

# Improvement on Electroluminescence of Red Organic Light Emitting Diode by Doping with Sensitizers

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## Abstract

The enhanced energy transfers and carrier trapping by doping with sensitizers improved the electroluminescence (EL) properties of the red organic light-emitting devices (OLEDs). High stability in EL efficiency was measured; when the current density was increased from 10 to 130 mA/cm<sup>2</sup>, the variations of current density were 10.8% and 9.6% for devices doped with rubrene and C6 sensitizers, respectively. High color purity of the red OLED with CIE coordinates at (0.62, 0.36) was obtained.

## 1. Introduction

OLEDs have attracted considerable attention because of their high brightness, high efficiency, and environment friendly [1,2]. However, for obtaining OLEDs with high quality images, the improvements on the hue saturation, brightness, and emission stability of the red OLEDs are required, which can be improved by altering the materials, structures, and fabrication processes of the devices [3].

In this study, red OLEDs with a single emission layer were fabricated. For achieving high color-purity and emission stability, sensitizers of rubrene and C6 were doped. The influence of sensitizer doping on the EL properties of the devices was investigated.

## 2. Experimental

Blue MADN and green Alq<sub>3</sub> were used as the host materials. DCJTb was used as the red dye; rubrene, and C6 were used as sensitizers to enhance the energy transfer between emitters and to improve the EL properties of the OLEDs. For device fabrication, all organic materials were evaporated layer by layer onto the substrate at a deposition rate of 0.5–1 Å/s in a high vacuum of about 5×10<sup>-6</sup> Torr. After that, a LiF electron injection layer and an Al cathode were deposited at a deposition rate of 2–3 Å/s. The emission area of the devices was 0.24 cm<sup>2</sup>. To measure the EL properties of the devices, voltage was applied using a Keithley 2410 programmable voltage–current source. All the measurements were carried out at room temperature in air without encapsulating the devices.

## 3. Results and Discussion

In this study, a high stability red OLED with a co-hosted emission layer (EML) was fabricated. For improving the EL efficiency, color-purity and emission stability of the red OLED, sensitizers, which promote

energy transferring from Alq<sub>3</sub> to the DCJTb, were doped. Rubrene and C6 were the suitable sensitizers, which can absorb the residual energy of Alq<sub>3</sub> and then transfer to the DCJTb via Förster energy transfer mechanism.

First of all, a device with structure of ITO/NPB (40 nm)/MADN:Alq<sub>3</sub>:DCJTb:sensitizer (30 nm)/Bphen (60 nm)/LiF (2 nm)/Al (200 nm) was fabricated, where the films were prepared under optimal thicknesses. The doping concentration of DCJTb was 1.5 wt%. The mixing concentration ratio of Alq<sub>3</sub> to MADN was 80%.

Figure 1 shows the relationship between luminance intensity and applied voltage for devices doped with rubrene sensitizer. It is found that luminance intensity and was improved by doping with low concentrations of rubrene. When the concentration of rubrene was 0.5 wt%, the device had the highest luminance of 10300 cd/m<sup>2</sup>, with a current density of 263.4 mA/cm<sup>2</sup> at 9 V; comparison with the device without rubrene doping at applied voltage of 9 V, the luminance intensity and current density of the device with rubrene were enhanced by 2.0 folds. This was attributed to the enhanced carrier trapping, the effective energy transfer between MADN and rubrene, and the cascaded partially energy transfer between Alq<sub>3</sub>, rubrene, and DCJTb. However, when the rubrene concentration was higher than 0.5 wt%, a self-quenched luminescence was observed, which was caused by intermolecular aggregation of dye molecules.

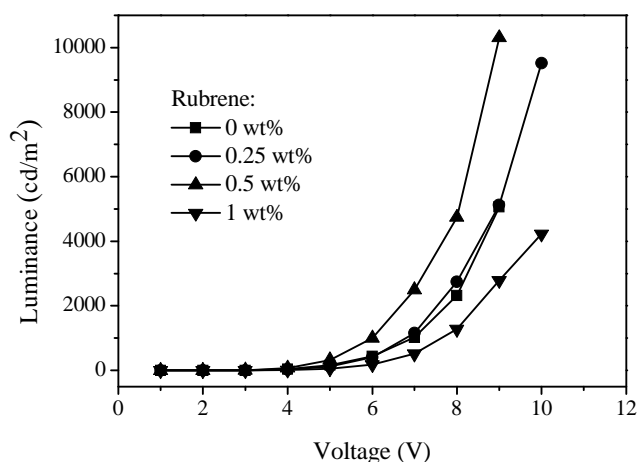


Fig. 1 Relationships between the luminance intensity and applied voltage for devices doped with rubrene sensitizer.

Figure 2 shows that high stability in EL efficiency was observed and the EL efficiency was actually improved by rubrene doping. In addition, it is found that by means of rubrene doping the residual emission of Alq<sub>3</sub> was effectively decreased, and a high stability in emission color was observed. The CIE coordinates at 9 V were (0.60, 0.38), (0.59, 0.40), (0.61, 0.39), and (0.60, 0.39) when rubrene concentrations were 0, 0.25, 0.5, and 1 wt%, respectively; and the CIE coordinates for rubrene concentration of 0.5 wt% were (0.59, 0.40), (0.61, 0.39), (0.61, 0.39), (0.60, 0.39), and (0.60, 0.40) at applied voltages of 8, 9, 10, 11, and 12 V, respectively.

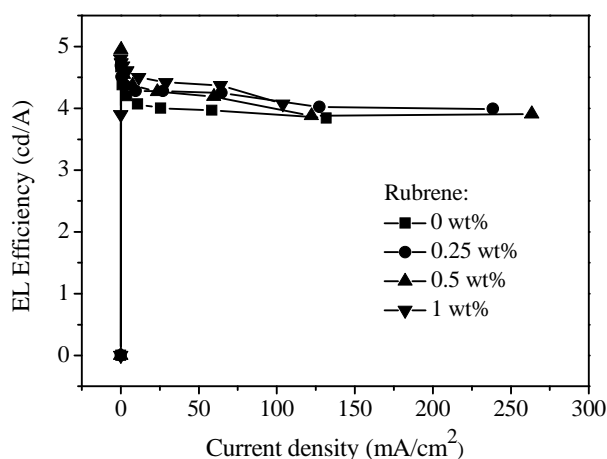


Fig. 2 EL efficiencies of the red OLED doped with different concentrations of rubrene.

In addition to rubrene, coumarin (C6) was another suitable sensitizer for this study. The EL properties of the red OLED with rubrene and C6 sensitizers were compared and discussed. The structural parameters for devices with C6 sensitizer were the same as those used for devices with rubrene sensitizer except the EML in this case was composed of MADN, Alq<sub>3</sub>, C6, and DCJTb; in which the concentration of DCJTb was set at 1.5 wt%; the concentration ratio of Alq<sub>3</sub>/MADN was 80%; and the C6 concentration was varied from 0.03 to 0.1 wt%.

The residual emission of Alq<sub>3</sub> was diminished by C6 doping, as shown in Fig. 3. Meanwhile, the EL peak was shifted from 605 nm (the wavelength when device without C6 doping) to 638 nm when the device was doped with C6. The emission peak was the same even though the concentration of C6 was varied. However, the EL intensity at wavelength of 517 nm, referring to the C6 emission, was increased with the doping concentration of C6. This was attributed to the HOMO level of C6 was higher than that of Alq<sub>3</sub> and DCJTb. The holes transporting from NPB to the EML were trapped and recombined more on C6 molecules while increasing C6 concentration. The maximum EL efficiency was 5.28 cd/A when the concentration of C6 was 0.05 wt%. Meanwhile, the effective carrier recombination

and Förster energy transfer resulted in a maximum luminance of 6734 cd/m<sup>2</sup> was measured at 9 V. However, the luminance and current density were decreased resulting from the severely carrier trapping by doping with high concentration of C6. The CIE coordinates were (0.63, 0.36) at 8 V when the C6 concentrations were 0.03, 0.05, and 0.1 wt%. As comparing with the device without doping C6 sensitizer, high stability in emission color was observed when the device was doped with C6 sensitizer.

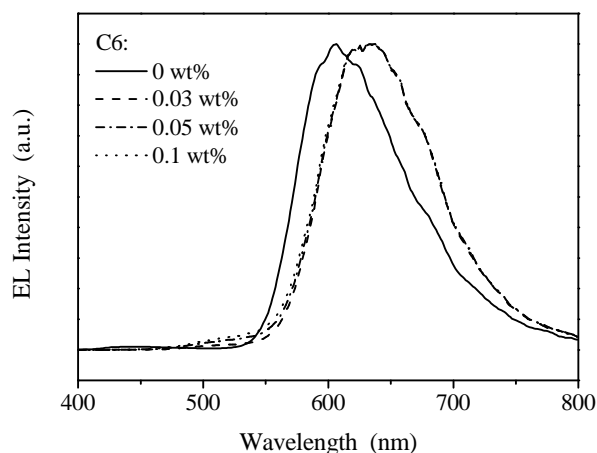


Fig. 3 EL spectra of the red OLED doped with different concentrations of C6.

#### 4. Conclusions

Comparison with the characteristics of the device just with DCJTb doping, the device with addition of rubrene sensitizer showed enhancements in luminance intensity and current density by 2.0 times, on the other hand, enhancements in luminance intensity by 1.3 times and in current density by 0.6 times were measured when the devices with addition of C6 sensitizer. High stability in EL efficiencies was measured for all of the devices. The variations of CIE coordinates were  $\Delta x = 1.7\%$ ,  $\Delta y = 2.5\%$  in 8–12 V for devices doped with rubrene; and those were  $\Delta x = 1.5\%$ ,  $\Delta y = 2.7\%$  in 6–10 V for devices doped with C6. High stability in emission color of red OLED was achieved.

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