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Photocatalytic activity of different morphologies TiO_2 nanofibers

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ABSTRACT

In this paper, one-dimensional TiO_2 nanofibers were synthesized by electrospinning utilizing sol–gel precursors. The surface morphology, crystal structure and microstructure were investigated by scanning electron microscopy (SEM), Raman spectroscopy (Raman) and X-ray diffraction (XRD). The nanofibers with smaller diameter were continuously and uniformly distributed. The photocatalytic activity of different nanofibers was evaluated by degrading Methylene Blue (MB) solution. The effects of surface morphology on photocatalytic activity were mainly investigated. The results show that the ultrafine nanofibers exhibit higher photocatalytic activity, which is in good agreement with the characterization results. Moreover, the activity of all nanofibers is higher than that of commercial Degussa P-25 TiO_2.

1. Introduction

Titanium oxide as one of the most common materials is well known for applications in nanoelectronics [1], photonics [2–4] and chemical sensors [5]. It has drawn much attention due to its chemical stability, nontoxicity and remarkable photocatalytic properties [6]. Therefore, many methods including sol–gel [7], hydrothermal [8] and electrospinning [9] have been developed to fabricate TiO_2 nanomaterials, such as nanoparticles [10], nanofilms [11], and nanofibers [12].

It is well known that one-dimensional nanomaterials like nanofibers display a key advanced feature in practical terms owing to their higher specific surface area [13,14]. In recent years, the electrospinning technique has been recognized as a versatile and effective method for the production of nanofibers with small diameters and high specific surface area [15], not only polymer materials [16] but also inorganic materials [17] could be synthesized into fibers by electrospinning. A typical set-up of the electrospinning has four major components: a high voltage power supply, a syringe pump, a spinneret and a collector. TiO_2 nanomaterials with different morphology could also be synthesized through changing viscosity, feeding rate, voltage [18–20]. In this paper, TiO_2 nanofibers with different morphologies were synthesized by electrospinning. Through change the content of PVP in precursors, bead-like, ultrafine and thick nanofibers could be obtained, respectively. We also investigate the relationship between photocatalytic activity and morphology of TiO_2 nanofibers through degrading Methylene Blue (MB), and compared with the commercial Degussa P-25 TiO_2.

2. Experimental details

2.1. Synthesis

Ethanol and acetic acid were supplied by Beijing Chemicals. Polyvinylpyrrolidone (PVP, K-30) was purchased from Tianjin Guangfu Company. Tetrabutyl titanate (TBT) was supplied by Beijing Golden Dragon Company.

First, TBT was added into a mixture of ethanol and acetic acid under vigorous stirring for 1 h, followed by the addition of x g of PVP, where x is 3, 3.5 and 4.0 g, which were designated as sample a, b and c, respectively. Subsequently, the mixture was magnetically stirred at room temperature for several hours, and then ejected from the stainless steel capillary with a voltage of 10 kV. The distance between the capillary and collector was 12 cm. The formed nanofiber mats were initially dried for 2 h at 100 °C under vacuum and then were calcined in an air atmosphere at 500 °C for 2 h with a heating rate of 2 °C min^{-1}.

2.2. Characterization

The Scanning electron microscopy (SEM) micrographs were obtained on a field emission SEM apparatus (JSM-7500F, JEOL) instrument operating at 3 kV. The samples were characterized by X-ray powder diffraction (XRD) with a Rigaku D/MAX-γA powder diffractormeter (Japan), using Cu Kα radiation (λ = 0.1506 nm). The

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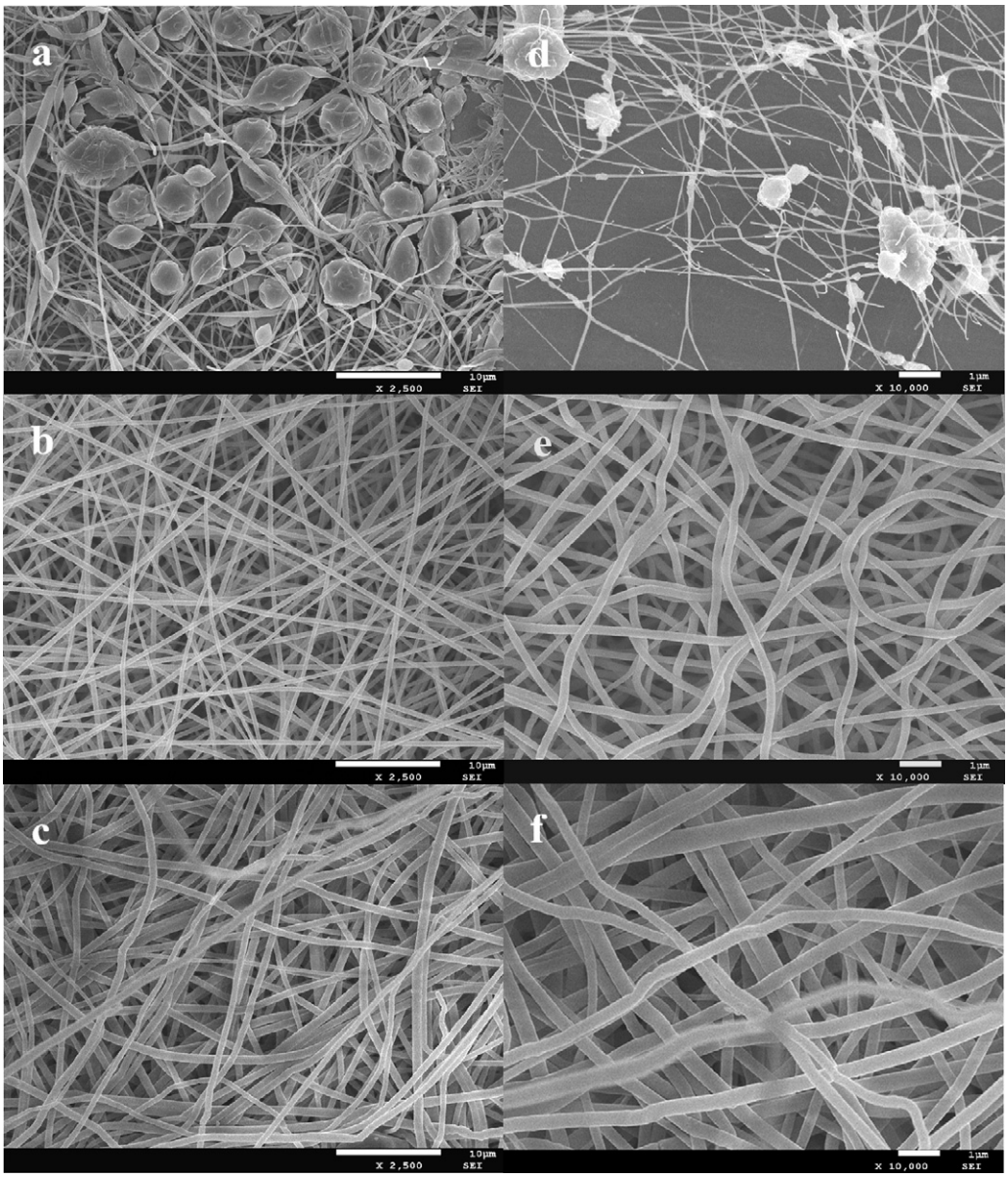

Fig. 1. SEM images of PVP/TiO_2 nanofibers prepared by using different PVP amounts (a: 3.0 g; b: 3.5 g; c: 4.0 g) and calcined at 500 °C for 2 h (d: 3.0 g; e: 3.5 g; f: 4.0 g).

Raman spectra of the samples were recorded with JOBIN YVON HR800 Raman spectrophotometer (France), and the used excitation wavelength was 458 nm.

2.3. Photocatalytic activity

The photocatalytic activity evaluation of TiO_2 nanofibers for the photo-degradation of Methylene Blue (MB) aqueous solution was carried out in a home-built reactor at ambient temperature. A 125 W high-pressure fluorescent Hg lamp was used as a light source. For each run, 0.1 g of TiO_2 nanofibers was dispersed in 20 mL of MB aqueous solution with a concentration of 10 mg L^{-1}. Prior to the beginning of illumination, the reactor contents were allowed to equilibrate in the dark with stirring for 20 min. Absorbance of irradiated samples was determined with a Perkin Elmer Lambda 900 UV/vis/NIR spectrometer immediately after irradiation and removal of the TiO_2 nanofibers. The photocatalytic performance of the obtained TiO_2 nanofibers for the degradation of MB was also compared with a reference TiO_2 sample, the commercial Degussa P-25, which was conducted under the same conditions.

3. Results and discussion

To investigate relationship between the morphology of the electrospun nanofibers and the content of the PVP, a series of mixed solutions containing various content of PVP were prepared. The SEM images of as-synthesized nanofibers obtained at 3.0 g, 3.5 g and 4.0 g PVP content are shown in Fig. 1, respectively. As shown in Fig. 1a, when the content of PVP was 3.0 g, the electrospun nanofibers appear irregular bead-like nanofibers morphology. Increasing the content of PVP to 3.5 g, the non-beaded nanofibers morphology could be obtained (Fig. 1b). When the content of PVP increased to 4.0 g, the diameter of nanofibers increased (Fig. 1c). The PVP/TiO_2 nanofibers uncalcined have smooth surface and the average diameter are 430 nm (Fig. 1b) and 540 nm (Fig. 1c) and the length of individual fiber is up to tens of micrometers. A possible