Study on the characteristics of white organic light-emitting diodes using a new material

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Abstract

In this study, we synthesized a new red emitting material of a Red225 doped into Alq_3 (tris(8-quinolinolato)aluminum (III)) and fabricated white organic light-emitting diodes (OLEDs) with a simple device structure. With a blue emitting material of DPVBi (4,4'-bis(2,2'-diphenylvinyl)-1,1'-biphenyl) that can transfer effectively both a hole and an electron, OLEDs with a narrow emission layer could be possible without a hole-blocking layer. Consequently, the driving voltage and stability of devices have been improved. The devices show the Commission Internationale d'Eclairage (CIE) chromaticity coordinates of (0.36, 0.35) at luminance of 2000 cd/m^2. The luminous efficiency is about 3.5 cd/A, luminance is about 12000 cd/m^2 and current density is about 350 mA/cm^2 at 12 V, respectively.

1. Introduction

Since Tang and VanSlyke reported efficient thin film organic light emitting diodes (OLEDs), there has been significant improvement in the performance and stability of OLEDs.[1] OLEDs have attracted much attention because of their low power consumption, fast response, wide viewing angle, flexibility and the possibility of wide application.[2-3] Considerable interest is given to OLEDs due to their potential applications namely in flat display technology.

White emission is important for applying OLEDs to full-color flat panel displays and a back-light for liquid crystal displays (LCDs). Doping an organic material host with red, blue, and green fluorescent dyes or a combination of several electroluminescent organic material blends has been shown to generate white-light emission.[4-6] By the way, when white OLEDs are fabricated with a stacked multi-layer structure, interdiffusion between organic thin films is created and a life-time of the device is shorten. Therefore, a simple device structure and use of materials having wide emitting region including a visible ray region may help the improvement of white OLEDs.

A new red emitting material, Red225 (DCJTB derivative), has good hole transfer property compared with the DCJTB. And then the incomplete energy transfer of Red225 can result in light emission from both the host and the dopant. Therefore, a Red225 can be used for white OLEDs.[7]

A blue emitting material of DPVBi has good electron and hole transfer property. Therefore, if a DPVBi is deposited between a hole-transport layer (HTL) and an electron-transport layer (ETL) as a blue emitting material, we can fabricate a blue emission device without extra hole blocking layer (HBL). Consequently, the driving voltage of devices and stability of devices have been improved.

In this paper, we have synthesized new red emitting materials having a wide wavelength and a good luminous efficiency, also fabricated with 20-nm-thick emitting layer in our OLEDs staked.

2. Experimental

ITO (indium-tin-oxide, sheet resistant: 30 Ω/sq) glass substrates were cleaned in the ultrasonic bath of acetone and methanol consecutively, and then rinsed with the distilled water. After dried, the glass substrates were loaded in a deposition chamber for successive thermal deposition of the organic and metal layers under $5□10^{-7}$ Torr. The deposition rates were 1-1.5 Å/s, and 5-10 Å/s for organics and metal, respectively. Figure 1 shows the organic materials used in the fabrication of the OLEDs in this study.

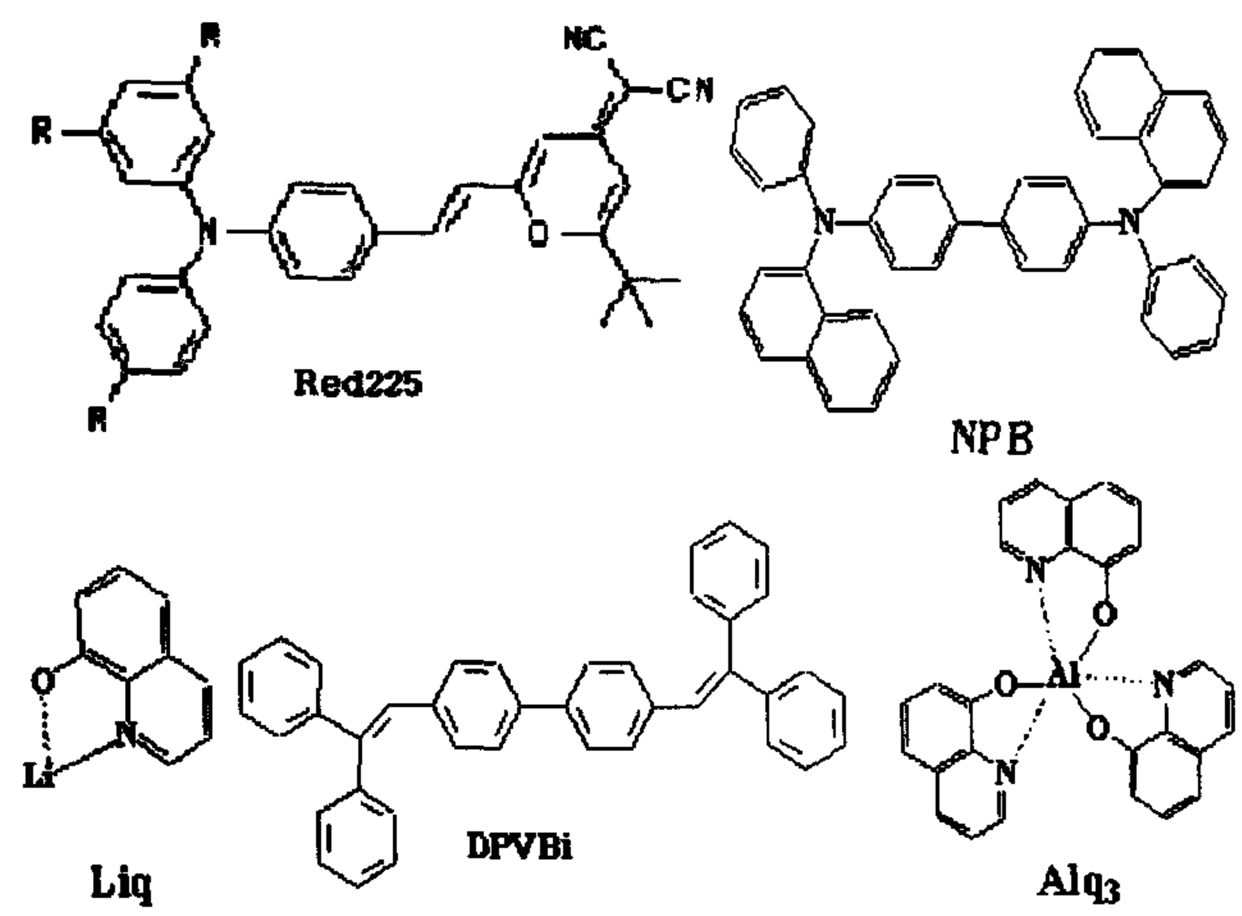


Figure1. The Molecular structures of the white OLEDs used.

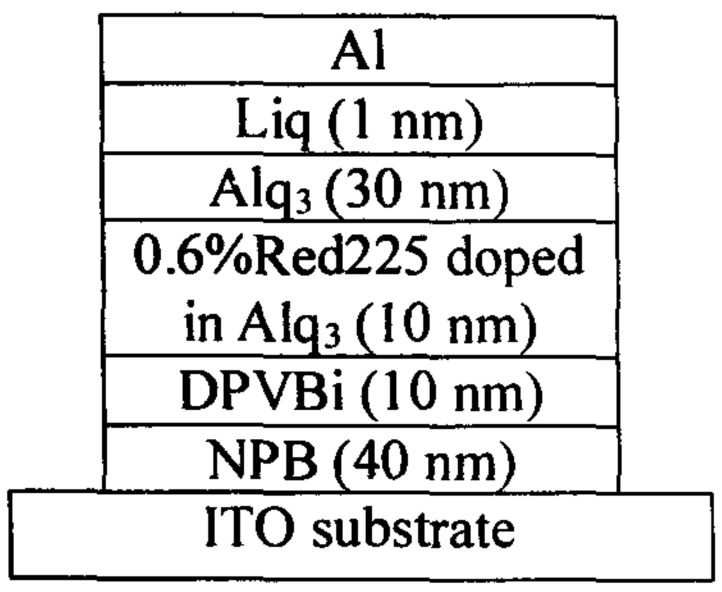


Figure 2. The configurations of the white OLEDs fabricated.

The configuration of the OLEDs manufactured in this study is shown in Figure 2

A scheme of device structure is ITO/NPB (40 nm) /DPVBi (10 nm)/0.6 % Red225 doped in Alq_3 (10 nm) /Alq_3 (30 nm)/Liq (1 nm)/Al. The device's pixel area was 0.3□0.3 cm^2. DPVBi was used as blue emitting layer and Red225 doped into Alq_3 was used as a red and green emitting layer.

The emitting color was tuned to white by controlling the concentration of dopant. Therefore, the structure should be considered to the incompleteness of energy transfer between the host and the dopant. In this paper, for a proper green and red emission ratio, several devices with various doping concentration were fabricated, and 0.6 % Red225 doped in Alq_3 was chosen for proper doping concentration of green and red emission in white OLEDs.[8] With this structure, exciton can be formed in both DPVBi (10 nm) and 0.6 % Red225 doped in Alq_3 (10 nm). To fabricate efficient white OLEDs, need to be efficient emitters and transport materials. DPVBi has good electron and hole transfer property. Therefore, if a DPVBi is deposited between a hole-transport layer (HTL) and an electron-transport layer (ETL) as a blue emitting material, we can fabricate a blue emission device without extra hole blocking layer (HBL).

The current-voltage-luminance (I-V-L) characteristics of the OLEDs were measured with programmable electrometer (Kiethly 617), source measure unit (Kiethly 236) and Roper Scientific photodiode (SI440-UV)

The luminance and CIE chromaticity coordinates of the fabricated devices were measured by using a MINOLTA CS-100 chromameter

3. Results and discussion

Figure 3 show the evolution of the EL with current density for device from 1 mA/cm^2 to 18 mA/cm^2. The EL peaks location of the OLEDs didn't change even if the current density is increased. Therefore, the devices were very stable. It is supposed that excitons were formed in both DPVBi layer and Alq_3 layer, and with low doping concentration of Red225 excitons in Alq_3 couldn't transfer to Red225 very well.[9] Consequently, the green emission in Alq_3 is caused as well as the red emission in Red225.

Color stability is an important issue in white OLEDs. Figure 4 shows CIE chromaticity coordinates of white OLEDs. The white emission shows in somewhat red color according to CIE chromaticity coordinate of x=0.38, y= 0.36 with the brightness bellow 1,000 cd/m^2. But it turns to the pure white emission of x=0.36, y=0.35 with the brightness above 2,000 cd/m^2, and it didn't change up to 10,000 cd/m^2. Therefore, we know that the devices were very stable.

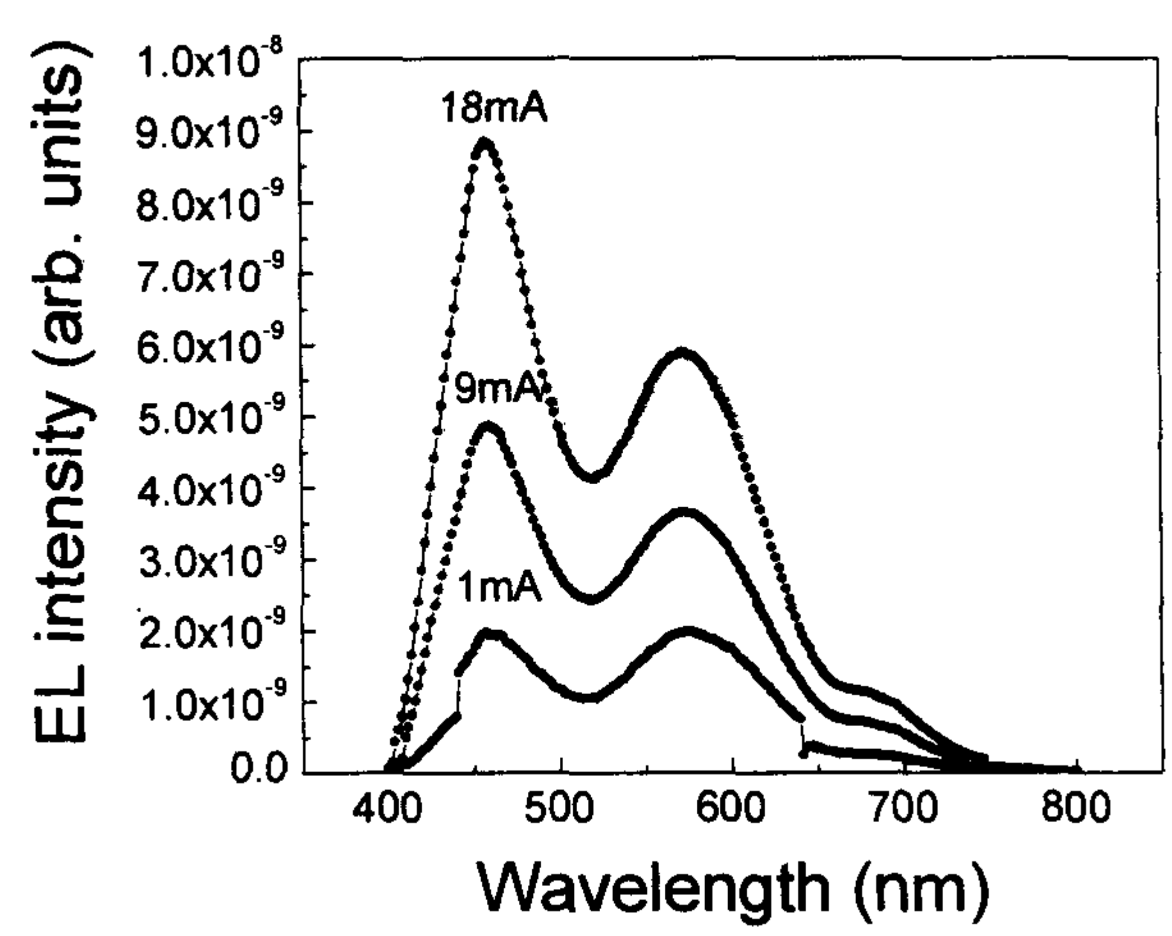


Figure 3. The EL spectra of the white OLEDs for ITO/NPB/DPVBi (10 nm)/0.6 % Red225 doped in Alq_3 (10 nm)/Alq_3/Liq/Al under various current densities between 1 mA/cm^2 and 18 mA/cm^2.

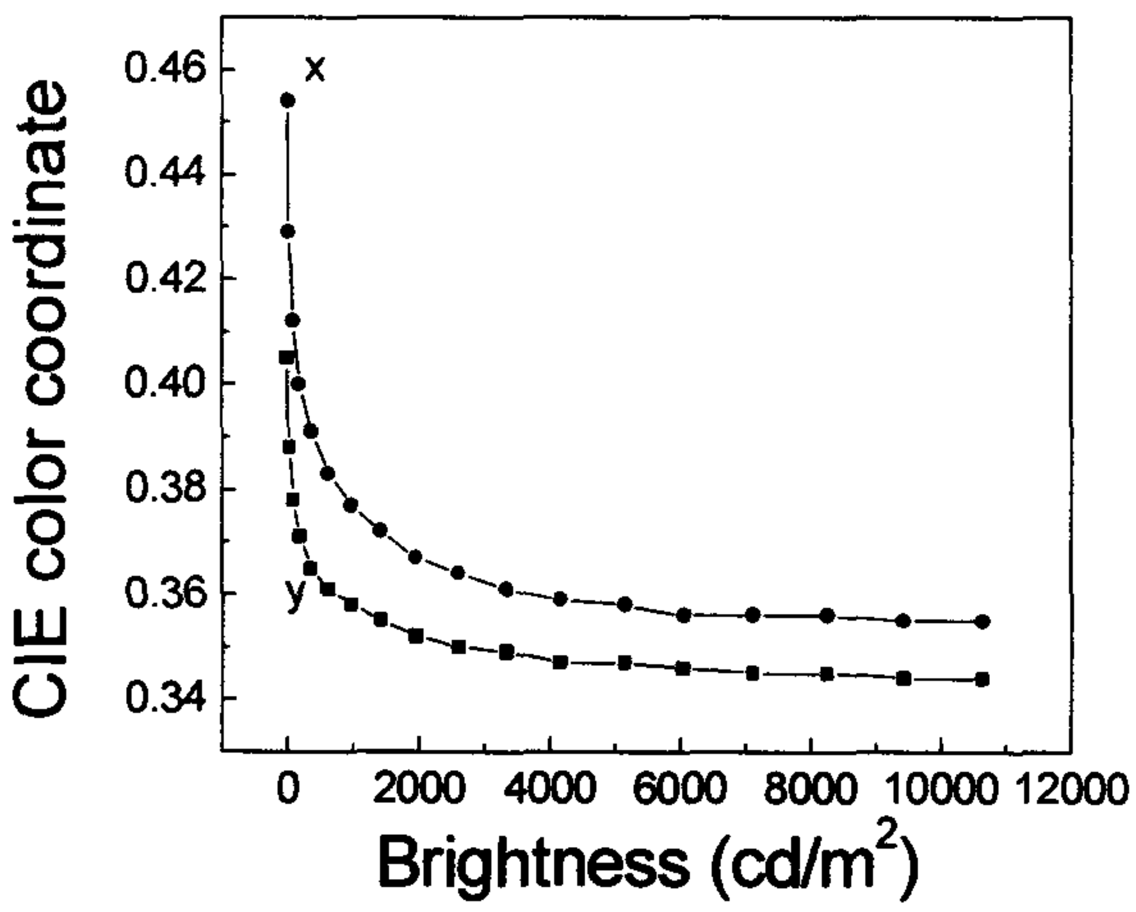


Figure 4. The CIE chromaticity coordinates of the white OLEDs fabricated.

Figure 5 shows characteristic of the brightness of the white OLEDs. The driving voltage is 3 V. And the maximal brightness reached to 12000 cd/m^2 at 12 V.

Figure 6 shows the current density and the luminance efficiency of the white OLEDs fabricated in this study. The luminous efficiency of the device was 4 cd/A with the current density of 8 mA/cm^2 and the driving voltage of 5.5 V. The luminous efficiency nearly didn't change even if the brightness is increased. Therefore, we know that the devices were stable. The power consumption with this condition was 42 mW/cm^2 at 5.5 V and 8 mA/cm^2. With the driving voltage of 6.5 V and the current density of 25 mA/cm^2, the brightness and the power consumption of OLEDs was observed 1,000 cd/m^2 and 150 mW/cm^2, respectively.

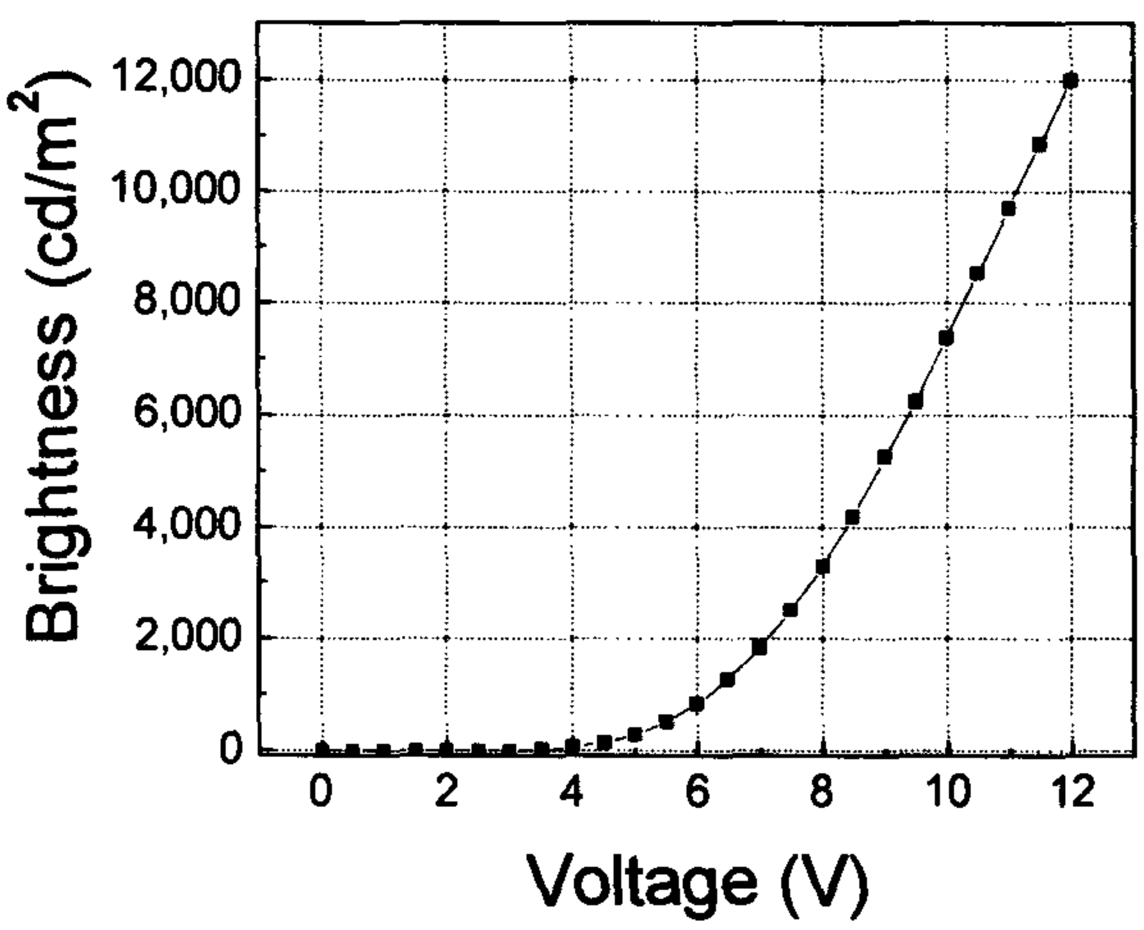
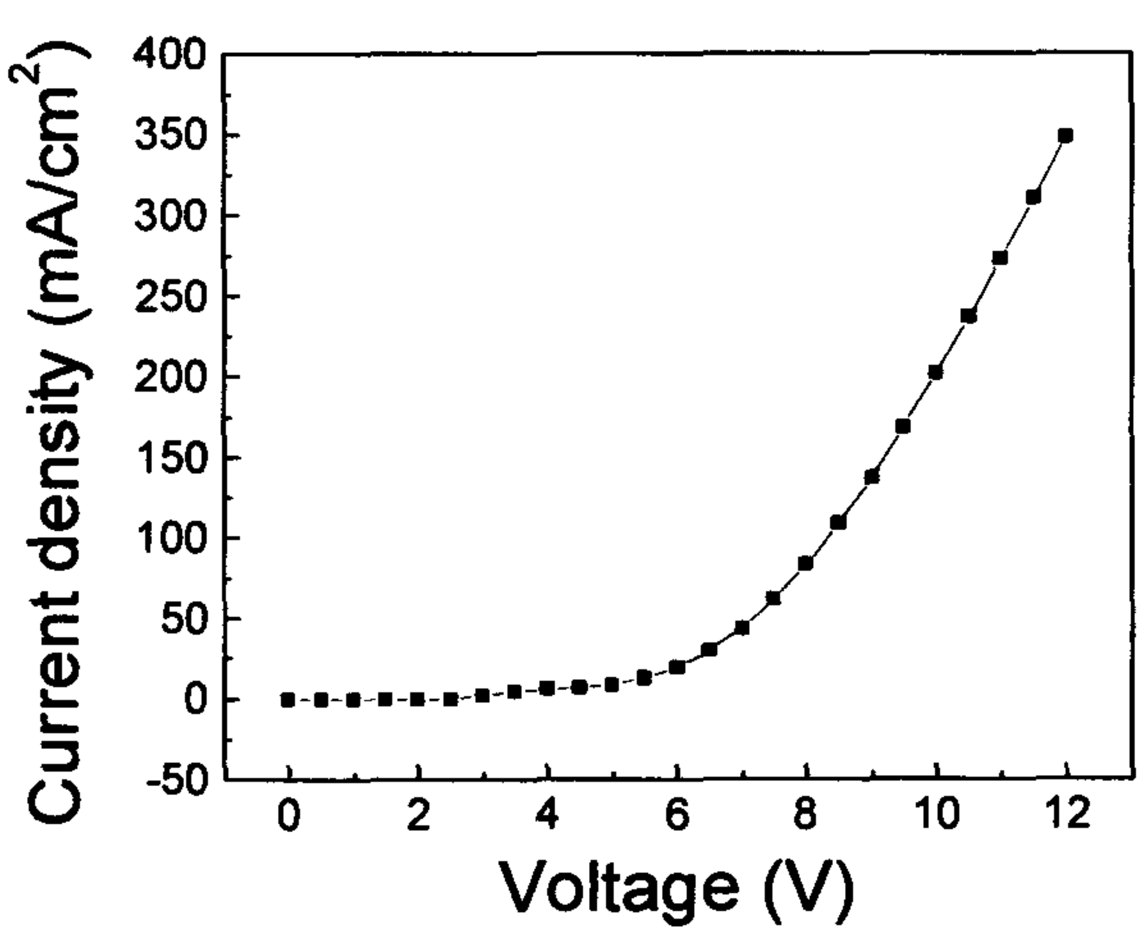
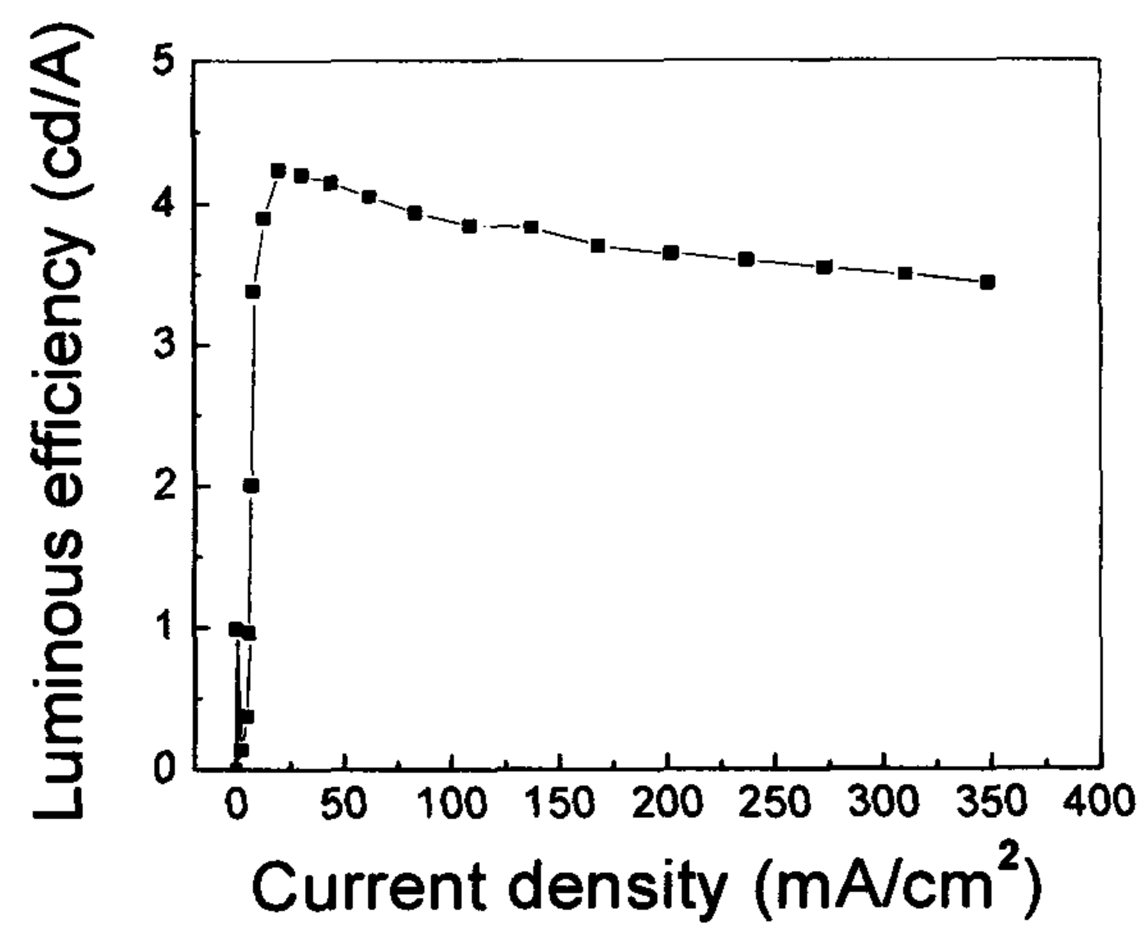


Figure 5. The Brightness of the white OLEDs with the structure of ITO/NPB/DPVBi (10 nm)/0.6 % Red225 doped in Alq_3 (10 nm)/Alq_3/Liq/Al as a function of voltage.



(a)



(b)

Figure 6. The characteristics of white OLEDs; (a) The current density and (b) the luminance efficiency

4. Conclusion

We have controlled the red and green emission rate by varying the doping concentration of Red225 doped in Alq_3. DPVBi has a great electron and hole transport properties. Therefore, by deposition of DPVBi between a hole-transport layer and an electron-transport layer as a blue emitting layer, we fabricated a blue emission device without extra hole blocking layer. By doping of a small amount of Red225 as a dye, an incomplete energy transfer from the Alq_3 to Red225 caused both the green emission of Alq_3 and the red emission of Red225, respectively. In the results, the pure white OLEDs with the high efficiencies could be fabricated.

The maximum brightness and luminous efficiency reached to 12000 cd/m^2 at 12 V and 4 cd/A at 5.5 V, respectively. The power consumption of 42 mW/cm^2 at 5.5 V and 8 mA/cm^2 is high level a little more than Light Emitting Diodes (LEDs) as TFT-LCD's backlight for mobile communication terminal. Therefore this is used to wide screen TFT-LCD, and it is level that moving picture embodiment is possible.

5. Acknowledgement

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6. References

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