Studies on Novel Blue Phosphorescent Organic Light-emitting Devices

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Abstract

Organic light-emitting devices (OLEDs) have attracted lots of attentions and have been subjects of intensive studies due to their great potential for plat panel display and solid state illumination applications. In this paper, we designed a new type of ultra-thin non doped organic blue electrophosphorescent devices of based on Firpic. We also studied that the impact of object layer thickness for single-layer ultra-thin non doped blue phosphor performance, and the performance of multilayer ultrathin non doped organic blue light device. We found that for the single ultra-thin non doped organic blue light device, with the FIrpic thickness increases, the photoluminescence peak blue shift gradually and occurred great changes. For the photoelectric performance of multilayer ultrathin non doped organic blue light device, we found that the device can be optimal performance with the maximum of 9.86 cd/A luminous efficiency, when the objectFIrpic layer is 3 layers, each layer FIrpic thickness of 1nm, subject layer thickness is 5 nm, and the thickness of the same luminous doped device compared to the performance of the proposed.

Keywords

Oleds, Novel, Blue Oleds, Non-Doped Emission Layer, Phosphorescent.

1. Introduction

Organic light-emitting diodes (OLEDs) have been energeti-cally studied because of their application to full-color at-panels, exible displays, and solid-state lighting[1].

Since doping (the subject and object according to certain proportion codeposition method) can make the luminescent material molecules are separated (in the isolated state) by main body molecular. Thereby reducing the aggregation effect of the light-emitting molecular [4] and improving the performance of the device greatly. Therefore, most of the reports are doped device [2]. At the same time, the doping technology has been widely used to improve organic phosphor and fluorescence external quantum efficiency of OLEDs (external quantum efficiency EQE). In doped OLEDs devices, in addition to select the best match of material system and device structure, precise control of the proportion of the subject and object (doping concentration) is the key to get the best performance. Due to the organic material is a typical thermal insulation material, different deposition rate will lead to different results. Organic material in conventional evaporation boat, there is only a part of the material from the direct contact evaporation boat first heated and formed the wellhead way of heating process. Uneven heating will causes changes in rapid deposition rate, thus change the doping concentration and leading to poor repeatability of experiments [3]. Especially for doped fluorescent devices, it is very difficult to accurate control for a long time with such a low doping concentration. Since its best doping concentration is very low (~ 0.5%), so the experiment less repetitive.

In order to improve the repeatability of the device, at the same time, under the premise of without sacrificing performance, a series of ultra-thin non doped devices have been reported. The so-called of ultra-thin non doped device is that the body of the device material and object in the form of the doping successively deposition in sequence to form a unit. The subject and object layer thickness of the unit in the range of a few ella to more than one hundred. And light-emitting device area consists of a

number of such unit to repeat similar to multiple quantum well structures. Its benefits is that it is easy to control the film thickness to reduce the difficulty of nano-electronic devices instead of precisely control the concentration of the luminescent material. So that they can better control the performance of the device and increase the repeatability of the experiment. While producing reunite state is unavoidable in the ultra-thin non doped devices, but it can be reduce to a minimum by deposit very thin material layer. We can get the similar device performance with traditional doped device by control subject/object thickness of the unit. In 2007, y. Divayana and X.W. Sun [4] reported a light-emitting layer by N DCM (0.1 nm)/Alq3 (15 nm) ultra-thin non doped red fluorescence device, its EQE reached as high as 3.38%, is currently the best red light OLED performance of DCM. Followed, In 2007, they reported ultra-thin non doped green phosphorescent devices, which based on Ir(ppy)3.In addition, they explored the quenching mechanism of ultra-thin non doped phosphorescent devices [5].In 2008, they reported the light-emitting layer for N BCzVBi/CBP of ultra-thin non doped blue fluorescent devices and its external quantum efficiency is 2.8%, which is quite to the two materials doped device [6]. In 2011, they adopt ultra-thin non doping mode of mixing phosphor and fluorescence. They realized high efficiency white light emission with the EQE, current efficiency and power efficiency of 16.3%, 41cd/A and 18.5 lm/W when the electric current density is 0.05 mA/cm2 [7]. At present, there is no about other material and structure of ultra-thin non doped literature reports.

In this work, we explored the ultra-thin non doped organic electroluminescent photoelectric properties of blue electrophosphorescent devices. We demonstrate efficient blue PHOLEDs by using iridium (III) bis [(4, 6-di-uoropheny)-pyridinato-N, C2] picolinate (FIrpic) as luminescent material.

2. Experiment procedure

The sheet resistivity and the thickness of the indium–tin-oxide (ITO) thin flms coated on glass substrates used in this study were 50/sq and 40nm, respectively. The ITO cleaning procedure included sonication in acetone, methanol, and ionized water at 60 ℃ for 15 min. The pre-cleaned ITO was then treated with O2 plasma under the conditions of 2×10^{-2} Torr and 80-100 W for 8 min. All organic layers were sequentially deposited onto the substrate without breaking the vacuum at a pressure of 4×10^{-4} Torr using thermal evapora-tion equipment. The deposition rates were 1.0–1.1 Å/s for the organic materials and 0.1 Å/s for lithium quinolate (Cs2CO3). After the deposition of the organic layers without a vacuum break, the aluminum (Al) cathode was deposited at a rate of 10 Å/s. The device structure is shown in figure 1.
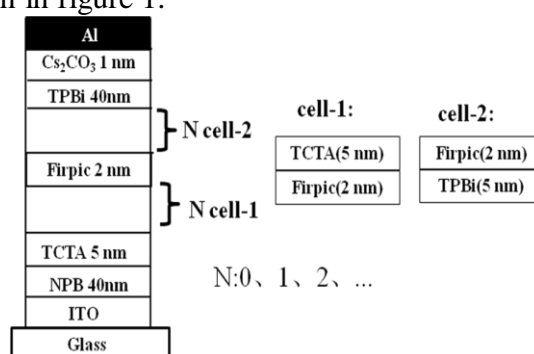

Fig.1 Structure of fabricated device

In figure 1, each light-emitting small unit (cell) in the organic layers are thin layer, and the thickness of within a few Egypt to dozens of Mr.We employed NPB as the hole transporting layer, TCTA as electron blocking layer and body material,TPBi as electron transport layer and host materials, and also as a hole blocking layer, FIrpic as the materials,Cs_2CO_3/Al as the cathode.

3. Results and discussion

3.1 The influence of FIrpic thickness for single‑layer ultra‑thin non doped organic blue light device performance

This work first studied the single ultra-thin non doped organic blue light device performance with the change of the thickness of the FIrpic. The device structure as follow: ITO/NPB/TCTA /FIrpic X nm/TPBi/Cs2CO3 / Al, where X is: 2, 4, 6, 8 nm.
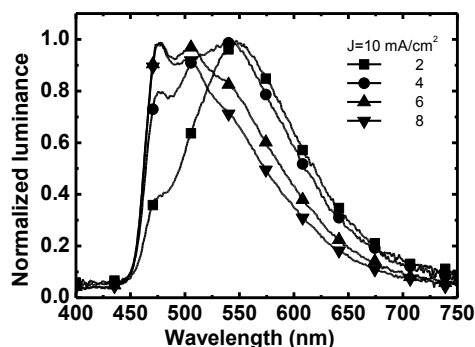

Fig.2 The EL spectra of the devices

As shown in Fig. 2, the electroluminescent spectra of these devices under the current density of 10 mA/cm2. We found that the photoluminescence peak blue shift gradually and occurred great changes as the FIrpic thickness increase. When FIrpic is 2nm, it is equivalent to electro phosphorescent devices of doping very small concentration since it has not been filmed. Therefore, the main emitting peak of yellow green at about 550 nm mainly by TPBi interacts with TCTA. In addition, very faint FIrpic photoluminescence peak appeared near the 470 nm. When FIrpic is 4nm, the blue peaks increases, at the same time, the main emitting peak becomes wide and crosse the yellow to blue light. When FIrpic is 6 nm, blue peak increases further and yellow composition, which become to give priority to light emitting peak. When further increase of FIrpic thickness to 8 nm, it main hair blue light and green light is reduced and the spectrum become narrow. In visible, by the simple method of changing the thickness of the object layer can change the emission spectrum of the device.
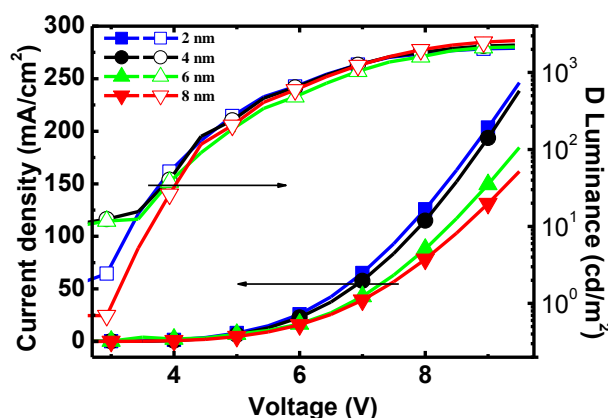

Fig. 3 The I-V-L characteristic curve of the device

The I-V-L properties of the device is shown in figure 3. With the increase of FIrpic thickness, the brightness changes little while the voltage current decreases gradually under the same voltage.

For instance, when the working voltage is 8v, the brightness of the device and current density were 1740.00 cd/m2 and 125.72 mA/cm2, 1804.38 cd/m2 and 114.93 mA/cm2, 1593.14 cd/m2 and 87.85 mA/cm2, 1978.03 cd/m2 and 78.09 mA/cm2.
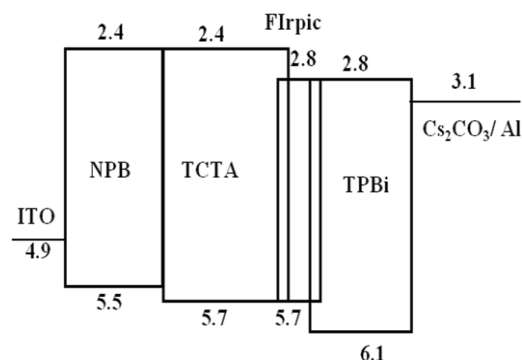
Fig.4 The energy level diagram of the device

Figure 4 is the energy level diagram of the device. We can know from the diagram that the HOMO and the LUMO energy level difference between the TPBi and TCTA were both 0.4 eV. Only overcome a lot of bases, can Electrons and holes get to the other electrode. When FIrpic thickness is 2 nm, far not film, it is equivalent to doping FIrpic at TPBi/TCTA screen and thus the current is larger. As the FIrpic thickness increase, the film gradually and the current decreases gradually.
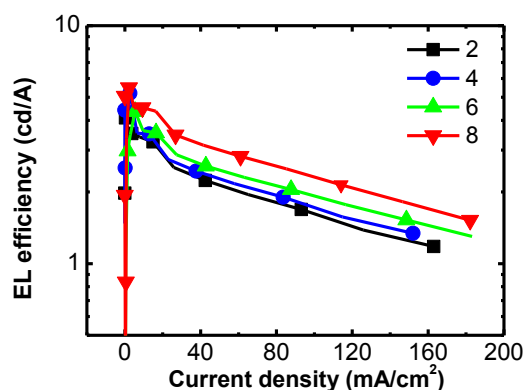

Fig.5 The E-I characteristic curve of device

From the figure 5, we found that the efficiency of the device with FIrpic thickness increases, followed by 4.1 cd/A, 4.4cd/A, 4.4 cd/A, 5.5 cd/A. Two main reasons for the device efficiency is not high: one is light emitting area is too narrow, the HOMO and the LUMO energy level difference between the TPBi and TCTA were both 0.4 eV. Electrons and holes need to overcome a large energy barrier to compound generated excitons, thus a large number of carriers accumulated in TPBi/TCTA interface and internal quantum efficiency is very low. Secondly, it is equivalent to the increase concentration of FIrpic with the increase of FIrpic thickness. There appeared a lot of concentration quenching center and produce a lot of concentration quenching.

3.2 Study on the performance of multilayer ultrathin non doped organic blue light device

Studies have shown that doped double blue light-emitting layer device performance is far superior to the traditional single device (8-9). So when study the performance of the multilayer ultrathin non doped organic blue light device, the hole and electron transport materials should between FIrpic layer in the symmetry position. Concrete structure is as follows:

Doped device A：ITO/NPB /TCTA/ FIrpic:TCTA 10wt% 10 nm/FIrpic: TPBi 10wt% 10 nm/ TPBi/Cs2CO3 /Al;

Ultra-thin non doped device B: ITO/NPB /TCTA / FIrpic 2 nm/ TPBi / Cs2CO3 /Al;

Ultra-thin non doped device C: ITO/NPB /TCTA /FIrpic 2 nm/TCTA /FIrpic 2 nm/ TPBi /FIrpic /TPBi / Cs2CO3 /Al;

Ultra-thin non doped device D：ITO/NPB/TCTA /FIrpic 2 nm/TCTA /FIrpic 2 nm/TCTA/FIrpic 2nm/TPBi/FIrpic 2 nm/TPBi/FIrpic 2 nm/TPBi/Cs2CO3/Al。

In order to facilitate comparison, device A is double doped blue light-emitting layer with light emitting area for 20 nm, the FIrpic layer of device B, C, D are 1, 3, 5 respectively.
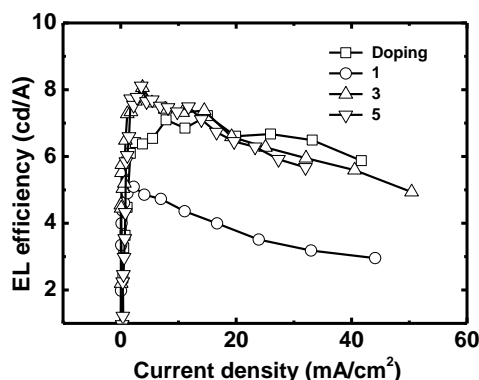

Fig.6 The E-I characteristic curve of devices

Electroluminescent efficiency of the devices are shown in figure 6, the maximum efficiency are: 7.22 cd/A, 8.06 cd/A, 5.10 cd/A, 8.11cd/ A, respectively. When FIrpic number increased to 3 layers, the efficiency of the device are basically the same. The maximum efficiency is greater than doped device of doping about 20 nm thickness, and the efficiency of the ultra-thin non doped device decreased rapidly with the current density decrease. As the current through the FIrpic layer, ultra-thin non doped device produced in triplet polaron obliterated [10]. In addition, because the FIrpic molecules into close packing or mostly are reunited state in the thin layer structure, which cause bipolar triplet polaron annihilate increases with large current injection and aggravate.

In order to further optimize the device structure, we explored the influence on the performance of the FIrpic thickness for the device when FIrpic layer is 3 layers. Device structure as follows: ITO/NPB /TCTA 5 /FIrpic x nm/TCTA 5 /FIrpic x nm/TPBI 5 /FIrpic x nm/TPBI / Cs2CO3/Al。

Considering the reunification can cause triplet polaron quenching, where x is 1 nm, 2 nm, 3 nm, 4 nm, respectively.
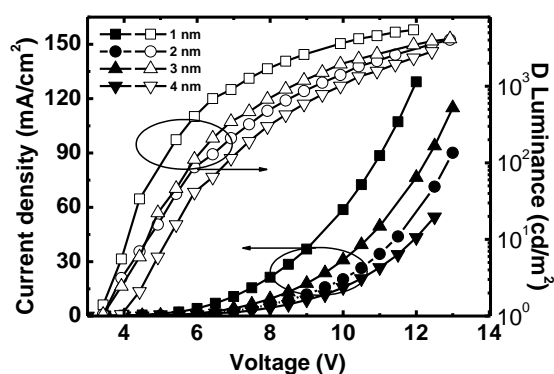

Fig.7 The I-V-L characteristic curve of the devices

Figure 7 is the I-V-L characteristic curve of the device. Besides device with FIrpic thickness is 2 nm, the turn-on voltage increase with the FIrpic thickness increase. At the luminescence of 1cd/m2, the work voltage are 3.36 V, 3.48 V, 3.48 V, 3.85 V, respectively. When the voltage is 10 V, the luminescence of the device and the current density are 3605.28 cd/m2 and 58.74 mA/cm2, 1373.56 cd/m2 and 18.54 mA/cm2, 1953.67 cd/m2 and 30.90 mA/cm2, 1009.55 cd/m2 and 15.72 mA/cm2. Under the same working voltage, the luminescence and current density are both the largest when t FIrpic thickness is 1 nm.
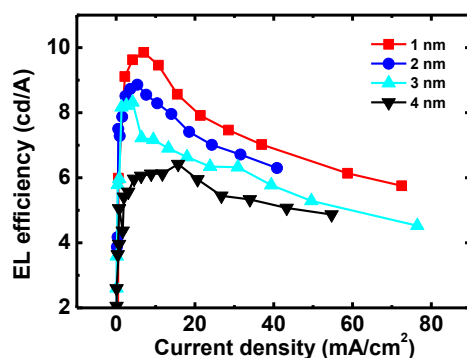
Fig.8 The E-I characteristic curve of devices

Electroluminescent efficiency of the device as shown in figure 8. With the increase of FIrpic thickness the efficiency of the device decreases, FIrpic thickness were 1 nm, 2 nm, 3 nm, 4 nm , the maximum efficiency were 9.86 cd/A, 8.68 cd/A, 8.32cd/A, 6.42cd/A. According to the generation process in the organic film, FIrpic molecules in close packing state or reunion and it haven't into film when FIrpic thickness is 4nm. When FIrpic thickness is 1 nm, FIrpic molecules are separated by the main body molecular. It can been that FIrpic doping in the main structure material, thus there little reunion status and slim exciton quenches chance, so it reached the optimal performance. As FIrpic thickness increases, FIrpic molecules increase and gradually formed island even mesh. Which equivalent to doping concentration increased, thus gradually generated a lot of concentration and concentration quenching and gradual decline in performance.
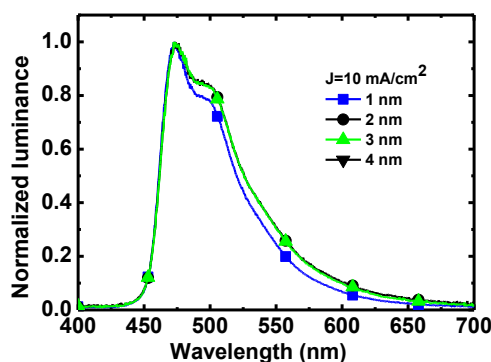

Fig.9 The EL spectra of the devices

As shown in figure 9, the electroluminescent spectra of the devices under the current density of 10 mA/cm2. So we know that typical FIrpic luminescence spectra after the layer increase. Its luminescence is consistent to the doped device, result from inhibiting the interaction between TCTA and TPBI.

4. Conclusion

This paper FIrpic blue phosphorescent materials as luminescent material, we studies the photoelectric properties of the ultra-thin non doped organic electroluminescent blue electro phosphorescent devices. We found that for the single ultra-thin non doped organic blue light device, with the FIrpic thickness increases, the photoluminescence peak blue shift gradually and occurred great changes. For the photoelectric performance of multilayer ultrathin non doped organic blue light device, we found that the device can be optimal performance with the maximum of 9.86 cd/A luminous efficiency, when the object FIrpic layer is 3 layers, each layer FIrpic thickness of 1 nm, subject layer thickness is 5 nm, and the thickness of the same luminous doped device compared to the performance of the proposed. While producing reunite state is unavoidable in the ultra-thin non doped devices, but it can be reduce to a minimum by deposit very thin material layer. By the simple method of changing the object layer thickness to chang the emission spectrum of the device under the condition of not changing device

efficiency. On the contrary, only by changing the doping concentration, can the traditional doped device achieve the change of the spectrum.

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