Microstructure of Magnetron Sputtered ZnO Films on Glass Substrate

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Introduction

Transparent conductive oxides (TCOs) have attracted much attention in recent years, because of their excellent electrical and optical properties. Among them, zinc oxide (ZnO) has several advantages with respect to other materials, such as low resistivity, high transparency, wide band gap, high thermal and chemical stability, low cost and nontoxicity. ZnO has many potential applications such as optoelectronic device [1], gas sensor [2], solar cell [3] and lasers [4]. ZnO is both transparent in visible region and electrically conductive. To obtain high quality ZnO films, a variety of preparation techniques can be used such as chemical vapor deposition, radio frequency magnetron sputtering, pulsed laser deposition and chemical bath deposition. Magnetron sputtering with high deposition rate, high reliability and good control of the film properties is the most attractive and common use technique. In this study, we have investigated the influence of substrate temperature on the surface morphology ZnO films deposited on glass substrate. A direct current magnetron sputtering system was adopted in this work as it provides high deposition rate and good control of the film properties. The surface morphology and roughness of ZnO films were observed using atomic force microscopy (AFM), scanning electron microscopy (SEM) and X-Ray diffraction (XRD).

Film Preparation

A series of ZnO films were prepared by RF magnetron sputtering system (ULVAC MB06-4703) on Corning 2000 glass substrate at different temperatures. The target is a an AZO with a diameter of 2 in, thickness of 3 mm. The distance between the target and substrate is approximately 10 cm. Prior to deposition, the substrates were cleaned in soap solution, submerged in acetone solution and in an ultrasound bath for 15 minutes after rising with distilled water. Then the substrates were dried in an oven at the temperature of 50^0C for 30 minutes before the application of deposition. The chamber is equipped with a rotary vane pump and a root pump. After a pumping time of one hour, the chamber was evacuated down to a base pressure 1.2×10^{-3} Pa. Highly pure (99.999 %) argon was used as the sputtering gas with the flow rate of 10 sccm. Before the application of deposition, the target and substrate were sputter-cleaned by Ar plasma for 10 minutes to remove the oxide and contaminant. ZnO films were deposited at an operation pressure of about 2×10^{-1} P*a* with the duration of 60 minutes for all the prepared samples. The sputtering power was 150 W. In this way, four sets of ZnO thin films were prepared by varying the substrate temperature (25^0C, 100^0C, 200^0C and 275^0C). The thicknesses of ZnO films were measured by surface profiler (KLA Tencor P16). To obtain the film thickness, a small tape was placed at the substrate prior to deposition to get a step on the sample surface as shown in Fig.1. The step height was measured in four different points on the sample surface and the film thickness was taken as the average of these values. The thicknesses of ZnO films prepared at different substrate temperatures of 25^0C, 100^0C, 200^0C and 275^0C are 410nm, 424nm, 505nm and 567nm, respectively. It shows that the film thickness is increasing with the increase of substrate temperature.

Microstructure and Surface Topography

The microstructure and surface topography of ZnO films were examined using atomic force microscopy (Seiko Instruments Inc. SPA 400) and field emission scanning electron microscopy (Jeol JSM6701F). The AFM was

operated in the tapping mode. Typical AFM images of the films deposited on the glass with substrate temperatures of 25^0C,100^0C, 200^0C and 275^0C are presented in Fig.2. The surface roughness of ZnO films deposited at temperatures of 25^0C, 100^0C, 200^0C and 275^0C are 3.45nm, 2.73nm, 5.17nm and 5.03nm, respectively. The FE-SEM images of the films prepared at different temperatures of 25^0C, 100^0C, 200^0C and 275^0C are displayed in Fig.3. The crystalline structure and preferential orientation of ZnO films was examined by X-ray diffraction (XRD) using Shimadzu LabX XRD-6000 with Cu K_α radiation and scanned from 20^0 to 80^0 at a rate of $2^0/\min$. A typically XRD spectra of ZnO films deposited at substrate temperatures of 25^0C is shown in Fig.4. All of the films show strong peaks in (002) direction, implying a polycrystalline hexagonal polycrystalline hexagonal wurzite crystal structure with a preferred c-axis orientation. The films exhibit fine polycrystalline grains with uniformly distributed round clusters.

Conclusions

The ZnO films were prepared on glass substrate by RF magnetron sputtering at different substrate temperatures. The effects of substrate temperature on the microstructure of ZnO films were investigated. The crystalline structure and surface morphology of the ZnO films were analyzed by XRD, AFM and SEM. It was observed that all the ZnO films exhibit a polycrystalline (002) orient structure. The crystalliniity was enhanced by increasing the substrate temperature.

References

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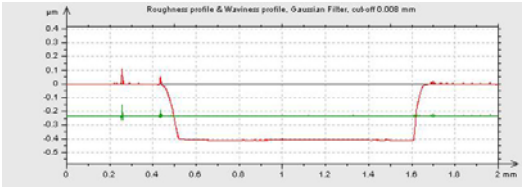
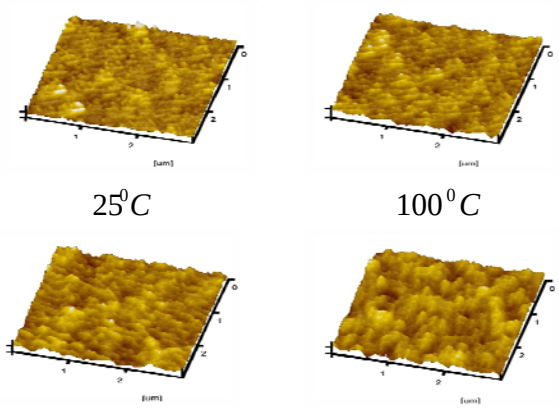
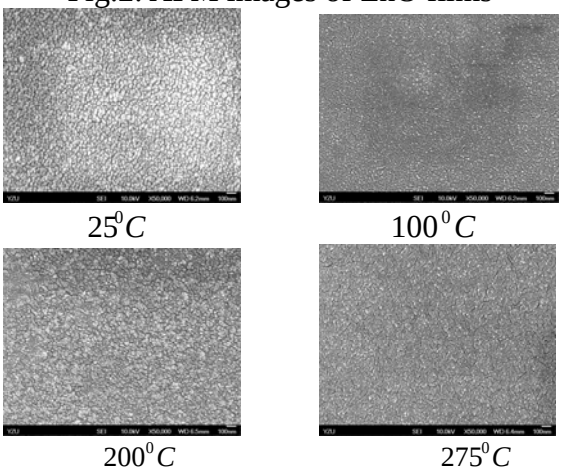


Fig.1: surface profiler measure film thickness



25^0C 100^0C 200^0C 275^0C

Fig.2: AFM images of ZnO films



25^0C 100^0C 200^0C 275^0C

Fig.3: SEM images of ZnO films

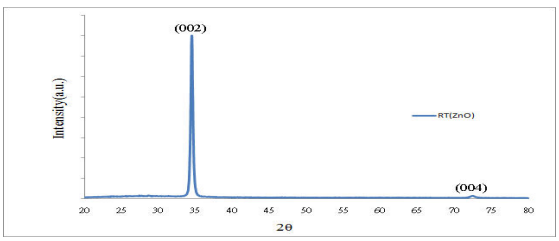


Fig.4: XRD spectra of ZnO film