IJASRM International Journal of Advanced Scientific Research and Management, Volume 3 Issue 7, July 2018
www.ijasrm.com
ISSN 2455-6378

Electron Injection Layer's Comparative Research Study on Devices for OLEDs Efficiencies

Yadevendra Kamal[1], Vandana[2], Rita Rana[3] and Rajesh Mehra[4]

[1] Electronics & Communication Engineering Department,
National Institute of Technical Teachers Training & Research,
Chandigarh, India.

[2] Electronics & Communication Engineering Department,
Punjab University,
Chandigarh, India.

[3] Electronics & Communication Engineering Department,
National Institute of Technical Teachers Training & Research,
Chandigarh, India.

[4] Electronics & Communication Engineering Department,
National Institute of Technical Teachers Training & Research,
Chandigarh, India.

Abstract

The approach to the most advantageous electron emitting layer has attained by the comparative simulation analysis. The analysis on the basis of electrical and optical parameters have been done on the various electron injection layer (EIL) being used having different deposition sequences accounting to the most advantageous electron emitting layer in the simulated devices. Enhancement in the performance of organic light emitting diode has been studied with the better and efficient electron emitting layer. The results displays out to be having current efficiency of 16.131[cd/A], luminance efficiency of 1613.10 [lm/W] and the EQE Lambertian of 0.23 for lithium fluoride based electron injection layer OLED and having current efficiency of 16.128 [cd/A], luminance efficiency of 1612.12[lm/W] and the EQE Lambertian of 0.23 for lithium carbonate based electron injection layer OLED.

Keywords: *Organic light emitting diodes, electron injection, improved charge, Lithium Fluoride, Lithium Carbonate*

1. Introduction

Organic light emitting diode (OLEDs) are the current trend-settlers and promising applicants for large area, full colour, flexible, flat panel and stretchable form owing to stupendous properties. Wide viewing angles, low power consumptions, high contrast ratio, flexibility are the characteristics of the OLED's having potential application in flat panel displays and solid-state lightening providing next generation displays. Convoluted architecture adopted by the OLED device with various functional layers as such hole injection layer (HIL),hole transport layer(HTL), electron injection layer (EIL), electron transport layer(ETL), emission layer(EML) [1]. Figure 1. Displays out the schematic structured Oled device with layer individual layer structuring

Fig.1 schematic device structure of OLED

The functionality of the various layers effects the commercialization and the mass productivity of OLED's due to their inevitable fabricating cost. Highest occupied molecular orbital (HOMO) of HTL being injected by the holes from the anode under the influence of more positive electrical potential with respect to the cathode, also Lowest unoccupied molecular orbital (LUMO) of HTL being injected with electrons from the cathode [2]. Under the influence of electric field the movements of electron-holes takes place leading to the recombination and excitational energy release. Under this schema at least one of the electrode should be made semi-transparent to enable the perpendicular emission of the light from the substrate [3-5]. Resulting to the better efficient light then the LCD and LED. Implementation of various technologies and a stacking structure are the generally used for the improvement of the efficiency of OLED. Increase in the recombination rate lead by the stacking structure. Improved device performance achievement requires the optimized charge injection and transportation at the interferences. Characteristics such as current to voltage are limited to the injection causing intrinsic carrier concentration in the organic materials to be low [6]. The most direct and economical method for the enhancement of device efficiency has been considered as to increase the number of electrons or reduction in the number of holes leading to the balance carriers providing the high brightness, electroluminescence efficiency and low operational voltage [7-10]. The insertion of EIL between the EML and the cathode has been considered a most-often and simplest approach to gain the device stability and efficiency. The use of metal having appropriate work function matching to that of electron- and hole- transport level and/or electrode and the carrier transport layer having insertion of interlayer between them [5, 6, 8, 11].The Electron injection efficiency to the EIL has been found to be direct in relational to device efficiency and proportional to the characteristics of Oled such as luminance, current efficiency and EQE (External Quantum Efficiency) lambertian. In OLED's, the injection efficiency has dependency on the work function of the electrode and a highly critical parameter. The injection efficiency is severely limited by the potential barrier. In this paper the authors have simulated the OLED devices with the various EIL and had their comparative study to choose the most advantageous EIL [12-13].

2. Simulation Design.

To facilitate the high performance of the OLED number of devices with different electron injection layers which have been simulated are tris(8-hydroxyquinoline)aluminium(III) (Alq_3), Bis(8-hydroxy-2-methylquinoline)-(4-phenylphenoxy)aluminium (BAlq), Bathocuproine (BCP), 4,4'-Bis(N-carbazlyl)-1,1'-biphenyl (CBP), Lithium Carbonate (Li_2CO_3), Lithium Fluoride (LiF) [14-15,21-22]. The comparative study of the devices in variation of use of EIL's, leading to the change in performance of OLED's has been calibrated. The best efficiencies of the simulated OLED devices have been found out with the use of EIL's in the devices. Fig.1 displays out the structured Oled with layers of different material used of different thickness, being Bathophenanthroline (Bphen) be emitting layer and use of various EIL layers. The use of Molybdenum trioxide (MoO_3) and Tungsten trioxide (WO_3) has been used for the anode buffer layers [16]. N, N-Di (1-naphthyl)-N, N-diphenyl-(1, 1-biphenyl)-4, 4-diamine (NPB) has been used to serve the purpose of hole transport and hole injection layer. Indium tin oxide and silver (Ag) serving as the anode, cathode respectively [17-19]. The Fig.2 displays out the chemical structures of the employed materials (a) being denoting Alq3 (b) BAlq (c) BCP (d) CBP (e) Li2CO3 (f) LiF. The Simulation has been done in consideration of different layers in the following Oled devices as shown Layered OLED Structure in Fig 3. The Table 1 ensembles the structured devices with the names in the detail to their layered thickness in nm.

3. Result Analysis

The device A results are been as such current efficiency 13.021[cd/A], luminance efficiency 1302.09[lm/W] and the EQE Lambertian 0.16. To that of when BAlq was used in device B the current efficiency 13.227 [cd/A], luminance efficiency 1326.85 [lm/W] and the EQE Lambertian 0.17

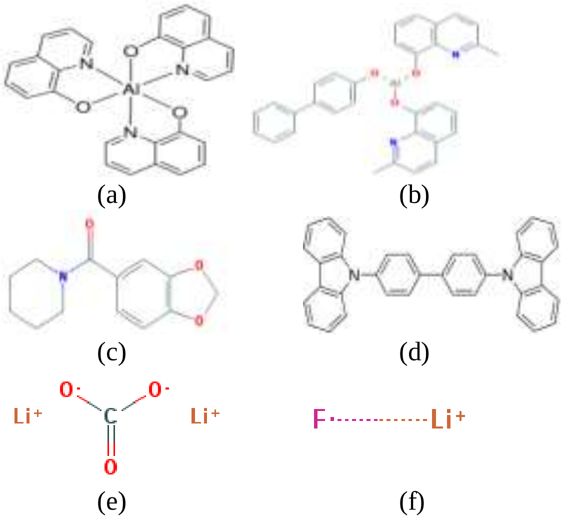

Fig.2 Chemical Structures of Materials

IJASRM
International Journal of Advanced Scientific Research and Management, Volume 3 Issue 7, July 2018
www.ijasrm.com
ISSN 2455-6378

Fig.3 Layered OLED Structure

Table 1: Structured Device with Names

Structure	Device name
ITO (100nm)/ MoO_3 (3nm)/ WO3 (3nm)/ NPB (60nm)/ Bphen (10nm)/ Alq3 (20nm)/ Ag (12nm).	A
ITO (100nm)/ MoO_3 (3nm)/ WO_3 (3nm)/ NPB (60nm)/ Bphen(10nm)/ BAlq (20nm)/ Ag (12nm)	B
ITO (100nm)/ MoO_3 (3nm)/ WO_3 (3nm)/ NPB (60nm)/ Bphen (10nm)/ BCP (20nm)/ Ag (12nm).	C
ITO (100nm)/ MoO_3 (3nm)/ WO_3 (3nm)/ NPB (60nm)/ Bphen (10nm)/ CBP (20nm)/ Ag (12nm).	D
ITO (100nm)/ MoO_3 (3nm)/ WO_3 (3nm)/ NPB (60nm)/ Bphen (10nm)/ Li_2CO_3 (2nm)/ Ag (12nm).	E
ITO (100nm)/ MoO_3 (3nm)/ WO_3 (3nm)/ NPB (60nm)/ Bphen (10nm)/ LiF (2nm)/ Ag (12nm).	F

Similar to that of simulation the results drawn from the device C, were current efficiency 13.134 [cd/A], luminance efficiency 1313.46 [lm/W] and the EQE Lambertian 0.22. With device D, current efficiency 11.83 [cd/A], luminance efficiency 1383.14 [lm/W] and the EQE Lambertian 0.20. With device E, current efficiency 16.128 [cd/A], luminance efficiency 1612.12[lm/W] and the EQE Lambertian 0.23. With device F, current efficiency 16.131[cd/A], luminance efficiency 1613.10 [lm/W] and the EQE Lambertian 0.23. The devices E and F having EIL's LiF and Li_2CO_3 displays out the most superior results. Table 2 ensembles the comparative values of the devices. Device E with having carbonate (Li_2CO_3) electron injection layer results current efficiency to 16.128 [cd/A], luminance efficiency to 1612.12[lm/W] and the EQE Lambertian to 0.23 which is in much closer to the results of LiF injection layer. Li_2CO_3 layer exhibits the luminance to current density increasing linearly in Fig.4, emission to wavelength having the highest at the 380 to 415 nm wavelength in Fig.5 and CE Color in Fig.6. LiF being alkaline material not only decrease the electron depletion layer when use as the electron injection layer but also limits the low work function metals use as cathodes necessity. Credible use of LiF has been done inverted OLEDs to increase the electron injection efficiency. The hole injection increase with the increase in the LiF buffer size increase leading to the less operating voltage.

Table 2: Comparative Value of Devices

Device	Electron injection layer	Current Efficiency [cd/A]	Luminance Efficiency [lm/W]	EQE Lambertian
Device A	Alq_3	13.021	1302.09	0.16
Device B	BAlq	13.227	1326.85	0.17
Device C	BCP	13.134	1313.46	0.22
Device D	CBP	11.831	1383.14	0.20
Device E	Li_2CO_3	16.128	1612.12	0.23
Device F	LiF	16.131	1613.10	0.23

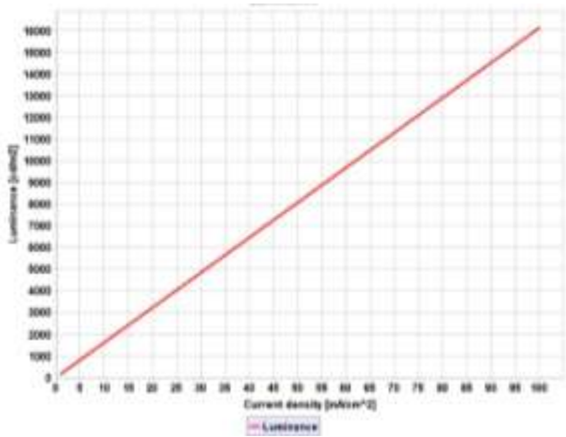

Fig.4 Luminance for Device E

So, the LiF buffer size should be bounded as thinner reduces the hole injection but at a limit thicker providing increase later start reduction in the injection of electrons. Fig.7 shows the LiF luminance graph in proportional to the current density [mA/cm^2]. The increase of luminance linear to the current density.

International Journal of Advanced Scientific Research and Management, Volume 3 Issue 7, July 2018
www.ijasrm.com
ISSN 2455-6378

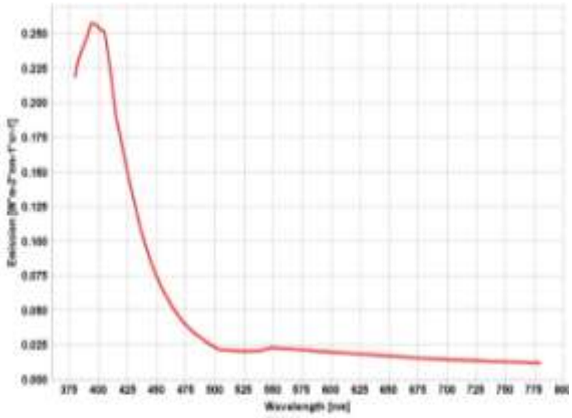

Fig.5 Emission for Wavelength of Device E

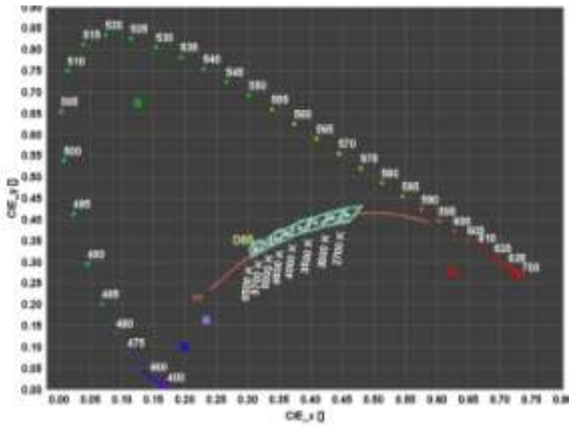

Fig. 6 CIE diagram of Device E

The increase in the current would lead to higher luminance. The graphical of Li_2CO_3 and LiF for the luminance, emission and CIE diagram results the similar representation.

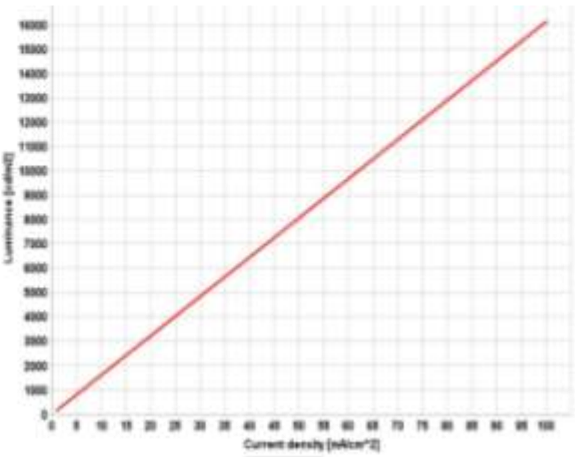

Fig.7 Luminance to the current density for Device F

Except, Fig.8 shows the emission pattern of the LiF device for the voltage sweep from 0-10 V, having the highest at the 380 to 415 nm wavelength. Fig.9 displays out the CIE Color diagram for the LiF structured device. The enhanced luminance as to the other may be attributed as the enhanced balance of electrons and holes. The organic LiF layer presence at the cathode. It's well observed now that with the use of EIL there is an increase in number of electrons in the emission region and the reduction in the hole pairs to reach the cathode.

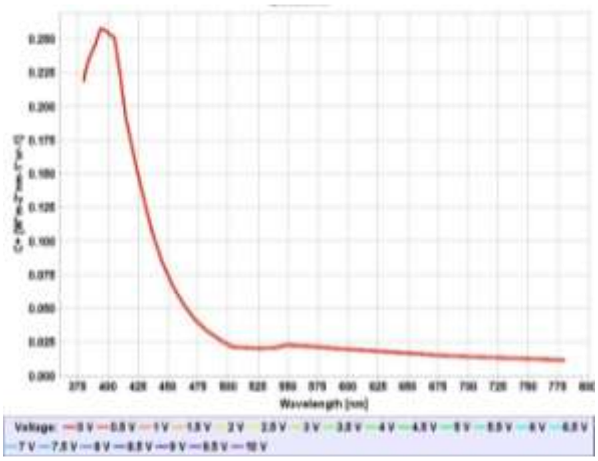

Fig. 8 Emission for wavelength sweep of Device F

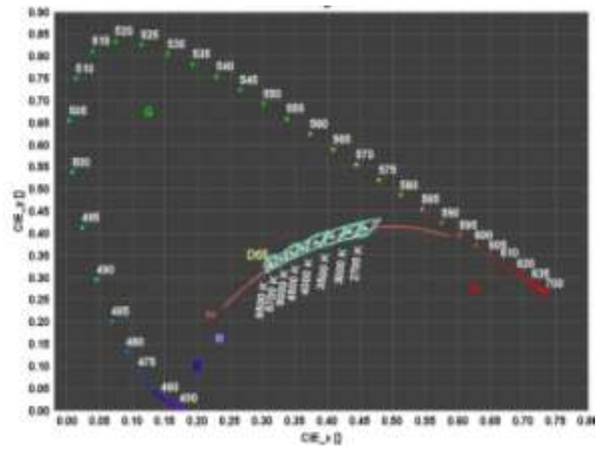

Fig.9 CIE diagram of Device F

4. Conclusion

Simulation of Oled devices A, B, C, D, E and F having different EIL's displayed a complete parametric analysis based on their efficiencies resulted that

Device E: ITO (100nm)/ MoO_3 (3nm)/ WO_3 (3nm)/ NPB (60nm)/ Bphen (10nm)/ Li_2CO_3 (2nm)/ Ag (12nm) and
Device F: ITO (100nm)/ MoO3 (3nm)/ WO3 (3nm)/ NPB (60nm)/ Bphen (10nm)/ LiF (2nm)/ Ag (12nm) have meritorious efficiencies from others. As of Device E and Device F, Device F having LiF as an EIL has the maximum efficiency being almost equivalent to Device E efficiencies.

References

[1] Zhang, Jiang, Khana, Cao, Ma, Zhang, Li, Haqa, Zhu, and Zhang, Enhanced electron injection in organic light-emitting devices by using a composite electron injection layer composed of 8-hydroquinolatolithium and cesium oxide, Solid State Communications, Vol 149, and Issue 2: 652 – 656, (2009).
[2] Schwab, Lussem, Furno, Gather, Leo and Dresden, Organic light-emitting diodes (OLEDs,)Handbook of Organic Materials for Optical and (opto)Electronic Devices, Woodhead Publishing, 508-534, (2013).
[3] Y. Karzazi, Organic Light Emitting Diodes: Devices and applications, Journal of Materials and Environmental Science, Vol 5, 1-12, (2014).
[4] Huang, Chu, Kao and Chen, Improvement of highly efficient organic light-emitting diodes using Mg-doped ZnO buffer layers, Thin Solid Films, Vol 516, 5664-5668, (2008).
[5] Kowalsky, Ammermann, Bohler and Dirr, Organic Light Emitting Diodes, Proceedings of 8th International Conference on Indium Phosphide and Related Materials, 450-453, (1996).
[6] Kim and Park, Enhancing light extraction efficiency of OLEDs with high and low refractive index inorganic materials, Organic Materials, Vol 36, 103-112, (2016).
[7] Cester, Bari, Framarin, Wrachien, Meneghesso, Xia, Adamovich and Brown, Thermal and electric stress effects of electrical and optical characteristics of Alq_3/NPD Oled, Microelectronics Reliability, Vol 50, 1866-1870, (2010).
[8] Fukagawa, Morii, Hasegawa, Gouda, Tsuzuki, Shimizu and Yamamoto, Effects of electron injection layer on storage and operational stability of air stable oled's, Society for Information Display, Vol 46, Issue 1, 696-699, (2015).
[9] Liu, Teng, Xu, Yang, Qian, He, Wang and Xu, Enhanced brightness and efficiency in organic light emitting diodes using SiO_2 as buffer layer and electron blocking layer, Journal of Luminescence, Vol 122-123, 656-659, (2007).
[10] Chen, Zuo, Li, Sheng, Duan, Zhao and Chen, High efficiency orange and white phosphorous organic light emitting diode based on homojunction structure, Organic Electronics, Vol 44, 183-188, (2017).
[11] Takada, Nagase, Kobayashi and Nato, Electron Injection in inverted organic light emitting diode with poly (ethyleneimine) electron injection layers, Organic Electronics, Vol 50, 290-295, (2017).
[12] Wang, Wang*, Gao, Zhang and Qiu, Efficient organic light emitting diodes with Teflon as buffer layer, Japanese Journal of Applied Physics, Vol 43,No, 10B, 1353-1355, (2004).
[13] Grover, Srivastava, Kamalasanan and Mehta, Novel organic electron injection layer for efficient and stable organic light emitting diodes, Journal of Luminescence, Vol 146, 53-56, (2014).
[14] Zhang, Wang, Zhang, Li and Liu, studying the Attributes of LiF in OLED by the C-V Characteristics, International Journal of Photonenergy, Vol 2010, 1-4, (2010).
[15] Liu, Wu, Xiao, Gao, Zhang, Rui, Lin, Zhang, Hua and Yin, Highly efficient tandem Oled based on C_{60}/ rubrene: MnO_3 as charge generation layer and LiF/Al as electron injection layer, Applied Surface Science, Vol 413, 302-307, (2017).
[16] Jesuraj, Hafeez, Rhee, Song, Ching, Song, Kim and Ryu, Enhanced device efficiency in organic light emitting diodes by dual oxide buffer layer, Organic Electronics, Vol 56, 254-259, (2018).
[17] Lee, Lin, Shih, Lin, Wang, Chiu Lin, Increase of current density and luminance in organic emitting diode with reverse bias driving, Organic Electronics, Vol 28, 330-335, (2017).
[18] Liu, Wu, Shi, Wang, Min, Wang, Yang and He, Highly efficient and stable electron injection layer for inverted organic light emitting diodes, ACS Applied Materials & Interfaces, Vol 7(12), 6438-6443, (2015).
[19] Wang, Wu and Wu*, Enhancement of current injection in inverted organic light emitting diodes with thermal annealing, Journal of Applied Physics, Vol 108, Issue 10, 1-4,(2010).
[20] Zhang, Jiang, Khan, Cao, Ma, Zhang, Li, Haq, Zhu and Zhang, Enhanced electron injection layer in organic light emitting devices by using a composite electron injection layer composed of 8-hydroquinolatolithiom and cesium oxide, Solid State Communications, Vol 149, 652-656, (2009).
[21] Jing, Zhenbo, Chunjun, Denghui, Ying and Dong, Effects of LiF buffer layer on the the performance of organic electroluminescent devices, Physica E: Low-dimensional Systems and Nanostructures, Vol 28, Issue 3, 323-327, (2005).
[22] Fleetham, Ecton, Li and Li, Improved out-coupling efficiency from green microcavity OLED with a narrow band emission source, Organic Electronics, Vol 37, 141-147, (2016).