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Comparison with electrical and optical properties of zinc oxide films deposited on the glass and PET substrates

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Abstract

Transparent oxide films derivating from wide band-gap semiconductors have found wide applications in recent years. The zinc oxide has most attention because of its excellent optical and electrical properties compared with the ITO film. In this work, different kinds of substrates (the glass and PET) were used to deposit zinc oxide films by RF magnetron sputtering. The structural, electrical and optical properties were studied using glass and PET substrates. The experimental results show that the films have proud (002) orientation on both substrates. The lowest resistivity obtained is 2.9×10^{-3} Ω cm and 4.0×10^{-3} Ω cm when the substrate is glass and PET respectively. The average transmittance in the visible spectrum can be above 80% no matter what kind of substrate was used. The results imply that the PET is as good as the glass and open a new field of low cost, lightweight, flexible process to produce unbreakable large area optoelectronic devices.

Keywords: RF magnetron sputtering; Zinc oxide; Resistivity; Visible spectrum

1. Introduction

The transparent conducting films have been investigated extensively because their electrical and optical properties make them suitable for a lot of applications. These applications include flat panel display (FPD) [1,2], liquid crystal display (LCD), organic light emitting diodes (OLED), hetero-junction solar cells and transparent window insulation. For producing the LCD (liquid crystal display), the transparent conductive films are mainly deposited on the glass [3]. But plastic substrates have the advantages of low lost, lightweight, and good transmittance or even flexibly. Due to the poor thermal endurance of plastic substrates, these films should be deposited at low temperature. The properties of ZnO thin films are currently of great commercial and scientific interest compared with the transparent conducting films. ZnO is a wide direct band-gap semiconductor with a hexagonal crystal structure of wurtzite [4–7]. Recently, zinc oxide films have attracted interest as a transparent and conductive material due to its many advantages: (1) cheap and abundant raw starting materials, (2) possible large scale coating, (3) good ultraviolet absorption behavior, (4) high stability in a hydrogen plasma, (5) electrical conductivity modified by appropriately doped or post-annealing [8], nontoxic and easy to fabricate [9]. In this work, we report the preparation and properties of zinc oxide films deposited on different kinds of substrates (the glass and PET) by RF magnetron sputtering. The dependence of the structural, electrical and optical properties of these films on varied substrates was studied in detail.

2. Experimental

The ZnO films were deposited on glass (corning 1737F) and PET (ethylene terephthalate) substrate by RF magnetron sputtering system with a base pressure of 1.33 Pa. Each substrate was ultrasonically cleaned in acetone and subsequently dried in flowing nitrogen gas before deposition. The target was material Zn (99.99% purity) and the diameter of target was 76.2 mm. The sputtering was conducted in a

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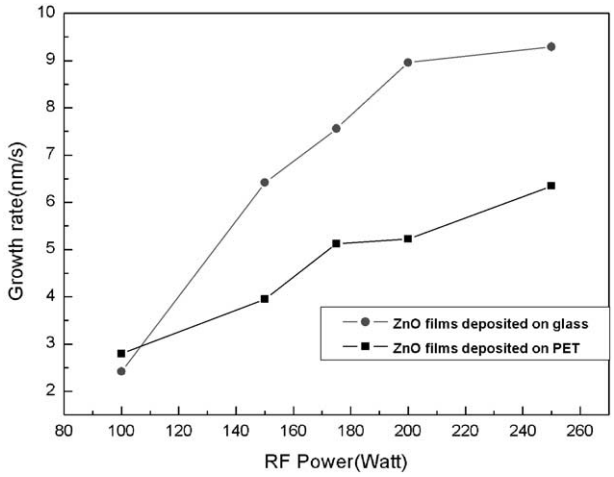

Fig. 1. The deposition rate for ZnO films deposited on glass (corning 1737F) and PET (ethylene terephthalate) substrates.

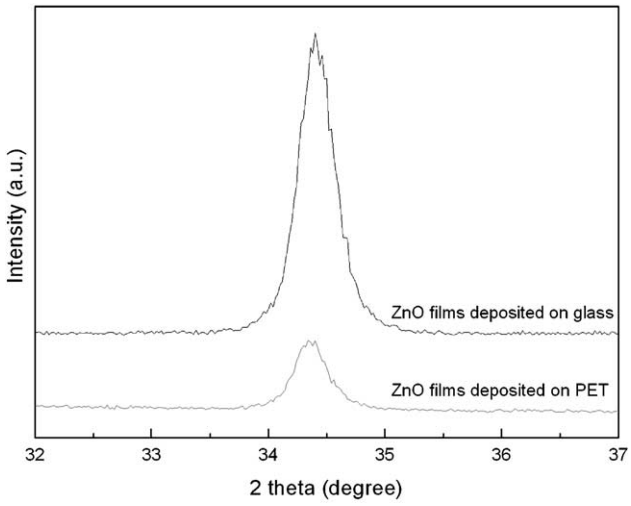

Fig. 3. The XRD patterns of ZnO films prepared at different substrates.

mixture of oxygen and argon atmospheres with a target to substrate distance of 45 mm.

Before deposition, the chamber was pumped to an ultimate background of 10−5 Torr for half an hour and then a pre-sputtering process was followed for 10 min to clean the target surface and remove any possible contamination. The RF power was set in the 100–250 W range, the substrate temperature was maintained at 26–45 °C, and the thickness of films was controlled by sputtering time at approximately 4600 Å.

A conventional stylus surface roughness detector (Alpha-step 200) was used to measure the film thickness and change this value to growth rates by divided sputtering time. The phases of the deposited films were studied by X-ray diffractometer (XRD). The XRD patterns of the films were determined with a Shimadzu XD-1 diffractometer using monochromatic high intensity Cu α radiation (λ=1.5418 Å), operating at 30 kV with 20 mA current, and a scanning speed of 3°/min. The optical transmittance measurements were performed with UV spectrophotometer. The transmittance spectra as a function of wavelength are in the range 350–850 nm. The resistivity of the films was measured by Hall measurements.

3. Results and discussion

Fig. 1 showed the deposition rate of ZnO films deposited on different substrates. The deposition rate of zinc oxide film increased with increasing RF power. When the RF power increases, the zinc atoms generated by sputtering and the probability of the zinc atoms arriving on the substrate increase. Therefore the deposition rate of zinc oxide film is increased. It is apparent that the deposition rate of zinc oxide on glass has a higher growth rate than that on the PET substrate.

Fig. 2 shows the XRD spectra for the ZnO films deposited on PET substrate of various RF powers. The

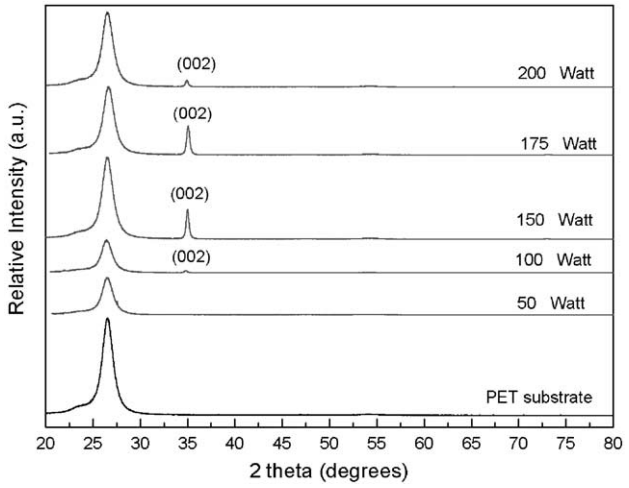

Fig. 2. XRD spectra for ZnO films deposited at different RF powers on PET substrates.

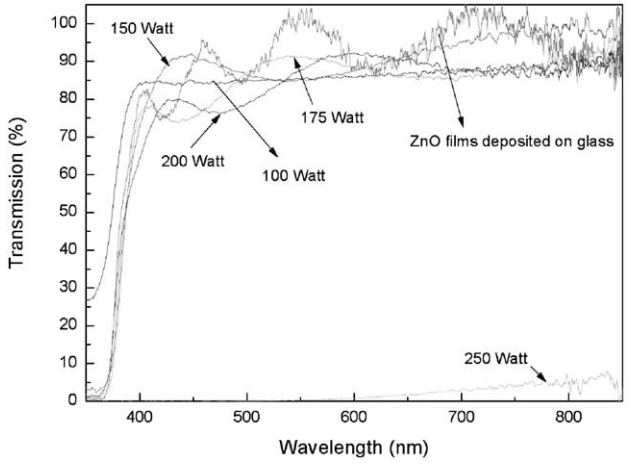

Fig. 4. Transmittance spectra as a function of wavelength in the range 350–850 nm deposited on glass and PET substrates.