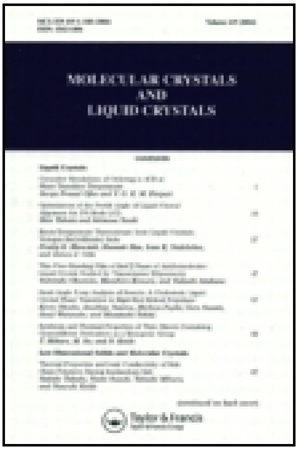

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Dual-Layer Light Emitting Devices Based on Polythiophene Derivative

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Electroluminescence (EL) and photoluminescence (PL) from dual-layer thin films made of poly(3-(2-benzotriazolo) ethylthiophene) (PBET) and Poly (2-methoxy-5-(2'-ethyl-hexyloxy)-1,4-phenylene vinylene) (MEH-PPV) have been investigated. In these devices, MEH-PPV was selected as a hole-transporting material based on the consideration of its electronic structures. The energy level of the highest occupied molecular orbital (HOMO) of MEH-PPV (-5.0 eV) lies between that of ITO (-4.8 eV) and that of PBET (-5.5 eV). We have found that the EL signal was almost exclusively generated within the emitting layer. The efficiency and the turn-on voltage measured from dual-layer device were improved 1.2 x 10^{-3} and 2.4 V, respectively.

Keywords polythiophene; hole transporting layer; PLEDs.

INTRODUCTION

The recent fabrication of polymer light-emitting diodes (PLEDs) requires a development of better electroluminescent materials with suitable thermal and mechanical properties. Since the fabrication of a PLED was reported in 1990,[1] many semiconducting polymers have been designed and synthesized. To achieve highly efficient PLED devices, charge (holes and electrons) injection and transport from both the anode and the cathode should be balanced at the junction of the emitting layer to yield the maximum excition formation.[2] However, in general the PLEDs efficiencies are still not high enough. In 1993, Greenham *et al.* reported an efficient LED heterostructure configuration in which a double layer was formed to achieve a better charge injection and charge confinement.[3] In our early study, PBET was synthesized to increase a quantum efficiency by introducing benzotriazole, an electron withdrawing moiety, to the thiophene. Even though the quantum efficiency was increased, enhancement could not satisfy our expectation. In this work, MEH-PPV is suitable for usage as the hole transporting layer (HTL) in the dual layer film made of MEH-PPV and PBET, because the energy level of the HOMO of MEH-PPV lies between that of ITO (-4.8 eV) and that of PBET (-5.5 eV). The dual-layer device offered enhanced quantum efficiency and reduced turn-on voltage compared to these of single-layer.

EXPERIMENTAL

PBET was polymerized by oxidation of ferric chlorid as previously described.[4] MEH-PPV was purchased from UNIAX and used without further purification. The structures of polymers are shown in Figure 1. No significant solubility of MEH-PPV material was observed in dimethylformamide (DMF). The HTL (13 nm) was fabricated by spin-casting the xylene solution (0.1 wt%) of MEH-PPV onto ITO substrates and then cured at 60 ℃ for 60 min in a vacuum oven. The emissive layer was spin-cast from its DMF solution (0.04 g / ml) on the HTL with a thickness of 80 nm. To investigate EL characteristics, on the top of this films, a 120 nm thick Al layer was vacuum-deposited (6×10^{-6}) through a mask. All processing steps for EL characteristic measurements were carried out air and room temperature.

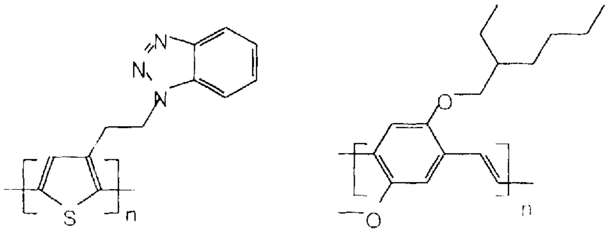
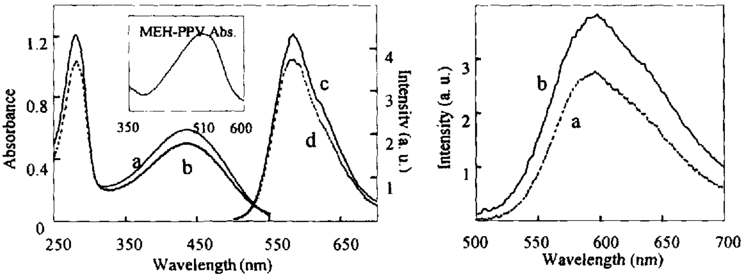


FIGURE 1. Structures of PBET and MEH-PPV.

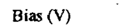
RESULTS AND DISCUSSION



(A) (B)

FIGURE 2. (A) Comparison of absorbance and PL spectra of thin films (a: Abs. of MEH-PPV/PBET, b: Abs. of PBET, c: PL of MEH-PPV/PBET, d: PL of PBET) (B) EL emission spectra (a: single-layer device, b: dual-layer device).

Figure 2 (A) shows a comparison of the absorbance and PL spectra from the PBET single-layer and MEH-PPV / PBET dual-layer films. In the inset of (A), the absorbance of MEH-PPV was also exhibited. We observed no change of absorption and emission peaks of dual-layer compared to these of PBET single-layer. In parallel, as shown Figure 2 (B), the EL peaks of single and dual-layer devices were also same. However, the EL intensity of the dual-layer system containing MEH-PPV as a HTL was more improved than that of the PBET single-layer system.



(A) (B)

FIGURE 3. (A) Energy diagram of the dual-layer device in zero bias. (B) I-V-L curves of single and dual-layer devices (a. c : I-V-L curve of ITO / MEH-PPV / PBET / Al, b. d : I-V-L curve of ITO / PBET / Al).

The energy diagram of polymers was presented in Figure 3 (A). The energy level of PBET estimated from the data of ultraviolet photoelectron spectroscopy and UV-vis spectroscopy. The electronic structure of MEH-PPV has LUMO at - 2.9 eV and HOMO at - 5.0 eV.[5] The insertion of MEH-PPV as a HTL layer between ITO and PBET creates a sizable offsets (0.5 eV) for hole injection from ITO to PBET. Therefore, under forward bias, efficiently the holes transported to the emitting polymer. In Figure 3 (B) as the current-bias-luminance (I-V-L) characteristics, compared to the PBET single-layer device without a HTL, the turn-on voltage of MEH-PPV / PBET dual-layer device was dramatically reduced from 10.4 V to 2.4 V. The external quantum efficiency was also improved from 3×10^{-4} to 1.2×10^{-3}.

CONCLUSIONS

We have shown a way in which MEH-PPV can be used for enhancement of performances in PLEDs. That was attributed to HTL having a sizable offset between a hole injection layer (ITO) and a emitting layer (PBET). The efficiency and turn-on voltage of dual-layer device were improved 1.2×10^{-3} and 2.4 V, respectively.

Acknowledgment

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