Preparation and Photocatalytic Performance of N-doped Nano ZnO/Polyvinyl Chloride Composites: Postprint

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Abstract

N-doped nano-ZnO/polyvinyl chloride composite materials were prepared. Infrared spectroscopy and UV-Vis diffuse reflectance absorption spectroscopy results demonstrated that this composite material exhibits strong absorption in both the ultraviolet and visible light regions. The efficiency of photocatalytic degradation of methyl orange by the composite material was investigated, and the results show that: the incorporation of polyvinyl chloride reduces the electron-hole recombination probability, also broadens the visible light spectral response range of the entire system, and enhances the photocatalytic performance of the composite material under visible light irradiation.

Full Text

Preparation and Photocatalytic Properties of N-doped Nano-ZnO/PVC Composites

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Abstract

Nitrogen-doped nano-ZnO/PVC composites were prepared and characterized. FT-IR and UV-visible diffuse reflectance spectroscopy measurements revealed strong absorption in both ultraviolet and visible light regions. The photocatalytic degradation of methyl orange was investigated under visible light illumination. Results demonstrate that the incorporation of PVC reduces electron-hole recombination probability in ZnO while broadening the spectral response range, thereby significantly enhancing the photocatalytic performance of the composite under visible light.

KEY WORDS: composites, ZnO, photocatalyst, PVC

Introduction

Solar-driven semiconductor photocatalysis offers a promising approach for degrading pollutants into H_2O and inorganic ions without secondary contamination or toxicity, with the added benefit of catalyst reusability. Consequently, semiconductor photocatalysis has become a major research focus worldwide. ZnO has attracted increasing attention as a semiconductor photocatalyst due to its wide bandgap and high activity [1-7]. However, two critical issues limit its practical application: first, the high recombination rate of photogenerated charge carriers (electrons and holes) results in low photocatalytic efficiency; second, ZnO can only be activated by ultraviolet light, which accounts for less than 5% of the solar spectrum below 400 nm, leading to poor light utilization efficiency. Since visible light (400-700 nm) constitutes approximately 43% of the solar spectrum, developing photocatalysts that can harness most or all of the visible range would substantially improve photocatalytic efficiency. This work reports the preparation of N-doped nano-ZnO/polyvinyl chloride (PVC) composites and investigates their structure, optical properties, and photocatalytic performance.

1. Experimental Methods

The primary reagents used were $Zn(NO_3)_2 \cdot 6H_2O$, hexamethylenetetramine ($C_6H_{12}N_4$), KNO_3, methanol, PVC tetrahydrofuran solution, and methyl orange. Nano-ZnO was prepared via electrochemical deposition and subsequently treated with NH_3 plasma to incorporate nitrogen dopants into the ZnO lattice [9]. To fabricate the composite, 0.8 g of N-doped nano-ZnO was dispersed in 100 ml of methanol through ultrasonication and magnetic stirring to form a homogeneous suspension. A PVC tetrahydrofuran solution was then gradually added dropwise to the methanol suspension under continuous stirring. The mixture was separated, dried at 85°C, and calcined at 220°C for 1 hour to obtain the N-doped nano-ZnO/PVC composite.

Photocatalytic experiments were conducted using methyl orange solution as a model pollutant under a 15W fluorescent lamp. The concentration of methyl orange was monitored at different time intervals using a spectrophotometer.

2. Results and Discussion

Figure 1 [Figure 1: see original paper] presents scanning electron microscopy images of the N-doped nano-ZnO/PVC composite. Compared with N-doped nano-ZnO [8], the composite with PVC maintained the basic structure but exhibited reduced particle size and decreased uniformity, likely due to the incorporation of PVC.

Figure 2 [Figure 2: see original paper] shows the FT-IR spectra of the samples, including N-doped ZnO (a), PVC (b), and the composite (c). Comparing curves b and c reveals that the PVC peaks at 1585 cm^{-1} and 1697 cm^{-1} merged into a stronger peak at 1610 cm^{-1} in the composite. This peak corresponds to the stretching vibration of conjugated double bonds [9], and its enhanced intensity indicates strengthened conjugation in the composite structure.

The UV-visible diffuse reflectance absorption spectra are displayed in Figure 3 [Figure 3: see original paper]. N-doped nano-ZnO shows weak absorption in the visible region (380-800 nm) but strong absorption in the UV region (200-380 nm). In contrast, the composite exhibits strong absorption across both UV and visible regions (200-800 nm). The UV absorption of the composite is slightly lower than that of N-doped nano-ZnO because UV absorption is dominated by ZnO, which is partially attenuated by the polymer. However, the visible light absorption of the composite is significantly higher than that of N-doped nano-ZnO, attributed to electron transfer in the conjugated complex formed by polymer incorporation.

Photocatalytic degradation kinetics were investigated by adding 0.13 g of composite to 100 mL of 15 mg/L methyl orange solution under fluorescent lamp illumination. The degradation curves are shown in Figure 4 [Figure 4: see original paper]. The composite demonstrates superior photocatalytic efficiency, achieving 99.5% degradation of methyl orange within 8 minutes, whereas N-doped nano-ZnO shows only approximately 10% efficiency. This enhanced activity stems from the composite' s significantly improved visible light absorption. However, the degradation rate decreases with prolonged reaction time, likely due to accumulation of reaction intermediates on the catalyst surface, which occupy active sites and reduce catalytic activity.

The mechanism involves electron transfer from the polymer to the conduction band of ZnO nanoparticles under visible light illumination, while electrons from the ZnO valence band transfer to PVC. This process reduces electron-hole recombination probability and broadens the visible spectral response range, substantially improving the photocatalytic performance of the composite under visible

light.

3. Conclusion

The N-doped nano-ZnO/PVC composite extends the spectral response range, exhibiting strong absorption from 200 nm to 800 nm. Degradation experiments on methyl orange solution demonstrate that the high photocatalytic efficiency of the composite arises from simultaneous reduction of electron-hole recombination and broadening of the spectral response range.

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Note: Figure translations are in progress. See original paper for figures.