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Preparation of Al doped ZnO thin films as a function of substrate temperature by a facing target sputtering system

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Al doped ZnO (ZnO:Al-AZO) thin films have been investigated for use as photovoltaic cells or as transparent conductive oxide (TCO) of displays, because AZO has good electrical and optical properties. In this study, ZnO:Al (AZO) thin films were prepared on substrates at temperatures room temperature, 100 °C and 200 °C by a facing target sputtering (FTS) system. The electrical and optical properties of the AZO thin films were investigated by a four-point probe (Changmin) and a UV/VIS spectrometer (HP). Also the roughnesses of AZO thin films were investigated as a function of substrate temperature. AZO thin films were deposited with a transmittance of over 80% and the resistivity was reduced from 1.36×10^{-3} Ω·cm to 4×10^{-4} Ω·cm by increasing the substrate temperature from room temperature to 200 °C. In particular, we could obtain a resistivity of 4×10^{-4} Ω·cm in an AZO thin film prepared at a working pressure 133 mPa, an input current 0.4A and a substrate temperature of 200 °C.

Key words: facing target sputtering, AZO, TCO, resistivity.

Introduction

Transparent conductive oxide (TCO) films, mainly indium tin oxide (ITO) films, have been widely applied to manufacture transparent electrodes for flat panel displays (FPD), solar cells and organic light-emitting diodes due to their high luminous transmittance, good electrical conductivity, good adhesion to substrates and chemical inertness [1-5]. Also Al doped ZnO thin films which are called AZO have promoted the development of inexpensive materials. Thus preparing AZO thin films with a low resistivity, high transparency and low cost has been extensively studied [6-8]. AZO thin films can be produced by various deposition techniques including plasma enhanced chemical vapor deposition (PECVD) [9], pulsed laser deposition (PLD) [3, 5], RF magnetron sputtering [2, 4] and facing target sputtering (FTS) [10, 11]. Among the reports about transparent conductive oxide thin films, the sputtering method has been widely used [12]. AZO thin film may be deposited with a high transmittance of over 80% and a low resistivity of about 10^{-4} Ω·cm as a function of sputtering conditions. In this study, AZO transparent conductive thin films were prepared by an FTS method and the electrical and the optical properties of AZO thin films as a function of substrate temperature have been investigated.

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Experimental

AZO thin films were deposited on glass substrates by an FTS method. The substrates were ultrasonically cleaned in de-ionized water-isopropyl alcohol-acetone-isopropyl alcohol and subsequently dried in flowing nitrogen gas before deposition. The sputtering conditions are shown in Table 1. The electrical resistivity was determined with a Hall effect measurement system (ECOPIA) using the van der Pauw method. The structural properties were analyzed using an X-ray diffractometer (Rigaku). The optical transmittance spectra were obtained on a UV/VIS spectrophotometer (HP) in the wavelength range from 200 to 1100 nm. The surface-images of AZO thin films were obtained by atomic

Table 1. Sputtering conditions

Deposition parameter	Conditions
Targets	Zn(5N) ZnO:Al(Al_2O_3:2 wt%)
Substrate	Glass slide
Target-target distance	100 mm
Target-substrate distance	100 mm
Base pressure	0.267 mPa
Working gas pressure	133 mPa
Thickness	100 nm, 200 nm
O_2 gas flow rate O_2 sccm/(O_2 sccm+Ar sccm)	0.2
Substrate temperatures	R.T, 100 °C, 200 °C
Sputtering current	0.4A

force microscope (PSIA).

Results and Discussion

Figure 1 shows XRD patterns of AZO thin films at an input current 0.4A and working gas pressure of 133mPa with substrate temperatures room temperature, 100 °C and 200 °C. The (002) plane diffraction peak of the AZO thin film prepared at 200 °C was higher than that at 100 °C. Also the peak of AZO thin films prepared at 100 °C and room temperature are similar to each other. The full width at half maximum (FWHM) of AZO thin films decreased with an increase in the substrate temperature. Figure 2 shows the resistivity and grain size of AZO thin films at an input current of 0.4A and a working gas pressure 133 mPa with substrate temperature room temperatures, 100 °C and 200 °C. The lowest value of the resistivity of an AZO thin film was about 4×10^{-4} Ω·cm at a substrate temperature of 200 °C, with a film thickness of 200 nm. The resistivity of AZO thin films decreased with an increase in substrate temperature. Also the grain size increased with an increase in substrate temperature. It is considered that the decrease in resistivity of AZO thin films was caused by a reduction of grain boundary area.

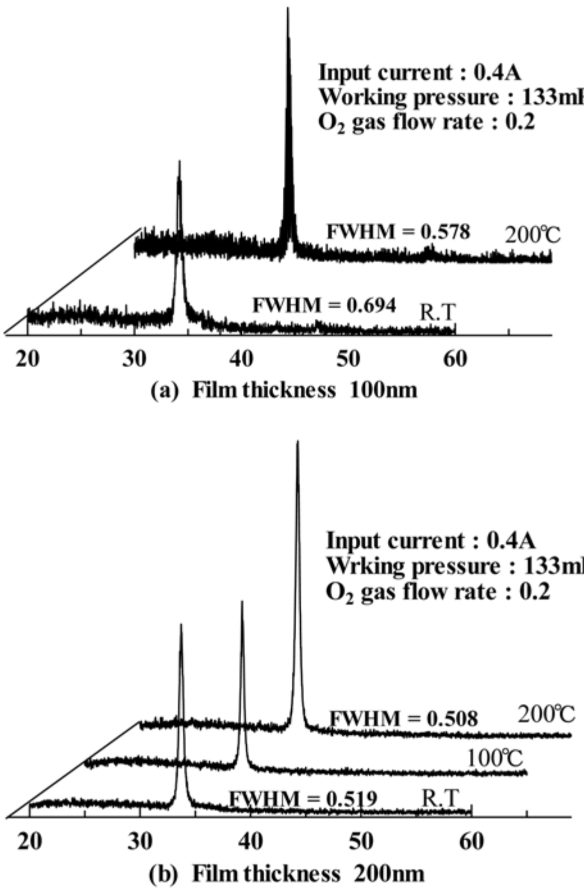

Fig. 1. XRD patterns of AZO thin films prepared as a function of substrate temperature.

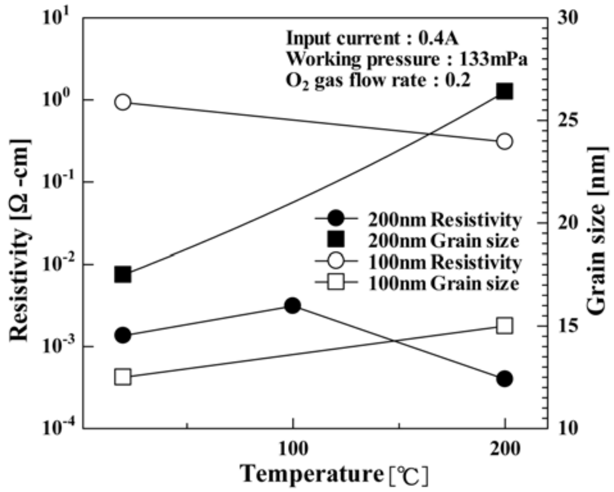

Fig. 2. The resistivity and grain size of AZO thin films prepared as a function of substrate temperature.

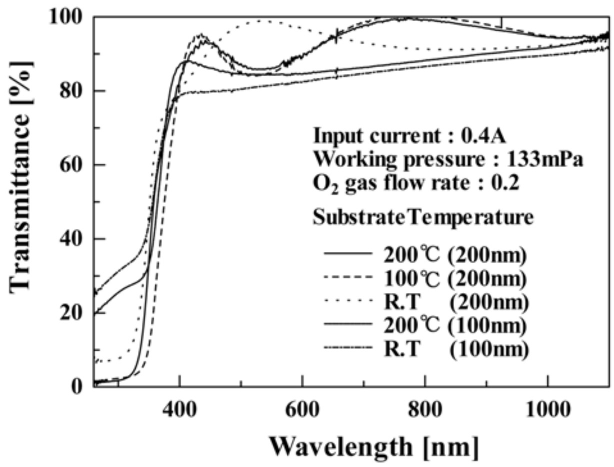

Fig. 3. Transmittance of prepared AZO thin films prepared as a function of substrate temperature.

Figure 3 shows the transmittance of AZO thin film at an input current of 0.4A, a working gas pressure of 133 mPa with substrate temperatures room temperature, 100 °C and 200 °C. With an increase in the substrate temperature, the transmittance of AZO thin films is over 80% in the visible range. Figure 4 shows the surface morphology of AZO thin films prepared at room temperature and 200 °C.

Conclusions

AZO thin films were prepared on glass slide at room temperature, 100 °C and 200 °C using an FTS method. We obtained AZO thin films with a low resistivity 4×10^{-4} Ω·cm at a film thickness of 200 nm and the transmittance of all AZO thin films had similar values (over 80%) regardless of the substrate temperature. Consequently, it was noted that the thickness of an AZO thin film should be at least 200 nm for use as a transmittance electrode of a display device.

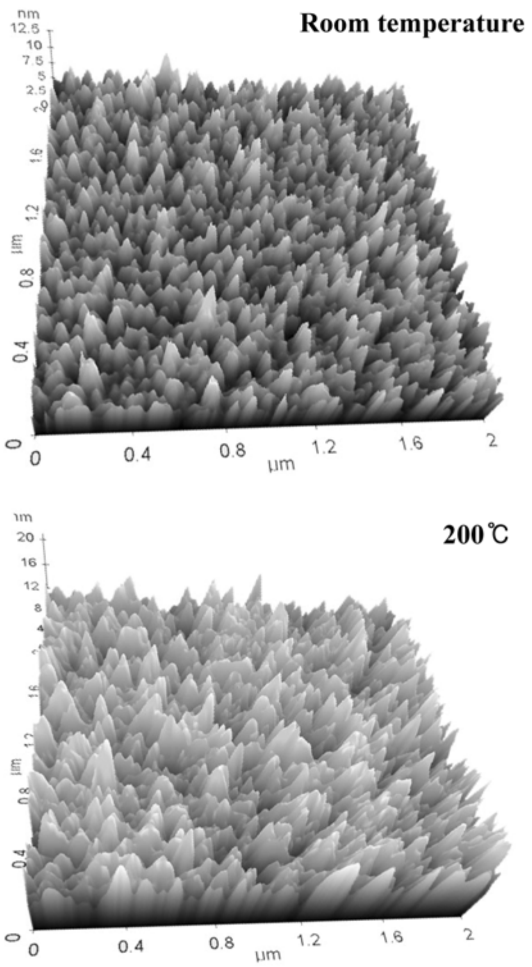

Fig. 4. AFM images of AZO thin films prepared at the substrate temperatures shown.

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