

Luminous Efficiency Improvement of OLED by Thickness Variation of Organic Materials

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Abstract: Organic light emitting diode is a Solid state lighting devices, the charge transporters must be infused from the anode and cathode yet the execution, lifetime, effectiveness and solidness of these devices are normally administered by the correct thickness of the material layers and terminal/organic interfaces at the anode contacts. In this paper we exhibit a new approach using different thickness of organic material of emissive layer and hole injection layer in OLED. We could enhance the effectiveness of doping materials by framing exciplex improved OLED devices and concentrate their execution enhancement by utilizing different thickness. In this work different thickness of emission layer, ETL layer and HIL is taken and maximum luminous efficiency of different devices were observed.

Keywords : ETL, EML, Thickness, External Quantum Efficiency, HIL, Maximum Luminous Efficiency.

I. INTRODUCTION

Organic light emitting Diode is made by organic thin films, placed in series between two conductors. Fabrication of an OLED is consists of emissive layers and conductive layers made of organic materials, all together sandwiched between two electrodes and deposited on a substrate made up of glass or plastic. There can be multiple organic layers of different thickness and different organic materials. These organic layers are named as hole injection layers (HIL), hole transport layers (HTL), Emissive layers (EML), Electron injection layers (EIL), Electron Injection layers (EIL), Hole blocking layers (HBL) and electron blocking layers (EBL) [1]-[2]. On applying external electric field, recombination take place in these organic thin films and a bright light is emitted. The unique features of OLED's, for example translucency, cost effectiveness, flexibility, brightness and thinner structure offer new possibilities for design and application. So an appropriate approach to increase performance and efficiency is to increasing light extraction of the device [3]. Organic light emitting diode is a lightening device that is completely different in appearance and lighting performance inorganic light emitting diodes, commonly known as LEDs. OLED have some unique properties which makes it advantageous for

making solid state lightening devices like large surface area, light in weight, low voltage, wide view angle(approximately 170°) high luminance efficiency, much thinner than LEDs, less power consumption, flexible display and importantly diffuse in appearance. The basic concept of OLED displays is electroluminescence. It is based on component devices containing organic substance that emits light when stimulated by electric current. The choice of electroluminescent materials can be taken as polymer materials or small molecule materials. The conducting layer is a film of organic plastic molecules or glass that transports holes from anode. Most commonly used anode is ITO due to its transparency. The emissive layer is made of organic molecules that transport electrons from the cathode and emits light when electric current is applied. The material of organic layer decides the color of light. Manufacturers take combinations of different organic material in order to attain desired color displays. [4]. In OLEDs, It is possible to shrink the thickness as a film for compact lighting and display devices. The organic thin film thickness is much thinner than hair, normally in the order of nm, the corrugated structure introduced near the device may seriously affect the electrical characteristics of OLED [5]. To suppress performance droop, thickness of quantum barriers (QB) plays a significance role, as on reducing the QB thickness, the performance droop increases. On reducing QB thickness in LED, more serious performance droop can be obtained. Previous studies have mainly described the reasons of performance and efficiency droop suppression by decreasing the QB thickness to the hole injection improvement [6]. The different emitting color of OLEDs can be obtained by changing combination of organic layer and by varying doping in organic materials. A blue phosphorescent OLED had focused on improving the device performance compared to fluorescent OLEDs. However, there is still demand deep blue emission and high efficiency for practical applications, such as solid state lighting and a bendable smart phone display [7]. Green phosphorescent devices are made by using doping of phosphor in an emissive layer that is formed by placing of an electron transporting organic layer and hole transporting organic layer combined [8].

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II. MATERIALS USED IN OLED AND DEVICE STRUCTURE SET UP

This section contains the device structure and organic materials which are used to simulate the OLED. The work is done using Silvaco Atlas TCAD software.

Fig. 1 shows the proposed device structure used for simulation. The upper most layer is made up of Al which acts as cathode. Cathode is chosen such as it should have low work function to match high efficiency and better performance of OLED. The work function of Al is 2.9eV. In this structure, a new organic material 2T-NATA is introduced as hole transport layer and results were observed.

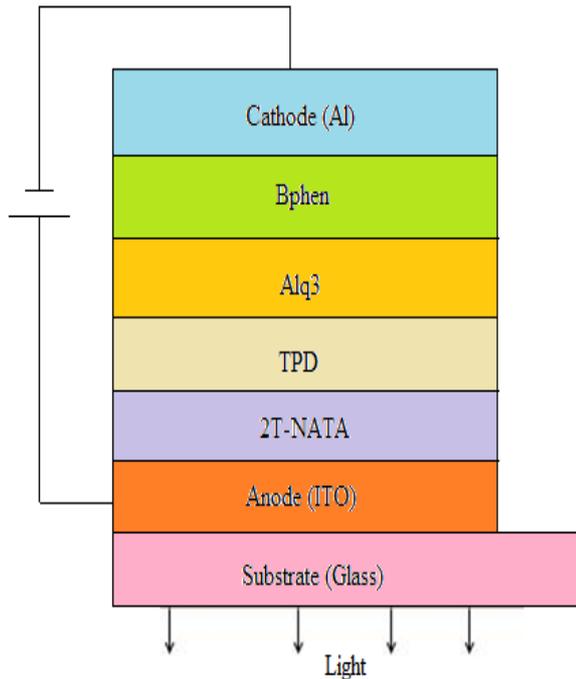


Fig. 1. Schematic Presentation of OLED

Bphen (4,7-di phenyl-1,10-phenantroline) layer works as electron transport layer (ETL). Alq₃ [Tris (8-hydroxy quinolinato) Aluminium] is working as emission layer (EML) from where light of OLED emits. Here, the material used for hole transport layer (HTL) is TPD (N,N'-bis (3-methylephenyl)-N,N'-phenyl-benzidine). 2T-NATA [4,4',4''-Tris[2-naphthyl(phenyl)amino] triphenylamine] layer is working as hole injection layer (HIL).

The Anode material is ITO, a high work function (4.7eV) material. For the choice of substrate, glass and plastic are the options. For flexible OLEDs, plastic is used as substrate material.

In this Simulation, thickness of 2T-NATA layer and Alq₃ layer is varied simultaneously. thickness of HIL is taken in decreasing order and thickness of emission layer is taken in increasing order, because from previous studies, it is clear that current density increases with increased emission layer thickness and decreased hole injection layer thickness.

III. RESULT AND DISCUSSION

This section contains result and discussion about various thicknesses of the material that takes into thickness variety of OLED device.

The performance of an OLED depends upon its Quantum efficiency, So two different parameters are taken into account: external quantum efficiency (EQE) and internal quantum efficiency (IQE). EQE is the ratio of number of emitted photons to injected charge carriers, and it is given by:

$$\eta_{EQE} = \eta_r R \eta_{out} \quad (1)$$

Where η_r is the probability to form exciton by recombination of electron and holes.

R is the probability of radiative decay, and generally its value is 1/4 for small molecule OLED. But for polymer material, its value is higher.

η_{out} is fraction of photons that can escape the device, commonly known as light out coupling efficiency. It can be given as

$$\eta_{out} = 1/2n^2 \quad (2)$$

Here n is represented by refractive index of the organic material, and its range lies in between 1.6 to 1.8. So only 15-20% of the optical power is actually extracted. Thus maximum external quantum efficiency in fluorescent OLEDs limited to 5%.

To evaluate Maximum EQE, various devices with different thickness of organic materials are taken into consideration, details are as followed:

Device A: Al(100nm)/Bphen(5nm)/Alq₃(20nm)/TPD(40nm)/2T-NATA(100nm)/ITO(140nm)

Device B: Al(100nm)/Bphen(5nm)/Alq₃(25nm)/TPD(40nm)/2T-NATA(85nm)/ITO(140nm)

Device C: Al(100nm)/Bphen(5nm)/Alq₃(35nm)/TPD(40nm)/2T-NATA(75nm)/ITO(140nm)

Device D: Al(100nm)/Bphen(5nm)/Alq₃(45nm)/TPD(40nm)/2T-NATA(60nm)/ITO(140nm)

Device E: Al(100nm)/Bphen(5nm)/Alq₃(60nm)/TPD(40nm)/2T-NATA(40nm)/ITO(140nm)

In all these devices, thickness of emissive layer and HIL layer is changing keeping thickness of ETL constant as 5nm. The voltage variation is taken in range 0V-20V, and turn on voltage is found at 8.7V.

Fig. 2 shows the V-I characteristic of the Structure shown in Fig. 1. It shows the relationship between anode voltage and anode current.

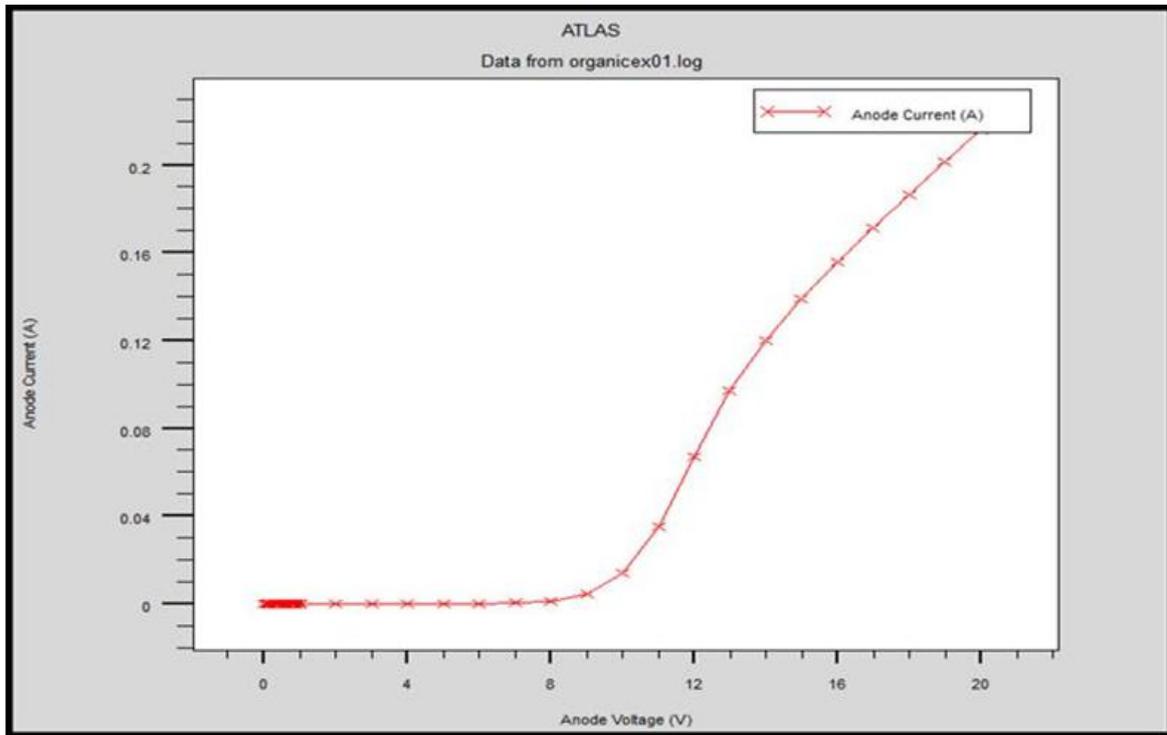


Fig. 2. I-V characteristic of proposed OLED structure

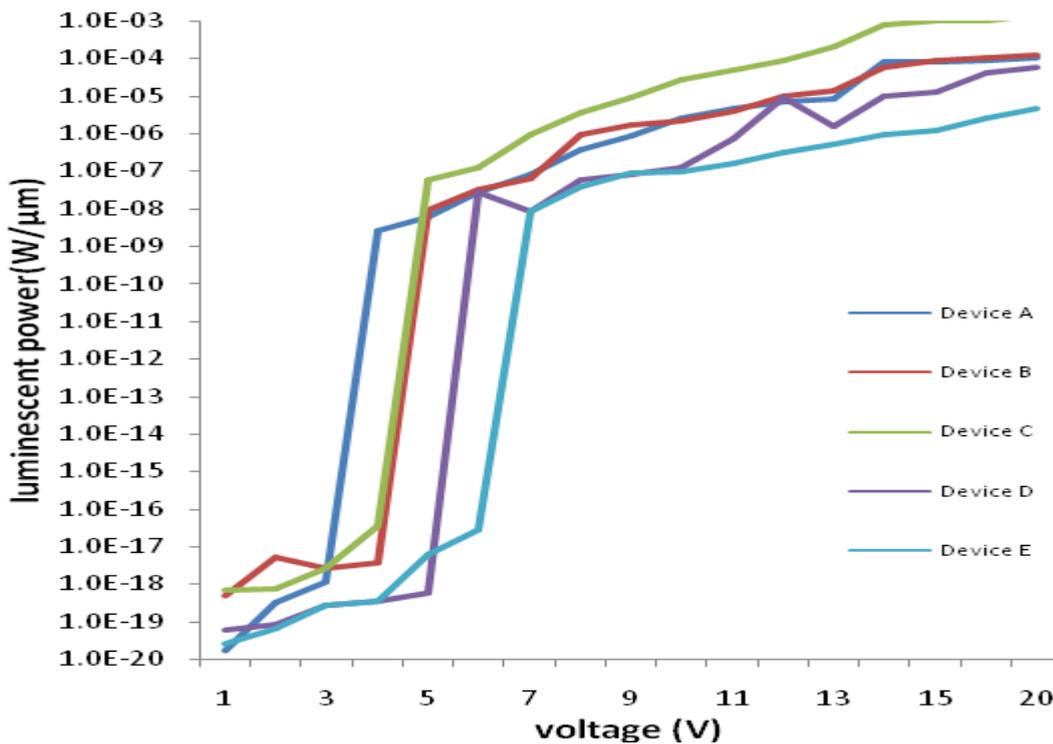


Fig. 3. Luminescent Power Comparison Graph Of All The Devices

In order to find the optimized thickness of the device, simulation is done and results are extracted. Which are shown in Fig 3. The graph is drawn between anode voltage and maximum luminescent power, and final Result shows that turn on voltage is minimum for device A, it makes device suitable for battery operated applications as it draws less power, but but its luminescent current is less. Maximum luminescent power is shown by device C, so it shows better efficiency in

terms of light emission, it makes it best suitable design for further studies.

Table I. Effect of HIL and EML layer thickness variation on efficiency

DEVICE	VOLTAGE/V@1000 CD/M ²	MAX. EQE %
A	3.1	5.19
B	4.8	5.89
C	5.3	6.21
D	6.2	6.18
E	7.8	5.27

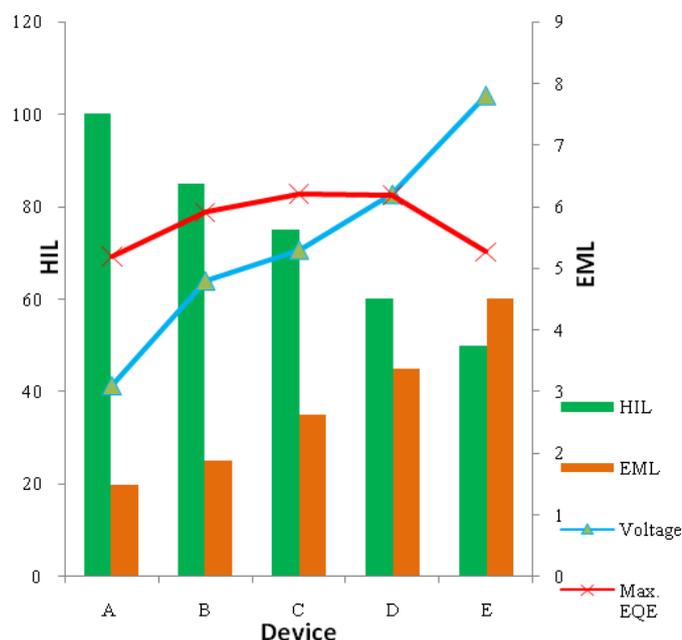


Fig. 4. Comparison Graph between maximum external quantum efficiency and anode voltage keeping varying thickness of HIL and EML

Refer with table I and Fig. 4, it is seen that the thickness of HIL varies from 40nm to 100nm (40nm, 60nm, 75nm, 85nm, 100nm) respectively and thickness of Emissive layer are 20nm, 25nm, 35nm, 45nm, 60nm respectively at turn-on voltages 3.1, 4.8, 5.3, 6.2 and 7.8, and result shows that the best external quantum efficiency obtained at 75nm HIL thickness and 35nm emissive layer thickness. Therefore it can be concluded that the thickness of HIL and EML has a direct effect on device performance.

IV. CONCLUSION

The characteristic of improved OLED performance and color tunable emission by the transfer of energy, doped organic materials were expected to be of high interest for optoelectronic devices. We find that at specific thickness of EML layer the luminance effectiveness of device structure is greatest. The optimum thickness of organic layer utilized as emitting layer were 35nm with 75nm thickness of hole injection layer.

So final device structure for improved efficiency is ITO /2T-NATA (75nm) /TPD (40nm)/ Alq₃ (35nm)/ Bphen layer (5nm)/ Al(110nm). The maximum external quantum efficiency were obtained as 6.21% at operating voltage 5.3 volt and Alq₃ layer thickness as 35nm and 2T- NATA Layer thickness as 75nm.

Subsequently, in future any organic light transmitting diode approach that could give better thicknesses and charge adjusting can be accomplished in the emissive district. Thickness could be executed to enhance the execution of OLED.

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Abhilasha is a Ph.D. Scholar in department of Electronics and computer Engineering. She has done his M.Tech and B.Tech from Mody University, Lakashmangarh, INDIA. Her areas of expertise are VLSI design and optoelectronics device. She has published over 20 research papers in prestigious journals and peer reviewed conference proceedings.



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