Pure Aluminum as the Anode in Top Emission OLED

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ABSTRACT

Good performance top emitting organic light emitting diode (TOLED) with pure aluminum metal layer as the bottom anode has been fabricated. The brightness of the device could reach 4500cd/m^2 at applied voltage 12V. The highest current efficiency is about 6.8cd/A at a driving current density 50mA/cm^2, which is much higher than that of the standard device and nearly twice as high as that of the TOLED with additional high work function silver deposited on aluminum as the anode.

INTRODUCTION

For high resolution active matrix OLED, a top emitting architecture is advantageous because the pixel transistors can be hidden underneath the OLED device. This will increase the aperture ratio as well as affording the possibility of decreasing the pixel size. Normally TOLED are built on the metal layer, which can be the same layer as the source or drain of the TFT in driving scheme [1]. The most widely used metal layer is aluminum. Hence, TOLED fabricated on aluminum is of interest in the active matrix driving technology.

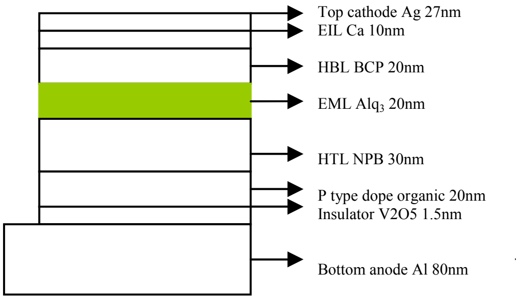
As is well known, the low work function (4.2eV) is the main hurdle of employing aluminum directly as the anode in TOLED. Hence, in previous studies, it was used as the cathode in an inverted top emission OLED (ITOLED) structure [2,3]. But this kind of device is rarely of good performance. Alternatively, it is possible to use an additional high work function metal layer deposited on top of the aluminum layer [4]. There have been some reports on TOLED with pure aluminum as the anode [5], but the hole injection material used in this method is not common and the driving current is high. In this paper, we report the fabrication of TOLED with pure aluminum as the anode, without any other high work function metal or ITO, while having very good performance. This method surely save us one step in anode fabricating of conventional active matrix TOLED.

EXPERIMENT

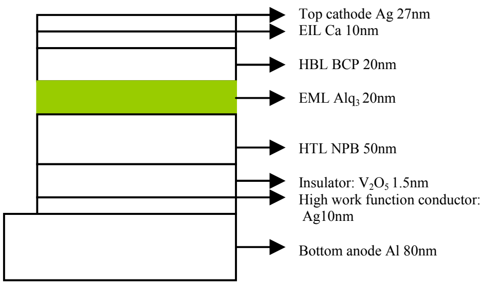
The glass substrate was cleaned using ultrasonic de-ionized (DI) water for 30min. The device was fabricated in a high vacuum evaporation system under a base pressure less than 2X10^{-4}Pa. The anode aluminum was ~80nm with an evaporation speed of 4~6Å/s. It was then followed by 1.5nm of vanadium pentoxide (V_2O_5) at a speed of ~0.5 Å/s. A ~20nm HIL, ~25nm HTL(N,N'-di(naphthalen-1-yl)-N,N'-diphenyl-benzidine (NPB)), 20nm EML (Tris-(8-hydroxy-quinolinato)-aluminium (Alq3)) and 20nm ETL/HBL (2,9-Dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP)) were then evaporated with the speed around 1.5 Å/s. Lastly, ~10nm calcium and ~25nm silver were deposited to form the cathode, with the evaporation speed of 2 Å/s.

The electrical and optical characteristics of the devices were measured with a R6145 DC voltage current source, FLUKE 45 dual display multimeter and Spectrascan PR650 in dark room and ambient air condition.

The structure of this kind of device is shown in Fig. 1(a). While Fig. 1(b) shows the configuration of the top emission device with additional deposited Ag layer as the anode, and Fig. 1(c) shows the cross section of the standard bottom emitting device.



(a)



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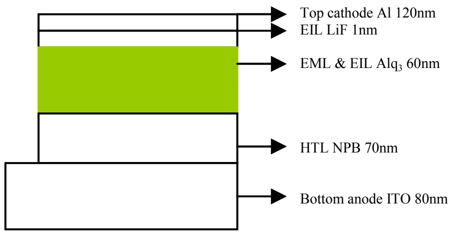
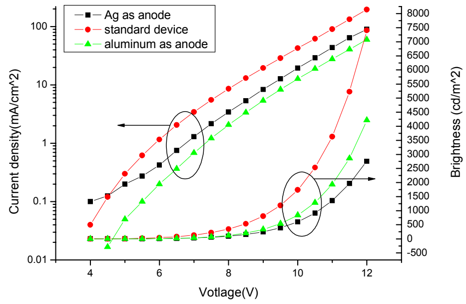


(c)

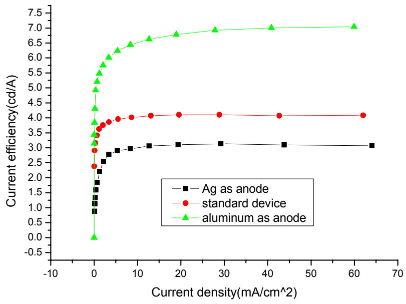
Fig 1. (a) Top emission device with pure aluminum as the anode, (b) high work function metal anode and (c) standard bottom emission device.

There are thus three kinds of devices, they are:

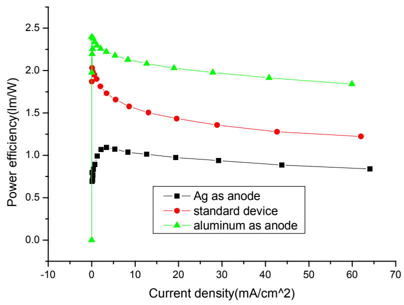
a) Al 80nm/V_2O_5 1.5nm/p-type dope HIL 20nm/ NPB 30nm/Alq_3 20nm/BCP 20nm/Ca 10nm/Ag 27nm
b) Al 80nm/Ag 10nm/V_2O_5 1.5nm/ NPB 50nm/Alq_3 20nm/BCP 20nm/Ca 10nm/Ag 27nm
c) ITO 80nm/ NPB 70nm/Alq_3 60nm/LiF 1nm/Al 120nm



(a)



(b)



(c)

Fig 2. (a) J-V, L-V (a), current efficiency, (b) and power efficiency and (c) comparison results of the three kinds of device: standard device (●), top emission device with Ag (■) as anode and Al as anode (▲).

The electrical and optical characteristics of three kinds of devices were compared. Fig. 2(a) and (b) shows the J-V, L-V and efficiency comparison results. From these figures, we can get the following conclusions:

(1) At the same applied voltage, the device with aluminum as anode has the lowest current density as compared to the other two kinds of devices. This may be explained by the relatively low work function of the metal aluminum. The low work

function makes the hole injection of this device smaller. But this is beneficial as the hole and electron injections are better balanced since the electron injection is always low. Hence, the efficiency of this kind of device can get much higher than the other two kinds in terms of the low current density and better balance injection condition.

(2) When the applied voltage is 12V, the brightness of the device with Al as anode could reach 4500cd/m^2, lower than that of the standard device, which is 7500 cd/m^2, but higher than that of the top emission device with Ag as anode.

(3) At the same driving current density 50mA/cm^2, the current efficiency of the device with aluminum as anode is about 6.8cd/A, much higher than both the other two devices, 4cd/A for standard one and 3cd/A for Ag as anode.

(4) The highest power efficiency of the top emission device with Al anode is 2.4lm/W, higher than that of the standard device and the Ag anode top emission device, which are 2.1 lm/W and 1.2 lm/W respectively.

(5) The current efficiency curve of device with Al as anode represents increased until the intensity of light emitted out was saturate for PR650, while the efficiencies of the other two devices decreased after reaching the peak value at about 20mA/cm^2.

As far as the microcavity effect in this kind of device, we measured the EL spectrum from different viewing angle. Fig. 3 shows these EL spectrums. In this figure, it can be concluded that the emission light is well coupled out in the range from 0˚ (524 nm) to 80˚ (500nm).

CONCLUSION

In summary, TOLED with the aluminum as the direct anode has been fabricated making use of both the insulating V_2O_5 layer and p-type doping hole injection layer. The efficiency of the device is much higher than the standard bottom emission device. Compared with the TOLED with a thin silver layer deposited on aluminum, the current efficiency of the present device is almost doubled. As well, the TOLED reported here reduces the number of steps for depositing or sputtering another high work function anode on the surface of S/D of the driving unit. For active matrix OLED, this method of fabricating TOLED can be quite attractive.

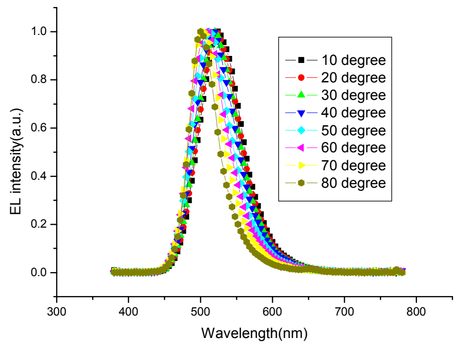


Fig 3. EL spectrum of the device with Al anode.

Acknowledgement – This research was supported by the Hong Kong Government Innovations and Technology Fund.

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