

Blue Organic Light Emitting Diodes with Carbazole Based Small Molecules

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Abstract

We synthesized Bis(3-N-ethylcarbazolyl) terephthalidene (BECP) and Bis(3-N-ethylcarbazolyl) cyanoterephthalidene (BECCP) and characterized EL properties of these materials. Our device shows a strong blue emission at 472 nm with a luminance efficiency of 0.9 lm/W at a voltage, a current density, and a brightness of 8 V, 5.7 mA/cm², and 130 cd/m², respectively.

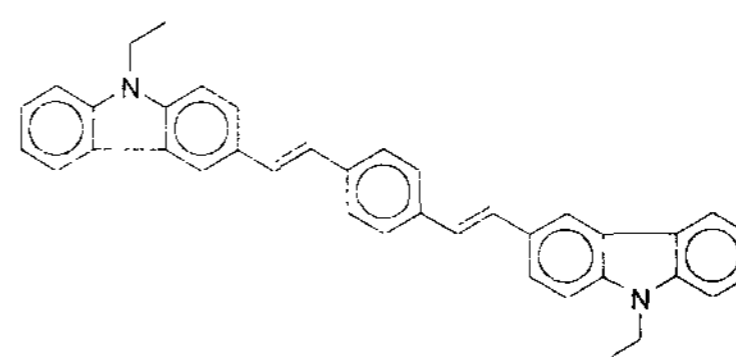
1. Introduction

We have fabricated blue emitting organic electroluminescent devices (OLEDs) with a carbazole based emitting molecule, Bis(3-N-ethylcarbazolyl) terephthalidene (BECP) that are stable in air. Our device emits strong blue at 472 nm with a peak efficiency of near 1 lm/W. Hosokawa *et. al.* [1] have used the same material as a fluorescent dopant with distyrylarylene derivative (DSA) as a host emitting molecule. They have reported a luminance efficiency of 0.7 lm/W and 1.5 lm/W for the DSA only and the DSA:BECP devices, respectively. Our result suggests that the use of BECP itself as an emitting material is possible, and it may eliminate the doping procedure. In order to demonstrate color tuning, we also compare the electroluminescence (EL) of a BECP device with that of Bis(3-N-ethylcarbazolyl)cyanoterephthalidene (BECCP) a derivative of BECP with a substituted cyano group.

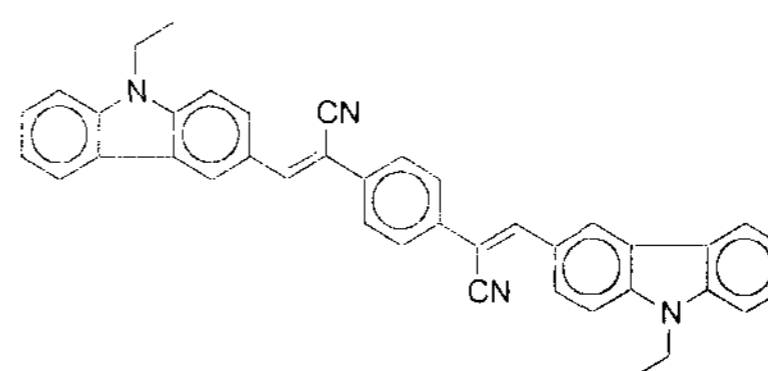
2. Experimentals

An emissive material, BECP, was synthesized by well known Wittig reaction: *p*-xylylenbistriphenyl phosphonium chloride (2.5 g), potassium *t*-butoxide (1.19 g) and DMSO (50 ml) were mixed and stirred with slow adding of 9-ethyl-3-carbazole carboxaldehyde (1.59 g) under the N₂ condition. After stirring at room temperature for about 7 hours, the reaction mixture was poured into an excess of methanol giving a yellow solid. This solid was finally

purified with appropriate solvents and filtered to give high purity bright yellow powder. Another emitting material, BECCP, was synthesized as reported elsewhere [2]. First a hole conducting buffer layer with film thickness of 20 nm was prepared by vacuum evaporation of alpha-copper-phthalocyanine (CuPc) onto the indium tin oxide (ITO) glass. A hole transport material, N,N-diphenyl-N,N-bis(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine (TPD), emitting materials, BECP or BECCP, and electron transport materials, tris-(8-hydroxyquinoline) (Alq₃) or an oxadiazole derivative Bu-PBD) were successively vacuum deposited with a thickness of 60 nm, 40 nm and 20 nm, respectively. For all the organic materials, deposition rate was about 0.1 nm/s. Cathode metal was prepared by successive deposition of LiF (1.5 nm) and Al (150 nm) with evaporation rate of 0.01 nm/s and 0.5 nm/s, respectively. A vacuum pressure of 5 X 10⁻⁶ Torr was maintained during the all vacuum depositions. A typical device structure is Device 1: ITO/CuPc(20nm)/TPD(60nm)/BECP(40nm)/PBD(20nm)/LiF(1.5 nm)/Al(150 nm), Device 2: ITO/CuPc(20 nm)/TPD(60nm)/BECP(40nm)/Alq₃(20nm)/LiF(1.5 nm)/Al(150nm) and Device 3: ITO/CuPc(20nm)/ TPD(60nm)/BECCP(40nm)/PBD(20nm)/LiF(1.5nm)/Al(150nm)



BECP



BECCP

3. Results and Discussion

The current-voltage characteristics of devices 1 and 2 are compared in Fig. 1 and the brightness and the luminance efficiency are shown in Fig. 2. It is clear

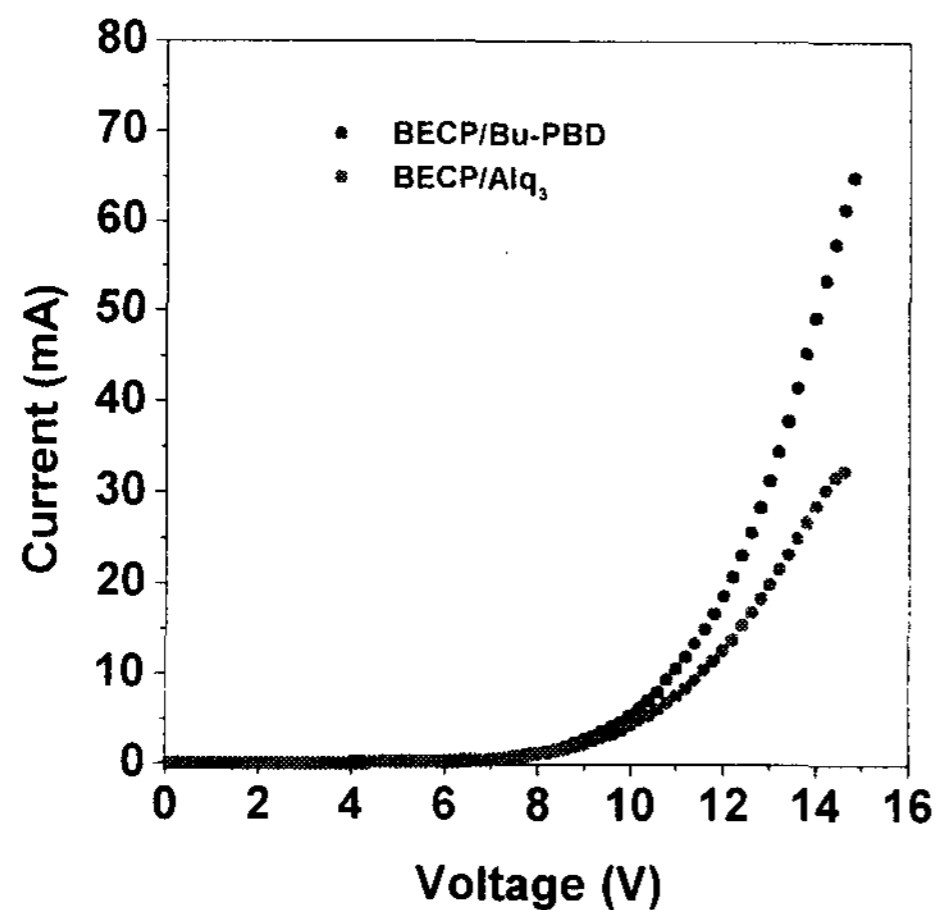


Fig. 1. I-V characteristics for devices 1 and 2.

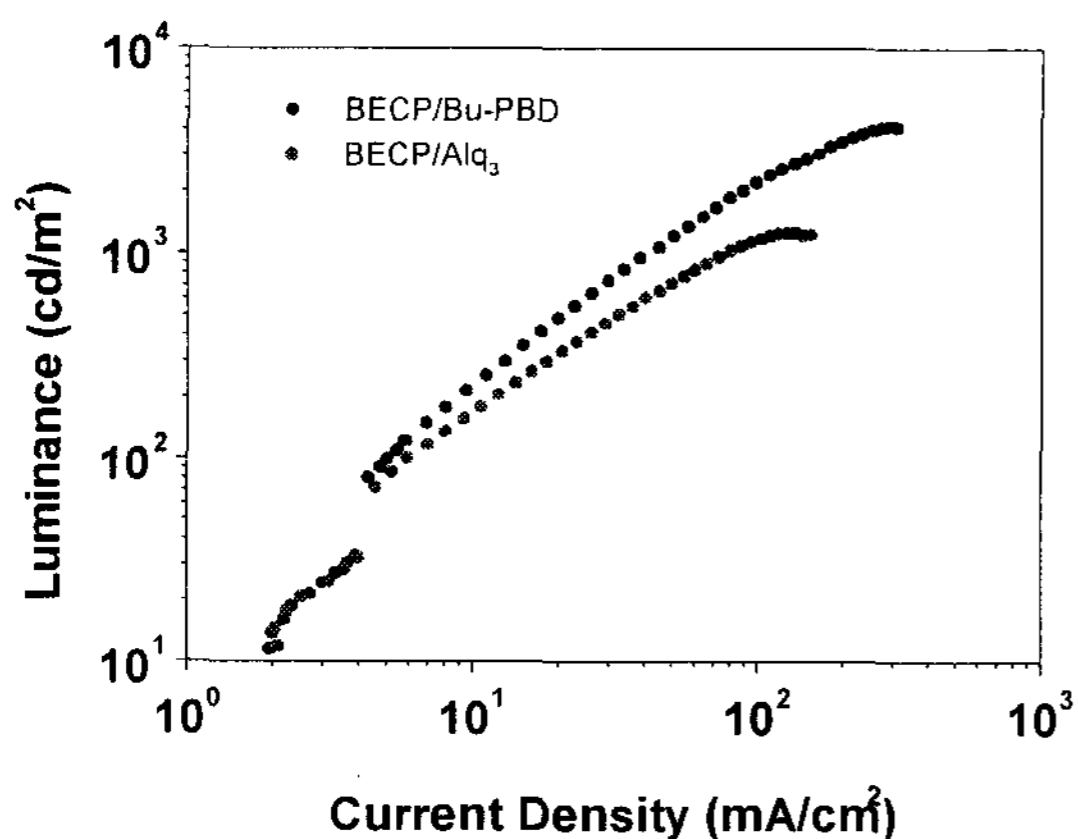


Fig. 2. Luminance-current characteristics for devices 1 and 2.

that using Bu-PBD as an electron transport layer gives better device performance than using Alq₃. This is probably due to the difference in the ionization potential, as well as the difference in the electron affinity, between BECP and the electron transport

materials, Bu-PBD and Alq₃. The ionization potential of BECP is known to be 5.5 eV [1] which is same as that of TPD, and the potentials of Bu-PBD and Alq₃ are 6.2 eV and 5.8 eV, respectively. This leads to a hole transport energy barrier of 0.7 eV and 0.3 eV between the BECP and the two different electron transport layers, Bu-PBD and Alq₃.

On the other hand, the electron affinities of BECP [1], Bu-PBD and Alq₃ are 2.5 eV, 2.6 eV, and 3.1 eV, respectively, which gives an electron transport barrier of 0.1 eV for BECP/Bu-PBD and 0.6 eV for BECP/Alq₃. Since BECP is naturally a hole transporting material, the minority charge carrier in the BECP layer is the electron. This implies that a larger injection of electrons through the interface of the BECP/Bu-PBD device contributes to the higher emission as compared to that of the BECP/Alq₃ device as shown in Fig. 2. Moreover, more hole blocking at the interface of BECP/Bu-PBD leads to a more balanced charge injection in the emitting layer, again giving a higher luminance efficiency. Our device shows a strong blue emission at 472 nm with a luminance efficiency of 0.9 lm/W at a voltage, a current density, and a brightness of 8 V, 5.7 mA/cm², and 130 cd/m², respectively. Since the cyano group in the main chain of BECCP donates an electron, it is expected that the emission energy of BECCP must be smaller than that of the BECP. The emission peaks of device 1 (BECP) and device 2 (BECCP) are shown at 472 nm and at 510 nm.

4. Acknowledgements

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5. References

- [1] C. Hosokawa, H. Higashi, H. H. Nakamura, and T. Kusumoto, *Appl. Phys. Lett.* **67**, 3853 (1995)
- [2] J. W. Park, J. H. Lee, D. Y. Kang, and T. W. Kim, *Thin Solid Films*, **363**, 90 (2000)
- [3] H. S. Woo, R. Czerw, S. Webster, J. Ballato, A. E. Strevens, D. L. Carroll, and W. J. Blau, *Appl. Phys. Lett.*, in press