

## 광학적 간섭효과에 따른 OLED의 발광효율 개선

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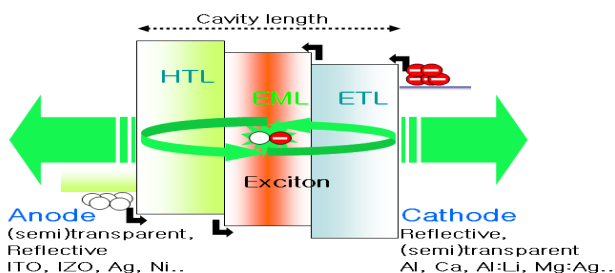
### Luminance Efficiency Improvement of OLED through Optical Interference Effect

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**Abstract** - In this study, a micro-cavity organic light-emitting device (OLED) with semi-transparent-Ag/AgO hole injecting layer (HIL) was fabricated and their performance was investigated. For the fabrication of OLEDs N,N-diphenyl-N,N-(3-methylphenyl)-1,1-biphenyl-4,4-diamine (TPD), known as a hole transporting material and tris (8-hydroxyquinolino)-aluminum (Alq<sub>3</sub>) as both electron-transporting layer (ETL) and emission layer (EML) were deposited using thermal evaporation technique. And Al layer as cathode was then deposited using thermal evaporation technique. Effects of the semi-transparent-Ag/AgO layers on the resulting OLED performance were investigated.

#### 1. INTRODUCTION

The energy levels at the interface of OLED have an important role[1]. In OLED, all charges are injected from the electrode to the organic material. During the injection, the charge carriers feel the potential barrier at the heterojunction because of the different energy levels of each material. The primary barriers exist at both electrodes/organic interfaces and small energy barriers are required to increase the charge injection. The energy level issues are summarized in other literature. The scope of this study was focused to the interface between anode and HTL (Hole Transporting Layer) with organic materials since the device characteristics are highly affected by this interface[2]. These investigations have been focusing on the mechanism of the improvement of devices characteristics by inserting hole injecting layer (HIL). From their result, the improved device performance is due to the high work function of inserted buffer layer[3]. a modification of the emission properties of organic materials is possible by using a microcavity, which can alter the optical mode density within it, and spatially and spectrally redistribute the electroluminescent (EL) emission of organic materials. This is due to the coupling of excitons to the confined electromagnetic field in the microcavity. Significant enhancement of light output efficiency and directionality, and tuning or purification of colors can be obtained. An OLED combined with a microcavity is also supposed to be an effective structure to develop electrically pumped organic lasers. The optically pumped organic microcavity laser has shown significant progress and is a milestone in the advancement of organic lasers[6].



〈Fig. 1〉 Various structure for OLEDs

#### 2. EXPERIMENTAL

##### 2.1 RF magnetron sputtering system for Ag/AgO thinfilm

After etching / cleaning procedures, deposited Ag/AgO thinfilms were deposited 20-40nm thick for buffer layer between ITO and organic material (TPD) by RF magnetron sputtering technique. The used equipment was standard sputter (A-tech System, Korea) with 2-3inch gun. The schematic diagram of RF magnetron sputter system is Rotary/turbo pumping system were used to evacuate the chamber. The Ar and O<sub>2</sub> gas flow ratio were adjusted to 35 and 20sccm respectively while keeping the total pressure at 5mTorr. The base pressure was  $1 \times 10^{-5}$  Torr and the various RF input power was 100-200W, and substrate was not heated. To investigate deposited thin film thickness, a SEM (S-4300SE) SEM. A rather widespread method of measuring thin film thickness is  $\alpha$ -step or ellipsometer, but the Ag/AgO thin films deposited in thi study were too thin to measure using these techniques. Fig.2 presents the sheet resistivity and thickness of Ag thin films prepared at various RF power, where the sheet resistivity were measured at room temperature(300K) using a four-point probe (MITSUBISHI Chemical corp.; model-Loresta-GP MCP-T610).

##### 2.2 Thermal evaporation system

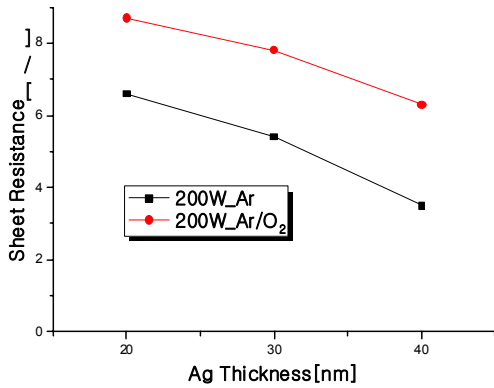
PVD reaction chamber used in this study which consists of three parts: exhaustion part, detection part, and reaction part. The exhaustion part consists of oil diffusion pump (JEIN Tech.) and rotary pump (Ulvac) which can maintain degree of vacuum of  $1.0 \times 10^{-3}$  torr. The detection part consists of thermocouple (Varian), thickness monitor (Inficon) and ion-gauge (Varian). And the reaction part consists of evaporation source, substrate and high voltage supply (Trek), respectively. The TPB and Alq<sub>3</sub> films were sequentially deposited with the same deposition rate of 1 Å/sec and without the substrate being heated. After the deposition of the organic layers, the substrates were moved to an metal evaporation chamber for the deposition of Al cathode. A metallic shadow mask was used to define the shape of counterpart electrode to the ITO anode. The completed OLED device structure was Al(150nm)/Alq<sub>3</sub>(X-nm)/TPD(X-nm)/Ag(AgO)/ITO(150nm).

##### 2.3 Voltage-Current-Luminance(V-I-L) Measurement

The current change and the characteristics of luminance according to the applied voltage change were measured by a source measurement unit (SMU; Keithley, model 2400) and luminance meter (TOPCON, BM-8). Using a personal computer to control the measurement steps, SMU controlled the apply of voltage through serial (RS-232C) interface and measured the current. At the same time, a luminance meter measured luminance through serial (RS-232C) interface. For the V-I-L measurement, the time delay for each measurement was 0.5 sec, and sampling width was 0.2 V.

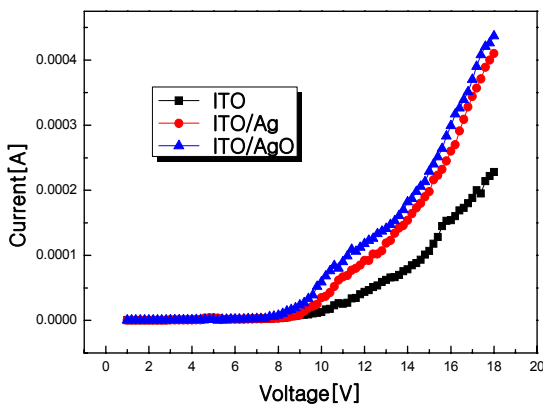
### 3. RESULTS AND DISCUSSION

Fig. 3 presents the sheet resistivity results of the Ag/AgO thin films prepared with different gas(Ar:Ar/O<sub>2</sub>) at fixed input RF power 200W. From the resistivity curve of Ag/AgO, we know that mixed Ar/O<sub>2</sub> gas caused a high sheet resistivity at the same deposition condition.



<Fig. 2> Sheet Resistivity of Ag/AgO thinfilm

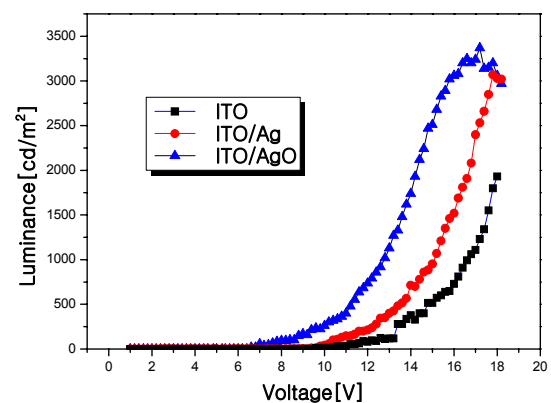
Effect of introducing additional O<sub>2</sub> gas [10scm] for sputtering was investigated and the Fig.3 and 4 presents the results. Through introducing additional O<sub>2</sub> gas in the sputtering resulted in AgO thin film deposition on the ITO anode. Fig. 3 and 4 shows that as the results of additional O<sub>2</sub> gas introduction, performances of the OLED was dramatically improved than other case.



<Fig. 3> The dependence of current vs. voltage for Ar : Ar/O<sub>2</sub>

Because of oxygen flow in the chamber, as is well known from the transport mechanism of metal oxides, resistivity of the resulting thin films increase. These films exhibit *n*-type conductivity as long as the number density of free electrons dominates. It is well known that almost all the non-stoichiometric metal oxides are *n*-type transparent conductors. Now arises the question of the origin of *p*-type conductivity in non-stoichiometric silver (sub) oxide thin films. The requirements for a *p*-type transparent conducting oxide (TCO) as reported in the literature [4] are: (i) chemical modulation of valence band (CMVB) and (ii) the electronic configuration of the

cationic species should preferably have a  $d^{10} s^0$ . The electronic configuration of Ag is  $4d^{10} 5s^1$ . From the concepts of silicon physics, it is well known that the holes are formed if there is localization of covalent bonds in the material. If the density of these localized states is considerably large in the film, the holes appear as majority carriers showing *p*-type conduction in Seebeck Coefficient and in Hall Effect. Thus, the silver sub oxide film possesses both *n*-type (due to electrons from metallic silver) and *p*-type (the oxide bond with silver) conduction. One possibility for understanding the covalence is through the bond energy; when the silver metal reacts with oxygen, if the bond energy for the suboxides (for example Ag<sub>2</sub>O<sub>3</sub>, AgO, Ag<sub>2</sub>O, Ag<sub>3</sub>O<sub>4</sub>) is less, this weak bond may give rise to the presence of an acceptor level leading to hole conduction in the film. So deposited AgO thinfilm had *p*-type semiconducting property.[5] It was assumed that its *p*-type property occurred higher hole injection efficiency of device.



<Fig. 4> The dependence of current vs. voltage for Ar : Ar/O<sub>2</sub>

### 4. SUMMARY AND CONCLUSION

In this study, efficient microcavity-OLEDs were fabricated with different device structure of ITO/TPD/Alq<sub>3</sub>/Al and ITO/Ag(AgO)/TPD/Alq<sub>3</sub>/Al. The semitransparent-Ag/AgO layer was deposited at various conditions using a RF magnetron sputtering technique. Then the Ag/AgO thin films were inserted as a semitransparent-Ag/AgO layer between ITO anode and HTL layer and their effect on enhancement of the resulting microcavity-OLED performance was investigated. From the sheet resistivity measurements of Ag/AgO, introduction of mixed Ar/O<sub>2</sub> gas rather than only Ar caused high sheet resistivity of the resulting thin film but resulted in enhancement hole injection, which was confirmed by V-I and I-L measurements of the microcavity-OLED. The microcavity-OLEDs fabricated in this way revealed the lower turn on voltage and improved the luminance characteristic: 13.3 V ⇔ 9.4V and 1780 cd/m<sup>2</sup> ⇔ 3370 cd/m<sup>2</sup>.

### [REFERENCES]

- [1] Tang, C.W.; VanSlyke, S.A. Appl. Phys. Lett. 1987, 51, 915
- [2] E.H. Rhoderick, R.H. Williams, Metal-semiconductor Contacts, Oxford University Press, Oxford 1988.
- [3] J.S.Lim, P.K.Shin, Appl. Sur. Sci., 253 (2007) 3828-3833
- [4] H.Kawazoe, H. Yanagi, K. Ueda, H.Hosono, Mat. Res. Bull.25 (2000) 28.
- [5] U. Kumar Barik et al. / Thin Solid Films 429 (2003) 129 - 34
- [6] X. Liu, D. Poitras, Y. Tao, and C. Py, J. Vac. Sci. Technol. 764 (2004) 0734-2101