Effects of TmPyPb as Interlayer on Color Purity for White OLED

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Abstract

The effects of TmPyPb as interyer on color purity was researched by inserting different thickness of TmPyPb into the interface between blue and green emissions based on ITO/NPB/TCTA/Ir(MDQ)2(acac):TCTA/TCTA/FIrpic:TmPyPb/Ir(ppy)3:TmPyPb/TmPyPb/ LiF/Al. The experimental results showed that thickness of interlayer has a significant impact on the exciton distribution and energy transfer. The best efficiency of device in this paper is 11.6 cd/A, and CIE coordinates of (0.33, 0.36) when the thickness is 4 nm.

Keywords

Interlayer, white, energy transfer, thickness.

1. Introduction

White Organic Light-emitting Diodes (WOLEDs) as a new type of display and illumination technology has the advantages of high contrast, low power consumption, flexible folding, good temperature performance, wide viewing angle, and no pollution [1-5]. Especially in the field of backlight and daily lighting, people have attracted great attentions [6-8]. White OLED devices are often designed for using the principle of three primary colors [9] or complementary colors [10]. At the same time, phosphorescent materials have been discovered and used to obtain high efficiency white light devices with 100% internal quantum efficiency. The device structure is one of the key factors that affect the performance of the OLED device. Kido [11] obtained a highly efficient white OLED using a doping structure. Sun [12]designed a BGR tricolor white light device with a luminescent layer structure of FIrpic: UGH2/Ir(ppy)3:mCP/PQIr:TCTA with an efficiency of 34 lm/W at 1000 cd/m^2. Since then, white OLED with interlayer structures have been successfully studied [13-14].

The triplet energy levels of the blue light material FIrpic and the electron host material TmPyPb are 2.65 eV and 2.62 eV respectively, which can form resonance. Therefore, the triplet excitons within the region of TmPyPb are almost free for moving. Not only that, because of the closeness of their triplet energy levels, their radiative luminescence processes include normal detonation and delayed degeneration. The long-life triplet excitons are on the way to the transmission. The energy transfer consists of two parts:one is to transmit the energy to the object and the other is to transfer the energy to other areas. This results in a low efficiency of the blue light emitting layer. Based on this, the blue light-emitting layer is disposed between the red and green light-emitting layer, and a certain thickness of TmPyPb is inserted between the light-emitting layers to ensure the full use of the exciton and the light emission of each light-emitting layer to get the high purity white light device.

2. Experiments

The structure of the four devices A, B, C and D prepared in this paper are as follows:

ITO/NPB(35 nm)/TCTA(5 nm)/Ir(MDQ)2(acac):TCTA 10%wt(6 nm)/TCTA(2 nm)/FIrpic:TmPyPb 20%wt(6 nm)/TmPyPb (y nm)/Ir(ppy)3: TmPyPb 10%wt(6 nm)/TmPyPb(40 nm)/LiF(1 nm)/Al(100 nm)

A: y=0; B: y=2; C: y=4; D: y=6.

The parameters of the ITO glass substrate used in the experiment are about 40 nm, and the sheet resistance is about 50Ω/□. The substrate is subjected to a conventional cleaning operation to remove oil and dust on its surface with acetone, anhydrous ethanol, and deionized water are ultrasonically cleaned. In order to obtain a higher surface cleanliness and ITO work function, oxygen plasma is used to treat the pre-cleaned substrate. During the treatment, the O_2 flow rate is maintained at 800 ml/min, the processing equipment power is 80-100W, and the processing time is 8 mins. Immediately into the vacuum chamber of the evaporation coater. A three primary colors phosphorescent white OLED device was prepared by vacuum thermal evaporation under high vacuum conditions(~10^{-5}Pa), and then its performance parameters were measured in the normal atmosphere. The structure and energy level of the devices are shown in Fig.1.

In this structure: NPB as hole transport layer, TCTA as hole blocking layer and host material, TmPyPb as host and electron transport layer material. Ir(MDQ)2(acac), FIrpic and Ir(ppy)3 as red, blue and green material respectively.

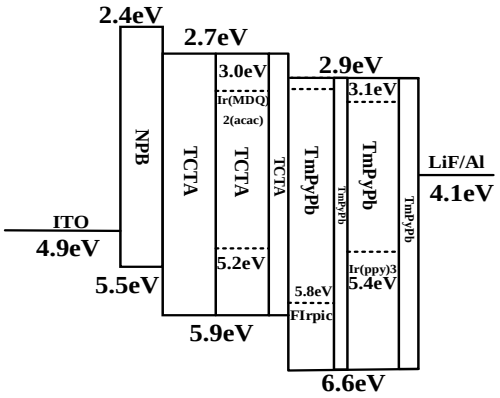

Fig.1 Energy levels and structure of devices

3. Analysis and Discussion

The electroluminescence (EL) spectrum of the device at the current density of 10 mA/cm^2 is shown in Fig.2. It can be seen from the figure that the blue light emission intensity is the largest, followed by green light and red light. The device contains a layer TmPyPb interlayer between the green and blue emission layers. As the thickness of the interlayer increasing, the red and green light emission intensities decrease, which is closer to the white light emission. This is because the insertion layer of TmPyPb is an electron transport material and same as the host material of the blue and green emission layers, it has hole block capability, so that electrons and holes meet in the blue emission layer to form excitons. On both sides of the transmission, a small portion of excitons are transmitted to the red light layer to exit the excitation light. Most of the excitons transmit in the blue emission layer to emit light. Since the host material and interlayer material are both TmPyPb, part of the excitons can be easily transmitted to the green emission layer to emit light. The thickness of the TCTA between the red and the blue of the device is 2 nm. However, the optimal distance for Dexter energy transfer is within 1-2 nm[15]. For iridium complexes, the typical distance for Foster energy transfer is less than 2 nm[16], making the above two kinds of energy transfer inhibited. The TmPyPb affects electron transmission. Therefore, with the increase of the thickness of the interlayer, excitons are mainly confined to the radiant emission in the blue emission layer, so that the exciton in the region of green and red emission layer gradually decreases, and the emission intensity decreases.

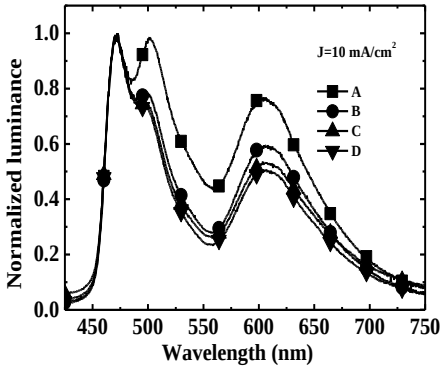

Fig.2 EL of devices at 10mA/cm^2

The EL spectrum of the devices at the current density of 30 mA/cm^2 is shown in Fig.3. From the figure, it can be seen that with the increase of thickness of the interlayer TmPyPb, the blue light emission intensity is maximum, and the green and red emission intensity all decrease in different degrees, and the overall trend is similar to Fig.2. However, the EL spectra of C and D devices are highly coincident. There are two main reasons: First, the diffusion length of triplet excitons in organics is about 100nm [17]. Under this current density, the effect of blocking holes on the 4m and 6 nm TmPyPb interlayers is relative to the green emission intensity. The influence of the difference in thickness between them and 2 nm caused the exciton diffusion to affect the light emission. The second is the quenching of triplet excitons due to exciton recombination between the blue and red luminescent layers[18]. The Dexter energy transfer is further suppressed. The exciton concentration of D device is higher than C, and the triplet exciton quenching effect is more serious, the red emission intensity of the D is comparable to C.

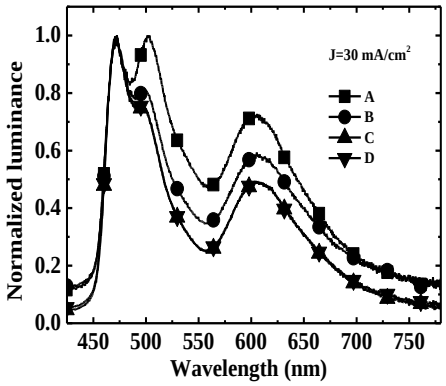

Fig.3 EL of devices at 30mA/cm^2

The EL spectrum of the device at the current density of 100 mA/cm^2 is shown in Fig.4. Compared with Fig.2, the red emission intensity of the B and C is similar, and the difference in the red emission intensity of the C and D devices increases. The reason is that the thickness of the interlayer TmPyPb has a negligible effect on the electron transport at the high current density of 100 mA/cm^2. Although the quenching of triplet excitons weakens as the thickness of the intercalation layer increases, the quenching effect of the triplet excitons exceeds the effect of the 2 nm thickness difference of the intervening layer in Fig.3 on the luminescence of the device. Therefore, the difference in emission intensity of red light increases for C and D. The triplet exciton quenching effect of device B is stronger than that C, so that the effect of Dexter energy transfer on the two devices is offset by the effect of exciton diffusion on the red light emission in the device. Therefore, the red light emission intensity difference between the B and C devices is small.

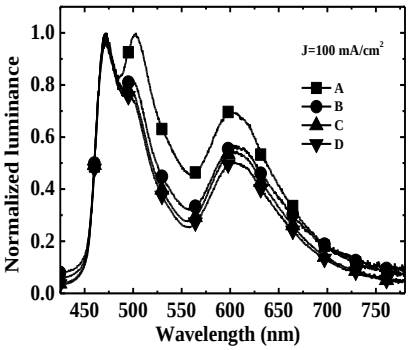

Fig.4 EL of devices at 100mA/cm^2

The current-voltage-luminance (J-V-L) characteristics of the device is shown in Fig.5. From the figure, there is a positive correlation between brightness and current density. As the thickness of the interlayer TmPyPb increases, the current density of each device sequentially decreases when the voltage is less than 9V. Above 9V, the current density of B gradually becomes maximum. This is because: When the voltage is less than 9V, it is mainly considered that the interlayer leads to a large internal resistance, and the current density decreases as the thickness of the interlayer increases. When the voltage is greater than 9V, the exciton in the A moves almost freely in the host material TmPyPb of the emission layer, the A without the interlayer diffuses and loses the least excitons, and more excitons move into the blue and green emission layers. , making the device luminous efficiency higher than B, while the current density drops below device B.

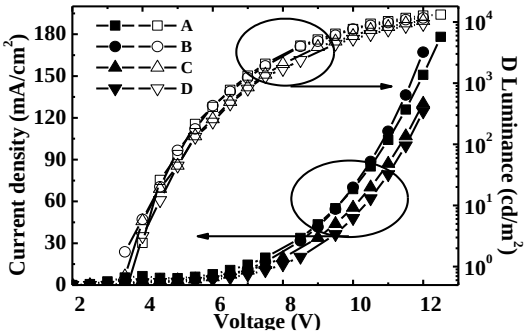

Fig.5 J-V-L characteristics of devices

The current-efficiency (E-J) curve of the device is shown in Fig.6. From the figure, we can see that at a small current density, the efficiency increases with the increase of the thickness of the interlayer. When the current density is larger, the efficiency decreases with the increase of the thickness of the interlayer, and the A has the maximum luminous efficiency and current density. Decline with the factor. This is due to the fact that, at low current densities, as the thickness of the interlayer increases, more excitons are confined within the narrower emission layer, making the Forster energy transfer mechanism and the luminescent emission effect of the light-emitting layer directly trapped by the guest material directly enhanced. The device luminous efficiency increases as the thickness of the interlayer increases. At larger current densities, as the thickness of the interlayer increases, the proportion of excitons that radiate in other emission layers decreases, and the utilization of exciton decreases. At higher current densities, the efficiency of the device is decreased by the annihilation of the triplet polaron and the quenching effect.

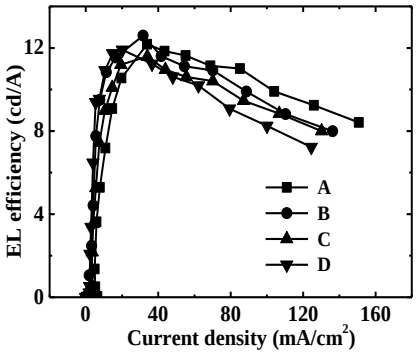

Fig.6 E-J characteristics of devices

The CIE for each device at three current densities is shown in Table 1. The CIE coordinates of A and B exhibit substantially more variation with the thickness of the interlayer at the same current density. The color coordinates of C and D are no longer change when the thickness of interlayer are 4 and 6 nm. It can be seen that when the thickness of the interlayer TmPyPb is greater than 4 nm, the color coordinates of the devices are stable, and the white color purity is good, which is close to the white light energy point.

Table 1 CIE of devices in different current densities

Device	10mA/cm2	30mA/cm2	100mA/cm2
A	(0.36, 0.40)	(0.35, 0.39)	(0.35, 0.40)
B	(0.35, 0.37)	(0.34, 0.36)	(0.33, 0.37)
C	(0.33, 0.36)	(0.33, 0.36)	(0.34, 0.36)
D	(0.33, 0.36)	(0.33, 0.36)	(0.33, 0.36)

In this paper, different thicknesses of TmPyPb were introduced between the green and blue emission layers of the white organic light-emitting device. The influence of the thickness of the interlayer on the color purity of the device was studied. It was found that with the increase of the thickness of the interlayer, the blue emission intensity of the device is always the maximum, and the red and green emission intensity decreases with the increase of the thickness. When the thickness of the interlayer is greater than 4 nm, the CIE at the current densities of 10 mA/cm^2, 30 mA/cm^2, and 100 mA/cm^2 is very stable, approaching the color coordinates of standard white light, and the color drift is small, its maximum efficiency 11.58 cd/A. This article does not investigate the effect of the interlayer between red and blue emission layers on performance. Studies have shown that it is possible to adjust the energy transfer and adjust the distribution of carriers by changing the thickness of the TmPyPb interlayer, thereby affecting the device's luminescence and realizing a three primary white OLED device.

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