The optical, electrical and structural properties in indium zinc oxide films deposited by LF magnetron sputtering

Eun Lyoung Kim*, Sang Kooun Jung, Myung Chan Kim[1], Yun Su Lee[1], Kap Duk Song[1], Lee Soon Park[2], Sang Ho Sohn and Duck Kyu Park

Department of Physics, Kyungpook National University, Daegu 702-701, Korea
Phone: +82-53-950-5895, E-mail: dkpark@knu.ac.kr
[1]Mobile Display Research Center, Kyungpook National University, Daegu 702-701, Korea
[2]Department of Polymer Science, Kyungpook National University, Daegu 702-701, Korea

Abstract

Using a indium zinc oxide (IZO) alloy target with a ratio of 90:10 in wt%, highly transparent conducting oxide (TCO) thin films are prepared on polyethersulfone (PES) substrates by low-frequency (LF) magnetron sputtering system. These films have amorphous structures with excellent electrical stability, surface uniformity and high optical transmittance. Experiments were carried out as a function of applied voltage. At optimal deposition conditions, thin films of IZO with a sheet resistance of 29 ohm/sq. and an optical transmission of over 82 % in the visible spectrum range were achieved. The IZO thin films fabricated by this method do not require substrate heating during the film preparation or any additional post-deposition annealing treatment.

1. Introduction

Recently, transparent conducting oxide (TCO) films have been widely used for optoelectronic devices such as touch panels, flat panel displays and thin film solar cells. TCO films must have high optical transmittance in the visible region, electrical conductivity, surface uniformity and process compatibility. Indium zinc oxide (IZO) is an important material in the construction of organic light emitting devices (OLEDs) because it combines many technologically interesting properties such as high optical transmittance, good electrical conductivity and very smooth surface morphology. Generally, these films have been deposited by a variety of methods, such as radio frequency (RF) magnetron sputtering, direct current (DC) magnetron sputtering, pulsed laser deposition (PLD) and reactive thermal evaporation (RTE)[1-2]. Low frequency (LF) 60 Hz plasma source has peculiar properties such as non-continuous discharge, relatively high electron temperature, and small bombarding damage. There are few experiment reports on the IZO films by the LF 60 Hz magnetron sputtering. We tried to obtain the high quality IZO films on flexible polyethersulfone (PES) substrate by LF 60 Hz magnetron sputtering.[3]

In this work, we investigate the optical and electrical properties of IZO thin films deposited on PES substrate by the LF 60 Hz magnetron sputtering.

2. Experiments

IZO films were deposited on PES substrate at room temperature by LF 60 Hz magnetron sputtering. The alloy target was In_2O_3:ZnO (90:10 wt %) with a diameter of 3 inch and thickness of 5 mm. The vacuum chamber was evacuated down to pressure 5×10^{-6} torr prior to deposition. The flow rates of argon gas (99.999 %) were kept at a constant value of 30 sccm by a mass flow controller. The discharges were performed under power of 280~320 V.

The sputtering conditions of IZO thin films on PES substrates are summarized in Table. 1.

We analyzed electrical, structural, and optical properties of IZO thin films prepared on PES substrate.[4-5] The sheet resistance of films was measured using 4-point probe (Mitsubishi chemical co., Loresta-GP, MCP-T601) and deposition rate were determined using FE-SEM (Oxford Model, Inca Energy for JSM-6335F) and alpha step (KLA Tencor, ASIQ). The optical transmittance of IZO films were investigated using UV-Visible spectrophotometer (Shimadzu, UV-3150). Mobility and carrier concentration of

IZO thin films were measured using hall effect measurement system(BIO-RAD, HL 5500PC-M).

Table 1. Sputtering conditions of IZO thin films deposited on PES substrate.

Sputtering parameters	Values
LF Power [V]	280 ~ 320
Base pressure [Torr]	5×10^{-6}
Working pressure [mTorr]	2.2
T-S distance [mm]	100
Frequency [Hz]	60
Deposition time [min]	20, 30
Ar flow rate [SCCM]	30
Temperature [℃]	Room Temp.

3. Results and discussion

The thickness value of IZO thin films on PES substrates are summarized in Table. 2.

Table 2. Thickness values of IZO films deposited on PES substrate as applied voltage from 280 V to 320 V and deposition time of 20 minute.

Voltage[V]	Thickness[nm]
280	52.4
290	70.8
300	91.0
310	110.9
320	130.6

Fig. 1 shows the optical transmittance of IZO thin films deposited on PES substrate as a function of applied voltage. The transmittance spectrum of IZO thin films was measured in the wavelength range from 300 to 1300 nm. As shown in Fig. 1, the bare substrate has a transmittance greater than over 90 % most of the visible range, and IZO films also show transmittance of 75~82 % in the range from 400 nm to 700 nm.

Fig. 2 shows the band gap of IZO thin films with sputtering applied voltages. It is well known that optical transmittance has a direct relation with the band gap of IZO thin films.

The optical band gap (E_g) of IZO thin film can be deduced from this graph. E_g is calculated using Cody' relation[6].

$$\alpha^2 = (hv - E_g)$$

Where α is an optical absorption coefficient and hv is a photon energy. Absorption coefficients of the films in different wavelengths have been calculated from transmittance and reflection data. Extrpolations of the straight regions of plot to α=0 give E_g.

It was observed that the direct band gap of the IZO thin films increased from 3.46 eV to 3.53 eV with an increase in applied voltage from 300 V to 320 V.

Fig. 3 shows the mobility and carrier concentration of IZO thin films deposited on PES substrate as a function of applied voltage by LF 60 Hz magnetron sputtering at room temperature. The increase in carrier concentration may have been due to an increase of the number of oxygen vacancies in the film, which may be coincidence with the fact that the optical transmittance (visible region) decreases in the IZO thin films deposited at applied voltage from 290 V to 310 V.

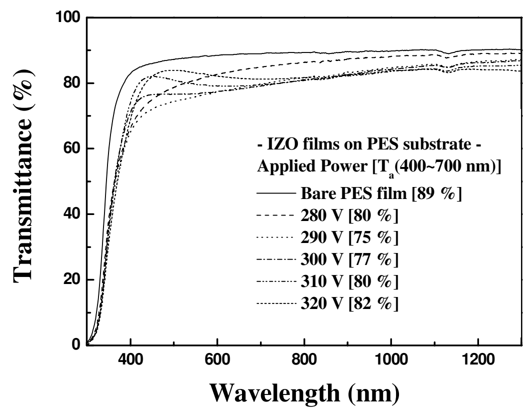


Figure 1. The optical transmittance of IZO films deposited at several applied voltage on PES substrate.

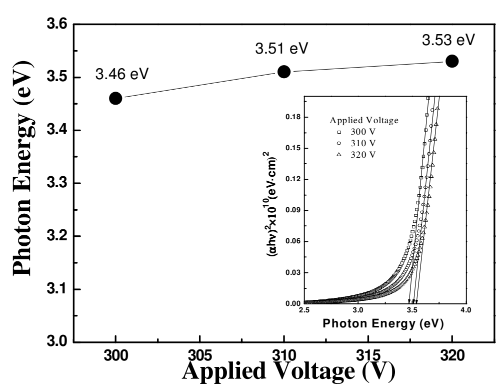


Figure 2. The band gap of IZO films as a function of the applied voltage.

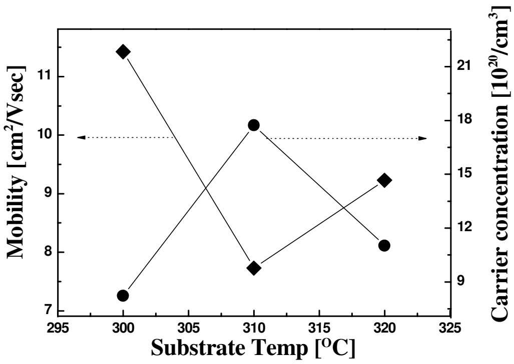


Figure 3. The mobility and carrier concentration of IZO thin films deposited on PES substrate.

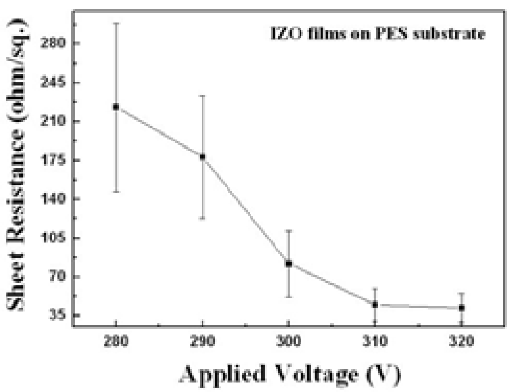
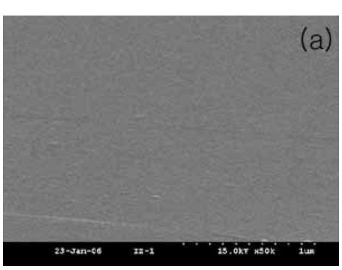


Figure 4. The sheet resistance of IZO thin films deposited on PES substrate.

Fig. 4 shows the sheet resistance of IZO thin films deposited on PES substrate as a function of applied voltage from 280 V to 320 V. With increasing applied voltage, photon energy is increased. This sheet resistance showed the lowest value of about 29 ohm/square.



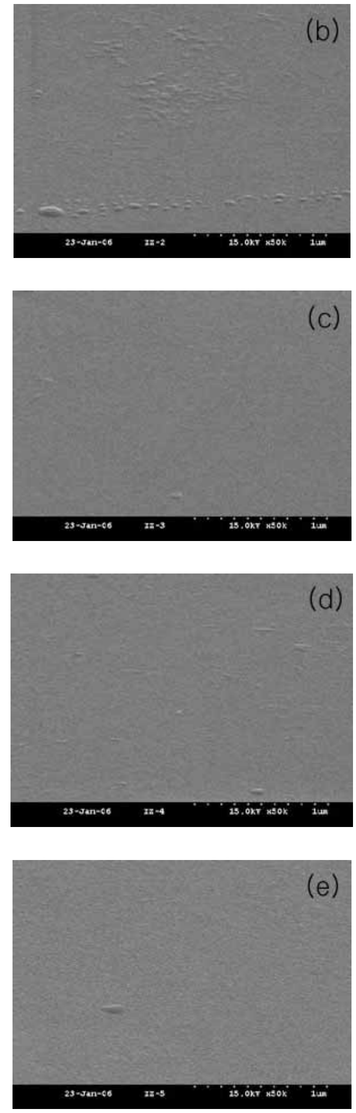


Figure 5. The FE-SEM images of IZO thin films deposited on PES substrate; (a) 280 V, (b) 290 V, (c) 300 V, (d) 310 V, (e) 320 V

Fig. 5 shows the FE-SEM images of the IZO thin film having the different applied voltage. With increasing the applied voltage of the IZO thin films on PES substrate, the thickness increased. The IZO thin films were deposited in the this method, it showed very smooth surface image.

4. Conclusions

We tried to find out a good way to grow high quality IZO thin films without any post treatments.

For the purpose of this, we used by low frequency 60 Hz magnetron sputtering system to deposit IZO films at room temperature and investigated the optical, electrical and structural properties of the PES films. The IZO films were deposited in this method, it showed very smooth surface morphology, high transmittance and low sheet resistance. The sheet resistance of IZO thin film at 320 V is 29 ohm/square. It suggest that the low frequency plasma processing can be a candidate for a useful method of fabricating high quality IZO thin films on the other polymer substrates at the room temperature.

We must develop materials of electrode in organic light emitting device (OLED). We will develop OLED to have better properties after those apply data to get in this research at new device.

5. Acknowledgements

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6. References

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