

# Fabrication of efficient and stable white organic light emitting diodes (WOLEDs) based on host-guest system

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## Abstract

Efficient white light emission has been obtained from blue fluorescent bis (2-(2-hydroxyphenyl) bezoxazolate) zinc [Zn(hpb)<sub>2</sub>] a host material doped with red phosphorescent Iridium bis(2-(2-benzothione)l pyridinato-acetyl-acetate [Ir(btpy)<sub>2</sub> acac] guest materials. The white emission spectrum was controlled by optimizing the concentration of guest molecules in the emissive layer. The electroluminescent (EL) spectra of the white OLED cover a wide range of visible region of the electromagnetic spectrum with three peaks around 450 nm, 485 nm and 610 nm. OLED device with the configuration ITO/ $\alpha$ -NPD/Zn(hpb)<sub>2</sub>:0.1% Ir(btpy)<sub>2</sub> acac/LiF/Al produced white light with CIE coordinates of (0.34, 0.27). The device gave a maximum brightness of 3500 cd/m<sup>2</sup> at 12 V.

## 1. Introduction

White organic light-emitting devices (WOLEDs) are of growing interest in next generation displays and solid-state lighting technologies [1]. Among the WOLEDs [2–8] reported, efficiencies of those [5] based on phosphorescent materials are outstandingly high due to their demonstrated potential for achieving 100% internal emission efficiency [9]. On the contrary, the efficiencies of fluorescence devices are relatively low because of the statistical limit of 1:3 for the singlet-to-triplet exciton ratio in molecular organic materials. Fortunately, these low efficiencies can be improved to the level of phosphorescent devices by phosphor sensitization [10] in which Förster energy transfer between triplet excitons in the phosphor and singlets in the fluorophore takes place. The use of dopants (guest) to modify the photo-physical as well as electronic properties of host molecules has become one of the most important subjects in OLEDs [11]. Doping of wide band gap materials, which emits in the blue region of the spectrum with lower band gap dopants, can modify the emission properties of the host molecules. With careful balancing of the doping it is possible to obtain white light emission that is required for many applications. The modification of emission properties upon doping is due to efficient energy transfer from the host molecules to the guest molecules (dopants). The energy transfer in this matrix occurs in different ways. They are (i) Förster type energy transfer, (ii) Dexter type energy transfer and (iii) trap assisted energy transfer. Keeping precisely this in view we have fabricated WOLED using a blue light emitting material namely [Zn(hpb)<sub>2</sub>] and tuning its spectral response for white light emission by optimally doping it with [Ir(btpy)<sub>2</sub> acac] that results in incomplete energy transfer between the two i.e. the host and the guest. This device results into stable color coordinates in a range of voltages, reasonable current efficiency and brightness. These new and interesting results are reported in this paper.

## 2. Experimental Details

$\text{Zn}(\text{hpb})_2$  was synthesized using the method reported in the literature [12]. The WOLED device configuration and the molecular structure of emitter materials are shown in Fig.1. Indium-tin oxide (ITO) coated glass substrate with a sheet resistance  $20\Omega/\square$  which was used as anode were patterned and cleaned using deionized water, acetone, trichloroethylene and isopropyl alcohol sequentially for 20 minutes using an ultrasonic bath and dried in flowing nitrogen. Prior to organic film deposition, the ITO surface was treated with oxygen plasma for 5 minutes. The hole transport layer and the emitting layer were deposited on to the substrate sequentially under high vacuum ( $1 \times 10^{-5}$  torr) at a deposition rate of 0.1nm/sec. Thickness of the deposited layers were measured in situ by a quartz crystal monitor. The N,N diphenyl-N'N'-bis(1-naphthyl)-1,1'-biphenyl-4,4'- diamine,  $\alpha$ -NPD (Sigma Aldrich) was used as hole transport layer,  $\text{Zn}(\text{hpb})_2$  doped with  $[\text{Ir}(\text{btpy})_2 \text{ acac}]$  (American Dye Source) as emitting layer, LiF (Merck, Germany) was as electron injection layer and aluminum (Cerac) as the cathode metal. The typical thickness of the different layers were ITO (120 nm)/ $\alpha$ -NPD (40nm)/ $\text{Zn}(\text{hpb})_2$ :  $[\text{Ir}(\text{btpy})_2 \text{ acac}]$  0.1 wt% (350 nm)/ LiF(1nm)/Al (150nm).The size of each pixel was  $5 \times 5 \text{ mm}^2$ .The electroluminescence (EL) spectra has been measured using a high resolution spectrometer (Ocean Optics HR-2000CG UV-NIR). The current density-voltage-luminescence ( $I$ - $V$ - $L$ ) characteristics have been measured with a luminance meter (LMT 1-1009) and a Keithley 2400 programmable voltage-current digital source meter. All the measurements were carried out at room temperature under ambient conditions.

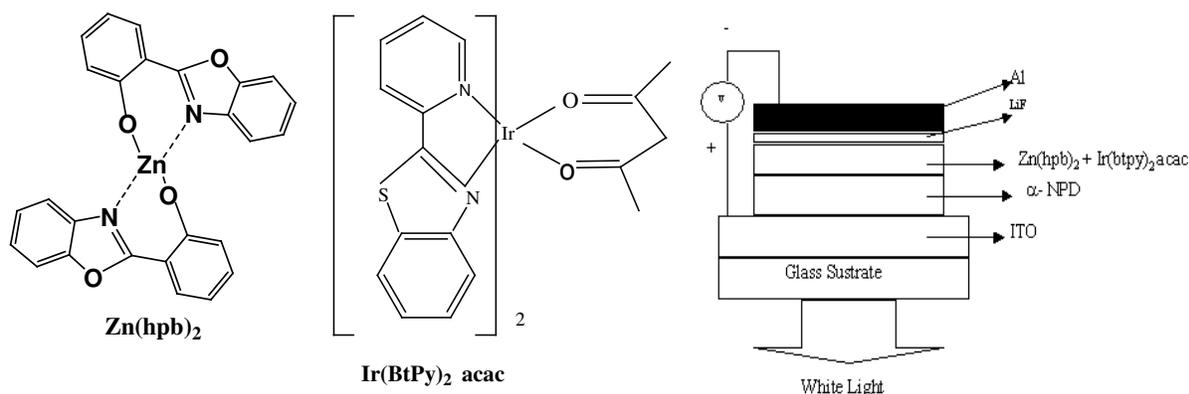


Figure. 1. The molecular structure of emitter materials and WOLED device configuration.

## 3.Result and Discussions

Figure.2 (a) shows the normalized optical absorption spectrum of the molecules  $\text{Ir}(\text{btpy})_2 \text{ acac}$  (A) and the normalized photoluminescence spectrum of the host  $\text{Zn}(\text{hpb})_2$  (B). The PL spectrum of the host  $\text{Zn}(\text{hpb})_2$  and the guest have partially overlap with each other which is very much favorable for Forster type energy transfer between the guest and the host [11].

Figure 2 (b) shows the normalized PL spectrum of pure  $\text{Zn}(\text{hpb})_2$  (curve A), 10 %  $\text{Ir}(\text{btpy})_2 \text{ acac}$  doped (Curve B), 1 %  $\text{Ir}(\text{btpy})_2 \text{ acac}$  doped (curve C), 0.1 %  $\text{Ir}(\text{btpy})_2 \text{ acac}$  doped (curve-D) and pure  $\text{Ir}(\text{btpy})_2 \text{ acac}$  (curve- E). At 10 % dopant concentration (B) the peak at 450 nm of the host material is suppressed by high dopant concentration effect and finally a dominant peak at 610 nm has been observed. At 1 % dopant concentration (Curve C), the 450 peak is still constant and have a broad peak with 610 nm peak of the guest molecules. It is seen at 0.1% dopant concentration the host spectrum is very prominent and energy transfer is incomplete complete. The reason for this inefficient energy transfer in PL may be that at low dye doping the distance between the excited host and guest molecules are too large to effect efficient Forster type energy transfer.

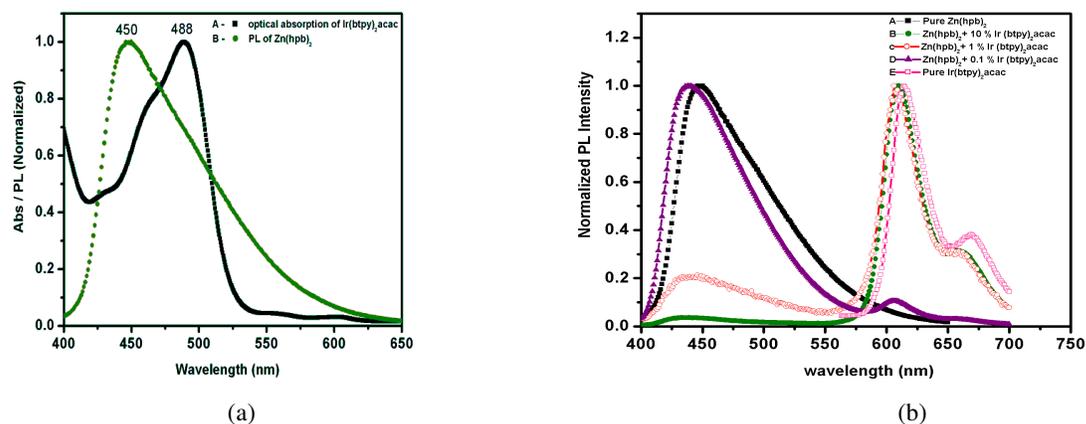


Figure.2. (A) Optical absorption spectrum of guest and PL spectrum of host molecules and (B) PL spectrum of pure Zn(hpb)<sub>2</sub>, pure Ir(btpy)<sub>2</sub>acac and different concentration of Ir(btpy)<sub>2</sub>acac in Zn(hpb)<sub>2</sub>acac.

On the basis of the PL spectrum we have fabricated an OLED device with 0.1% dopant concentration for white light emission. Figure.3 (a) shows the EL spectrum of most balance white OLED. The white spectrum covering whole visible spectrum with three peaks at 450, 485 and 610 nm respectively. Figure.3 (b) shows EL spectrum of white OLED at different voltages from 6 to 12 volts.

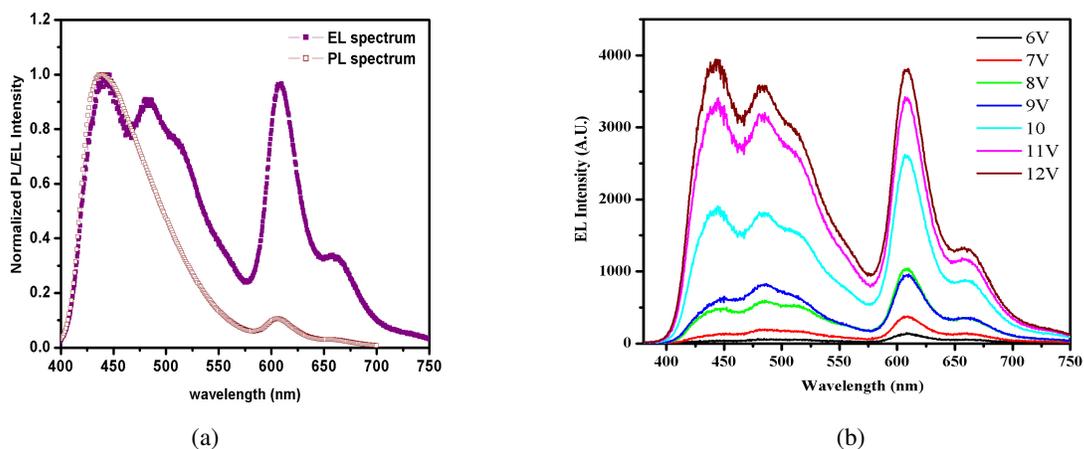


Figure.3 (a) Comparison of PL and EL spectrum of the 0.1 % of the dopant in host molecules and (b) EL spectrum of WOLEDs at different voltages.

## 4. Conclusion

A white light OLED device is demonstrated by tuning the PL spectra and EL spectra of blue emitting material Zn(hpb)<sub>2</sub> by doping of Ir(btpy)<sub>2</sub>acac to it. The host-guest combination emits white light at dopant concentration 0.1 wt %. The emission parameter of WOLED device is the CIE coordinates (at 12 V  $x=0.34$ ,  $y=0.27$ ) and the maximum brightness of 3500 Cd/m<sup>2</sup> at 12 V. The CIE coordinates stayed practically constant when the bias voltage increased with 5 to 12 V.

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