Wide-bandgap bipolar material with high thermal stability

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ABSTRACT

A new organic compound was synthesized with bipolar carrier mobility, high singlet/triplet energies, and high thermal stability (193 °C) with suitable molecular design. As the host of blue phosphorescent OLED, it shows maximum current efficiency, power efficiency, and external quantum efficiency of 58.7 cd/A, 59.3 lm/W, and 28.6%, respectively.

1 INTRODUCTION

In recent year, organic light emitting diode (OLED) had been widely used in display application such as OLED-TV, smart phone, and lighting [1-3]. Compared with red and green phosphorescent OLED, blue one is still a bottleneck. The efficiency, lifetime and color purity of blue phosphorescent OLED need to be improved. One of the important issue for blue one is the selection of wide-bandgap host in the emitting layer (EML). Such a material should exhibit electron and hole mobility for bipolar carrier transport. Besides, singlet and triplet energies must be kept high to avoid exciton quenching by the host [4-5]. Connecting hole- and electron-transporting moiety with certain interruption in conjugation length is a good strategy. However, sometimes it limits the molecular weight and reduces the thermal stability [5-6].

In this work, we improved the thermochemical property of a bipolar organic material by increasing the molecular weight while keeping the single and triplet energy as high as at 3.26 and 2.89 eV. In this material, glass transition temperature (Tg) was higher than 190 °C and decomposed temperature (Td) was more than 450 °C. With incorporation of conventional sky-blue phosphorescent dopant, bis[2-(4,6-difluorophenyl)pyridinato-C2,N](picolinato)iridium(III) (FIrpic), into this material as the host of the EML, 58.7 cd/A, 59.3 lm/W, and 28.6% in current efficiency, power efficiency, and external quantum efficiency (EQE), respectively, were achieved in this blue phosphorescent OLED (PhOLED). Due to bipolar characteristics and wide recombination zone, efficiency roll-off was alleviated which still had 56.05 cd/A at 1000 nits.

2 EXPERIMENT

In our PhOLED, patterned ITO was used as the anode. Before transferring to the evaporation chamber, ITO anode were treated by oxygen plasma to enhance work function from 4.7 to 5.1 eV and also improve the surface contact of the ITO, for decreasing the driving voltage. After the oxygen plasma process, we sent the ITO substrate to the vacuum chamber with multi-source thermal evaporator. We use 50 nm TAPC (4,4'-Cyclohexylidenebis[N,N-bis(4-methylphenyl)benzenamine]) as hole transporting layer (HTL), 10 nm mCP (1,3-Bis(N-carbazolyl)benzene) as electron blocking (EBL) layer. And 30 nm host doped with x% FIrpic as sky-blue emitter, where the dopant ratio x is 9%, 12%, and 15%. And 55 nm DPPS (Diphenylbis(4-(pyridin-3-yl)phenyl)silane) as electron transporting layer (ETL) deposited in sequence through the shadow mask under high vacuum around 5 × 10-6 torr. Then, 0.8 nm LiF as electron injection layer and 120 nm Al as cathode with another shadow mask. After the evaporation process, the OLED were transferred to the glove box and encapsulated under N2. After OLED fabrication, we use Keithley 2400 to drive device and use Minolta CS-1000 to record spectrum. Figure 1 shows the energy diagram of the PhOLED.

3 RESULTS and DISCUSSION

Figure 2 shows the differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) curves for studying the thermochemical properties of the material. From DSC measurement, Tg was higher more than 190 °C. And from TGA measurement, Td was higher than 450 °C, showing the good thermal property.

Figure 3 shows the summary of electrical and optical performance, including J-V and L-V of the device with various emitter dopant ratio 9%, 12%, and 15% in 30 nm EML. After optimizing the device, we obtained the best performance at 12% FIrpic with 40 nm EML. The driving voltage increased with increasing dopant concentration because FIrpic played as electron trap in the EML. Fig. 3(b) shows that brightness decreased with increasing dopant concentration. OLED with 9% FIrpic exhibited lowest driving voltage as 6.57 V at 20 mA/cm2 and highest brightness. Among different FIrpic concentration, the OLED with 12% dopant ratio achieved 57.26 cd/A in Fig. 3(c). In order to improve the charge balance, we optimized the device and increased the EML to 40 nm. The electrical and optical performance also shown in Fig. 3. The current efficiency was improved to 58.73 cd/A.

Figure 4 shows the efficiency of device versus luminance. Among different FIrpic concentration, the OLED with 12% dopant ratio achieved 57.26 cd/A in Fig. 3(c). In order to improve the charge balance, we optimized the device and increased the EML to 40 nm. The electrical and optical performance also shown in Fig. 3. The current efficiency was improved to 58.73 cd/A. Because of the bipolar characteristics of the EML which resulted in a wide recombination zone, efficiency roll-off was alleviated which still had 56.05 cd/A and 27.73% at 1000 nits with 40-nm EML and 12% FIrpic.

4 CONCLUSIONS

In summary, we demonstrate a novel material with wide band-gap (high singlet and triplet energy), bipolar, and excellent thermal property. The material can serve as the host material for blue PhOLED. After device optimization, high current efficiency with 58.73 cd/A, power efficiency with 59.31 lm/W and EQE with 28.58% was achieved. Besides, efficiency roll-off was alleviated which still had 56.05 cd/A and 27.73% EQE at 1000 nits.

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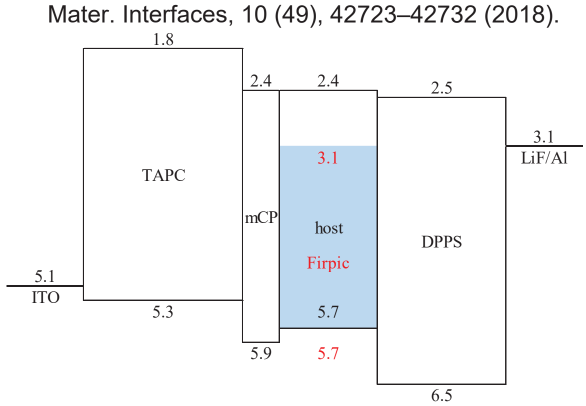

Fig. 1 Energy diagram of blue PhOLED.

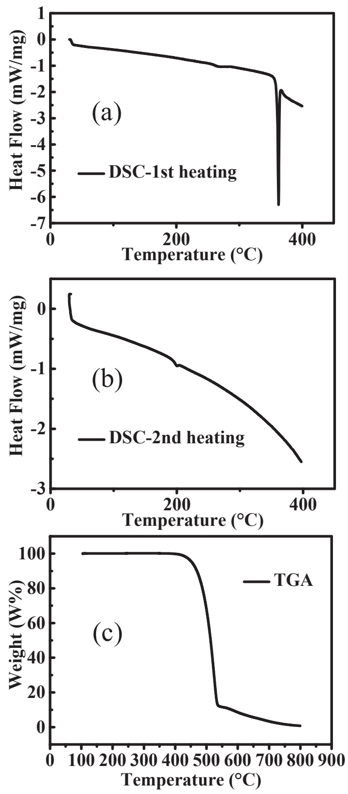

Fig. 2 Thermal properties of materials.

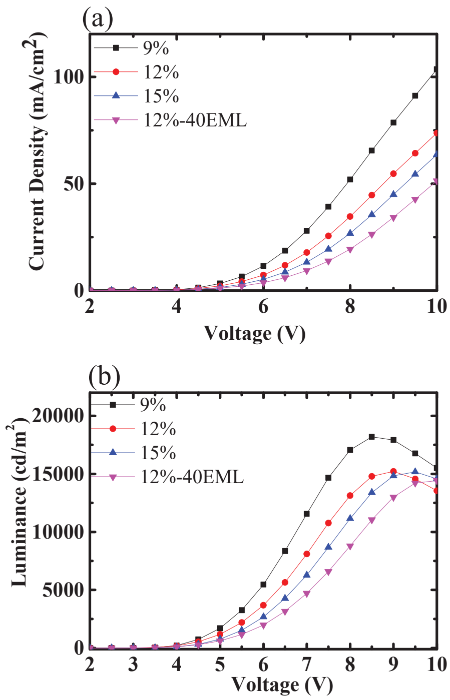

Fig. 3 (a)J-V, (b)L-V curves of blue PhOLEDs.

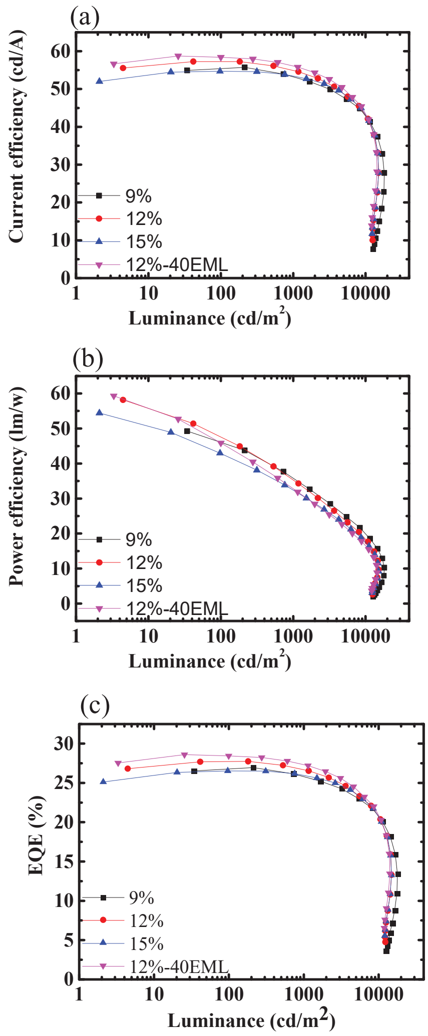

Fig. 4 (a)current efficiency, (b)power efficiency, (c) external quantum efficiency versus luminance curves of blue PhOLEDs.