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Fabrication of Nanostructured ZnO films on the Seedless Flexible ITO Substrate

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Abstract

The aim of this work is to fabricate nanostructured ZnO films on the seedless flexible indium doped tin oxide substrate by a simple, inexpensive, and uncovered hydrothermal method. The deposition temperature varies from 55-105°C. The structural orientation has changed from (100) to (101) due to increase of deposition temperature. The size (diameter: 475~825 nm) and shape of ZnO nanorods (NRs) have also changed with the increase of deposition temperature. The ZnO NRs are also more photoactive due to red-shifted band-edge and surface morphology with the higher deposition temperature, which can be applied for different device applications.

1. Introduction

ZnO is a most promising, and versatile semiconductor for the fabrication of several kinds of devices [1] due to its some unique properties such as wide bandgap (3.37 eV), large exciton energy (60 meV), and high electron mobility (115-155 $cm^2V^{-1}s^{-1}$) at room temperature [2]. The various methods have been reported for the synthesis of ZnO nanostructures such as vapor liquid solid process and metal-organic chemical vapor deposition [3-5]. These methods produce high crystalline ZnO nanostructures. However, the strict requirement of the high crystallinity of seed layer on the substrate [3] and the high deposition temperature seriously limit the compatibility of these methods for the applications in flexible electronics [6]. Compared to above mentioned method, the low-temperature synthesis of hydrothermal method offers the potential for much lower cost since no need for high-temperature manufacturing and vacuum processing [1, 6]. Some researchers had already prepared ZnO nanostructures on seedless patterned glass, and Au-coated substrate [1, 3]. Moreover, sophisticated autoclave system avoids here due to its high cost and maintenance difficulties [7]. So in this work, nanostructured ZnO films have been deposited on seedless flexible polyethylene terephthalate/indium doped tin oxide (PET/ITO) substrate by uncovered hydrothermal method at various deposition temperatures ranges from 55-105°C. The structural, optical and surface morphological properties of ZnO films have been characterized and discussed, which may be applied for device applications.

2. Experimental Section

At first, the PET/ITO substrates were cleaned by the ultrasonic system in acetone-distilled water-acetone, and then dried in pure N_2 steam flow. The ZnO nanostructures were fabricated by simple and inexpensive uncovered hydrothermal method [7] at different temperature of 55, 65, 75, 85, 95 and 105°C. A 50 mM of zinc nitrate hexahydrate was dissolved in 50 ml of deionized water (Millipore Milli-Q Plus purification system, 18.2 M-Q-cm) water, and then 50 mM of HMTA was dripped under constant stirring at room temperature to ensure well dispersion of the reactant. After completion of deposition process, the ZnO coated PET/ITO substrate was removed from the solution, then immediately rinsed with deionized water to remove any residual salt from the surface, and dried at 150°C in air for 30 min. The surface morphologies were investigated using field emission scanning electron microscope (FE-SEM, JEOL 6700F). The crystal structure of the ZnO films were examined by X-ray diffractometer (XRD, Bruker Discover 8) analysis with Cu-Kα line. The data were recorded from 2θ values 10° to 90° with a step of 0.04°. The optical properties of the films were measured by UV/VIS spectrophotometer (Hitachi U-1900) at RT within the wavelength range 300-900 nm.

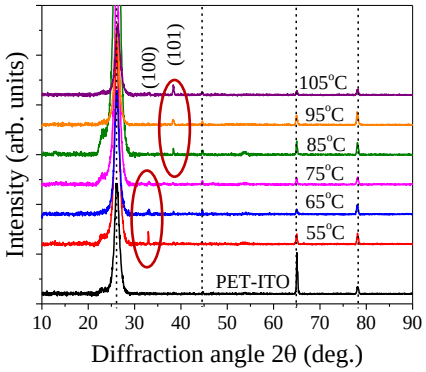

Fig. 1 XRD pattern of ZnO films prepared on PET/ITO substrate at different deposition temperature.

3. Results and Discussions

Figure 1 shows the XRD patterns of ZnO films prepared at different deposition temperatures of 55-105°C. Two crystalline peaks are observed, which are in agreement with the typical wurtzite structure of ZnO films. Interestingly, the (100) peak has found for the ZnO films with deposition temperatures of 55-75°C and (101) peak has found for ZnO films with the 85-105°C deposition temperature. The crystallite size has been calculated by Debye Sheerer equation [8]. The crystallite size of ZnO films prepared at 55-105C deposition temperature is varied from 4.95-8.25 nm, respectively.

Fig. 2 (a) exhibits the transmittance spectra of ZnO films

deposited at different temperatures of 55-105°C. The average transmittance of ZnO films is changed averagely from 30~20% with the deposition temperature of 55~105°C, respectively.

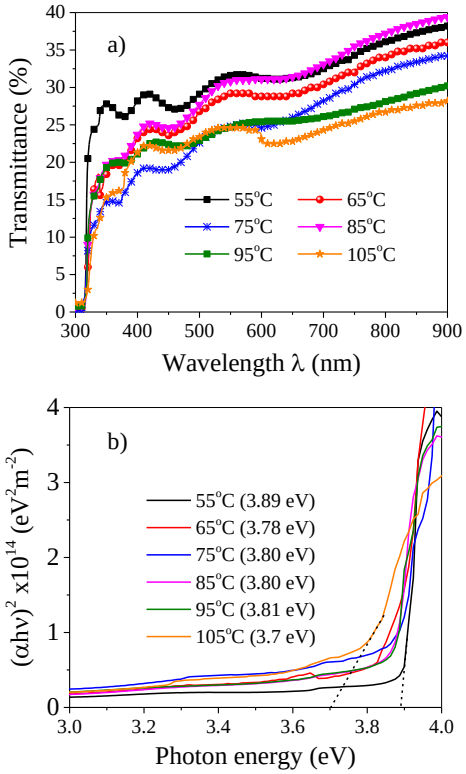

Fig. 2 (a) Transmittance spectra and (b) $(\alpha h\nu)^2$ versus photon energy, of ZnO films prepared on PET/ITO substrate at different deposition temperature.

The absorption edge and optical bandgap (Eg) of nanostructured ZnO films depends on the phase structure and crystallite size of the particle, which has been calculated using the method of Tauc and Menth [9]. Figure 2(b) shows $(\alpha h\nu)^2$ versus photon energy curves of the direct transition bandgap of ZnO films grown at different deposition temperatures. In both cases, the ZnO film prepared at 105°C, shows the lowest band gap. The bandgap of the ZnO films is little bit red-shifted from 3.89 to 3.70 eV with the increase of deposition temperature. Decreasing of band gap indicates the more photoactivity of ZnO films [10]. Figure 3 (a)-(f) shows the FE-SEM images of ZnO films with deposition temperatures of 55-105°C, respectively. The nanoparticles are found on the surface of ZnO films with 55°C. The short nanorods (NRs) like structures are started to grow on the surface of flexible substrate. The average diameter is around 475 nm. The clear hexagonal shape of ZnO NRs is observed with the deposition temperature of 65-105°C. The size of ZnO NRs is varied from 475~825nm with the temperature of 65~105°C. Moreover, the shape of NRs has also changed with the increase of deposition temperature.

4. Conclusions

Nanostructured ZnO films were successfully prepared on seedless flexible PET/ITO substrate by a simple, inexpensive and uncovered hydrothermal method at different deposition temperatures of 55-105°C. The crystal orientation had changed due to increase of deposition temperature. The size of ZnO NRs was increased from 475~825 nm with the deposition temperature of 65~105°C. The band edge also little bit red-shifted due to increase of deposition temperature. This prepared ZnO films can be used for the device applications such as light emitting diode, photocatalytic, dye-sensitized and perovskite solar cells.

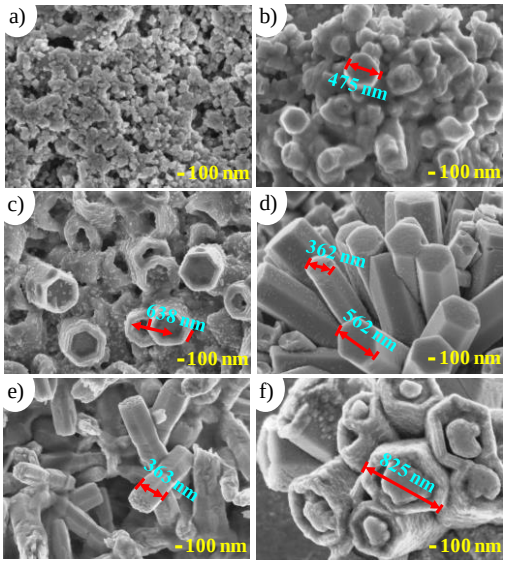

Fig. 3 FESEM images of ZnO films prepared on PET/ITO substrate at different deposition temperature of (a) 55, (b) 65, (c) 75, (d) 85, (e) 95, and (f) 105°C.

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