P-112: Passivation for flexible organic light emitting diodes using parylene

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Abstract

In this study, we tested parylene as the passivation layer for flexible organic light emitting diodes (FOLEDs).Parylene as passivtion layer has several advantages which are good optical transparent and low moisture penetration. For more an effective passivation of FOLEDs, we suggest hybrid passivation layer with parylene and silicon oxide. We compared electrical properties and stability of the device with and without passivation layer. The lifetime of FOLED with hybrid passivation layer was increased over three times than that of non-passivated of FOLED.

1. Introduction

Since organic light emitting diodes (OLEDs) were introduced by Tang and VanSlyke in 1987[1)] OLEDs have been extensively studies due to their properties such as low cost, low driving voltage and high brightness. Especially, flexible OLED (FOLED) has been expected novel application with some advantages, flexible, thin, and lightweight. Although OLEDs have many advantages, its stability and reliability are still a major problem[2-4)]. Particularly organic material is very sensitive to oxygen and moisture. As a result, when device is exposed in atmosphere included oxygen and moisture, its properties is decreased by degradation and brought about short lifetime. To overcome these weaknesses, encapsulation techniques using metal can or glass have been performed to protect the device from oxygen and moisture[5)]. Generally OLED based on glass adapted glass can and metal, those do not limit to application. However because glass and metal have demerits such as rigid and heavy weight, glass and metal are not suitable for FOLED based on plastic. So to reliability of FOLED, several methods have been suggested by other researchs[6-7)]. However, plastic substrates have weakness such as low thermal stability and scratch resistance. Also to increase of lifetime of FOLED, plastic substrates are subjected to permeation by moisture and oxygen is required gas barrier.

In this study, we use parylene and silicon oxide as passivation layer. Parylene can be used as insulator and protective coating material because of their high optical transparency, low gas and moisture penetration. Also they are deposited without pinhole[8)]. In order to improve stability of FOLED, silicon oxide was deposited as additional passivation layer over the device coated parylene. Generally, silicon oxide can be thought as a passivation layer for OLEDs because inorganic materials have great insulation property.

In this study, the effect of the passivation layer of FOLED using parylene and silicon oxide were investigated, and the results are discussed.

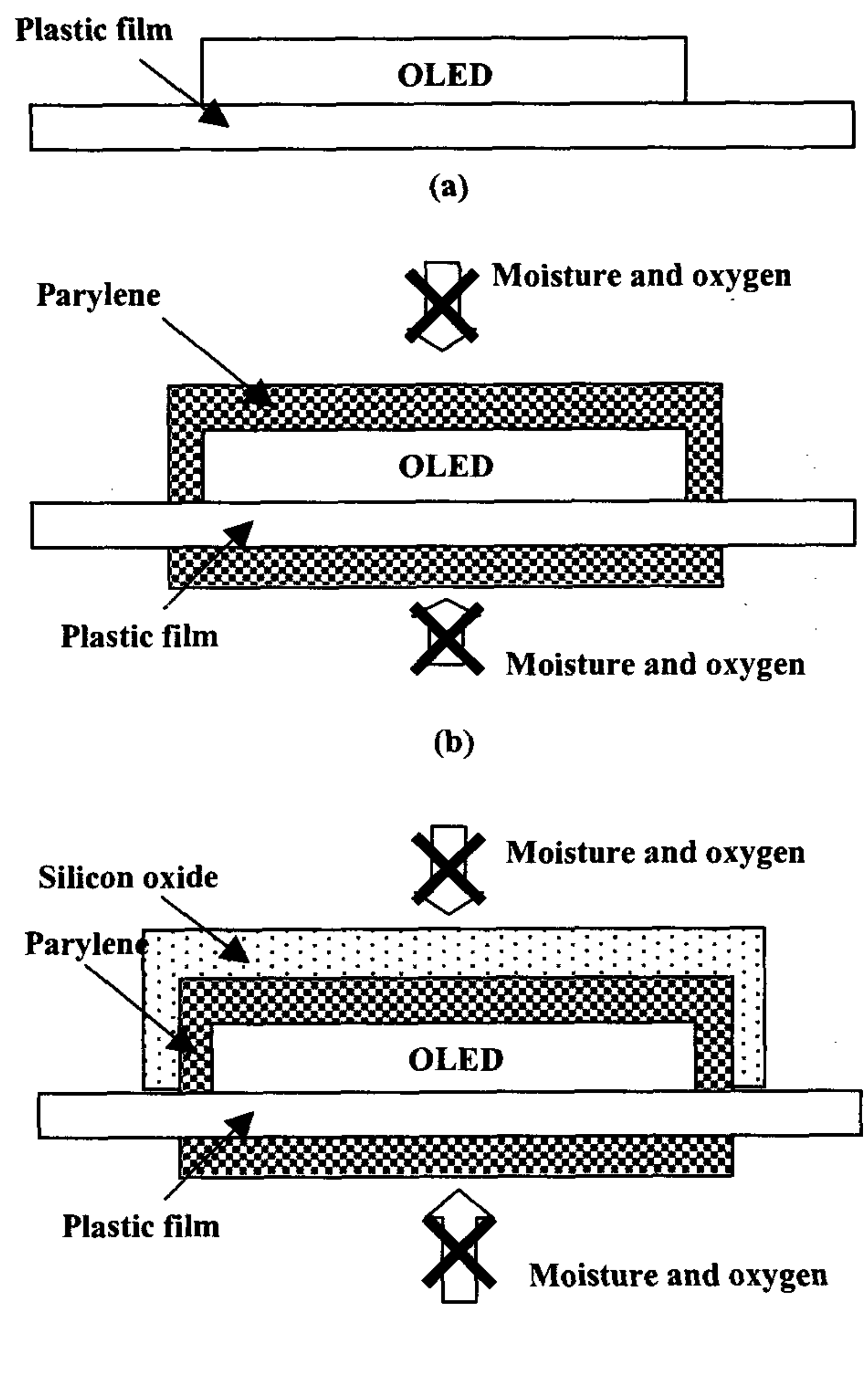


Fig. 1 Structure of flexible OLED as passivation layer

2. Experimental

For fabrication of FOLED, polycarbonate (PC) film with 200μm was used as the substrate. PC film was cleaned and patterned by photolithography process. Organic materials was deposited in this order: 20nm of 2-TNATA(4,4',4"-tris[N-(1-naphthyl)-N-phenylamino]-triphenylamine), 30nm of NPD (N,N'-Diphynyl-4N,N'-bis(1-naphthalyl) benzidine), 40nm of Alq3 (tris(8-hydroxyquinoline)aluminum). And then cathode that included LiF (1nm) and Al (120nm) was deposited. The device successively deposited by thermal evaporator below 2×10^{-6} Torr without breaking the vacuum. Parylene (5μm) was coated on device using dimmer C by vapor polymerization immediately, and then silicon oxide (300nm) was cover on parylene by e-beam evaporator. All passivation fabrication process proceeded at low temperature.

As passivation, we fabricated device of three types,

Device A: non-passivation : Fig. 1(a)

Device B: only-parylene passivation : (b)

Device C: hybrid passivation layer : (c)

I-L-V characterization of the device was measured by keithley 2400 source/measure units with brightness-calibrated photodiodes.

3. Results and discussion

Parylene is coated on all sides of device with uniform thickness. So, protective property of parylene affects both plastic film and device. In case of parylene coated on plastic film, it prevents oxygen and moisture to penetrate to organic layer through plastic substrate. Also, parylene directly covered with OLED, it prevents delamination of device and oxidation of cathode by moisture and oxygen.

When parylene is deposited on view side of film, optical transmittance must be considered since added layer is possible to decrease brightness and change spectrum.

Fig. 2 shows the optical transmittance of parylene with 5μm. Transmittance of parylene is over 90% in the visible range and less difference as wavelength. Above all parylene is thought to be acceptable to use as barrier coating layer of plastic film.

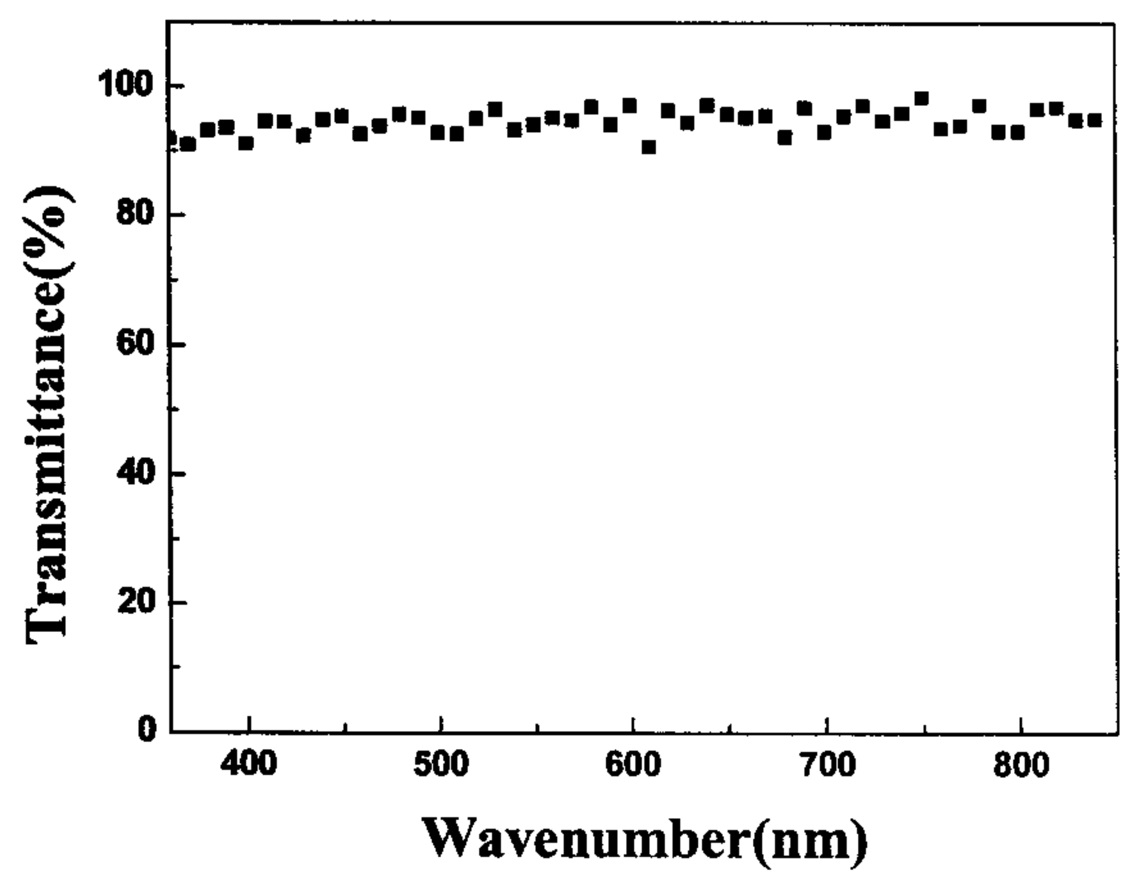
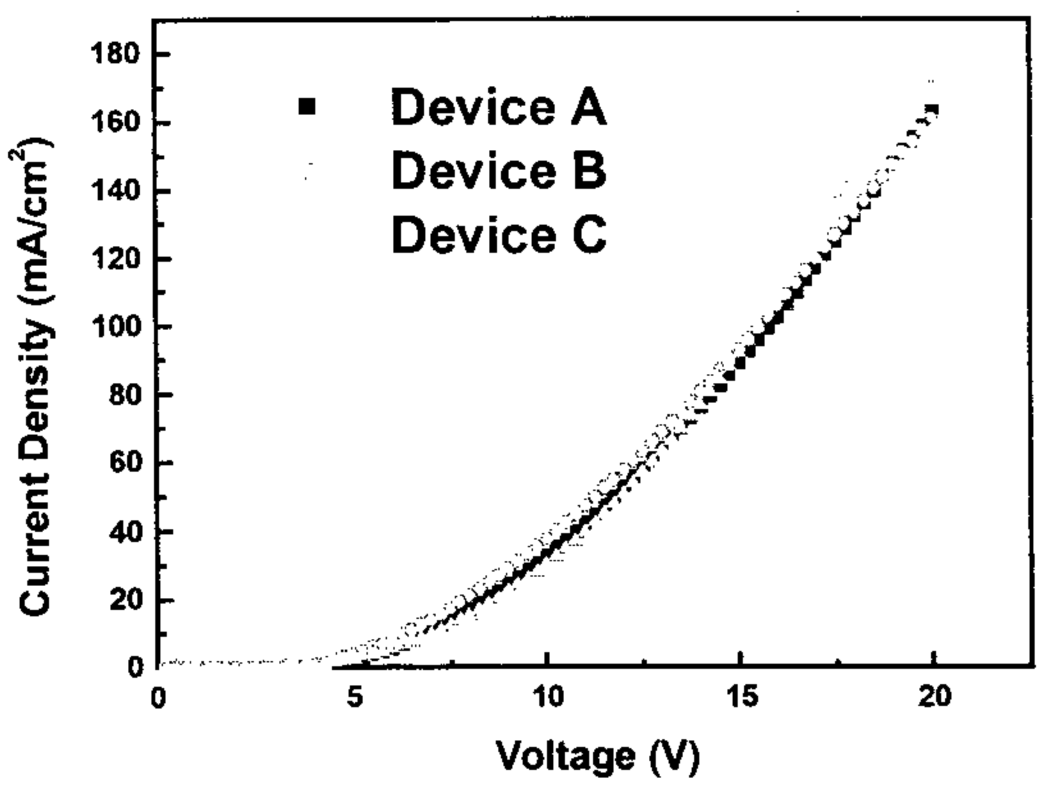


Fig.2 Transmittance of parylene 5μm

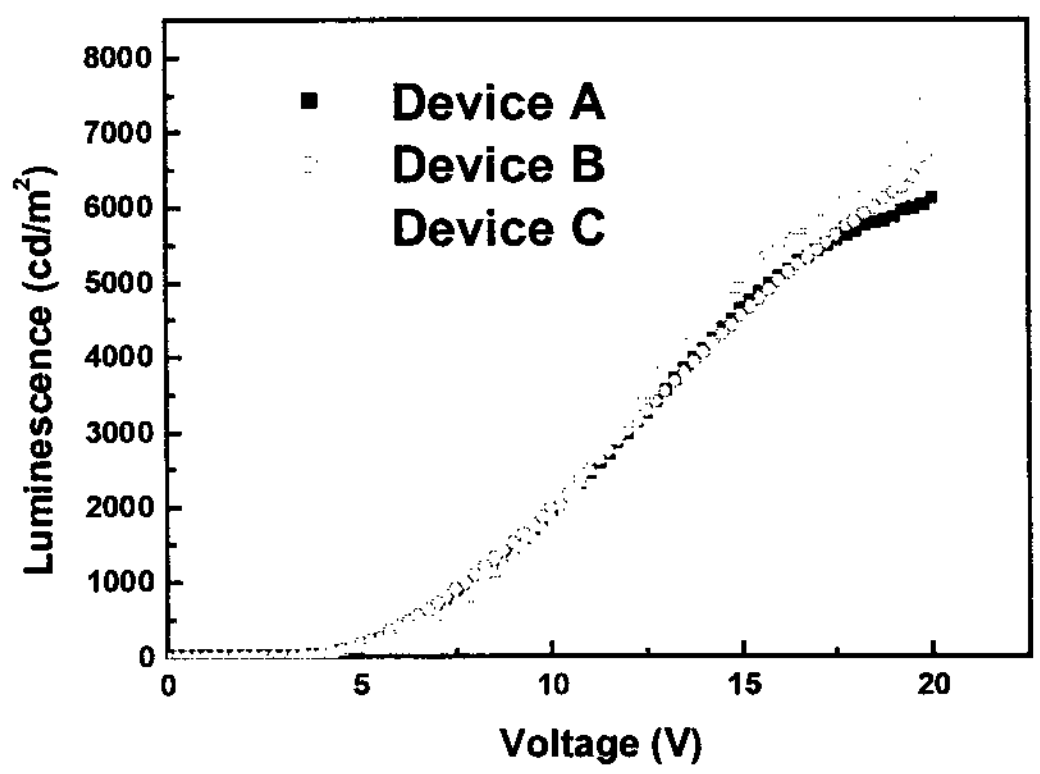
For comparison of electrical properties the devices with and without passivation layers were investigated. Fig. 3 shows the current-voltage characteristic curves and brightness-voltage characteristic curves of FOLEDs. The threshold voltage of the devices was 5V and maximum current is 160mA/cm^2. A brightness of device with active layer of 20mm^2 was achieved 1000cd/m^2 at approximately 8.5V. As passivation method, electrical properties of devices practically make no difference. It is shown that passivation layer doesn't affect electrical properties of devices.

After the operation of devices for 3 hours at constant current of 100mA/cm^2, we took an image of FOLEDs (Fig. 4). Device A was generated many dark spots because of moisture and oxygen permeation in atmosphere. On the other hand, dark spot of device C was distinctly reduced. We can assume that operation time of 3 hours is insufficient to moisture and oxygen permeation through plastic substrate. As a result, we consider that dark spot is not the effect of water and oxygen permeation through plastic substrate, but the effect of that from the top aspect.

The hybrid passivation layer of parylene-silicon oxide was good barrier to protect the top aspect of device from moisture and oxygen permeation in ambient.



(a) I-V curve



(b) L-V curve

Fig. 3 Electrical characteristics curve of flexible OLEDs as passivation layer

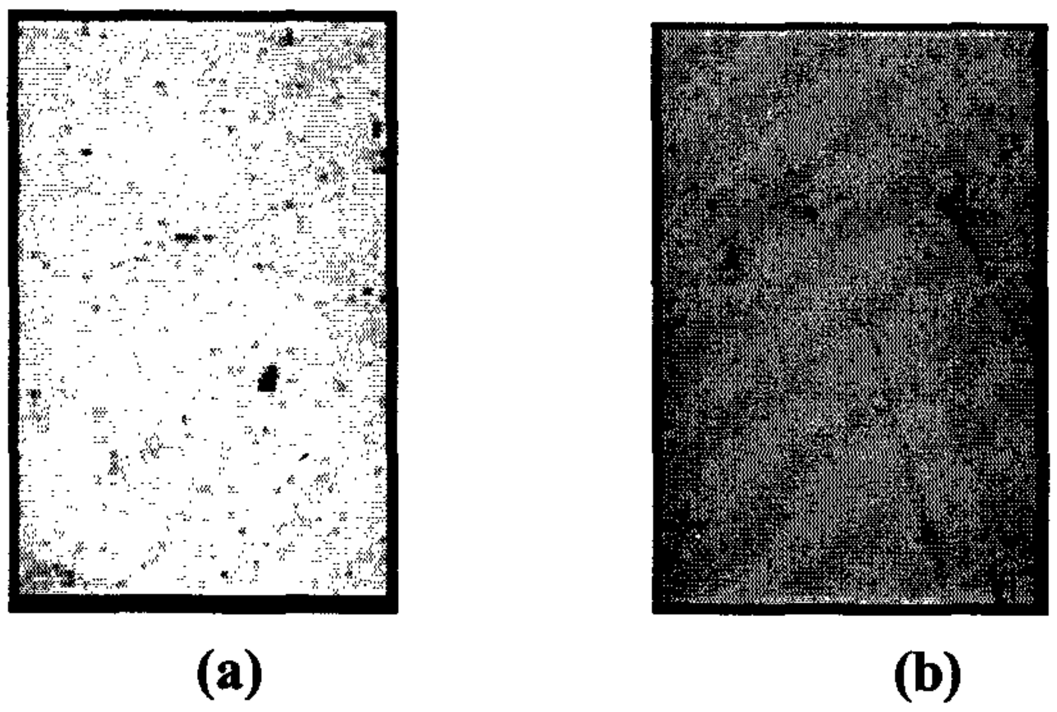
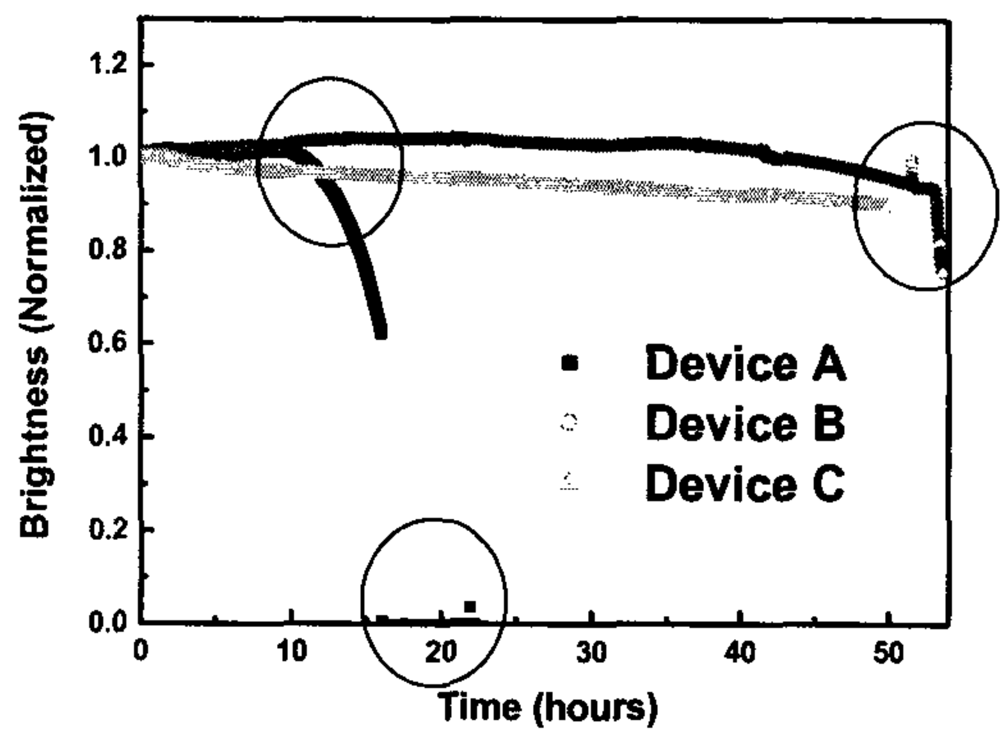
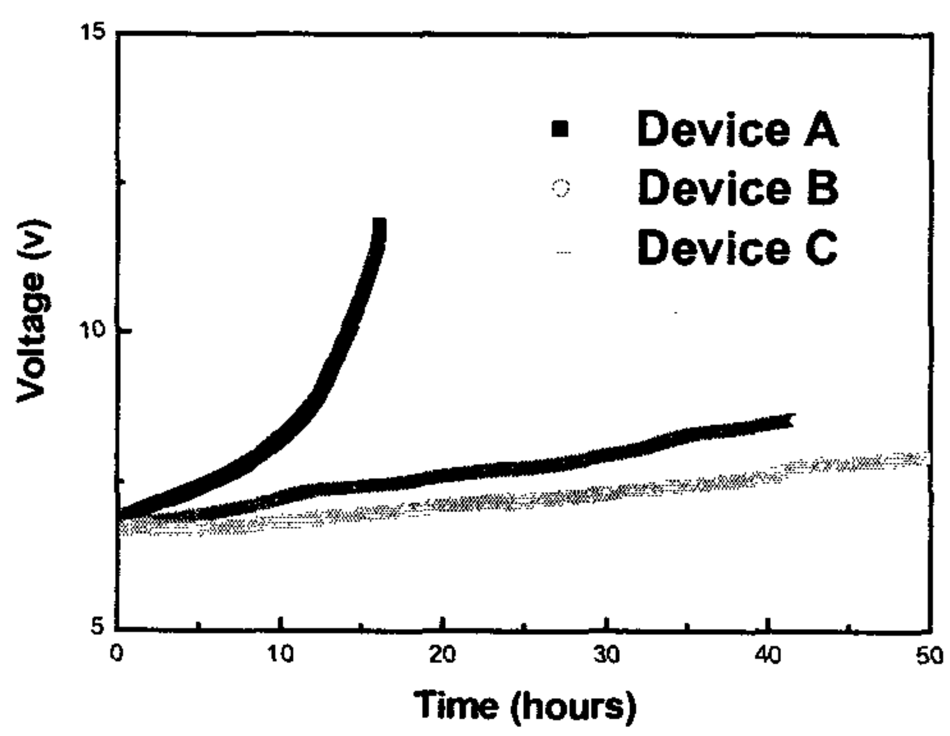


Fig. 4 Photos of the devices after 3 hours operation at constant current. (a) Device A (b) Device C



(a) Normalized Brightness of flexible OLED



(b) Voltage as operating time of flexible OLED

Fig. 5 Lifetime of flexible OLED

Fig. 5 shows lifetime of the device when operating at constant current. A brightness of device A rapidly decreased at 10 hours. After all, device A is not operating at 15 hours. However, the emitting light from device B and C was lasted over 40 hours from initial value of brightness. Device B has higher voltage and brightness as operating time than that of device C. The voltage and the brightness of device B was gradually increased by increasing resistance as formation dark spot in active layer. Above all, the brightness was rapidly decreased after 50 hours. We estimated that out coming light of device B would be weak by many dark spot. As a result, the device with hybrid passivation layer shows the longest lifetime, which is much better than device with parylene passivation layer or without passivation layer.

4. Conclusion

In this paper, we investigated electrical properties and lifetime of device with and without passivation layer. Although Parylene coating is more effective passivation layer because passivation layer is coated through all aspect, using only parylene as passivation layer is not perfect. Therefore we demonstrated hybrid passivation layer of parylene-silicon oxide.

Finally, flexible OLED with passivation layer of parylene and additional inorganic layer has more strong the stability of device based on plastic substrate.

5. Reference

[1] C. W. Tang, and S. A. Van Slyke, Appl. Phys. Lett. 51, 913 (1987).

[2] H. Aziz, Z. Popovic, S.Xie. A. M. Hor, N. X. Hu, C. Tripp, and G. Xu, Appl. Phys. Lett. 72, 756 (1988).

[3] R. Ono, M. Kiy, I. Biaggio, P. Gunter, Mater: Sci. Eng: B85, 144 (2001).

[4] S. F. Lim, L. Ke, W, and Wang, S.J. Chua, Appl. Phys. Lett. 78, 2116 (2001)

[5] Y. Kijima, N. Asai and S. Tamura, Jpn. J. Appl. Phys. 38, 5274, (1998)

[6] M. S. Weaver, L. A. Michalski, K. Rajan, M. A. Rothman, J. A. Silvernail, J. J, Brown, P. E. Burrows, G. L. Graff, M. E. Gross, P. M. Martin, M. Hall, E. Mast, C. Bohnam, W. Bennett, and M. Zurnhoff, Appl. Phys. Lett. 81, 2929 (2002).

[7] A. B. Chang, M. A. Rothman, S. Y. Mao, R. H. Hewitt, M. S. Weaver, J. A. Silvernail, K. Rajan, M. Hack, J. J. Brown, X. Chu, L. Moro, T, Krajewski, and N. Rutherford, Appl. Phys. Lett. 83. 413 (2003).

[8] Y. S. Jeong, B. Ratier, A. Moliton and L.Guyard, Synthetic Metal. 127, 189 (2002).