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Visible Light Responsive Electrospun TiO_2 Fibers Embedded with WO_3 Nanoparticles

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TiO_2–WO_3 composite fibers were prepared by electrospinning. The fibers have an average diameter of 1.0 μm. The XRD pattern of the TiO_2–WO_3 composite fibers indicates the presence of anatase and rutile phases of TiO_2 and an orthorhombic phase of WO_3. The photocatalytic degradation of acetaldehyde under visible light was achieved with the TiO_2–WO_3 composite fibers.

Photocatalysis based on TiO_2 is widely used for many applications such as air and water purification, self-cleaning and antibacterial surfaces.[1–3] A current effort in photocatalysis is the improvement of the photocatalytic performance of TiO_2, which is only able to use UV light (<400 nm) comprising 3% of the solar spectrum. Thus, it is very important to develop efficient photocatalysts that can be driven by visible light comprising about 42% of the energy of the solar spectrum. TiO_2–WO_3 composites have been shown to be efficient photocatalysts driven by visible light because of the combination of the narrow band gap of WO_3 and charge separation at the interface of TiO_2 and WO_3.[4–7]

Another approach to improve the efficiency of TiO_2 is the introduction of a micro- or nanostructure because micro- or nanostructured materials have a larger surface area and a stronger adsorption capacity, which favors photocatalytic performance. Electrospinning is a significant process because it allows for the preparation of fibers with facility and versatility.[8–10] The electrospun fibers can be treated as self-standing film and have 3-D open structure, which is an advantage for photocatalytic reaction.

In this work, the preparation, characterization, and evaluation of the photocatalytic performance of a TiO_2–WO_3 composite fiber prepared by electrospinning was examined.

The preparation of the TiO_2–WO_3 composite fiber was carried out as follows: poly(vinylpyrrolidone) (PVP) was dissolved in a mixed solution containing EtOH (13 mL) and acetic acid (1.9 mL) followed by stirring for 1 h. The obtained solution was added to titanium tetraisopropoxide (6.3 mL). After further stirring for 1 h the solution was added to WO_3 particles (1.0 g, Aldrich). The as-prepared solution was loaded into a syringe and the nozzle, which was connected to a positive electrode from a high voltage generator, and a metallic plate covered with a piece of aluminum foil was used as a collecting substrate; this was grounded. The voltage was set at 15 kV and the working distance was 15 cm. The electrospun fiber was calcined at 600 °C for 2 h in air to remove the PVP and to crystallize it.

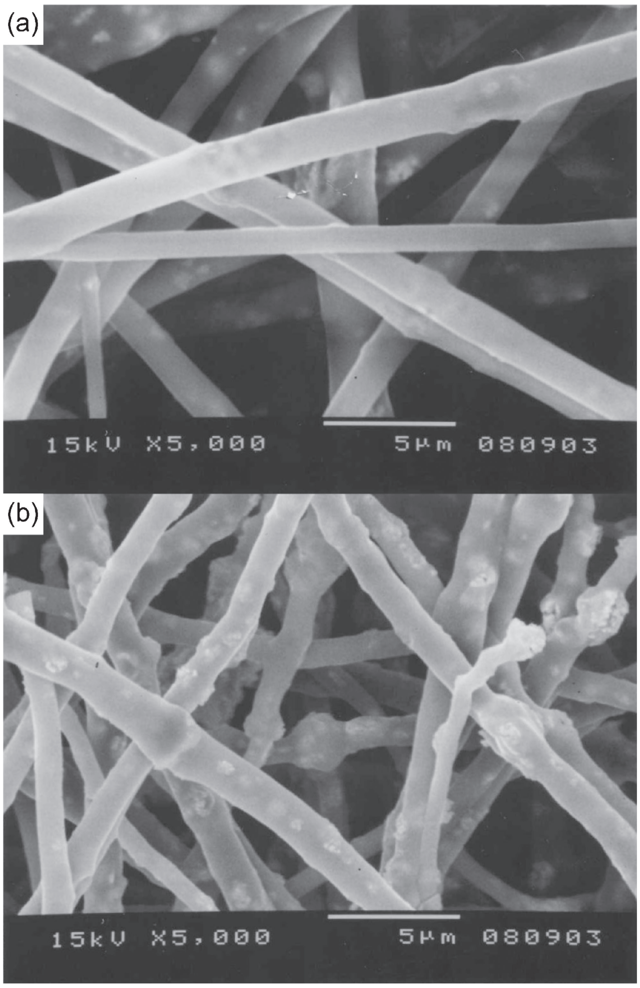

Figure 1. SEM images of the TiO_2–WO_3 composite fiber (a) before and (b) after calcination.

Figure 1 shows SEM images of the as-spun and calcined TiO_2–WO_3 composite fibers. The fibers had an average diameter of 1.2 μm before calcination. It seems that the fibers contain WO_3 particles. After the calcination the average diameters of the fibers decreased slightly (ca. 1.0 μm) because the organic component, PVP, was selectively removed by combustion and the inorganic components became crystallized.

Figure 2 shows an XRD pattern for the TiO_2–WO_3 composite fibers after calcination. The TiO_2–WO_3 composite

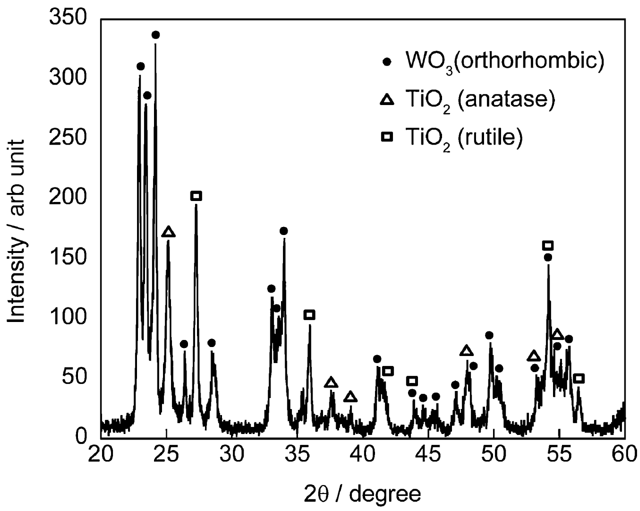

Figure 2. XRD pattern of the TiO_2–WO_3 fibers.

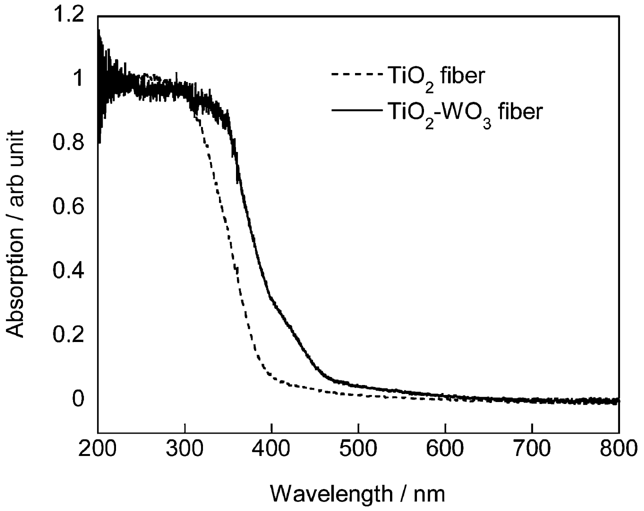

Figure 3. UV–visible absorption spectra of the TiO_2 and TiO_2–WO_3 composite fibers.

fibers contain an anatase phase and a rutile phase of TiO_2 and an orthorhombic phase of WO_3.

UV–vis spectra for the TiO_2 and TiO_2–WO_3 composite fibers are shown in Figure 3. A significant increase in the absorption at wavelengths shorter than 400 nm is assigned to the intrinsic band gap absorption of TiO_2. The absorption spectrum of the TiO_2–WO_3 composite fibers indicates the absorption of more visible light than that of pristine TiO_2 fibers, which is attributed to the fact that WO_3 has a narrow band gap.

We investigated the photocatalytic decomposition of acetaldehyde and the simultaneous production of CO_2 under visible light (>420 nm) using the TiO_2–WO_3 composite fiber after it was calcined, as shown in Figure 4. After reaching equilibrium in the dark over 1 h the concentration of acetaldehyde decreased to 70 ppm from an initial concentration of 100 ppm, and this was due to the physical adsorption of acetaldehyde on the surface of the TiO_2–WO_3 composite fiber. Upon irradiation by visible light at an intensity of 6000 lx, the concentration of the acetaldehyde decreased whereas that of CO_2 increased; its concentration reached 78 ppm after 90 min. Based on the degradation reaction of acetaldehyde, the production of CO_2 will be twice (200 ppm) that of the initial concentration of acetaldehyde.[8] In this case, the concentration of CO_2 was lower than expected for this experiment because of the generation of the intermediate product, acetic acid, during the degradation process instead of CO_2,[11] which is similar to the case that pristine WO_3 showed uncompleted photocatalytic degradation for acetaldehyde.[12]

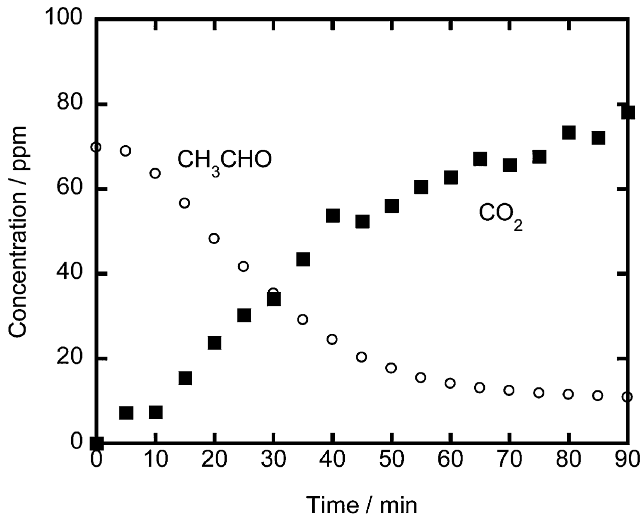

Figure 4. Photodecomposition of acetaldehyde and the production of CO_2 on the TiO_2–WO_3 composite fibers after calcination as a function of visible light irradiation time.

In conclusion, a TiO_2–WO_3 composite fiber was prepared by electrospinning. The composite fiber shows visible light absorption. The photocatalytic degradation of acetaldehyde under visible light was achieved for the TiO_2–WO_3 composite fibers.

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