Extended Abstracts of the 2010 International Conference on Solid State Devices and Materials, Tokyo, 2010, pp665-666

A-5-5L

Passivation Effect of Diamond Like Carbon Films for Organic Light-Emitting Diodes

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1. Introduction

Organic light emitting devices (OLEDs) has been put to practical use[1]. In order to stabilize device operation, passivation layer is necessary. In addition, for flexible applications, barrier film between flexible substrate and OLED and its process conditions below 150°C are required[2,3]. From these standpoints, there are many reports, such as, multilayer films[4-6], SiN, and SiNx/ CNx:H[7-9], are reported.

In this time, we have studied organic light emitting devices (OLEDs) with double-layered inorganic/ diamond like carbon (DLC)[10,11] as a passivation films. Without inorganic films, device durability was seriously shorter than that of double layered structure while the initial stage of device characteristics was the identical. By adding the MoO_3 as passivation layer for reducing plasma damage, identical durability that compared to the glass encapsulation was observed.

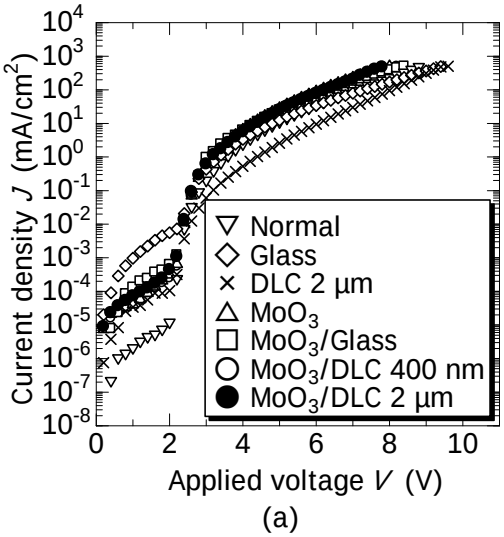
2. Experimental

For a hole transportation layer and an emission layer, 4,4'-bis[N-(1-naphtyl)-N-phenyl-amino]biphenyl (α-NPD) and tris-(8-hydroxyquinoline)aluminum (Alq_3) were used, respectively. Thickness of α-NPD and Alq_3 were both of 500 Å and these layers are evaporated using conventional vacuum evaporation on ITO glass substrate. Finally, a bilayer cathode of LiF (10 Å)/ Al (700 Å) was deposited sequentially using a tungsten basket or boat without breaking vacuum. Miyashita *et al.* reported that MoO_3 was effective for a buffer layer in order to reduce plasma damage during IZO sputtering[12]. This material can be evaporated using resistive heating evaporation method. Therefore, heating damage during evaporation can be reduced. The MoO_3 of 20 nm was deposited on cathode before DLC deposition in order to reduce a plasma damage. Evaporation of MoO_3 was done under the condition of vacuum level of about 2.0×10^{-6} Torr.

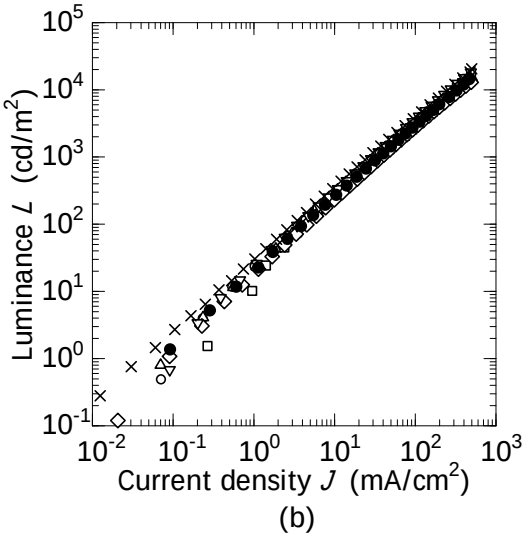
The DLC film was deposited on the devices using RF plasma (13.56MHz) chemical vapor deposition (CVD) method. The CH_4 gas is introduced in a chamber with a flow rate of 30 sccm. The plasma deposition was performed at the pressure of 50 mTorr, and power was maintained at 20 W. Substrate temperature was room temperature. Before deposition, the back pressure was 5.0×10^{-5} Torr. The device structure was ITO (200 nm)/ α-NPD (50 nm)/ Alq_3 (50 nm)/ LiF (1 nm)/ Al (70 nm)/ with or without MoO_3 (20 nm)/ DLC (400 nm or 2 μm). To compare with DLC device, the device was encapsulated using the glass cap and epoxy resin in a nitrogen atmosphere using a glove bag without DLC sample. The device area is 2×2 mm^2.

3. Results and Discussion

Figures 1 (a), (b) and (c) show current density (J) versus applied voltage (V) characteristics, the luminance (L) versus current density characteristics and EL efficiency (η) versus current density characteristics, respectively.



(a)



(b)

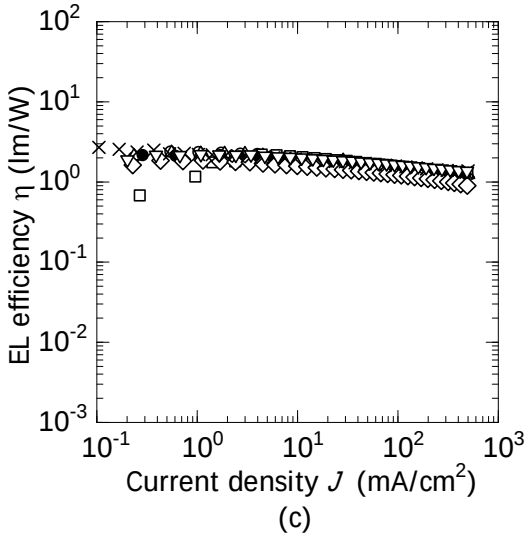


Fig. 1 (a) Current density vs applied voltage characteristics, (b) luminance vs current density characteristics of OLEDs and (c) EL efficiency vs current density characteristics.

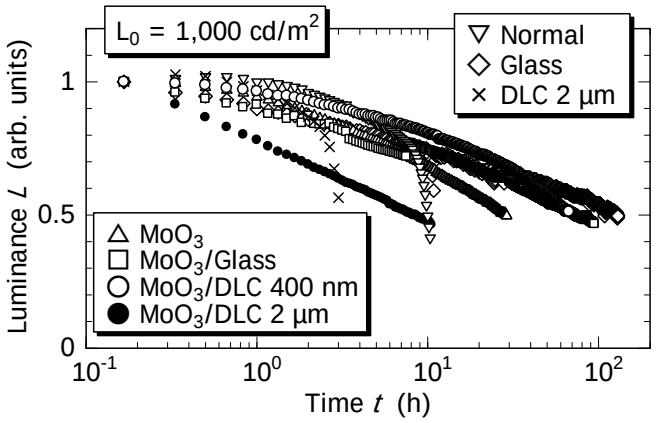


Fig. 2 Long-term durability of OLEDs.

Table 1 Lifetime data (Initial luminance = 1,000 cd/m^2)

Device structures	Current density (mA/cm^2@1,000 cd/m^2)	Half lifetime (h)
Normal	28.3	10
Glass cap	29.6	128
DLC 2 μm	29.9	3
MoO_3	36.7	29
MoO_3/ Glass	39.2	80
MoO_3/ DLC 400 nm	38.9	70
MoO_3/ DLC 2 μm	40.8	9

The *L-J* characteristics were almost identical, and high luminance over 10,000 cd/m^2 was obtained for all devices. In addition, *η-J* characteristics were also almost identical without the glass devices. All devices show the highest EL efficiency of 2.3 lm/W. However, only glass device shows the highest EL efficiency of 1.8 lm/W. This device degradation was due to the leakage current during sealing process. On the other hand, *J-V* characteristics with DLC without MoO_3 layer were shifted toward higher voltage. Figure 2 shows the result of durability tests with varied passivation structure under a constant-current mode, at an initial luminance of 1,000 cd/m^2. In addition, the data of lifetime for all devices are shown in Table 1. The half luminance lifetime of bare, glass cap, and DLC (2 μm) without MoO_3 devices were 10, 128 and 3 h, respectively. In the device with DLC, the half luminance life was extremely short in comparison with other devices. This result shows that plasma damage during DLC deposition process was serious problem. On the other hand, the half luminance lifetime of bare, glass cap, DLC (400 nm), and DLC (2 μm) with MoO_3 devices were 29, 80, 70 and 9 h, respectively. The half luminance lifetime was extended by insertion of MoO_3.

4. Conclusions

We had investigated passivation effect of the DLC films for OLEDs. The DLC film with double-layered MoO_3 plasma protection layer was effective for improvement of lifetime. The DLC film will be expected as passivation layer of flexible devices, such as the OLED and another kinds of organic devices.

Acknowledgment

This work was supported by regional innovation of R&D projects, overseen by the Ministry of Economy, Trade and Industry (METI), Japan

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