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A highly sensitive and self-powered ultraviolet photodetector composed of titanium dioxide nanorods and polyaniline nanowires

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ABSTRACT

A highly sensitive and self-powered ultraviolet (UV) photodetector was fabricated using a low-cost, low temperature and convenient process. The designed multilayer structure device was a self-powered UV photodetector based on p–n hetero-junction and it was composed of two layers of n-type titanium dioxide nanorods (TiO_2 NRs) and one layer of p-type polyaniline nanowires (PANI NWs). The TiO_2 NRs were synthesized by a hydrothermal method and the PANI NWs were synthesized by a chemical oxidation method. The morphologies of TiO_2 NRs and PANI NWs were characterized by scanning electron microscopy (SEM). The *I–t* and *I–V* curves of the nanodevices were measured by a CHI660D electrochemical workstation. The fabricated UV photodetector with the TiO_2/PANI/TiO_2 multilayer structure was able to work without any external power source and generated different photocurrents when irradiated with different wavelengths UV light, that is to say it exhibited excellent sensitivity to UV light.

1. Introduction

In the past decades, nanodevices capable of working independently without any external auxiliary have been achieved by integrating multifunctional nanomaterials into nanosystems [1–3]. In particular, semiconductor UV photodetectors and sensors with nanostructure have great potential applications in many fields such as aerospace UV monitoring, UV imaging, flame sensing, medical diagnostics and so on [4–8]. In recent years, various oxide semiconductors such as TiO_2, ZnO and NiO have been investigated for photodetectors in the UV band [9–12]. Besides, the wide band semiconductors were exploited for UV photodetectors, including MnO_2, TiO_2 and ZnO [13–16], and most of these photodetectors require external bias voltages as the driving force to generate photocurrent, which will enlarge the size of the nanodevices and limit their independent working systems.

On the other hand, the fabrication of highly sensitive and self-powered UV photodetectors is still a challenge [17,18]. Herein, we present a UV photodetector composed of the TiO_2/PANI/TiO_2 multilayer structure. The designed UV photodetector, capable of working without any external bias voltage, generated different UV photocurrents when irradiated with different wavelengths UV light, and generated a high photocurrent ($\sim 3.5 \times 10^{-4}$ A) when the UV light wavelength was 365 nm. The findings may contribute to the development of the UV photodetectors.

2. Experimental

The TiO_2 NRs were synthesized by a hydrothermal method [19]. The nanocomposites of TiO_2/PANI were prepared by a low speed spin coating method. First, the PANI NWs were synthesized from aniline monomers by a chemical oxidation method [20]. When the reaction was completed the PANI solution was taken out and concentrated by a centrifugal process, and then the concentrated PANI solution was coated onto the obtained TiO_2 NRs through a low speed spin coating method. The TiO_2/PANI nanocomposites on the FTO substrate were obtained after drying in air at room temperature. Furthermore, in order to enhance the transition probability of electrons from valence band to the conduction band in the TiO_2 and increase the photocurrent [21], the TiO_2 NRs and TiO_2/PANI nanocomposites were functionalized by immersing in 50 mg/mL poly(styrene sulfonic acid) sodium salt solution for 6 h. Finally, the functional TiO_2 and TiO_2/PANI were put together face to face and clipped tightly. The designed UV photodetector of TiO_2/PANI/TiO_2 multilayer structure was obtained.

The morphologies of the samples were observed by SEM (JEOL, JSM-7001F). The UV–vis absorption spectra of the TiO_2 NRs and TiO_2/PANI nanocomposites were obtained using a UV–vis spectrophotometer (UV 2450, Shimadzu). The *I–t* and *I–V* curves of the nanodevices were measured by a CHI660D electrochemical

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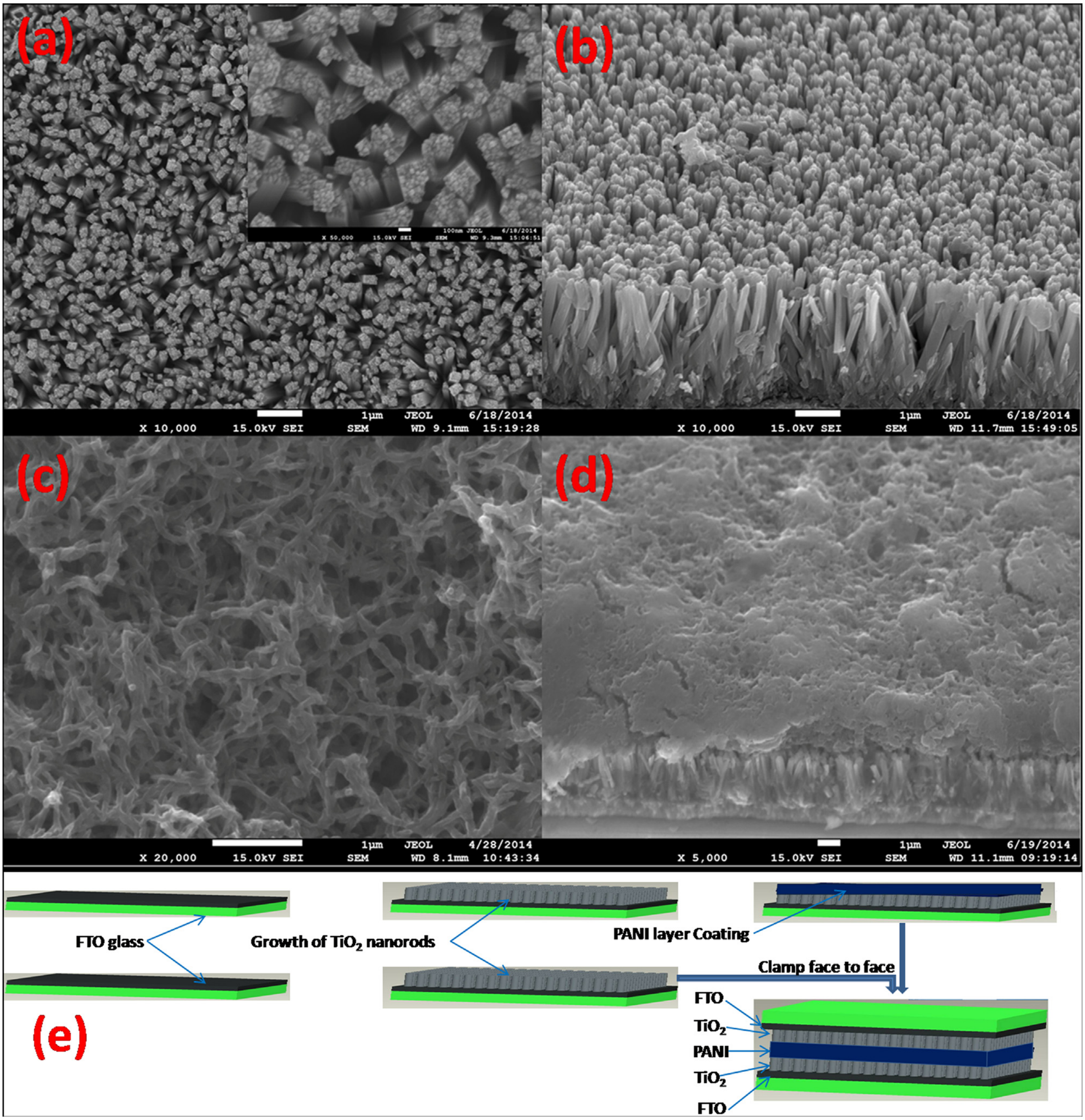

Fig. 1. SEM images of TiO_2 NRs (a, b) and TiO_2/PANI nanocomposites (c, d) on the FTO substrate, and (e) fabrication process of the self-powered UV photodetector.

workstation. The UV source was provided by a portable UV lamp (8W, ENF-280C, USA).

3. Results and discussions

Fig. 1(a) and (c) shows, respectively, the top views of the TiO_2 and TiO_2/PANI, Fig. 1(b) and (d) shows, respectively, the 30° tilted SEM images of the TiO_2 and TiO_2/PANI. The magnified SEM image in Fig. 1(a) shows that the average diameter of the TiO_2 NR is ~180 nm and each TiO_2 NRs is composed of many TiO_2 nanowires, Fig. 1(b) shows that the average height of the TiO_2 NRs is ~2 μm and the surface of the TiO_2 NRs is smooth, Fig. 1(c) shows that the average diameter of PANI NWs is ~85 nm, and Fig. 1(d) shows that the thickness of the PANI NWs layer is ~2 μm and the surface of the TiO_2/PANI nanocomposites is smooth. The smooth surfaces were beneficial in increasing the contacting area of TiO_2/PANI and TiO_2, which facilitated forming the p–n hetero-junction between TiO_2 and PANI when they were put together face to face. The fabrication process of the self-powered UV photodetector is detailed in Fig. 1(e).

The UV–vis absorption spectrum in Fig. 2 shows that both TiO_2 NRs (curve I) and TiO_2/PANI nanocomposites (curve II) have strong absorption peaks in the 330–400 nm UV band but the intensity of absorption peaks in the band of 200–330 nm is much lesser than in 330–400 nm. In order to study the UV photosensitivity of the TiO_2/PANI/TiO_2 device, we choose 254 nm from 200–330 nm with weak UV absorption and 365 nm from 330–400 nm with strong UV absorption to test *I–t* curves and the results are shown in Fig. 3. Fig. 3(a) shows the *I–V* characteristic of the TiO_2/PANI device. Curve I in Fig. 3(a) was measured in a dark environment, and curve II was measured under the 365 nm wavelength UV light