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Green Fluorescent Organic Light Emitting Device with High Luminance

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Abstract: In this work, we fabricated the small molecule green fluorescent bottom-emission organic light emitting device (OLED) with the configuration of glass substrate/indium tin oxide (ITO)/Copper Phthalocyanine (CuPc) 25 nm/ N,N'-di(naphthalen-1-yl)-N,N'-diphenyl-benzidine (NPB) 45 nm/ tris(8-hydroxyquinoline) aluminium (Alq_3) 60 nm/ Lithium fluoride (LiF) 1 nm/Aluminum (Al) 100 nm where CuPc and NPB are the hole injection layer and the hole transport layer, respectively. CuPc is introduced in this device to improve carrier injection and efficiency. The experimental results indicated that the turn-on voltage is 2.8 V with a maximum luminance of 23510 cd/m^2 at 12 V. The maximum current efficiency and power efficiency are 4.8 cd/A at 100 cd/m^2 and 4.2 lm/W at 3 V, respectively. The peak of electroluminance (EL) spectrum locates at 530 nm which is typical emission peak of green light. In contrast, the maximum current efficiency and power efficiency of the device without CuPc are only 4.0 cd/A at 100 mA/cm^2 and 4.2 lm/W at 3.6 V, respectively. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Fluorescent OLED, CuPc, High luminance, Current efficiency, Power efficiency.

1. Introduction

Since the first observation of light emission in organic electroluminescent devices, organic light emitting device (OLED) have attracted much attention in terms of solid state lighting application and flat-panel displays [1, 2]. Compared to the liquid crystal displays (LCD), OLEDs have various superior advantages such as low power consumption, high brightness, ultra-light-weight, wide viewing angle and fast response.

Currently, it is widely accepted that phosphorescent OELD has higher current efficiency than fluorescent OLED because of the waste of triplet energy. However, the EL efficiency of phosphorescent OLED decreases with 1 mA/cm^2 at a practical current range due to triplet-triplet exciton annihilation [3-6]. In addition, the manufacture cost of fluorescent materials is much lower than that of phosphorescent materials.

There is growing interest and demand in fluorescent OLED community, especially in passive matrix OLED display. Tang, Vanslyke, etc. conducted studies to make high-efficiency lighting emitting diode by using Alq_3 [7]. In order to improve the device efficiency and stability, CuPc is considered as one of the most efficient hole conductor inn OLED [8], with mobility 0.02-0.04 cm^2/Vs at room temperature. However, it is reported that CuPc easily induces the crystallization of hole transporting layer NPB [9] and its thickness often leads to substantial increase in device operational voltage [10]. Therefore, the thickness of hole injection layer has to be exactly controlled.

In this paper, we fabricated a high luminance green fluorescent bottom-emitting OLED with the structure of ITO/ CuPc 25 nm/ NPB 45 nm/ Alq_3 60 nm/ LiF 1 nm/ Al 100 nm. It is found that 25-thickness CuPc as the hole injection layer not only obviously reduce the operational voltage but also enhance the current and power efficiency. As the experimental results shown, the turn-on voltage is as low as 2.8 V and the operational voltage was 12 V at 23510 cd/m^2 luminance. The maximum luminance, the maximum current efficiency and luminous efficiency reaches 23510 cd/m^2, 4.8 cd/A and 4.2 lm/W, respectively.

2. Experimental Details

OLED with an active area of 2" × 2 " was grown on a glass substrate precoated with a 100 nm-thick ITO anode having a sheet resistance of 50 Ω/sq [11]. The chemical structures of organic materials and the architecture of the OLED are shown in Fig. 1 and Fig. 2. Prior, the substrate was cleaned in ultrasonic bath of isopropanol alcohol, acetone and deionized water sequentially for 10 min and blown dry by a nitrogen gun, respectively. Before depositing organic layers by thermal evaporator, the surface of ITO was treated with UV ozone for 10 min in order to increase the amount of oxygen and work function. All organic layers were deposited in succession on the ITO coated glass by thermal evaporation without breaking vacuum at 1×10^{-4}Pa.

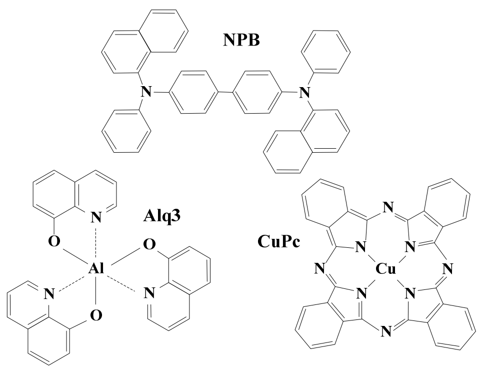

Fig. 1. Chemical structures of the employed organic materials.

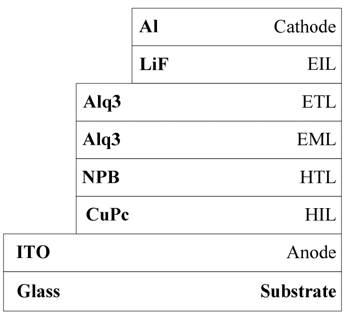

Fig. 2. Architecture of the fabricated OLED.

The multiple LiF/Al cathode was fabricated by depositing a 1 nm thickness LiF layer and then capping the device with a 100 nm Al layer still without breaking the vacuum. Finally, the fabricated device was hermetically sealed in an ultrahigh purity nitrogen-filled glove box.

The OELD consists of three organic layers, taking CuPc, NPB and Alq_3 as a hole injection layer, a hole transport layer and an emitting layer/electron transport layer (making 20 nm Alq_3 close to cathode as electron transport layer), respectively. The 1 nm-thickness insulating layer of LiF is used for balancing the injection of both types of carriers, increasing the efficiency of electron injection and thus improving the luminous efficiency of the device. The current density–voltage-luminance (J-V-L) characteristics and electroluminescence (EL) spectra were measured with a Keithley SA0253A digital electrometer and a spectrometer USB4H00570.

3. Results and Discussion

All measurements were carried out at room temperature in the dark condition. Alq_3 is considered as the most efficient EL emitter with a photoluminescence of 25–30 % and a stable electron transport layer material with high quantum efficiency and the mobility of 10-5 cm^2/Vs. It is believed that the emission spectrum from an OLED is strongly dependent on the Alq_3 thickness, so that usually shifts from 525 nm to 555 nm [12]. Fig. 3 depicts the Electroluminescence (EL) of the fabricated OLED. The EL spectrum result has shown a peak at 530 nm, which means is a high purity green color.

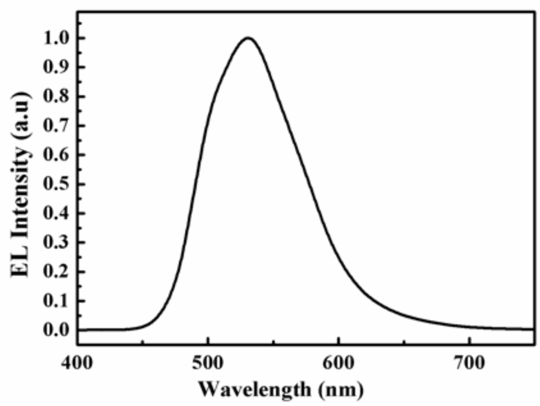

Fig. 3. Normalized EL spectrum characteristic of device.

It is well-known that CuPC is a superb hole injection material for ITO because of its band gap of ~1.8 eV. Fig. 4 shows the current density–voltage and luminance–voltage characteristics of the two devices. As evident from the graphs, the turn-on voltage (defined as the voltage required for the luminance of 1 cd/m^2) of the device with and without the introduction of 25 nm CuPc laye are 2.8 V and 3.2 V, respectively. Moreover, with the growth of current density, the luminance of OLED with CuPc layer is increasing faster than that of OLED without CuPC layer, as indicated in Fig. 5.

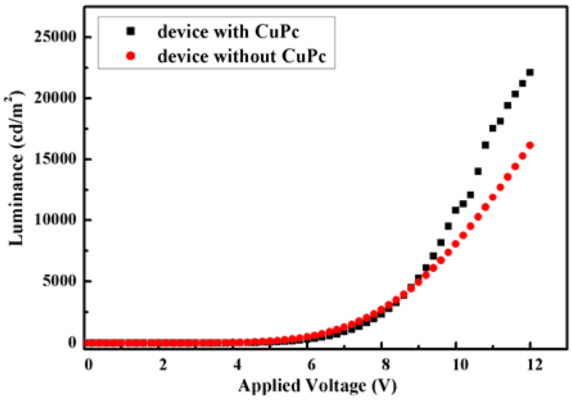

Fig. 4. Applied voltage-luminance characteristics of CuPc-based and normal OLEDs.

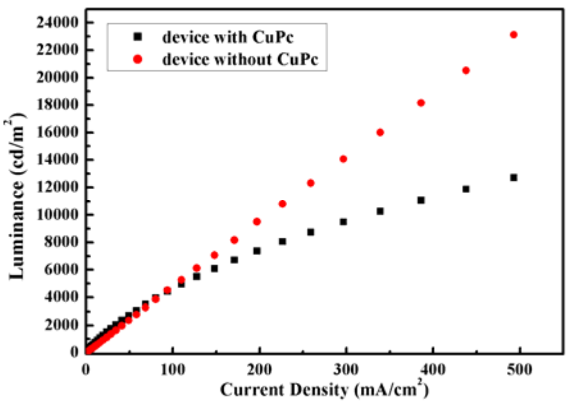

Fig. 5. Current density-luminance characteristics of CuPc-based and normal OLEDs.

For typical OLED device, there are three factors for significant enhancement power efficiency [13-15]. First, a balanced charge transporting capability was achieved by effectively dispersing the charge carriers into the interface. Second, the efficient trapping of holes were increased when the CuPc is used as hole injection material. Last, both charge carrier trapping and energy transfer mechanism took place in the EL process. Due to low operational voltage, the devices with CuPc layer exhibit higher power efficiency. The power efficiency and luminance efficiency as a function of driving current density for OLED are illustrated in Fig. 6 and Fig. 7, respectively.

The maximum power efficiency of the device with CuPc layer is higher than that of the device without CuPc layer, being 9.58 lm/W at 2.2 mA/cm^2 and 5.34 lm/W at 2.3 mA/cm^2, respectively, as indicated in Fig. 6.

As seen from Fig. 7, the current efficiency of the CuPc-based OLED increase with increasing current density at low currents under 5 mA/cm^2 and level off at around 7 cd/A in a wide range from 5 to 500 mA/cm^2. This is in contrast with non-CuPc layer OLEDs whose current efficiencies dramatically decrease by over 30 % from a current density of 5–500 mA/cm^2. Moreover, the maximum luminous efficiencies are 6.91 cd/A and 5.03 cd/A for two devices, respectively.

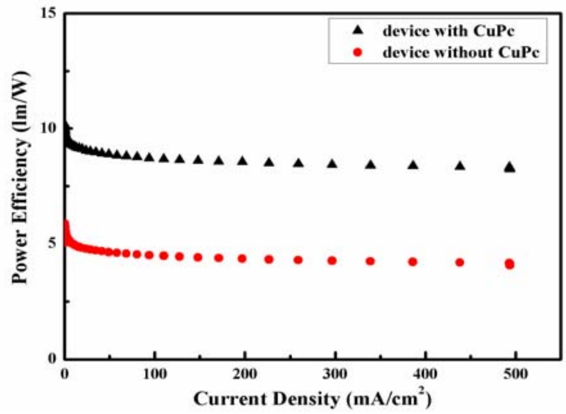

Fig. 6. Power efficiency dependency of driving current density for two OLEDs.

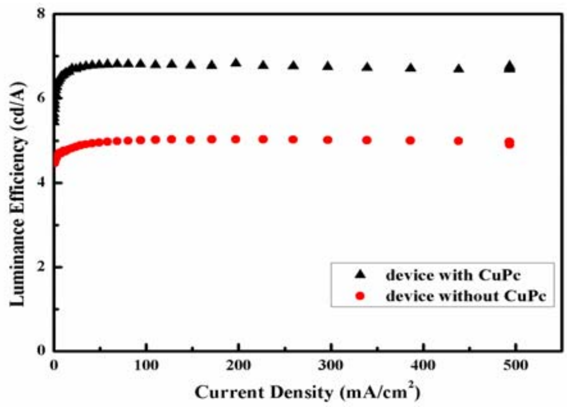

Fig. 7. Current density-luminance efficiency characteristics for two OLEDs.

4. Conclusion

In summary, we have developed the small molecule green fluorescent OLED with structure ITO/ CuPc 25 nm/ NPB 45 nm/ Alq_3 60 nm/ LiF 1 nm/ Al 100 nm, exhibiting high luminance of nearly 23510 cd/m^2.

The maximum current efficiency and power efficiency are 4.8 cd/A at 100 cd/m^2 and 4.2 lm/W at 3 V, respectively.

Because CuPc material has higher hole injection efficiency, compared to non-CuPc devices, CuPc-based OLED shows lower turn-on voltage and higher power efficiency and luminance efficiency, which can be also attributed to the better interface with ITO as well as the LiF layer.

Acknowledgements

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