

Color-Tunable Polymer Light-Emitting Diodes with Conjugated Polymer Homojunctions

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1. Introduction

Organic and polymer light-emitting diodes (OLEDs and PLEDs) have attracted a great deal of attention due to their applications such as full color or large-area flat panel displays [1,2]. For PLEDs, particular solution processibility makes them have the advantages of low-cost manufacturing and homogeneity in a large area. Though the large-area flat panel displays made by PLEDs are not demonstrated so far, PLEDs with high brightness, high efficiency, and long operation lifetimes were reported [3,4]. To obtain high performance PLEDs, the conjugated polymers are the most used and investigated emissive materials. The emission spectrum of conjugated polymer is adjustable via methods such as polymer blending, nanocrystal or dye doping, bilayer exciplex, or functional groups [5-6]. In this study, we have achieved a novel color-tunable PLED with homojunction structure. In the homojunction, poly(9,9-dioctyl-fluorene) (PFO) acts as the host material, and it is doped with poly[2-methoxy-5-(2'-ethylhexyloxy)-1,4-phenylene vinylene] (MEHPPV) for red light emission. Consequently, the emission color of our PLEDs is gradually shifted from orange or light blue to white due to the carrier over flow.

2. Experimental Details

The emissive materials, PFO and MEHPPV, are firstly dissolved in toluene, separately. The concentration of two PFO-derivatives is 3.5 and 0.05 wt % and they are used as blue and green emission units, respectively, while the concentration of MEHPPV-toluene solution is 0.5 wt %. The absorption and photoluminescence (PL) spectra of PFO solutions are shown in Fig. 1. The first absorption peaks of both PFO solutions are at about 390 nm. Obviously, the only discrepancy between their absorption spectra is the absorption of photons with wavelengths ranging from 430 to 500 nm. According to previous reports, the emission of yellowish-green light from PFO is attributed to keto defect sites that efficiently trap singlet excitons [7]. To avoid confusing, the blue-emitting and green-emitting PFO are named as PFO-B and PFO-G, respectively. The homojunction active region of our devices comprises two PFO layers. The first active layer is obtained by spin-coat the PFO-G solution doped with 2 % MEHPPV (Blend 1). Subsequently, we mix the PFO-B and PFO-G solutions in a

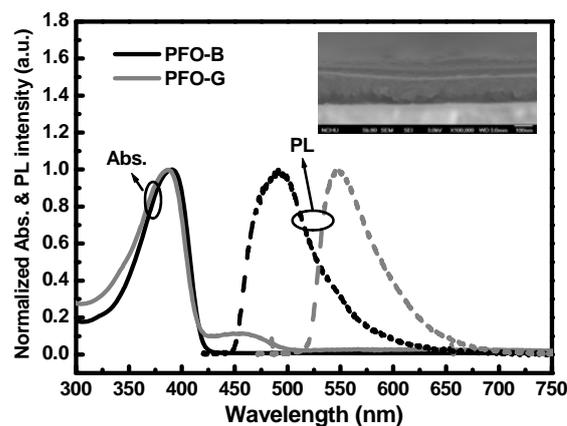


Fig. 1. The absorption and PL spectra of PFO derivatives used as the blue-emitting and green-emitting units in our devices. Inset is the cross-section SEM image of the homojunction.

volume ratio of 1:1 (Blend 2) and used the blending solution to spin-coat the second active layer. The inset of Fig. 1 shows the cross-section SEM image of the homojunction. One can clearly observe the interface. Therefore, our devices can be described as ITO/PEDOT:PSS/(PFO-G+MEHPPV)/(PFO-B+PFO-G)/Ca/Al. We will call them as type I devices in the following description. After fabrication, the devices were preserved in glove-box.

3. Results and Discussion

The measurements of devices' characteristics are also performed in the glove-box. Figure 2 shows the current-voltage (I - V) and luminance-voltage (L - V) curves of devices. Due to the limitation of voltage source, the maximum injection current and luminance were not obtained. The luminance efficiency as a function of current is plotted in the inset of Fig. 2. The low efficiency may be attributed to the leakage current or the unbalance of the amount of electron/hole carriers. Due to the direct contact of the second active layer and the cathode metal, the cathode quenching effect should also be responsible, and it can be eliminated by inserting a thin insulating layer such as LiF. If the minority carrier is the electron, the insertion of an insulating layer can also help to improve the probability of electron injection by reducing the built-in

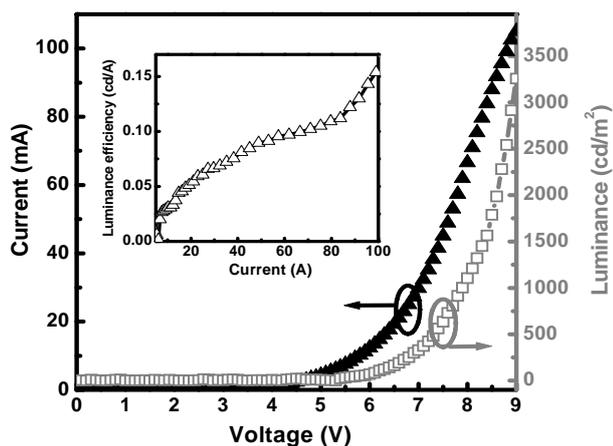


Fig. 2. The I - V and L - V , and curves of type I devices. Inset is the corresponding η - I curve.

potential.

The injection current-dependent electroluminescence (EL) spectra of the type I devices are measured from 10 to 50 mA. As shown in Fig. 3(a), the emission peaks around 456 and 484 nm are the emission from PFO-B. From easy comparison, the spectra are normalized to the peak at 484 nm. The emissions from PFO-G and MEHPPV respectively peaked at 570 and 620 nm, are increased with current increasing. Since the mobility of electron is lower than that of hole, the recombination of electron and hole are basically happened in the second emission layer next to the cathode. When the current is increased, the electrons in the second layer can easily flow into the first active layer because there is no potential barrier between them (homojunction). As a result, the recombinations of carriers in the first layer contribute the EL intensity, and the emission color of the devices is shifted from light blue to pure white. To confirm this assumption, we exchange the deoposition sequence of the first and second layer in type I devices and mark them as type II devices. Obviously, the EL intensity from the first active layer (PFO-B+PFO-G) in type II device is also increased with current increasing as

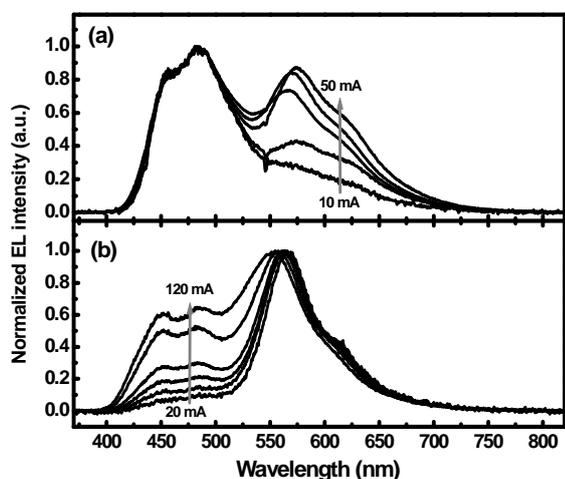


Fig. 3. The normalized, injection current-dependent EL spectra of (a) type I and (b) type II devices.

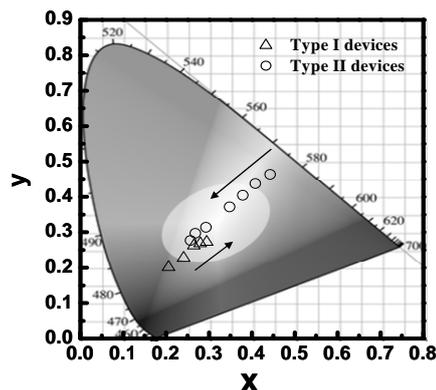


Fig. 4. The CIE-1931 coordinates corresponding the current-dependent spectra of type I and type II devices. The arrows indicate the trends with current increasing.

shown in Fig. 3(b). From this demonstration, most of the green emission is clearly from the PFO-G blended with MEHPPV, instead of that blended with PFO-B. The Commission Internationale de l'Eclairage (CIE-1931) chromaticity coordinates corresponding the current-dependent spectra of type I and II devices are shown in Fig. 4.

4. Conclusions

In conclusion, the color-tunable LEDs with a polymer homojunction structure are demonstrated. When the injection current is increased, partial electrons can easily pass through the second active layer and flow into the first layer because there is no potential barrier existing in the homojunction. However, to make the novel devices practical, more precise color engineering is necessary to reduce the current induced variation of brightness.

Acknowledgements

The authors are grateful to the National Science Council of the Republic of China, Taiwan, for financially supporting this research under contract no. NSC 98-2218-E-006-005-MY2.

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