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Top emission organic light emitting diodes with double metal layer anode

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1. Introduction

Conventional OLED pixels are bottom emission structure where TFT and data lines would block the passage of light. To improve the aperture ratio and keep the bottom-layer TFT from affecting the passage of light, the use of top emission organic light emitting diodes (TEOLED) is an inevitable trend [1]. The fabrication of TEOLED requires a high-reflectivity anode that must possess high work function to increase hole injection into the organic layer. Many scholars have attempted to use metallic material with high work function as anode, while Lee et al. selected Ni [2]. This paper employs double metal layers Al /AuGeNi as anode to achieve high reflection and high hole injection efficiency, and uses the multi-layer structure of LiF/Al/Ag [3,4] as cathode. The thicknesses of organic layers are also varied to obtain optimum luminescence characteristics. We predict that Al/AuGeNi will perform longer lifetime than Al/Au [5].

2. Experimental

In this study, the OLED device is fabricated on a glass substrate. The glass substrate was placed in the metal evaporation chamber, and Al and AuGeNi (alloy ratio of 84:14:2) were deposited under 3×10^{-6} torr to create an anode at first. Next, the substrate was moved to the organic evaporation chamber for the deposition of organic thin films under 2×10^{-6} torr. The hole injection layer (HIL) was 4,4',4''-tris(N-3-methphenyl-N-phenyl-amino)-triphenyl-amine (m-MTDATA), the hole transport layer (HTL) was N,N'-diphenyl-N,N'-bis(1-naphthyl)-(1,1'-biph-enyl)-4,4'-diamine (NPB), and the emitting and electron transport layer (ETL) was tris(8-hydroxyquinoline) aluminum (Alq_3). The device was then moved back to the metal evaporation chamber for the deposition of metal cathode LiF/Al/Ag. SpectraScan PR650 and Keithley 2400 were employed to measure the luminance and current-voltage characteristics.

3. Results and Discussion

This study used Al/AuGeNi as anode. Figure 1 shows the current density vs. voltage of different anode structures. When Al was collocated with ultra-thin high work function alloy (AuGeNi) in the double metal anode, the turn-on voltage dropped from 22 to 8V. Fig. 2 and Fig. 3 compare respectively luminance vs. current density and luminance yield vs. current density of different anodes. It is found that devices with thermally evaporated Al/AuGeNi anode had better luminance and yield. This is because Au, Ge and Ni in AuGeNi alloy all have high work function (5.1 - 5.0 - 5.3 eV), which produces better hole injection effect as compared to Au-Ge (5.1 - 5.0 eV) and Au-Sn (5.1 - 4.4 eV). As shown in Fig. 2 and Fig. 3, double metal layer structure of Al/AuGeNi is an excellent choice for OLED anode.

Next we examine the effect of HIL and HTL thickness

Table I Device Parameters unit: nm

Device #	Anode			m-MT	NPB	Alq3	LiF	Al	Ag
A	Al 60		0	0	40	80	0.2	2	15
B		AuGeNi	2						
C		AuGe	2						
D		AuSn	2						
E	Al 60	AuGeNi	2	20	20	80	0.2	2	15
F				30	10				
G				35	5				
H	Al 60	AuGeNi	2	30	10	90	0.2	2	15
I						100			

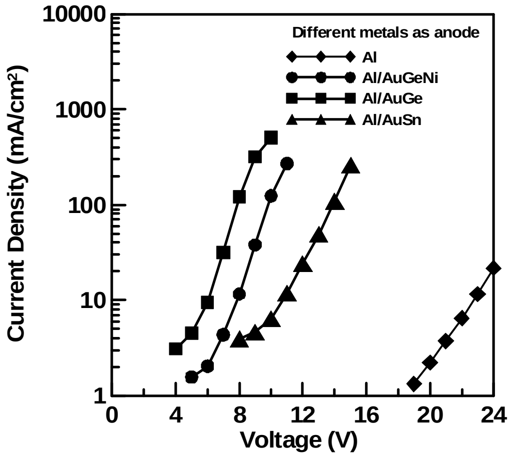

Fig. 1 Current density vs. voltage of different anode structures

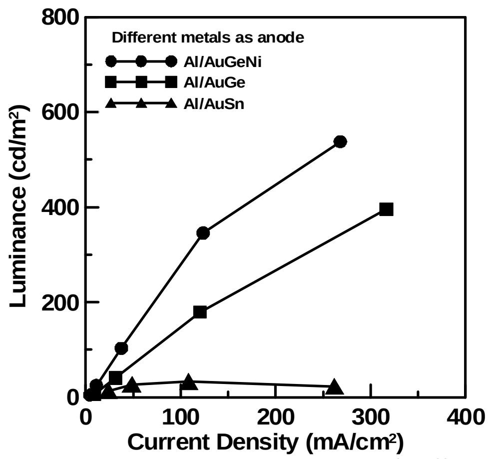

Fig. 2 Luminance yield vs. current density of different anode structures

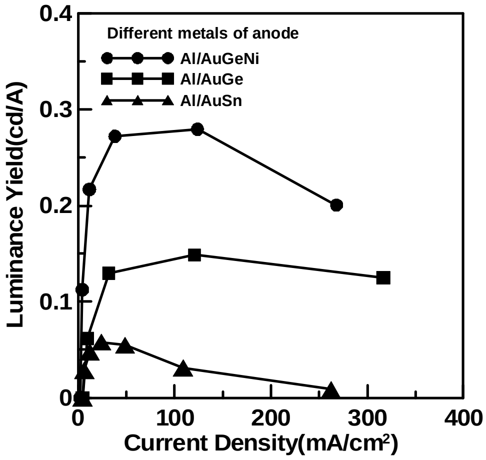

Fig. 3 Luminance yield vs. current density of different anode structures

on OLED performance. The devices (E - G) also had m-MTDATA for HIL with incremental thickness from 20 to 35 nm, and NPB for HTL with thickness decreasing from 20 to 5 nm, but the combined thickness of m-MTDATA and NPB was maintained around 40 nm (i.e. the total thickness of organic layer was kept constant). As shown in Fig. 4, luminance yield of the device were effectively enhanced, and reached its optimum level of 0.88 cd/A with m-MTDATA/NPB/Alq_3 thickness at 30/10/80 nm (Device F). This is because the increase in m-MTDATA thickness effectively increases the number of holes being injected into the organic layer from Al/AuGeNi, thereby improving the chance of hole-electron recombination to produce more excitons and enhance luminance and luminance yield [13]. But when the thickness of m-MTDATA reached 35 nm as in the case of Device G (dashed line in Fig.4), luminance and yield turned for the worse. This is because the number of injected holes has reached saturation condition when the HIL was at optimum thickness.

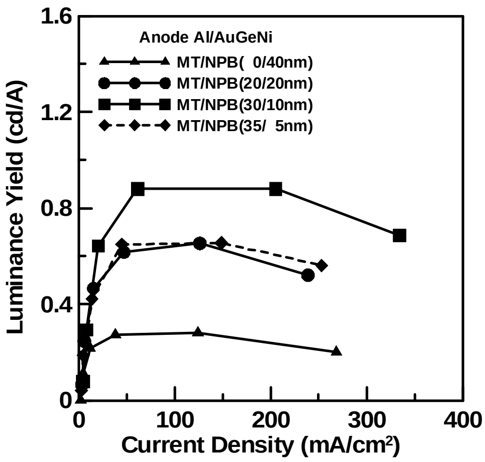

Fig. 4 Luminance yield vs. current density of different hole injection layers and hole transport layers

Lastly we examine the effects of ETL thickness on luminescence characteristics. The thickness of Alq_3 layer increased incrementally from 80 to 100 nm as in the case of Devices F, H, and I in Table 1, respectively. As shown in Fig. 5, when Alq_3 thickness was increased to 100 nm (Device I), the yield of device were raised to 1.4 cd/A at 105 mA/cm^2. This is because when the ETL thickness increases, it increases the effective dissipation distance of excitons to give the excitons sufficient space to release energy in the form of light before they reach cathode, thereby reducing the quenching phenomenon [6] and effectively enhancing the luminescence performance.

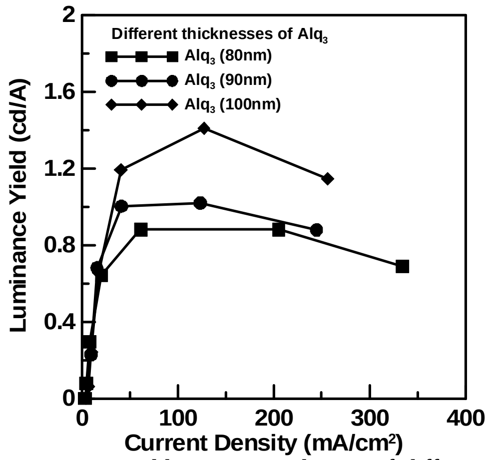

Fig. 5 Luminance yield vs. current density of different electron transport layers

4. Conclusions

This study uses Al/AuGeNi as the anode of top-emission OLED and demonstrates the enhancement of hole injection efficiency. Finally by adjusting the thickness of electron transport layer to bring the thickness of organic layer m-MTDATA/NPB/Alq_3 to 30/10/100 nm, luminescence intensity and yield of the device is greatly enhanced to reach 2930 cd/m^2 at 250 mA/cm^2 and 1.4 cd/A at 105 mA/cm^2, respectively.

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