The Analysis of the Characteristics according to Polymer Concentration for Polymer Light Emitting Diode Fabricated on Flexible Substrates

Woo Jin Cho[1], Su Hwan Kim[1], Byoung Ho Kang[1], Do Eok Kim[1] and Shin Won Kang[2]

[1]Dept. of Electronic Engineering, Kyungpook National University, Daegu 702-701, Korea

[2]School of Electrical Engineering and Computer Science, Kyungpook National University, Daegu 702-701, Korea

TEL:82-53-950-6829, e-mail: swkang@knu.ac.kr

Keywords : PLED, LiF, Flexible substrate, PET

Abstract

In this paper, to compare thermal and chemical stabilities of poly-ethylene-terephtalate (PET) and poly-ether-surphone (PES), we fabricated Polymer Light Emitting Diode (PLED) on each substrate and analyzed these characteristics. Moreover, we analyzed the characteristics of the device deposited LiF (1 ㎚) before cathode deposition.

1. Introduction

Flexible display is a next generation display that has merits of good display characteristics, bendability and foldability. Among the flat panel displays, Organic Light Emitting Diode (OLED) can achieve those characteristics so it has been studying very much. Generally, OLED is classified into small molecule OLED (SMOLED) and polymer (PMOLED) according to molecular weight and has many merits of low power consumption, high-definition, wide viewing angle and so on. It can be applicable to flexible display by fabricating on glass substrates or bendable materials [1].

Recently, the small form factor is not more differentiated point under the present condition that Flat Panel Display (FPD) technique is broadly growing. Currently TFT-LCD or PDP by using glass substrate must employ Batch process manufactured sequentially. However if flexible substrates are applied to OLED, mass production by using continuous Roll-to-Roll process which is similar to the printing a newspaper is possible [2]. Therefore this process has a merit that the fabrication cost can be much down. Now then the applicable material is limited to the polymer of the ink-type. To enhance the characteristic of these flexible Polymer Light Emitting Diode (PLED) devices, multiple thin films, in that, Hole Transfer Layer (HTL), Hole Injection Layer (HIL), Electron Transfer Layer (ETL), Electron Injection Layer (EIL) except Emission Layer (EL) is optionally fabricated. In the future, if the weakness about Water Vapor Transmission Rate (WVTR), that is, one of the biggest problems that these flexible devices have is covered with the thin film encapsulation, we can get a better flexible OLED device.

In this paper, the device of the 4 layers (ITO/PEDOT/EL/Cathode) on the PET substrate and the 5 layers which consist of LiF (1 ㎚) between emission layer and cathode is fabricated. Moreover we confirm the characteristics of the luminance and efficiency according to the polymer concentration.

2. Experimental

1. The fabrication & characteristics of flexible OLED

Thin films of high-performance low-temperature indium–tin–oxide (ITO) anode for OLED were deposited on a poly-ethylene-terephthalate (PET) substrate [3]. The device is the type of 2 ∗ 2 arrays and the emitting dimension is 4 mm^2. ITO electrode is patterned by photolithographic process and its processing temperature is not over 120 ℃ because of the weakness against high temperature. PEDOT (Poly(3,4-ethylenedioxythiophene)) is coated on the ITO substrate about 40 ㎚ thick. The spin velocity is

2500 *rpm* and the duration time is 100 seconds. The polymer as the emission layer is respectively made of 0.5 wt% and 0.7 wt% at toluene. Lastly aluminum of 150 nm electrode is evaporated as the cathode. The luminance and efficiency are measured with the fabricated device.

2. Thermal evaporation of Lithium Fluoride

Recently, the various materials are being researched to enhance the efficiency and driving voltage of the device. There are calcium and lithium fluoride as the favorite materials. In this study, we use LiF because the high pure calcium is difficult to handle. Previously on the evaporation of cathode layer, LiF (1 nm) is evaporated. Then we confirm the characteristic of the device. Figure 1 shows the schematic diagram of the fabricated device.

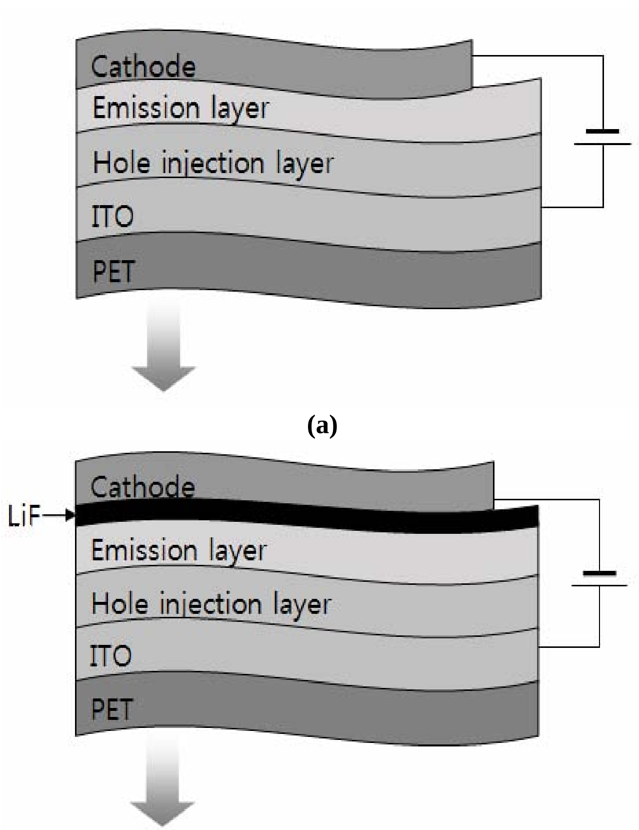

Fig. 1. Schematic diagram of the device; (a) 4 layers (b) 5 layers.

3. Results and discussion

The surface morphology of the flexible substrate was examined using atomic force microscopy (AFM). Figure 2 shows the result image of AFM which measured the surface of ITO film about before and after wet-etching process.

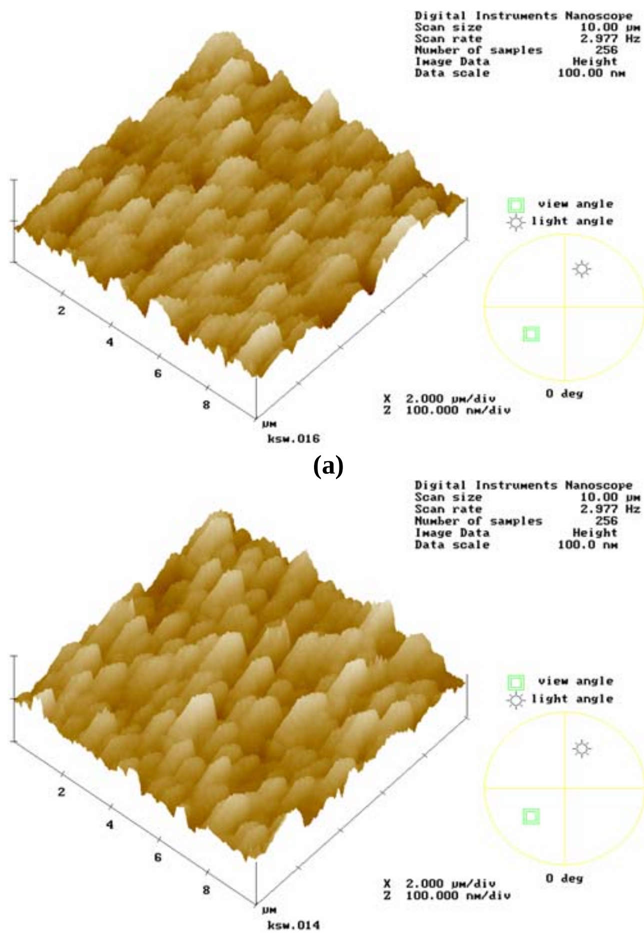

Fig. 2. AFM images of ITO surface; (a) before (b) after wet-etching.

The roughness of the wet-etched ITO is 12.09 nm and the roughness of the bare ITO is 11.51 nm. From this, the roughness of ITO because of wet-etching process shows almost no change. After spin-coating PEDOT as the hole injection layer on the ITO and coating polymer ink fabricated with the concentration respectively 0.5 wt% and 0.7 wt%, the luminance and efficiency are measured. Figure 3 and 4 show the above data.

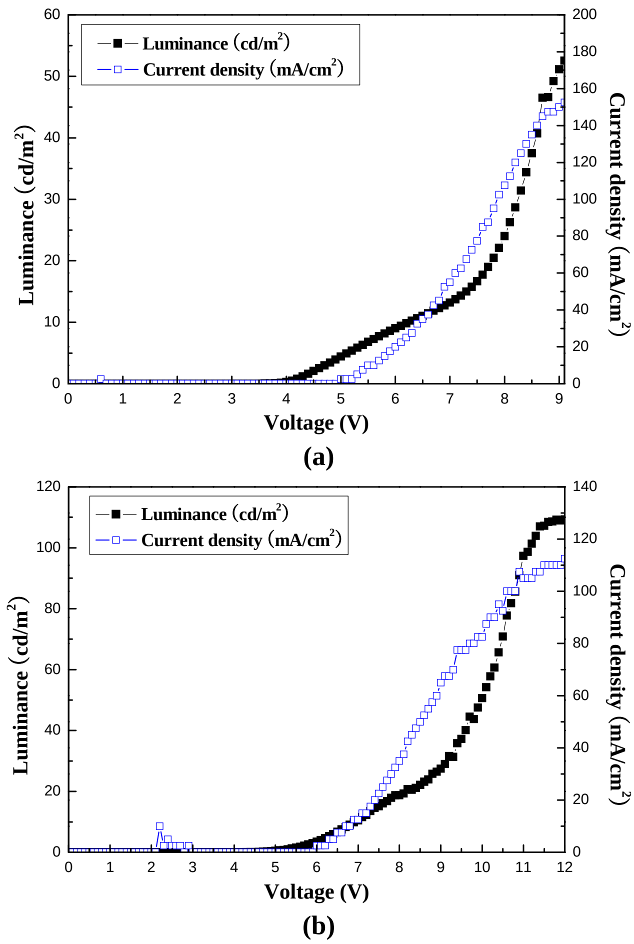

Fig. 3. Luminance of fabricated device; (a) 0.5 wt% (b) 0.7 wt% @ toluene.

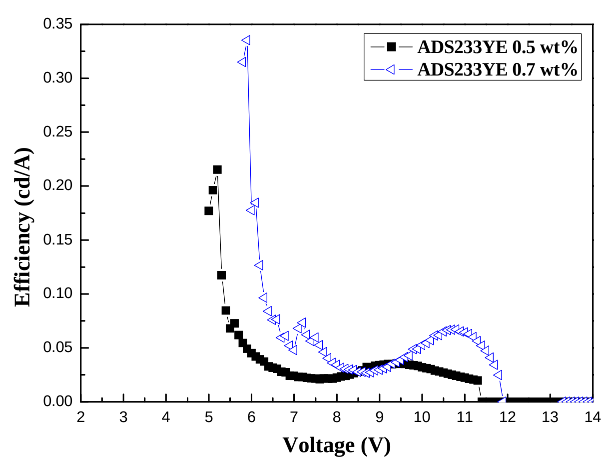

Fig. 4. Efficiency of fabricated devices.

As a result, the driving voltage is lower when the polymer ink is low concentration, but the luminance and efficiency decrease. Furthermore, the luminance and efficiency increase when the polymer ink is high concentration, but the driving voltage is higher. It shows that the more thickness of the polymer film increases the more driving voltage. However if the polymer ink is very high concentration, the luminance rather decreases. From this, the characteristic is reduced because the mobility of carrier decreases as a result of high cohesion among the molecular and the excitons in the film don't contribute to emission [4].

LiF evaporated as the buffer layer under the cathode decreases the driving voltage. Moreover, not only is applicable it on the PET substrate, but also glass substrate. Figure 5 shows that LiF monolayer affects the driving voltage and figure 6 is the photograph of the fabricated device.

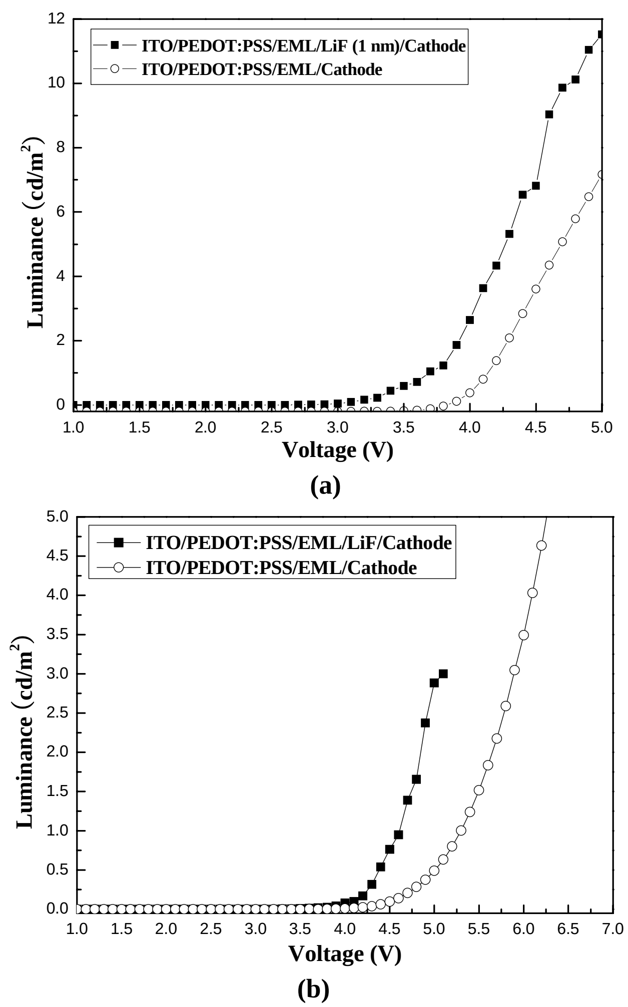

Fig. 5. Driving voltage dependence of LiF layer; (a) 0.5 wt% (b) 0.7 wt% @ toluene.

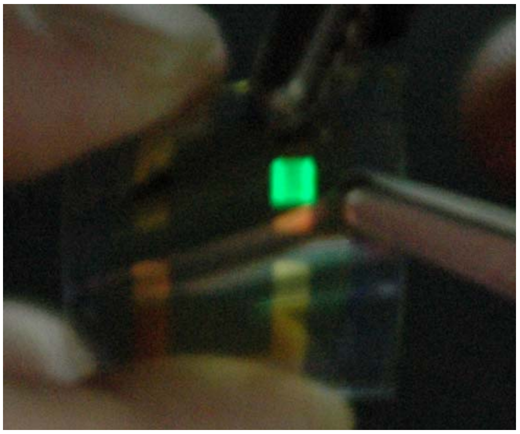

Fig. 6. Photograph of the fabricated device.

4. Summary

At first, the device of 4 layers structure is fabricated and the luminance and efficiency according to the polymer concentration is measured preparing ITO on the PET substrate having sheet resistance of 50±5 Ω/sq. As a result, the driving voltage of 4 V, the luminance of 53 cd/m^2 and the maximum efficiency of 0.22 cd/A are obtained under the polymer ink of 0.5 wt%. However, the driving voltage of 6 V, the luminance of 110 cd/m^2 and the maximum efficiency of 0.35 cd/A are obtained under the polymer ink of 0.7 wt%. Also, the driving voltage is possible to decrease about maximum 1 V by evaporating LiF buffer layer on the flexible substrate.

If the technique of the multiple thin film encapsulation using organic/inorganic materials is applied to secure the reproductivity and reliability of the fabricated device, it is possible to fabricate the better device.

5. Acknowledgment

This research was financially supported by the Ministry of Commerce, Industry and Energy (MOCIE) and Korea Industrial Technology Foundation (KOTEF) through the Human Resource Training Project for Regional Innovation and this work was supported by 2007 Regional Innovation System of Ministry of Commerce, Industry and Energy.

6. References

1. B. A. MacDonald, K. Rollins, D. MacKerron, K. Rakos, R. Eveson, K. Hashimoto and B. Rustin, *Flexible flat panel displays*, John Wiley & Sons, Ltd., pp.11-33 (2005).
2. F. Zhu, X. T. Hao, O. K. Soo, Y. Li and L. W. Tan, *IEEE*, Vol. 93, No. 8, August (2005).
3. K.J. Allen, *IEEE*, Vol. 93, pp.1394-1399, August (2005).
4. S. C. Gong, *Dankook Univ.,* p.42 (2005).