Lithium Quinolate Complex as an Electron Injection Layer in Organic Light Emitting Devices

Kyung Hoon Choi [a], Young Kwan Kim [a], Byung Chung Sohn [a], Yun Kyung Ha [b], Sung Min Kim [c], Bong Ok Kim [c], Mi Young Kwak [c] and Young Jun Cho [a]
[a]Dept. of Chemical Eng., Hong-Ik Univ., Sangsu-Dong, Mapo-Gu, Seoul 121-791, Korea
[b]Dept. of Science, Hong-Ik Univ., Sangsu-Dong, Mapo-Gu, Seoul 121-791, Korea
[c]Research Institute of Science and Technology, Hong-Ik Univ., Sangsu-Dong
Mapo-Gu, Seoul 121-791, Korea
Phone : +82-2-3142-3750 , E-mail : hoonee75@orgio.net

Abstract

We investigated the effect of lithium 8-hydroxyquinolinolatolithium (Liq) as an electron injection layer on the performance of organic light emitting devices (OLEDs) and optimized the device efficiency by varying thickness of Liq layer. The device with 1nm Liq layer showed significant enhancement of the device performance and device lifetime. We also compared Znq_2 *and LiBBOX with Liq as an electron injection layer.*

1. Introduction

Since the discovery of efficient organic light emitting devices (OLEDs), there has been considerable interest in developing OLEDs with high brightness, high efficiency, and long lifetime for applications [1][2]. To achieve the best device performance, it is desirable to use cathode metals having a low work function for electron injection into organic layer [3]. However, OLEDs with a low work function metal catodes such as Li, Ca and Mg exhibit poor device reliability due to the reactive nature of these metals.

The use of high work function metals, such as Al, though less reactive, shows low efficiency due to less efficient electron injection [4]. Recently, it was reported that the introduction of a thin layer of an ionic insulator such as LiF, CsF, MgO, Al_2O_3 between Al and organic layer, significantly enhances electron injection and prolongs the device lifetime [5][6].

In this study, we present the effect of lithium complex as an electron injection layer on the performance of OLEDs and optimization of the device efficiency by varying the thickness of Liq layer [7].

2. Experimental

OLEDs were fabricated by high vaccum (~10^{-6}torr) thermal deposition of organic materials onto the surface of an indium tin oxide (ITO, 30Ω/□, 80nm) coated glass substrate chemically cleaned using acetone, methanol, distillated water and isopropyl alcohol. The organic materials were deposited in the following sequence: 40nm of α-napthylphenylbiphenyl (NPB) was used as a hole transporting layer, followed by a 50nm thick tris-(8-hydroxyquinoline) aluminum(Alq_3) used as an electron transporting and emitting layer. Finally a 0.5, 1, 2, 5, 10nm thick electron injection material, was deposited, as shown in Fig. 1. The chemical structures of these materials are shown in Fig. 2. Typical organic deposition rate was 0.2nm/sec. Finally the 150nm of Al was deposited as a cathode. An active area of the OLED was typically 0.09cm^2.

The electrical and the optical properties of device were measured under ambient conditions in air without any encapsulation against degradation. Current - voltage – light intensity of the OLEDs were measured with programmable electrometer (keithy 617), source measure unit (keithy 236) and Roper Scientific photodiode (SI440-UV). To study the stability of OLED, we measured the operational lifetime.

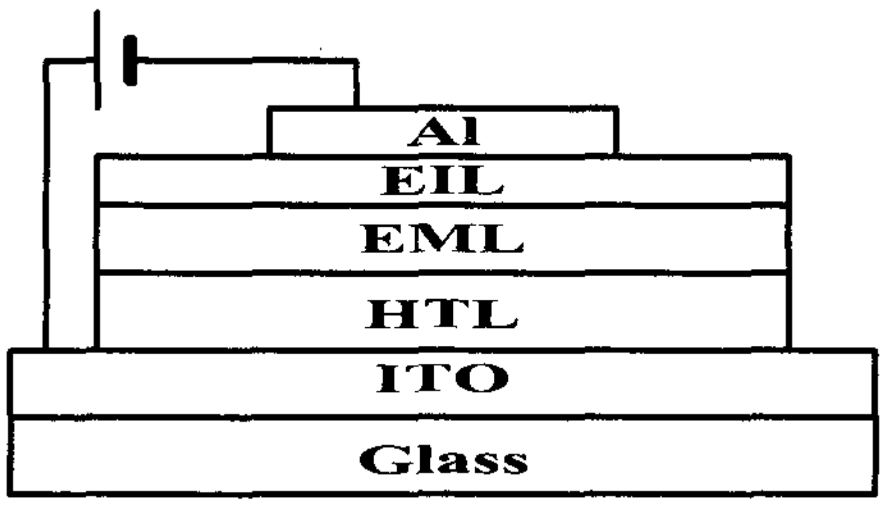

Fig. 1. Structure of the OLED

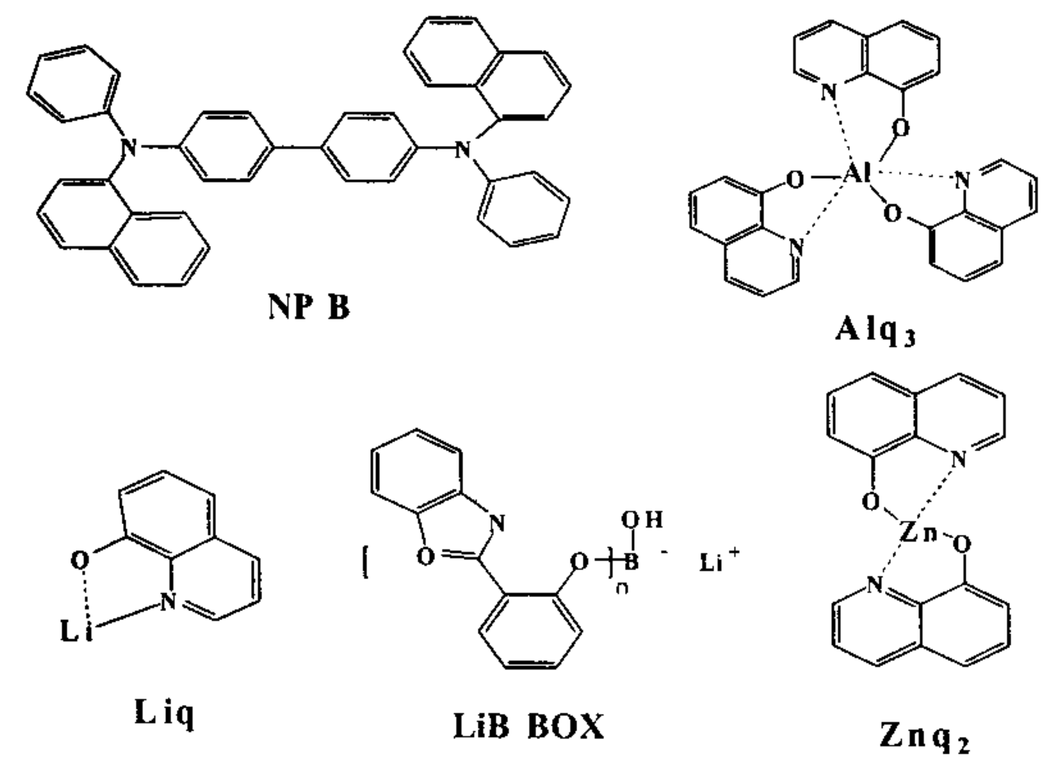

Fig. 2. Molecular structure of the materials used

3. Results and discussion

Fig. 3. 4 show the OLED characteristics for various thickness of Liq. OLEDs with Liq layer show significant increment of the current density and the light intensity compared with one without Liq layer. The enhancement of current density and light intensity is due to improved electron injection thru Liq layer from Al cathode since electron is the minor charge carrier. For OLED with various thickness of Liq, only very thin Liq layer enhances the device characteristics significantly as like LiF.

Fig. 5. 6 show the OLED characteristics for various thickness of LiBBOX. In case of LiBBOX, the performance of OLEDs is almost identical to that of the devices with Liq.

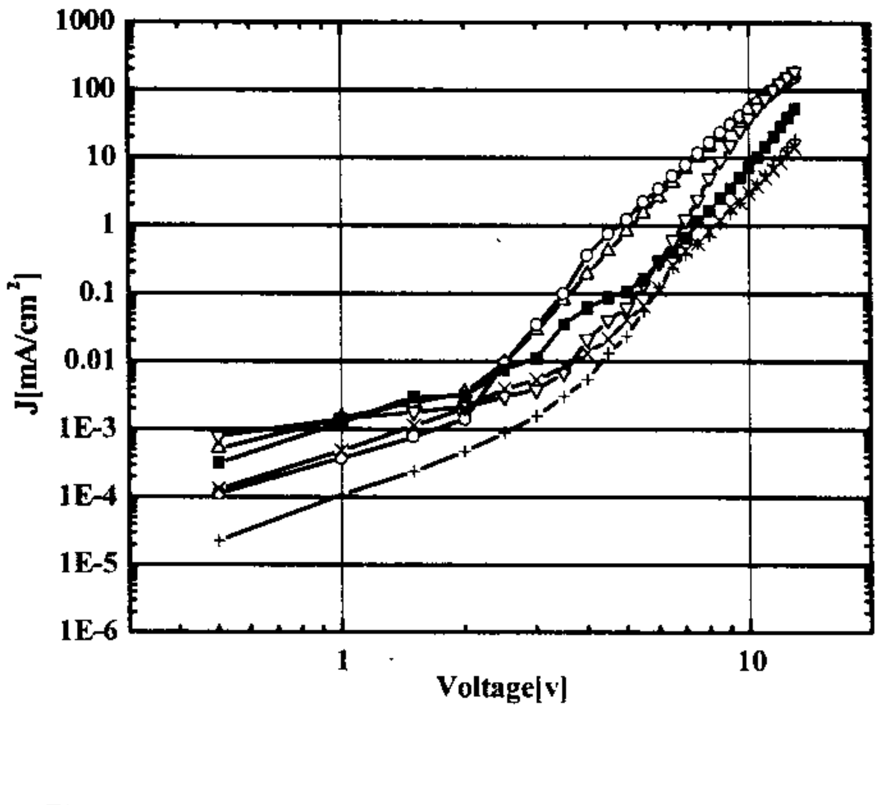

Fig. 3. Current density vs driving voltage for the various thickness of Liq layer : (■) 0 nm, (△) 0.5nm, (○),1nm, (▽) 2nm, (×) 5nm, (+) 10nm

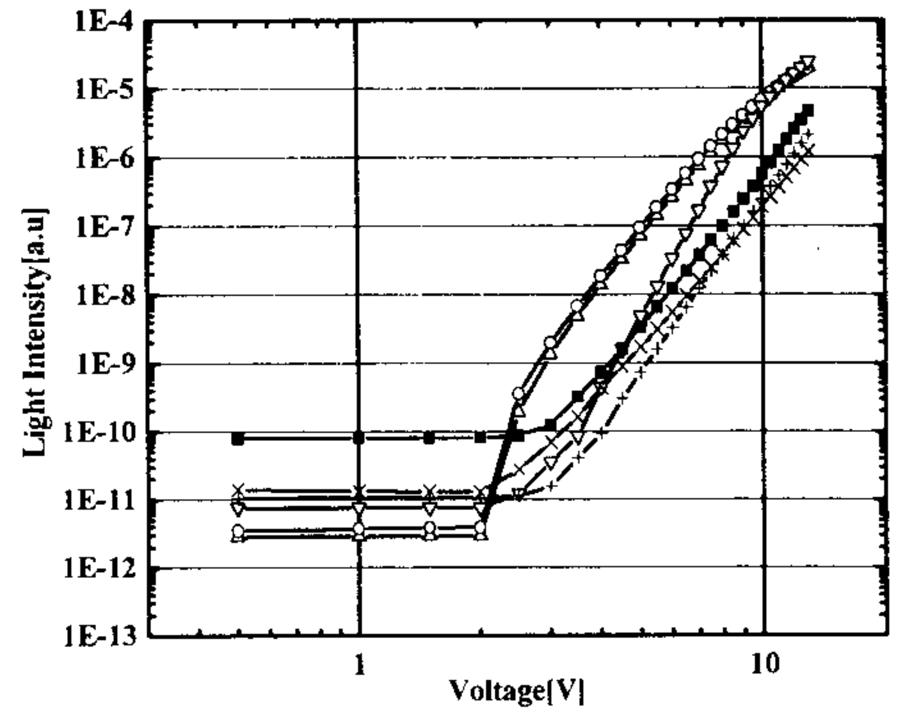

Fig. 4. Light intensity vs driving voltage for the various thickness of Liq layer : (■) 0 nm, (△) 0.5nm, (○) 1nm, (▽) 2nm, (×) 5nm, (+) 10nm

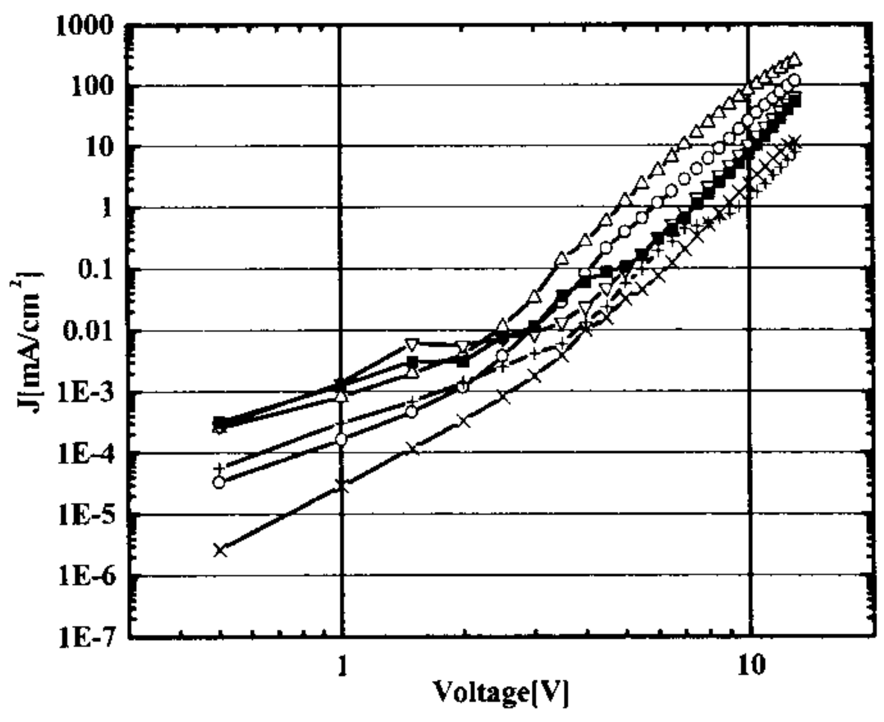

Fig. 5. Current density vs driving voltage for the various thickness of LiBBOX layer : (■) 0 nm, (△) 0.5nm, (○) 1nm, (▽) 2nm, (×) 5nm, (+) 10nm

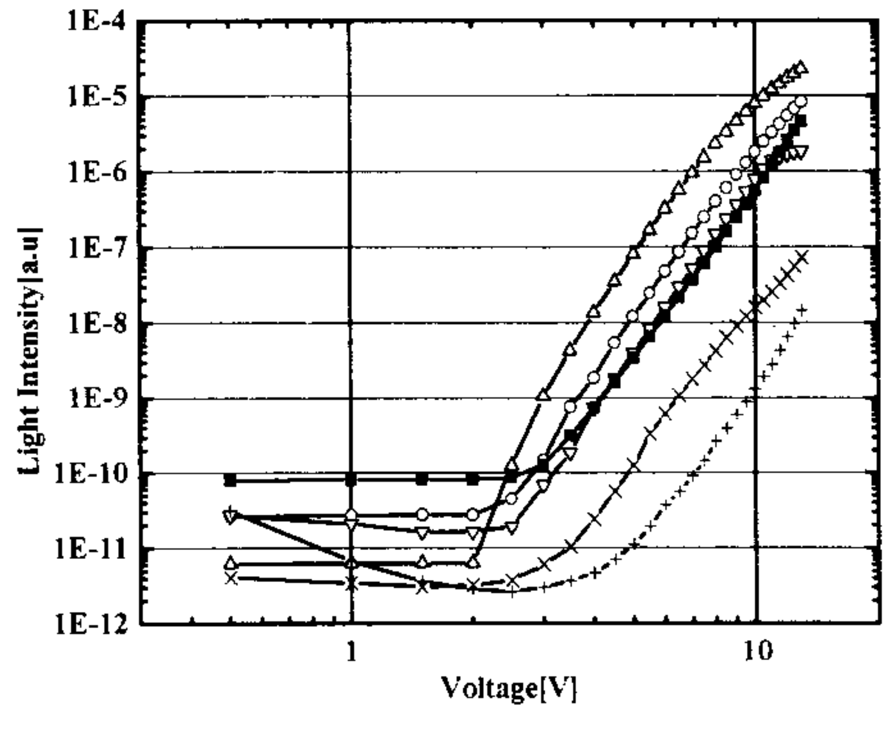

Fig. 6. Light intensity vs driving voltage for the

various thickness of LiBBOX layer : (■) 0 nm, (△) 0.5nm, (○) 1nm, (▽) 2nm, (×) 5nm, (+) 10nm

Fig. 7. 8 show the performance of Znq_2 as an electron injection layer. For Znq_2, the effect of EIL thickness is less significant, compared to Li complex. It is because Znq_2 has higher carrier mobility than Li complex.

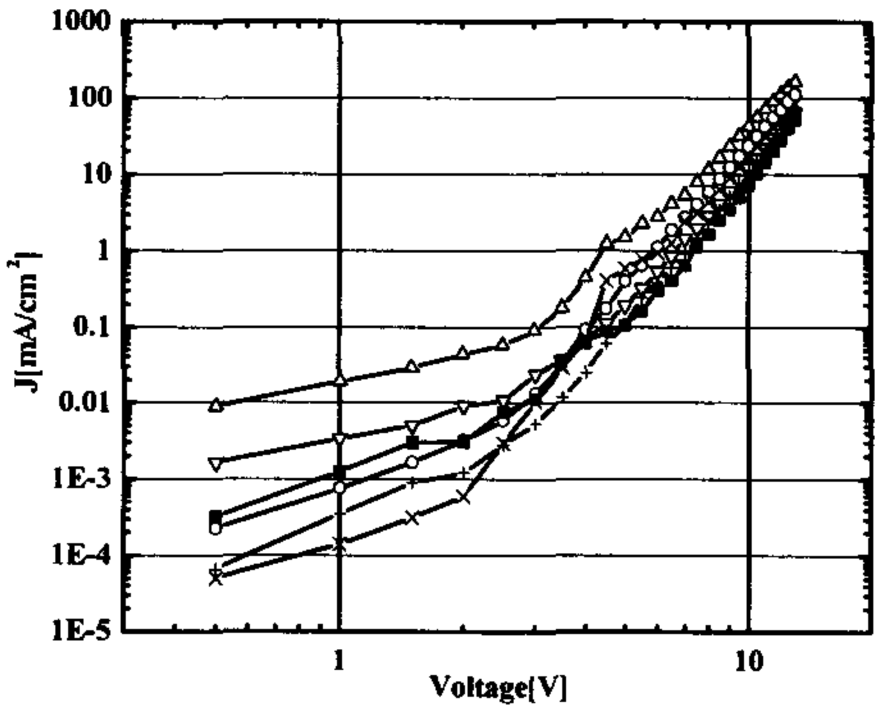

Fig. 7. Current density vs driving voltage for the various thickness of Znq_2 layer : (■) 0 nm, (△) 0.5nm, (○) 1nm, (▽) 2nm, (×) 5nm, (+) 10nm

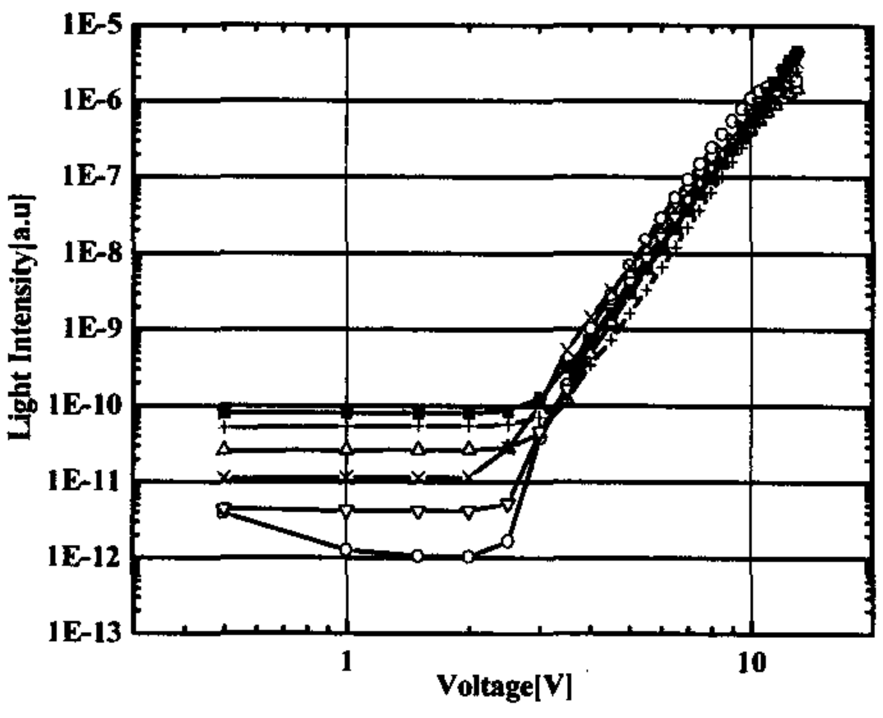

Fig. 8. Light intensity vs driving voltage for the various thickness of Znq_2 layer : (■) 0 nm, (△) 0.5nm, (○) 1nm, (▽) 2nm, (×) 5nm, (+) 10nm

Fig. 9. 10 show the OLED characteristics of having Al, Al/EIL as a cathode. The OLEDs with optimal Liq or LiBBOX layer show significant increment of the current density and the light intensity compared to one without EIL. The OLED with Liq has lower turn on voltage (2.3V) than OLED with only Al cathode (2.7V). Only lithium (Li) metal complexes increase the light intensity this can be interpreted as to different factors for the effective electron injection material-insulating nature and containing low work function metal.

We assume the role of Liq is similar to that of LiF- helps to form Alq_3 anion, resulting in enhancement of electron injection from cathode to organic layer.

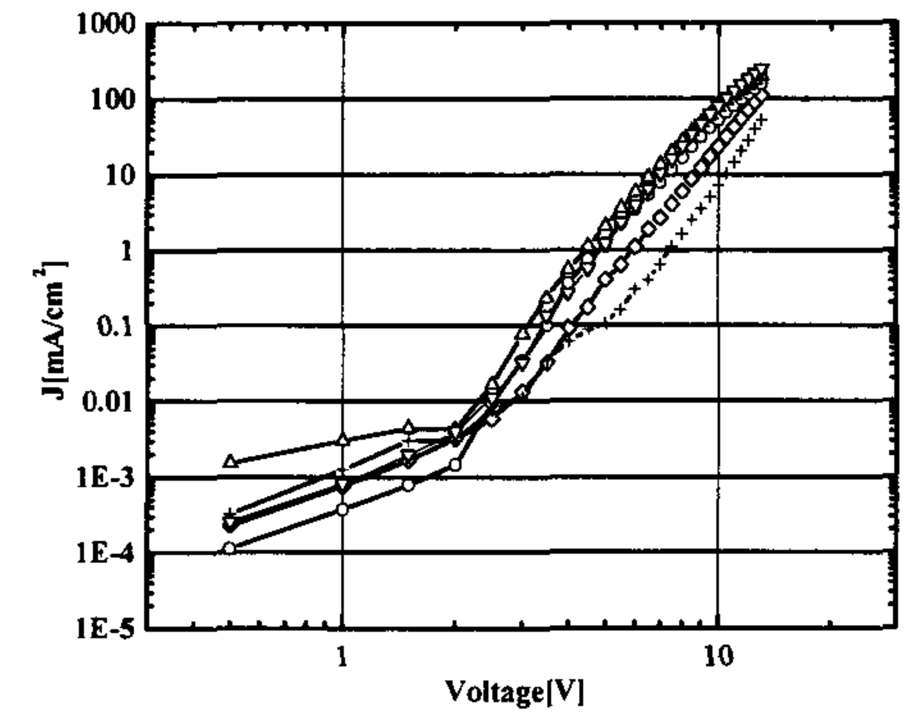

Fig. 9. Current density vs driving voltage of device NPB(40nm)/ Alq_3(50nm)/ EIL / Al (150nm) : (○) Liq 1nm, (▽) LiBBOX 0.5nm , (△) LiF 2nm, (◇) Znq_2 1nm, (+) No EIL

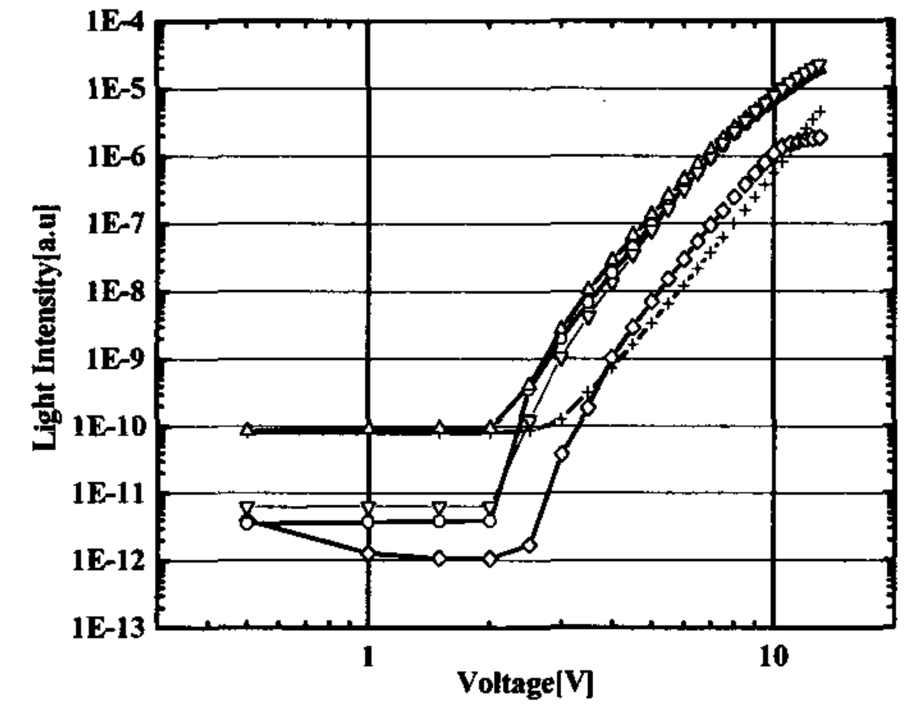

Fig. 10. Light intensity vs driving voltage of device NPB(40nm)/ Alq_3(50nm)/ EIL / Al (150nm) : (○) Liq 1nm, (▽) LiBBOX 0.5nm , (△) LiF 2nm, (◇) Znq_2 1nm, (+) No EIL

Fig. 11. shows the device lifetime calibrated at 100cd/m^2 when operating at constant voltage. The

device with 1 nm Liq shows the longest device lifetime, which is much better than the device with LiF or LiBBOX layer. We think this is due to the better durability of Liq to ambient environment compared with LiF and LiBBOX.

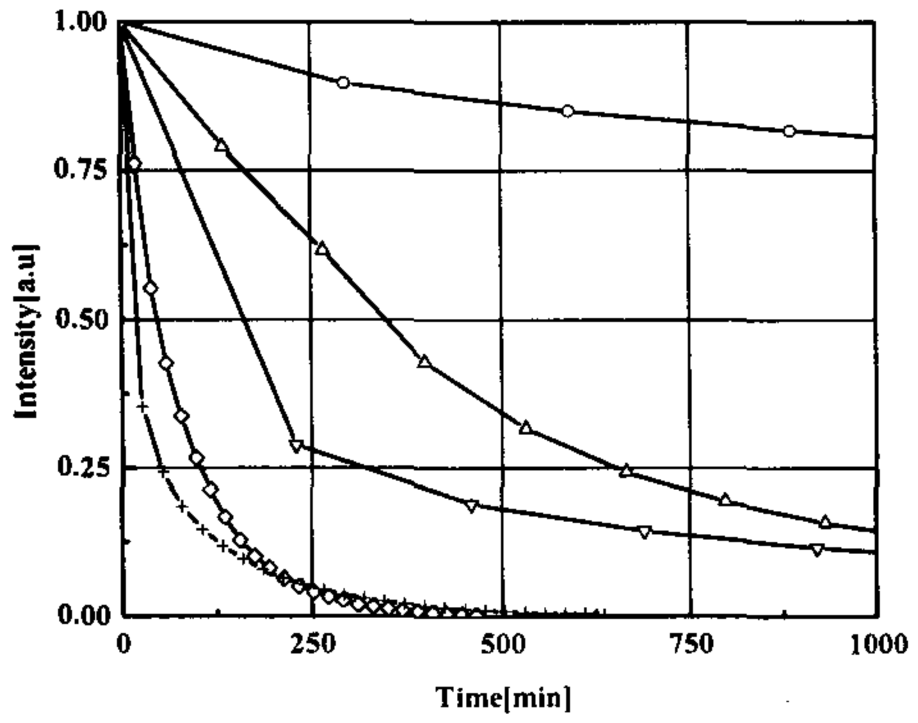

Fig. 11. Light intensity vs device operating Lifetime : NPB(40nm)/ Alq_3(50nm)/ EIL / Al (150nm) : (O) Liq 1nm, (∇) LiBBOX 0.5nm , (△) LiF 2nm, (◇) Znq_2 1nm, (+) No EIL

4. Conclusion

Liq layer between cathode and electron transporting layer acts as a very effective electron injection layer and makes much more stable device than the one with LiF. Furthermore, the easily controllable thermal deposition nature of Liq makes much better choice for electron injection materials than LiF.

5. References

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