Lifetime improvement of Organic Light Emitting Diode by Using LiF Thin Film and UV Glue Encapsulation

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Abstract

Before the ultra-violet glue encapsulation, the research evaporated LiF thin film on device surface to be the extra packaging layer for improving the lifetime of organic light-emitting diode. The formula of UV glue was specially developed. We found 100 nm LiF is the optimum thickness. The best lifetime obtained by using LiF and special UV glue is 2.4 times longer than those by commercial UV glue.

1. Introduction

Organic light-emitting diode (OLED) is a flat panel display with great potential for developing; however, the organic materials of its devices are very sensitive to oxygen and moisture. Hence, OLED needs be treated with packaging after being completely made.

Cost-down is the essential factor of manufacturing processes for meeting the requirement of the industry. Lifetime is the critical issue on the way of developing OLED; long lifetime device produced from low cost processes will always be a promise of the industry. Therefore, the study wishes to directly apply cured ult ra-violet (UV) glue onto OLED devices to reach the target of low-cost and simplified packaging.

2. Experimental

The indium-tin-oxide (ITO) glass substrate applied in the research has 5Ω/□ sheet resistance. We ultrasonically cleaned the patterned ITO substrate in proper order with acetone, methanol and DI water for 5 minutes; then, we dried it via blowing nitrogen and put it into oven for roasting. Then, put the substrate into O_2 Plasma to be treated for 90 seconds. After that, the substrate can be put into organic vacuum chamber for evaporating, in proper order, with organic layers, i.e. NPB (hole transport layer), Alq3 (emitting layer and electron transport layer), electron injection layer LiF and cathode Al. Finally, before taking the sample out of the vacuum chamber, a layer of LiF thin film was evaporated onto the surface of the sample to be one of the packaging layers. The basic structure of the device is Glass/ ITO/NPB/Alq3/LiF/Al/LiF (as shown in Fig.1(a)).

Make use of the structure to study how the device lifetime is affected by various LiF thicknesses. The other sample was spin-coating with UV glue developed by Material Research Laboratories of Industrial Technology Research Institute (ITRI), first stage 1500 rpm for 20 seconds, second stage 3500 rpm for 30 seconds onto the surface of LiF thin film (as shown in Fig. 1 (b)). KEITHLEY 2400 and Spectra Scan PR650 were applied to measure the light-current-voltage (L-I-V) character curve and luminescence spectrum of the completely manufactured devices. Moreover, the lifetime measuring system specialized for OLED was applied to measure lifetime of the device; measuring condition is at 5mA constant current.

3. Results and discussion

In the study, we found that the thickness of LiF considerably affect lifetime of the OLED device. First, we studied how single LiF thin film packaging affected lifetime of the device. From Fig. 2, we found the best half lifetime of the device with 120nm thickness LiF thin film is 48 hours, but half lifetime of the device without any packaging is only 4 hours. The LiF thin film packaging increased lifetime of the device for 12 times. Moreover, evaporating speed of LiF and film thickness are the key factors for affecting the result of OLED packaging, and will affect the LiF quality and level-and-smooth condition of the surface of LiF. Furthermore, they will affect the result after UV glue packaging. After several experiments, we determined that the following conclusions: Too fast evaporating speed of LiF thin film on the device surface will decrease the packaging thin film quality and cause the level-and-smooth condition of the thin film surface to become worse. LiF packaging thin film is easy to peel off because of the stress exerted between LiF thin film and UV glue, caused by the process of spin-coating UV glue packaging onto LiF thin film. UV glue will directly permeate through LiF layer and harm OLED device. Hence, during the process of experiment, we controlled LiF evaporating rate at 0.5nm/s to assure the thin film quality; then, UV glue was spin-coated onto LiF thin film surface as packaging at the condition of first stage 1500 rpm for 20 seconds and second stage 3500 rpm for 30 seconds. After that, we applied UV light on UV glue for 6 seconds to cure it. At last, we measured the lifetime of the device. From Fig 3, we found that 100nm thickness of LiF packaging thin film plus one layer of UV glue could gain the best half lifetime of 72 hours; comparing with un-packaging OLED device, the half lifetime will be increased about 18 times. However, the lifetime of device with LiF thin film plus UV glue encapsulation will be shortened because of the factor of easily peel-off LiF thin film. Hence, the best packaging condition is 100nm thickness LiF thin film plus UV glue encapsulation.

Then, compare the effect on lifetime of OLED device encapsulated with UV glue made by our group with those with commercialized UV glue. From Fig 4, we found that commercialized UV glue plus 100nm LiF thin film encapsulation would have only 30-hour half lifetime, but UV glue made by our group increased half lifetime up to 72 hours. It is 2.4 times of that of the commercialized UV glue. The key factors are different cure time of UV light applied on the UV glue and different glue materials. Normally, commercialized UV glue needs 1.5 minutes curing time, but ours only needs 6 seconds. Since UV light directly incident to OLED device will considerably harm the organic materials in OLED device, the curing time would be the key factor of affecting the lifetime of the device. The molecular structures of the UV glue made in this experiment are shown in Fig 5.

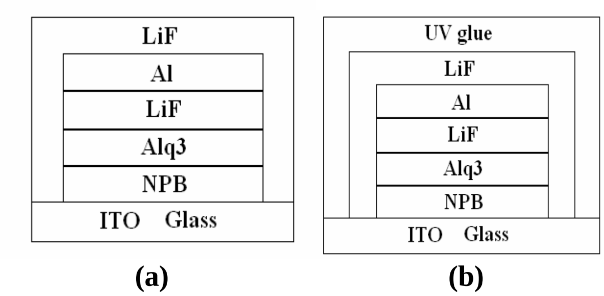


Fig. 1. Device structures (a) only LiF packaging (b) applied LiF as protection layer, then spin-coated UV glue as second encapsulation layer.

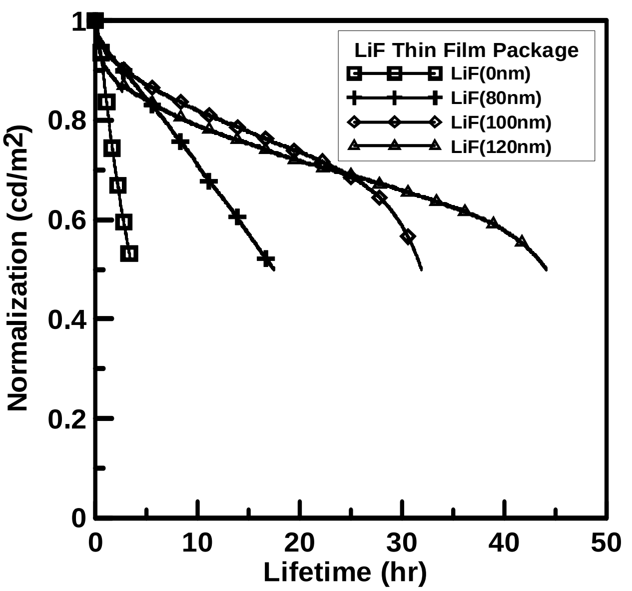


Fig. 2. Comparison of different LiF thicknesses packaging affect the lifetime of OLED device

4. Summary

In this study, the optimum LiF thickness for encapsulation of OLED was obtained. We found that generally commercialized UV glue plus 100nm LiF thin film encapsulation would have only 30-hour half lifetime, but UV glue made by our group increased the half lifetime up to 72 hours. It is 2.4 times of that of the commercialized UV glue.

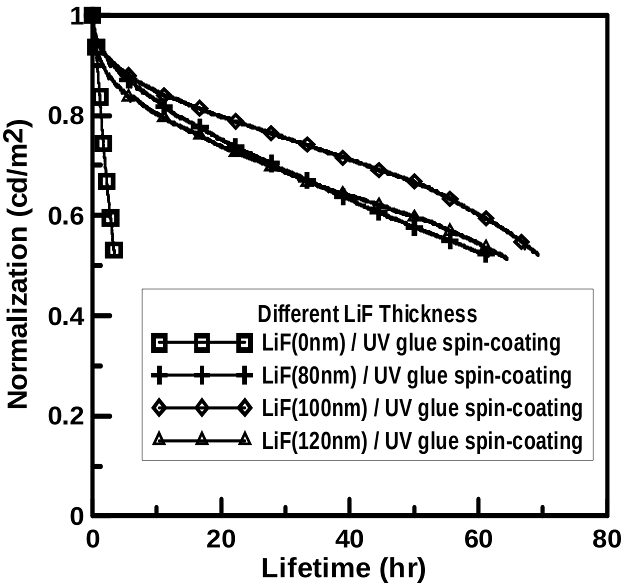


Fig. 3. Comparison of how OLED lifetime being affected by various thicknesses of LiF thin film encapsulation plus UV glue developed in this experiment.

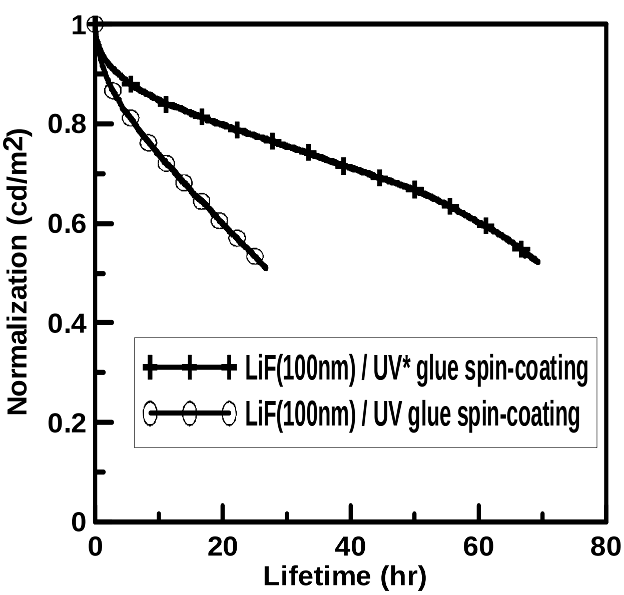
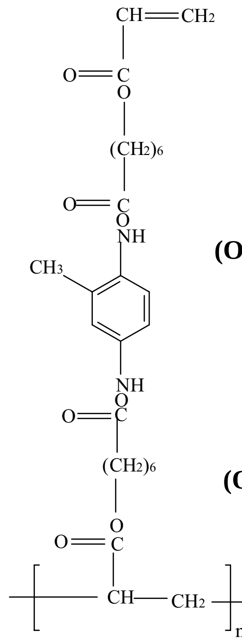
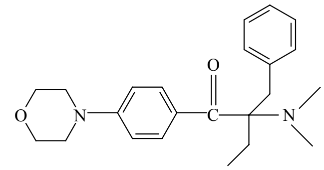
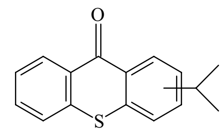


Fig. 4. At the condition of 100nm thickness of LiF, different glue materials for encapsulation are used for comparison of OLED lifetime. UV*: UV glue made by our group, UV: generally commercialized UV glue





Irgacure 369 (1 wt%)
(Obtained from Ciba chemical Co.)



Irgacure ITX (0.5 wt%)
(Obtained from Ciba chemical Co.)

PU / Acrylics resin (98.5 wt%)
Viscosity = 18500 cps (at 25℃)
(Obtained from UCB chemical Co.)

Fig. 5. The structure of the UV glue developed by ITRI is composed of high density epoxy and special photo-initiator. The UV glue mentioned above is helpful to blocking moisture from harming device and shortening UV curing time.

5. References

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