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Original Research Paper

Synthesis and photocatalytic activity of N-doped TiO_2/ZrO_2 visible-light photocatalysts

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ABSTRACT

Visible-light responsive N-doped ZrO_2/TiO_2 photocatalysts were synthesized via a sol–gel process. To obtain the optimum nitrogen doping content and operational conditions for photodegradation of NO, several key factors (including nitrogen doping, initial NO concentration, light intensity, reactor temperature, etc.) were investigated under both UV and visible light irradiation. Physical characterization of the photocatalysts was performed using X-ray diffraction (XRD), UV–visible absorption spectroscopy, transmission electron microscopy (TEM), and Fourier transform infrared spectroscopy (FT-IR). The observed results suggest that nitrogen was doped in the lattice of TiO_2 and had an effect on the translation of phase, photodegradation activity, and visible-light response. Among synthesized photocatalysts, 0.1 M Zr and 0.15 M N supported on TiO_2 exhibited the best visible-light response and the highest NO photodegradation activity.

1. Introduction

NO classified as NO_x is an especially harmful atmospheric pollutant, and contributes to the formation of photochemical smog, peroxy acetyl nitrates (PAN), and acid rain which affect forests, crops, aquatic life, as well as buildings [1,2]. To resolve these environmental problems, researchers have focused on finding an economical and environmentally friendly method that can degrade NO emission from flue gases and car exhausts.

Over the past few decades, TiO_2 has been to be advantageous in photodegradation of pollutants in both water and air, owing to its stability, high photocatalytic activity, and easy and low-cost preparation. However, owing to its wide band-gap energy (3.2 eV for anatase and 3.02 eV for rutile TiO_2), the photocatalytic activation of TiO_2 is restricted to the UV light region, which occupies only 5% of the solar energy spectrum, Therefore, for TiO_2 the energy band does not utilize a majority of the solar energy spectrum for photocatalytic reactivity. Researchers have focused attention on discovering a method that can shift the activation of the TiO_2 photocatalyst to the visible light region [3–9]. And it has been reported that the incorporation of nitrogen into the titania crystal lattice achieves this objective [3,5,7,8,10,11].

Wang et al. [5] reported that TiO_2 photocatalysts doped with 10% nitrogen are effective for the photocatalytic degradation of methyl orange. Joshi et al. [7] looked into N-doped mesoporous TiO_2 (1:2) in the same field. Sreethawong et al. [12] found that urea was the optimum nitrogen doped content for the N-doped mesoporous-assembled TiO_2 and N-doped commercial TiO_2 with a TiO_2 molar ratio of 1:1 and 0.5:1 using their own preparation method for achieving the highest photocatalytic H_2 production activity. Nitrogen content that was more or less than the optimum content resulted in decreased photocatalytic activity. Additionally, modification of semiconductors is another application of visible-light induced photocatalytic TiO_2.

The ZrO_2/TiO_2 composite has been widely used as a photocatalyst. Typically, Zr plays the role of transition metals, which decrease the particle size of TiO_2 and increase the total surface area, thus promoting photocatalytic activity [13,14]. Although the nitrogen-doped ZrO_2/TiO_2 can be used as a photocatalyst in visible light region, there is a lack of knowledge on the effect of the doping amount of nitrogen, and operational conditions such as initial concentration of NO, reactor temperature and light intensity.

We previously reported [15] the preparation of ZrO_2/TiO_2 powder dope with metal ions using a polymer complex solution method (PCSM) to enhance the quantum efficiency, photocatalytic activity, surface area, crystallization, and phase stability of the

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