Top-emitting Organic Light-Emitting Diode with a Cap Layer

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ABSTRACT

For top emitting Organic Light-Emitting Diodes (OLED), the study of top layer is very important aiming to acquire good device performance. In this report, Pt as anode for CuPc/TPD/Alq3 OLEDs, and using LiF/Al as cathode capped with TPD or without capped layer. The radiation angle distribution has been investigated. It was proven that the cathode capped layer will strong effect of the angle distribution and the top-emitting OLEDs give out more total radiation flux then bottom-emitting OLEDs with the same organic structure of CuPc/TPD/Alq_3.

Keywords: Organic light-emitting diodes, top emitting, cap layer.

INTRODUCTION

Organic light-emitting diodes (OLEDs) [1] is challenging liquid-crystal display (LCD) as an alternative flat-panel display technology because of its ease of manufacturing due to its all solid-state nature as well as its relative merits of having a faster switching speed and being self-emitting with a wider viewing angle.

With the current trend towards the OLEDs fabrication on thin film transistor (Active Matrix OLEDs) is particular interested [2,3], due to active-matrix drive is required for high information content OLED display. Because OLEDs display is a current drive devices, so it need more than two transistors to drive each pixel of OLEDs[3,4]. As a backplane design, this significantly diminishes the aperture ratio in displays employing conventional bottom-emitting OLEDs, limited the resolution of the pixel and forcing the OLEDs to operate at a higher luminance level, reducing the lifetime[5].

Top-emitting organic light-emitting diodes (TOLEDs) is of considerable interest, particularly for displays fabricated on opaque substrates such as on silicon [6,7,8]. Top-emitting OLEDs can be used on TFT without diminishing the aperture ration problem and can serve as a high resolution display. Otherwise, the TOLEDs theoretically can give out the emitting without suffering the substrate waveguide limitation that the conventional bottom-emitting OLEDs have [9], so it should have higher efficiency than conventional bottom-emitting OLEDs [10]. However, TOLEDs fabricated on n-type and p-type silicon, or coated aluminium on silicon have demonstrated less efficiency than conventional bottom-emitting, [6,7,8], Because of the efficiency of the OLEDs is sensitive to the electrodes [11-15].

It was reported that thin Platinum (Pt) film [14,15] and thin Praseodymium oxide (Pr_2O_3) film [16] can improve hole injection of the OLED. In this paper, we report using Pt coated on glass as anode, copper (II) phthalocyanine (CuPc) as organic buffer layer, N,N'-diphenyl-N,N' bis(3-methylphenyl-1,1'-biphenyl-4,4'-diamine (TPD) as hole transport layer and tris-8-hydroxyquinoline aluminium (Alq_3) as emitting layer and electron transport layer, LiF(10Å)/Al(150 Å) as cathode coated TPD as cap layer and without capped layer. This structure TOLEDs with cap layer give out high efficient emitting.

OLED FABRICATION

The starting substrates coated (100nm) Pt on glass. The sequence of pre-cleaning prior to loading into the evaporation chamber consisted of ultra-sonic DI water soak for 30mins, oven bake-dry for 1-2hrs and UV/O_3 illumination for 9mins [17].

The constituent organic layers for the OLEDs were next deposited using thermal vacuum evaporation of commercial grade CuPc, TPD and Alq_3 powder. The base pressure in the evaporator was ~8μTorr. The deposition rates of the organic thin films were 0.2-0.4nm/s. While glass coped Pt was used as the anodes, 0.1nm lithium fluoride (LiF) topped with 17nm aluminum (Al) were used as the cathodes then coated 50nm TPD composite layers as cap layer. The deposition rates of LiF and Al were 0.02-0.05nm/s, 1-1.5nm/s, respectively. Film thickness was determined *in situ* using a crystal balance.

Three types of 4mm x 4mm OLEDs were fabricated for comparison:

Type C: Glass/ITO(75nm)/CuPc(20nm)/TPD(40nm)/Alq_3(50nm)/LiF(1nm)/ Al(150nm).

Type TN: Glass/Pt(100nm)/ CuPc/TPD/Alq_3/LiF(1nm)/Al(17nm)/ITO(80nm).

Type TC: Glass/ Pt(100nm)/CuPc/TPD/Alq_3/LiF/Al/TPD(50nm)/CuPc(5nm).

Unless specified otherwise, the thickness values of the various films in device Types TN and TC are the same as those of the corresponding films in the control conventional bottom-emitting device Type C, the structure of the latter is shown in the Inset of Figure 1.

The devices were characterized in room ambient and temperature without encapsulation. EL intensity was measured using a (Division of Kollmorgen Instruments Corporation) PR650 SpectraScan spectrophotometer. Current-voltage (I-V) characteristics were measured using a Advantest R6145 DC Voltage Current Source and Pluke 45Dual Display Multimeter.

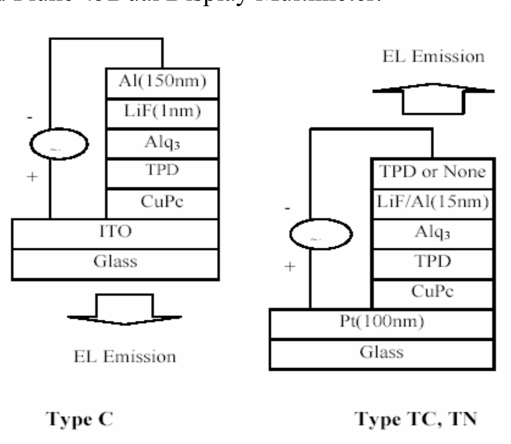

Fig. 1 Schematics of the TOLEDs structure studied

RESULTS AND DISCUSSION

The luminance in normal direction-current density (*L-J*) and voltage-current density (*V-J*) characteristics of Types TC and C devices are shown in Figure 2. Compared to those of the Type TC reference device, it can be seen that voltage (*V*) at the give current curve is a little decreased.

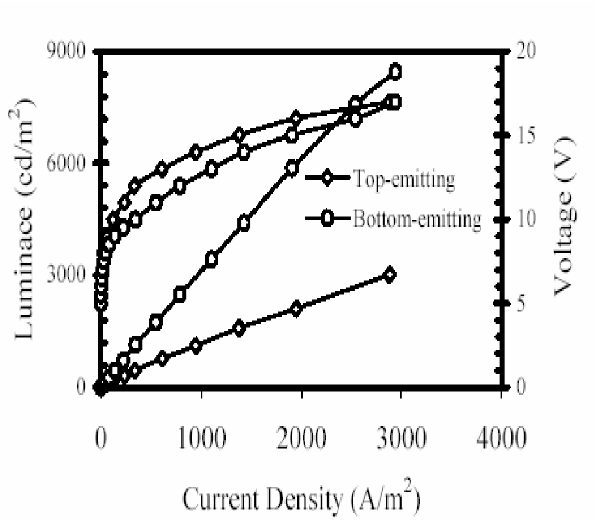

Fig.2 The El luminance(L) in normal direction -Current Density(J)- Voltage (V) Characteristic of the devices

L at a given current density is decreased for Type TC devices compared with Type C reference in the normal direction. For the top emission devices TC, the bottom anode mirrors have reflection around 90% , corresponding to Pt. When light travels through the top layers, the transmission is less than about 40%, which causes the lower luminance of top-emitting devices compared with conventional device.

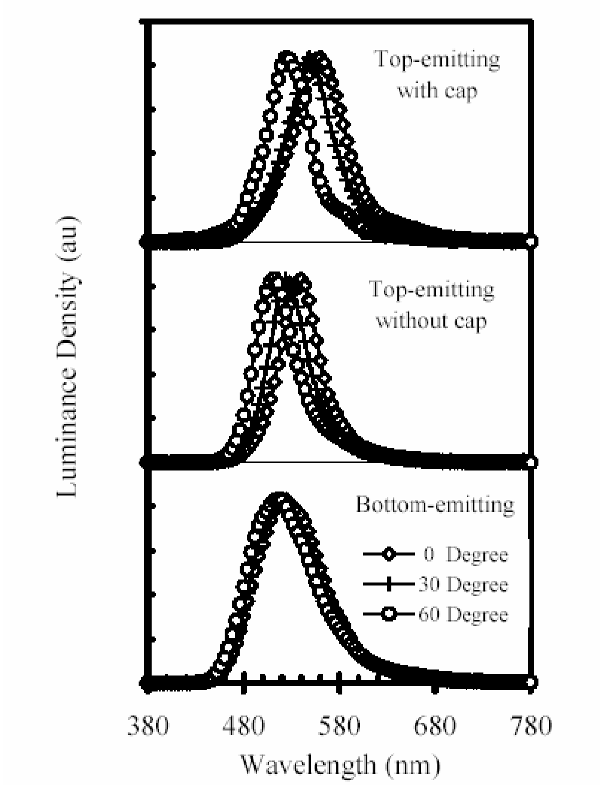

Fig.3 EL spectra of the devices with different angle

The figure 3 give out the spectra of the EL emission of the device type TC, TN and C in different direction from normal direction, it can be seen that the spectra have been changed. The spectra of the Top- emitting without cap layer became narrower than with cap layer and bottom-emitting device. The peak of the top-emitting both with cap layer and without cap layer will be blue shift with the angle, the peak of the bottom emitting is unchanged with angle.

Figure 4 shows the angular dependence of the luminance for the three types of devices. The data are normalized with respect to the value measured from normal direction. And the lambertian distribution is given for comparison. The emission profile of the device type C is close to Lambertian, giving a weak angular dependence.

However, there is a strong angular dependence for the emission of top emitting devices both with and without cap layer. The emission profile of top-emitting device with cap layer have stronger than that of top-emitting without cap layer. We believe it is due to the low waveguiding loss and strong microcavity effect in the top emitting devices. For the conventional device, there is around 50% light lost to waveguiding modes in the glass.

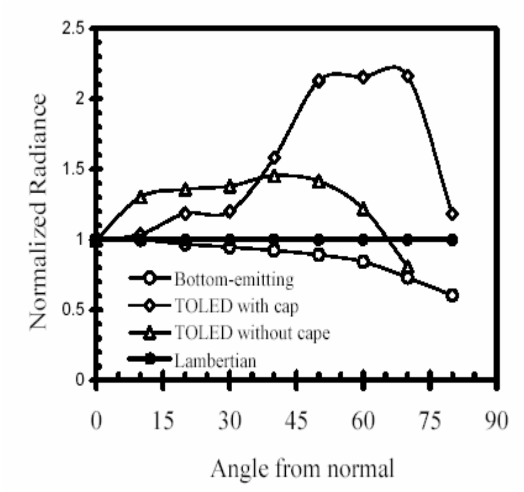

Fig.4 Angler distribution of emission of the devices

However, the light from top emitting devices is extracted after passing through an ultrathin metal film and a thin TPD cup layer. The thin TPD layer is effective for modifying the top mirror's reflection and optimizing the cavity effects. Our calculation shows addition of the thin TPD layer can effectively suppress the waveguide modes loss. So more light is coupled out for surface emission. The total internal reflection effect is not as severe for conventional structure device as for top emitting devices. Consequently, at the large viewing angle, higher luminance was obtained from top-emitting devices. The discrepancy between device TC and TN is believed to be induced by the different microcavity effects inside. More analysis will be given elsewhere.

CONCLUSION

TOLEDs with Pt as anode and LiF/Al as semi-transmission cathode caped with TPD or without cap layer have been investigated. It is found that Top-emitting device have strong angle distribution emission, and top-emitting device with cap layer has stronger angle distribution emission than without cap layer. These TOLEDs can give out efficient emission. Compare with convention bottom OLEDs,

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