# Indium tin oxide films grown on polymer substrate by a low-frequency magnetron sputtering method

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## Abstract

*In this study, we have grown indium tin oxide (ITO) thin films by using a low-frequency (60~300 Hz) magnetron sputtering method and investigated characteristics of ITO thin films deposited on polyethersulfone substrates. The experimental results show that the films have good qualities in surface morphology, transmittance, and electrical conduction.*

## 1. Introduction

Because of electrically conductive and optically transparent characteristics, indium tin oxide thin films are widely used as an electrode in optoelectronics device, electroluminescent device, liquid crystal display, photovoltaic device, energy-efficient device, and so on [1-3]. Generally, ITO films have been deposited by the high frequency sputtering or direct current magnetron sputtering. We have tried to deposit them by a low-frequency (LF) method to obtain the high quality films, based on the fact that the low-frequency plasma has peculiar properties such as non-continuous discharge, relatively high electron temperature, and small sample damage[4].

This study will report on ITO thin films prepared by a LF magnetron sputtering method and their properties.

## 2. Experiments

ITO films were deposited on polyethersulfone (PES) substrate at room temperature by low-frequency (60~300Hz) magnetron sputtering method. The schematic diagram of experimental setup for a LF magnetron sputtering system was shown in Fig. 1. A sintered $In_2O_3$ target containing 10 % wt $SnO_2$ was used as the source material. The Ar plasma was generated by very low-frequency (60~300 Hz) power source.

The sputtering conditions of ITO thin films are summarized in Table. 1. Type A and B denote the thin films grown at different deposition condition as seen in Table 1.

We analyzed electrical, structural, and optical properties of ITO thin films. The sheet resistance of films was measured using 4-point probe (Mitsubishi, MCP-T360) and deposition rate was determined using alpha-step (Veeco, Dektak 3) and SEM (Hitachi S-4200). 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.

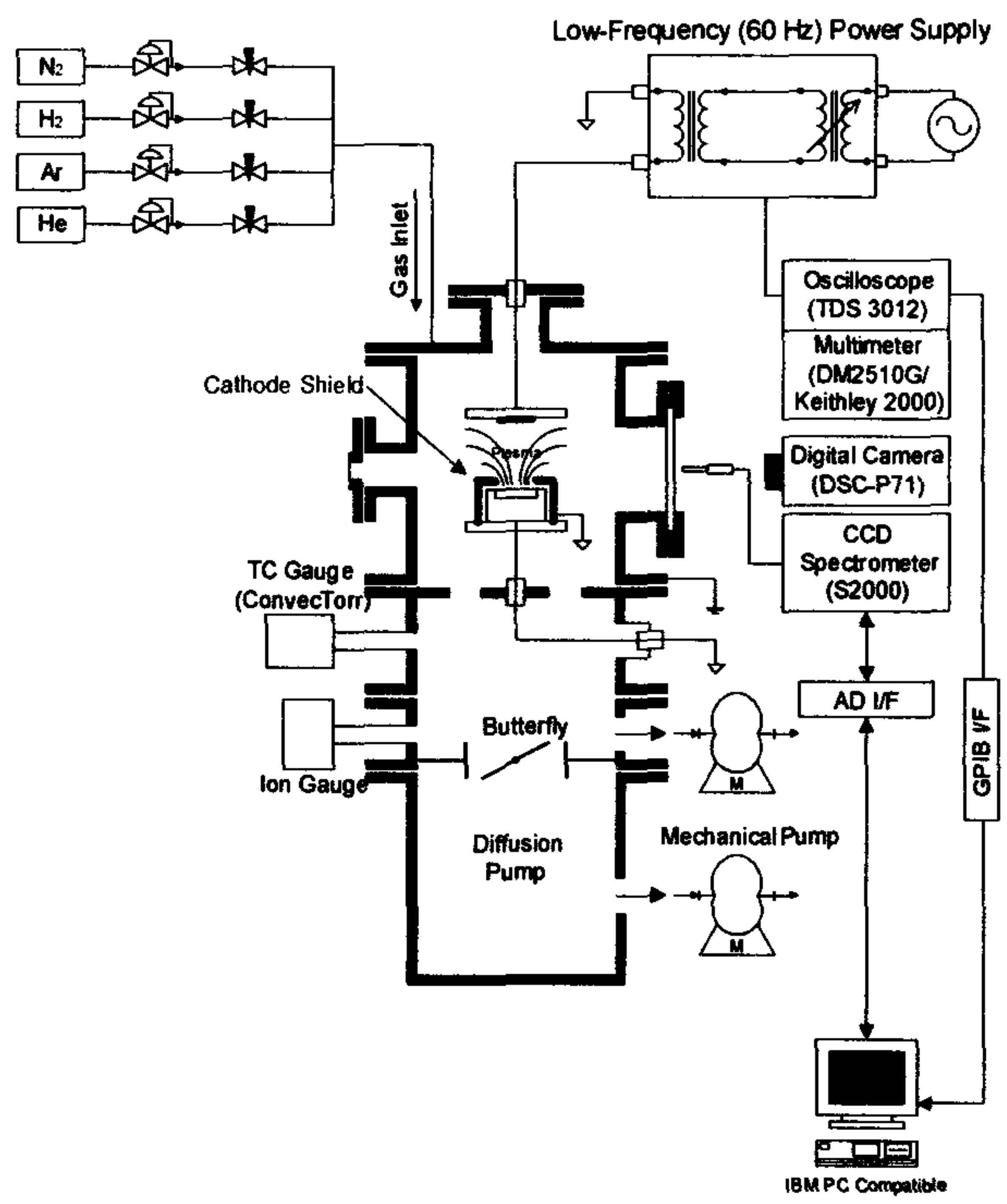


**Figure 1. LF magnetron sputtering system.**

**Table 1. The sputtering conditions of ITO thin films.**

| Sputtering parameters | Ranges |
|---|---|
| | **(Type A)** |
| LF Power [V] | 340 |
| Base pressure [Torr] | $5 \times 10^{-5}$ |
| Working pressure [mTorr] | 36 |
| T-S distance [mm] | 46 |
| Frequency [Hz] | 60 |
| Deposition time [min] | 10~30 |
| | **(Type B)** |
| LF Power [V] | 280, 300 |
| Base pressure [Torr] | $5 \times 10^{-5}$ |
| Working pressure [mTorr] | 6 |
| T-S distance [mm] | 55 |
| Frequency [Hz] | 100~300 |
| Deposition time [min] | 5~15 |

## 3. Results and discussion

Fig. 2 shows the XRD pattern of ITO films deposited on PES substrates. Mainly observed XRD peaks in the ITO films are (222) and (400) preferred orientation, representing that the structure of the ITO films is a body-centered cubic structure.

Fig. 3 shows AFM images of ITO thin films as a function of film thickness. From the figures, the surface morphologies of the films are known to be very smooth. The value of roughness (Rms) is about 2 nm. This can be explained by the fact that the LF-plasma is low-rate processing and has energetic species[5].

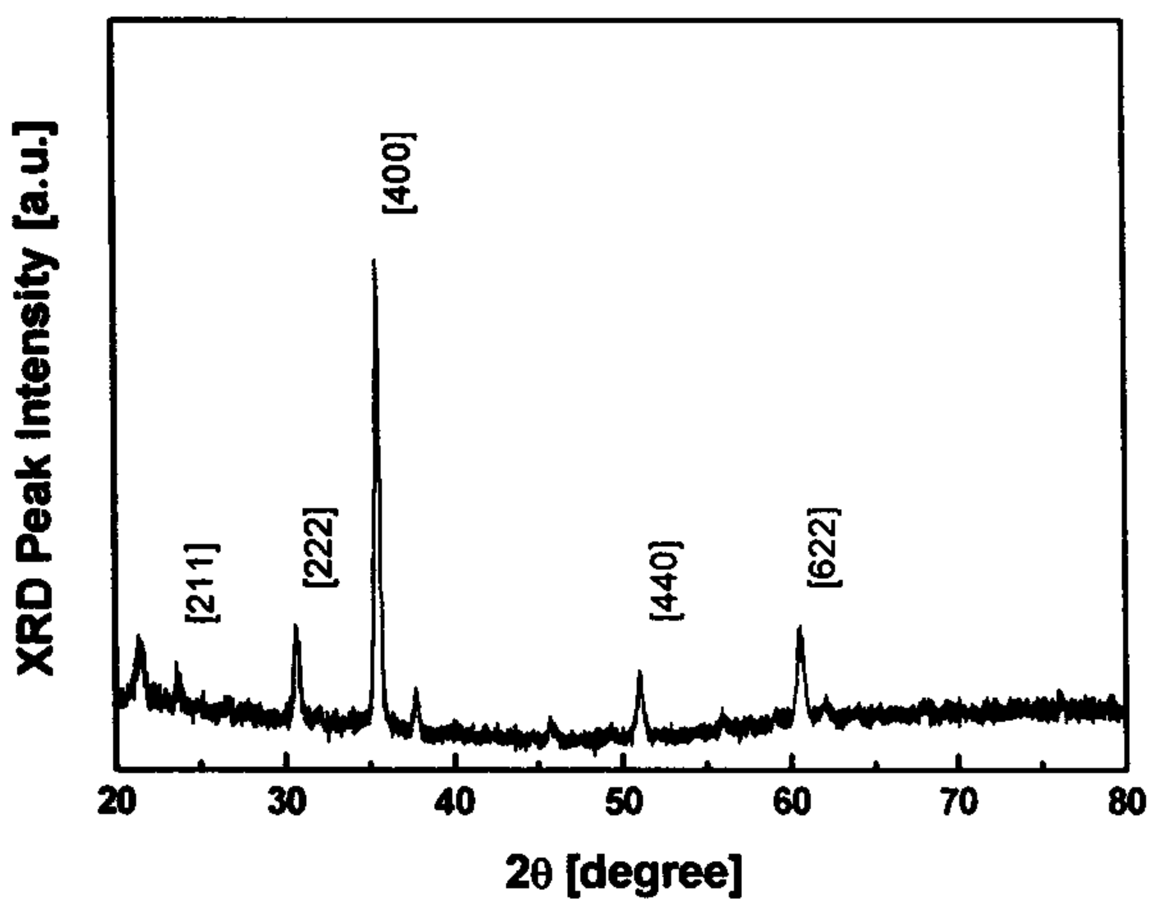


**Figure 2. XRD pattern of ITO films deposited at room temperature on PES substrate (Type A).**

Fig. 4 shows the sheet resistance as a function of film-thickness. The sheet resistance decreases with an increase of the film thickness. The value of the resistance is ranged from 700 to 400 Ω/sq.

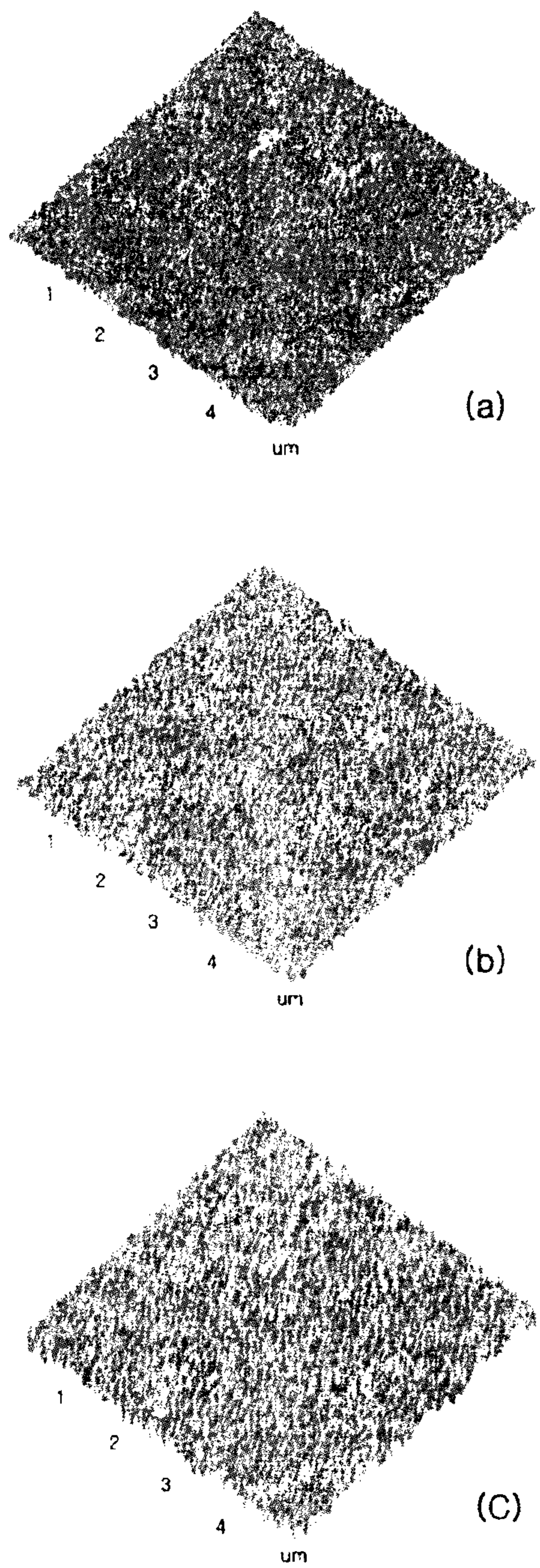


**Figure 3. AFM images of ITO thin films with thickness of 77.7 nm(a), 212.6 nm(b), and 245.8 nm(c) (Type A).**

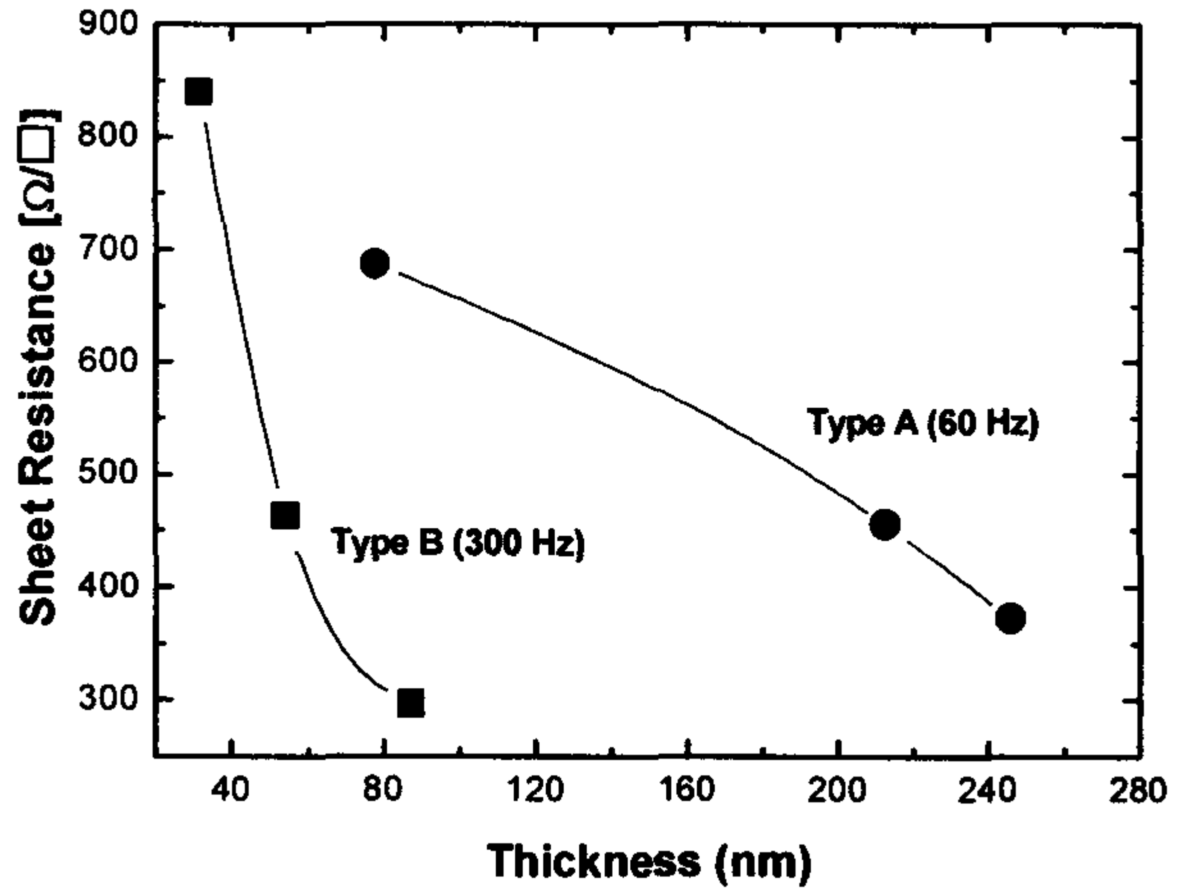


**Figure 4. The sheet resistances of ITO thin films as a function of the film thickness.**

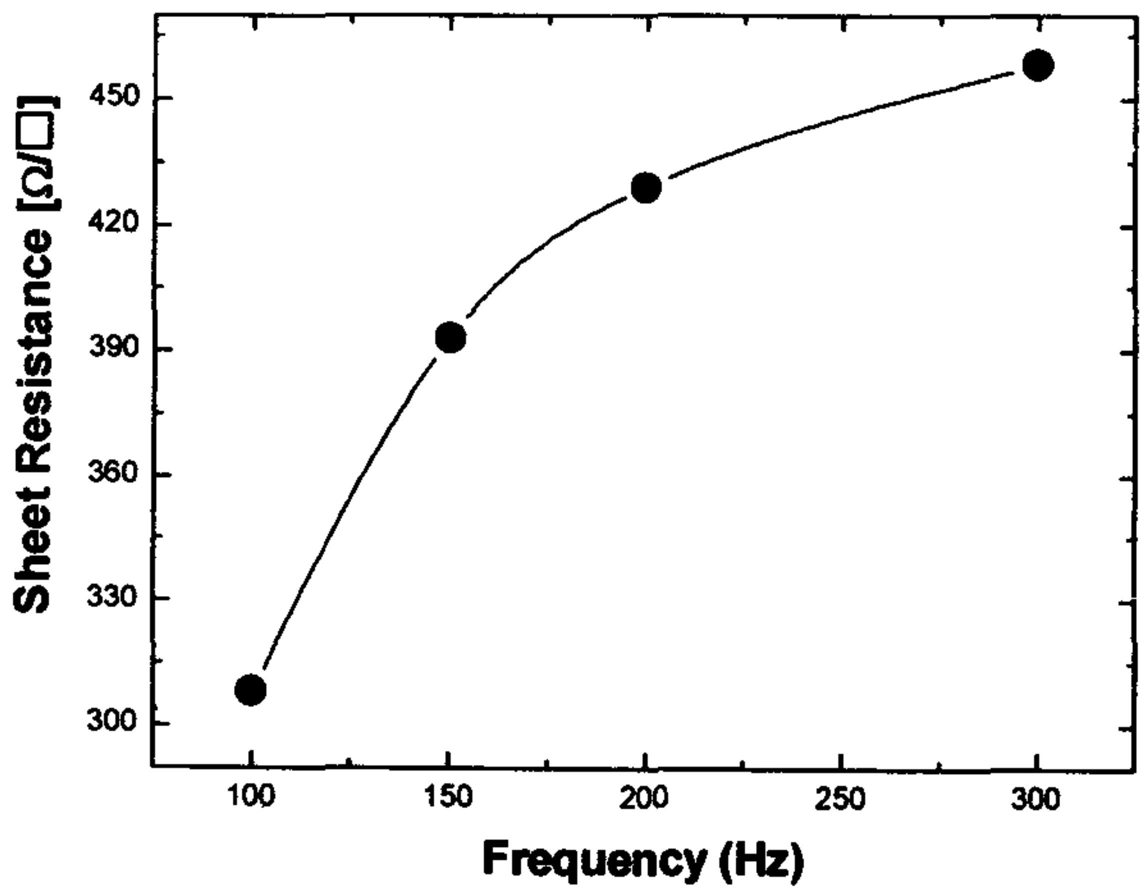


**Figure 5. The sheet resistances of ITO thin films as a function of the frequency(Type B).**

Fig. 5 shows the sheet resistance of type B films grown by using 280 V with various frequency. They have relatively high resistance value, but this problem can be solved by increasing the power and the deposition time.

Fig. 6 shows the transmittances of the ITO films prepared with deposition time of 10, 20 and 30 minutes. The transmittances of all films exceed 82 %, implying high optical transparency in the visible region.

Fig. 7 shows the transmittance of the type B films having the different deposition time, before and after heat treatment. The results indicate that the heat treatment gives an increase of the transmittance by 5~10 %.

Fig. 8 shows $(\alpha h\nu)^2$ as a function of the incident photon energy. The optical bandgap $E_g$ of ITO thin film can be deduced from this graph. $E_g$ is calculated using Cody's relation[6].

$$\alpha^2 = ( h\nu - E_g )$$

where $\alpha$ is an optical absorption coefficient and $h\nu$ is a photon energy.

The calculated band gaps of ITO films are shown in Fig. 9. The value of optical band gap is about 3.7 eV. This value is similar to ones reported in other studies[7].

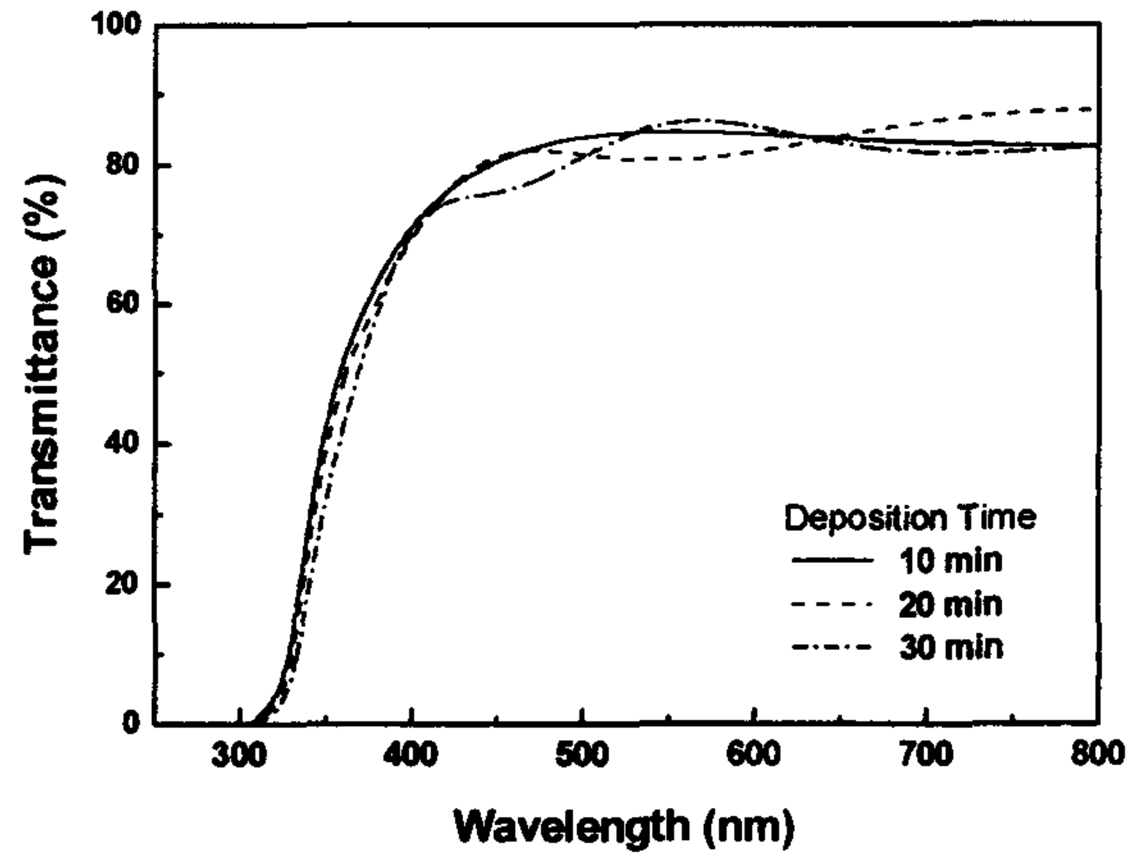


**Figure 6. The transmittances of ITO thin films prepared at several deposition time(Type A).**

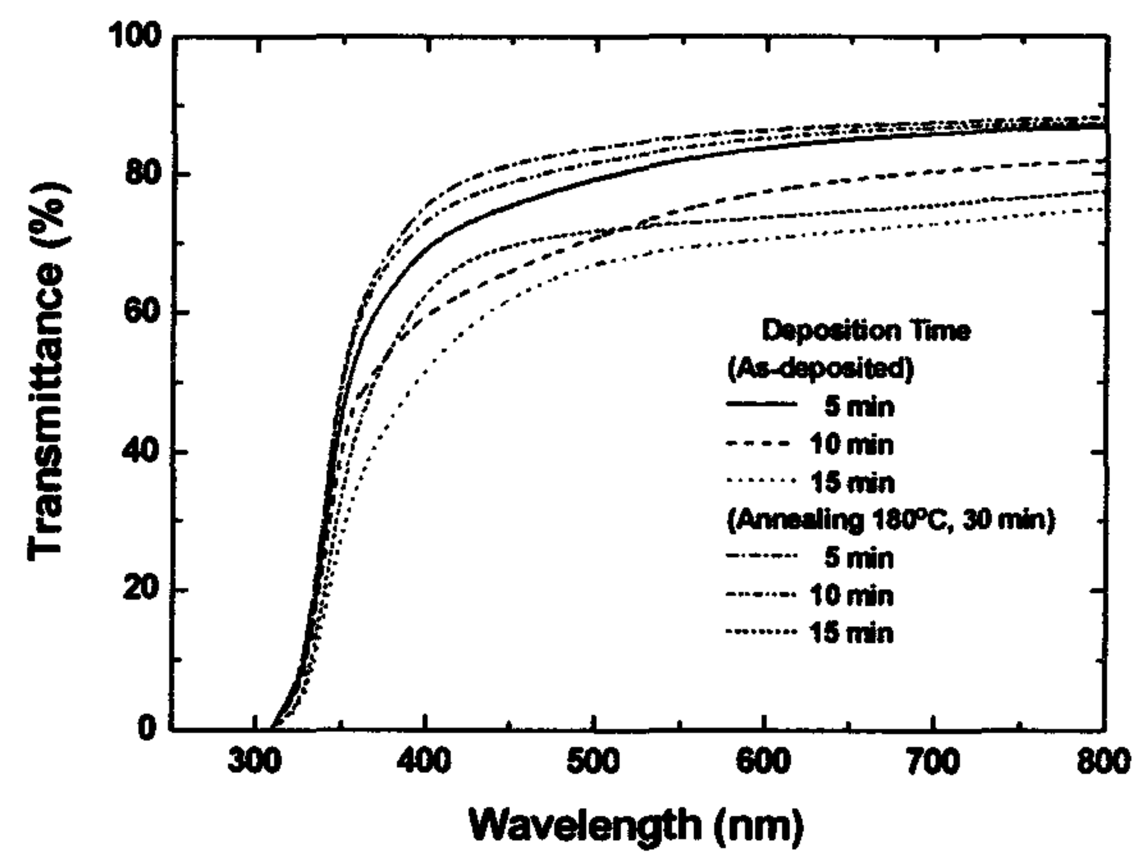


**Figure 7. The heat treatment transmittances of ITO thin films prepared by low-frequency (300 Hz, Type B).**

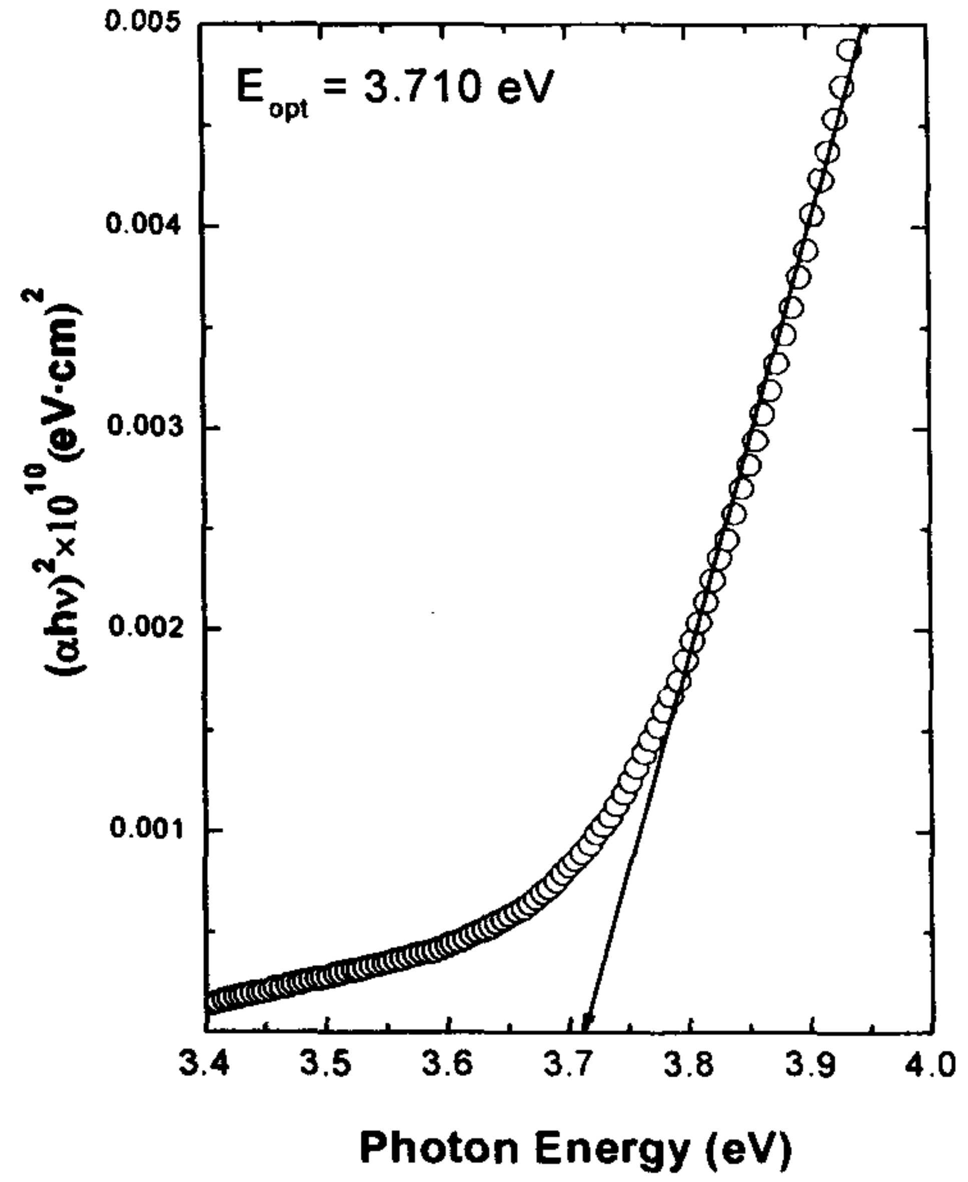


**Figure 8. $(\alpha h\nu)^2$ as a function of incident photon energy(Type A).**

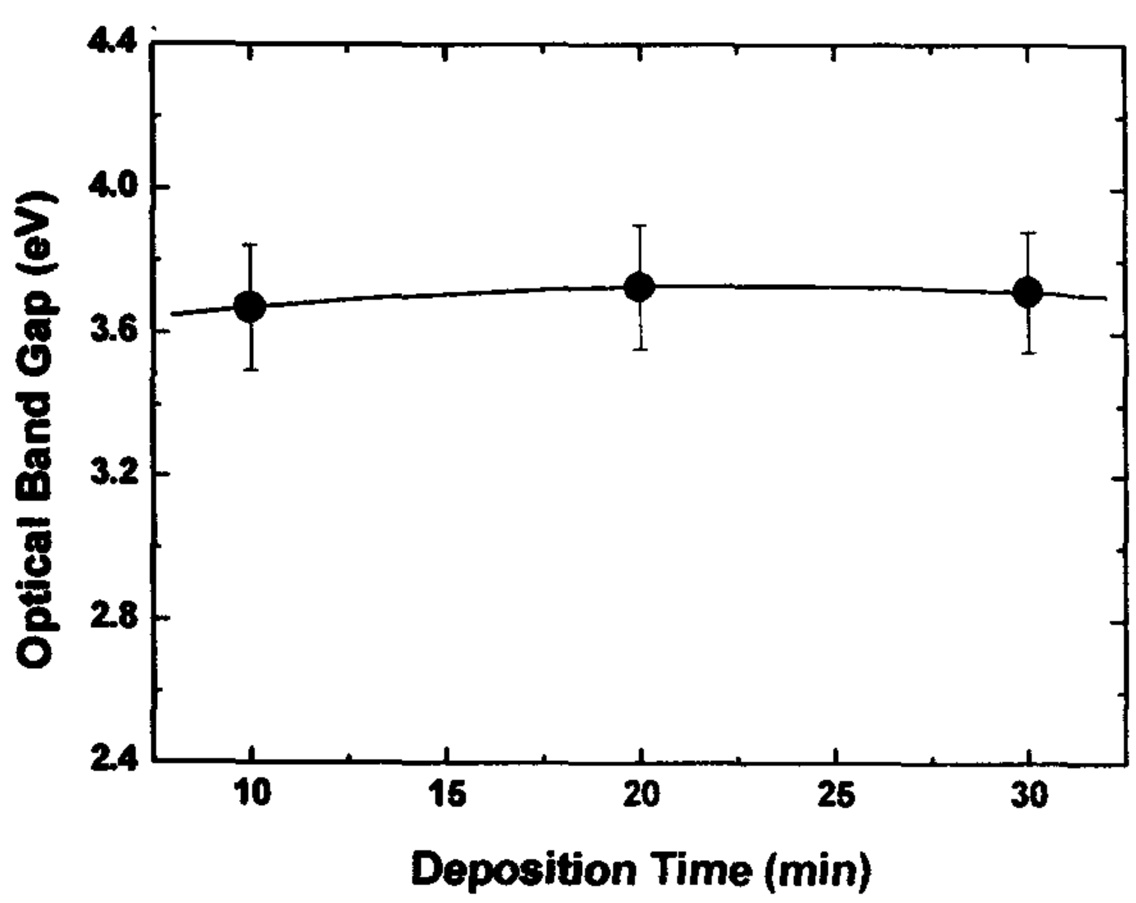


**Figure 9. Optical band gaps of ITO thin films as a function of deposition time(Type A).**

## 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 the low-frequency method to deposit ITO films at room temperature and investigated the optical, electrical and structural properties of the films. The ITO films were grown in this method showed very smooth surface morphology, high transmittance (<85%) and good electrical conductance. This method is not including the post-treatment such as an annealing and mechanical polishing.

The post-treatment is not our object for obtaining better film characteristics even if the heat treatment yields an increase in the transmittance of type B films.

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

## 5. Acknowledgements

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## 6. References

[1] L.J.Meng *et al*, J. Lumin, 39, 11 (1987).

[2] J.R.Bellingham *et al*, Appl. Phys. Lett, 58, 2506 (1991).

[3] A.Valentini *et al*, J. Appl. Phys, 73, 1143 (1993).

[4] H.T.Kim *et al*, ADMD, 7, 61 (2003).

[5] H.T.Kim and D.K.Park, J. Korean phys. Soc, 42, S916 (2003).

[6] C.Rotaru *et al*, Phys. Stat. Sol, 171, 365 (1999).

[7] K.Zhang *et al*, Thin Solid Film, 376, 255 (2000).