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Effect of lithium doping in electron injection layer on the LED performance in reverse structure

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ABSTRACT

Light emitting diodes (OLEDs) are one the newest lighting in industrial lighting which can be a promising candidate in this area. A typical reverse OLED is made from cathode, injection/transport electron and hole layers, emissive layer (EM). Electrons and holes after injection to EM are recombined in emissive layer which is an organic material. In reverse structure, holes inject EM well while electrons cannot be easily injected to emissive layer. Here, effect of lithium doped zinc oxide (LZO) on the led performance was investigated. The results showed that lithium can be increased conductivity of injection electron layer and facile to inject electron to emissive layer.

Keywords: Lighting; OLED; Injection electron; Lithium doping; Thin film

1. Introduction

The Deep research on organic light emitting diodes (OLEDs) starts with Tang's research [1]. After that time researchers focused on this area with higher acceleration [2–5]. OLEDs are made of several thin layer consist of injection/transport electron and hole layers and an emissive layer which is a place for electron and hole recombination. Regarding deposition method of layers which is very easy to scale up and doesn't need to vacuum systems, OLEDs are a good candidate to substitute of another lighting in industry lighting. According to configuration there are two structure for OLEDs; conventional and reverse. In conventional usually ITO is used to anode and metals with low work function are used to cathode (ca, al, LiF/Al) [6] and in reverse structure ITO is used to cathode and metals with high work function are used to anode (Au, Ag and Pt) [7]. In reverse structure one of challenging issue is injection of electron to emissive layer [8]. Therefore work on injection electron layer in reverse structure is very important [9].

Here, we used lithium doped zinc oxide (LZO) introduced an electron injection layer leading to increase efficiency and decrease turn on voltage. Varying of amount of lithium, the optimum condition was obtained. Current-voltage, luminance-voltage, and efficiency-luminance characteristic of devices was well indicated that how lithium can affect on LED performance.

2. Experimental

Materials and methods

Lithium doped Zinc Oxide (LZO) precursor was prepared with solving of zinc acetate.4H_2O and lithium acetate (sigma Aldrich) in ethanol at concentration of 100 mM for zinc precursor. The milky solution was refluxed at 60 °C for 12 h. the solution would be suitable for deposition after filtration. Values of percent volume lithium was selected 2%, 10%, and 30%. About 30 nm LZO deposited top on clean ITO/glass substrate. To prepare clean ITO/glass, it was down by successive cleaning in acetone, methanol, and IPA in ultrasonic bath, each for 15 min. Finally, the substrates were treated by UV/ozone irradiation for 15 min to avoid any organic contaminant. The LZO thin film were baked at 200 °C for 15 min. To increase electron injection ability Cs_2CO_3 ultrathin deposited top of LZO layer. The precursor of Cs_2CO_3 was dissolve in 2-methoxyethanol with 5% volume concentration. After layer is emissive polymer, here is PDY or super yellow, deposited about 70 nm. After that samples moved to vacuum chamber at pressure of 10-9 torr. Two successive layers of MoO_3 and Ag were deposited at rate of 0.2 nm/s with 10 nm and 100 nm, respectively. Finally, the devices are encapsulated in the glove box.

The current-voltage and luminance–voltage characteristics are measured using Konica Minolta CS100A luminance meter (with 0.001 cd accuracy) coupled with a Keithley 2635A (with pico Ampere accuracy) voltage and current source meter, with a 1 sec time steps (in continuous mode).

3. Results and discussion

The configuration of devices fabricated and related thickness has been showed in Fig. 1. Electrons are injected from ITO/LZO/Cs_2CO_3 and holes from Ag/MoO_3 injected to emissive layer. In emissive layer the reached electrons and holes are recombined and emit light. Due to transparency of ITO/LZO/Cs_2CO_3 layers light exits from bottom of device. In Fig. 2 current-voltage (J-V) characteristic of three device of fabricated has been drawn. In the linear presentation J-V it is seen that with increasing of lithium dopant conductivity of devices improved. In this trend can be attributed to being of meal properties of lithium. In the fact, increasing of lithium amount in LZO thin film leads to have a more conductive layer. The maximum of current for three device is approximately is the same (300 mA/cm^2). In the rest, semi-logarithmic representation J- V characteristic is observed. The magnitude order of measured range of current variation is about 10, it means the currant starts from 10-8 mA/cm^2 to about 300 mA/cm^2. According to this figure, device fabricated with LZO (30%) has better diodic properties. It is noted that Cs_2CO_3 ultrathin layer is a factor to improve electron inject characteristic.

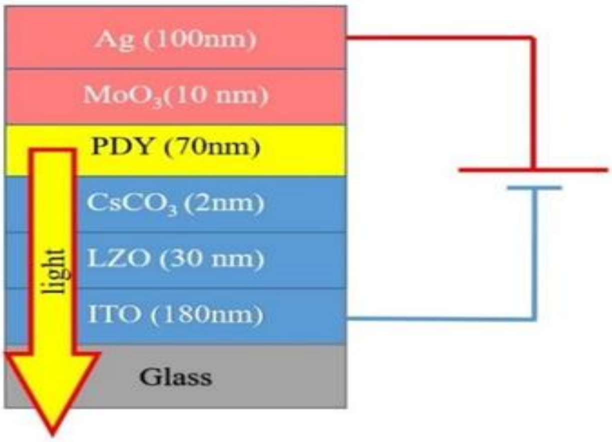

Fig. 1: configuration of LED and related thickness

Luminescence-voltage characteristic of the devices is depicted in Fig. 3. These behavior is very similar to J- V properties. The maximum luminance is 21 cd/m2 for device fabricated to LZO (20%). Regarding to higher conductivity in LZO (30%) we too have lower turn on voltage for the related device. In every device, luminesce is dropped suddenly that according to J-V characteristic it can be due to degradation of devices in very high current.

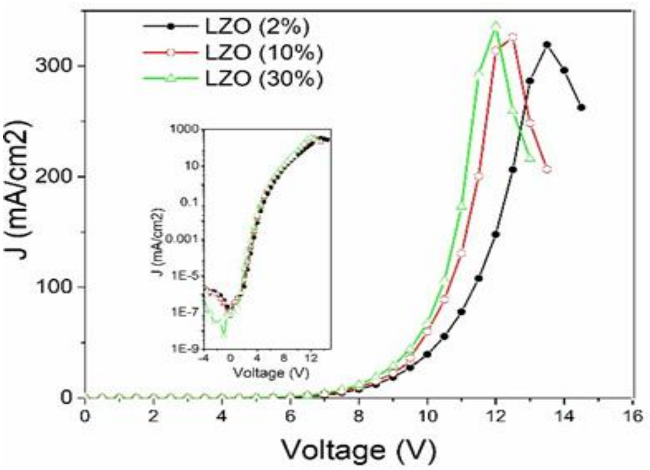

Fig. 2: current-voltage characteristic of LEDs fabricates by different amount of lithium doping in ZnO

Performance of a LED is indicated when its efficacy is measured. In order to compare devices performance current-luminescence-voltage (J-L-V) was recorded with measuring of J-V and L-V simultaneously. Fig. 3 shows current efficiency or efficacy (a) and power efficiency versus on luminance (b). In Fig. 3 (a) is seen that efficacy of device fabricated by LZO(10%) is the best although turn on voltage of LZO(30%) is the lowest. the efficacy of LEDs can reach to 7.5 cd/A that is very acceptable for inverted structure. Higher efficacy means LED emits light in lower current that causes to increase the device performance and lifetime. Conductivity of LZO (30%) is so high that it cannot have a good efficacy due amount of current is higher than luminance in comparing to other devices. If a device turns on in low voltage and low current, it has high power efficiency. The highest power efficiency owns to LZO (10%) (In Fig. 3 (a)) with amount of 2.3 lm/W. lithium doping leads to electron inject to emissive layer better.

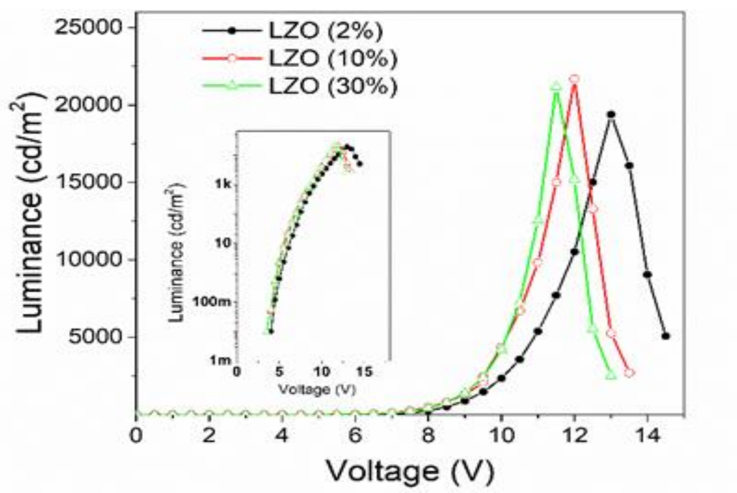

Fig. 3: effect of lithium doping in ZnO layer on the Luminance-voltage characteristic.

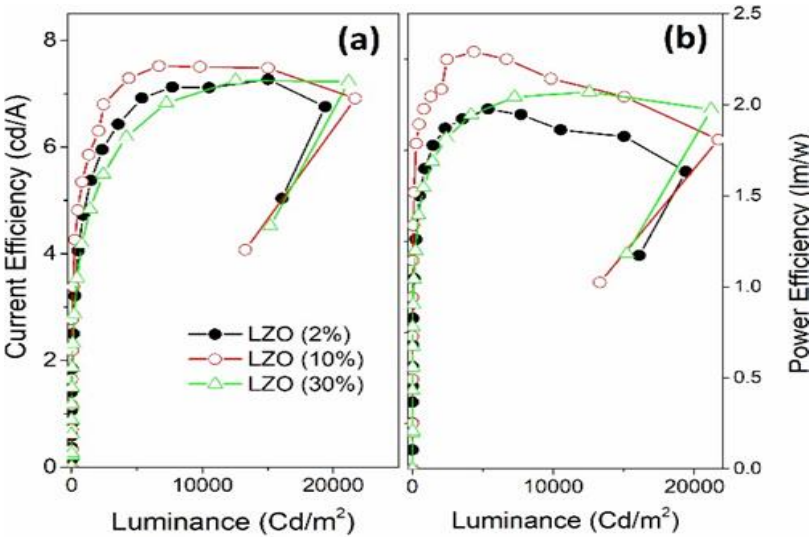

Fig.4: effect of lithium doping in ZnO layer on currentefficiency (a) and power efficiency (b)

4. Conclusions

In aim to understand and compare of effect of lithium doping in ZnO thin film, different amount of lithium was mixed to Zn precursor. After baking, LZO thin film prepared to enter a LED device. From J-V characteristics it was concluded conductivity of LZO is improved as amount of lithium is increased. The lowest turn on voltage owned to device fabricated to LZO (30%). According to the efficiency results it was indicated efficiency of device fabricated by LZO (10%) is the best and optimum due to facile injection of electrons to emissive layer.

Acknowledgment

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