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Visible-blind solid-liquid heterojunction ultraviolet photodetector based on an active layer of TiO_2 nanorod array grown by hydrothermal process

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1. Introduction

Ultraviolet (UV) photodetectors (PDs) present a wide range of civil, industrial, and military applications [1-3]. Conventional UV-PDs are based on various solid-state junctions such as p-n, p-i-n, Schottky barrier, and so forth [1-3]. Moreover, in order to obtain a high photosensitivity, these are usually made from epitaxial processes and single crystal substrates that result in high production cost.

Recently we reported a novel structure of solid-liquid heterojunction (SLHJ) that is used for UV-PD application [4], demonstrating that the SLHJ UV-PD has an exceptional competence for UV-light detection. The reported device is based on an active layer of TiO_2 thin film, which is grown by a vacuum-coating technique of the atomic layer deposition (ALD) [5].

In this work, a nanostructured active layer of TiO_2 nanorod array (TNA) used for the SLHJ UV-PD is reported. It is noticed that the TNA is grown on FTO-glass substrate by a vacuum-free, low-cost hydrothermal process. Moreover, the results show that the TNA SLHJ UV-PD exhibits numerously outstanding properties such as excellent spectral selectivity (visible-blind), high photosensitivity (photo-to-dark current ratio), fast response, and linear variations in photocurrent.

2. Experiments and Results

Hydrothermal growth of TNA:

In order to grow the TNA on FTO-glass substrate, 1 mL of titanium butoxide (97 %, Aldrich), 30 mL of hydrochloric acid (36 wt%, J. T. Baker), and 30 mL of deionized water were mixed and stirred in a tank for 10 min. After stirring, the mixed solution and a FTO-glass substrate were put into a Teflon-lined stainless steel autoclave. Then the autoclave was heated at 150 ^{o}C for 2h in an electric furnace. Finally, after the autoclave was cooled to room temperature, took the sample out, thus the hydrothermal process of the TNA grown on FTO-glass was finished.

Characteristics of as-prepared TNA:

The typical surface morphology of the TNA grown on FTO-glass was observed by scanning electron microscopy (SEM, Hitachi SU-8000) as shown in Fig. 1. It can be clearly seen that a uniformly distributed TNA is successfully grown on FTO-glass substrate by hydrothermal process. The crystalline structure of TNA was analyzed by X-ray diffraction (XRD, Rigaku D/MAX2500) and the XRD pattern of the TNA was shown in Fig. 2. According to the XRD pattern, the crystalline structure of the TNA is identified as rutile structure.

Characteristics of TNA SLHJ UV-PD:

The fabrication procedure and analysis methods of an SLHJ UV-PD have been described in detail elsewhere [4]. Fig.3 shows the spectral responsivity of the TNA SLHJ UV-PD. It can be clearly seen that the device displays a visible-blind behavior with a spectral response of 300 – 400 nm and a maximum responsivity of 3 mA/W located at 350 nm. The photocurrent and photosensitivilty of SLHJ UV-PD versus incident UV-light power plots (as shown in Fig. 4) show that the photocurrent and photosensitivity are almost linear increased with increasing incident UV-light intensities. It is noticed that the wavelength of incident UV-light is 365 nm and the light intensities are varied from 48 nW to 479 μW (0.244 $\mu W/cm^2$ to 2.440 mW/cm^2). Moreover, the corresponding photosensitivities are varied from 6 to 16800. Besides, the I-T plots of SLHJ UV-PD (as shown in Fig. 5) exhibit a reproducible photoresponse and fast response time (both decaying and rising times are less than 0.5 s).

3. Conclusions

In this work, an SLHJ UV-PD based on a nanostructured active layer of TiO_2 nanorod array (TNA) is reported. The TNA SLHJ UV-PD exhibits numerously outstanding properties such as excellent spectral selectivity, high photosensitivity, fast response, and linear variations in photocurrent that presents a high potential for future development of low-cost and high sensitive UV-detecting devices via a vacuum-free, low-cost hydrothermal process.

References

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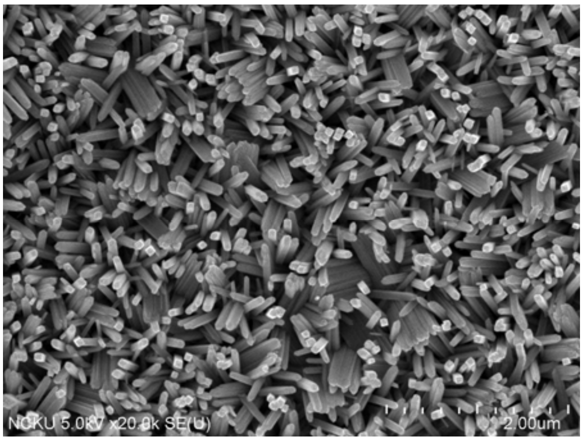

Fig. 1 Typical surface morphology of the TiO_2 nanorod array grown on the FTO-glass substrate by hydrothermal process.

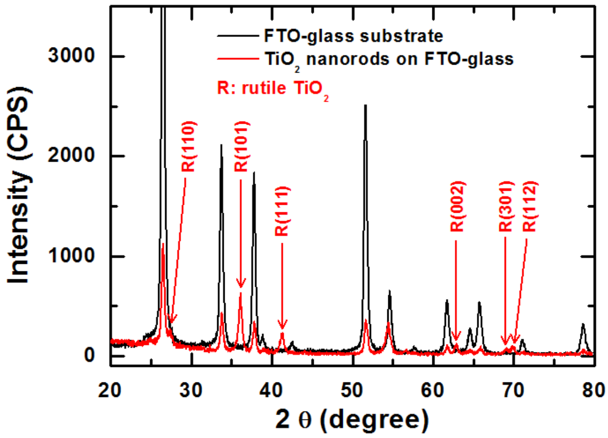

Fig. 2 X-ray diffraction patterns of the FTO-glass substrate and TiO_2 nanorod array grown on FTO-glass by hydrothermal process.

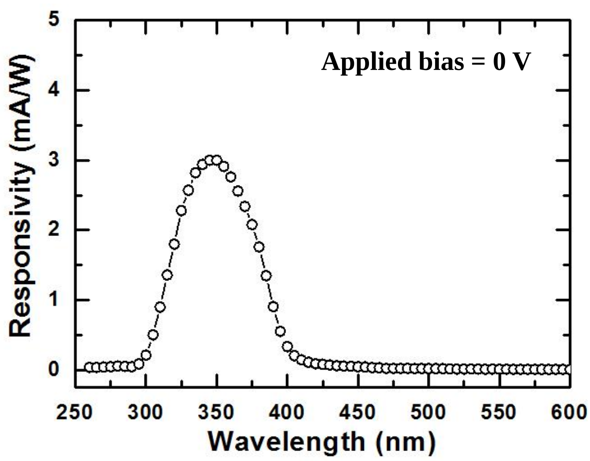

Fig. 3 Spectral responsivity of the SLHJ UV-PD based on an active layer of TiO_2 nanorod array.

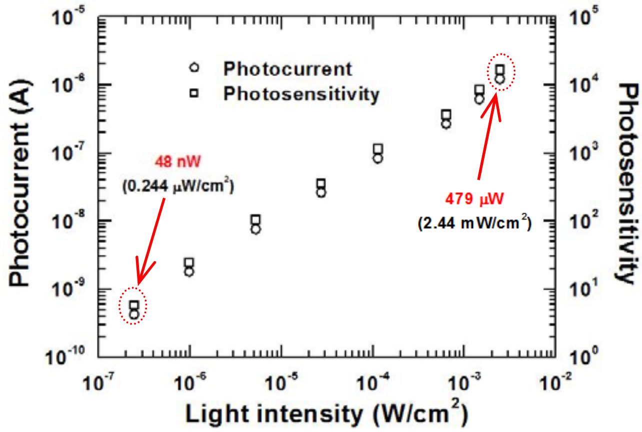

Fig. 4 Photocurrent and photosensitivity versus incident UV-light intensity plots of the SLHJ UV-PD based on an active layer of TiO_2 nanorod array. The measurements are carried out at 0 V bias and under 365 nm UV-light irradiation with light intensities varied from 48 nW to 479 μW ($0.244 \mu W/cm^2$ to $2.440\ mW/cm^2$).

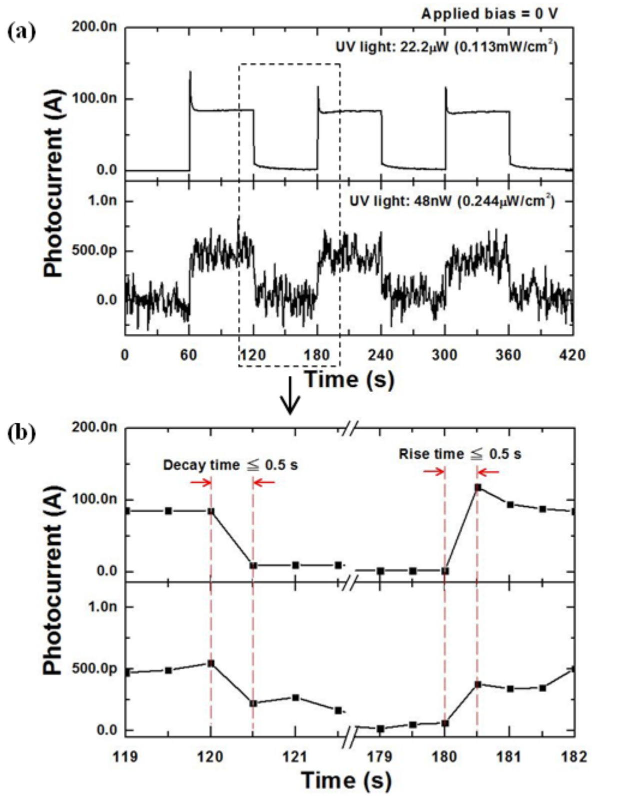

Fig. 5 (a) I-T plots of the SLHJ UV-PD based on an active layer of TiO_2 nanorod array under the UV-light on/off switching irradiation (top: 22.2 μW, and bottom: 48 nW). (b) The enlarged portions of 119 – 121 s and 179 – 182 s ranges that related to Fig. 5a.