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Original Research Paper

Optical and photocatalytic properties of the Fe-doped TiO_2 nanoparticles loaded on the activated carbon

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A B S T R A C T

In this work, Fe-doped (1 wt%) TiO_2 loaded on the activated carbon nano-composite was prepared using a sol-gel method. A prepared nano-composite was characterized by X-ray diffraction (XRD), field emission scanning electron microscopy (FE-SEM), BET surface area, Fourier transform infrared spectroscopy (FTIR), photoluminescence (PL) spectroscopy and UV–Vis diffuse reflectance spectroscopy (DRS). The photocatalytic activity of the nano-composite was evaluated through degradation of synthetic textile wastewater, reactive red 198, under visible light irradiations. The XRD result indicated that the TiO_2 nano-composite contained only anatase phase. The surface area of the TiO_2 increased from 48 m^2/g to 100 m^2/g through the fabrication of the nano-composite. The FE-SEM results indicate that the TiO_2 particles with an average particle size of 35–70 nm can be deposited homogeneously on the activated carbon surface. DRS showed that the Fe doping in the TiO_2 -activated carbon nano-composite induced a significant red shift of the absorption edge and then the band gap energy decreased from 3.3 to 2.9 eV. Photocatalytic results indicated that the photocatalytic activity of the Fe doped TiO_2 increased under visible light irradiation in the presence of the activated carbon.

1. Introduction

Nowadays, water contamination due to population and industrial growth has been increased. Water contamination is a critical environmental problem in the world [1,2]. Dyes due to extensive use in the textile industry, slow biodegradation and high toxicity are the most common water contamination [3]. Dyes in the wastewater change the water appearance and decline the dissolved oxygen which has adverse effects on the ecology [4,5]. Among the using dyes in the textile industry, reactive dye because of the higher concentration and carcinogenic effect has to expose to be water treatment to remove it [6,7]. Commonly, there are several methods (such as flocculation, carbon adsorption, reverse osmosis, activated sludge process and biological methods) to wastewater treatment. These methods have difficulties in complete destruction of the dye pollutants and they only transfer the contaminants (dyes) from one phase to another, thus generating secondary pollution [8,9]. As an ideal green technology to degradation of the dye molecules, advanced oxidation processes based on a semiconductor metal oxide photocatalyst have attracted much attention to the wastewater treatment [1]. Photocatalytic process acts at ambient conditions and many tenacious organic pollutants can be degraded without the addition of chemical oxidants [10]. Among the different photocatalyst used, TiO_2 is the most promising semiconductor metal oxide photocatalyst due to its chemical stability, water insoluble, non-toxicity and low cost [10,6,11]. However, there are two drawbacks which limit the use of the TiO_2: (1) high degree of recombination between photogenerated charge carriers, (2) due to the wide band gap energy of TiO_2 anatase, it can only absorb five percent of the solar spectrum (UV region). Thus, very consideration has been made to alter the electronic structure of the TiO_2 anatase to overcome these problems. The introduction of defects in electronic structure of the TiO_2 has been proved to be an effective approach to the charge carriers separated and also to shift the TiO_2 absorption edge [8,12]. Extensive studies indicated that transition-metal doping into the TiO_2 structure enables the formation of doping conduction and valence bands, subsequently moving the TiO_2 band gap to the visible region. A dopant ion is also able to behave as an electron trapping which enhances the TiO_2 photocatalytic activity due to the reducing of the electron hole recombination rate [13]. It is confirmed that doping TiO_2 with transition metals elements altered the electronic structure of the TiO_2. Some researches indicated that doping

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TiO_2 with iron decreased the band gap and increased the charge carrier (photo-generated electron and hole) lifetime. The radius of the Fe^{3+} (0.69 Å) is close to that of Ti^{4+} (0.745 Å) and hence Fe^{3+} can be entered into the TiO_2 crystal lattice. Moreover, Fe^{3+} ion can provide a trap center for charge chargers, and consequently photogenerated electron–hole pair separation, since the energy level of Fe^{2+}/Fe^{3+} locates near to that of Ti^{3+}/Ti^{4+} [12]. Recently Moradi et al [14] have reported that the formation of the Fe doped TiO_2 degredated reactive red 198 under visible light irradiation. Their results indicated the photocatalytic activity of the TiO_2 increased by Fe doping and the optimum doping concentration was 1 wt%. However, TiO_2 in powder form has some drawbacks during the photocatalytic process such as the powders are not easy to precipitate and recover from water and the TiO_2 suspended particles aggregate at wide concentrations [3,15]. Therefore, many researches loaded TiO_2 nanoparticles on various substrates. Different supports for TiO_2 nanoparticles have been utilized including perlite, silica, clay, zeolites and activated carbon [3,15]. Activated carbon with porous structure and a large specific surface area is commonly used for wastewater treatment [1]. Eshaghi et al. [16] utilized TiO_2 -activated carbon catalyst to degradation of the reactive red 198. They showed that activated carbon increased the TiO_2 photocatalytic activity. However, photocatalytic decolorization of the reactive red 198 in the presence of Fe-doped TiO_2 loaded activated carbon under visible light irradiation is not reported yet. In this work, Fe-doped TiO_2 loaded activated carbon was produced. Then, the photocatalytic activity of the Fe-doped TiO_2 loaded activated carbon was evaluated via the degradation of reactive red 198 under the UV light irradiation.

2. Experimental

2.1. Preparation of the Fe-doped TiO_2 loaded activated carbon nanocomposite

Ultrasound assisted synthesis of Fe-doped TiO_2 loaded activated carbon was prepared as follows: Firstly, to prepare TiO_2 sol, 5 mL Tetrabutyl titanate [Ti $(OC_4H_9)_4$, 98%] was dissolved in 50 mL absolute ethanol (46.07 M). A solution containing of 0.33 mL H_2SO_4 (98%), and 250 mL deionized water added above solution under stirring. Then, to produce Fe-doped TiO_2 sol, a certain amount of Iron (III) chloride 6-hydrate powder dissolved in the TiO_2 sol and sonicated for 30 min (Ultrasonic processor, SONOREX SUPER RK 106, 35 kHz).

The Fe concentration was 1 wt%. For the synthesis of the Fe-doped TiO_2 loaded activated, first, activated carbon (AC, Appli-Chem), was prewashed with boiling water. To avoid the formation

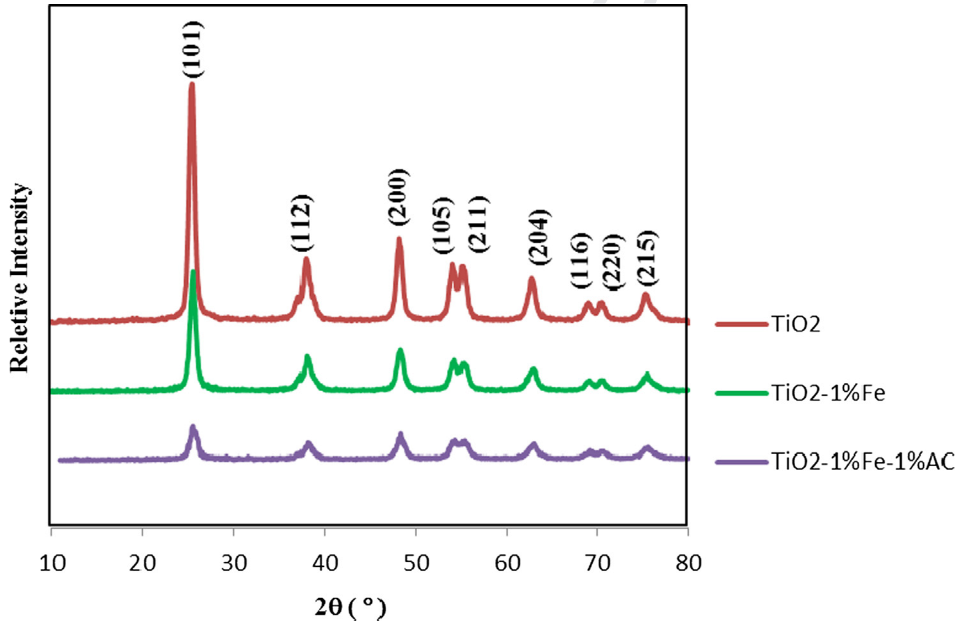

Fig. 1. XRD patterns of the TiO_2, Fe-doped TiO_2 and Fe-doped TiO_2-AC nanocomposite.

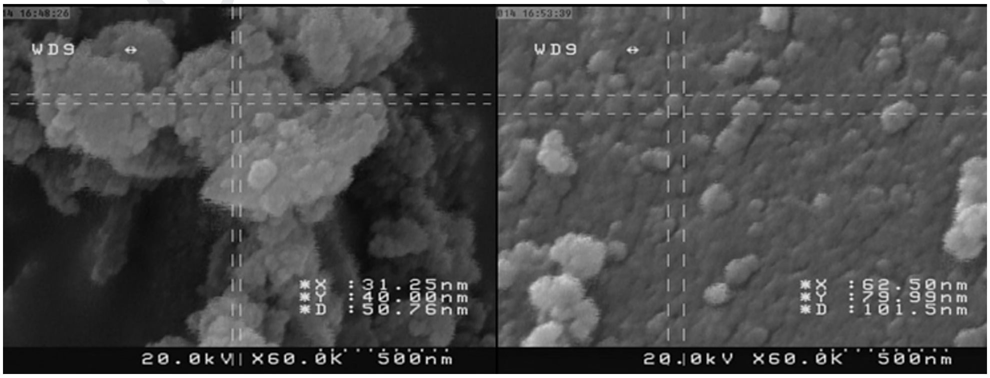

Fig. 2. FE-SEM images of the TiO_2.

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