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A novel white organic electroluminescent device based on a thin LiF interlayer

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ABSTRACT

A novel white organic electroluminescent device was fabricated by inserting a thin lithium fluoride (LiF) layer in the emitting layer (tris-(8-hydroxyquinoline) aluminum (Alq_3)). The electroluminescence device with the configuration indium tin oxide (ITO)/N,N′-diphenyl-N,N′-bis(l-napthyl)-1,1′-biphenyl-4,4′-diamine (NPB; 45 nm)/tris-(8-hydroxyquinoline) aluminum (Alq_3; x nm)/LiF (0.3 nm)/Alq_3 ((45 − x) nm)/Al (150 nm) showed expanded electroluminescence (EL) spectra. The spectra contain tricolor, so this should be a simple method to realize white light emitting. We also elucidated the mechanism of expanded EL spectra formation and investigated the properties of these devices.

1. Introduction

Organic light-emitting diode (OLED) is one of the most promising next generation flat panel displays [1,2] and has been widely studied since the display was manufactured by Japanese OLED manufacturer, Pioneer was put on to the market in 1998 [3,4]. In general, two approaches have been used to realize full color OLED display. One is based on the selective deposition of three primary colors (red, green, and blue). The other is based on white light emission combined with color filters. Therefore, efficient and stable white light emitting is very important in flat panel displays. There have been several studies reporting white organic electroluminescent devices [5–12]. They suggested a white OLED using a multilayer structure with two or more emitting layers. However, the Commission International de l'Eclairage (CIE) coordinates varied with the change of current density.

In this paper, we expanded the EL spectra and realized white light emitting through inserting a thin lithium fluoride (LiF) layer in tris-(8-hydroxyquinoline) aluminum (Alq_3) layer. This method is very simple. We also elucidated the mechanism for expanded EL spectra formation and investigated the properties of these devices. It is believed that this simple device structures are beneficial to the industrialization of white OLEDs displays.

2. Experiment

The OLEDs are based on Alq_3, N,N′-diphenyl-N,N′-bis(l-napthyl)-1,1′-biphenyl-4,4′-diamine (NPB) layer and a LiF buffer layer. NPB, LiF and Alq_3 layers are deposited on glass coated with indium–tin–oxide (ITO) under a pressure of 3×10^{-3} Pa. The ITO glass was cleaned using ultrasonic baths of acetone, isopropyl alcohol and methanol. The deposition rates were 0.05 nm s^{-1} and 0.02 nm s^{-1} for the organic materials and LiF, respectively. Finally, the metallic layer (Al) was fabricated at a pressure of 3×10^{-3} Pa. The thickness of each layer was measured by a quartz oscillating thickness monitor (IL-400). Luminance of the device was measured using a luminance meter (PR-650). The EL spectra were recorded with a Fluorcent-3 spectrophotometer. All the measurements were carried out at atmosphere and room temperature.

By inserting a thin LiF layer in the emitting layer (Alq_3), the EL spectra expanding is realized. The structure of the device is: ITO/NPB (45 nm)/Alq_3 (x nm)/LiF (0.3 nm)/Alq_3 ((45 − x) nm)/Al (150 nm). As a parallel comparison, three devices were prepared. For x = 5, 10 and 15, the device structures are: (1) ITO/NPB (45 nm)/Alq_3 (5 nm)/LiF (0.3 nm)/Alq_3 (40 nm)/Al (150 nm); (2) ITO/NPB (45 nm)/Alq_3 (10 nm)/LiF (0.3 nm)/Alq_3 (35 nm)/Al (150 nm); (3) ITO/NPB (45 nm)/Alq_3 (15 nm)/LiF (0.3 nm)/Alq_3 (30 nm)/Al (150 nm). In order to investigate the mechanism of EL spectra expanding, other two kinds of devices were also studied [(4) ITO/NPB (45 nm)/LiF (0.3 nm)/Alq_3 (45 nm)/Al (150 nm); (5) ITO/NPB (45 nm)/Alq_3 (45 nm)/Al (150 nm)] [13].

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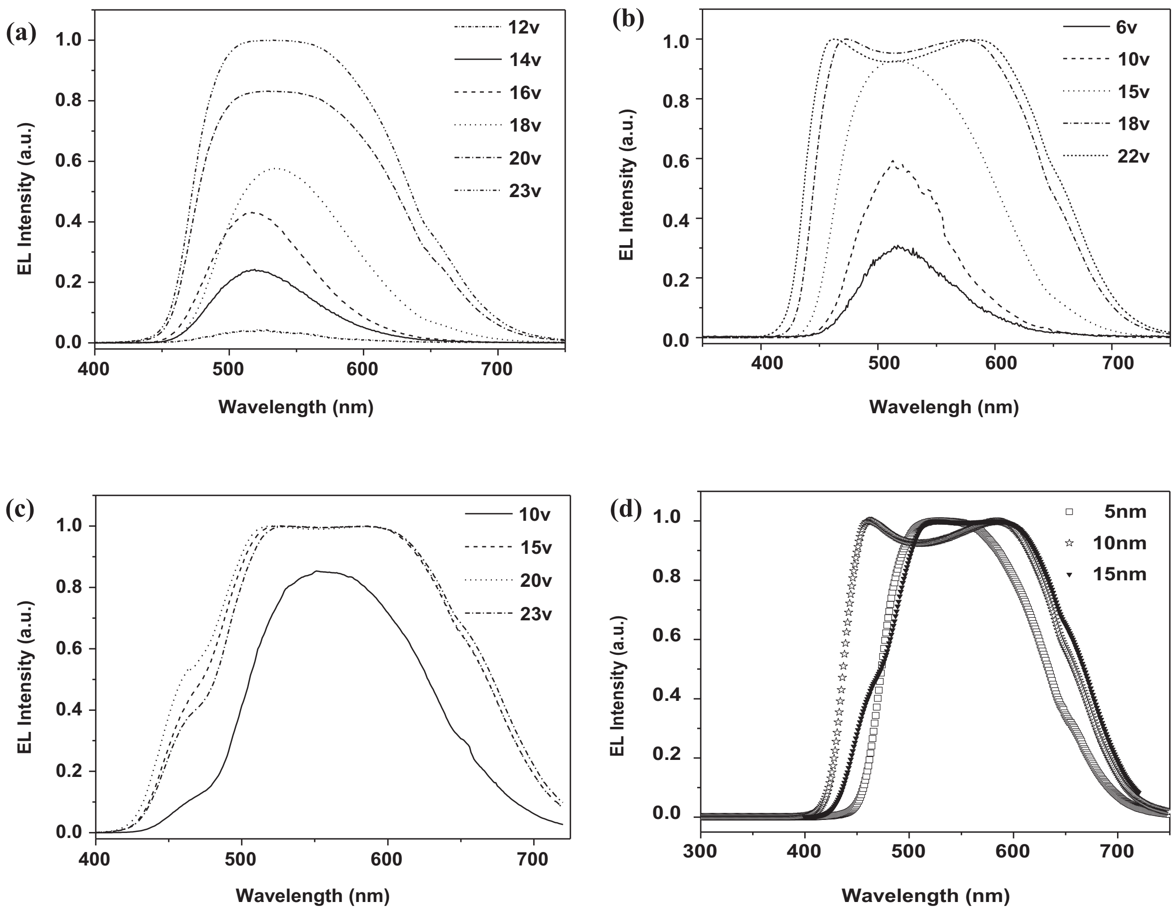

Fig. 1. EL spectra of the devices with the configuration ITO/NPB (45 nm)/Alq_3 (x nm)/LiF (0.3 nm)/Alq_3 ((45 − x) nm)/Al (150 nm) ((a) x = 5; (b) x = 10; (c) x = 15) and the contrast of EL spectra at 20 V (d).

3. Results and discussion

Fig. 1(a)–(c) shows the EL spectra of devices (1)–(3). The presence of LiF layer in the emitting layer (Alq_3) led to a shift of the electron–hole recombination zone to a region close to the NPB-Alq_3 interface due to enhanced electron injection, therefore the device showed expanded EL spectra obviously. Fig. 1(d) shows the contrast of EL spectra for devices (1)–(3) at the same applied voltage (20 V). The EL spectra expanding for device (2) (x = 10) was more prominent compared with the other two devices (x = 5 and 15).

Fig. 2(a) shows the brightness–voltage curves of the three devices. It was obvious that the highest brightness of the device with x = 10 reached 5820 cd/cm^2 at a fixed bias of 22 V and the brightness was higher than the others (x = 5 and 15). And the highest brightness of the other two devices was 3148 cd/m^2 and 2848 cd/m^2 at a fixed bias of 23 V respectively. The typical current density–voltage (J–V) characteristics of conventional and proposed OLEDs are plotted in Fig. 2(b). The J–V characteristics are sensitive to the position of a LiF layer in the Alq_3. In addition, the driving voltages of devices (1)–(3) are much higher than that of conventional device (5) at the same current level. The reason of this phenomenon

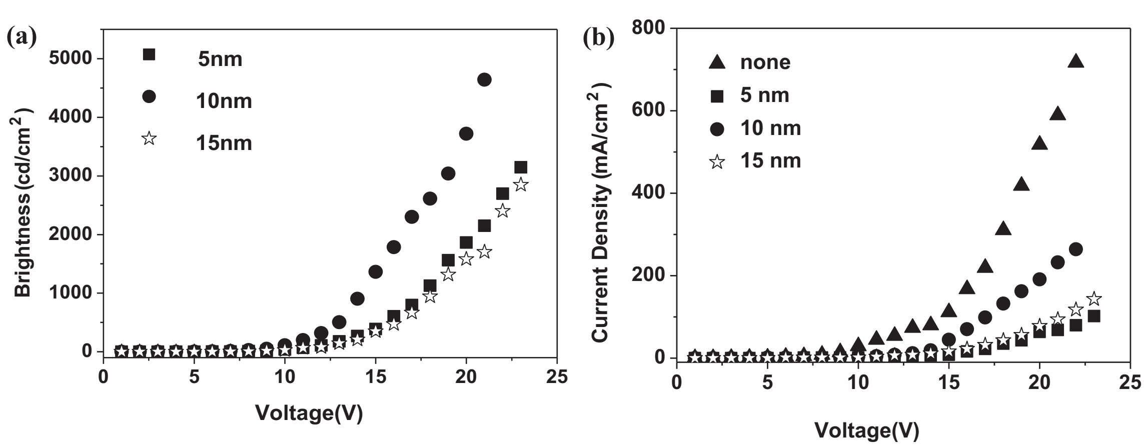

Fig. 2. The brightness–voltage (a) and current–voltage (b) characteristics of devices (1)–(3).