Lithium Complex as a New Electron Injection Layer in Organic Light Emitting Devices

Min Woo Lee, Jae Goo Lee, Sung Min Kim[1], Bong Ok Kim[1], Mi Young Kwak[1], Kyung Hoon Choi[2], Hyo Jung Lim[2], Sang Man Si[2], Byung Chun Sohn and Young Kwan Kim

Department of Chemical Engineering & Center for Organic Materials and Information Devices (COMID), Hongik Univ., 72-1, Sangsu-Dong, Mapo-Gu, Seoul 121-791, Korea

[1]**Research Institute for Science and Technology & Center for Organic Materials and information Devices (COMID), Hongik Univ., 72-1, Sangsu-Dong, Mapo-Gu, Seoul 121-791, Korea**

[2]**GRACEL Corp. 374-2, 284-25, Samyang Technotown, Seungsu2-Ga, Seungdong-Gu, Seoul, 133-833, Korea**

Phone : +82-2-3142-3750 , E-mail : lee45min@hanmail.net

Abstract

This study is the effect of lithium Lithium Complex as an electron injection layer(EIL) on the performance of organic light emitting devices (OLEDs) and optimized the device efficiency by varying thickness of EIL layer. The device with 2nm GDI 101 layer showed significant enhancement of the device performance and device lifetime. We also compared GDI 109 and GDI 117 with GDI 101 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 electron injection layer .

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 1, 2, 3nm thick electron injection material was deposited, as shown in Fig. 1. The chemical structures of these materials are shown in Fig. 2. Optical 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.

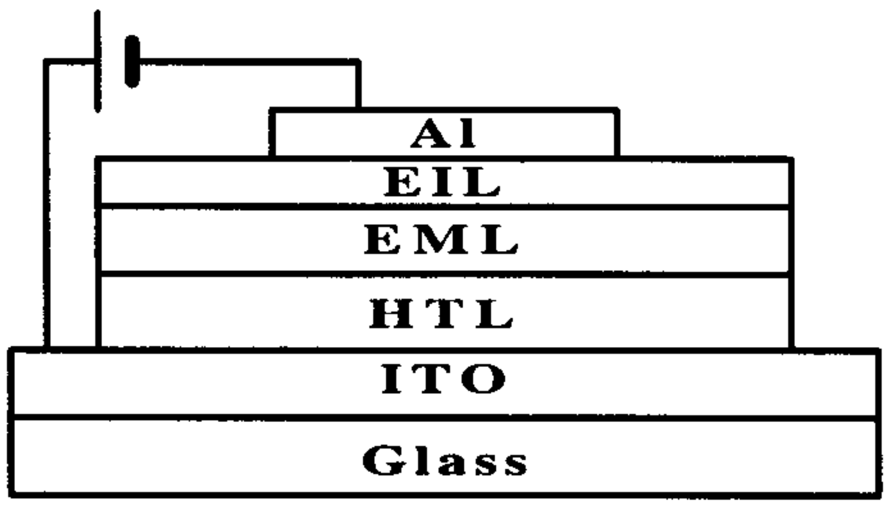
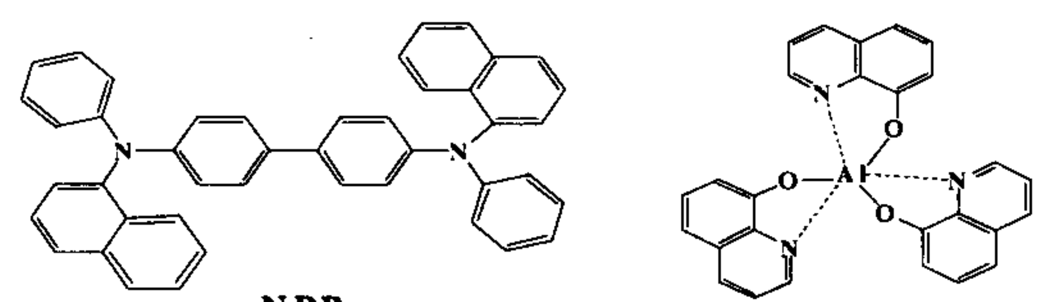


Fig. 1. Structure of the OLED



NPB Alq_3

Fig. 2. Molecular structure of the materials used

3. Results and discussion

Fig. 3. 4 show the OLED characteristics for various thickness of GDI 101. OLEDs with GDI 101 layer show significant increment of the current density and the light intensity compared with one without GDI 101 layer. The enhancement of current density and light intensity is due to improved electron injection thru GDI 101 layer from Al cathode since electron is the minor charge carrier. For OLED with various thickness of GDI 101, only very thin GDI 101 layer enhances the device characteristics significantly as like LiF.

Fig. 5. 6 show the OLED characteristics for various thickness of GDI 109. In case of GDI 109, the performance of OLEDs is almost identical to that of the devices with GDI 109.

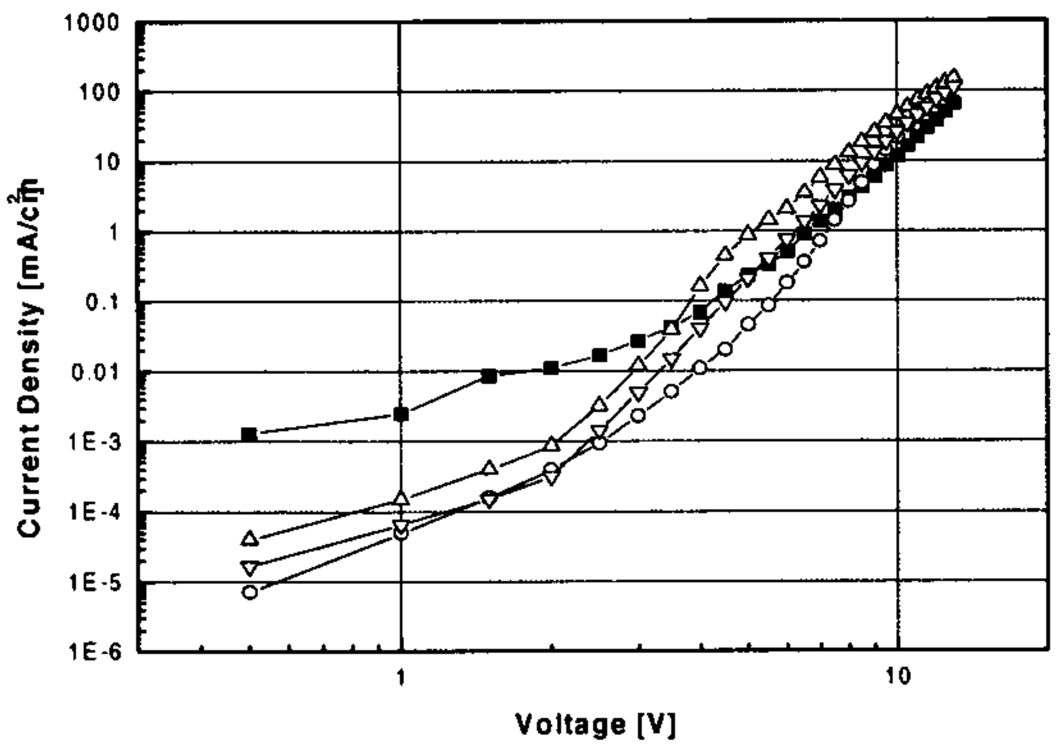


Fig. 3. Current density vs driving voltage for the various thickness of GDI 101 layer : (■) 0 nm, (O) 1nm, (Δ) 2nm, (∇) 3nm

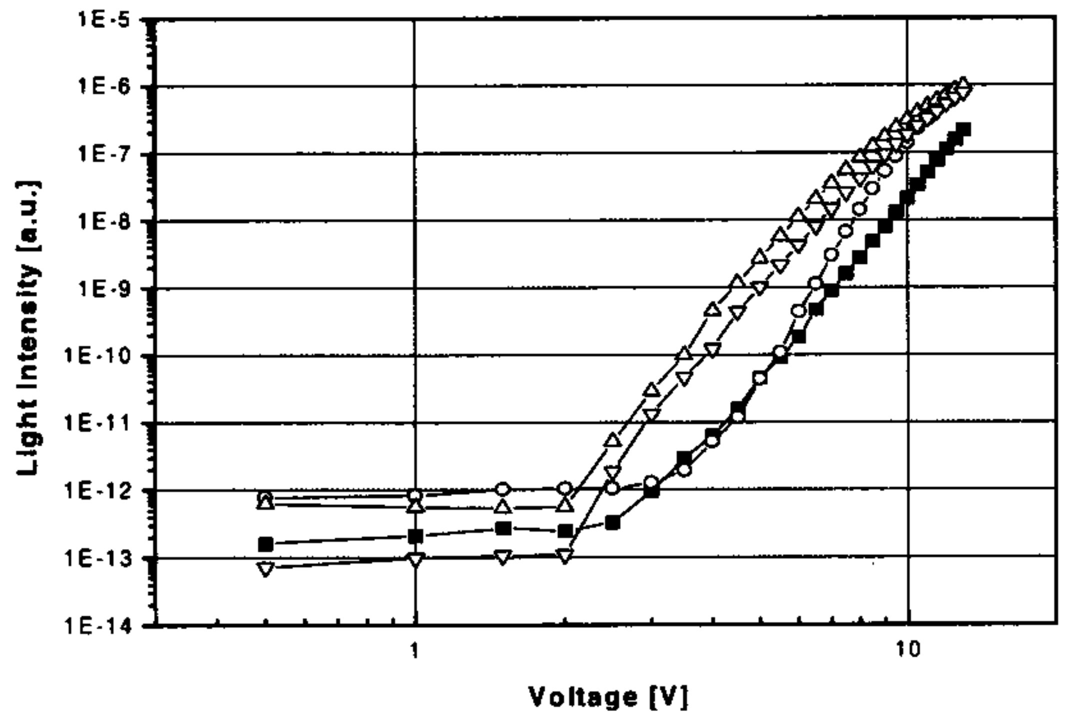


Fig. 4. Light intensity vs driving voltage for the various thickness of GDI 101 layer : (■) 0 nm, (O) 1nm, (Δ) 2nm, (∇) 3nm

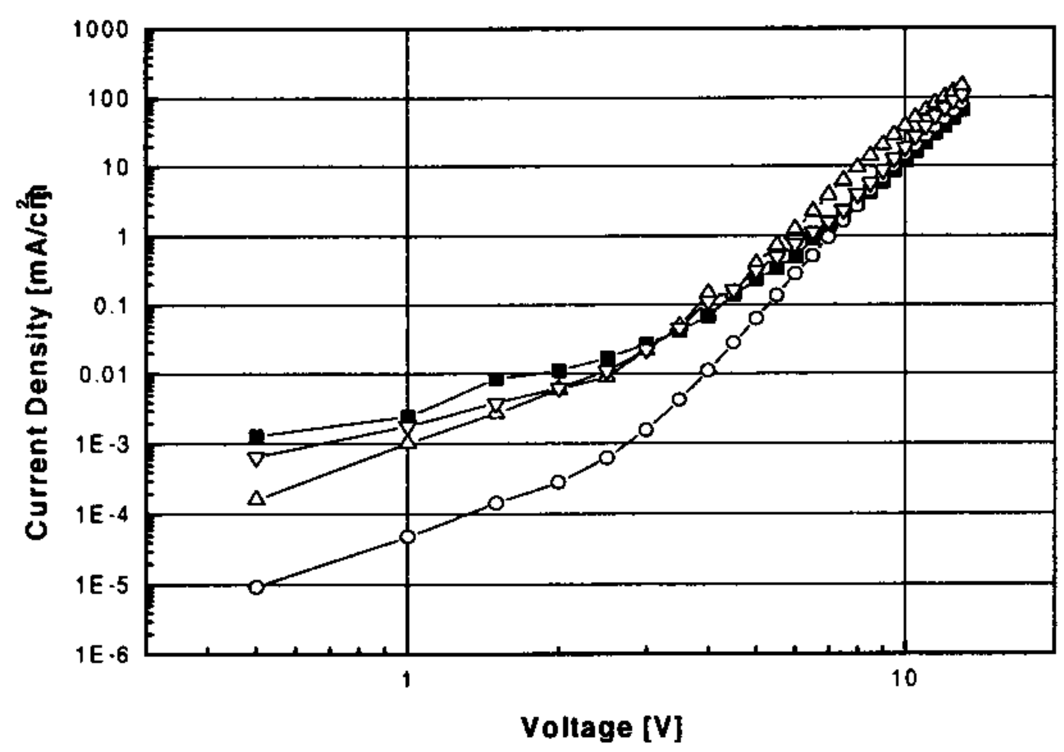


Fig. 5. Current density vs driving voltage for the various thickness of GDI 109 layer: (■) 0 nm, (O) 2nm, (Δ) 3nm, (∇) 4nm

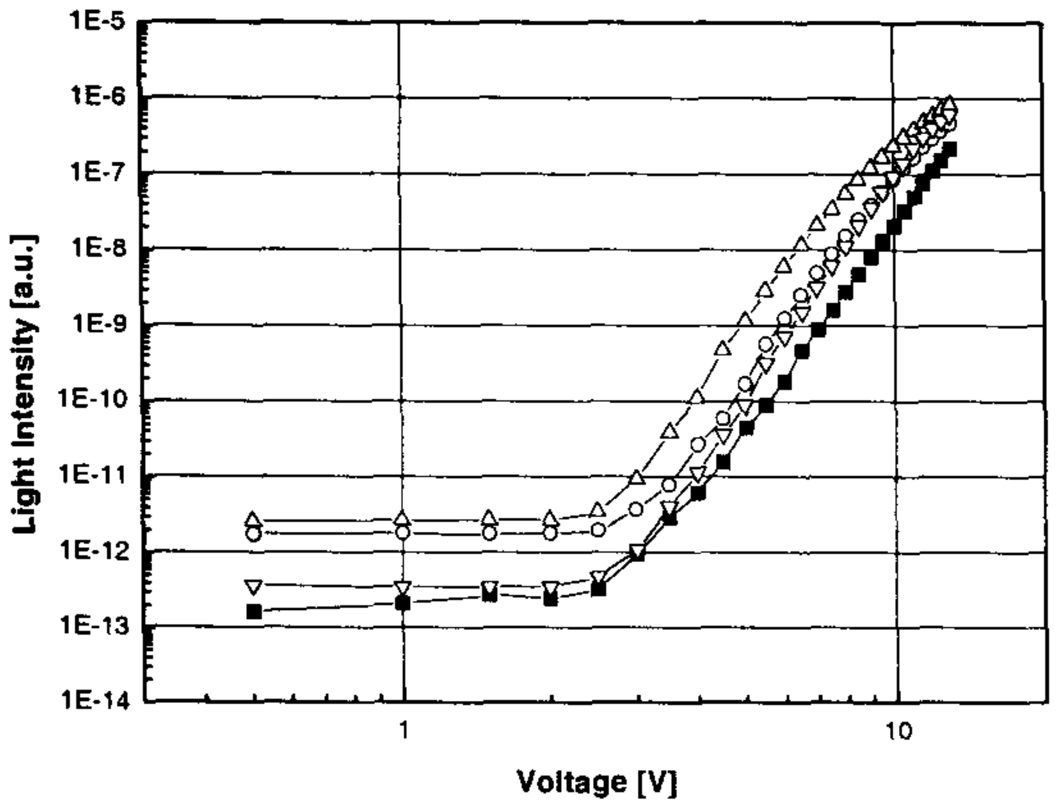


Fig. 6. Light intensity vs driving voltage for the various thickness of GDI 109 layer: (■) 0 nm, (O) 2nm, (△) 3nm, (∇) 4nm

Fig. 7. 8 show the performance of GDI 117 as an electron injection layer. For GDI 117, the effect of EIL thickness is less significant, compared to other Li complex.

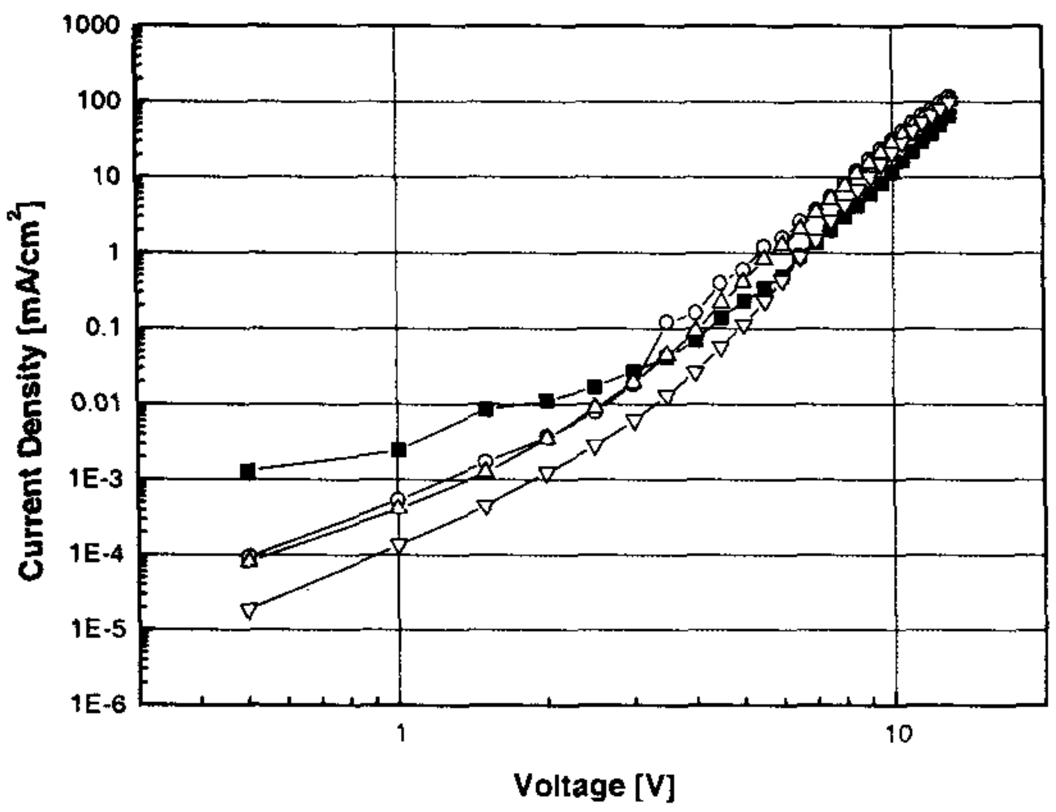


Fig. 7. Current density vs driving voltage for the various thickness of GDI 117 layer : (■) 0 nm, (O) 2nm, (△) 3nm, (∇) 4nm

Fig. 9. 10 show the OLED characteristics of having Al, Al/EIL as a cathode. The OLEDs with optimal GDI 101 and GDI 109 layer show significant increment of the current density and the light intensity compared to one without EIL. The OLED with GDI 101 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.

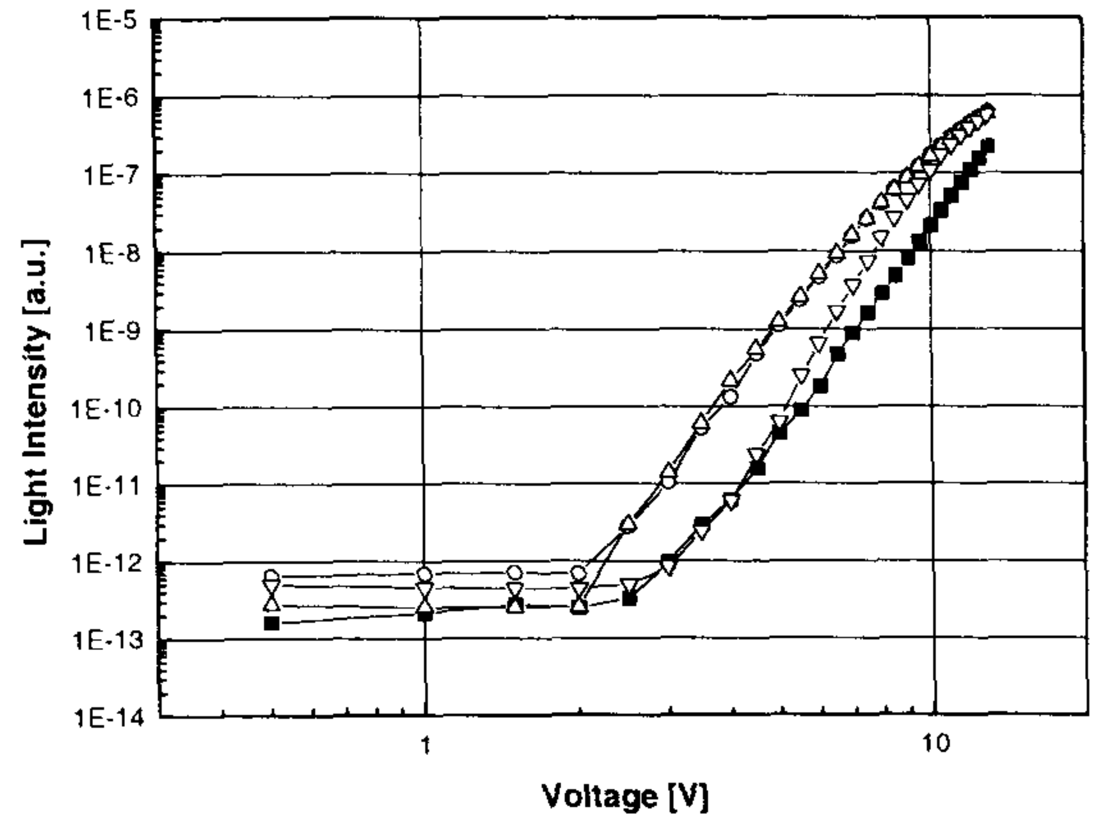


Fig. 8. Light intensity vs driving voltage for the various thickness of GDI 117 layer : (■) 0 nm, (O) 2nm, (△) 3nm, (∇) 4nm

We assume the role of GDI 101 and GDI 109 is similar to that of LiF helps to form Alq_3 anion, resulting in enhancement of electron injection from cathode to organic layer.

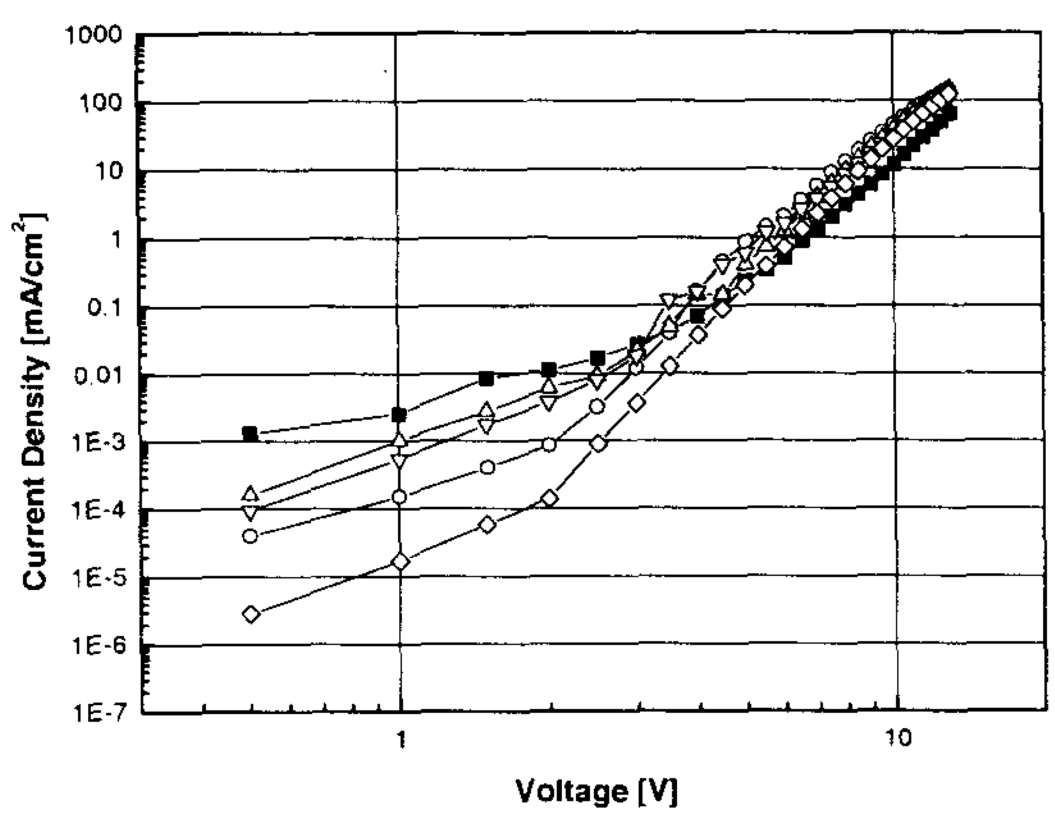


Fig. 9. Current density vs driving voltage of device NPB(40nm)/ Alq_3(50nm)/ EIL / Al (150nm) : (■) No EIL, (O) GDI 101 2nm, (△) GDI 109 3nm, (▽) GDI 117 3nm, (◇) LiF 2nm

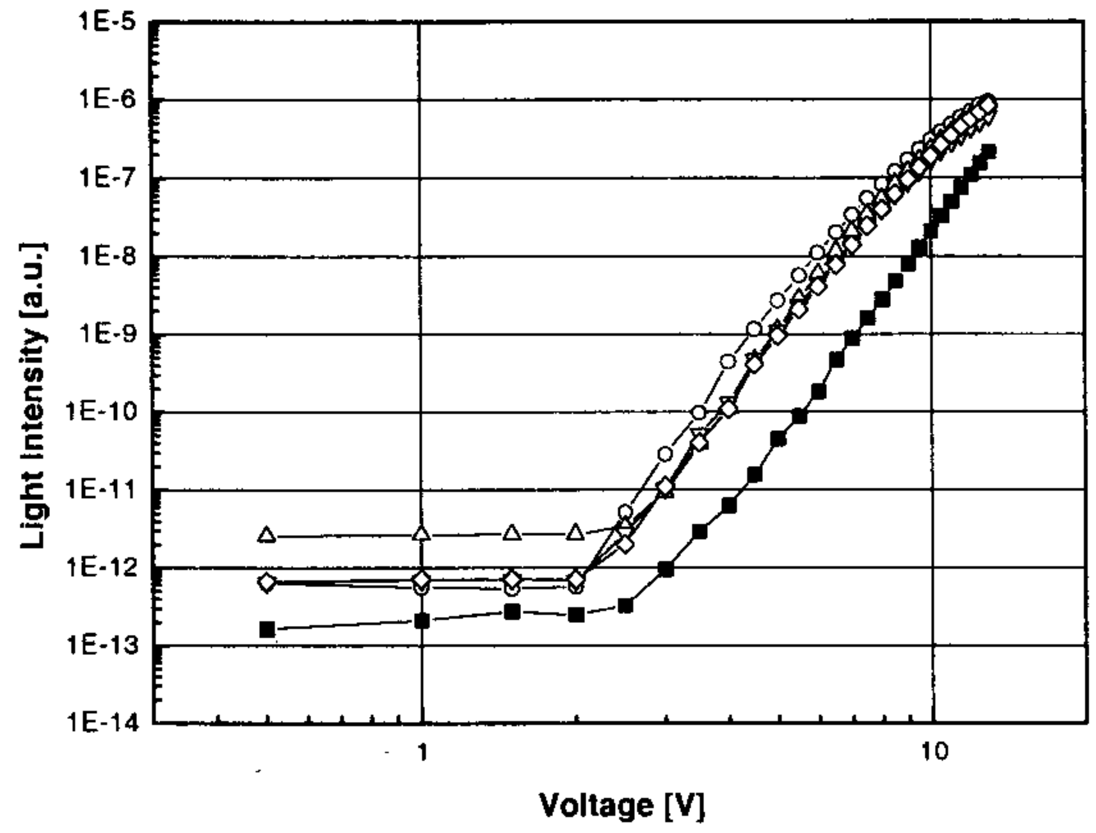


Fig. 10. Light intensity vs driving voltage of device NPB(40nm)/ Alq_3(50nm)/ EIL / Al (150nm) : (■) No EIL, (O) GDI 101 2nm, (△) GDI 109 3nm, (▽) GDI 117 3nm, (◇) LiF 2nm

Fig. 11. shows the device lifetime calibrated at 300cd/m^2 when operating at constant voltage. The device with 2 nm GDI 101 shows the longest device lifetime, which is much better than the device with GDI 109 or LiF layer. We think this is due to the better durability of GDI 101 to ambient environment compared with GDI 109 or LiF.

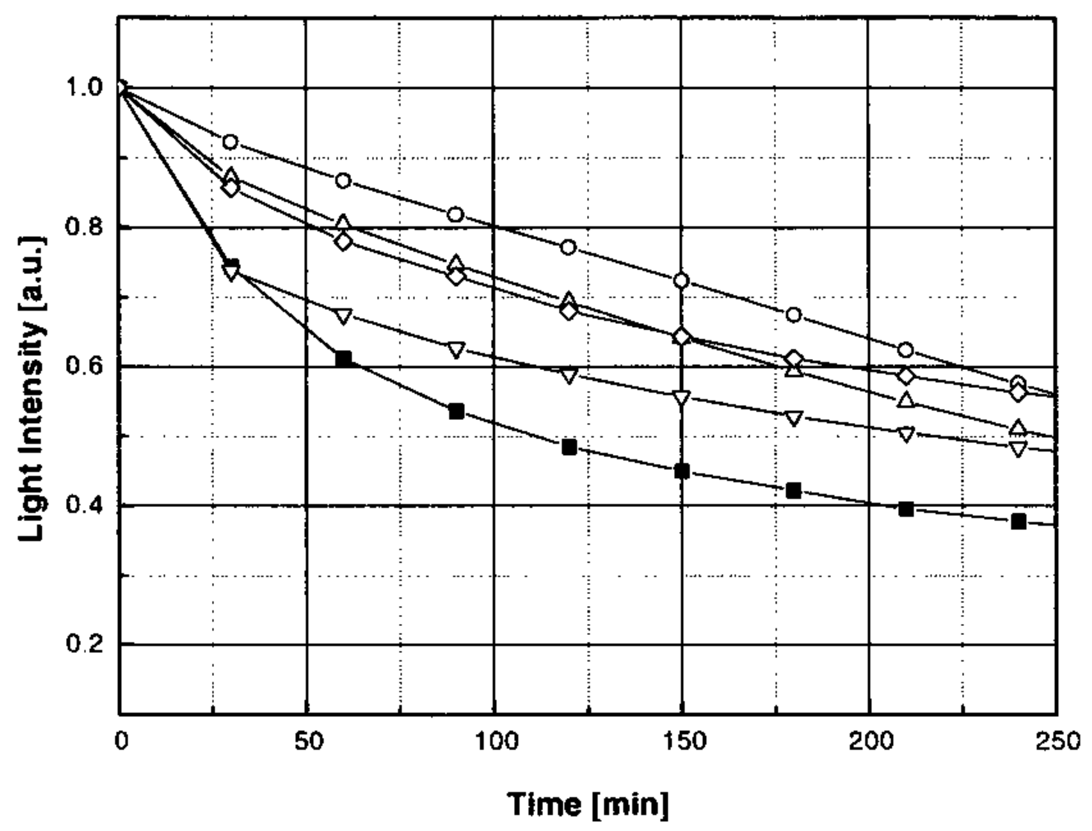


Fig. 11. Light intensity vs device operating Lifetime : NPB(40nm)/ Alq_3(50nm)/ EIL / Al (150nm) : (■) No EIL, (O) GDI 101 2nm, (△) GDI 109 3nm, (▽) GDI 117 3nm, (◇) LiF 2nm

4. Conclusion

GDI 101 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 GDI 101 makes much better choice for electron injection materials than LiF.

5. References

[1] T. Wakkimoto, R. Murayama, H. Nakada, K. Imai, G. Sato and M. Nomura, Polym. Reprints, Jpn., 40, 3600 (1991).

[2] C. W. Tang, SID International Symposium 1996, Digest of Technical Papers, San Diego (1996), 181

[3] C. W. Tang and S. A. VanSlkye, Appl. Phys. Lett., 51, 913, (1987)

[4] C. W.Tang, S. A. VanSlkye and C. H. Chen, J. Appl. Phys., 65, 3610, (1989)

[5] T. Mori, H. Fujikawa, S. Tokito and Y. Taga, Appl. Phys. Lett., 73, 2763, (1998)

[6] M. Matsumera, Y. Jinde, Appl. Phys. Lett., 73, 2872, (1998)