AZO Films Prepared by Facing Target Sputtering System

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Al doped zinc oxide (AZO) films were prepared by Facing Targets Sputtering (FTS) system for TCO applications. The electrical, optical and structural properties of AZO thin films have been investigated with input current, oxygen gas flow ratio and substrate temperature. Deposition was carried out at room temperature and 200 ℃. Working gas pressures were fixed at 1mTorr. As a result, AZO thin film deposited with an optical transmittance over 80 % and a resistivity about $10^{-4}\Omega$•cm.

Keywords : AZO, FTS, TCO

1. INTRODUCTION

Recently, many interests about the Transparent Conductive Oxide (TCO) rise as display begins to get into the spotlight. Therefore, a large number of TCO have been widely studied. Nowadays, Indium tin oxide (ITO) film is the most commonly selected TCO electrode. But, because of their low resistivity, high transparency and low cost, Al doped zinc oxide (AZO) films have been investigated recently as the TCO which was used for the display applications. Many deposition techniques have been used to prepare AZO thin films, such as plasma enhanced chemical vapor deposition (PECVD)[1], pulsed laser deposition (PLD)[2] and sputtering[3,4], etc.. Among these deposition methods, sputtering method is widely used for its tendency to grow highly oriented AZO films and its high productivity[5]. AZO thin film could be deposited with the high transmittance over 80 % and the low resistivity about 10^{-4} Ω•cm as a function of sputtering conditions. Especially, due to the possibility at low- temperature deposition, sputtering method is suitable for OLED applications that require deposition at room temperature. The FTS (Facing Targets Sputtering) system that was used in this study has two targets facing each other and substrate located apart from plasma so it could deposit the AZO thin film with plasma free state. And because of the round screw moving-electrons between arrays two faced targets, we can promote the ionization of working gas; therefore, high-speed deposition is possible at low working gas pressure. Additionally, insert the plasma- arresting magnetic field to the parallel direction of the center axis of both targets, perpendicular magnetic field caused to effective restrain of round screw moving-electrons[6]. In this study, the structural, electrical and the optical properties of the AZO thin film that were prepared by FTS system, with input current, the oxygen gas flow ratio and the substrate temperature have been investigated.

2. EXPERIMENTAL

The FTS system has two targets. One of the targets is a Zn(4N) metal target, and the other is a ZnO:Al ceramic target doped with 2 wt% Al_2O_3. The distance between both targets is 10 cm. Figure 1 shows the schematic diagram of FTS apparatus that is used in this study. Also Fig. 2 shows the shape of plasma when the FTS apparatus discharge. The sputtering conditions for preparing the AZO thin films are given in Table 1.

The AZO films on the glass substrate were prepared as a function of input current 0.1~0.6 A and oxygen gas flow ratio 0.1~0.5(total 10 sccm). The deposition was carried out at room temperature and 200 ℃. The total working gas pressures during the film deposition were kept constant at 1 mTorr.

The structural properties of AZO films were analyzed by X-ray diffractometer (Rigaku) with Cu-kα line, the optical transmittance of AZO films was measured using UV–Vis spectrometer(Hewlett Packard). The film thickness was determined using a surface profile measurement system (Tencor Alpha-step), The film resistivity of AZO thin films was determined from the sheet resistance measurement by a four- point probe technique (Chang-min).

Table 1. Sputtering conditions.

Deposition parameter	Conditions
Targets	Zn(4N) ZnO:Al(Al_2O_3:2 wt%)
Substrate	Slide Glass (corning glass)
Sputtering Gas	Ar, O_2
Background Pressure	$2x10^{-6}$ Torr
Working gas Pressure	1 mTorr
Substrate Temperature	R.T., 200 ℃
Input current	0.1 ~ 0.6 A
Oxygen Gas Flow Rate	0.1~0.5 (O_2/O_2+Ar[sccm])

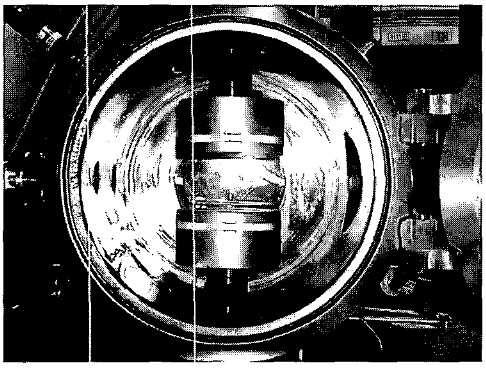

Fig. 1. Schematic diagram of FTS system.

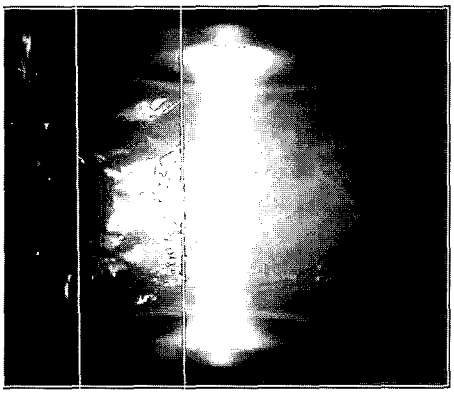

Fig. 2. The shape of discharge plasma.

3. RESULTS AND DISCUSSION

Figure 3 shows the XRD patterns of AZO thin film deposited at fixed input current 0.1 A and constant working gas pressure 1mTorr as a function of O_2 gas flow ratio. All the films deposited at room temperature and 200 ℃ were found to be crystalline and high c-axis oriented with only (002) reflections observed in XRD

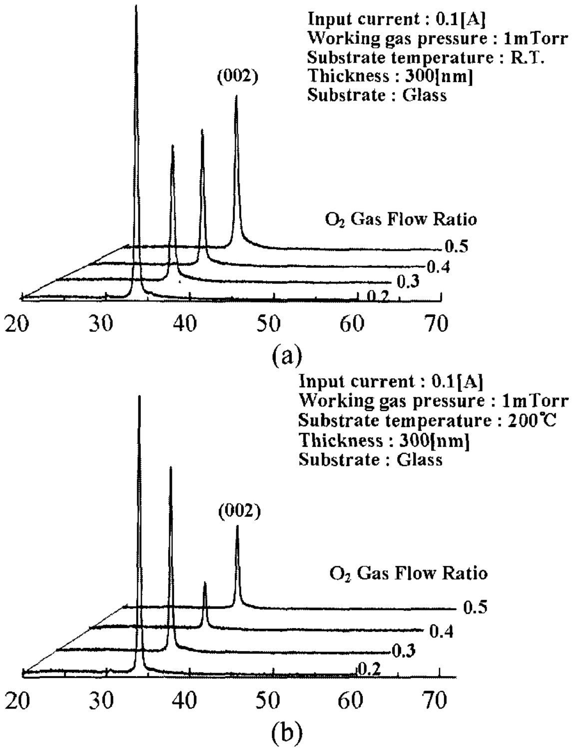

Fig. 3. XRD patterns of AZO films prepared with different O_2 flow ratio (a) room temperature and (b) substrate temperature 200 ℃.

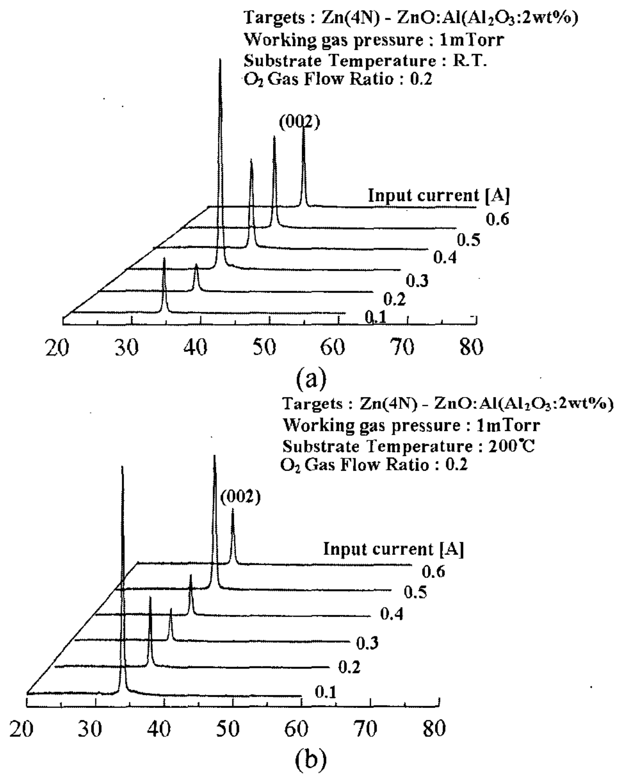

Fig. 4. XRD patterns of AZO films prepared at 0.2 O_2 flow ratio with different input current (a) room temperature and (b) substrate temperature 200 ℃.

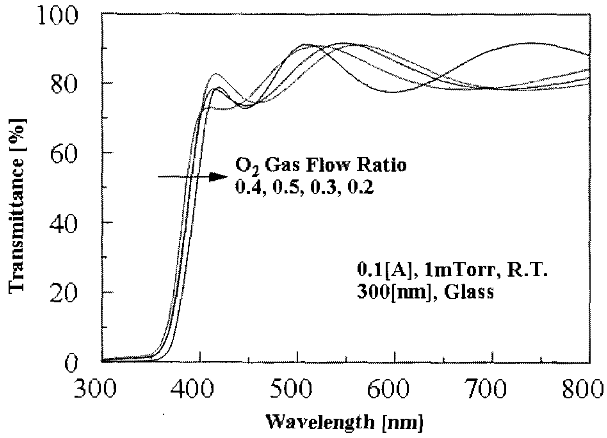

Fig. 5. Wavelength dependent optical transmittance of AZO films prepared with O_2 gas flow ratio at input current 0.1 A and room temperature.

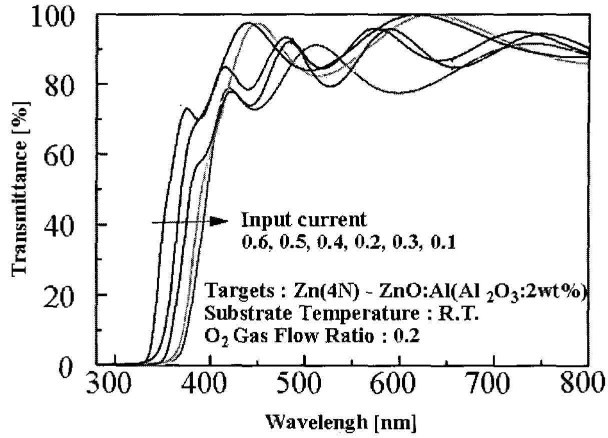

Fig. 7. Wavelength dependent optical transmittance of AZO films prepared with input current at O_2 gas flow ratio 0.2 and room temperature.

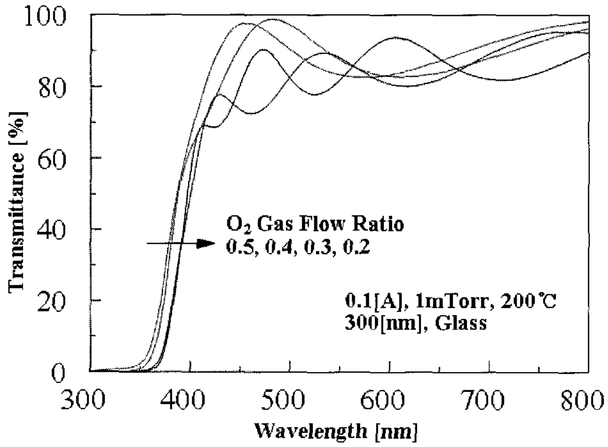

Fig. 6. Wavelength dependent optical transmittance of AZO films prepared with O_2 gas flow ratio at input current 0.1 A and substrate temperature 200 ℃.

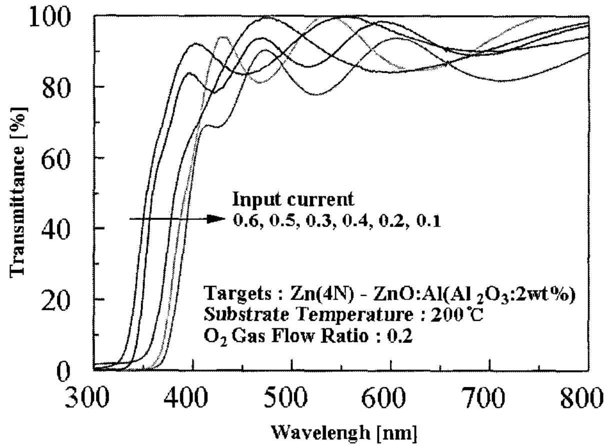

Fig. 8. Wavelength dependent optical transmittance of AZO films prepared with input current at O_2 gas flow ratio 0.2 and substrate temperature 200 ℃.

patterns. The substrate deposition temperature and gas flow ratio were found to have any significant effect on the structure of the AZO films. But we found the strongest (002) peaks at O_2 gas flow ratio 0.2 at both of substrate deposition temperature room and 200 ℃. So we deposited AZO films fixed with O_2 gas flow ratio 0.2 and working gas pressure 1mTorr as a function of input current.

Figure 4 shows the XRD pattern of AZO thin film deposited at O_2 gas flow ratio 0.2 and working gas pressure 1 mTorr as a function of input current. AZO films with a good orientation were prepared at input current 0.3 with room temperature substrate deposition and input current 0.1 with substrate deposition temperature 200 ℃. An orientation of the c-axis representing the peak of the (002) plane exhibits a similar value above input current 0.3 at room temperature deposition.

Therefore, it could be implied that input current has influence on the AZO thin films properties but can not find any dependence of substrate deposition temperature room and 200 ℃.

Figure 5~8 shows the optical transmittance of the AZO thin film at working gas pressure 1 mTorr. The optical transmittances of AZO thin films were measured by UV/VIS spectrometer in the wavelength range between 300 and 800 nm. Transmittance of prepared TCO thin films by FTS is over 80 % and absorption edge is clearly shown in the ultra violet area about 350 nm. The absorption edge shifted to lower energy side by decreasing the O_2 gas flow ratio. This was understood by the Burstein-Moss effect where the Fermi level energy

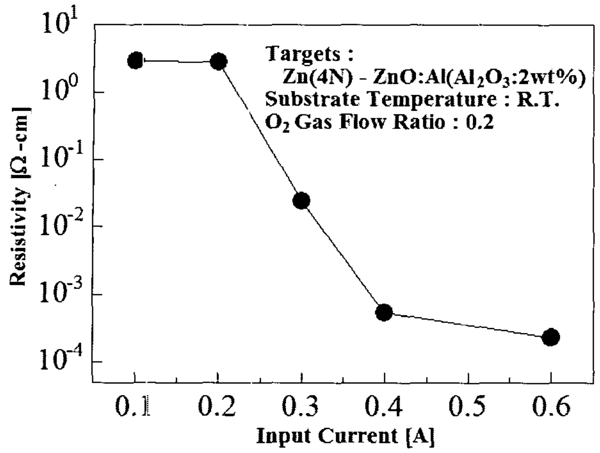

Fig. 9. Resistivity of AZO films as a function of input current at O_2 gas flow ratio 0.2 and room temperature.

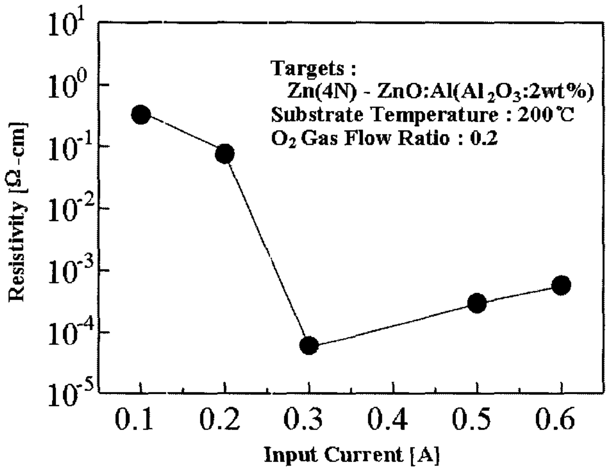

Fig. 10. Resistivity of AZO films as a function of input current at O_2 gas flow ratio 0.2 and substrate temperature 200 ℃.

shifts to the higher energy side with carrier concentration[7]. It could be implied that input current and O_2 gas flow ratio has an influence on the carrier concentration. Additionally, transmittance exhibits substrate temperature independence.

Figure 9, and 10 show the resistivity of AZO thin film at O_2 gas flow ratio 0.2 and working gas pressure 1mTorr as a function of input current. Substrate temperature was R.T. and 200 ℃. Resistivity decreased to 2.3×10^{-4} Ω•cm at substrate temperature R.T. and 1.0×10^{-4} Ω•cm at substrate temperature 200 ℃. The resistivity of AZO thin films increased rapidly at input current below 0.2 A. Moreover, resistivity increased at O_2 gas flow ratio above 0.3. Because the oxygen voids in the films were substituted for oxygen atoms and the additional oxygen atoms in the films effectively function as carrier traps[8].

4. CONCLUSION

We prepared the AZO film on slide glass at room temperature and 200 ℃ using FTS apparatus. As a result, AZO thin film with a good crystal structure was prepared at oxygen gas flow ratio 0.2 and any special dependence of input current is unobserved. Optical transmittance and resistivity of the prepared AZO films remarked over 80 % and about 10^{-4} Ω•cm. It is enough for TCO application device. But resistivity of AZO thin film prepared at room temperature with 0.1A input current was not good properties about 10^{0} Ω•cm. Also, we could obtain a bad result was made at input current 0.1 A and substrate temperature 200 ℃ about 3.32×10^{-1} Ω•cm. Therefore, we have come to know that resistivity of AZO film is influenced by input current and substrate temperature. Additionally, we could observe that transmittance exhibits substrate temperature independence. Also, we could think that the FTS method could prepare the AZO thin film for TCO application with high transmittance and low resistivity at room temperature.

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