

# IMPROVING THE PERFORMANCE OF PHOSPHORESCENT BASED WHITE POLYMER LIGHT EMITTING DEVICES USING IRIIDIUM COMPLEXES

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## ABSTRACT

*Polymer White-light-emitting devices WPLEDs with single layer structures are fabricated by the spin-coating method. The device structure used here is indium-tin-oxide(ITO)/polyethylene dioxythiophene(PEDOT:PSS)/polymer blend/Ca/Al, whose blend consists poly N-vinylcarbazole(PVK) hole transporting host polymer, an electron transporting materials 2-4-biphenyl-5-tert-butylphenyl-1,3,4-oxadiazole(PBD), doped with blue emitting and orange light emitting Ir complexes. The white light emission with CIE coordinates of (0.33, 0.36) is achieved in a large voltage range, the maximal luminance efficiency of 1.8 cd/A is obtained at 6V, and the maximal brightness is 3000 cd/m<sup>2</sup> at 9 V.*

## KEYWORDS

*Electroluminescence; Polymer light emitting Devices; Electrophosphorescent*

## 1. INTRODUCTION

White organic light emitting devices (WOLEDs) have drawn intense attention in both scientific and industrial communities due to their potential applications in full-color flat panel displays, back-lighting sources for liquid-crystal displays and solid-state lighting sources[1-10]. To achieve white emission, mixtures of the three red, green and blue(RGB) primary colors or two complementary colors, are typically required. Various approaches towards realizing WOLEDs have been reported, including multilayer structures capable of sequential energy transfer, multiple component emissive layers containing an appropriate of RG phosphorescent or fluorescent dopants[11-15]. Polymer blends containing RGB emitting species, charge transfer exciplexes or excimers broad emission and single component layers that utilize a polymer with broad emission[16-22].

Polymer light emitting devices (PLEDs) offer the advantages of solution processing, including screen printing and ink-jet deposition, large area coverage, low power consumption. PVK is one

of the most often used polymer host materials for optoelectronic devices based on molecularly doped systems, due to its good film-forming properties, relatively high hole mobility, and large highest occupied molecular-orbital-lowest unoccupied molecular orbital(HOMO-LUMO) separation. Since pure PVK has poor electron-transporting properties, oxadiazole compound such as 2-tert-butylphenyl-5-biphenyl-1,3,4-oxadiazole(PBD) have often been added to PVK. In fact, many studies have shown that PVK:PBD blends with PBD concentrations in the range of 30-50% serve as good hosts for small molecule emitters and highly efficient polymer-based LEDs based on this system have been reported[12-19]. In this study, we report single layer white PLEDs with an emission layer containing a blend of two phosphorescent iridium complexes within a PVK-PBD host matrix. Despite their simple architectures and straightforward fabrication procedures, these devices show excellent color purity and considerably improved luminance efficiencies, when compared to other polymer-based white emission devices.

## 2. EXPERIMENTAL

White Polymer light emitting devices were fabricated on the ITO-coated glass substrates. The substrates were ultrasonically cleaned with detergent, deionized water, acetone, and isopropyl alcohol. A layer of 40 nm thick poly(3,4-ethylene dioxythiophene):poly(styrene sulfonic acid) (PEDOT:PSS, H.C. Stack) was spin coated onto the precleaned and UV-O3 treated ITO substrates. The PEDOT:PSS layer was first baked at 150°C for 30 min to remove residual water and then moved into a glovebox under the N<sub>2</sub> environment to performance the subsequent multilayer integration process. PVK and PBD were obtained from sigma-Aldrich and used as received. FIrpic and Ir (Btp)<sub>2</sub>(acac) were purchased from Luminescence technology corp. The blends of PVK:PBD(60:40) with different FIrpic and Ir(Btp)<sub>2</sub>(acac) concentrations in chlorobenzene solution were spin coated on top of ITO/PEDOT:PSS. The blend layers were about 70 nm thickness. To remove residual solvent, the samples were annealed at 60°C before cathode deposition. Then, the Ca(60nm) and Al(120nm) electrodes were thermally evaporation in a vacuum of about  $2 \times 10^{-6}$  Torr.

## 3. RESULTS AND DISCUSSION

Typical current density-voltage and luminance –voltage characteristics of devices shown in Fig.1(a) and (b). The turn-on voltage(defined as the voltage where 1 cd/m<sup>2</sup> is measured) about 8.0V is low among PVK based with white PLEDs, where usually high drive voltages are required because of low hole transport mobility( $10^{-5}$  V<sup>-1</sup>S<sup>-1</sup>), unmatched charge carrier injection barrier heights and charge trapping defects. The low operation voltages of the devices are important for reducing powder consumption.

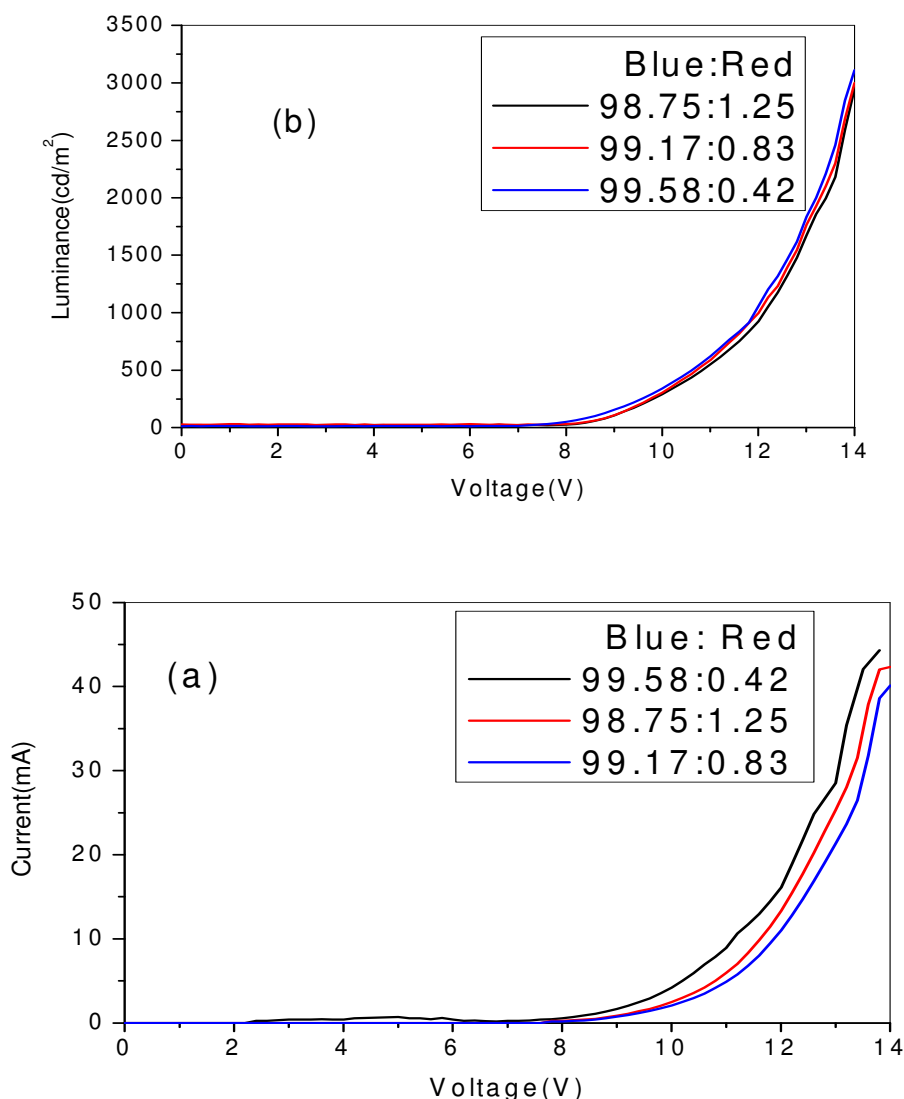


Fig.1. (a) I-V characteristics of PLEDs with different Irpic and Ir(Btp)2(acac) doping levels. Device structure is ITO/PEDOT:PSS/PVK0.6:PBD0.4:Irpic(blue):Ir(Btp)2(acac)(red)/Ca/Al ; (b) L-V characteristics of the PLEDs with different Irpic(blue), Ir(Btp)2(acac)(red) doping levels.

One of the main problems of the white PLED is the color stability of the device, which means the emission of the device may change with increasing applied voltages.

The EL spectra of the device with different weight ratios are shown in Fig.2a. As seen from this figure two main emission peaks appeared and the red peak was slightly blue shifted at 8V. But the white PLED showed good stability. For the device with the different Ir complex weight ratios of the white emission color is stable. For the luminance varying from 300 cd/m<sup>2</sup> (which is necessary for display applications) to 3100 cd/m<sup>2</sup>, the CIE coordinates slightly shift from (0.34, 0.37) to (0.36, 0.39). This probably because the exciton recombination zone shifts slightly under an electric field.

The device(blue 99.58, red 0.42) has maximum efficiency of 1.8 cd/A, and maximum luminance reaches 3100 cd/m<sup>2</sup> at 14V. The WPLEDs with doping concentration of 99.79 for FIrpic blue and 0.21 for Ir(btp)<sub>2</sub>(acac) red emit white light at the CIE coordinates from (0.30, 0.42) to (0.33, 0.44) at 8V to 14V. Electroluminescence (EL) efficiency versus current of devices are plotted in Fig.2b. The maximum luminance and efficiency are 3100 Cd/m<sup>2</sup> and 1.8 Cd/A. We have considered efficient energy transfer from the conjugated polymer to the phosphorescent dopants from the point of view of miscibility, but it can be also explained by a triple energy level. Recently, it was reported that energy transfer from conjugated polymers to phosphorescent dyes is difficult because of phosphorescence quenching owing to the relatively low triplet energy levels of the conjugated polymers[23-25]. On the other, PVK has a higher triplet energy than that of commonly used heavy metal phosphorescent dopants, which means that it cannot quench the triplet state of dopant[25].

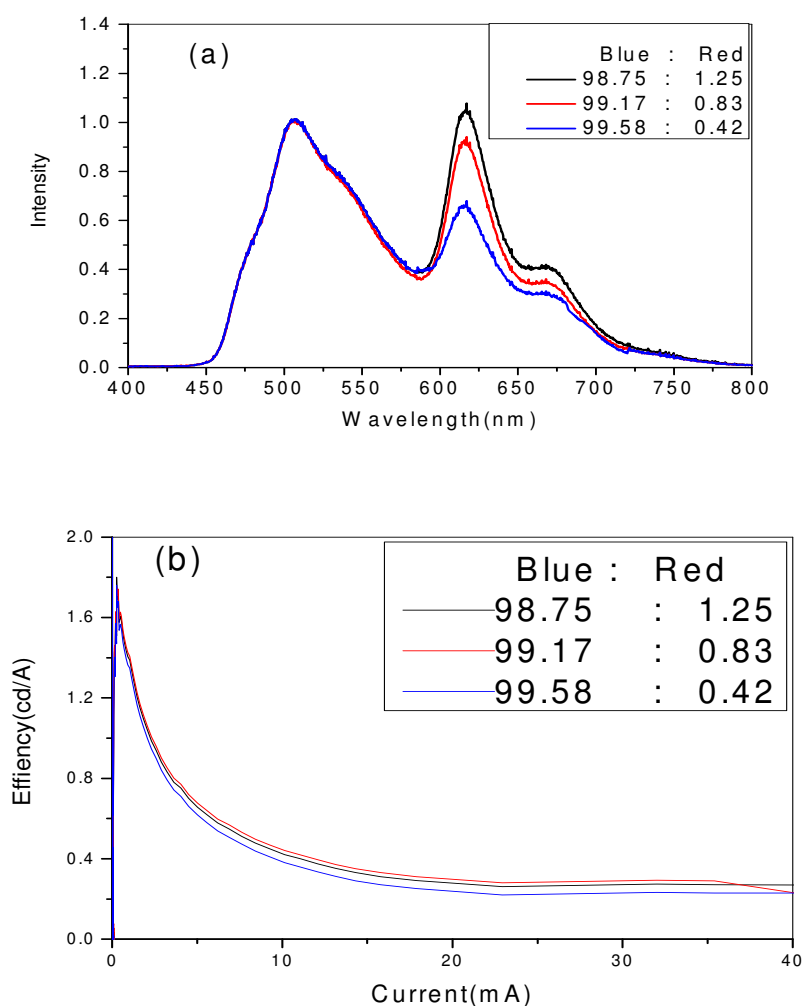


Fig. 2 (a) Normalized EL spectra of PLED (b) The luminescence efficiency versus current characteristics of PLEDs with different FIrpic(blue) Ir(Btp)<sub>2</sub>(acac)(red) doping levels; Device structure is ITO/PEDOT:PSS/PVK0.6:PBD0.4: FIrpic(blue): Ir(Btp)<sub>2</sub>(acac)(blue)

## 4. CONCLUSIONS

In summary, the white light emitting PLEDs were single layer devices fabricated by spin-casting the polymer blend from solution. The simple device structure and the promise of low-cost manufacturing make these electro-phosphorescent PLEDs attractive for development for solid-state lighting applications. The devices have one polymer blend layer PVK, PBD, and Ir complexes. We have demonstrated that the EL device can provide high EL performances. When the weight ratios of the blend layer is 98.75:1.25, the pure white-light emission with CIE coordinates of (0.34, 0.37) is achieved, and changing slightly in a large voltage range, the maximal luminance efficiency 1.8 cd/A is reached at 0.26mA, and the maximal brightness is 3100 cd/m<sup>2</sup> at 14V

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