

Enhanced Properties of IZO Thin Film Prepared by Nano-Powder Target

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Abstract

Compared to the indium zinc oxide (IZO) film fabricated by micro-powder target, the IZO film with nano-powder target exhibited improved optoelectronic properties of wide band-gap, high transmittance, surface uniformity, and low sheet resistance due to the high film density.

1. Introduction

Transparent conductive oxide(TCO) films have been widely used as transparent electrodes of optoelectronic devices such as a touch screen, flat panel displays(FPDs), and organic solar cells[1-3]. A zinc-doped indium oxide(IZO) film has drawn enormous interest as anodes for several devices because of their high conductivity, transparency over the visible range, and their high work function[4-5]. Moreover, the TCO films including ZnO component are more stable against hydrogen plasma, more abundant, and less expensive in comparison with the conventional tin-doped indium oxide(ITO) film[6]. Recently, the enhanced characteristics and application of the TCO film with nano-powder are reported elsewhere. In order to obtain a low electric resistance and high transparency in the ITO film, generally, it is necessary to set the substrate temperature at 200-300 °C. However, since the ITO film prepared at high temperature has a poor etching property and a very rough surface morphology, they can damage to process and lifetime of the devices. In particular, it is difficult to set the substrate temperature at 200-300 °C and to make an ITO film with a low electric resistance and high transparency when ITO layer was deposited on polymer substrates such as polyethylene terephthalate(PET), polyethylene naphthalate(PEN), polycarbonate(PC) for flexible display. On the other hand, the IZO film deposited at a comparative low temperature has a high transmittance over 90 % in the

visible light range and a low resistivity of $\sim 10^{-4} \Omega\text{-cm}$.

In this work, the electrical, optical, and structural properties of the IZO films deposited with sputtering target of nano- or micro-size powder by using rf-magnetron sputtering system were investigated. A mixed IZO powder with a composition ratio of 78:22 wt.%(In₂O₃:ZnO) with nano- and micro-size power were calcined at 1000 °C in air for two hours and were used as a sputtering target. The IZO films fabricated by nano- and micro-powder target were respectively refer to as IZO(n) and IZO(m), and their film properties were also compared.

2. Experimental

In₂O₃(99.999%) and ZnO(99.999%) nano- and micro-powder with a composition ratio of 78:22 wt.% were respectively mixed for 24 hours by ball mill. The mixed powder were calcined at 1000 °C in the air for two hours and it were used as a sputter targets for the IZO(n) and IZO(m) films. IZO(n) and IZO(m) films were respectively deposited by conventional rf-magnetron sputtering system. The depositions were carried out at room temperature(R.T.) in a pure Ar gas pressure of 2×10^{-3} Torr. Corning 7059 glass was used as substrates. IZO(n) and ITO(m) films were deposited with a parallel distance of 6.5 cm between substrate and target surface, and their film thicknesses were fixed with 180 nm. The deposition rate is constantly maintained as about 18-20 nm/min by rf power of 100 W. For the nano-powder target and micro-powder target, their surface morphologies were analyzed by field emission-scanning electron microscope(FE-SEM, JEOL Co.). The film thickness were measured by using an α -step profiler(VEECO Co.).

3. Results and discussion

Fig. 1 shows the SEM images of the targets prepared using (a) micro-powder and (b) nano-powder. In_2O_3 and ZnO particles in Fig. 1 (a) are certainly distinguished due to difference of their size, and also this target has somewhat loose structure while the nano-powder target in Fig. 1 (b) is difficult to discriminate between In_2O_3 and ZnO particles. Because the two particles in Fig. 1 (b) were combined by repetition of pressure and calcination in process of the target preparation, the target with nano-powder shows considerably the dense structure as compared with the micro-powder target, which can affect the grown characteristics such as the grains, the deposition rate of films, the film density, and the adhesion to substrate.

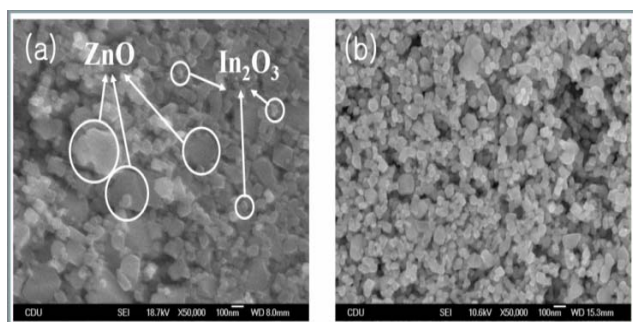


Fig. 1. SEM images of (a) micro-powder target and (b) nano-powder target.

Table 1 shows the sheet resistance of the IZO(m) and IZO(n) films as a function of the deposition thickness. The IZO(n) films deposited by nano-powder target at R.T. showed a lower sheet resistances than the IZO(m) films with micro-powder target. The sheet resistances were rapidly decreased with increasing film thickness with unit surface in all the samples. All IZO films were deposited on the glass substrates with a size of $5 \times 5 \text{ cm}^2$ to measure the sheet resistance of the films.

TABLE 1. Sheet resistance of IZO films as functions of film thickness.

Thicknesses of films	IZO (micro-powder)	IZO (nano-powder)
150 nm	37.5 Ω/\square	32.1 Ω/\square
200 nm	26.3 Ω/\square	25.5 Ω/\square
250 nm	20.3 Ω/\square	17.8 Ω/\square
300 nm	16.2 Ω/\square	14.5 Ω/\square
400 nm	12.8 Ω/\square	11.1 Ω/\square

In general, the sheet resistance (R) is inversely proportional to the film thickness like $R = \rho/t$, where ρ and t are the electrical resistivity and film thickness, respectively. The sheet resistance are calculated by $\rho = 5.1 \times 10^{-4} \Omega\cdot\text{cm}$ for IZO(m) film and $\rho = 4.5 \times 10^{-4} \Omega\cdot\text{cm}$ for IZO(n) film. The measured resistances of films with the thickness of 180 nm well agreed with the calculated values. The low electrical resistivity of IZO(n) film is mainly contributed to the surface uniformity and the improved film density due to the nano-size powder.

4. Summary

The electrical and optical properties of IZO films prepared by nano-powder target showed the enhanced performance with the higher conductivity and the improved structural property compared with the films with micro-powder target. It was related to the improvement of the film density due to the increased refractive index.

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6. References

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