Development with multi-layer passivation films for OLED with longer life time

Jae Hoon Jung, Jong Sun Lim, Jung Soo Rhee, Hoon Kim, Sang Pil Lee, Nam Deog Kim,
Byeong Kwon Ju*, Joo Won Lee*, and Kyuha Chung
FPD Device Team, LCD R&D Center, Samsung Electronics Co., Ltd., Kyunggi-do 449-711, Korea
* Microsystem research center, Korea Institute of science and Technology, Seoul 136-791, Korea

Abstract

We have developed multi-layer passivation films of UV-polymerized film/inorganic composite film to improve the long lifetime of passivated OLEDs for very thin flat panel applications. Preliminary lifetime to half initial luminance (L_{50}~ 3,000 cd/m^2) of order 300 Hr is achieved on the conventional encapsulated test pixel using a passive matrix drive at room temperature; 570 Hr lifetime is achieved on a dc tested multi-layer passivated 9mm^2 test pixel.

I. Objective and Background

Organic light emitting device (OLED) technology is widely recognized for its potential in future flat panel display applications where low power consumption, low cost, and superior viewing ability are desired.[1-3] The thin cathodes of these devices consist of reactive metals that degrade even more rapidly than the organic EL material. OLED display require, therefore, substrate and encapsulation extremely impermeable to water and oxygen.[4]

Thin film diffusion barrier encapsulations and substrates based on vacuum deposited organic-inorganic multi-layers [5] are very promising option for transparent packaging for OLED application. However in such conditions the inorganic films with a thickness of a few micrometers often crack or peel off by the thermal stress because they are hard and fragile. In order to achieve both feature, the multi-layer structure using soft organic films and hard inorganic films is considered to be effective.[6]

In this study, we have chosen UV-polymerized films as the soft organic films and have developed multi-layer passivation films (UV-polymerized film / thin composite inorganic film) for OLED displays. Thus this passivation is considered to have specific features of high barrier against moisture, high stress relaxation, and good coverage, and to be appropriate for the OLED passivation.

II. Results

The OLED was prepared on a non-alkaline glass substrate by the vacuum evaporation system and the multi-layer passivation film was fabricated by forming into UV-polymerized organic film and grown by E-beam evaporation system forming into inorganic composite film. The passivated OLED was fabricated not exposing to the air by carrying the samples with a N_2 gas purged

box between the globe box of these apparatuses.

The typical OLED in this study consist of Al/LiF/ETL (Electron Transporting Layer)/EML (Emission Layer)/HTL(Hole Transporting Layer)/ HIL (Hole Injection Layer)/ITO(Indium Tin Oxide) with emitting area of 9 mm^2.

Since the organic film has a low adhesion force and a low tolerance to high temperature, the deposition condition of these layers using physical vapor deposition is quite destructive for organic layer. And the density of thin film by physical vapor deposition is lower than that of chemical vapor deposition. Table-1 depict the reported the water vapor transmission rates (WVTRs) of inorganic compound film, and that shows relatively higher value as a passivation layer for OLED.[7]

To prepare the inorganic composite material, the most candidate materials are grained into powder and the powder is mixed together. To use an evaporation source in the e-beam deposition system, the mixed powder is pressed into composite pellet. The prepared composite materials are depicted in table 1. The various kinds of inorganic films using the prepared composite were deposited on the plastic film. And then the WVTR was measured to compare the passivation properties. In this measurement, the Permatran-W 3/31 made by MOCON Corporation was used to measure the WVTRs for the various kinds of inorganic thin films. During the WVTR measurements, the temperature and relative humidity in the test system is set to 37℃ and 100% RH, respectively.

Figure 1 shows the EPMA spectra for the PES film and SM series thin film. In this figure, we can see that the weight and atomic percentages of both SiO_2 and MgO were strongly depending on the mixing ratio of themselves.

The crystal structure of thin composite film as a function of mixture ratio was investigated by XRD, and the XRD spectra of the PES film, SM-11, SM-12 and SM-13 was presented in figure 2. As shown in figure 2, the spectra in this figure have only one peak, which represents the PES film. Thus, we can understand that the crystal structure of composite films, SM-11, SM-12 and SM-13, is amorphous structure. As mentioned in introduction, the crystal structures for protection of water permeation should be having glass-like amorphous structure.

The WVTRs of thin composite films were presented in figure 3. This figure shows also the WVTRs as a function of composition rate of composite materials. In this figure, the WVTRs of SM-12 and SM-13 shows almost same value in spite of increase the composition rate of cooperated material. In the case of SM-13 deposited on PES plastic film, the WVTR with almost same thickness is lower than that of others as 0.29 g/m^2day. However, we can understand that the WVTR was dramatically lowered than those of inorganic compound films as depicted in table 1, and the WVTRs are quite depended on the mixing ratio of composite film. This result can be simply understood that the permeation rate of the thin film depend on the packing density of the solid-state structure, and thus the permeation rate can be

decreased by increasing the rate of the impurity in the thin compound film as mentioned in the introduction..

In order to estimate the lifetime of the multi-layer passivated OLED, the photo-current from OLED was measured from the initial photo-current to 50% of initial value at a constant dc current of 20mA/cm^2. And the lifetime properties of the passivated OLED were carefully compared with non-passivated OLED, as shown in figure 4. In ambient conditions, we can see that the OLED without the passivation layer has a shorter lifetime than that of passivated OLED. Because the Al cathode and organic was much sensitive to moisture and oxygen, the non-passivated OLED cannot operate for long. But, the passivated OLED had a comparably long lifetime of about 570 hours. This result can be simply explained that the forming of multi-layer thin film with a low permeation rate effectively enhanced the lifetime of OLED. Also, the passivation method could be easily applied to the fabrication of OLED and continuously carried out in a vacuum chamber.

Figure 5 shows the transmittance of the PES film and multi-layer films, respectively. In this figure, we can see that the PES film is perfectly clear, and the transmittance of the SM composite films shows almost same value as ~90% even though there are some fluctuations as a function of wavelength. Thus, we can consider that the thin composite film has great potential as a passivation layer for the top-emitting OLED as well as conventional OLED.

III. Impact

We have developed multi-layer passivation films of UV-polymerized film/inorganic composite film to improve the long lifetime of passivated OLEDs for very thin flat panel applications. We could achieve the longer lifetime than that of can lid encapsulated OLED. It is considered that the good characteristics of the multi-layer passivation derived from the stress relaxation ability of the UV-polymerized film. Thus the multi-layer passivation is expected to apply to OLED mass-production.

IV. References

[1] S. H. Ju et al., *SID 02 Digest* **33**, 1096 (2002).

[2] K. Werner, *Information Display* **18**, 12 (2002).

[3] Y. Kuo and K. Suzuki, *MRS Bulletin* **27**, 859 (2002).

[4] K. Pichler, *Phil. Trans. R. Soc. Lond.* **A355**, 829 (1997).

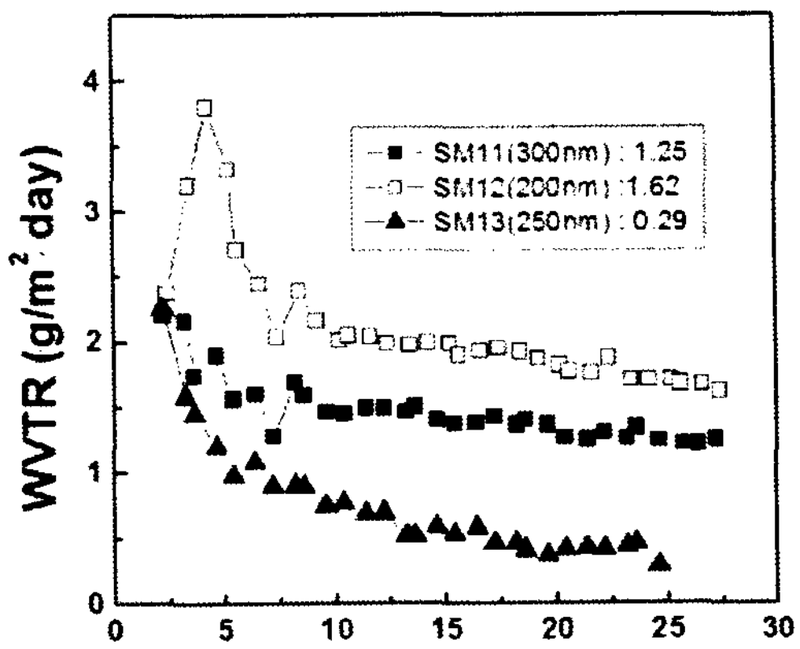
[5] J. D. Affinito, M. E. Gross, C. A. Coronado, G. L. Graff, E. N. Greenwell and P. M. Martin, *Thin Solid Films* **290-291**, 63 (1996).

[6] P. E. Burrows, G. L. Graff, M. E. Gross, P. M. Martin, M. K. Shi, M. Hall, E. Mast, C. Bonham, W. Bennett, and M. B. Sullivan, *Displays* **22**, 65 (2001).

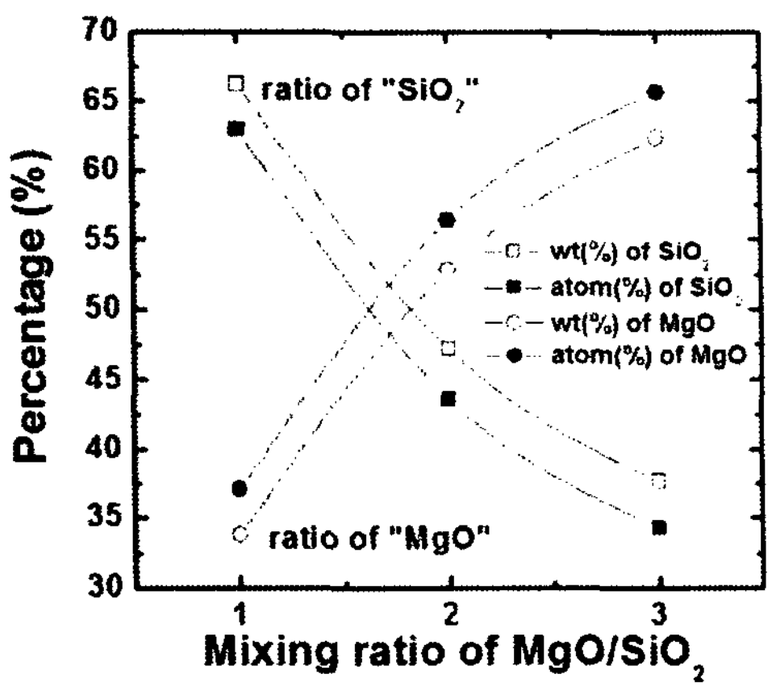
[7] K. H. Kim, H. Kim, H. M. Gu, J. K. Kim, Y. C. Kim, J. I. Han, D. G. Moon, J. Jang and B. K. Ju, *Proceeding of Society for Information Display*, 563 (2003).

[Table1.] The WVTRs for the various kinds of inorganic compound film.

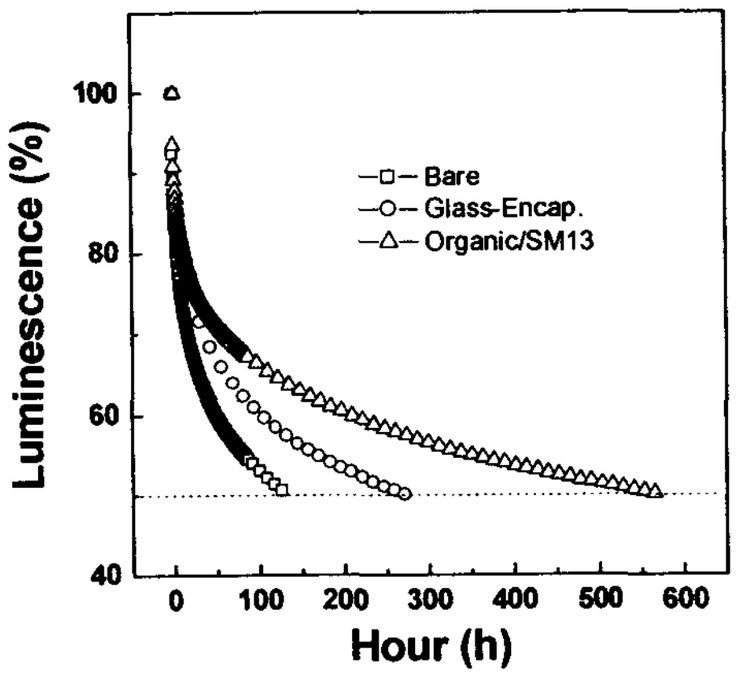
Material	Thickness(nm)	WVTR (g/m^2.day)
CeO_2	340	39.08
SiO_2	1,000	33.97
MgF_2	100	29.93
Al_2O_3	10	36.77
ZrO_2	10	36.70
TiO_2	25	35.47
Ta_2O_5	50	34.64
MgO	1,100	3.30



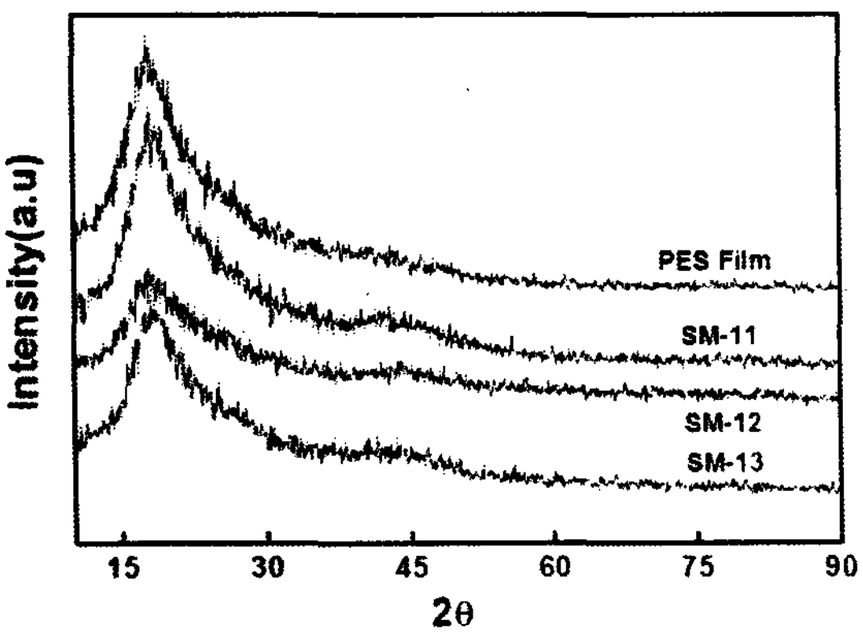
[Figure.3] The WVTRs of thin composite films as a function of mixing ratio of MgO and SiO_2.



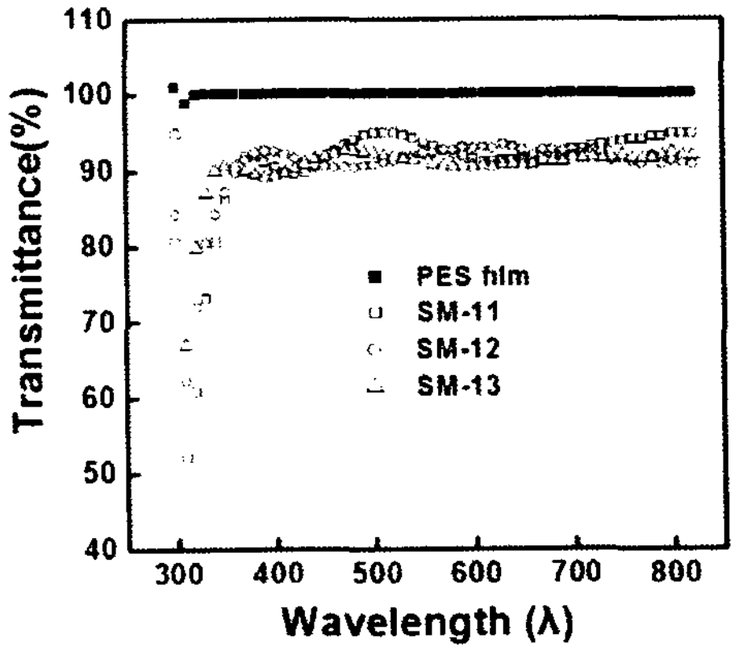
[Figure.1] The weight and atomic percents as a function of mixing ratio of MgO and SiO_2.



[Figure.4] The lifetime properties of the bare, glass-encap. and organic/SM-13 passivated OLED.



[Figure.2] The weight and atomic percents as a function of mixing ratio of MgO and SiO_2.



[Figure.5] The transmittance of PES, SM-11, SM-12 and SM-13, respectively.