

C-10-3

## Passivation of organic light emitting diodes with plasma polymerized p-xylene thin films deposited by PECVD

Sunyoung Sohn, Samil Kho, Daeyong Cho and Donggeun Jung\*

Department of Physics, Brain Korea 21 Physics Research Division and Institute of Basic Science  
Sungkyunkwan University, Suwon 440-746, Republic of Korea  
Phone: +82-31-290-7055 \*E-mail: djung@yurim.skku.ac.kr

### 1. Introduction

Organic light emitting diodes (OLEDs) have been studied widely due to advantages such as active emission, high brightness, wide viewing angle, low operating voltage and ease of fabrication [1-3]. Relatively short lifetime of the OLEDs, however, is still a major obstacle for their commercial applications. There are two main factors to degrade the OLEDs. One is the crystallization of organic materials by joule heating during operation [4,5] and the other is the oxidation of them by interaction with water and/or oxygen in the atmosphere [6]. To increase the lifetime of OLEDs by preventing degradation of OLEDs, prevention of water and/or oxygen from diffusing into the organic material layers and then interacting with organic materials, *i.e.*, passivation of OLEDs, is attempted. While passivation of OLEDs with glass plates or metal-cans has been established [7], passivation of OLEDs by thin films is still being developed. Recently, many works on the applications of plasma polymers in electronic devices have been reported [8-10]. Thin films of plasma polymers can be deposited by plasma enhanced chemical vapor deposition (PECVD). In PECVD of plasma polymers, monomeric precursors are transported into the deposition chamber, are activated and/or decomposed into reactive species by plasma and then condense on the substrate, forming thin films of plasma polymers. The properties of plasma polymer thin films are considered to be different from those of conventional chemically synthesized polymer films [11]. Due to the highly cross-linked network structure of plasma polymers, plasma polymer thin films are pin-hole free, mechanically and chemically stable, and strongly adherent to underlying layers. Therefore, plasma polymer thin films are expected to prevent water and/or oxygen diffusion into the OLEDs and to be an effective passivation layer for OLED passivation [12].

In this work, we report OLED passivation using thin films of a plasma polymer deposited by PECVD using para-xylene precursor, which is referred to as plasma polymerized para-xylene (PPpX). Characteristics of an OLED without the PPpX passivation layer (control device) and an OLED with the PPpX passivation layer (passivated device) were compared to investigate the effectiveness of the PPpX passivation.

### 2. Experiments

Figures 1 show the device structures of an OLED

with the PPpX passivation layer (passivated device). Indium-tin-oxide (ITO) coated glass was used as the substrate. N,N'-diphenyl-N,N'-bis(3-methylphenyl)-1,1'-diphenyl-4,4'-diamine (TPD) and tris-8-hydroxyquinoline aluminum (Alq<sub>3</sub>) were used as the hole transport layer (HTL) and the emitting layer (ETL), respectively. TPD (32 nm) / Alq<sub>3</sub> (48 nm) was deposited on ITO by thermal evaporation. Deposition rates for the organic layers were 0.6-1.2 Å/s. Thermal evaporation deposition of the 150 nm Al cathode layer was performed with the deposition rate of 5-10 Å/s. Some of the as-prepared OLED devices were moved to the PECVD chamber for deposition of the PPpX passivation layer. Details of the PECVD system used in this work is described elsewhere [8]. PPpX passivation films were deposited at plasma power of 30 W at a deposition pressure of 0.2 Torr. The thickness of the PPpX film was 160 nm. The OLEDs were operated in room air for all the experiments.

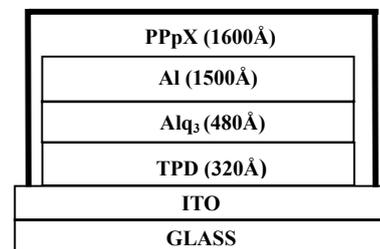
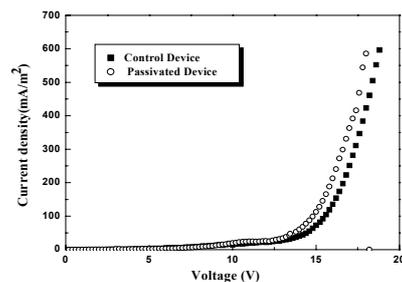


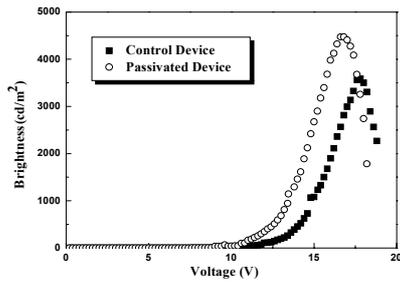
Fig. 1 Schematic diagram of an OLED With PPpX passivation layer.

### 3. Results and discussions

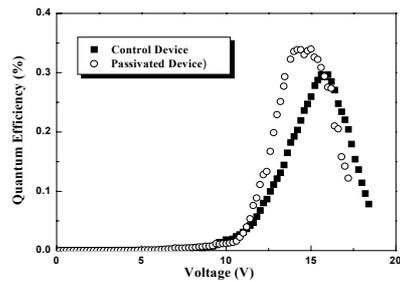
Figures 2(a), 2(b) and 2(c) show the current-voltage (I-V) characteristics, brightness-voltage (B-V) characteristics and external quantum efficiencies, respectively, of the control OLED device and the passivated OLED device.



(a)



(b)



(c)

Fig. 2 Current density versus applied voltage (a) and brightness versus applied voltage (b) characteristics and external quantum efficiency (c) for the control device and the passivated device.

The passivated device showed similar I-V and B-V characteristics and external quantum efficiency to those of the control device, indicating that during the deposition of the PPpX passivation films, the PECVD process, which involves radicals, ions, electrons and energetic radiations, did not damage the OLEDs notably.

Figure 3 shows the degradation characteristics of the control device and the passivated device. The time duration required for the brightness of the OLED device to become half the initial value was referred to as the lifetime of the OLED device. The lifetime of the control device was 300 sec while that of the passivated device was 8000 sec.

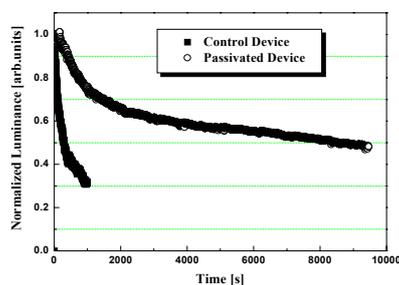


Fig. 3 Degradation characteristics of the control device and the passivated device.

However, the enhancement of lifetime by PPpX passivation in our work is not so dramatic as that reported previously [13]. One reason for this is that our PPpX films may not completely prevent water and/or oxygen

diffusion. Another possible reason can be speculated as follows. In our experiments, the organic layers were exposed to room air before deposition of the Al cathode layer, which was inevitable for alignment of the shadow mask for Al deposition. Due to the exposure of the organic layers to room air before the deposition of the PPpX passivation layer, even though the PPpX film prevented water and/or oxygen from diffusing from room air into the OLED, there is a certain amount of water and/or oxygen inside the OLED devices, resulting in degradation of the OLED devices.

#### 4. Conclusions

The PPpX passivated device showed similar I-V and B-V characteristics and external quantum efficiency to those of the control device, indicating that the PECVD process for the deposition of the PPpX films did not degrade the performance of the OLEDs notably. The lifetime of the passivated device was more than twenty times longer than that of the control device, indicating that the PPpX film was, to some extent, effective in passivating the OLED.

#### References

- [1] F. Li, H. Tang, J. Anderegg and J. Shinar, *Appl. Phys. Lett.* 70 (1997)
- [2] T. Shimada, Khamaguchi and A. Koma, *Appl. Phys. Lett.* 72, 1233 (1998)
- [3] G. Parthasarathy, P. E. Burrows, V. Khalfin, G. G. Kozlov and S. R. Forrest, *Appl. Phys. Lett.* 72, 17 (1998)
- [4] H. Aziz, Z. Popovic, S. Xie, A.M. Hor, N.X. Hu, C. Tripp and G. Xu, *Appl. Phys. Lett.* 72, 756 (1988).
- [5] T. Mori, T. Mitsuoka, M. Ishii, H. Fujikawa and Y. Taga, *Appl. Phys. Lett.* 80, 3895 (2002)
- [6] M. D. Lee, K.J. Kim, T.H. Zyung, H.K. Shim and J.J. Kim, *Appl. Phys. Lett.* 70, 3470 (1997)
- [7] Y. Kijima, N. Asai and S. Tamura, *Jpn. J. Appl. Phys.* 38, 5274 (1998)
- [8] D. Jung, H. Pang, J.H. Park, Y.W. Park and Y. Son, *Jpn. J. Appl. Phys.* 38, L84 (1999)
- [9] C. Shim, J. Choi, D. Jung, N.E. Lee and C.W. Yang, *Jpn. J. Appl. Phys.* 39, L1327 (2000)
- [10] J. J. Senkevich and S.B. Desu, *Appl. Phys. Lett.* 72, 258 (1998)
- [11] N. Inagaki, *Plasma Surface Modification and Plasma Polymerization (Technomic Publishing, Lancaster, PA, U.S.A., 1996)*, (1996) Chapter 6.
- [12] L. F. Quattropani, P. Groening, D. Ramseyer and L. Schlapbach, *Surf. Coat. Technol.* 125, 377 (2000)
- [13] S. H. Kwon, S. Y. Paik and O. J. Kwon, *Appl. Phys. Lett.* 79, 4450 (2001)