A study analysis of different hole injection layers on the OLED performance

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***Abstract*—**Considering the importance of OLEDs in today's technology enhancement era, this paper considers different OLED structures using various hole injection layers namely, Pedot, WO_3, MoO_3 and compared the performance of corresponding device based on different parameters. The parameters considered are Current Efficiency(Cd/A), Luminance(cd/m2) and Luminous efficacy(lm/W). It is found that among above three devices, device with Pedot as HIL performs better at 40nm thickness as compared to other devices based on above parameters. The improved performance of Pedot at 40nm is due to enhanced constructive interference in OLED device. The current efficiency and luminance using Pedot HIL are increased by 33.91% as compared to WO_3 as HIL and increased by 26.37% as compared to MoO_3 as HIL. The luminance efficacy using Pedot HIL is increased by 5% as compared to WO_3 as HIL and increased by 4.35% as compared to MoO_3 as HIL.

***Keywords*—** *Organic light-emitting diode, Hole injection layer, Luminance, Current efficiency, Pedot*

I. INTRODUCTION

Optoelectronic devices may consist of devices that convert electric current to light and those that convert light to electric current. LEDs and OLEDs come under category one. Mostly near-IR, visible and UV region of electro-magnetic spectrum is utilized by electronic devices. Both LEDs and OLEDs are electroluminescent devices in which electric field excites electrons to a higher energy level and these excited electrons when return to their ground state, emit energy in the form of heat or light[1]. In OLEDs, the emissive layer is an organic material sandwiched between anode and cathode. The carriers injected in the emissive layer recombine to emit light. The recombination occurs across the Homo and Lumo levels of OLED[2]. The Homo and Lumo levels of OLED are discrete electron energy states. The wavelength of light emitted depends upon the energy gap between these Homo and Lumo energy levels. Thus different organic compounds are used to emit different color of light. Some commonly used organic materials in OLED are organometallic chelates and fluorescent dyes[3]. A commonly used organic material is Alq3 which stands for Tris (8- hydroxyquinolinato) Aluminium which has chemical formula $Al(C_9H_6NO)_3$ as shown in figure1. OLEDs can have multilayered conductive and emissive layers. The most commonly used anode material in OLED is Indium Tin Oxide (ITO) which is transparent so that the light emitted is extracted out of the device[4]. In contrary, the material used as cathode is reflective in nature like a metal film. The device structure of an OLED is shown in figure2 which clearly explains the recombination of electrons and holes in the emissive layer of OLED emitting light of a particular wavelength depending on the organic material used in the emissive layer.

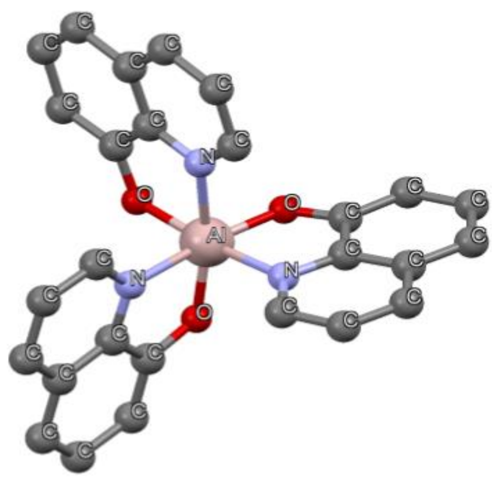

Figure 1. Alq_3 structure

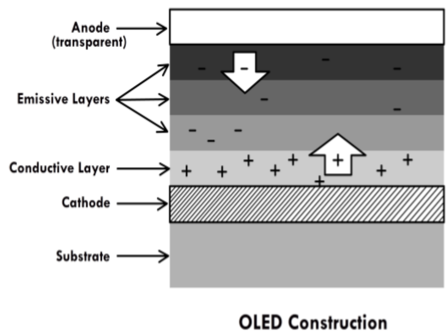

Figure 2. The basic structure of an OLED

The various layers used in OLED are Cathode layer, Emissive layer, Conductive layer, Anode layer and Substrate layer. OLED structure is being supported by the substrate layer, which is made of clear plastic layer or foil being transparent and conductive in nature. Anode layer removes the electrons and is active in nature. The electrons are being replaced by holes when the flow of current passes through this device. It is also known as transparent layer and is a thin layer that can be deposited on anode surface. ITO can behave both as electrode and anode. The conductive layer plays vital role in structure of OLED , which supports the transportation of holes from the anode layer. Organic plastic and the polymers used include light-emmiting polymers, polymer light emitting diode etc. are the constituents which this layer is made up of. Polyaniline, polyethylenedioxythiophene are the conductive polymers used in OLED. This layer uses derivatives of polystyrene and p-phenylene vinylene and is an electroluminescent layer. This layer's constituents are different from the conducting layers and supports transportation of electrons from anode layer. For the emission of wide range of wavelengths there is a multiple availability of choices of materials and processing variables. Polyfluorene, poly para phenylene are the polymers used for the emission in this layer which normally emits green and blue light respectively. The special organic molecules having electricity conduction property builds up this layer. Calcium, barium, aluminium and magnesium are responsible for making of cathode layer. It is solely responsible for injection of electrons when there is a flow of current through the device. Depending on the type of OLED, it can be transparent or opaque in nature The advantages of OLED over LED are the thinner, lighter and more flexible organic layers of OLED than crystalline layers in LED. Moreover OLEDs are brighter than LEDs. OLEDs don't require backlighting as it generates light on its own. OLED is successfully commercialized device in mobile and television displays. The OLEDs are light weight, have faster response time and wider viewing angles. However OLEDs are costlier as compared to LEDs and have a short lifespan as the organic layer degrades with time. Various research initiatives are going on to increase the lifespan of OLEDs.

II. SIMULATION AND ANALYSIS

The suggested OLED structure consists of ITO , NPB, Alq_3 and LiF/Al. Pedot/WO_3/MoO_3 are compared as different buffer layers and the results are taken in form of the current efficiency, luminance and luminous efficacy. Various thickness of 30nm, 40nm and 50nm are taken into consideration to compare the above mentioned parameters for Pedot/WO3/MoO3 as the buffer layer. The current efficiency, luminance and luminous efficacy for each of buffer layer with each value of thickness is then analysed. The graphs for emittance, transmittance and luminescence are obtained for OLED structure with Pedot as HIL layer. The various structures for the devices A ,B and C having different hole injection layers are considered for analysis and provided in Table1. Setfos 4.6 is the platform for analysis of the above mentioned parameters. Figure 3 shows the general structure of proposed OLED in which the HIL layers are varied to obtain devices A, B and device C. It is found that among above three devices, device C with Pedot as HIL performs better at 40nm thickness as compared to other devices based on above parameters. The improved performance of Pedot at 40nm is due to enhanced constructive interference in OLED device

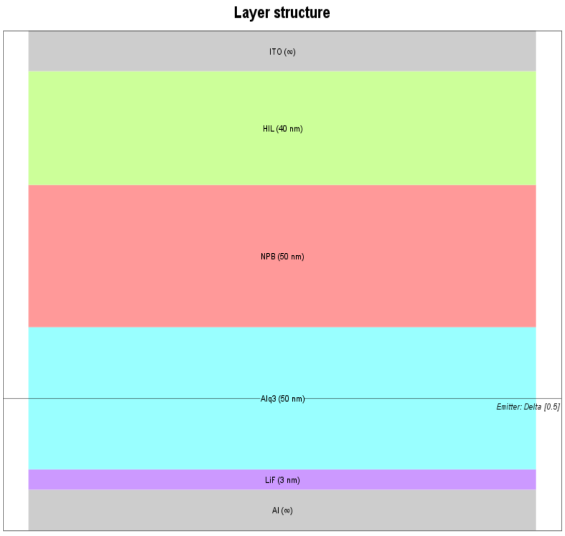

Figure 3: Proposed OLED structure

TABLE1 STRUCTURE OF PROPOSED DEVICES

Structure	Device
ITO/WO_3/NPB/Alq_3/LiF/Al	A
ITO/MoO_3/NPB/Alq_3/LiF/Al	B
ITO/Pedot/NPB/Alq_3/LiF/Al	C

III. RESULTS

The general structure of proposed OLED is shown in Figure3. The corresponding results are the best for Pedot as hole injection layer and are shown in the form of the graphs for emittance, transmittance and luminescence are obtained as shown in figure 4a, 4b and 4c. The emission takes place at around 537.5 nm wavelength as shown in figure 4b. Pedot with 40nm thickness provides better performance with respect to parameters named current efficiency, luminance and luminous efficacy. The improved performance of Pedot at 40nm is due to enhanced constructive interference in OLED device. The current efficiency and luminance using Pedot HIL are increased by 33.91% as compared to WO3 as HIL and increased by 26.37% as compared to MoO3 as HIL. The luminance efficacy using Pedot HIL is increased by 5% as compared to WO3 as HIL and increased by 4.35% as compared to MoO3 as HIL. Thickness is varied at 30nm, 40nm and 50nm for each of the hole injection layer and the results are compared which are shown in table2. Setfos 4.6 is the tool for analysis and provide accurate analysis. The improved current efficiency, luminance and luminous efficacy in device with pedot as hole injection layer provide make such an OLED structure significant for use in portable devices like mobile phones and display devices like television, computer display etc.

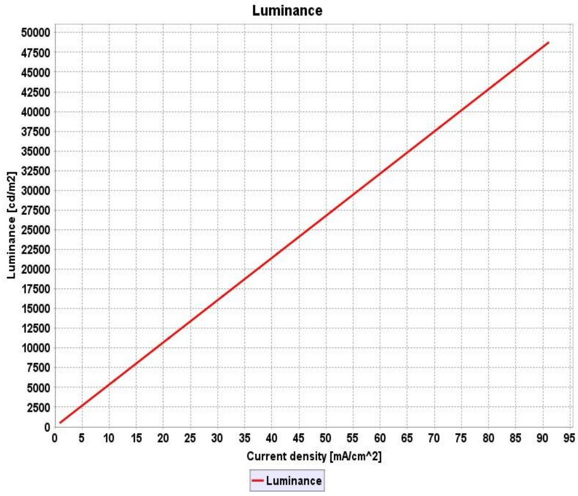

Figure 4a : Luminance

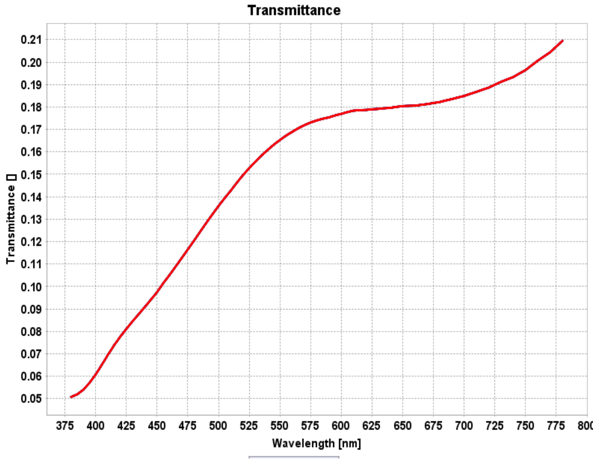

Figure 4c : Transmittance Spectra

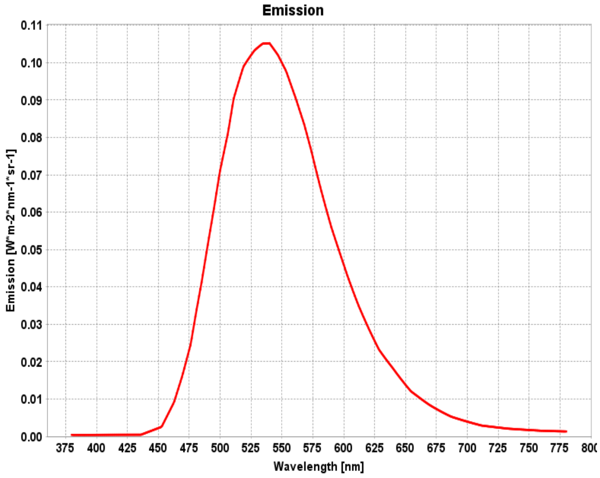

Figure 4b : Emittance Spectra

TABLE2 OLED COMPARATIVE ANALYSIS

Parameters with thickness (nm)	Pedot			WO_3			MoO_3		
	30	*40*	*50*	*30*	*40*	*50*	*30*	*40*	*50*
Current Efficiency(Cd/A)	53.5338	53.0558	52.4564	39.8751	39.9761	41.0189	42.3591	42.3602	42.8304
Luminance(cd/m2)	5353.3805	5305.5815	5245.6414	3987.5094	3997.6123	4101.8878	4235.9088	4236.0224	4283.0446
Luminous efficacy(lm/W)	449.3031	445.4575	451.0788	428.0773	427.2355	427.5482	430.9813	430.5701	430.7197

IV. CONCLUSION

The characteristics of OLED with Pedot/ WO_3/ MoO_3 as buffer layer were analysed using different thickness(30,40 and 50nm) of layers. Using Pedot as buffer layer ,the current efficiency, luminance and luminous efficiency is the highest among the above mentioned buffer layers. The current efficiency, luminance and luminous efficacy is minimum for WO_3. The current efficiency, luminance and luminous efficacy of MoO3 lies in-between pedot layer and that of WO_3. Pedot buffer layer has better performance at 40nm thickness as compared to 30nm and 50nm for both current efficiency(53.5338 Cd/A) and luminance(5353.3805 cd/m^2). However, luminous efficacy is high at 50nm(451.0788 lm/W). WO_3 buffer layer has better performance at 50nm thickness as compared to 30nm and 40nm for both current efficiency(41.0189 Cd/A) and luminance(4101.8878cd/m^2). However, luminous efficacy is high at 30nm(428.0773 lm/W). MoO_3 buffer layer has better performance at 50nm thickness as compared to 30nm and 40nm for both current efficiency(42.8304 Cd/A) and luminance(4283.0446cd/m^2). However, luminous efficacy is high at thickness of 30nm(430.9813 lm/W).

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