The Fabrication of OLED using PBD as a Hole Blocking Layer

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Abstract
Oganic light emitting diodes (OLEDs) using PBD(2-(4-biphenylyl)-5-(4-tert-butylpheny)-1,3,4oxadiazole) as a hole blocking layer were fabricated and their device performances were investigated. The devices have a structure of glass substrate \ indium tin oxide (ITO) \ TPD (HTL) \PBD, BCP (HBL) \Alq3 (ETL)\Mg:Ag(cathode). In this work Bathocuproine(BCP:2,9-Dimethyl-4,7-diphenyl-1,10-phenanthroline) and PBD which were previously known as a good ETL material were used as a HBL. By employing HBL, the luminance and quantum efficiency of OLEDs could be improved due to the increase of recombination probability of electrons and holes.

1. Introduction

Since first reported by Tang and Van Slyke in 1987, OLEDs have been extensively studied as a candidate of next generation flat panel displays because of their high luminance efficiency, lower driving voltage, and full color emission [1,2]. The OLED usually composed of ITO anode, hole transporting layer, emitting layer, electron transporting layer, and a metal cathode. Varieties of organic materials such as sublimed monomers, conjugated polymers, and dye-polymer composites have been used for the fabrication of OLEDs [3].

The light emission in OLED is due to the recombination of holes and electrons injected from metal electrodes. Such recombination in the emitter layer creates molecular excitons, and the decay of excitons to ground state results in the luminescence. A concept of hole-blocking layer has been found effective to improve luminance efficiency of OLEDs . The effect of hole-blocking layer is to confine holes within an emitting layer. As the hole transport is more efficient than electron in organic films, hole-blocking layer inserted between HTL and ETL balances the number of holes and electrons in the emitting layer, and this improves the recombination probability. Recently a few materials have been employed as a HBL. Blue-emitting OLEDs were fabricated by using Bathocuproine and Salq, and a green-emitting OLEDs were fabricated using 2,4,6-Triphenyl-1,3,5-triazine(TTA). In this work, we have fabricated various green-emitting OLEDs using Bathocuproine and PBD as a HBL. We have found that PBD can be used as a HBL when inserted between ETL and HTL. Better device performances were observed with PBD as a HBL than BCP. We also have fabricated OLEDs using different materials for HTL. TPD have been used as a HTL and Mg:Ag (10:1) as a cathode. In this paper, we report the EL device performances of various types of OLEDs. The improvement of luminance efficiency via hole-blocking layer

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and the dependencies of EL efficiency on HBL thickness are discussed.

2. Experiments

The molecular structure of materials used are shown in Fig. 1. All the devices in this work have the configuration of indium-tin-oxide (ITO) anode/ HTL(TPD)/ HBL(Bathocuproine, PBD)/ ETL (Alq3)/cathode (Mg:Ag). The organic materials were purchased from Sigma-Aldrich and used as received. Indium-tin-oxide (ITO) coated glass having a sheet resistance of 10 / (Samsung Corning) was used as a substrate. The stripe pattern with a 2-mm wide ITO layer was etched by means of a conventional photolithographic technique. Prior to the organic deposition the patterned ITO glass was cleaned by ultra sonic treatment in a detergent solution, de-ionized water, acetone, and methanol and then dried with N_2 gas.

Organic materials were deposited by thermal evaporation under pressure of 6.5×10^{-6} torr at room temperature. On the ETL, cathode stripes with a 2 mm width perpendicular to anode stripes were prepared with a metal shadow mask by e-beam evaporation (Mg:Ag = 10:1). The thickness of HTL, ETL, and cathode was set to 450 Å, 650 Å, 2000 Å, respectively, and the thickness of HBL was varied.

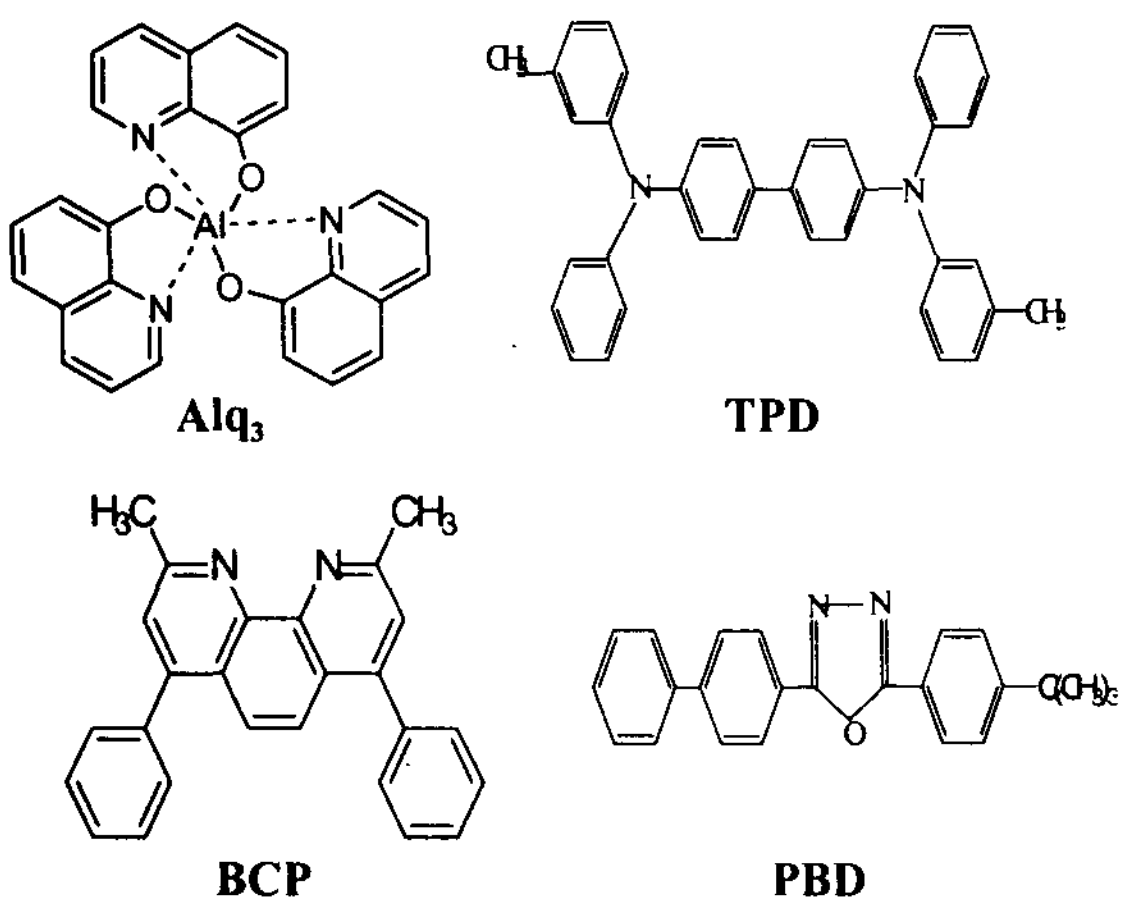


Fig. 1. Device configuration and molecular structure of the materials used in the present work.

Voltage versus current density was determined by Keithley 2400 electrometer, and the luminance and quantum efficiency of the devices were measured by Keithley 485 autoranging picometer. Surface image and roughness of the films were obtained using Atomic Forces Microscopy (AFM, D.I. Instrument).

3. Results and discussion

Fig. 2 shows AFM images of TPD film on Si wafer. Surface roughness of the films was compared by measuring their Rms (root mean squared roughness) value. The Rms values of TPD were 0.601 nm. When BCP was subsequently deposited on TPD films, the Rms values were increased to 0.708 nm.

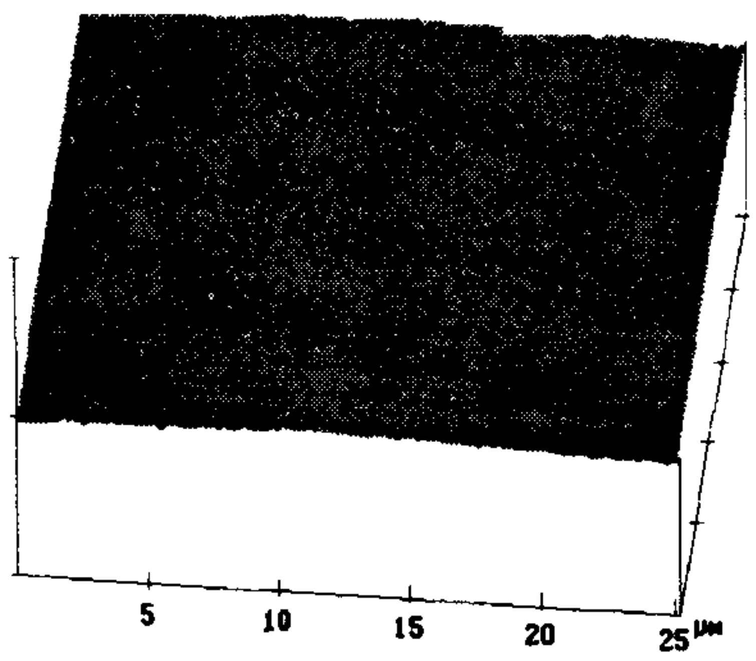
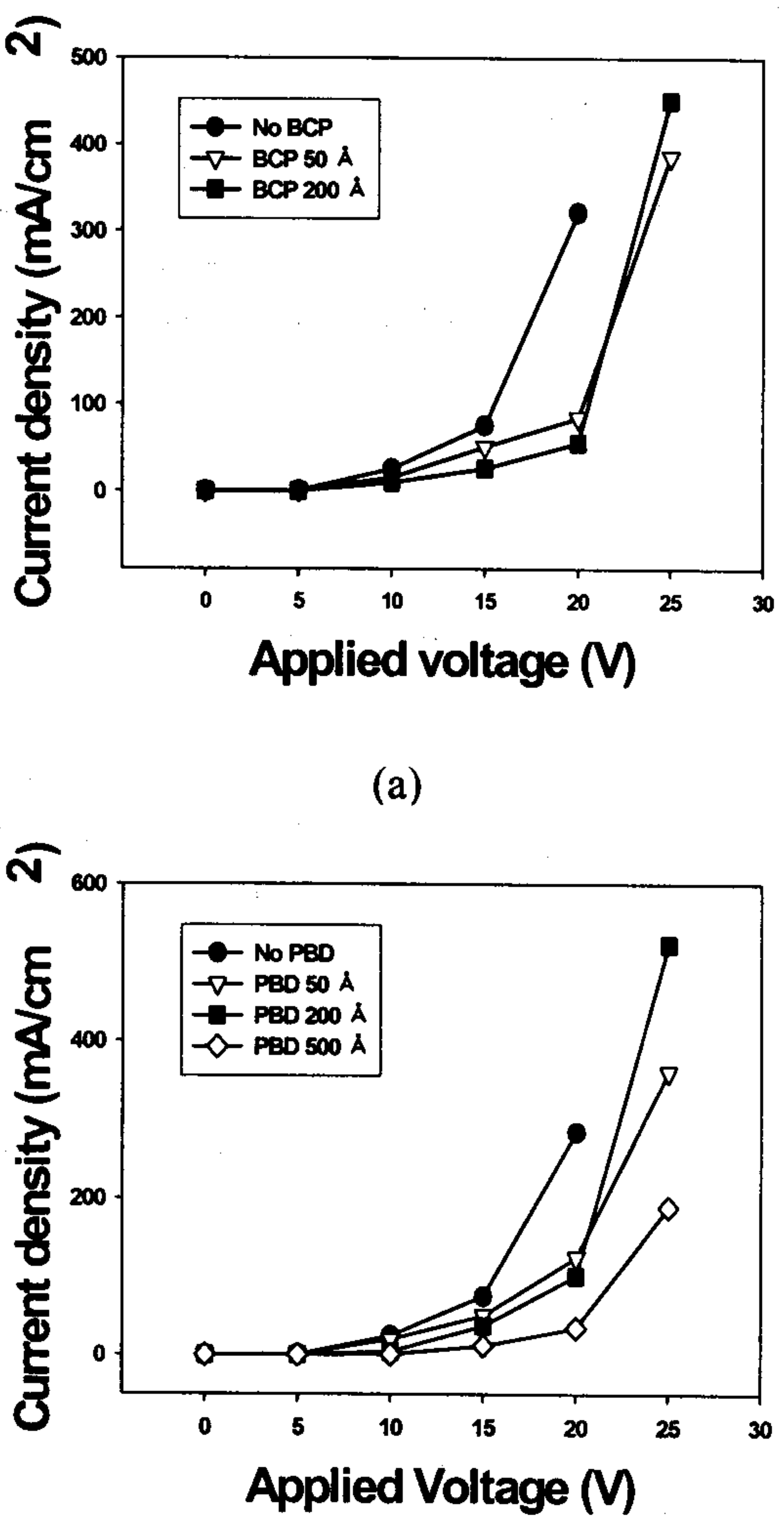


Fig.2. AFM image of TPD film by vacuum deposition method.

Fig. 3 shows the dependence of current density on applied voltage characteristics of EL devices with various thickness of HBL. The EL devices without HBL show lower turn on voltage, and as the applied voltage of the device increases, current density increases. The increment of the current density varies depending on the thickness of HBL. The maximum current density of 520 mA/ cm^2 was observed from device with 200 Å of PBD.

Fig. 4 shows the luminance-voltage characteristics of the devices. The luminance of the device increases as the thickness of HBL increases.

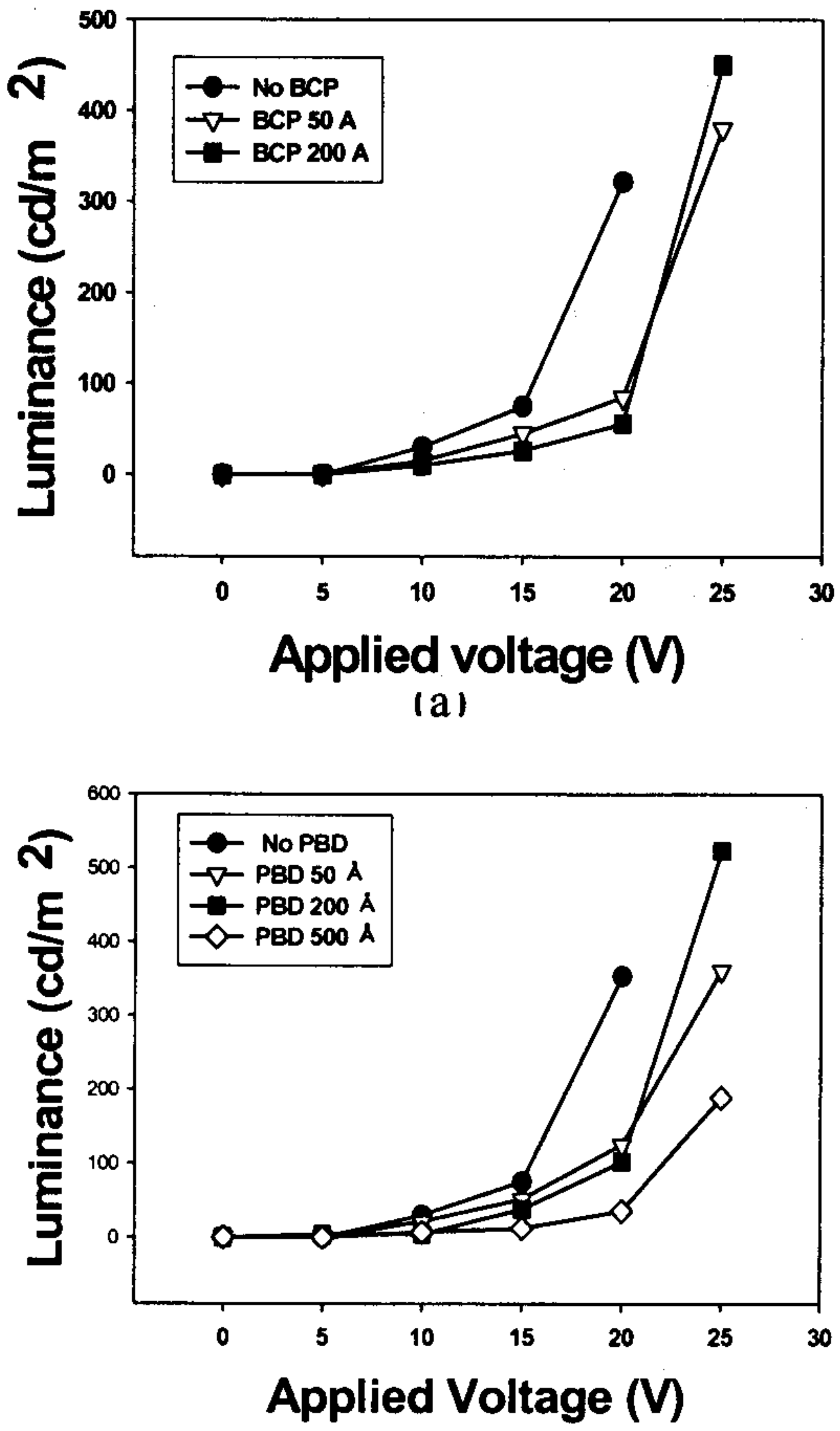


(a)

(b)

Fig. 3. Current-Voltage characteristics of EL devices with (a) BCP and (b) PBD as HBL

The similar trend was observed from other devices. The figure shows that insertion of HBL enhances the luminance of EL device, but its thickness should be optimized. The figure also shows that higher luminance can be observed when PBD are used as HBL. The highest luminance, 560 cd/m^2, was obtained from device with 200Å thick PBD operated at 25 V. Fig. 5 shows the external quantum efficiency dependence on current density of EL devices. Quantum efficiency expresses the

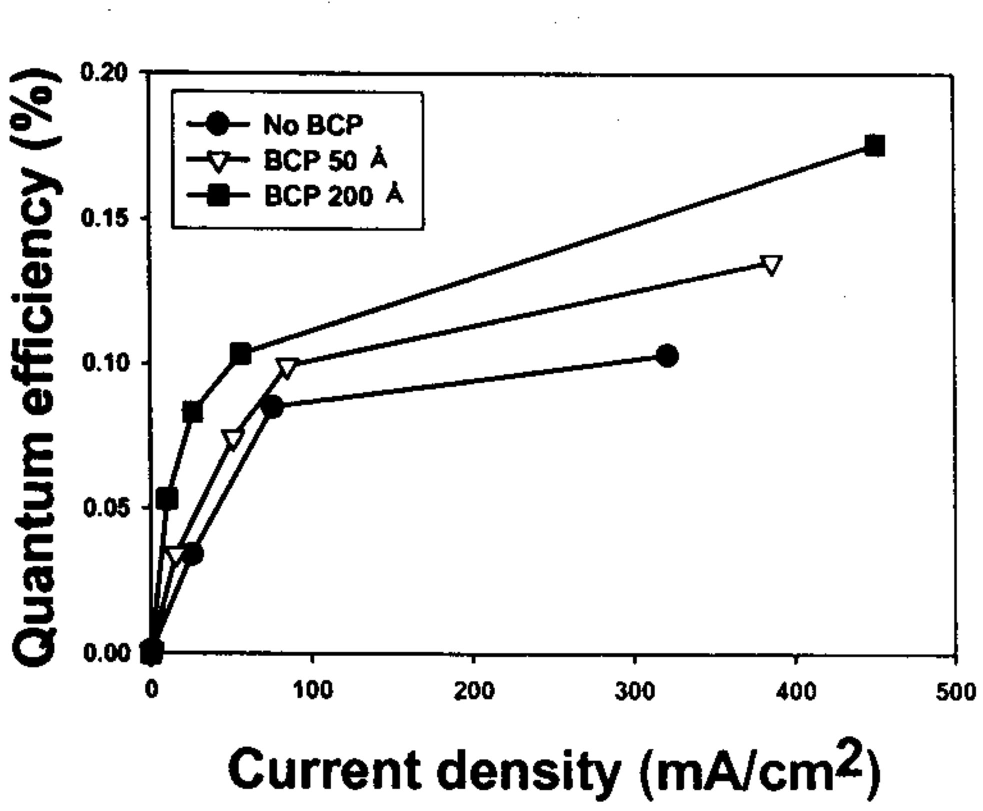


(a)

(b)

Fig. 4. Luminance-Voltage characteri- stics of EL devices with (a) BCP and (b) PBD as HBL

number of emitted photons to the number of injected electrons. The quantum efficiency of the HTL increases with the increase of current density. The highest quantum efficiency, 0.44%, was obtained from device with PBD thickness of 200Å. The figure shows that by the insertion of HBL, quantum efficiency of EL device can be improved. Higher quantum efficiency was obtained when PBD was used as HBL. Fig. 6 shows the energy band diagram of the EL devices. The HOMO (highest occupied molecular orbital) level and LUMO (lowest unoccupied



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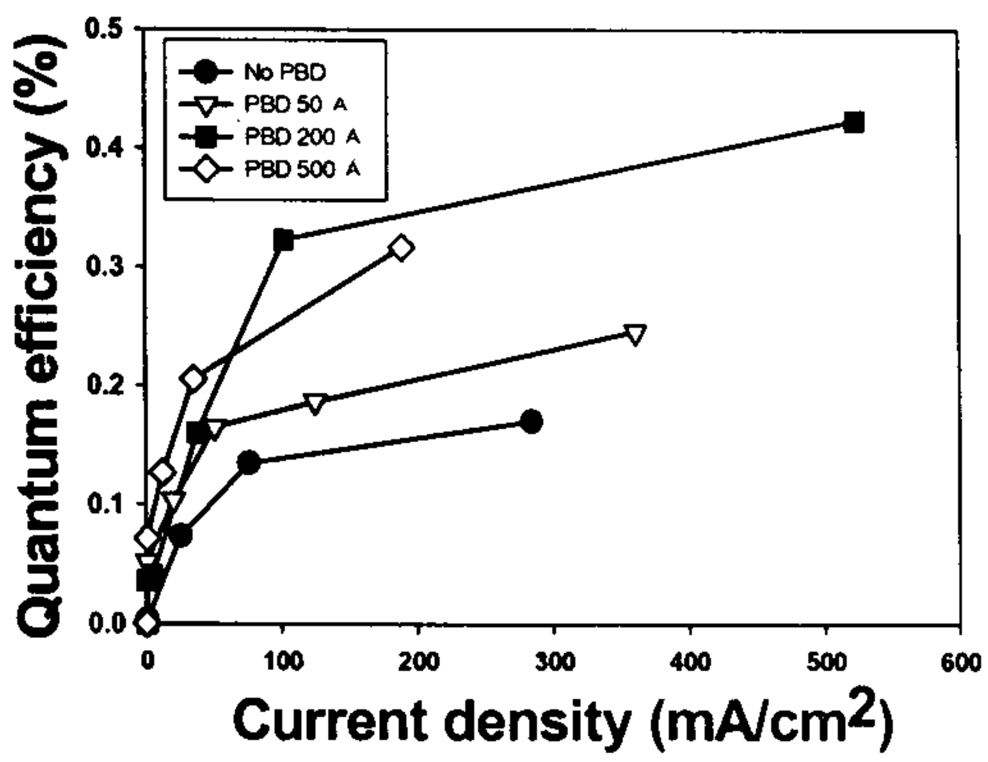

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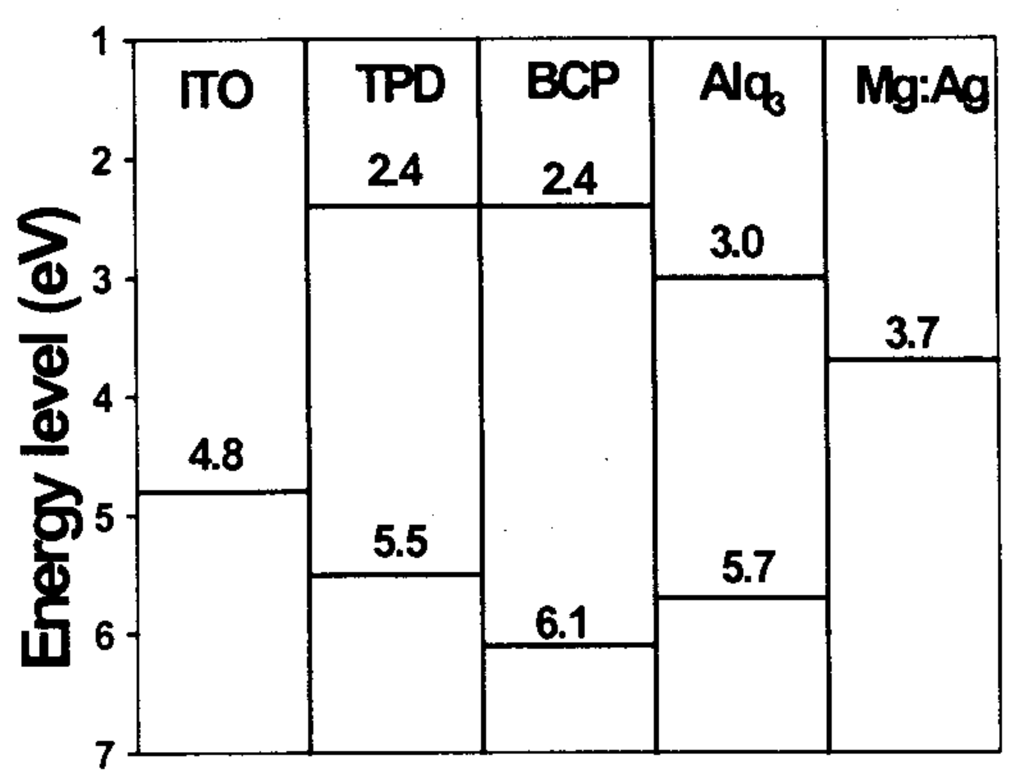
Fig. 5. The external quantum efficiency versus current density of the EL devices with (a) BCP and (b) PBD as HBL



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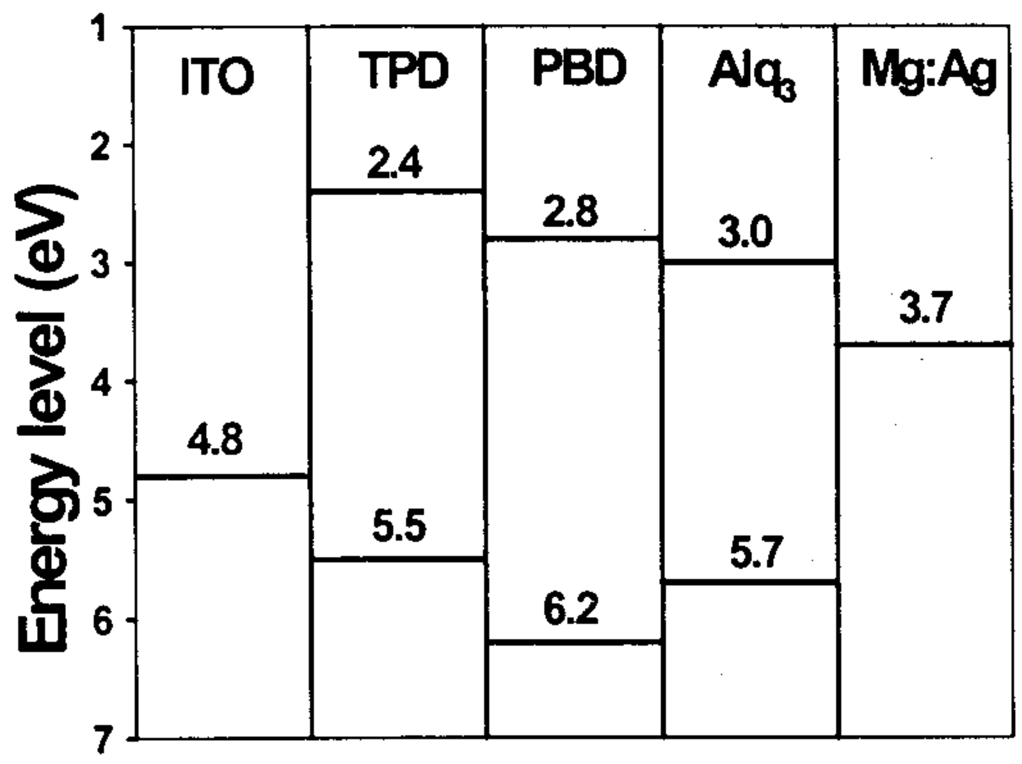

(b)

Fig. 6. The energy level diagrams of EL devices with (a) BCP and (b) PBD as HBL

each layer are listed. The injected holes from the ITO anode are transferred to the HOMO states of the HTL. But holes are blocked by HBL due to the energy barrier between HTL and HBL. The energy barriers between HTL and HBL of the devices with BCP and PBD are 0.6, and 0.7 eV, respectively. Both BCP and PBD can be used as HBL, and the recombination of holes and electrons are occurred between HTL and HBL.

4. Conclusion

OLEDs with a HBL were fabricated and their EL performance was studied. The insertion of HBL improves EL performance due to the increase of recombination probability of holes and electrons, but the thickness should be optimized to get high efficiency.

5. Acknowledgement

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6. References

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

[2] Tang, C.W., Van Slyke, S.A., and Chen, C.H., "Electroluminescence of Doped Organic Thin Films", *J. Appl. Phys.*, **65**, 3610 (1989).

[3] Baigent, D.R., Marks, R.N., and Friend, R.H., "Conjugated Polymer Light-emitting Diodes on Silicon Substrates", *Appl. Phys. Lett.* **65**, 2636 (1994).