Characteristics of the indium tin oxide film grown on PES and PET substrates by a low-frequency magnetron sputtering method

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Abstract

In this study, we introduce indium tin oxide (ITO) thin films grown by using a low-frequency magnetron sputtering method (LFMSM). Characteristics of the ITO thin films deposited on polyethersulfone (PES) and polyethylene terephthalate (PET) substrates are investigated. Experiments were carried out as a function of deposition time. ITO thin films on polymer substrates revealed amorphous structure. The optical, the electrical and structural properties of the films on PES substrate are better than those on PET substrates.

1. Introduction

Indium tin oxide (ITO) films have been the topic of many studies due to their high visible transparency and electrical conduction, which make them useful in various applications such as solar sells, liquid crystal displays, optoelectronics, organic light emitting diode, etc[1-2].

Generally, ITO films are deposited by the radio frequency magnetron sputtering, chemical vapor deposition, spray pyrolysis, pulsed laser deposition, and electron beam method.

Low frequency (60 Hz) plasma source has peculiar properties such as non-continuous discharge, relatively high electron temperature, and small bombarding damage[3-4]. There are few experiment reports on the ITO films by the low frequency (60 Hz) magnetron sputtering films (LFMSM) up to now. We tried to obtain the high quality ITO films on polymer substrates by LFMSM .

In this work, we investigate the optical and electrical properties of ITO thin films deposited on polythersulfone (PES) and polyethylene terephthalate (PET) substrates by LFMSM.

2. Experiments

ITO films were deposited on PES and PET substrates at room temperature by LFMSM.

The alloy target was In_2O_3:SnO_2 (90:10 wt %) with a diameter of 3 inch and thickness of 6 mm. The vacuum chamber was evacuated down to pressure 6×10^{-6} torr prior to deposition.

The flow rates of argon gas (99.999 %) were kept at a constant value of 25 sccm by a mass flow controller. The discharges were performed under constant power of 280 V. The target was pre-sputtered in an argon atmosphere of 2.6 mtorr in order to remove the surface oxide layer.

The sputtering conditions of ITO thin films on PES and PET substrates are summarized in Table. 1.

We analyzed electrical, structural, and optical properties of ITO thin films prepared on polymer substrates[5].

The sheet resistance of films was measured using 4-point probe (Mitsubishi, MCP-T360) and deposition rate was determined using FE-SEM (Oxford Model, Inca Energy for JSM-6335F).

The structural morphology and optical transmittance of ITO films were investigated using AFM (Digital Instrument, Nanoscope IIIa) and UV-Visible spectrophotometer (Shimadzu, UV-1601PC), respectively.

The crystal structure and phase of the ITO films were measured using X-ray diffraction with a CuKa source under an applied voltage 40 kV and a current of 30 mA (Mx Labo). The Hall effect was measured using Hall effect measurement system (EGK, HEM-2000).

Table 1. The sputtering conditions of ITO thin films deposited on PES and PET substrates.

Sputtering parameters	Values
LF Power [V]	280
Base pressure [Torr]	8×10^{-6}
Working pressure [mTorr]	2.6
T-S distance [mm]	100
Frequency [Hz]	60
Deposition time [min]	15 35
Ar flow rate [SCCM]	25

Table 2. The roughness values of ITO films deposited deposition time of 35 min. on PES and PET substrates.

Roughness parameters	Values
PES	
Ra [nm]	0.88
Rms [nm]	2.11
Rp-v [nm]	5.63
PET	
Ra [nm]	0.83
Rms [nm]	1.59
Rp-v [nm]	10.75

3. Results and discussion

Figure 1 shows the XRD pattern of ITO films deposited on PES and PET substrates. ITO thin films on both polymer substrates have amorphous structures.

Table 2 shows the roughness value of ITO films deposited on PES and PET substrates. The average roughness Ra values of the ITO films prepared on PES and PET are 0.88 nm and 0.83 nm. Rms and Rp-v in the table are the root-mean-square value of the surface roughness profile from the centerline, and peak-to-valley roughness, respectively[6].

Figure 2 shows the sheet resistance of ITO thin films grown by discharging under 280 V on the polymer substrates. The films on PES substrate show lower sheet resistances than those on PET substrates. All films have relatively high resistance values, but this problem may be solved by increasing the power and the deposition time[7].

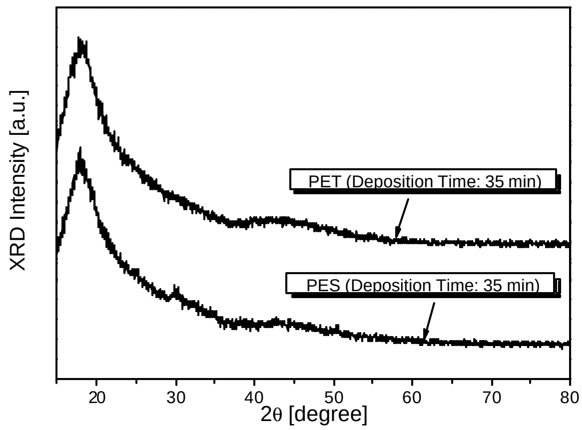


Figure 1. The XRD patterns of ITO films deposited at deposition time of 35 min. on PES and PET substrates.

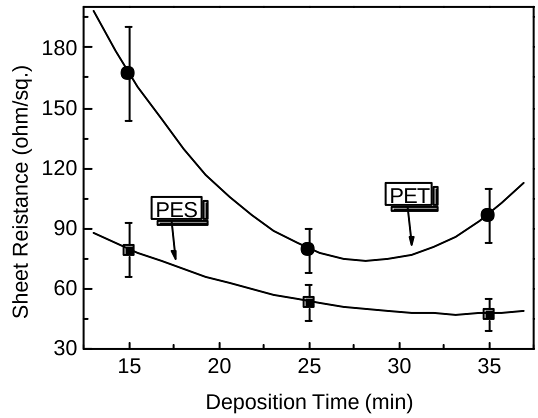


Figure 2. The sheet resistances of ITO thin films as a function of the deposition time.

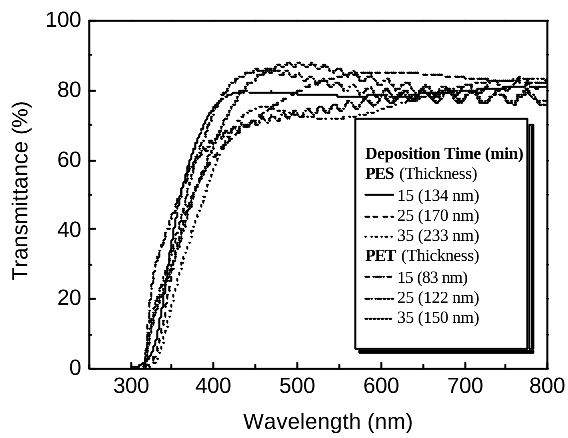
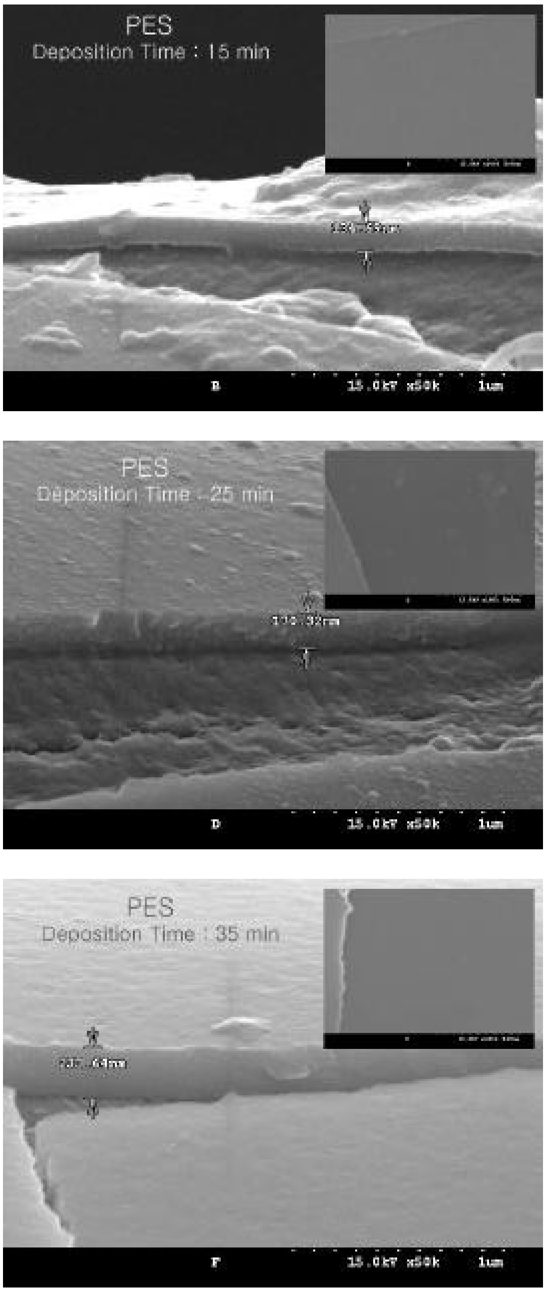


Figure 3. The transmittances of ITO films deposited at several deposition time on PES and PET substrates.

Figure 3 shows the transmittances of the ITO films prepared by changing deposition time as 15, 25 and 35 minutes. The transmittances of all films exceed 80 %, implying high optical transparency in the visible region[8].

Figure 4 shows the FE-SEM images of the polymer films having the different deposition time. With increasing the deposition time of the ITO thin films on polymer substrate, the thickness increased.



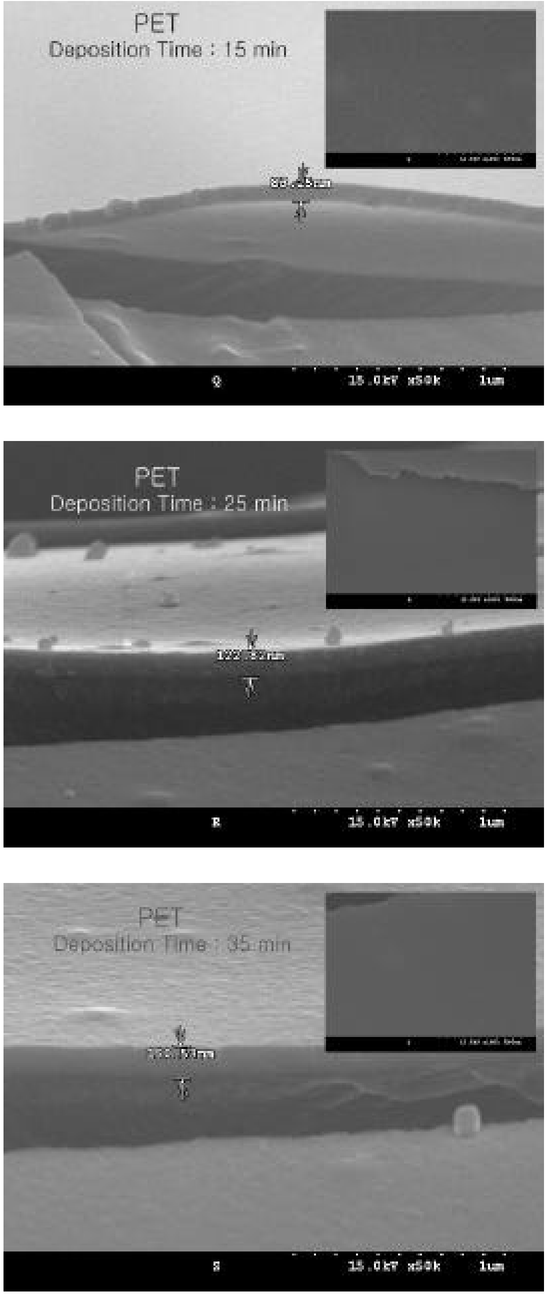


Figure 4. The FE-SEM images of ITO thin films prepared at a different deposition time on PES and PET substrates.

Figure 5 shows the Hall mobility and carrier density of ITO films prepared at a different deposition time on PES and PET substrates. The carrier density values of our ITO films at a deposition time of 35 minutes on PES and PET show similar values to the earlier data of 2.42×10^{20} /cm^3 and 1.27×10^{20} /cm^3[9].

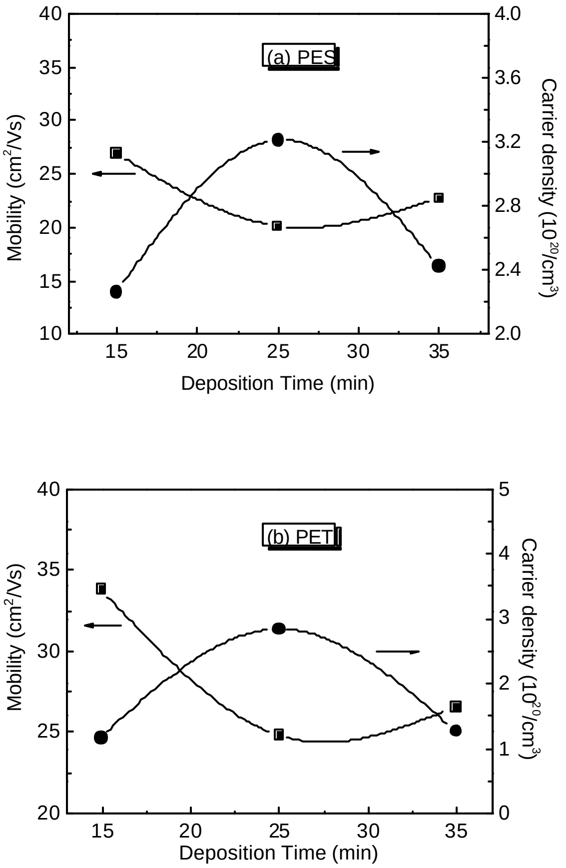


Figure 5. The Hall mobility and carrier density of ITO thin films prepared at a different deposition time on (a) PES and (b) PET substrates.

4. Conclusions

We tried to find out a good way to grow high quality ITO thin films without any post-treatments. For the purpose of this, we used by LFMSM to deposit ITO films at room temperature and investigated the optical, electrical and structural properties of the polymer films. The ITO films grown in this method showed very smooth surface morphology, high transmittance (<80%) and good electrical conductance. This method is not including the post-treatment such as an annealing and mechanical polishing. The optical, the electrical and structural properties of the films on PES substrate are better than those on PET substrates.

We suggest that the low frequency plasma processing can be a candidate for a useful method of fabricating high quality ITO thin films on the polymer substrates at the room temperature.

5. Acknowledgements

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