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Blue mixed host organic light emitting devices

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Abstract

The lifetime is one of the main issues in the development of organic light-emitting devices (OLEDs). In this paper, we present a new OLED with an emitting layer (EML) based on a blue mixed-host (MH) structure. Compared to the conventional host-dopant system, the MH structure consists of two different hosts and one-dopant materials. Using the structure with different host ratio and fixed dopant concentration, the Commission International de L'Eclairage (CIE 1931) coordinates will shift from (0.17, 0.32) to (0.15, 0.22). The operating lifetime of optimal device is much improved over the heterostructure OLEDs, which shows the lifetime of approximately 110 h with initial luminance of 10 000 cd/m^2. The luminance reaches 80 370 cd/m^2 at 10 V, which corresponds to a luminous efficiency of 1.8 cd/A. The significant improvement in device lifetime is attributed to the elimination of the heterojunction interface and the prevention to the formation of fluorescence quenchers. These results demonstrate that the MH structure can extend lifetime without significantly changing the EML with common host material.

Keywords: Blue organic light-emitting devices; OLED; Mixed host; Lifetime

1. Introduction

Their potential low cost, high brightness and capability of full colors, the OLEDs have the potential to become the main stream of the next generation flat panel displays (FPDs) [1–3]. In order to meet the practical applications, it is necessary to demonstrate that these devices have sufficient reliability and color purity [4]. Most of the earlier reports, however, show relatively poor stability [5], and the lifetime usually amounts to only a few hours at high luminances (approx. 10 000 cd/m^2). This short lifetime is attributed to the formation of intrinsic degradation in organic layer, and the EL performance is highly dependent on the device configuration [6]. Recently, in the multilayer structures, doping rubrene in the hole transport layer (HTL) [7] or adding CuPc as the hole injection layer (HIL) [8], is found to significantly improve the stability of the device. In this letter, a OLEDs with an emitting layer (EML) based on a blue mixed-host (MH) structure is investigated. The EL characteristics and lifetime data of the devices will also be described.

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2. Experimental

The blue mixed-host (MH) OLEDs were deposited by high-vacuum (2×10^{-6} Torr) thermal evaporation on ITO substrates with a sheet resistance of approximately 20 Ω^2 (ITO thickness approx. 1000 Å). The ITO was first treated by an UV-ozone cleaner before the organic film deposition. The emitting area was 0.4 mm^2. The device structure consisted of α-naphthylphenylbiphenyldiamine (NPB) as the hole transport layer (HTL), MH structure as the EML, bis(10-hydroxybenzo[*h*]quinolinato)beryllium ($Bebq_2$) as the electron transport layer (ETL), and finally a LiF/Al alloy as the cathode. The experimental recipes of the device were listed in Table 1.

The MH structure was composed of a mixture of Host1 (NPB) and Host2 (BNA = 9,10-bis(2′-naphthyl) anthracene) doped with organic fluorescent dyes (DPVBi = 4,4′-bis(2,2-diphenylvinyl) biphenyl), which was achieved by co-deposited process at a temperature between 230 and 350 °C and a deposition rate between 0.5 and 2 Å/s. The chemical structures of the organic materials and their energy level diagram are shown in Fig. 1.

The luminance–current density–voltage (*L*–*J*–*V*) and electroluminescence (EL) spectra measurements were

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Table 1
The experimental recipes of devices

Unit:Å	HTL	Mixed EML			ETL	Cathode
		Host1 450	Host2	Dopant		
	NPB	NPB (%)	BNA (%)	DPAVBi	$Bebq_2$	LiF/AI
B-MH-1	400	100	0			
B-MH-2		75	25			
B-MH-3		50	50	2%	150	12/1000
B-MH-4		25	75			
B-MH-5		0	100			

done with the PR-705 spectrophotometer. For lifetime test, the data were obtained using packaged devices under the conditions of constant current drive. The initial luminance was 10 000 cd/m^2 measured with a Minolta CS-1000 Chroma Meter. The photoluminescence (PL) spectra of the organic films were measured with a fluorescence spectrophotometer (Hitachi F-4500). The ionization potential of the organic films was measured with a Ritken Keiki AC-2. All measurements were carried out at room temperature and atmosphere.

3. Results and discussion

The performance of devices is evaluated by varying the host ratio of the MH structure as shown in Table 1. Fig. 2 shows the normalized PL spectra of NPB, BNA, DPAVBi and $Bebq_2$ solid films. In order to use DPAVBi as the dopant, the emission of two hosts should have a significant spectral overlap with the absorption of DPAVBi (absorption peak at 392 nm).

The current density–voltage (J–V), luminance–voltage (L–V), and efficiency–luminance (E–L) characteristics of the devices are shown in Fig. 3. As can be seen, the current density of these devices increases steadily with respect to the NPB concentration. In addition, the concentration of NPB is 25% in the MH structure as the optimal ratio, at which the maximum luminance reaches 80 370 cd/m^2 at 10 V. This is because the optimal MH structure can improve the luminance of the device [9] and significantly confinement of the recombination zone in the EML.

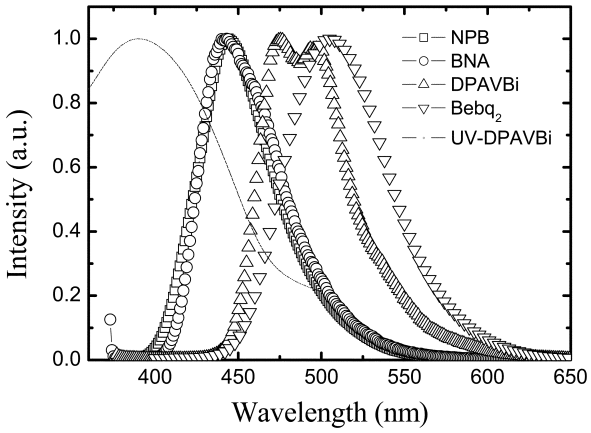

Fig. 2. Normalized PL spectra of NPB, BNA, DPAVBi and $Bebq_2$ films.

Fig. 4 shows the EL spectra. When the concentration of NPB increases, the hole-electron recombination will delocalize. It indicates that EL occurs in the excited singlet state of the $Bebq_2$, where the peak wavelength is close to 500 nm. However, when the concentration of BNA increases, the light emission is still confined in the doped region and the EL spectra are dominated by DPAVBi. Furthermore, by adjusting the composition of

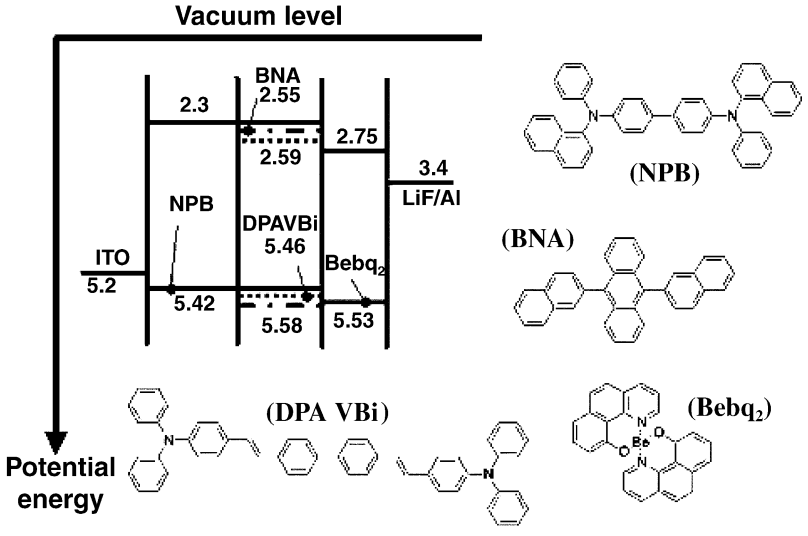

Fig. 1. Schematic chemical structure and energy level diagram of MH-OLEDs.

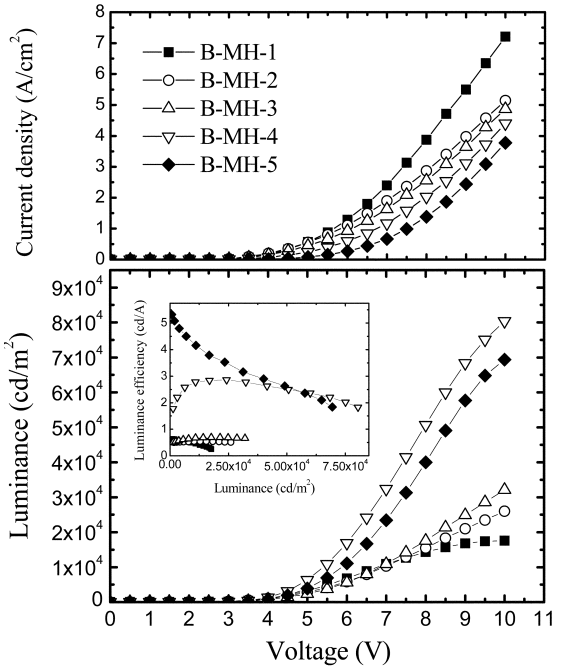

Fig. 3. Current density–voltage (J–V), luminance–voltage (L–V) and efficiency–luminance (E–L) characteristics of the MH-OLEDs.

the MH structure, the CIE coordinates can be tailored to generate a wide gamut of color, as shown in Table 2.

Fig. 5 shows the lifetime data for the MH devices. In order to compare the lifetime ($t_{1/2}$), defined as the time when the luminance of the device decreases to half of its initial value, these devices are fabricated in the same lot with the same batch of materials. The results show that the B-MH-4 has the longest lifetime because the carrier injection and transport is balanced. In the B-MH-1, B-MH-2 and B-MH-3, these structures clearly show that the higher hole/electron ratios in the EML lead to the formation of fluorescence quenchers. In the B-MH-5, the recombination zone is near HTL/EML interface, and the high local field at the abrupt heterojunction can adversely affect the device reliability [10].

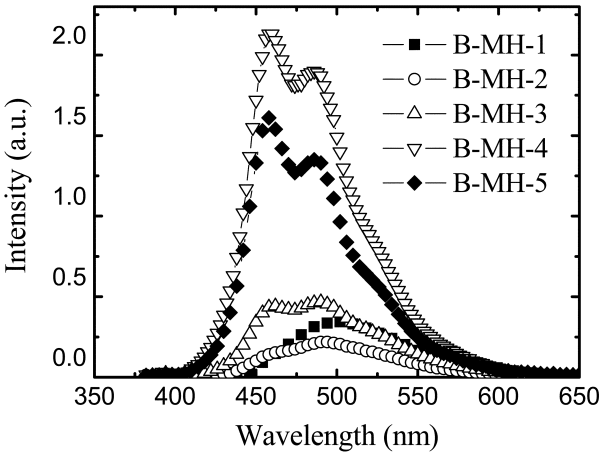

Fig. 4. EL spectra of the different devices.

Table 2
Measured EL parameters of different devices

	Lumiance (cd/m²)	ClE-x	CIE-y	V	J (A/cm²)
B-MH-1	@10 000	0.21	0.46	5.66	1.78
B-MH-2		0.17	0.32	5.59	1.92
B-MH-3		0.17	0.29	5.72	1.56
B-MH-4		0.15	0.22	5.04	0.33
B-MH-5		0.15	0.21	5.56	0.23

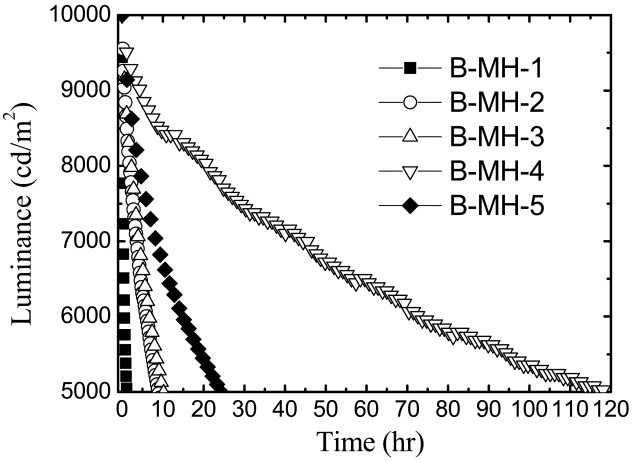

Fig. 5. Lifetime data under dc drive of different devices.

4. Conclusion

We have demonstrated an OLED with the EML based on a blue mixed-host structure. The EL performance and lifetime of optimal device are much improved over the heterostructure OLEDs. The significant lifetime improvement is attributed to the elimination of the heterojunction interface and the prevention to formation of fluorescence quenchers. These results suggest that the MH structure is well suited for OLEDs, especially in the mass-production setting, where lifetime and color tunability are critically important.

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