Electroluminescent Characteristics of White OLED using (POB)$_2$Ir(pic)

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1. Introduction

White organic light-emitting diodes (OLED) have drawn much attention due to their potential applications in full color displays with the help of color filters, in backlight for LCDs, and eventually in solid-state lighting sources. Based on these we get the idea that white light is the most important color in the lighting application. A number of strategies have been reported to make white OLED, including multilayer structure consisting of two or more emitting layers [1,2]. For multilayer structure different emissions from different layers can be combined to give the white color, or using the doping technique to take appropriate amount of dopants in the same host, or using the micro cavity effect of one emission layer, etc [3,4].

In this study, we synthesized the red emission materials, Ir(POB)$_2$(pic) and previous research was synthesized Zn(HPB)$_2$ as blue emitting materials [5]. The ionization potential (IP) and electron affinity (EA) of (POB)$_2$Ir(pic) were measured by cyclic-voltammetry. We studied white OLED using emitting materials, Zn(HPB)$_2$ layers and Alq$_3$: (POB)$_2$Ir(pic). We varied the doped rate of Alq$_3$: (POB)$_2$Ir(pic). When the doped rate of the Alq$_3$: (POB)$_2$Ir(pic) was 0.6%, white emission is achieved. And we measured the temperature dependence of current density-voltage and luminous efficiency characteristics. And we observed the electroluminescent spectrum intensity.

2. Experimental

A white OLED was fabricated in which a green light emitting host Alq$_3$ was doped with a red dye Ir(POB)$_2$(pic). The Zn(HPB)$_2$ was blue emitting layer. The structure of the devices were NPB (40 nm) / Zn(HPB)$_2$ (40 nm) / Alq$_3$: (POB)$_2$Ir(pic) (30 nm) / LiF / Al. The doped rate of the Alq$_3$: (POB)$_2$Ir(pic) was 0.4%, 0.6%, 0.8 and 1.2%, respectively. Table 1 shows the device structure. The organic materials were evaporated on top of the ITO substrate under 5 x 10$^{-6}$ torr with a deposition rate of about 1.0 Å/s. A metal was deposited under 5 x 10$^{-4}$ torr with a deposition rate of about 10 Å/s. We measured the temperature dependence of current density-voltage and luminous efficiency characteristics. And we observed the electroluminescent spectrum intensity.

Table 1. The structures of white OLED

<table>
<thead>
<tr>
<th>Device</th>
<th>Structure</th>
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<tbody>
<tr>
<td>Device 1</td>
<td>ITO/NPB/ Zn(HPB)$_2$/Alq$_3$: Ir(POB)$_2$(pic) (0.4%)/LiF/ Al</td>
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<tr>
<td>Device 2</td>
<td>ITO/NPB/ Zn(HPB)$_2$/Alq$_3$: Ir(POB)$_2$(pic) (0.6%)/LiF/ Al</td>
</tr>
<tr>
<td>Device 3</td>
<td>ITO/NPB/ Zn(HPB)$_2$/Alq$_3$: Ir(POB)$_2$(pic) (0.8%)/LiF/ Al</td>
</tr>
<tr>
<td>Device 4</td>
<td>ITO/NPB/ Zn(HPB)$_2$/Alq$_3$: Ir(POB)$_2$(pic) (1.2%)/LiF/ Al</td>
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3. Results and Discussion

Fig. 1 shows PL spectrum and the molecular structure of (POB)$_2$Ir(pic). The PL peak of (POB)$_2$Ir(pic) was observed at 600 nm. (POB)$_2$Ir(pic) showed red emission.

![Fig. 1 PL spectrum and Molecular structure of (POB)$_2$Ir(pic).](image)

The cyclic voltammetry used to measure the energy gap of Ir(POB)$_2$(pic). It was found that the films of Ir(POB)$_2$(pic) could be oxidation and reduction. The oxidation onset potential and the reduction onset potential of Ir(POB)$_2$(pic) was measured to be +1.1V and –1.40V. The electron affinity (EA) of Ir(POB)$_2$(pic) is 3.4eV and the ionization potential (IP) of Zn(HPB)$_2$ is 5.7eV. Fig. 2 shows the energy level alignment of the devices.

Fig. 3 shows the luminance of device 1, 2, 3and 4 varying with current density. The maximum of the luminance of device 2 is 14500 cd/m$^2$ while the voltage is 10.75 V. This may due to the thicker emission layer Alq$_3$: (POB)$_2$Ir(pic), which also leads improvement of the fluorescence quenching by the cathode.
Fig. 2 The energy level alignment of the devices.

Fig. 3 The luminance-current density of devices.

Fig. 4 The normalized EL spectra of devices.

Fig. 4 shows the normalized EL spectra of devices 1, 2, 3 and 4. The proportion of red emission increases with the increasing doping rate and blue emission decreasing with increasing doping rate. When the doped rate of the Alq₃:(POB)₂Ir(pic) layer was 0.6%, white emission can be obtained. The CIE coordinates are (0.316, 0.331) at a voltage 10.75 V.

This phenomenon might be explained as follows. At increasing the doping rate, red emission was increased because of more electron and hole recombination in Alq₃:Ir(POB)₂(pic) layer than Zn(HPB)₂. Because in this case, the Zn(HPB)₂ is working as a hole blocking layer. In order to understand the relationship between the activation energy for EL spectrum and material parameters, in particular ionization potentials, an energy diagram of the OLED studied in this letter is presented in Fig. 2. In the mixed layer, holes will be transported by hopping between Zn(HPB)₂ molecules, and electrons by hopping between Ir(POB)₂(pic) molecules.

4. Conclusions

We synthesized blue emissive materials of (POB)₂Ir(pic). Ir(POB)₂(pic) measured energy level values using cyclic-voltammetry. The IP and EA of Zn(HPB)₂ was measured to be 5.7 eV, 3.4 eV. This material was used the red emitting layer in white OLED. We varied the doped rate of (POB)₂Ir(pic). When the increasing of doping rate, the red emission increase with the increase doping rate and the blue emission increase with the increase doping rate. We realized a white emission using Ir(POB)₂(pic). When the doping rate was 0.6% white emission is achieved. The CIE coordinates are (0.316, 0.331) at an applied voltage of 10.75V. We realized a white OLED using the red emitting material of Ir(POB)₂(pic).

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References