Analyzing the Effect of Hole Buffer Layers on OLED Performance

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Abstract- In this paper, Silver (Ag) is used as an alternate electrode, instead of the usual Indium Tin Oxide (ITO) materials in the transparent Organic Light Emitting Diode. The flexibility and transparency of the Ag electrodes makes it ideal for use in flexible OLED devices. Through experimentation it can be verified that Silver (Ag) electrodeedges better alternative than Aluminum (Al) electrodeby about 34.65% because of its high transmittance, conductivity and stability. Rhenium Oxide (ReO3) layer acts as a buffer layer which is placed between the Ag electrode layer and the emissive layer. This buffer layer is then varied to see at which thickness value it produces optimized luminous efficacy.This buffer layer is compared with Molybdenum oxide (MoO3) and Tungsten oxide (WO3). Comparatively it can be shown that the luminous efficacy using the MoO3 device is about 68.88% as against using ReO3 buffer layers. And using WO3 layer gives about 55.33% luminous efficacy as against the same ReO3 layer device. Hence using ReO3 layer seems to produce optimized luminous efficacy.

Keywords- Buffer layers, Electrodes, Flexible, Organic Light Emitting Diodes.

I. INTRODUCTION

Organic Light Emitting Diode (OLED) is a type of diodes that conducts current when forward biased and open circuits when reversed biased. Unlike an ordinary diode that uses semi-conductor p type and n type devices, it uses thin organic films between two conductors. When forward biased, it emits bright light through the process of electron-hole recombination. OLED are called organic as they are made up of carbon and hydrogen compounds which is also known as a "*real green technology*". The typical structure of a OLED consists of six fundamental layers. The top and bottom layer are made up of protective glass or plastic material. The top layer is called the lid or cover and the bottom layer is called the substrate. In the middle of the top and bottom layer is the cathode which is a negative terminal and the anode which is a positive terminal. For flexible OLED, Ag or Al electrodes are used at the top and bottom of the device to improve its flexibility and hence the name dual electrodes. Both have got low work function. But the deposits of Ag have got more high rough surface as compared to Al, due to bad infiltration deposits and leads to severe short circuit. Al as compared produces excellent morphology for surface roughness. Experimentation with both Al and Ag electrodes are conducted and the current luminescent for varied thickness layer is being experimented. Again sandwiched in between the anode and cathode are the two organic layers called the emissive layer (where the light is produced, which is next to the cathode) and the conductive layer (next to the anode). Light is produced near the emissive layer and placed right next to the cathode, while the conductive layer is placed next to the anode. Figure 1 shows the structure of a typical OLED device.

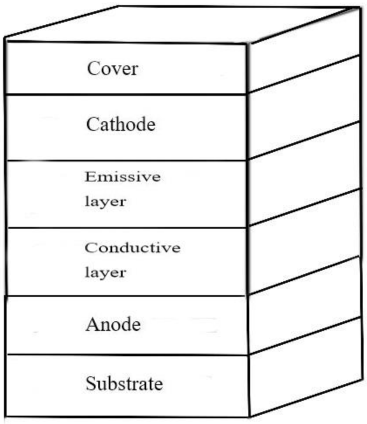

Fig.1 Structure of a typical OLED

ITO (Indium Tin Oxide) [1,3] is an excellent translucent electrode material and is being widely used in OLEDs. Nevertheless, due to a reasonably work function of ITO, it overwhelms the addition of electron and decreases the performance of the device. Indium is also a very expensive element and is considered as a rare earth element. The high energy sputtering technology will damage the organic functional layer. Also, due to its fragility, ITO is unfavorable to be used in flexible devices. Hence, as a better and economical replacement of ITO, Ag electrode is reconnoitered as a better alternative. It is cheaper and more transparent electrode material for fabricating the transparent OLED device for commercial applications.The buffer layer is used here to eliminate this short circuit issue. The use of ReO3 as a buffer layer helps in efficient hole injection and anti-short circuit layer to protect the Ag electrodes. NPB acts as a hole injection layer and Alq3 is used as a luminescent layer. [3] [4]

The main advantages of using OLED over LCD is that it does not require any backlighting, much thinner, flexible and adaptable to transparent displays. In this paper, we consider a transparent OLED where its substrate, cathode and anode allows light to pass through them in either direction. After some general considerations, a summary of different OLED materials and structures is obtained focusing mainly on electroluminescence efficiency and device lifetime. The advantage of using Ag electrode is also studied instead of the traditional ITO metals used in transparent OLED. Experiments have been conducted considering several conditions such as weak micro cavity in thickness, experiment of ReO3 materials to overcome the short circuiting problems.

II. SIMULATION DESIGN

First the flexible OLED is being simulated using Ag electrode for both the anode and cathode electrode with different thickness of each layer stacked on top of each other. The emitting position is between the interface of Alq3 and NPB layer. The OLED structure for the corresponding structure is as shown in figure 2.

Fig.2: Structure of OLED with dual Ag electrode

The emission wavelength for the fluorescent green Alq3 device is shown in figure 3 which typically ranges between 545nm to 560nm wavelength. The buffer layer ReO3 is being varied for different thickness from 30nm to 70nm and the corresponding current efficiency and the relevant peak wavelength for the fluorescent green emitting layer is being determined.

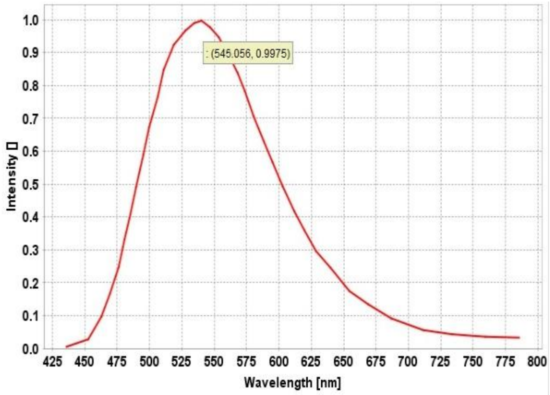

Table I shows that the maximum current efficiency is being achieved for the right fluorescent wavelength only with the thickness of the electrode material noted form the simulation.

TableI. Comparative analysis with dual Ag electrodes

For Ag electrode		
Thickness (nm)	**Current Efficiency (cd/A)**	**Peak Wavelength (nm)**
30	20.8122	515
40	31.5652	515
50	41.4199	530
60	45.7403	545
70	41.5384	560

For comparison purpose, we simulate the same structure but Ag electrode is being replaced by Al electrode on both the cathode and anode. The OLED structure for Al electrode with varying buffer thickness is as shown in figure 4.

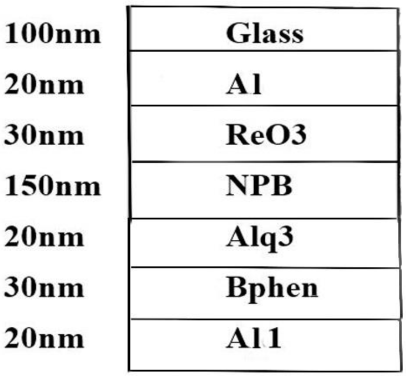

Fig. 4 Structure of OLED with dual Al electrode

relevant peak wavelength for the fluorescent green emitting layer is being determined. Table II shows that maximum current efficiency being achieved for the right fluorescent wavelength only and its relevant electrode thickness being noted from the simulated result.

TableII. Comparative analysis with dual Al electrodes

For Al electrode		
Thickness (nm)	**Current Efficiency (cd/A)**	**Peak Wavelength (nm)**
30	1.5198	470
60	9.763	515
70	13.5677	530
80	15.8517	545
90	13.4365	560

Fig.3: Emission region of green Alq3 for OLED

By comparison of table I with tableII we can see that the current efficiency is improved with Ag electrode and hence by selecting the Ag electrode material instead of the Al electrode, we next design three different OLED structureby introducing different buffer layer viz.,Molybdenum Oxide (MoO3), Rhenium Oxide (ReO3) and Tungsten Oxide (WO3) respectively. The thickness of this buffer layer is varied from 40nm to 70 nm to study the optimum current efficiency it gives. The three OLED layers designed is as shown below:

Table III. Different Structure of OLED device

Structure	**Device**
Glass(100 nm)/Ag (20 nm)/MoO3 (40-70 nm)/NPB (150 nm)/Alq3 (30 nm)/BPhen (20 nm)/BPhen1 (10 nm)/Ag1 (20 nm)	A
Glass(100 nm)/Ag (20 nm)/ReO3 (40-70 nm)/NPB (150 nm)/Alq3 (30 nm)/BPhen (20 nm)/BPhen1 (10 nm)/Ag1 (20 nm)	B
Glass(100 nm)/Ag (20 nm)/WO3 (40-70 nm)/NPB (150 nm)/Alq3 (30 nm)/BPhen (20 nm)/BPhen1 (10 nm)/Ag1 (20 nm)	C

The table IV. shows the result of the simulation. The current efficiency for the OLED being simulated, out of the three buffer layer viz., Moo3, Reo3, and WO3; the Reo3 buffer layer gives the optimized performance with the layer thickness of 50 nm. So with this Reo3 layer selected, next the emissive layer Alq3 is varied from 20nm to 40nm and current efficiency is being simulated and observed.Table Vshows the different current efficiency observed for different thickness of Alq3 emissive layer.

Table IV. OLED devices simulation result

Layer Thickness (nm)	**Device A**	**Device B**	**Device C**
40	48.09	49.14	43.97
50	36.91	53.58	29.65
60	25.28	47.60	18.35
70	16.21	35.91	0.883

Table V. Effect of Alq3 thickness variation

Thickness (nm)	**Current Efficacy (cd/A)**
20	41.4199
30	53.5849
40	51.4629

The luminance and emission curve graph is as shown below in Fig 5 and Fig 6 respectively:

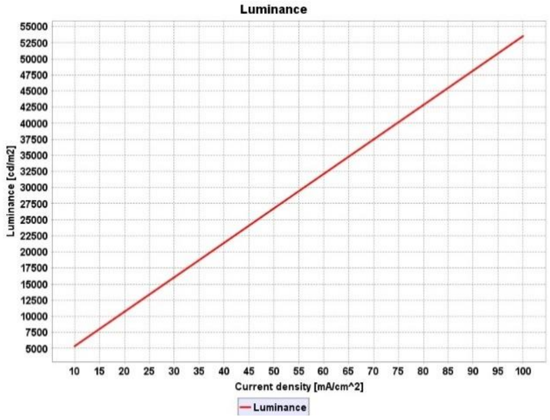

Fig.5: Luminance vs Current Density Curve

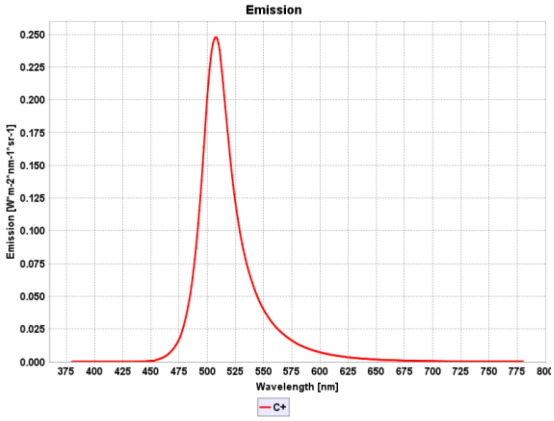

Fig.6: Simulated Emission Graph

An efficient layer thickness of this buffer layer helps in knowing a uniform layer, which helps in improving the overall current efficiency. This effectively enhances the transmittance of OLEDs by suppressing reflectance with appropriate optimization of thickness. From the above simulation, for dual Ag electrode maximum current efficiency of 45.7403 cd/A is found to be at buffer thickness of 60nm and emitting a peak wavelength of 545nm which is typical of green fluorescent emission. By considering the Al electrode in place of Ag electrode, for same structure the maximum current efficiency was found to be only 15.8517 cd/A to emit in the same peak wavelength of 545nm with the buffer thickness of 80nm. With the Ag electrode selected, three different buffer layer is being simulated: Woo3, Reo3, and Moo3. By simulated result it is observed that Reo3 buffer layer at 50nm thickness gives the maximum current efficiency of 53.58 cd/A. so Reo3 buffer layer gives the best hole transport layer and buffer layer to the emissive layer. With 50nm Reo3 layer thickness selected in the OLED structure, the emissive layer ALq3 is varied from 20-40 nm thickness and its current efficiency is studied.

In this OLED structure, the emissive layer of the OLED Alq3 is located confined within a resonant optical cavity space. The spontaneous emission from this emissive layer is restricted to the optical modes of the cavity. Hence it results in narrow spectral width of the device. The emitted wavelength is reflected by the Al electrode and the buffer material and causes both the constructive and destructive interference between the resonant cavity. This theory is demonstrated in the Alq3/NPB/ReO3/Ag device structure. When the distance of the resonant cavity is increased by decreasing the layer thickness or decreased by increasing the layer thickness of the Alq3, it results in destructive interference which reduces the current efficiency. Because of resonant cavity length, different frequency of the emissive wavelength adds up together cancelling each other's amplitude resulting in reduced wavelength amplitude, it is known as destructive interference. Hence the need to find an optimized layer thickness that adds the emissive wavelength with same frequency and larger amplitude also known as constructive interference, resulting in maximum current efficiency. The simulations show a maximum current efficiency over a wavelength range of 545 nm for an emissive layer ALq3 layer thickness of 30nm. Current efficiency reduces as compared to the reference 545nm thickness on either side as shown in the table. The efficiency simulated is confirmed for a green ALq3 emission layer with an emission between 500nm and 650 nm. It gives a maximum current efficiency of 53.5849 cd/A for a layer thickness of 30nm. One can try to reduce this absorbance by studying the optimum thickness of the buffer layer.

III. CONCLUSION

A high transparent OLED is prepared by using the amalgamation of Reo3 layer with the Ag electrode for its flexibility. Green emission spectra around 545 nm is obtained on both the top and bottom side of the transparent OLED. Because of high roughness of Ag film, short circuit effect is being researched further and to overcome it, ReO3 layer is being added as a buffer for conductivity. With the proposed method, it is demonstrated that to have an efficient transparent OLEDs it is better to use Ag electrode on both the cathode and the anode region than the Al electrode. Ag gives better current efficiency of 45.7403 cd/A with much higher buffer thickness of 60nm, having a luminous peak transmittance value of 545nm. Al electrode could give only 15.8517 cd/A current efficiency for buffer thickness of 80nm for the same wavelength. Hence, for flexible OLED with Ag electrode is preferred having a ReO3 buffer thickness of 60nm for green luminescent spectrum. Comparing three different buffer materials viz., Moo3, Reo3, Woo3 it is concluded that Re3 with buffer thickness of 50nm gives the optimum result. Hence with Reo3 layer selected, by varying the ALq3 thickness it gives the optimized current efficiency value of 53.5849 cd/A for a layer thickness of 30nm. The future research could include the study of resonant cavity length for better buffer material thickness study and its relation to the luminous efficacy for the OLED using silver electrode; and to find for different materials of buffer layer to find optimal solution.

IV. REFERENCES

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