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Growth of titanium dioxide nanorod arrays through the aqueous chemical route under a novel and facile low-cost method

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ABSTRACT

Titanium dioxide (TiO_2) nanorod arrays were successfully synthesized through a facile aqueous chemical route on a fluorine tin oxide-coated glass substrate in a Schott bottle with cap clamps. Distinct rutile-phase TiO_2 peaks were observed via X-ray diffraction and micro-Raman spectroscopy. The surface morphology depicted in field-emission scanning electron microscopy and atomic force microscopy images showed that the nanorod arrays were successfully synthesized on the substrate. Moreover, these arrays possessed an average diameter of 120 nm and an average length of 1.52 μm. The prepared TiO_2 nanorod arrays exhibited high absorbance properties in the ultraviolet (UV) region (< 400 nm). In this study, the synthesized arrays may be applied in optical sensing based on the steady photocurrent results obtained under UV irradiation in a sodium sulfate electrolyte solution.

1. Introduction

The optical, electrical, and photochemical properties of nanostructured titanium dioxide (TiO_2) are unique and outstanding; this material has gained significant interest over the previous decade as an alternative material for photocatalysts [1] and electronic devices [2]. Numerous deposition methods have been examined for nanostructured TiO_2 synthesis, including sputtering, chemical vapor deposition, pulsed-laser deposition, and solution-based methods. Various studies on solution-based methods have attempted to extend the deposition process to synthesize a preferred nanorod array structure of the TiO_2 layer given the high surface area-to-volume ratio [3,4]. However, the process requires a high-pressure vessel or autoclave even at a low synthesization temperature. The main purpose of our research is to develop a fast, low-cost, and reliable solution-based method to prepare TiO_2 nanorod arrays for photosensor use.

In the present study, we propose a novel aqueous chemical route that uses a facile Schott bottle with cap clamps to produce an aligned TiO_2 nanorod array structure. This bottle has never been used for the dissolution condensation growth of TiO_2 nanorod arrays because the bottle cap is incapable of compressing the increasing pressure at elevated temperatures. Thus, cap clamps are introduced for clenching purposes. This low-cost, simple, yet fast method facilitates rapid progression and extensive study on the one-dimensional growth of a TiO_2 nanorod array structure. Finally, the synthesized arrays are characterized in terms of its structural, optical, and electrical properties.

2. Experimental

A fluorine tin oxide (FTO)-coated glass substrate was used for the growth of the TiO_2 nanorod arrays. The substrates were cleaned with acetone, ethanol, and deionized (DI) water in an ultrasonic bath. The hydrothermal process was performed for 10 min in a Schott bottle containing a mixture of hydrochloric

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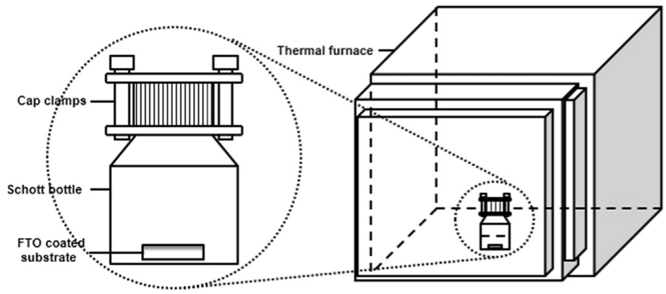

Fig. 1. Setup for TiO_2 nanorod array synthesis in a Schott bottle with cap clamps.

(HCl) acid and deionized water in a 1:1 volume ratio. Titanium (iv) butoxide (0.07 M) was added to the solution under vigorous stirring for another 30 min. A cleaned FTO-coated glass substrate was incorporated into the resultant transparent solution with the conducting side facing upward; then, the Schott bottle was sealed and fastened with cap clamps to retain the high pressure inside the bottle for 2 h at 150 °C. A schematic of this process is shown in Fig. 1. The synthesized sample on the substrate was then rinsed with DI water and dried at room temperature. Subsequently, the sample was annealed in a furnace at 450 °C for 30 min to improve crystallinity.

The morphology, topology, and crystallinity of the synthesized TiO_2 samples were observed via field-emission scanning electron microscopy (FESEM, ZEISS Supra 40VP), atomic force microscopy (AFM, Park System), and X-ray diffraction (XRD, Shimadzu XRD-6000), respectively. The sample was also characterized through micro-Raman spectroscopy (Renishaw InVia microRaman System, 514 nm laser). An ultraviolet–visible (UV–vis) spectrophotometer (Cary 5000) was used to characterize the optical properties of the synthesized TiO_2 nanorod arrays at wavelengths of 200–800 nm, whereas the electrical properties of these arrays were characterized with a direct current (DC) two-probing system (Advantest R6243) to identify the current–voltage (*I–V*) characteristic. The photocurrent was measured under UV irradiation using a two-probe measurement system (Keithley 2400) and a UV lamp (365 nm, 4 W) with a bias voltage of 1 V.

3. Results and discussion

The surface morphology depicted in Fig. 2(a) and (b) reflects the top view of the synthesized TiO_2 at magnifications of 100,000 × and 30,000 ×, respectively. The nanorods, which display an average diameter of approximately 120 nm, were uniformly deposited on the substrate with dense arrays. Fig. 2

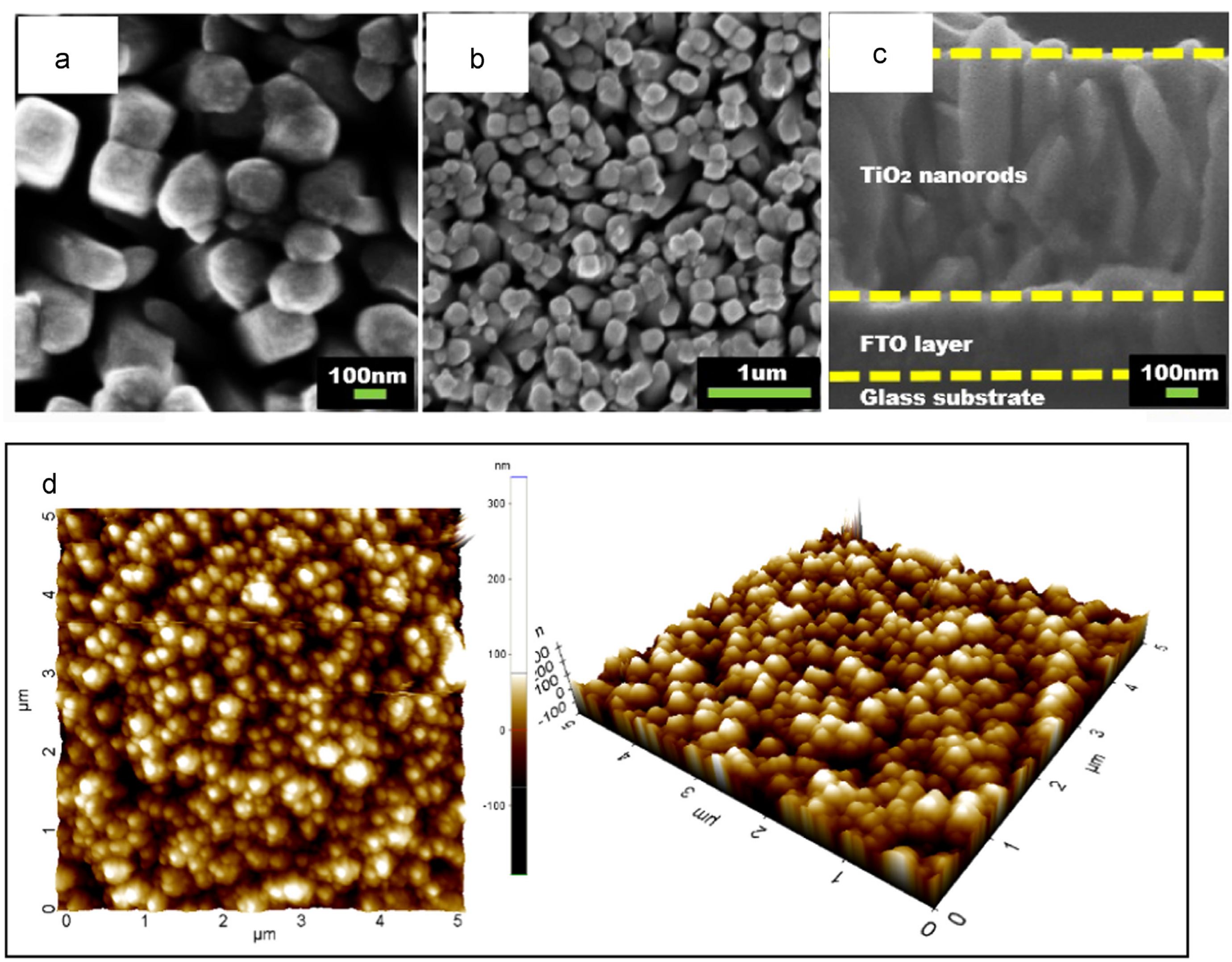

Fig. 2. FESEM images of the TiO_2 nanorod arrays at magnifications of (a) 100,000 × and (b) 30,000 ×. (c) Cross-sectional and (d) AFM images of the synthesized TiO_2 nanorod arrays.