activity than pure ZnO.
- The composite photocatalyst inhibited the photocorrossion of ZnO to some extent.
- The novel photocatalyst could be easily separated by external magnetic field.

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ABSTRACT

Magnetically separable $ZnFe_2O_4$@ZnO nanoparticles with enhanced photocatalytic activity were successfully synthesized by two steps. First, $ZnFe_2O_4$ nanoparticles (NPs), which served as seeding materials, were synthesized using a solvothermal method. Second, wurtzite ZnO was coated on the $ZnFe_2O_4$ particle surfaces on the basis of a chemical precipitation method. The as-prepared samples were characterized with X-ray diffraction (XRD), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), High Resolution Transmission Electron Microscopy (HRTEM) and Energy-dispersive X-ray spectroscopy (EDS). Photodegradation experiments of the samples were carried out by choosing Methylene Blue (MB) as a model target under UV irradiation with homemade photocatalytic apparatus. The results indicated that the obtained core–shell $ZnFe_2O_4$@ZnO NPs exhibited higher photocatalytic activity than pure ZnO. In addition, when the molar ratio of $ZnFe_2O_4$ to ZnO was 1:10, the obtained product showed the highest photocatalytic activity. Furthermore, the core–shell $ZnFe_2O_4$@ZnO NPs could be conveniently separated by using an external magnetic field and the photocorrosion of ZnO was inhibited to some extent.

1. Introduction

Nano ZnO with wide band gap and large exciton binding energy, has attracted increasing attention in the application of photocatalysis [1,2]. In recent years, some researches have revealed that ZnO NPs as photocatalysts exhibit superior advantages than TiO_2, which is ascribed to their lower cost, higher quantum efficiency, environmental friendly and biodegradation [3,4].

It is well known that nanosized photocatalysts should be separated and recycled after photodegradation reactions. However, nanomaterials are extremely probable to be lost due to their small size and large surface energy when recycled by using traditional separation methods [5]. Hence, it is of great importance to fabricate photocatalysts with well recyclability. Recently, magnetic separating technology has aroused many researchers' interests because it provides an extremely convenient route for removing and recycling magnetic particles by external magnetic field [6–8]. Notably, the coupling between magnetic nanoparticles and semiconductor photocatalysts, such as ZnO and TiO_2 especially the formed core–shell structures, is of considerable interest of photocatalysis research [9,10]. Fe_3O_4 nanoparticles, which serve as magnetic cores have been examined extensively in view of their unique properties such as water solubility and biocompatibility [11–13]. However, the drawbacks of Fe_3O_4 nanoparticles as magnetic cores in the application of photocatalysis are also obvious. For instance, high temperature and inert atmosphere are almost necessary for the preparation of Fe_3O_4-based core–shell photocatalysts, which hinders the potential application in an amplified scale. Meanwhile, the dissolution of iron ions will induce the conversion from Fe^{2+} to

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