유기 전기발광 소자에서 버퍼층이 미치는 영향

Effects of Buffer layer in Organic Light-Emitting Diodes

김상걸*, 정동회*, 이호식**, 정택균***, 김태완***, 민항기***, 박종욱****, 송민종*****, 이준웅******
(S. K. Kim*, D. H. Chung*, H. S. Lee**, T. G. Chung***, T. W. Kim***, H. K. Min***, J. W. Park****, M. J. Song*****, J. U. Lee******)

Abstract

We have seen the effects of buffer layer in organic light-emitting diodes using poly(N-vinylcarbazole)(PVK). Polymer PVK buffer layer was made using spin casting techniques. Two different types of spin casting have been applied; static coating and dynamic coating. Two device structures were fabricated; one is ITO/TPD/Alq_3/Al as a reference, and the other is ITO/PVK/TPD/Alq_3/Al to see the effects of buffer layer in organic light-emitting diodes. Current-voltage characteristics and luminous efficiency were measured with a variation of spin-casting methods and rpm speeds. We have obtained an improvement of luminous efficiency by a factor of two and half when the PVK buffer layer is used.

Key Words : Organic light-emitting diodes, Buffer layer, Spin-casting, luminous efficiency

1. Introduction

Organic light-emitting doides(OLEDs) have received attention because of potential application to full color flat-panel display. They are attractive because of low-driving voltage and capability of multicolor emission by the selection of emissive materials [1-5]. In 1987, Tang and VanSlyke reported a stacked electroluminescent(EL) cell structure, which has a luminous efficiency of 1.5 lm/W and a luminance of 1,000 cd/m^2 for green light under the low-operating voltage below 10V[6].

In order to enhance the OLEDs performance, some organic materials are adopted for hole-injection buffer layer inserted between indium-tin oxide(ITO) anode and the emissive layer. Copper phthalocyanine(CuPc), PEDOT, starburst amines and polyaniline(PANI) are the common hole-injection buffer layer materials[4]. The buffer layer is used to improve the performance of OLEDs in several aspects, such as a good mechanical contact, energy band adjustment, suppressing noisy leakage current, reducing the operating voltage, and enhancing the thermal stability and quantum efficiency. However, a unique buffer layer that can efficiently provides all the above mentioned functions is yet to be found.

There is a report that the CuPc buffer layer in OLEDs improves the electrical stability of the OLEDs based on Alq_3 thin films[7]. The CuPc layer prevents the OLEDs from deteriorating the organics as well as the electrode layers[8]. Not

* Dept. of Electrical Eng., Kwangwoon Univ.
** Dept. of Electrical & Control Eng., Hongik Univ.
*** Dept. of Physics, Hongik Univ.
**** Dept. of Polymer Eng., Chungju National Univ.
***** Dept. of Medical Eng., Kwangju Health Univ.
****** KIEEME

many Studies have been done regarding on the effects of poly(N-vinylcarbazole)(PVK) buffer layer in OLEDs.

In this paper, we have studied the effects of PVK buffer layer in OLEDs based on Alq_3 thin films by investigating current-voltage characteristics, luminance-voltage characteristics and luminous efficiency.

2. Experimentals

Fig. 1 shows a device configuration. The PVK layer was spin coated. And the TPD, Alq_3, and Al were vacuum deposited. We have fabricated the OLEDs with a use of well-known emissive material, 8-hydroxyquinoline aluminum(Alq_3). Indium-tin-oxide(ITO) glass, having a sheet resistance of 15Ω/□ and 170nm thick, was received from Samsung Corning Co.

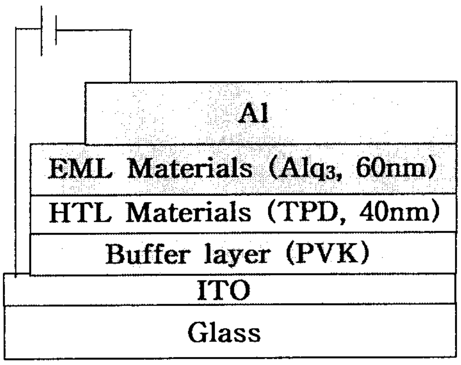
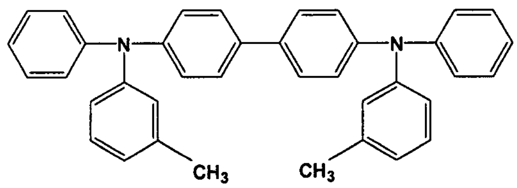


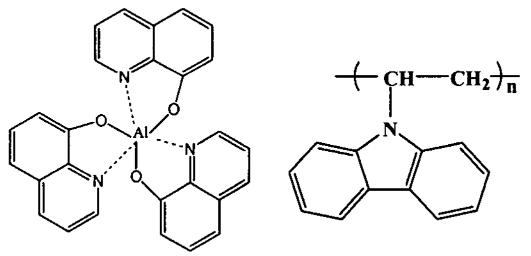
Fig. 1 Device configuration

Fig. 2 shows the molecular structures of (a)TPD, (b)Alq_3, and (c)PVK. Polymer PVK buffer layer has been fabricated either by static or dynamic spin-casting method in the range of 1000~ 5000 rpm. And then the organic materials were successively evaporated onto pre-cleaned ITO at 10^{-6} torr, and Al cathode was deposited at 1.0×10^{-5} torr. Light-emitting area was defined by using a shadow mask to be 0.3×0.5 cm^2. Two device structures were made; one is ITO/TPD/Alq_3/Al as a reference and the other is ITO/PVK/TPD/Alq_3/Al to investigate the effects of buffer layer. A PVK solution(1mg/cc) was made with a solvent of dichloro ethane ($ClCH_2CH_2Cl$).

Current-voltage characteristics, luminance-voltage characteristics, and luminous efficiency of OLEDs were measured using Keithley 236 SMU electrometer and Minolta CS-100 chroma meter. Luminous efficiency was calculated based on the luminance, EL spectra and current densities.



(a) TPD



(b) Alq_3 (c) PVK

Fig. 2 Structures of (a) TPD, (b)Alq_3, and (c) PVK materials.

3. Results and Discussion

Fig. 3(a) and (b) shows typical nonlinear current-voltage characteristics of ITO/TPD/Alq_3/Al (reference) and ITO/PVK/TPD/Alq_3/Al devices with several different spin-casting speeds for PVK layer coated either by static spin-casting or dynamic spin-casting method, respectively.

The spin-casting speed refers to the thickness of PVK layer. As the spin-casting speed increases, the thickness of the film decreases due to a centrifugal force acting on the film.

Fig. 4(a) and (b) are luminance from device depending on the applied voltage with spin-casting methods. As the voltage increases above 5V, the current density starts to increase rapidly and there occurs a green-light emission at the same time. And the current density of OLEDs for PVK made by dynamic spin-casting method is less than that of static spin-casting method.

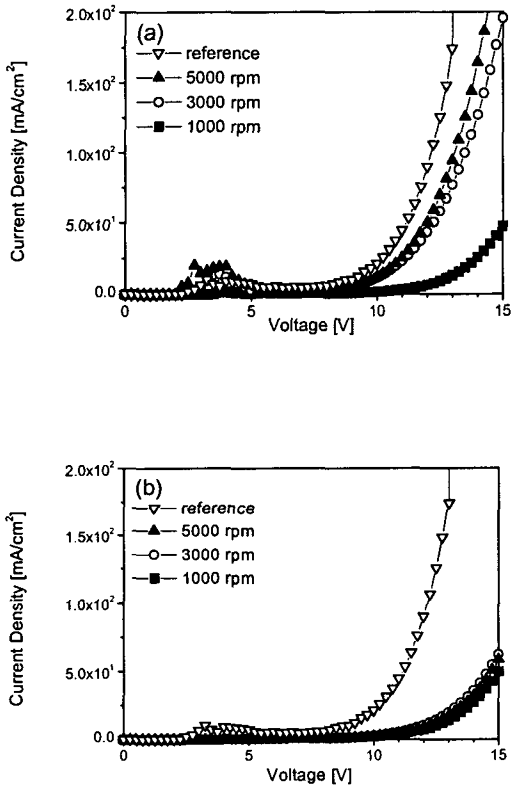


Fig. 3 Current-voltage characteristics of ITO/PVK/TPD/Alq_3/Al devices when the PVK layer was made by (a) static spin-casting, and (b) dynamic spin-casting.

Using Fig. 3 and 4, luminous efficiency was calculated. As is seen in Fig. 5, the luminous efficiency starts to increase from 5V and becomes a maximum near 10~12V. As the thickness of PVK layer becomes thicker, the luminous efficiency becomes higher. This reflects that the PVK buffer layer affects on the hole injection from the ITO. While the maximum efficiency of reference device(without PVK layer) is close to 0.1 lm/W, the maximum efficiency of device with PVK layer is about 0.25 lm/W. That is, there is an improvement of efficiency by factor two and half. Thus, the PVK buffer layer is a useful hole-injection buffer to enhance the device performance.

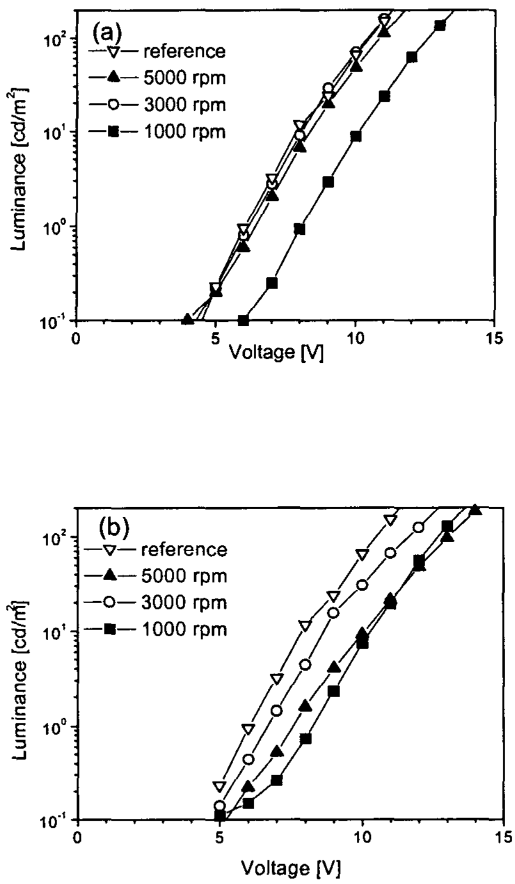


Fig. 4 Luminance-voltage characteristics of ITO/PVK/TPD/Alq_3/Al devices when the PVK layer was made by (a) static spin-casting, and (b) dynamic spin-casting.

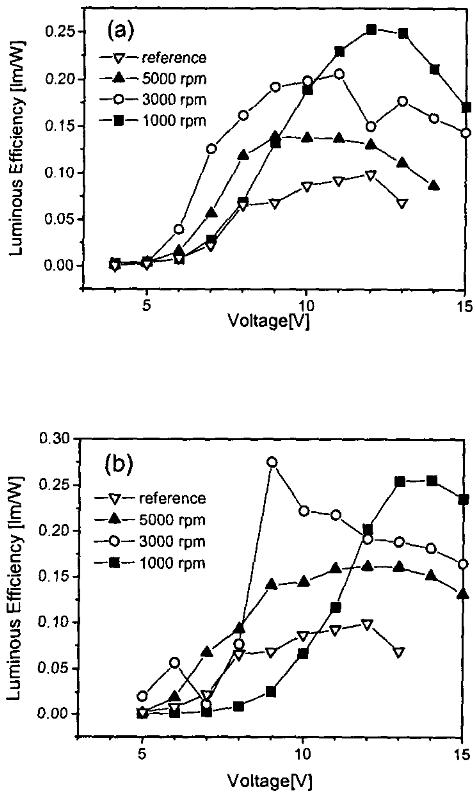


Fig. 5 Luminous efficiency-voltage characteristics of ITO/PVK/TPD/Alq_3/Al devices when the PVK layer was made by (a) static spin-casting, and (b) Dynamic Spin-casting.

4. Conclusions

We have fabricated the efficient OLEDs using the PVK hole-injection buffer layer in a device structure of ITO/PVK/TPD/Alq_3/Al. By using the PVK buffer layer, the luminous efficiency of device has improved by factor of two and half. We are going to study further how the buffer layer affects on the stability of the device.

[Reference]

[1] C.W. Tang, S.A. VanSlyke, C. H. Chen, J. Appl. Phys., 65 (1989) 3610.
[2] C. Adachi, S. Tokito, T. Tsutsui, S. Saito, Jpn. J. Appl. Phys., 27 (1989) L713.
[3] Y. Ohmori, A. Fujii, M. Uchida, K. Yoshino, Appl. Phys. Lett., 62 (1993) 3250.
[4] C. Hosokawa, H. Higashi, T. Kusumoto, Appl. Phys. Lett., 62 (1993) 3238.
[5] Z.-L. Zhang, X.-Y Jiang, X.H. Xu, T. Nagatomo, O. Omoto, Synth. Met., 91 (1997) 131.
[6] C. W. Tang, S. A. VanSlyke, Appl. Phys. Lett., 51 (1987) 913.
[7] S. A. Van Slyke, C. H. Chen, and C. W. Tang, Appl. Phys. Lett., 69 (1996) 2160.
[8] P. E. Burrows, F. Bulovic, S. R. Forrest, L. S. Sapochak, D. M. McCarty, and M. E. Thompson, Appl. Phys. Lett., 65 (1992) 2922.