

High Efficiency White Organic Light Emission Device Based On New Orange Phosphorescence Material

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ABSTRACT

White light emitting device based on a new orange phosphorescent material $\text{Ir}(\text{DPA-FIpy})_3$ ((DPA-FIpy)H = (9,9-diethyl-7-pyridinylfluoren-2-yl)diphenylamine) has been fabricated. The white OLED consists of it and a blue phosphorescent material FIrPic (iridium-bis(4,6-difluorophenylpyridinato-N,C²)-picolinate). The threshold voltage is 4.2V, and the brightness reaches 3200 cd/m² at 10V, 30.3 mA/cm². The color of the light corresponds to a CIE coordinate of (0.31, 0.41). The highest efficiency of the device can reach 17.8 cd/A or 7 lm/W at 8V, 2mA/cm².

INTRODUCTION

White light organic light emission diode (WOLED) plus color filter (CF) is one of the most important methods for making full color displays. WOLED also has the potential to be used as large area light source and as LCD backlight, due to its low cost, high efficiency, and large area uniformity.

There are several methods to make WOLED. White OLED can be fabricated with the multiple emission layers in one device, each of which emits one of the primary colors, R, G or B, respectively. White OLED with high efficiency was presented in SID 2004 [1]. Rubrene (tetraphenylanthracene) was used to emit red and green light. This was matched with the blue emission from another source [2]. Polymer material [3], small molecule

material [4], and phosphorescence material [5] have been tried for WOLED. As far as efficiency is concerned, phosphorescent material surely produced the best results. Hence, high efficiency white OLED can be fabricated in a relatively simple way if blue and orange phosphorescent materials are used.

Recently a new kind of orange light emission phosphorescent material $\text{Ir}(\text{DPA-FIpy})_3$ has been produced. We used this new material and the blue phosphorous material FIrPic to make a WOLED. Its EL CIE coordinates are (0.31, 0.41), and the highest current efficiency could reach 17.8 cd/A. As far as we know, this is the high efficiency soft white light reported.

EXPERIMENT

The glass substrate with ~80nm ITO was cleaned using ultrasonic de-ionized (DI) water and modified with ultraviolet ozone (UV Ozone) discharge. The OLED devices were fabricated in a high vacuum evaporation system under a base pressure less than 2×10^{-4} Pa. We measured the electrical and optical characteristics of the devices with a R6145 DC voltage current source, FLUKE 45 dual display multimeter and Spectrascan PR650 in dark room and ambient condition.

In the first experiment, the orange light emitting diode with the new material was studied.

Fig 1 shows the molecular structures of the material used.

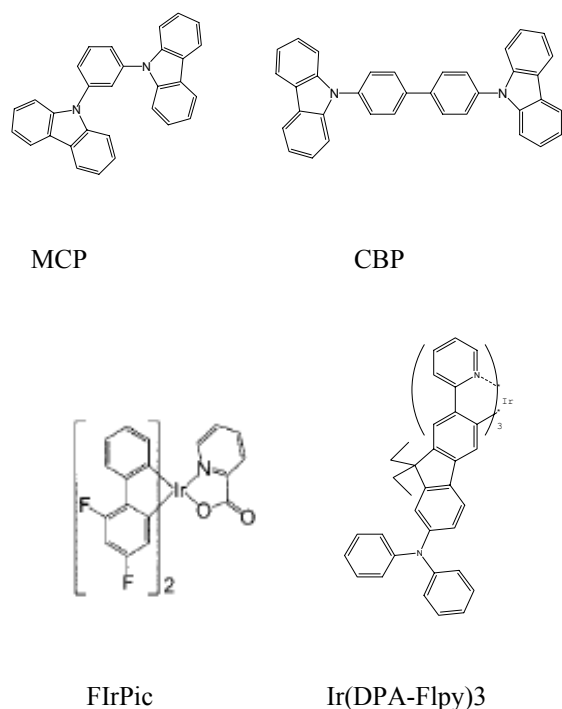
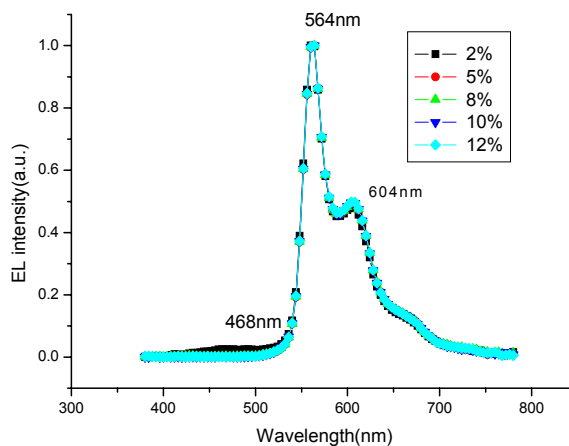


Fig. 1. Molecular structures of materials used.

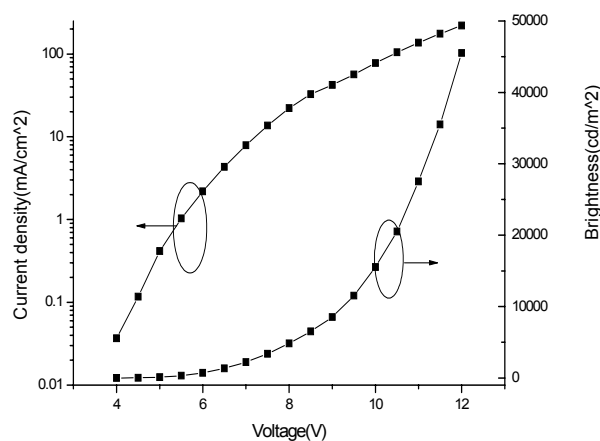
NPB (N, N'-di(naphthalen-1-yl)-N, N'-diphenyl-benzi-dine) was used as the hole transport layer, and was deposited at a rate of 1 Å/s. CBP (4, 4'- bis(carbazol-9-yl)-biphenyl) was used as the host material, doped with Ir(DPA-Flpy)₃ with different concentrations, to form the emission layer. TPBi(2,2',2''-(1,3,5-benzinetriyl)tris(1-phenyl-1-H-benzimidazole)) was used as both the hole blocking layer and the electron transport layer. It was deposited at a rate of about 1 Å/s. Finally, 1nm LiF (lithium fluoride) and 120nm Al (aluminum) were evaporated as the cathode at an evaporation rate of 0.3 Å/s and 4~6 Å/s respectively.

In order to optimize the device, we changed the doping concentration in CBP from 2% to 12% and also adjusted the thicknesses of each layer. It was found that the best performance was obtained with 55nm, 25nm and 40nm, respectively for the HTL, EML and ETL. A wide doping concentration range of 5-10% is accepted. The main peak of these EL spectrums always occurs at 564nm, with a shoulder around 604 nm, as shown in Fig. 2 (a). The CIE coordinate is (0.50, 0.49), with the color

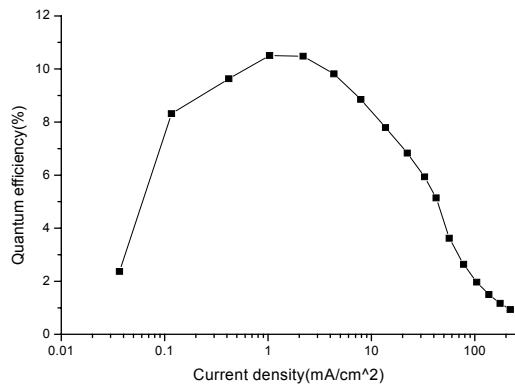
saturation of about 93%. Measured J-V, L-V and quantum efficiency results are shown in Fig 2(b) for the 5% doping concentration device. In this figure, it can be seen that a brightness of 4800cd/m² can be reached at 8V. The highest efficiency is 34.8 cd/A at 1mA/cm² at 6V.



(a)



(b)

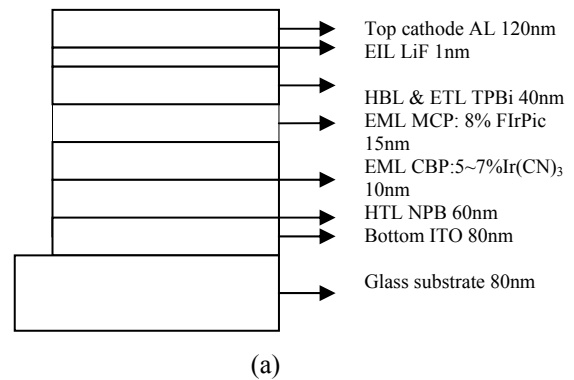


(c)

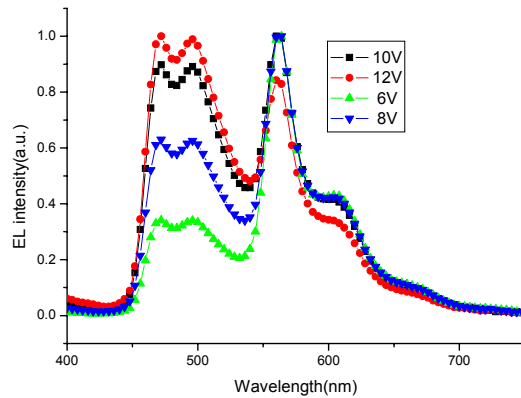
Fig. 2. (a) EL spectrum, (b) J-V, L-V, (c) quantum efficiency in the optimized orange OLED.

The white OLED was made with an additional blue light emitting layer, composed of the host material MCP(9H-carbazole-9,9'-(1,3-phenylene)-bis-(9C1)) and the blue light phosphorescent dopant FIrPic(Iridium-bis(4,6difluorophenylpyridinato-N,C²)-picolinate). 55nm of NPB was used as the hole transport layer (HTL) and 40nm TPBi as the both electron transport layer and hole blocking layer. The cathode was still consisted of the 1nm LiF and 120nm Al. The emission layer consisted of two independent layers: FIrPic doped MCP as the blue light emitting device, and Ir(DPA-FIpy)₃ doped CBP as the orange light emitting layer.

In order to get the best white light performance, the thicknesses of these two layers were optimized. They were found to be 10nm and 15nm for the orange and blue emission layers respectively. The final device structure is shown in Fig 3 (a). The EL spectrum of this white light emission device is shown in Fig 3 (b). It can be seen that when the applied voltage was 10V, the EL spectrum has two almost equivalent peaks at 472nm and 496nm for FIrPic, and 560nm for Ir(DPA-FIpy)₃, respectively. The CIE coordinate is (0.31, 0.41).



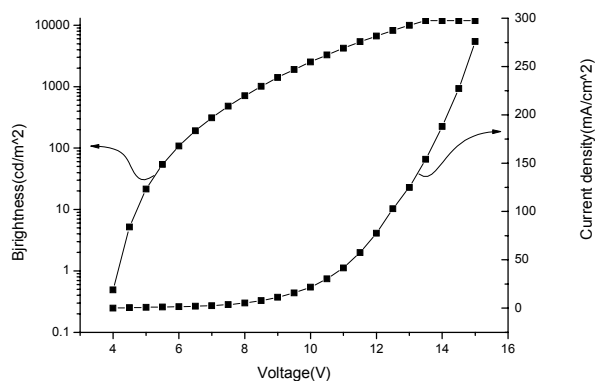
(a)



(b)

Fig 3. WOLED device structure (a) and EL spectrum of it (b) under different voltage: 6V(▲), 8V(▼), 10V(■), and 12V(●)

Fig. 4 (a) shows its J-V and L-V curves. Fig. 4(b) shows the result on power efficiency. It can be seen that the threshold voltage at 1 cd/m² is about 4.2V. The brightness reaches 3200 cd/m² at 10V, with the current density of 30.3 mA/cm². The highest power efficiency could reach 7.6lm/W at the current density of 1 mA/cm². Fig. 5 shows the white light emission device under a driving voltage 10V.



(a)

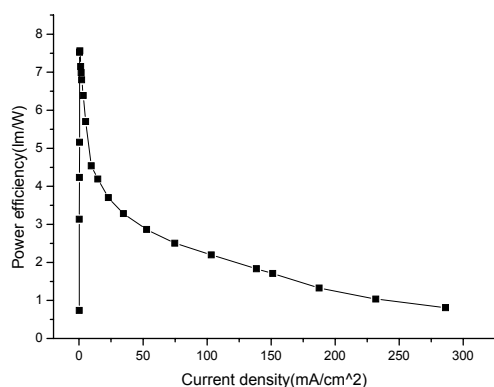


Fig 4. (a)J-V, L-V and (b)power efficiency of the white light emission device

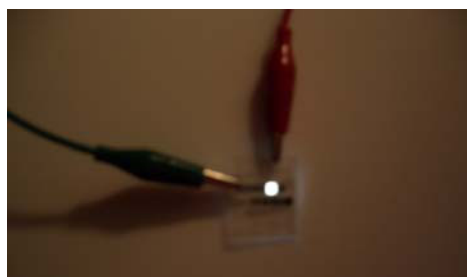


Fig 5. White light emitting device with applied voltage 10V.

CONCLUSION

In summary, by using a new phosphorescent material Ir(DPA-FIpy)₃, orange OLED with a CIE coordinate of (0.50, 0.49) can be obtained. It

reaches a brightness of 4800cd/m² at 8V, with an efficiency of 34.8 cd/A at 1mA/cm² at 6V. Combining this new emission material and the blue phosphorescent material FlrPic, a WOLED device can be made. This new WOLED has a CIE coordinate of (0.31, 0.41), a threshold voltage at 1 cd/m² of about 4.2V, and a brightness of 3200 cd/m² at 10V. The highest power efficiency could reach 7.6lm/W at the current density of 1mA/cm².

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References

- [1] Y.-J. Tung, T. Ngo, M. Hack, J. Brown N. Koide, Y. Nagara, Y. Kato, H. Ito, SID 2004, paper 5.2.
- [2] G. Li and J. Shinar, Appl. Phys. Lett. **83**, 5359 (2003).
- [3] Gernot Trattnig, Alexander Pogantsch, Gregor Langer, Wolfgang Kern, and Egbert Zojer, Appl. Phys. Lett. **81**, 4269 (2002).
- [4] Jung-An Cheng and Chin H. Chen. Mater. Chem., **15**, 1179 (2005).
- [5] Shizuo Tokito, Toshiki Iijima, Toshimitsu Tsuzuki and Fumio Sato, Appl. Phys. Lett, **83**, 2459 (2003).