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Characteristics of ITO Thin Films for the Plasma Display Panel Prepared by a MF Dual Magnetron Sputtering in the Oxygen Atmosphere

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Tin-doped Indium Oxide (ITO) thin films for plasma display panels (PDP) were deposited on KCC KM65-2 PDP glass substrates by a medium frequency (MF) dual magnetron sputtering (DMS). During growing films, the oxygen and argon ratios were varied from 0% to 2.67%. We investigated the film structure, the surface morphology, the electro-optical characteristics and film thickness by X-ray diffraction (XRD), four point probes, spectrophotometer and ellipsometer, respectively. In electrical and physical characteristics with peak transmittance of over 90% at $470 \sim 480\,nm$*, sheet resistance of under* $20\,\Omega/sq$ *and film thickness of* $1100 \pm 50 \mathring{A}$*, available to PDP without any post-treatments.*

Keywords: medium frequency (MF) dual magnetron sputtering (DMS); plasma display panel (PDP); the oxygen and argon ratios; tin-doped indium oxide (ITO)

INTRODUCTION

Recently, PDP is a promising type of flat panel display now commonly used for large TV display(typically above 37″). Many tiny cells located between two panels of glass hold an inert mixture of noble gases (Ne and Xe). The gas in the cells is electrically turned into a plasma which excites phosphors to emit light.

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Because ITO thin films have unique properties of low resistivity and high transparency, they are formed on a front glass substrate and play roles of sustaining the electric discharge and passing the visible lights emitted from the phosphors in a PDP [1–3]. Today, we need ITO thin films for PDP with low resistivity, high transmittance in a visible range and high peak transmittance to decrease PDP discharge voltages. Moreover, it is needed to improve optical properties, especially in short wavelength ranges for the purpose of increasing the transmittance of the weak blue emission of PDP.

In this study, ITO thin films were deposited by a medium frequency (MF) in-line dual magnetron sputtering (DMS) system under the different oxygen and argon ratios and their properties were investigated.

EXPERIMENTAL

ITO thin films for PDP were deposited on KCC KM65-2 PDP glass heated over 250°C, using a MF DMS deposition system. The schematic illustration and diagram of MF DMS deposition systems is shown in Figure 1. The target used In-Sn alloyed target (In_2O_3:SnO_2 = 90:10 wt%). Base pressure was pumped below 5.0×10^{-5} hpa by turbo molecular pumps. ITO films were deposited in the working pressure ranges of $2.5\times10^{-3}\sim2.7\times10^{-3}$ hpa. Sputtering power density and discharge voltage maintained 9.5 W/cm^2 and 460 ~ 470 V, respectively. During the film growth, the substrates temperature was fixed at 250°C and the ratios of discharge gases composed of oxygen and argon were varied from 0% to 2.67% in order to modify the properties of ITO

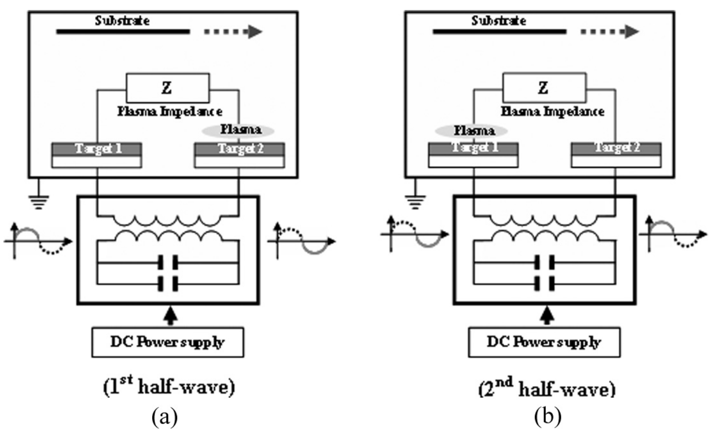

FIGURE 1 The schematic illustration of MF DMS deposition systems.

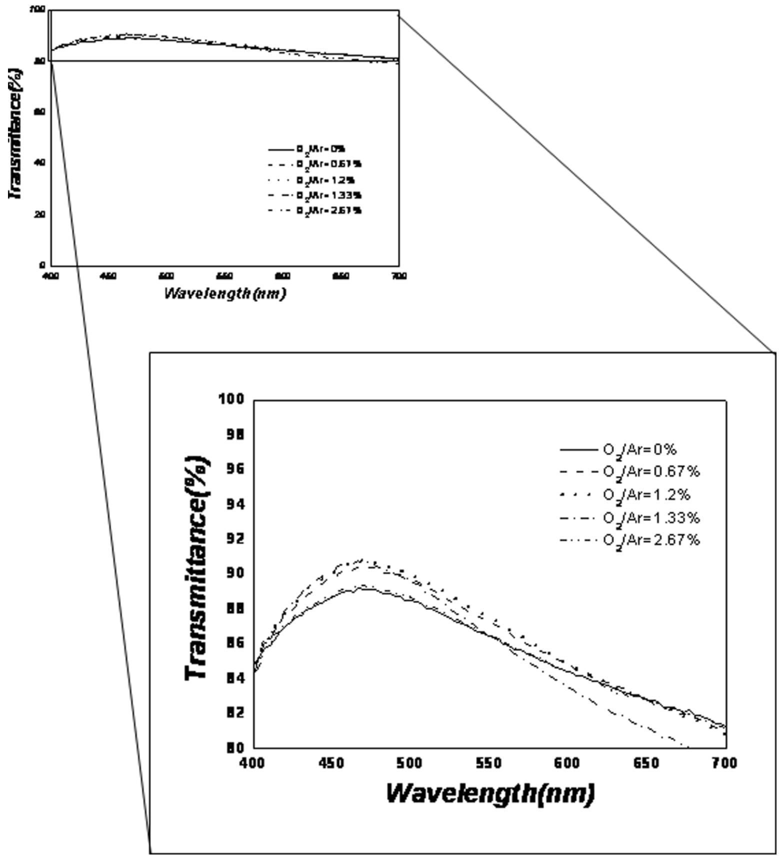

FIGURE 2 Transmittance of ITO films for PDP as functions of oxygen partial pressures.

films. All films were deposited with thickness of $1100 \pm 50\,\text{Å}$ in order to have transmittance peak value in $470 \sim 480\,\text{nm}$ wavelength ranges, by using a relation of a fourth wavelength.

Transmittance in visible ranges, thickness and refractive index of ITO thin films for PDP were measured with spectrometer (Carl ZEISS OPTOFLEX II Q CRT), alpha-step (Tencor α-step 500 profilometer) and ellipsometer (SEN TECH SE800), respectively. The sheet resistance of ITO films was determined by the four point probe method. The crystallographic structure of films was analyzed by a high resolution X-ray diffraction (Philps X'pert pro MRD). The image and the average roughness of surface were measured with a field emission scanning electron microscope (Hitachi S-4300).

RESULTS AND DISCUSSION

We analyzed and compared characteristics of ITO films grown under different partial pressures of $P(O_2)/P(Ar)$. In Figure 2, it is noted that that films have transmittance peak value near 470 $\sim$ 480 nm wavelengths where Xe plasma intensity in PDP module is known to be weak at these wavelength ranges. As seen in Figure 2, an increase in the O_2 partial pressure ($O_2/Ar = 0.67 \sim 1.33\%$) yields an increase in the peak of transmittance. This behavior can be explained by a reflection of the electromagnetic wave due to the plasma oscillation of free carrier, which is well known in degenerated ITO films with very high carrier density [4]. Figure 3 shows that the refractive index decreases as a whole by introduction of oxygen, compared with the

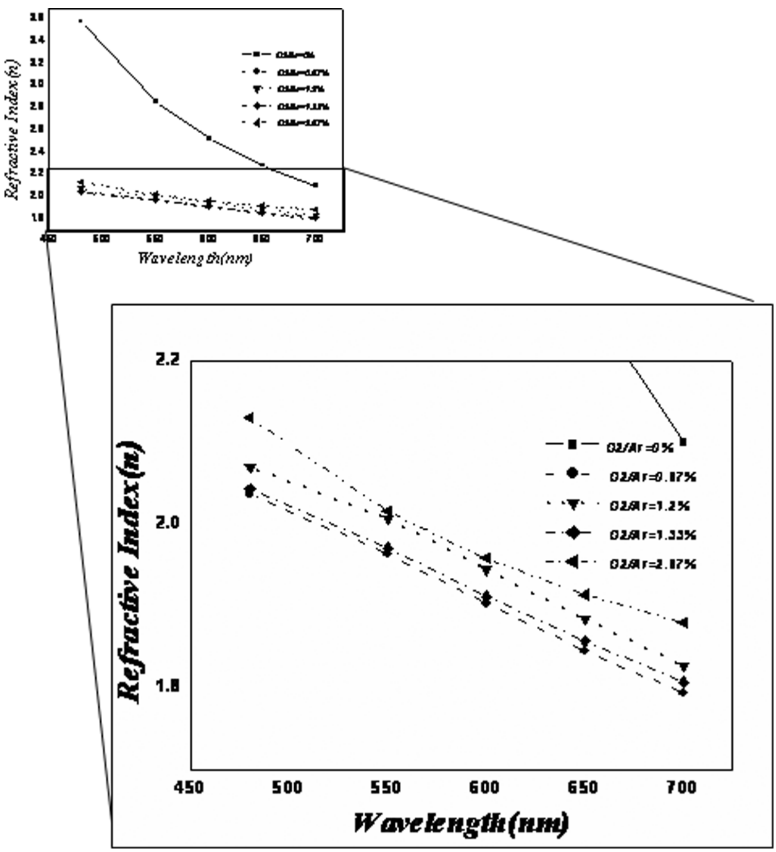

FIGURE 3 Refractive index of ITO films versus oxygen partial pressures.

case of non-oxygen atmosphere(O_2/Ar = 0%), at the 470 nm wavelength range, we obtained refractive index values slightly changing from 2 to 2.16 when we change oxygen ratios.

The influence of O_2 partial pressure on XRD profiles was shown in Figure 4. Grains of films prepared in non-oxide atmosphere by MF DMS were grown mainly in (400) direction while those prepared in oxygen atmospheres were mainly grown in (222) and (400) directions. But in over-oxygen atmosphere, the grain of (400) direction decreased to large amount, resulting in the ratio of I(222)/I(400) had maximum value, as seen in Figure 4(b).

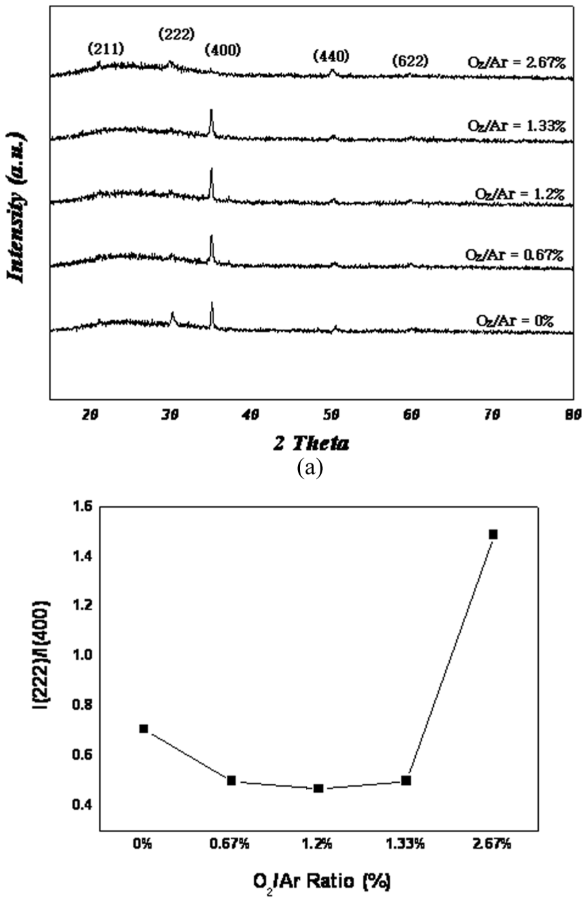

FIGURE 4 The XRD profile of ITO films. (a) XRD profile, (b) the relative peak intensity of the (222) and (400) plane.

Figure 5 shows the field emission SEM images of films grown at different O_2 partial pressures and Figure 6 indicates the grain size versus resistivity of films as a function of oxygen rates. As seen in Figure 5, there is a tendency of increasing of the grain size and decreasing of roughness (average roughness R_a notated in Fig. 5) with increasing of oxygen rates, except the case of over-oxygen condition ($O_2/Ar = 2.67\%$). From the results, it is suggested that over-oxygen

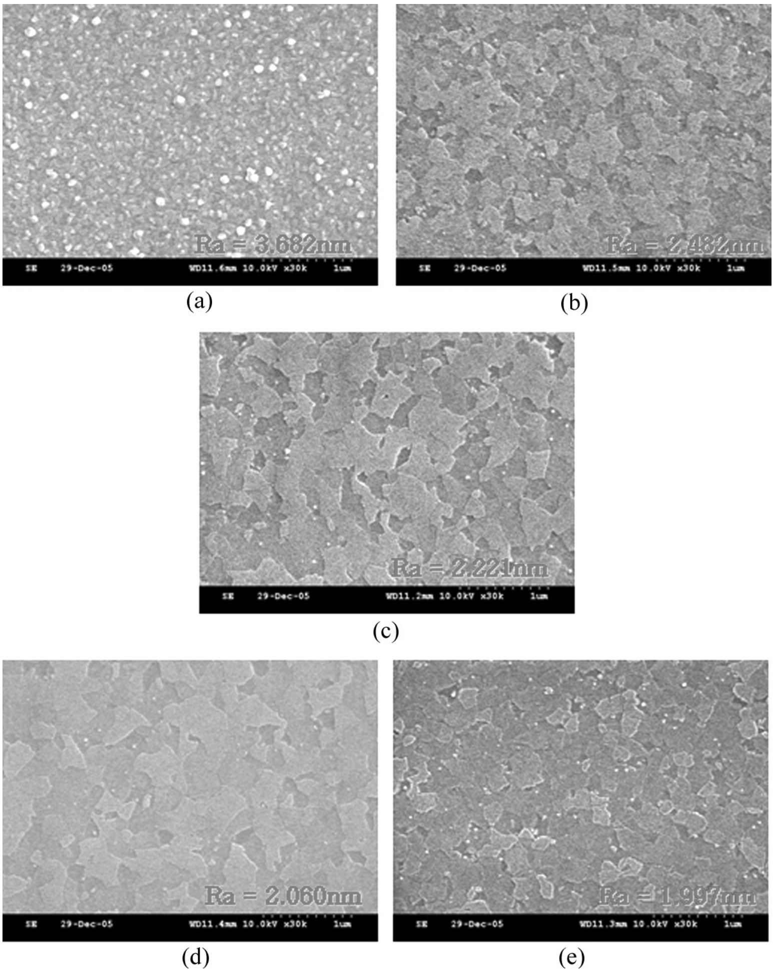

FIGURE 5 Field emission SEM images of films grown at different O_2 partial pressures. (a) $O_2/Ar = 0\%$, (b) $O_2/Ar = 0.67\%$, (c) $O_2/Ar = 1.2\%$, (d) $O_2/Ar = 1.33\%$, (e) $O_2/Ar = 2.67\%$.

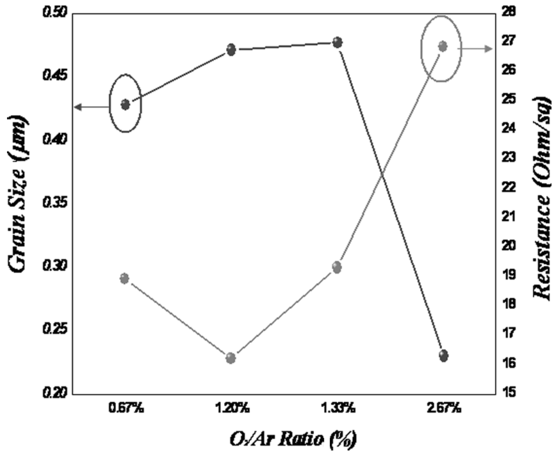

FIGURE 6 Grain size versus resistivity of ITO films.

condition was not promising to grow films with large grains. Even though we have tangible evidences, larger grain size seems to be responsible for the decrease of resistivity as revealed in Figure 6. Nevertheless, we cannot rule out the role of surface roughness on the resistivity because the surface scattering of carriers cannot be negligible. O_2 ratio showing the lowest film resistivity was 1.2%.

CONCLUSIONS

In this study, we fabricated ITO thin films available to PDP by MF sputtering in-line sputtering system. We found that the ratio of $P(O_2)/P(Ar)$ affects various characteristics such as transmittance, refractive index, crystal directions, grain size, and resistivity of ITO films. From the several useful data, we confirmed that the optimized partial pressure for ITO films grown by a MF sputtering system is $P(O_2)/P(Ar) = 1.2\%$.

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