Blue OLED with LT95=2709 Hours by Using Anthracene-Bidibenzofuran as the Emitting Layer

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Abstract

In this paper, we demonstrated a blue OLED with anthracene-bidibenzofuran (AnDBO) as the emitting layer (EML). In a non-doped configuration, deep blue OLED with EQE of 8.82% and CIE at (0.143, 0.097) was achieved. When applying dopant into AnDBO together with bi-EML structure, 14.54% in EQE was achieved, together with T95 of 2709 hrs at 1000 cd/m^2 with peak wavelength 466 nm.

Keywords

blue OLED, bi-EML, high efficiency, long lifetime

Introduction

Organic light-emitting diode (OLED) is widely used for displays such as mobile phones, TVs, and smart watches [1]. Among red, green, and blue devices, blue OLED exhibits lowest efficiency and shortest lifetime due to the wide bandgap nature. Triplet-triplet fusion (TTF) emission is typically used for mass production due to the acceptable operation lifetime. However, efficiency of blue OLED is still lower than red and green ones with phosphorescent or thermally activated delayed fluorescent emitters. In this paper, a series of anthracene-bidibenzofuran (AnDBO) derivatives were synthesized which exhibited an anthracene core for facilitating TTF process, achieving maximum external quantum efficiency (EQE_{max}) of 8.82% with CIE coordinates of (0.143,0.097) in non-doped configuration [2]. By inserting a triplet tank layer (TTL) between hole-transporting layer (HTL) and TTF emitter, device efficiency and operation lifetime can be significantly improved due to efficient management of triplet excitons, which is called bi-emitting layer (bi-EML) structure [3]. By using 1,1'-(2,5-Dimethyl-1,4-phenylene)dipyrene (DMPPP) as the TTL, together with high photoluminescence quantum yield (PLQY) emitter into DMPPP and AnDBO, bi-EML OLED showed EQE of 14.54 %. Besides, the operation lifetime, measured as T95, which is time of luminance decay to 95% of initial level, achieved 2,709 hours at initial luminance of 1000 cd/m^2 with peak wavelength at 466 nm.

Result

Three AnDBO derivatives were synthesized as the EML. Electroluminescence (EL) characteristics of non-doped DBO-ANC OLEDs were shown in **Fig. 1**. **Table I** is the summary of device performances. As shown in **Fig. 1 (a)**, J-V characteristics of OLEDs with three different AnDBO were similar, while the brightness of AnDBO-2 was slightly lower. **Fig. 1 (b)** showed the EQE versus current density. OLED with AnDBO-1 achieved highest maximum EQE value, which was 8.82%. Emission spectra of the three OLEDs were shown in **Fig. 1 (c)** with spectral peak at 448-452 nm, resulting in the deep blue emission. OLED with AnDBO-3 showed lowest CIE-y coordinates, which achieved 0.08, as shown in **Fig. 1 (d)**.

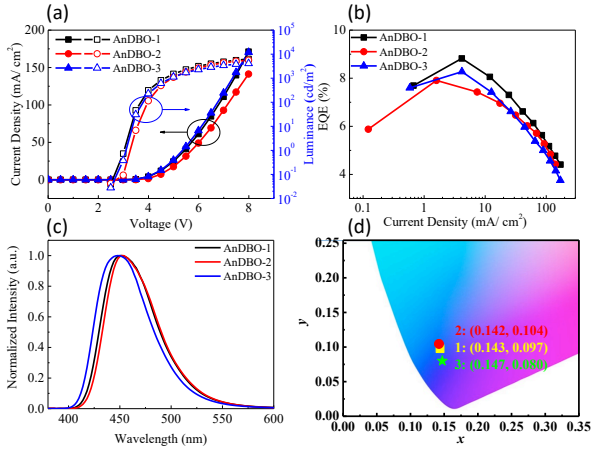

Fig 1 Device performances of non-doped DBO-ANC devices: **(a)** current density (J)- luminance (L)- voltage(V) curve, **(b)** EQE (%)- versus different current density, **(c)** normalized EL spectrum, and **(d)** CIE coordinates.

Table 1 EL performance of non-doped OLEDs with three different AnDBO as the EML.

Device	Turn-on Voltage[a] (V)	C.E.[b] (cd/A)	P.E.[b] (lm/W)	EQE[b] (%)	Delay ratio	CIE[c] (x,y)		EL peak (nm) @7V
AnDBO-1	3.03	7.57	6.17	8.82	0.17	0.143	0.097	450
AnDBO-2	3.26	7.22	5.68	7.90	0.20	0.142	0.104	452
AnDBO-3	3.10	7.50	4.76	8.27	0.11	0.147	0.080	448

[a] voltage at L= 1cd/m^2; [b] C.E./ P.E./ EQE measured at maximum; [c] measured at max C.E.

To boost up EQE, a high PLQY emitter was doped in AnDBO-1 (denoted as si-EML). Furthermore, bi-EML structure was used for improving device performances by inserting DMPPP between HTL and AnDBO-1, as shown in **Table 2** and **Fig. 2.** EQE_{max}, $P.E._{max}$ and $C.E._{max}$ of bi-EML OLED with AnDBO-1 host reached 14.54%, 15.26 lm/W and 18.87 cd/A, respectively, with CIE coordinate of (0.137, 0.231). Delay emission ratio of OLED with bi-EML structure increased to 19%, compared to si-EML OLED (15%).

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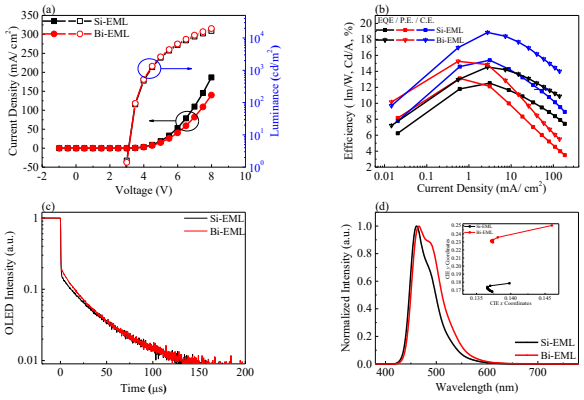

Fig 2 Device performances of Si-EML and Bi-EML device: **(a)** current density (J)- luminance(L)- voltage(V) curve, **(b)** EQE (%)- C.E. (cd/A)- P.E. (lm/W)- versus different current density, **(c)** TrEL at 3.5 V and **(d)** operation lifetime.

Table 2 EL performance of Non-doped, Si-EML and Bi-EML device

Device	Voltage[a] (V)	C.E.[b] (cd/A)	P.E.[b] (lm/W)	EQE[b] (%)	Delay ratio	CIE[c] (x,y)	WL(nm) @4V	LT95 (hr)
Non-doped	4.37/3.03	7.57	6.17	8.82	0.18	0.143 0.097	450	-
Si-EML	4.55/2.94	15.40	13.12	12.52	0.15	0.136 0.172	462	58
Bi-EML	4.67/2.94	18.87	15.26	14.54	0.19	0.137 0.231	466	375

[a] driving voltage at J= 10 mA/cm² / Turn on voltage at L= 1cd/m²; [b] C.E./ P.E./ EQE measured at maximum; [c] measured at max C.E.

Fig. 3 (a) showed operation lifetime of OLEDs with si- and bi-EML, respectively. In this measurement, constant current was supplied with Initial luminance of OLEDs set at 3000 cd/m^2. For si-EML OLED, LT95 (i.e. time of luminance decay to 95% of initial level) value was 58 hours. When applying bi-EML structure, LT95 increased significantly to 375 hours, corresponding to 6.47-times improvement. E. Tankeleviciūte et al., summarized LT95 of OLEDs with Initial luminance of OLEDs set at 1000 cd/m^2 for different emission mechanisms, including fluorescence (FL), phosphorescence (Ph), thermally activated delayed fluorescence (TADF), multiple resonance (MR), and results from industry with different dominant wavelength [4]. By using the following equation

$$L_0^n \times T95 = \text{const.} \quad (1)$$

Where L_0 is the initial luminance, and n=1.8 [1]. We can obtain that LT95 of our bi-EML OLED achieved 2709 hours with the initial luminance of 1000 cd/m^2 at the dominant wavelength of 466 nm. That is also the highest value ever reported in blue OLED [4].

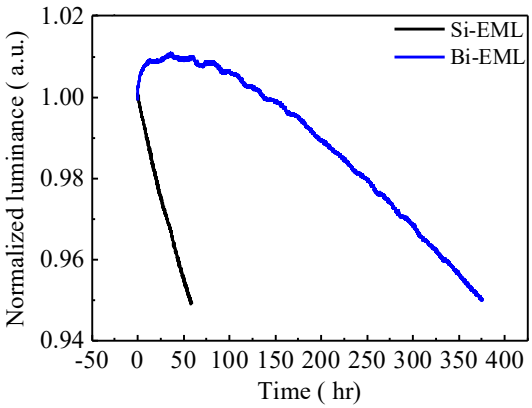

Fig 3 Operation lifetime of OLEDs with si- and bi-EML.

Impact

In this research, blue anthracene materials, AnDBO, were synthesized for OLED application. In a non-doped device, we demonstrated high efficiency and deep-blue device achieving EQE_{max} of 8.8% with CIE coordinates of (0.144, 0.098). By applying bi-EML architecture and high PLQY dopant, device performances achieved $P.E._{max}$ of 15.26 lm/W, $C.E._{max}$ of 18.87 cd/A and EQE_{max} of 14.54%. LT95 of our bi-EML OLED was 2709 hours with the initial luminance of 1000 cd/m^2 at the dominant wavelength of 466 nm, which is the longest operation lifetime ever reported.

Acknowledgements

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