The Effect of Excitons Recombination Zone in Organic Light-Emitting Devices with Single No-doped Structure

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Abstract. Ultrathin non-doped DBQA emissive layer (EML) has been employed in organic light-emitting diodes. We have investigated the recombination zone in the organic light-emitting devices with single non-doped structure. Yellow material was inserted before or after the electron transport layers for fabricating the devices. The electroluminescence spectrum was dependent upon the position of DBQA in the device. The resulting device exhibits a maximum current efficiency 9.05 cd/A and a maximum power efficiency of 3.27 lm/W were achieved by optimizing the recombination zone.

Introduction
Organic light-emitting diodes (OLEDs) have been actively investigated for both display and lighting applications because of their potential applications in full-color flat-panel displays, mobile displays, and lighting devices due to their excellent advantages of ultra-thin thickness, high-contrast ratio, wide-viewing angle, fast response, high-flexibility, and low power-consumption. Remarkable improvements have been made in 1987 by Tang and VanSlyke[1]. Organic and polymer light-emitting devices (OLEDs/PLEDs) based full color flat panel displays have been successfully commercialized [2-9]. In recent years, considerable work has been done on improving the device structure in order to enhance the luminescence efficiency and durability of the devices. To fulfill this requirement, one may utilize a very thin emitting layer to ensure that their combination zone is fixed and carrier confinement is automatically achieved [10], thereby stabilizing the EL emission [11]. Doping dye molecular in the emitting layer has become a very important way to improve the behaviors of the OLEDs. Many kinds of dyes, such as DCM [12], Rubrene [13], Perylene [14] and DCJTB [15], have been synthesized and introduced into the fabrication of OLEDs. Generally, the doping concentration of the dye is very low. In order to overcome this problem, another way of no-doping technique to fabrication of OLEDs has been reported by Tsuji et al. and Xie et al. [16-18]. The simple device structures and excellent reproducibility make this well suited to low-cost lighting applications and beneficial to industrialization. In this paper, we select DBQA as yellow material, using no-doping way to fabricated the devices with different position, especially the EL spectra of the devices have been studied. The OLED have simpler device structure compared with those reported methods. OLEDs consist of various thin layers such as hole transport layer (HTL), emitting layer (EML), electron transport layer (ETL).

Experimental
Figure 1 shows the device structure of the OLEDs. The structure of this device is: ITO /NPB (40 nm)/ Alq3 (40 nm) /LiF (0.5 nm)/Al, ITO /NPB (40 nm)/DBQA(0.6 nm) /Alq3 (40 nm) /LiF (0.5 nm)/Al and ITO /NPB (40 nm)/ Alq3 (40 nm) / DBQA(0.6 nm) /LiF (0.5 nm)/Al, and the corresponding devices are named A, B and C, respectively. In our devices, N, N’- di (naphthalene-1-yl)- N,N’-diphenyl-benzidine (NPB) were used as hole-transporting layer, DBQA was used as yellow
emitting layer, tris (8-hydroxyquinoline) aluminium (Alq$_3$) acts as the green emitting layer electron-transporting layer, LiF buffer layer as an electron injecting layer, and Al as cathode electrode, respectively.

Figure 1. The device structure of the OLEDs.

Organic layers and other layers were deposited by high-vacuum ($4 \times 10^{-6}$ Torr) thermal evaporation onto a cleaned indium tin oxide (ITO) coated glass substrate. The layer thickness of the deposited material was monitored using an oscillating quartz thickness monitor. EL spectra and CIE coordination of the devices were measured by PR655 spectra scan spectrometer and the current–voltage–brightness characteristics were simultaneously measured by a Keithley 2400 programmable voltage–current source. All measurements were carried out at room temperature under ambient conditions.

Results and Discussion

Figure 2. (a). Normalized EL intensity of the devices A-C at different voltage and Normalized EL intensity of devices A-C at 8V.

Figure 2(a) shows the Normalized EL intensity of the different devices at different voltage. As shown in Fig.2 (a), the devices A-B have the same emission EL spectra come from the Alq$_3$ layer. The normalized EL spectra of the device C shows two main emission peaks at 546 nm and 584 nm originating from DBQA, respectively. In case of no DBQA layer, the device A shows green emitting. As DBQA insert after Alq$_3$ layer, it did not emit and block electron injection, resulting decrease luminance and efficiency. When DBQA insert before Alq$_3$ layer, the excitons recombine in DBQA
layer and emitting the yellow light. Besides, as the applied voltage increases, the intensity of yellow inside the devices add. This observation is attributed to the fact that more excitons are captured by DBQA.

Figure 2(b) showing the CIE coordinates of devices A-C at different voltage, we can see devices A-B and C have the different CIE coordinates, which indicates that DBQA can trapping the carrier. Similar, at the no-doping way of DBQA in device, we observe the emission from the DBQA itself.

Figure 2. (b). CIE coordinates of devices A- C at different voltage.

Figure 3 shows characteristics of the current density versus voltage and the luminance versus voltage of devices A-C. The device A, B and C achieve the maximum luminance of 17490 cd/m², 9895 cd/m² and 528.8 cd/m² at 11 V, respectively, and the corresponding current density is 645.2 mA/cm², 257.6 mA/cm² and 10.58 mA/cm², respectively.

Figure 3. The current density-voltage and the luminance-voltage characteristics of devices A- C.

Figure 4 shows the current efficiency versus voltage and the power efficiency versus voltage characteristics of devices A-C. The peak current efficiency of devices A-C achieves 7.89 cd/A at 6 V, 4.47 cd/A at 6 V and 9.05 cd/A at 7 V, respectively. The power efficiency of devices A-C achieves 2.28 lm/W at 6 V, 1.72 lm/W at 5 V and 3.27 lm/W at 6 V, respectively. The current efficiency and power efficiency of OLEDs are significantly affected by the DBQA layer. Inefficient charge and exciton confinement severely reduces efficiency when the DBQA layer is inset after Alq3. So the
DBQA layer of appropriate position is often used to control the amount of exciton formation and increase the current efficiency. The better performance of device C can attribute to the DBQA layer is an excellent trapping material.

Summary
We have discussed no-doping method to fabricate the OLED, ultrathin non-doped DBQA layer has been employed for organic light-emitting diodes in different site. To investigated the recombination zone in the organic light-emitting devices with single non-doped structure. Yellow material was inserted before or after the electron transport layers for fabricating the devices. The electroluminescence spectrum was dependent upon the position of DBQA in the device. The resulting device exhibits a maximum current efficiency 9.05 cd/A of and a maximum power efficiency of 3.27 lm/W were achieved by optimizing the recombination zone.

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