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# The preparation of indium tin oxide films as a function of oxygen gas flow rate by a facing target sputtering system

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**Indium tin oxide (ITO) thin films for use as cathode electrodes in top-emitting organic light-emitting diodes (TOLEDs) were prepared by a facing targets sputtering (FTS) system under different sputtering conditions, which were varying oxygen gas flow rate, input current at room temperature on glass slide substrates. Then a function of sputtering conditions, the electrical and optical properties of prepared ITO thin films was evaluated. In the results, with increasing oxygen gas flow rate 0.1 sccm to 0.7 sccm, resistivities of ITO thin films increased with a decrease in carrier concentration, with an oxygen gas flow rate above 0.3 sccm. Transmittance of prepared ITO thin films was improved at increasing oxygen gas flow rate 0.1 sccm to 0.7 sccm. And transmittance of all of the prepared ITO thin films was over 80%. We could obtain resistivity $6.19\times10^{-4}$ Ω·cm, carrier mobility 22.9 $cm^2/Vs$, carrier concentration $4.41\times10^{20}$ $cm^{-3}$ and transmittance over 80% of ITO thin film prepared at working pressure 133 mPa, input current 0.4A without any substrate heating.**

**Key words: TOLED, Facing Target sputtering, ITO, TCO.**

## Introduction

Many type of transparent conducting oxide (TCO) thin films such as indium oxide, tin oxide, and zinc oxide have been widely used as transparent conductors for numerous opto-electronic applications [1, 2]. In particular, tin-doped indium oxide (ITO) thin films have been extensively studied for application in flat panel display devices because ITO thin films have a low resistivity, high transmittance, and chemical stability. Presently, ITO thin films on flexible substrates or organic layers which are used in organic light emitting diodes (OLED) [3, 4] are in strong demand. There is a requirement that the preparation of ITO thin films is done at a low substrate temperature and with a suppression of highly energetic particles such as secondary electrons or negative oxygen ions, in order to prepare ITO thin films on organic layers with little damage by a sputtering method. With many conventional sputtering methods [5, 6] it has proved difficult to obtain ITO thin films on organic layers with a low damage of organic layers because high energy particles, such as energetic atoms and ions impinge on the organic layer and transfer their energy to the organic layer or growing film. These interactions between negative oxygen ions and the organic layer may cause substantial damage to the substrate and result in degraded device performance [7]. Additionally, conventional sputtering methods need substrate heating to obtain low resistivity ITO thin films.

Therefore, in this study, in order to reduce the damage to the organic layer by bombardment with negative oxygen ions, ITO thin film were prepared as a function of oxygen gas flow rate by a facing target sputtering (FTS) system [8, 9].

## Experimental

ITO thin films were prepared by an FTS system which consists of two targets and the substrate located as shown in Fig. 1. Thus the energetic charged particles are restricted by the magnetic force within the plasma. Therefore the FTS system contributes to suppress bombardment by high energy particles of the substrate. The result is that FTS system can deposit high quality thin films at a low temperature.

ITO thin films were prepared on Corning-glass substrates without any substrate heating in an argon (Ar) and oxygen ($O_2$) mixture gas. The thicknesses of the ITO thin films were fixed at 100 nm. More detail concerning the sputtering conditions are shown in Table 1.

The electrical characteristics of the ITO thin films prepared were measured by Hall effect measurements (EGK). Also the thickness and transmittance of thin films were estimated by α-step (Tencor) and UV-VIS spectrometer (HP).

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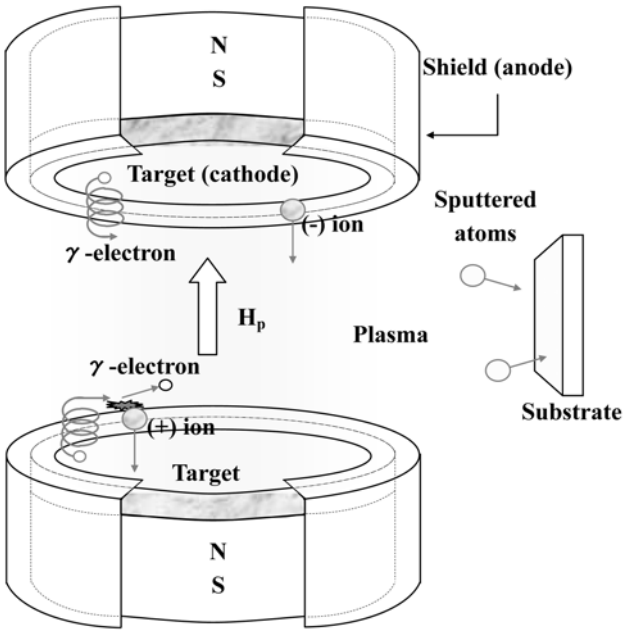


**Fig. 1.** Schematics diagram of the FTS system.

**Table 1.** Sputtering conditions

| Parameters | Conditions |
|---|---|
| Targets | ITO (99.99%) |
| Substrate | Corning-glass |
| $D_{T-T}$ | 70 mm |
| $D_{T-S}$ | 100 mm |
| oxygen gas flow rate | 0.1~1.0 sccm |
| Base pressure | 0.267 mPa |
| Working pressure | 133 mPa |
| Input current | 0.2, 0.4, 0.6, 0.8A |

## Results and Discussion

Figure 2 shows the deposition rate of ITO thin films prepared by the FTS system. The deposition rate increased with increasing input current. However, the deposition rate was independence of the oxygen gas flow rate. It is considered that the oxygen gas flow rate was too small to increase the deposition rate.

Figure 3 shows electrical properties of ITO thin films prepared as a function of varying the oxygen gas flow rate and input current at 133 mPa. The resistivity of ITO thin films decreased rapidly between an oxygen gas flow rate of 0 and 0.2 or 0.3 sccm. When above 0.4 sccm, the resistivity of ITO thin films increased because the oxygen vacancies in the ITO thin films were substituted by oxygen atoms and the additional oxygen atoms in the ITO thin films function as carrier traps. Also we know that the region of lowest resistivity (dotted line) shifts to the right with an increase in the input current. Thus we could obtain the lowest resistivity $3.5\times10^{-4}$ Ω·cm, mobility 22.9 $cm^2/V\cdot s$, carrier

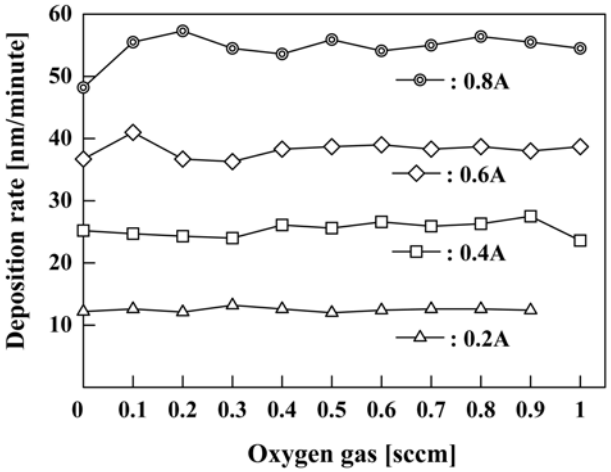


**Fig. 2.** Deposition rate of prepared ITO thin films with input current at 133 mPa.

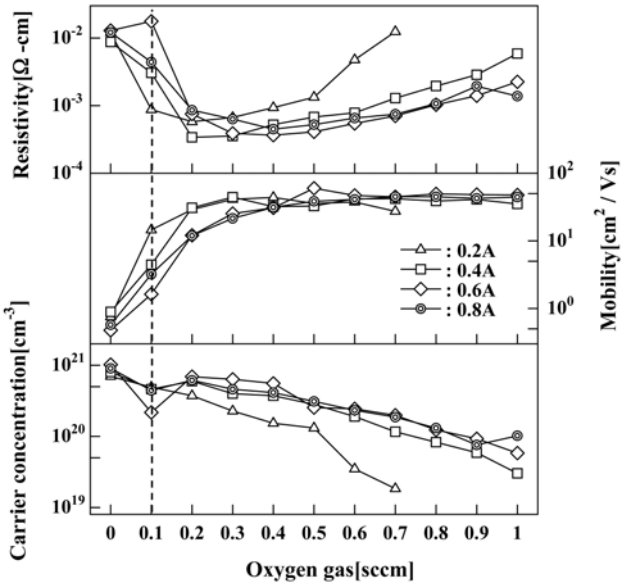


**Fig. 3.** Discharge properties of prepared ITO thin films with oxygen gas flow and input current.

concentration $4.41\times10^{20}$ $cm^3$ for an ITO thin film prepared at an oxygen gas flow rate of 0.2 sccm, input current 0.4A without any substrate heating.

Figure 4 shows the transmittance of ITO thin films prepared with varying input currents and oxygen gas flow rate. With an increase of the oxygen gas flow rate, the transmittance of ITO thin film was improved. The average transmittance in the visible range was above 80%. However, when the oxygen gas flow rate was 0 and 0.1sccm, the transmittance of ITO thin films was below 70%. The X-ray diffraction patterns of ITO thin films were measured. However, no crystalline peaks from ITO thin films were seen. This means that the ITO thin films prepared were amorphous because the ITO thin film thickness was not enough for crystallization [10].

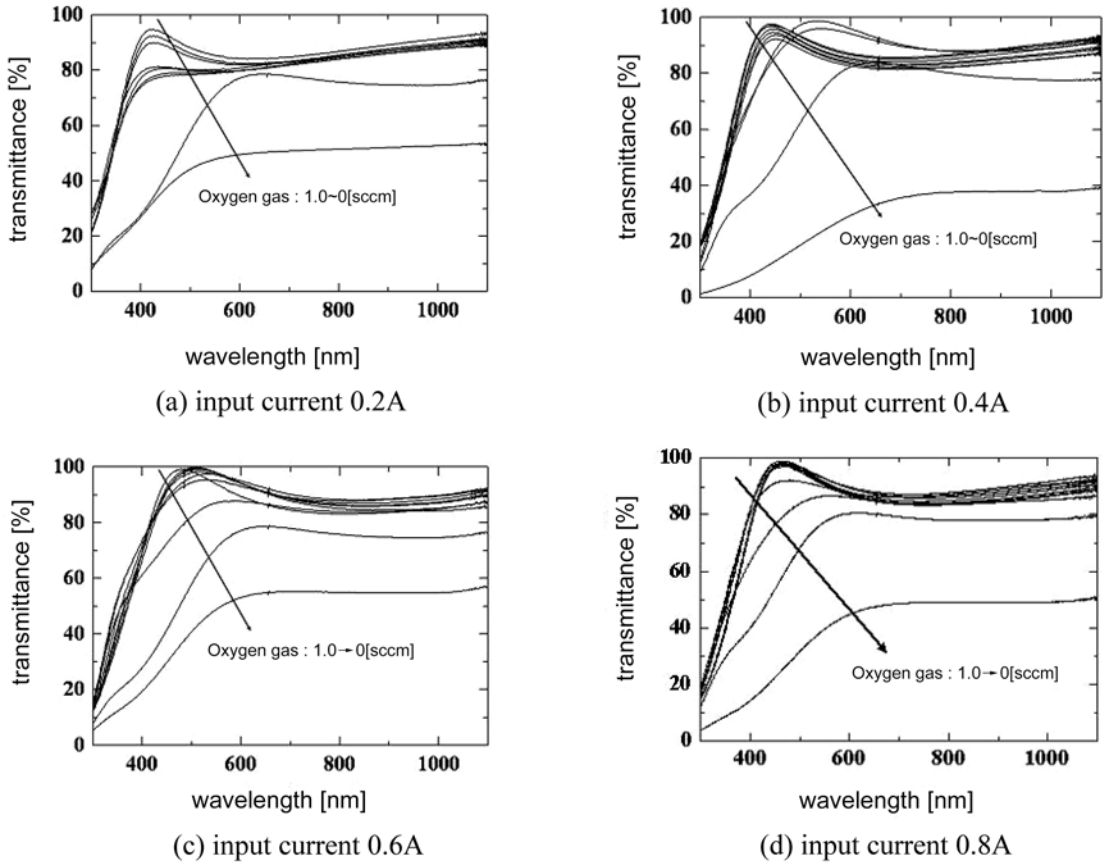


**Fig. 4.** Transmittance of prepared ITO thin films with oxygen gas flow and input current.

## Conclusions

ITO thin films were prepared on glass slide with input current (0.2~0.8A) and oxygen gas flow rate between 0 to 1.0 sccm by an FTS method. In conclusion, we obtained ITO thin films with the good electrical properties (resistivity $3.5\times10^{-4}$ Ω·cm, mobility 22.9 $cm^2$/Vs, carrier concentration $4.41\times10^{20}$ $cm^3$) and a transmittance above 80% when the oxygen gas flow rate was 0.2 sccm. The ITO thin film electrical properties could be controlled by the oxygen gas flow rate. With an increase of the oxygen gas flow (0 to 0.2 sccm), the resistivity of ITO thin films decreased rapidly and the transmittance was increased. However, the resistivity of ITO thin films increased with an increase of the oxygen gas flow rate above 0.3 sccm. These results indicate that ITO thin films with good electrical and optical properties can be prepared at a low oxygen gas flow rate (0.2 sccm).

Therefore, we conclude that the FTS system is a suitable sputtering method for preparing ITO thin films for OLED devices which requires a room temperature process with low damage of the organic layer due to bombardment by negative oxygen ions.

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