Effect of Interlayer on White Phosphorescent Organic Light-emitting Devices

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Abstract

We demonstrated a novel white electrophosphorescent organic light emitting diodes (PHOLEDs), which structure was ITO/NPB (35 nm)/MCP (5 nm)/Firpic: MCP 10 wt% (15 nm)/ Ir (MDQ)2(acac): TPBI X wt% (2 nm)/Firpic:TPBI 10 wt% (10 nm)/TPBI (40 nm)/LiF (1 nm)/Al (100 nm). The luminescent properties were studied by inserting different doping concentration of the red emitting layer (Ir(MDQ)2(acac):TPBI) located between the double blue-emitting layers (D-BEML) to adjust the distribution of carriers and excitons. The results showed that the optimum performance of OLED was achieved when the doping concentration of Ir(MDQ)2(acac): TPBI red emitting layer is 5 wt%. Combining the D-BEML and the red emitting layer, we achieved a WOLEDs with peak efficiencies of 11.90 cd/A and CIE coordinates of (0.333, 0.334).

Keywords

Oleds, Novel, White Oleds, Phosphorescent.

1. Introduction

White Organic light-emitting diode (White Organic Light-emitting Diodes, WOLEDs) can be made into a large area, has the advantages of low power consumption, high efficiency, wide viewing angle, solid surface luminescence, and in two aspects of flat-panel display and solid-state lighting has a bright prospect and much attention [1-4]. In particular, the application of white organic light-emitting devices (OLEDs) in liquid crystal backlight and lighting has been widely concerned.

In the preparation of WOLEDs, high efficiency light-emitting dyes play an important role in the performance of devices. Among them, the phosphorescent dye can utilize both singlet excitons and three excitons radiation, internal quantum efficiency of 100% is widely used[5-8]. White light can be obtained by the principle of three primary colors, that is, mixed red, green and blue three kinds of dye light [9], but also through the complementary color principle, namely yellow and blue light-emitting mixed two dyes obtained [10].

In order to obtain high performance WOLEDs, the light emitting efficiency of the device is improved by the multi-layer doping method, and the blocking layer is introduced to stabilize the composite region of the exciton, thus suppressing the change of the color coordinates and obtaining the white light with good chromaticity. In this paper, a red light doped layer with 2 nm thickness is inserted between the light-emitting layers of the dual-light-emitting layer blue light-emitting device. By changing the doping concentration of the red light-emitting layer, the carrier and exciton are adjusted in each light-emitting layers, And Combined with MCP and TPBI on the effective blocking effect of carriers and excitons in the luminescent layer, high quality organic electroluminescent white light devices were obtained. The results show that the white light emission with color coordinates (0.33,0.33) and maximum luminous efficiency of 11.90 cd/A is achieved when the thickness of the red light emitting layer is 2 nm and the mass concentration is 5%.

2. Experimental

The structure of the WOLED prepared in the experimental study is: ITO / NPB (35 nm) / MCP (5 nm) / FIrpic: MCP 10 wt% (15 nm) / Ir (MDQ) 2 (acac): TPBI X wt% Y / (2 nm) / TPBI (40 nm) / LiF (1 nm) / Al (100 nm). On the basis of this, the influence of the red layer doping concentration on the performance of the device is studied when the red layer thickness is 2nm.

The substrate was STN-40 ITO glass substrate, ITO thickness of about 40 nm, The sheet resistance is about 50 Ω/□, Before the experiment, the substrates were cleaned by conventional acetone, ethanol and deionized water to remove oil and dirt from the surface. To further improve the cleanliness of the anode surface and ITO work function, and then by oxygen plasma treatment. The processing parameters were O_2 flow of 800 ml / min, treatment power was 80-100 W, treatment time was about 8 mins. And then immediately put it into the vacuum chamber of the evaporation coating instrument. WOLEDs devices were prepared under high vacuum conditions (4 x 10^{-4} Pa) by vacuum hot deposition. Device structure and energy level shown in Figure 1.

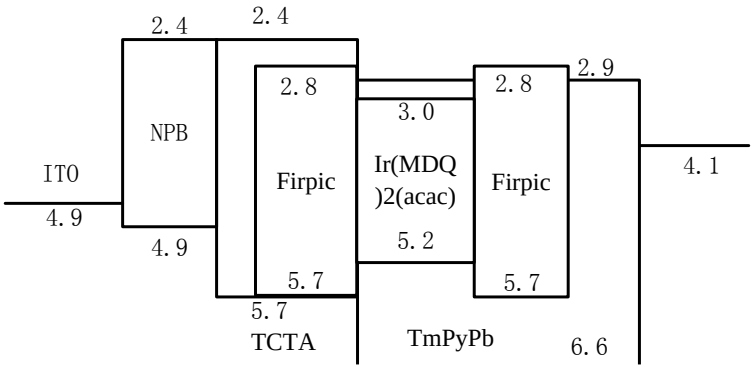

Fig.1 Structure and energy level of the device

Using NPB as the hole transport layer, MCP as the electron blocking layer and the host material, TPBI as the electron transport layer and the host material, and also as a hole blocking layer, FIrpic as a blue material, the doping concentration of 10 wt%, Ir (MDQ)2(acac) as a red material, LiF/Al as a cathode. The key feature of the device structure is that holes and electrons do not overcome any potential barriers, respectively, from the NPB into the blue layer FIrpic: MCP and from TPBI into the blue layer FIrpic: TPBI, Then the carrier recombination occurs.

Because the triplet exciton level of FIrpic is greater than the triplet exciton level of TPBI, forming resonance, triplet exciton can move freely in the blue layer of Firpic: TPBI, This leads to a blue luminescent exciton deexcitation process from normal and delayed deexcitation radiation, and the host and guest exciton energy back. Because the guest triplet energy is greater than host triplet exciton level, leading to delayed detonation radiation. A part of the exciton energy of guest material back to the host material, forming the host triplet exciton, and the life of the host triplet excitons is longer, in the process of transfer, the host exciton is transmitted to the guest, so it is delayed luminescence.

Therefore, the red light emitting layer is distributed on the right side of the blue-emitting emitting layer FIrpic: MCP and the left side of the blue-emitting layer FIrpic: TPBI, combined with the exciton blocking layer MCP and TPBI, It is ensured that the red light emitting layer can capture the excitons that have not been used in the process of diffusion of excitons, improve the internal quantum efficiency of the device, ensure that the three light-emitting layer are involved in, which can realize the white light emission.

3. Results and discussion

The thickness of the red light emitting layer is 2 nm, the doping concentration of 5 wt%, 10wt%, 15wt%, 20wt%, corresponding to device A, B, C, D.

Figure 2 shows the J-V-L characteristic of the device at different doping concentrations. The turn-on voltage of device are very close. When the doping concentration is more than 10%, the device

luminance and current density change little with the increase of doping concentration. When the luminance is 1 cd/m^2, the turn-on voltage of these devices are 6.4 V, respectively. When the voltage is 13V, the luminance and current densities of devices A, B, C and D are 5325.65 cd / m^2 and 52.63 mA / cm^2, 4479.57 cd / m^2 and 51.65 mA / cm^2, 1231.65 cd / m^2 and 47.53 mA / cm^2,889.63 cd / m^2 and 45.35 mA / cm^2. This is due to the greater the doping concentration, the more serious the exciton concentration quenching, at the same voltage, its luminance is lower, so the luminance of the device A is the largest, and have the maximum current.

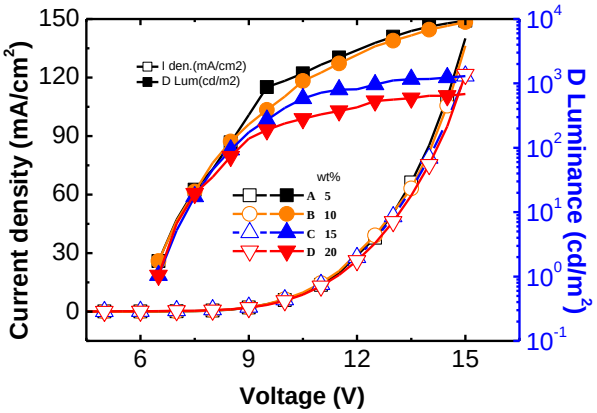

Fig. 2 The J-V-L characteristics of devices

As shown in Figure 3, the maximum efficiency of the device is: 11.90 cd/A, 11.65 cd/A, 7.55 cd/A, 7.39 cd/A. The efficiency of the device decreases with the increase of the concentration. This is with the doping concentration increasing, the guest material gradually become not isolated molecules are dispersed in the host material, but the formation of agglomerates size, the greater the concentration, the larger the size of agglomerates, the concentration quenching of excitons quenching is more serious, the luminous efficiency is low.

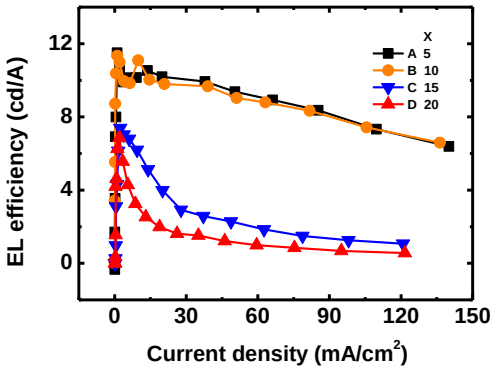

Fig.3 The E-J characteristics of devices

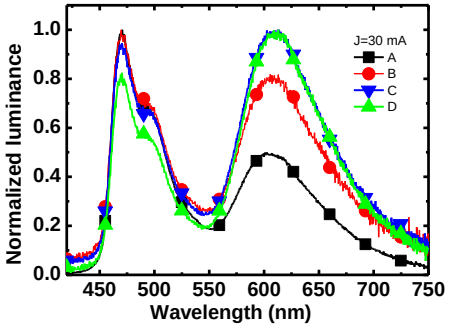

Fig.4 The EL spectra of devices

Figure 4 shows the normalized spectrum of the device at current density of 30 mA/cm^2. As the doping concentration increases, blue emission peak gradually weakened, red peak gradually increased, the color coordinates of the device respectively (0.333, 0.334), (0.435, 0.439), (0.199, 0.390), (0.238, 0.409), when the doping concentration is 5 wt%, The device achieves a pure white light emission. The overall performance of the device is shown in table 1.

Tab.1 The performance of the WOLEDs

		Device A	Device B	Device C	Device D
Turn on voltage at 1 cd/m^2 (V)		6.40	6.40	6.40	6.40
Operating voltage at 100 cd/m^2 (V)		8.40	8.30	8.50	8.75
Operating voltage at 10 mA/cm^2 (V)		10.50	10.50	10.50	10.73
Luminance at 10 mA/cm^2 (V)		929.16	1092.02	283.27	583.60
Current density at 13 V (mA/cm^2)		52.63	51.65	47.53	45.35
Luminance at 13 V (cd/m^2)		5325.65	4479.57	1231.65	889.63
Luminous Efficiency (cd/A)	Maximum	11.90	11.65	7.55	7.39
	At 100 cd/m^2	11.90	10.37	6.26	6.15
CIE coordinates	X	0.333	0.435	0.199	0.238
	Y	0.334	0.439	0.390	0.409

4. Conclusion

By inserting a red light doped layer of 2 nm thickness between the light emitting layers of the dual light emitting layer blue light emitting device, By changing the doping concentration of the red layer and adjusting the carrier and exciton in the luminescent layer by using MCP and TPBI, the distribution of carriers and excitons in the luminescent layers is adjusted to improve the utilization of excitons, access to high-quality high-performance organic electroluminescent white light emitting diodes.

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