Lifetime characteristics of flexible organic light emitting diodes on PET substrate with plasma polymer barrier layers

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Abstract

Plasma polymerized para-xylene (PPpX) deposited by plasma-enhanced chemical vapor deposition (PECVD) was used as the barrier layer on the polyethylene terephthalate (PET) substrate to improve lifetime of the flexible organic light-emitting diodes (FOLEDs). The PPpX barrier layer deposited on top of the PET substrate with plasma power of 30 W at deposition pressure of 0.2 torr showed transmittance spectra good enough to be applied in FOLED on PET substrates. FOLEDs with the PPpX barrier layer (barrier-FOLEDs) showed similar I-V and B-V characteristics to FOLEDs without the PPpX layer (control-FOLEDs). The lifetime of barrier-FOLED was two times longer than that of the control-FOLED. With PPpX passivation layers, lifetimes of both control- and barrier-FOLEDs were improved by more than 4 times. These results show that PECVD deposited PPpX layers can be used as barrier layers for FOLEDs on plastic substrates as well as passivation layers for general OLEDs.

1. Introduction

In many cases, OLEDs have been fabricated on glass substrates, however, conventional OLEDs were several disadvantage for certain applications such as portable communication display, because the glass substrates are fragile and heavy. In order to overcome these disadvantages of conventional OLEDs, flexible OLEDs (FOLEDs) were made on plastic substrates by many research groups [1-6]. Generally, plastic substrates have water vapor permeation rates of $10\text{-}10^{-1}$ g/m^2/day at 25 °C, which is inadequate for OLEDs. Further lowered moisture permeability of 10^{-5} g/m^2/day is adaptable in OLEDs. For the purpose of reducing moisture permeability through plastic substrates, it is attempted to insert a barrier layer between the OLEDs and the plastic substrates. The plasma polymerized thin films can be deposited by plasma enhanced chemical vapor deposition (PECVD) [7]. Because of the highly cross-linked network structure, plasma polymerized thin films are pinhole free, mechanically and chemically stable, and strongly adhere to underlying layers. Therefore, plasma polymerized thin films are expected to prevent water and/or oxygen diffusion into the OLEDs and to be an effective barrier layer for OLEDs on plastic substrates.

In this work, we report FOLED lifetime enhancement by the plasma polymerized para-xylene (PP*p*X) barrier layer.

2. Results

In our experiment, polyethylene terephthalate (PET) was used as the plastic substrate. The PP*p*X barrier layer was deposited by PECVD at 0.2 torr. The deposition plasma power was varied in the range of 30-90 W. Figure 1 shows the transmission spectra of PP*p*X films on PET substrates for various plasma deposition power between 30 W and 90 W. Transmittance of PPpX in blue light range decreased as the plasma power increased. The PP*p*X deposited by plasma power 30 W showed a similar transmittance spectra of the PET substrate. It is considered that, the optical band gap of plasma polymerized film was related to concentration of C-H bond in the film [10]. Fourier transform infrared (FTIR) spectroscopy results showed that PPpX deposited at 30 W contains larger density of C-H bond than the other PP*p*X films deposited at higher plasma power. The indium-tin-oxide (ITO) anode was deposited with r.f. sputtering power of 50 W for 15 min and thickness of ITO was 150 nm. N,N'-diphenyl-N,N'-bis(3-methylphenyl)-1,1'-diphenyl-4,4'-diamin (TPD), tris-(8-hydroxyquinoline) aluminum (Alq_3), and Al were used as hole transport layer (HTL), emitting layer (EML), and cathode, respectively.

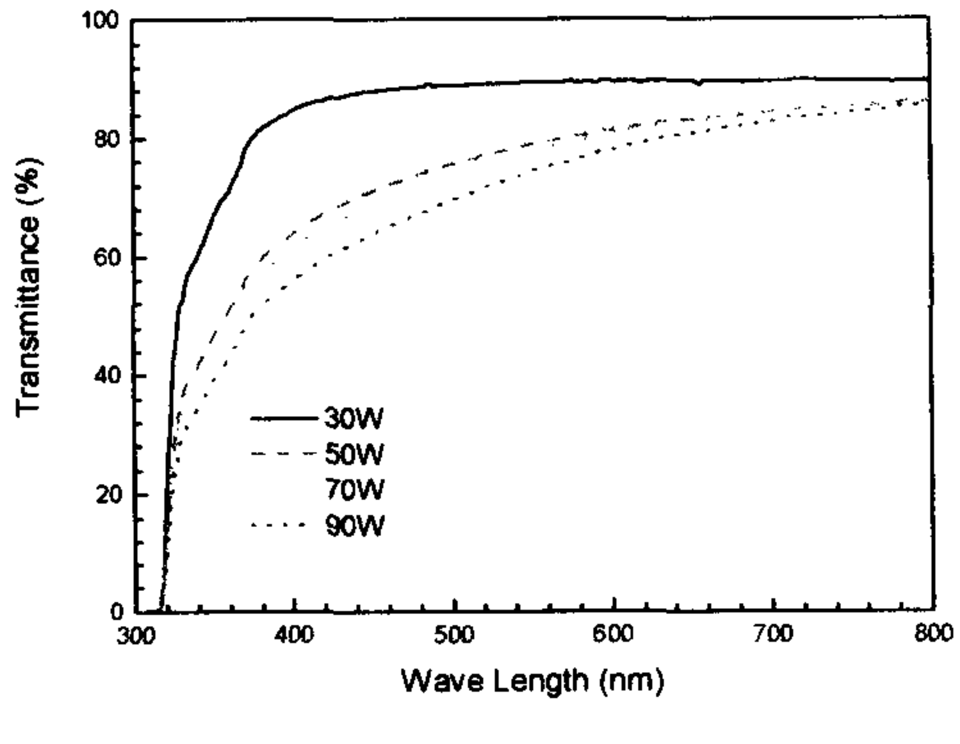

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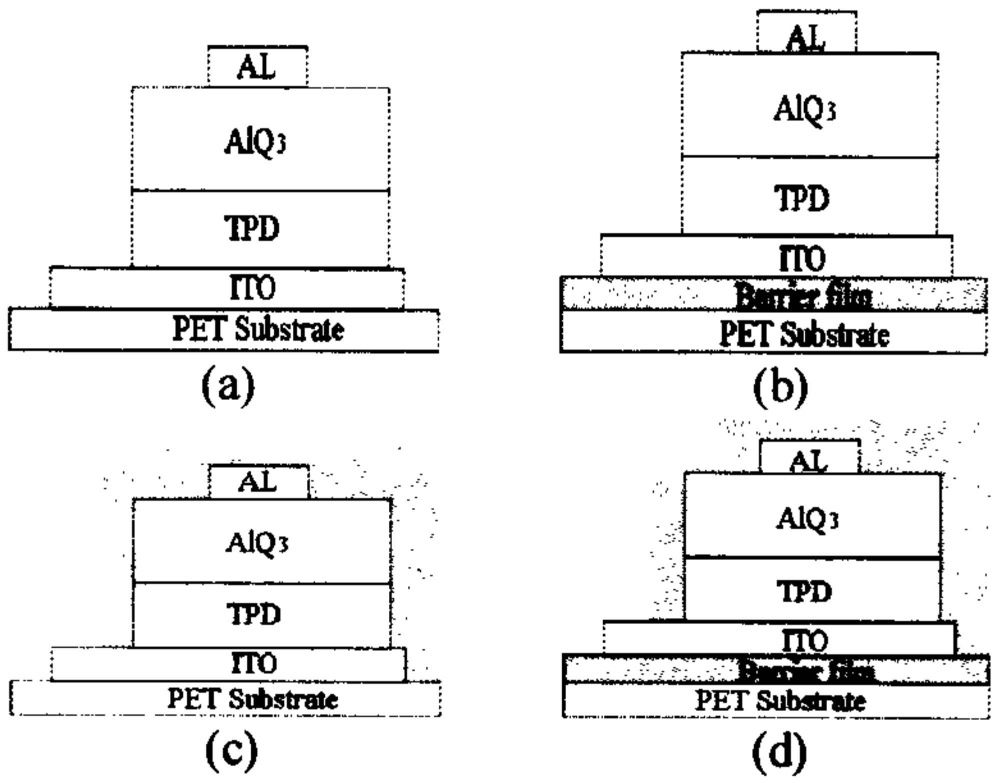
Figure 1. Transmission spectra of PPpX films on PET substrates deposited with different plasma power.

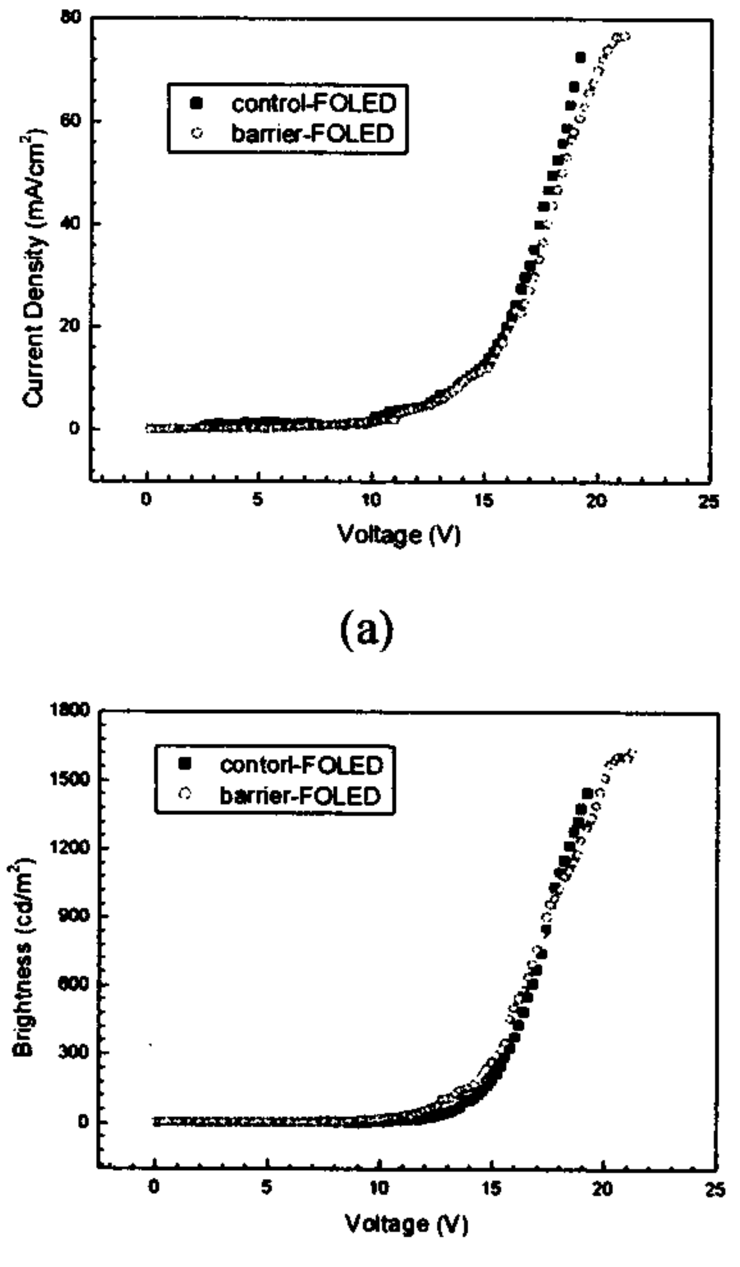
Figures 2(a) and 2(b) show structures of the FOLED without a barrier layer (control-FOLED) and the FOLED with a barrier layer (barrier-FOLED). The PP*p*X barrier layer was deposited with plasma power of 30 W at deposition pressure of 0.2 torr for 10 min. The thickness of barrier layer was 75 nm. In addition to a barrier layer, which was needed to prevent moisture penetration through the PET substrate, a passivation layer was also applied to our FOLEDs to prevent moisture penetration from surrounding ambient into FOLEDs. Use of the plasma polymer layer as an OLED passivation layer was previously reported [8,9]. Figures 2(c) and 2(d) show structures of the control-FOLED with passivation layer (passivated control-FOLED) and the barrier-FOLED with passivation layer (passivated barrier-FOLED). The thickness of PP*p*X passivation layer was 300 nm.



(a) (b)

(c) (d)

Figure 2. Structures of control-FOLED (a), barrier-FOLED (b), passivated control-FOLED(c), and passivated barrier-FOLED(d).



(a)

(b)

Figure 3. Current density versus applied voltage (a) and brightness versus applied voltage (b) for both the control-FOLED and barrier-FOLED.

Figures 3 (a) and 3(b) show the current density-voltage (J-V) and brightness-voltage (B-V) characteristics of control-FOLED and barrier-FOLED. The barrier-FOLED showed similar J-V and B-V characteristics to those of the control-FOLED.

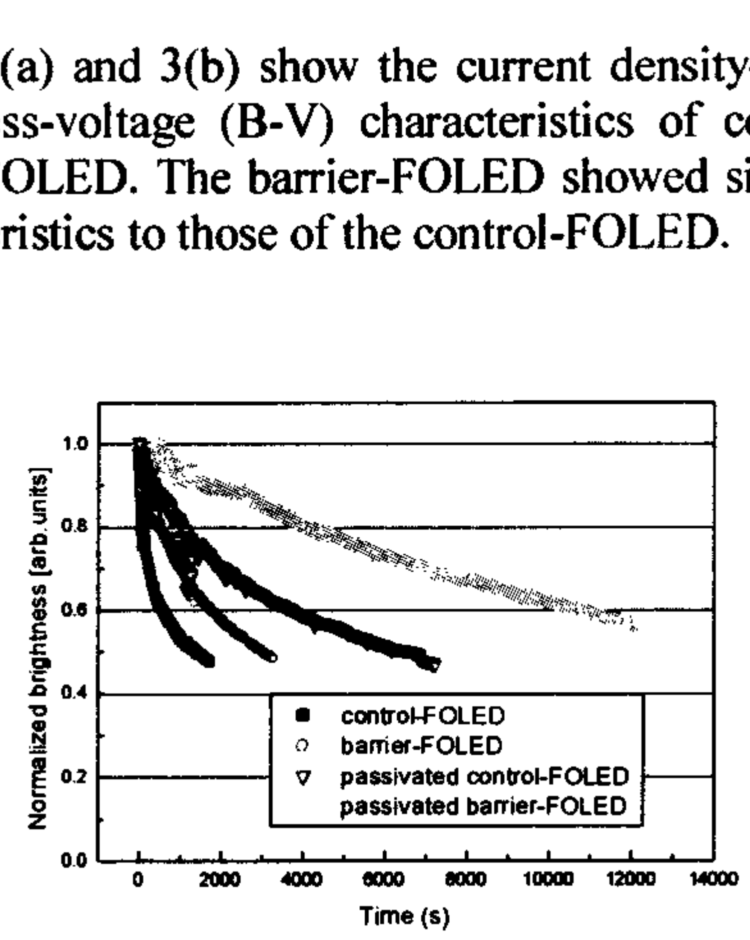


Figure 4. Lifetime characteristics of control-FOLED, barrier-FOLED, passivated control-FOLED, and passivated barrier-FOLED.

The lifetime characteristics of FOLED was measured at initial brightness of ~100 cd/m^2, and dc constant current of ~6.5 mA/cm^2 in air at room temperature. Figure 4 shows degradation characteristics of control-FOLED and barrier-FOLED. The time duration required for the brightness of the FOLED device to become half the initial value was referred to as the lifetime of the FOLED device. The lifetime of control-FOLED was 1,429 s while the barrier-FOLED was 3,022 s, twice larger than that of the control-FOLED. It is thought that the PP*p*X barrier layer reduced the penetration of moisture and/or oxygen through the PET substrate into FOLEDs, increasing lifetime of barrier-FOLEDs. With PP*p*X passivation layers, lifetimes of both control- and barrier-FOLEDs were improved by more than 4 times, as shown previously [11]. The passivated control-FOLED and the passivated barrier-FOLED showed device lifetimes of 6,690 s and 12,577 s.

3. Summary

The PPpX film was used as a barrier layer between FOLEDs and PET substrates. Barrier-FOLEDs showed similar J-V and B-V characteristics to those of control-FOLEDs. The lifetime of barrier-FOLED was two times longer than that of the control-FOLED. With PPpX passivation layers, lifetimes of both control- and barrier-FOLEDs were improved by more than 4 times. These results show that PECVD deposited PPpX layers can be used as barrier layers for FOLEDs on plastic substrates as well as passivation layers for general OLEDs.

4. Acknowledgements

This work was supported by Korean Science and Engineering Foundation through Center for Nanotubes and Nanostructured Composites.

5 Reference

[1] C. W. Tang, and S. A. VanSlyke, Appl. Phys. Lett. **51**, 931 (1987).

[2] T. Shimada, K. Hamaguchi, and A. Koma, Appl. Phys. Lett **72**,

1869 (1998).

[3] R. H. Friend, R. W. Grmer, A. B. Holmes, J. H. Burroughes, R. N. Marks, C. Taliani, D. D. C. Bradley, D. A. D. Santos, J. L. Bredas, M. Logdlund, and W. R. Salaneck, Nature **397**, 121 (1999).

[4] A. B. Chwang, M. A. Rothman, S. Y. Mao, Richard H. Hewitt, M. S. Weaver, J. A. Silvernail, K. Rajan, M. Hack, and J. J. Brown, Appl. Phys. Lett **83**, 413 (2003).

[5] G. Gu, P. E. Burrows, S. Venkatesh, S. R. Forrest, and M. E. Thompson, Opt. Lett. **22**, 173 (1997).

[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] D. Jung, H. Pang, J. H. Park, Y. W. Park, and Y. Son, Jpn. J. Appl. Phys. **38**, L84 (1999).

[8] H. Kubota, S. Miyaguchi, S. Ishizuka, T. Wakimoto, J. Funaki, Y. Fukuda, T. Watanabe, H. Ochi, T. Sakamoto, T. Miyake, M. Tsuchida, I. Ohshit and T. Tohm, J. Luminescence **87-89**, 56-60 (2000).

[9] A. L. Brody, Glass-coated flexible films for packaging: an overview, packag. Technol. Eng. February p. 44 (1994).

[10] A. Bubenzer, B. Dischler, G. Brandt and P. Koidl, J. Appl Phys. **54**, 4590 (1983).

[11] S. Kho, D. Cho and D. Jung, Jpn. J. Appl. Phys. 41, L1336 (2002).