# Highly Conductive and Transparent Electrodes for the Application of AM-OLED Display

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## Abstract

*We prepared highly transparent and conductive Oxide/Metal/Oxide(OMO) multilayer by sputtering and developed wet etching process of OMO with a clear edge shape for the first time. The transmittance and sheet-resistance of the OMO are about 89% and 3.3 Ω/sq., respectively. We adopted OMO as a gate electrode of transparent TFT (TTFT) array and integrated OLED on top of the TTFT to result in high aperture ratio of bottom emission AM-OLED.*

## 1. Introduction

Indium-Tin-Oxide (ITO), transparent conductive oxide (TCO), has been used as a transparent electrode in the flat panel display. Commercially available ITO film has sheet resistance of 10 Ω /sq. and maximum transmission of higher than 97% compared to the transmission of float glass. However, the conductivity of TCOs should be increased as well as the transparency for the wide application to the flat panel display.[1] To obtain these characteristics of TCOs, ITO/metal/ITO (IMI) has been intensively investigated.[2-4] IMI multilayer has a sheet resistance of about 5 Ω /sq. and maximum transmission of about 83%. The main issue of using IMI multilayer in the display fabrication is a etching, for it is very difficult for IMI multilayer to be made in a fine pattern due to the big difference of etch rate between the metal and ITO. Therefore we have to develop new material structure to establish the patterning process.

In the present work, we report fabrication and patterning of highly transparent and conductive Oxide/Metal/Oxide (OMO) for the first time. OMO can be deposited by DC- and rf-magnetron sputtering in a vertical inline sputtering system (ULVAC co. japan). Furthermore, we adopted this OMO into the transparent TFT (TTFT) array as a gate electrode. Integration of OLED on the TTFT array with OMO gate electrode could result in high aperture ratio of 2.5” bottom emission AM-OLED.

## 2. Experimental

Ulvac inline-sputtering system was used to deposit OMO mutilayers by DC-magnetron sputtering for the metal layer and by rf-magnetron sputtering for the oxide layers. The target diameter was 4 inch. The oxide layers consisted of various transparent conducting oxides (TCO) such as indium-tin oxide, indium-zinc oxide and doped zinc oxide etc. The metal is Ag. The film thickness was measured with an alpha-step profilometer. The sheet resistance was determined by using a four-point-probe system. The transmission measurement was performed with spectrometers. For the fabrication of bottom emission AM-OLED which has top gate oxide TFT array (figure 1), 150 nm thick ITO coated glass was used for the substrate. After patterning of ITO (S/D), 20nm thick ZnO semiconductor film was deposited by means of PEALD at the substrate temperature of 200°C. After 9 nm alumina, which acts ZnO protection layer (PL) as well as first gate insulator, was deposited by means of ALD, the active layer and PL were patterned by wet etching at once. The alumina (2nd gate insulator) was deposited with the thickness of 176 nm at the temperature of 150°C by

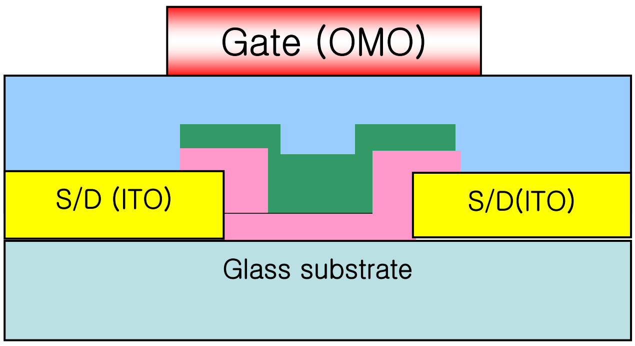


Fig. 1. Cross sectional view of top gate ZnO TFT with OMO gate layer.

means of ALD, followed by S/D pad opening by wet etching of alumina. Sputtered OMO layer with thickness of 100nm was used as a gate electrode. For the integration of OLED, ZnO TFT array was coated with commercially available transparent polymer dielectric material for the planarization. OLED anode, ITO, was deposited by sputter and patterned by wet process, followed by OLED bank process. The structure of OLED grown by vacuum thermal deposition was NPB/DPVBi:BD/ LGET185/LiF/Al and OLED encapsulation was carried out using cover glass.

## 3. Results and Discussion

The sheet resistance of the whole OMO multilayer is mainly determined by the metal layer, for the resistivity of the metal layer (Ag) is about $10^{-6}$ Ω cm and the resistivity of TCO layer is above $10^{-4}$ Ω cm. Therefore the function of the oxide layer in OMO is to protect Ag layer and to adjust optical properties of OMO to high level of transmittance in the visible range. And the choice of oxide material is the key parameter in establishing etching process including even dry etching. Table 1 and figure 2 shows sheet resistance and transmittance of OMO layer 1 and 2. In the case of layer 1, increasing deposition temperature increased transmittance and made OMO film surface-roughness smoother as shown in the table 2.

Table 1. Characteristics of OMO multilayers.

| Layer | OMO structure | Rs(Ω/sq.) | Transmittance ($T_{max}$) |
|---|---|---|---|
| 1 | IZO/Ag(10nm) /AZO | 4 | 89% |
| 2 | AZO/Ag(10nm )/AZO | 3 | 95% |

Table 2. Surface roughness of OMO films grown at room temperature and 150°C

| Layer 1 | Roughness (nm) | |
|---|---|---|
| Growth temp.(°C) | R(rms) | Peak to Vally |
| Room temperature | 0.483 | 2.350 |
| 150°C | 0.245 | 1.822 |

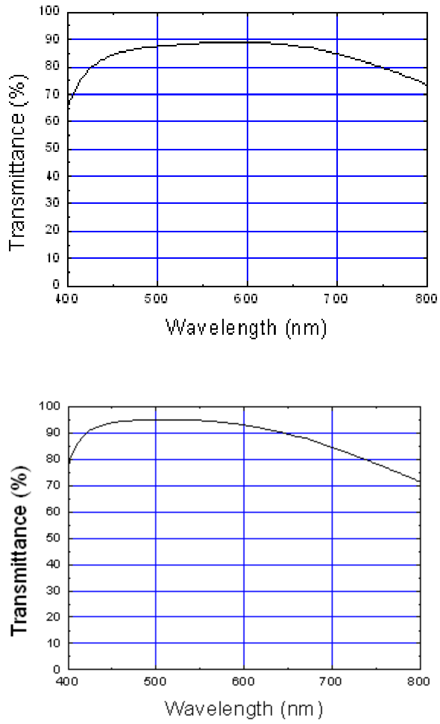


Fig. 2. The transmission spectra of the OMO multilayer sample.

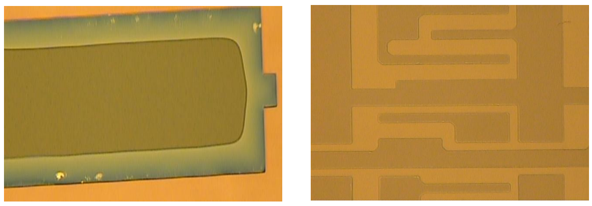

Fig. 3. Optical images of patterned IMI and OMO multilayer

Figure 3 illustrates optical images of IMI and OMO film patterned by wet etching process. For the patterning of OMO, commercially available etchant supplied by DongWoo Fine-Chem co.(korea) was used. While IMI pattern shows severely under-cut Ag layer, OMO film was patterned with clear edge define. We have developed transparent ZnO TFT arrary consisted of 2 transistor and 1capacitor in unit pixel using OMO layer as gate electrode and power line. Then we integrated OLED to fabricate high aperture ratio bottom emission AM-OLED.
Figure 4 shows operation image of transparent AM-OLED using OMO gate electrode.

| Panel size | 2.5” |
|---|---|
| resolution | 176 x 220 |
| Pixel pitch | 210 x 230 $\mu m^2$ |

Figure 4. Operating image of AM-OLED using OMO electrode.

## 3. Summary

We developed a wet etching process for oxide/metal/oxide multilayer with highly conductive and transparent characteristics. Using the wet etching process, we developed 2.5 inch 176 x 220 transparent ZnO-TFT fixel array using highly conductive and transparent OMO electrode.

## 5. Acknowledgement

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## 6. References

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