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Blue organic light emitting diodes with carbazole based small molecules and color tunning by controlled side group

Y. B. Kim, Y. J. Ahn, J. H. Park, M. W. Khang, and H. S. Woo, *J. W. Park
Wooyoung Inst. of Tech., Seoul Korea, *Catholic University, Korea

Abstract

We have fabricated an air stable blue emitting organic electroluminescent devices (OLEDs) with a carbazole based emitting molecule, Bis(3-N-ethylcarbazolyl)terephthalidene (BECP). Our device emits strong blue at 472 nm with the luminance efficiency of near 1 lm/W at a voltage and current density of 8 V and 5.7 mA/cm2, respectively, reaching the brightness up to 5000 cd/m2 at 270 mA/cm2. Finally, in order to tune the emission color from blue to green, we have used Bis(3-N-ethylcarbazolyl)cynoterephthalidene (BECCP), a derivative of BECP by adding cyno group in side chain, and compared the electroluminscence (EL) of OLEDs prepared by BECCP to that of BECP based OLEDs.

Key Words : OLED, carbazole, blue emitting, color tunning

1. Introduction

Organic and polymeric materials are of interest recently because of their potential applications in electronic devices such as OLEDs, flat panel displays that can be operated at low voltages with high external quantum efficiency. Small molecules are attracting in this field due to distinct advantages over polymers such as uniformity of thin films, better control of film thickness, and easy device fabrication with multi-layered structures. Blue emitting molecules are specially interest to realize the full color OLEDs. Recently, blue emitting metal chelate compounds such as metal complexes based on oxadiazole has been reported [1]. Some others include unidentate organometallic complex containing lithium as the emitting layer and benzaxole derivatives have been synthesized [2, 3].

In this report, we present a bright blue emitting OLED with a carbazole based small molecule, BECP, as an emitting material. A previous work showed that the BECP can be used as a fluorescent dopant in a host emitting molecule[4]. Our work suggests that the BECP can be directly used as an emitting material with a better choice of electron transport material. For the color tunnability, we have also compared the EL of BECP device with that of BECCP, a derivative of BECP with a substituted cyno group.

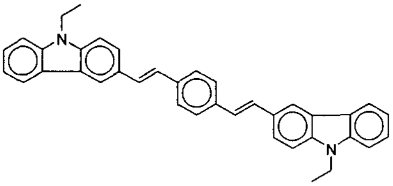
2. Experimental

An emissive material, BECP, was synthesized by well known Wittig reaction: p-xylylenbis (triphenylphosphonium chloride (2.5 g), potassium t-butoxide (1.19 g) and DMSO (50 ml) were mixed and stirred with slow adding of 9-rthyl-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 power. Another emitting material, BECCP, was synthesized as reported elsewhere [5]. The molecular structures of these materials are shown in Fig. 1. First a hole conducting buffer layer with film thickness of 20 nm was prepared by vacuum evaporation of 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 1-4,4-diamine (TPD), emitting materials, BECP or BECCP, and electron transport materals, 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. The device configurations are summarized as follow:

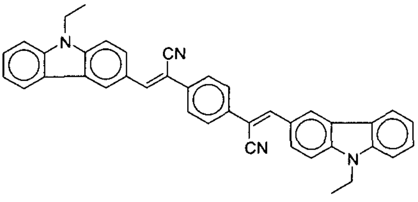
Device 1 : ITO / CuPc(20 nm) / TPD (60 nm) / BECP (40 nm) / PBD (20 nm) / LiF (1.5 nm) / Al (150 nm)

Device 2 : ITO / CuPc(20 nm) / TPD (60 nm) / BECP(40 nm) / Alq3 (20 nm) / LiF (1.5 nm) / Al (150 nm)

Device 3 : ITO / CuPc(20 nm) / TPD(60 nm) / BECCP(40 nm) / PBD(20 nm) / LiF(1.5 nm) / Al (150 nm)



BECP



BECCP

Fig. 1. Molecular Structures (BECP and BECCP).

3. Results and discussion

The current-voltage characteristics and luminance-current relation are shown in Fig.2. and Fig. 3., respectively. It is clear that using Bu-PBD as an electron transport layer gives better device performance than using Alq3. This is probably due to the difference of energy barrier of ionization potential as well as the electron affinity between the BECP and the electron transport materals, Bu-PBD and Alq3. The ionization potential of BECP is known as 5.5 eV [4] and those of Bu-PBD and Alq3 are 6.2 eV and 5.8 eV, respectively. This leads the hole transport energy barrier of 0.7 eV and 0.3 eV between the BECP and those two different electron transport layers, Bu-PBD and Alq3, respectively. 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 the electron transport barriers of 0.1 eV for BECP/Bu-PBD and 0.6 eV for BECP/Alq3. Since the BECP is naturally the hole transporting material, the minority charge carrier in BECP layer is electron. This implies that the more injection of electron through the interface of BECP/Bu-PBD contributes the higher emission than that of BECP/Alq3, as shown in Fig. 3. Moreover, higher hole blocking property at the interface of BECP/Bu-PBD leads more balanced charge injection in the emitting layer, again giving higher luminance efficiency. Our device shows a strong blue emission at 472 nm with the luminance efficiency of 0.9 lm/W at a voltage, current density, and brightness of 8 V, 5.7 mA/cm2, and 130 cd/m2, respectively. Hosokawa et. al.[4] have used the BECP as a fluorescent dopant with a host emitting melecule, distyrylarylene derivative (DSA). They have reported that the 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 unnecessary doping procedure. Finally we have compared the EL from the devices of BECP and BECCP as shown in Fig.4. Since the cyno group in main chain of BECCP donates the electron, it is expected that the emission energy of BECCP must be smaller that that of the BECP. This is clearly shown that the emission peaks of device 1 (BECP) and device 2 (BECCP) are at 472 nm and at 510 nm, respectively. This implies that the emission colors can be tuned easily from blue to green.

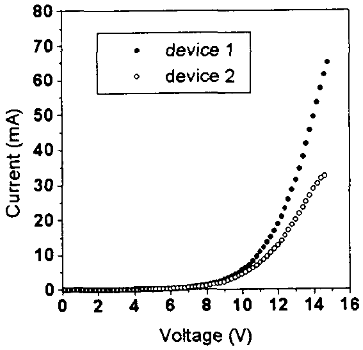


Fig. 2. I-V characteristics for devices 1 and 2.

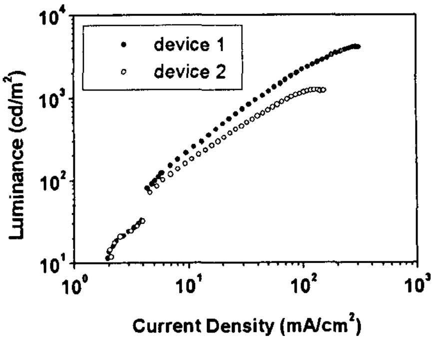


Fig. 3. Luminance-current characteristics of device 1.

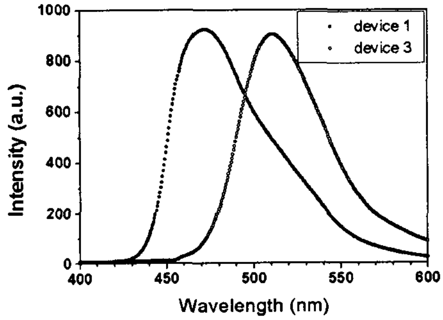


Fig. 4. EL spectra of device 1 and 3.

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