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Characteristics of ITO Thin Films for Organic Light Emitting Diode by using a Low-Frequency Magnetron Sputtering Method

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Characteristics of ITO Thin Films for Organic Light Emitting Diode by Using a Low-Frequency Magnetron Sputtering Method

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In this study, we have tried the growth of indium tin oxide (ITO) thin films by using low-frequency magnetron sputtering method (LFMSM). Characteristics of ITO thin films deposited on polyethersulfone (PES) and polyetyleneterephthalate (PET) substrates are investigated. Experiments were carried out as a function of deposition time. With increasing the deposition time of the ITO thin films on PES substrate, the sheet resistance is decreased. ITO thin films on polymer substrates were amorphous structure.

Keywords: indium tin oxide; low-frequency magnetron sputtering method; optical transmittance; roughness; sheet resistance; thin film

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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 optoelectronics, solar sells, liquid crystal displays, 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 sample damage [3–4]. This source made to use by magnetron sputtering system adaptively in an experiment. This is no experiment report by low frequency (60 Hz) magnetron sputtering method (LFMSM) up to now. We tried to deposit them by LFMSM to obtain the high quality polymer films.

In this work, we investigate the optical and electrical properties of ITO thin films deposited on polyethersulfone (PES) and polyetyleneterephthalate (PET) substrates.

EXPERIMENTAL

ITO films were deposited on PES and PET substrates at room temperature by LFMSM. The sputtering system was evacuated using a turbo molecular pump. 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 controlled by a mass flow controller. The discharges were generated at constant power of 280 V. At first the target was pre-sputtered

TABLE 1 The Sputtering Conditions of ITO Thin Films

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

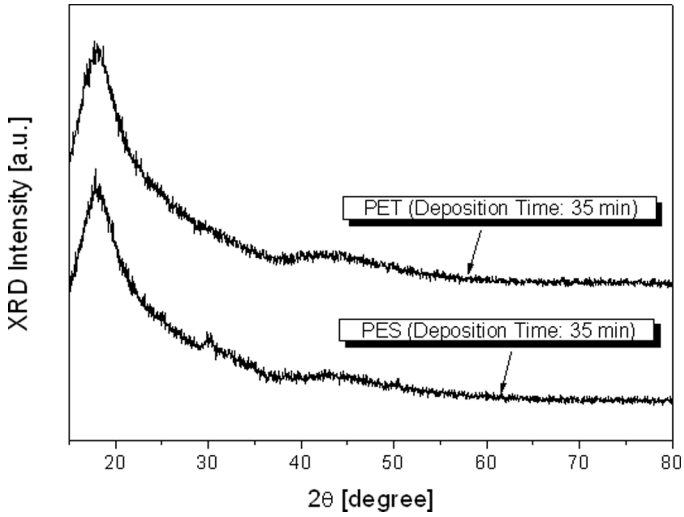

FIGURE 1 The XRD patterns of ITO films deposited at deposition time of 35 minute on PES and PET substrates.

in an argon atmosphere of 2.6 mtorr in order to remove the surface oxide layer. Then the deposition started.

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 on polymer substrate [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

TABLE 2 The Roughness Values of ITO Films Deposited Deposition Time of 35 minute on PES and PET Substrates

Roughness parameters	Ranges
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

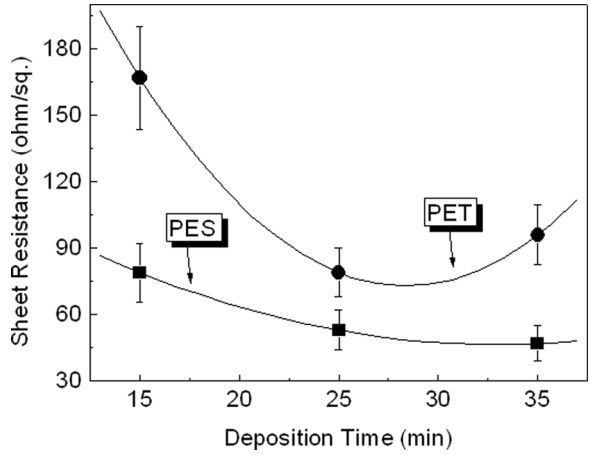

FIGURE 2 The sheet resistances of ITO thin films as a function of the deposition time.

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 (Mx Labo).

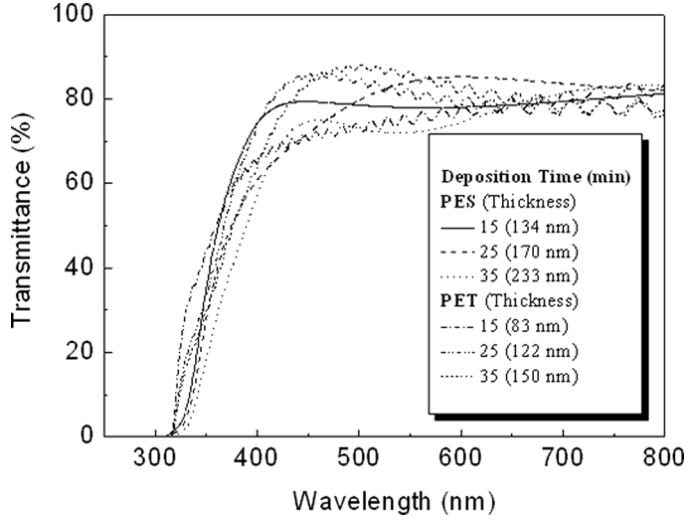

FIGURE 3 The transmittances of ITO films deposited at a different deposition time on PES and PET substrates.

RESULTS AND DISCUSSION

Figure 1 shows the XRD pattern of ITO films deposited on PES and PET substrates. ITO thin films on polymer substrates are amorphous structure.

Table 2 shows the roughness value of ITO films deposited on PES and PET substrates. As the deposition time of ITO thin films on polymer substrates increases, the surface roughness slightly increases [6]. The corresponding Ra values of the ITO films prepared on PES

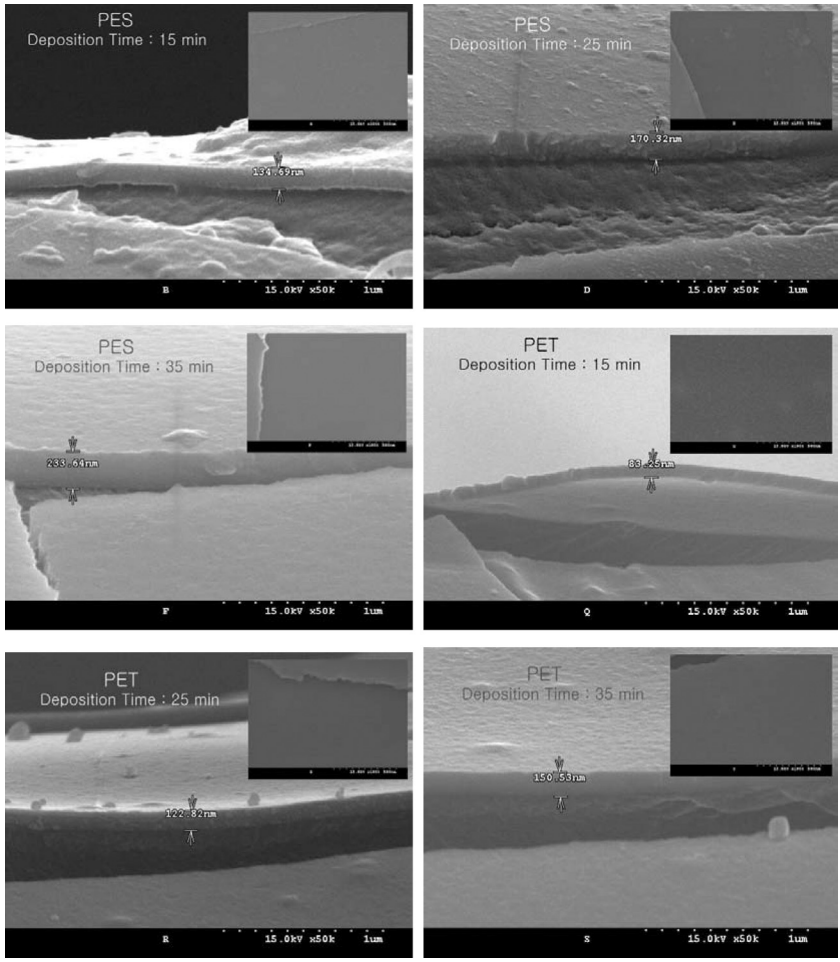

FIGURE 4 The FE-SEM images of ITO thin films prepared at a different deposition time on PES and PET substrates.

and PET are 0.88 nm and 0.83 nm. The definition of Rms is the root-mean-square value of the surface roughness profile from the center-line, and peak-to-valley roughness (Rp-v) is the vertical distance between the highest and lowest points.

Figure 2 shows the sheet resistance of ITO thin films grown by using 280 V with various polymer substrates. They have relatively

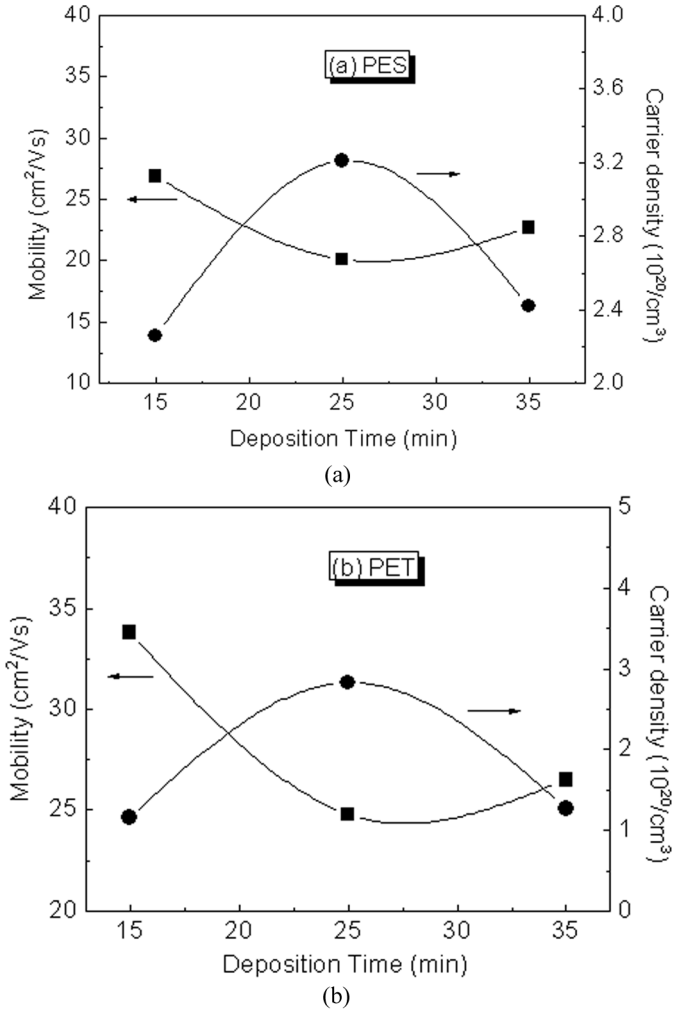

FIGURE 5 The hall mobility and carrier density of ITO thin films prepared at a different deposition time on (a) PES and (b) PET substrates.

high resistance value, but this problem can be solved by increasing the power and the deposition time [7].

Figure 3 shows the transmittances of the ITO films prepared with deposition time of 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 is increased.

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 ITO films deposited by LFMSM at deposition time of 35 minute on PES and PET are $2.42 \times 10^{20}/\text{cm}^3$ and $1.27 \times 10^{20}/\text{cm}^3$ [9].

CONCLUSIONS

We tried to find out a good method 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 were 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. Compared with the results the ITO films deposited at different polymer substrates, the optical, the electrical and structural properties of the films on PES substrate were better.

The experimental results showed that the properties of the ITO thin films for OLED by using a low-frequency magnetron sputtering could provide us with good characteristics such as surface morphology, transmittance, and electrical conduction.

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