



Influence of the hole transport layer on spectral stability in the white phosphorescent organic light emitting diode with non-doped structure

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ABSTRACT

In order to decrease the fabrication process complexity and improve the color stability, a series of two complementary colors white phosphorescent organic light emitting diodes (WOLED) are fabrication. The color stability of WOLED can be realized by increasing the thickness of the second hole transport layer (HTL2), which can weaken the hole mobility rapid raising with the increase of voltage and stabilize the recombination zone. The electroluminescence characteristic and color stability can be further improved by inserting ultrathin Irpic emitting layer in HTL2. In device B1, the color coordinate (CIE1931) is $(0.335 \pm 0.003, 0.442 \pm 0.002)$ while luminance changes from 100 cd/m^2 to 5000 cd/m^2 , the maximum values of luminance, current efficiency and power efficiency can reach 5709 cd/m^2 , 29.65 cd/A and 19.62 lm/W , respectively.

1. Introduction

Since Tang and Vanslyke report a new kind of structure about multilayer organic light emitting diodes (OLEDs), OLEDs show greatly potential for a new generation of full color panel displays and solid-state lighting source due to the wide viewing angle, high brightness, high contrast and energy conservation [1–4]. In white organic light lighting diodes (WOLEDs), the phosphorescent material can harvest both the singlet and triplet excitons during luminescence, which makes internal quantum efficiency reach to be 100% in principle, so the efficiency of white phosphorescent OLEDs (PHOLEDs) is higher than that of fluorescent OLEDs (FLOLEDs) [5,6]. Generally speaking, the doping method is often used in the emitting layer (EML) of WOLEDs [7–11]. It can lead to high efficiency and low efficiency roll-off due to the decrease of severe concentration quenching effect. Xue et al. report a highly efficient white PHOLED device with maximum power efficiency of 40.6 lm/W by using a mixed host system [12]. However, because that the doping concentration of orange or red emitters must be accurately controlled at a very low level ($\sim 0.5\%$), which increases the fabrication process complexity and raises the commercialization cost [13,14], the non-doped WOLEDs with simple the structure and fabrication process have attracted increasing attention [15–18]. Zhao et al. demonstrate high efficiency and good white emission device with ultrathin non-doped EML, indicating the universality of the ultrathin non-doped EML for most phosphorescent dyes [19]. Xue et al. report that two colors, three colors and four colors WOLEDs have maximum current efficiencies of 30.9 cd/A , 30.3 cd/A and 28.9 cd/A , respectively [20]. In

addition, it is clearly seen that the color stability of the non-doped WOLEDs is far from the requirement of practical solid-state lighting applications, which urgently needs to be further improved, and both color stability mechanism and effect factors are also necessary to deeply understand and elucidate. Because the thickness of EML is too thin in non-doped WOLED, the carrier balance in EML is more important than the recombination zone for the color stability.

In this paper, we fabricate a serial of white phosphorescent OLED devices with the simple non-doped structure, which the basic structure is ITO (100 nm)/HAT-CN (10 nm)/TAPC (30 nm)/mCP (x nm)/PO-01 (0.15 nm)/mCP_{1-y}:TPBi_y (3 nm)/Irpic (0.1 nm)/TmPyPB (30 nm)/Liq (2 nm)/Al (100 nm). The mCP_{1-y}:TPBi_y layer between PO-01 and Irpic layers is used as the spacer layer (SL) to adjust the relative emission intensity. The mCP layer between TAPC and PO-01 layers is used as the second hole transport layer (HTL2), TAPC is the first HTL (HTL1). The thickness of HTL2 and the mobility of SL material can change the carrier balance in EML. We will investigate influence of HTL2 thickness and SL material on efficiency and color stability in white phosphorescent OLED devices, respectively.

2. Experimental

Before film deposition, the glass substrates coating Indium-tin-oxide (ITO) are ultrasonically cleaned in order by detergent, deionized water and isopropyl alcohol for 15 min, respectively. The sheet resistance is $15 \Omega/\text{sq}$. All the devices are fabricated by vacuum deposition under a base pressure lower than $5 \times 10^{-5} \text{ pa}$ without breaking the vacuum.

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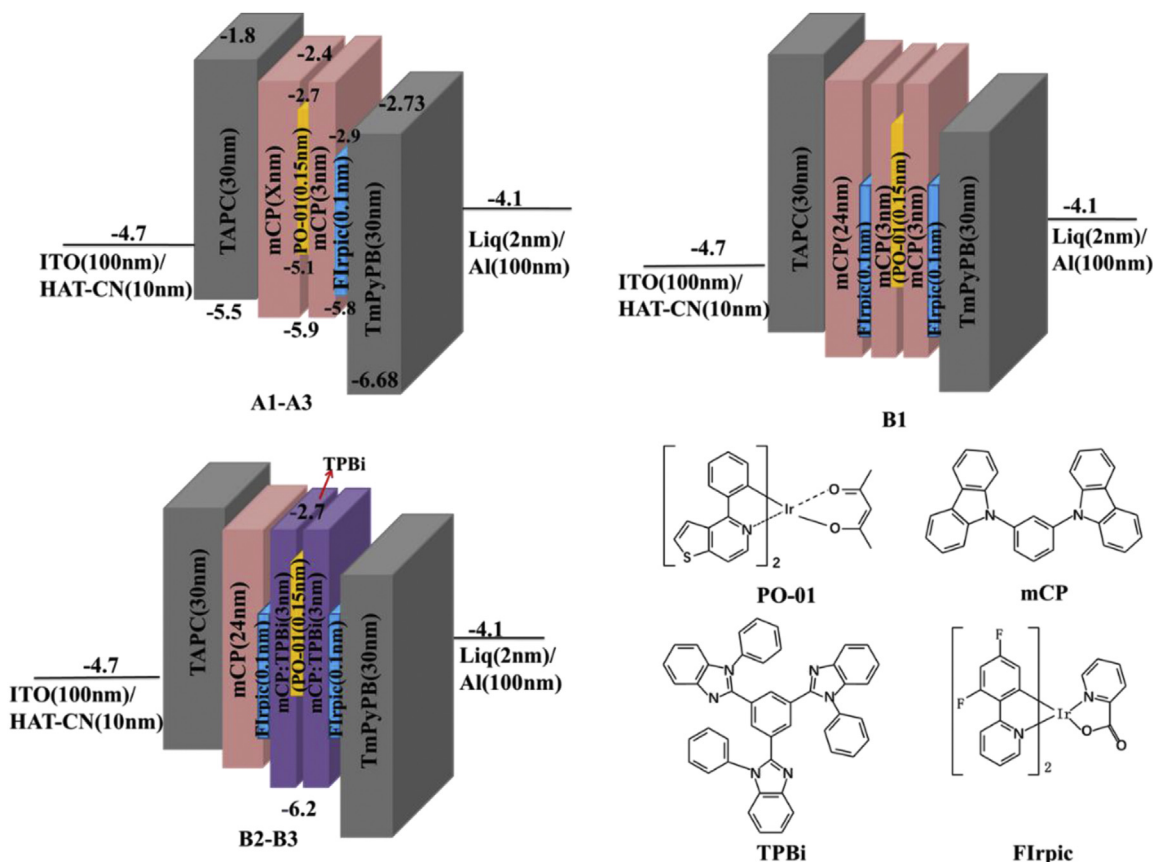


Fig. 1. Schematic diagrams of structure in devices A1 (x = 7 nm), A2 (x = 13 nm), A3 (x = 27 nm), B1 (y = 0), B2 (y = 1/5) and B3 (y = 1/4). The insert diagram shows the molecular structures of main materials.

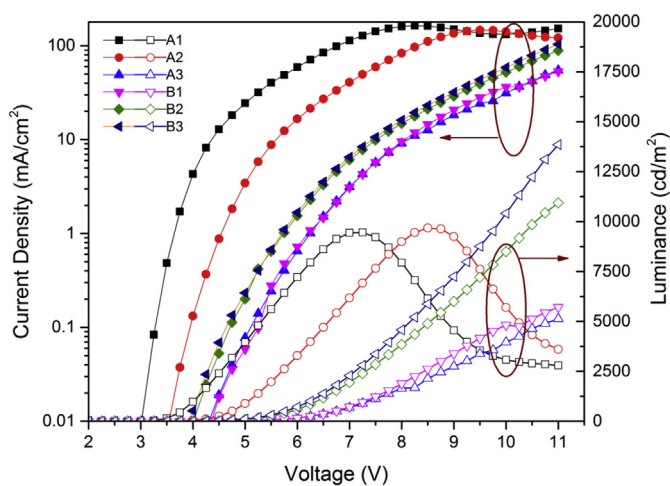


Fig. 2. Current density and luminance versus voltage curves of devices A and B.

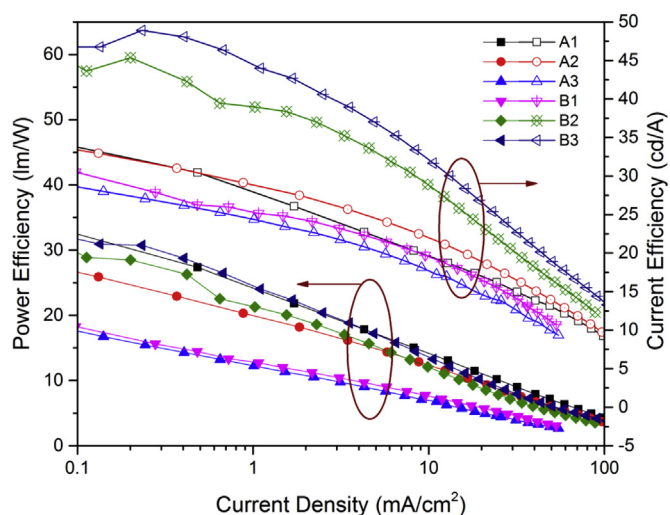


Fig. 3. Power efficiency and current efficiency versus current density curves of devices A and B.

The organic materials are deposited at a rate of 1 Å/s. The metal cathode (Al) is deposited at a rate of 2 Å/s. The luminous area of each device is about 9 mm². After the devices are fabricated, the electroluminescence (EL) spectra and luminance characteristic are measured and recorded by PR655 spectrometer and Keithley 2400 digital power.

1,4,5,8,9,11-hexaazatriphenylene-hexacarbonitrile (HAT-CN) and 8-Hydroxyquinolinolato-lithium (Liq) are used as a hole injection layer (HIL) and electron injection layer (EIL). Di-(4-(N,N-ditolyl-amino)-phenyl)cyclohexan (TAPC), 1,3-bis(N-carbazolyl)benzene (mCP), and 1,3,5-tri(m-pyrid-3-ylphenyl)benzene (TmPyPB) are used as HTL1, HTL2 and electron transport layer (ETL), respectively. mCP and 2,2',2''-

(1,3,5-benzinetriyl)-tris(1-phenyl-1-H-benzimidazole) (TPBi) are also used as the spacer layer (SL) between EMLs to adjust the relative emission intensity. Bis(3,5-difluoro-2-(2-pyridyl)-phenyl)-(2-carboxypyridyl)iridium (III) (FIrpic) and Iridium (III)bis(4-phenylthieno [3,2-c]pyridinato-N,C20)acetylacetonate (PO-01) are blue and orange phosphorescent dyes, respectively. Fig. 1 shows the chemical structure, energy level of the main material and the schematic structure diagrams of six devices A1-B3. The basic structure of devices A1-A3 is as follows: ITO (100 nm)/HAT-CN (10 nm)/TAPC (30 nm)/mCP (x nm)/PO-01

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