ENHANCED PERFORMANCE OF TANDEM ORGANIC LIGHT EMITTING DIODE USING ORGANIC CHARGE GENERATION LAYER

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Abstract*— In this paper, highly efficient Tandem Organic Light Emitting Diode (OLED) is proposed. The advantage of using Tandem OLED is the elongated lifetime and over two fold enhancement in the current efficiency in contrast to the conventional OLED. This enhancement in the performance of Tandem OLED can be attributed to use of two or more electroluminescent units in the device that are separated from one another by the charge generation layer (CGL). In this work, the bulk heterojunction of P3HT-PCBM is used as charge generation layer. The proposed device structure is optimized on the basis of thickness and material selection for different OLED layer so as to get better results. The results show that the current efficiency at 10 mA/cm^2 and external quantum efficiency of proposed Tandem device are 35.36 cd/A and 23.8% respectively which is over 1.87 and 1.69 times greater than that of single emissive device having current efficiency and External quantum efficiency of 18.87 cd/A and 14.02% respectively, Thus with the proposed CGL. there is efficiency enhancement in the proposed Tandem device as compared to the single emissive unit device.

Keywords-charge generation layer, efficiency improvement, organic heterojunction, Tandem OLED.

I. INTRODUCTION

There are resources of energy. All these resources are divided into into two classes: nonrenewable and inexhaustible. Nonrenewable energy assets, similar to coal, atomic, oil, and flammable gas, is accessible in constrained supply.Once used they cannot be recycled i.e. they cannot be used again and again and they are available in the limited quantities. It takes over millions of years for their formation. Over 150 years ago people have extracted the energy from the fossils, which in termed as the coal energy, natural gas and oil etc. But over this span of time the human beings have exploited these resources to a greater extent. Such that these resources are now limited and cannot be used in coming years. These resources are termed as the nonrenewable resources of energy.

Thus due to the lack of availability of these resources the human beings and the scientists are now shifting towards the renewable sources of energy. These resources are present in abundance in the environment and in the surrounding that it can be used for more than hundreds of years by the human habitat. Sustainable resources are renewed normally and over generally in brief timeframes. The five noteworthy sustainable power source are sun based, wind, water (hydro), biomass, and geothermal. Thus the advancement in the field of the renewable resources is at its peak. Solar energy is one such promising renewable resource that is used worldwide for research purpose. As sun is the only resource that would be available to us over millions of years it will not vanish hence sun energy can be utilized and can be used for various purposes like solar panels are used to enlighten bulbs, heating the water any many more works. This comes under the study of the solar cells. Another area of interest of research now a day is on the OLEDs. Researchers are trying to enhance the working efficiency of both. solar cells and OLEDs for our bright future [1]-[3].

II. OLED

An OLED is a gadget which emerges light under utilization of an outside voltage. OLED is based on the electroluminescent phenonomenon that is light is generated only when the voltage is applied .There are two fundamental classes of OLED gadgets. Those made with little natural particles and those made with natural polymers. Small molecules based OLEDs are usually sedimented by vacuum deposition techniques which is a costly fabrication technique. Polymer based OLEDs are usually deposited by inkjet printing and spin coating techniques. These techniques are simple to implement and provides a cost-effective solution OLEDs have the of many properties lightweight, adaptable, straightforward, flexibility, thin, and shading tune capacity, which makes them a perfect present day light source. OLED consists of the emissive layer where the light is generated and it is sandwiched between the anode and cathode and the thickness of the oled varies in the range of the 100-500nm [4]-[8].Organic OLEDs provides us with the higher electroluminescence, which further increments the current efficiency of the OLED [2].

The typical OLED consists of anode, Hole injection layer(HIL), hole transport layer (HTL), emissive layer which is used to emit light, emissive layer generally is composed of the polymer material, Electron injection layer (EIL), Electron transport layer (ETL), and cathode. HIL and EIL layers are used to enhance the performance of the OLEDs. as they work as the buffer layers which speed up the injection of electrons and holes. The typical OLED can provides us with 20% of the, total generated light as rest of the light is lost due to waveguide modes, surface Plasmon , opical lossed etc. thus the research are going on to enhance the value of the parameters obtained from the general conventional OLEDs. Fig.1 shows schematic the diagram of the conventional OLED[9]-[11].

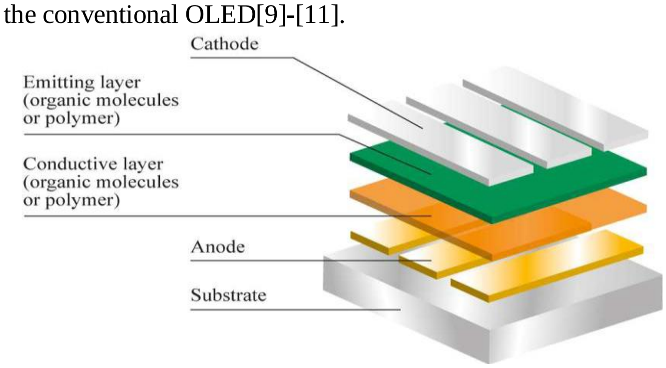

Fig1: Basic structure of OLED[1]

For enhancing the current efficiency more the another structure that is used is Tandem Oled.

III. TANDEM OLED

A tandem organic light- emitting diode (OLED) is an organic optoelectronic device that has two or more electroluminescence (EL) units connected electrically in series with unique intermediate connectors within the device. This new OLED architecture with growing interest and have found that the current efficiency of a tandem OLED containing *N* EL units (*N* > 1) should be *N* times that of a conventional OLED containing only a single EL unit. i.e. with the increase in the electroluminescent units the performance of the device enhances. It has been known that that the low-temperature processed charge generation layer not only provides efficient stacking of the two electroluminescent units, but it also enhanced the compatibility of the flexible device on a thin plastic substrate for in-line mass production. To reach thegoal of improved device performance , their goal, the researchers formed the charge generation layer (CGL) through a stable co-deposition of the organic p-type dopant and an n-type metal dopant in a single organic chamber. ***Tandem*** structure also has the merit of extending the lifetime of an ***OLED*** device. Tandem organic light-emitting diodes (OLEDs) have been studied to improve the long-term stability of OLEDs for 10 years. The key element in a tandem OLEDs is the charge generation layer (CGL), which provides electrons and holes to the adjacent sub-OLED units. [12]-[14].

Among different types of CGLs, n-doped electron transporting layer (ETL)/ transition metal oxide (TMO)/ hole transporting layer (HTL)), organic PN junction, organic heterojunction, Organic photovoltaic based CGL has been intensively studied. Past studies indicate that Transition metal, metal/metal kind of CGL can achieve the desired efficiency enhancement, however, its long-term stability was reported not good and sometime even poor than a single OLED. ~~T~~hese kind of CGLs can react with the n type dopant present in the adjacent ETL layers and can form complexes. So research is now shifted towards the organic heterojunction for improving the lifetime issues. [15]-[16].

IV. EXPERIMENTAL DESIGN

. In this paper, three device structures are proposed to show the effectiveness of proposed CGL. The detailed device structure is given in Table 1. The simulation is carried using Fluxim SETFOS version 4.6 In these structures the P3HT-PCBM is proposed as CGL, ITO (Indium tin oxide) as anode, MoO3 (Molybdenum Trioxide) as HTL layer, BAlq BIS(2-Methyl-8-Quinolinolato-N1,O8)-(1,1'-Biphenyl-4-Olato)aluminium as Emissive Layer, LIF(Lithium fluoride) as HTL Layer and Al (Aluminum) as cathode, Layer we connect two simple conventional OLED structures are connected with interconnecting charge generation Layer by In device B, bulk organic heterojunction of P3HT(Poly(3-hexylthiophene-2,5-diyl)-PCBM(Phenyl-C_{61}-Butyric-Acid-Methyl Ester) is used as charge generation layer. To show the efficiency of proposed CGL, another, device C is designed with combination of Al/AZO(aluminium zinc oxide)/Au(gold) (metal and metal oxide) layer ~~is~~ as CGL.

Table1: proposed layered structures of different OLED's

	Layers used
Device A	Simple OLED ITO (100)/MoO3 (10)/BAlq (20)/LIF (10)/AL(100)
Device B	Tandem Oxide Junction ITO (100)/MoO3 (10)/BAlq (20)/CSF2(10)/ Al(2)/Azo(3)/Au(15)/MoO3(10)/ BAlq (20)/CSF2(10)/Al(100)
Device C	Tandem Heterojunction ITO (100)/MoO3 (10)/BAlq (20)/LIF(10)/ P3HT-PCBM(20)/MoO3(10)/BAlq(20)/LIF(10)/Al(100)

Fig.2: layered structure of the Device A

Fig.3: Layered structure of the Device B

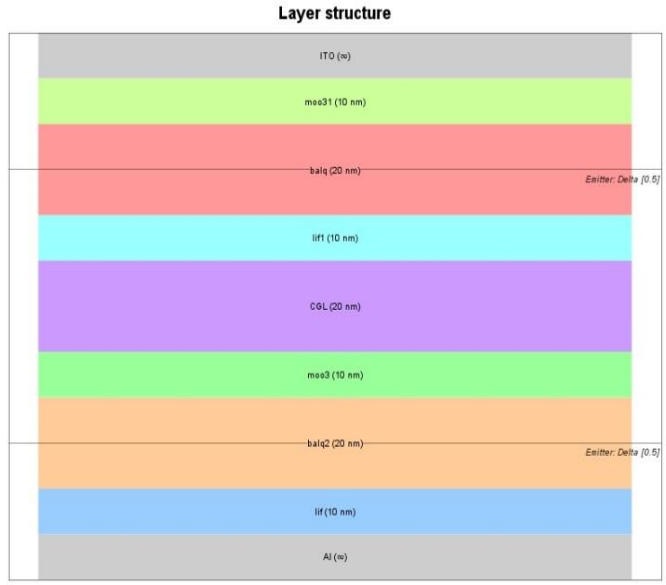

Fig.4: layered structure of Device C

V. RESULTS AND DISCUSSION

Simulations are carried out for various structures of OLED and enhancement in luminance and current efficiency Of Tandem device in contrast to conventional device can be seen as shown in Table 2. Table2 shows the results obtained from the simulation of the three device structures proposed and highest value of the current efficiency is obtained by the bulk organic heterojunction structure of P3HT-PCBM.

The results of the current efficiency and luminance of the different devices is shown in the figures given below.

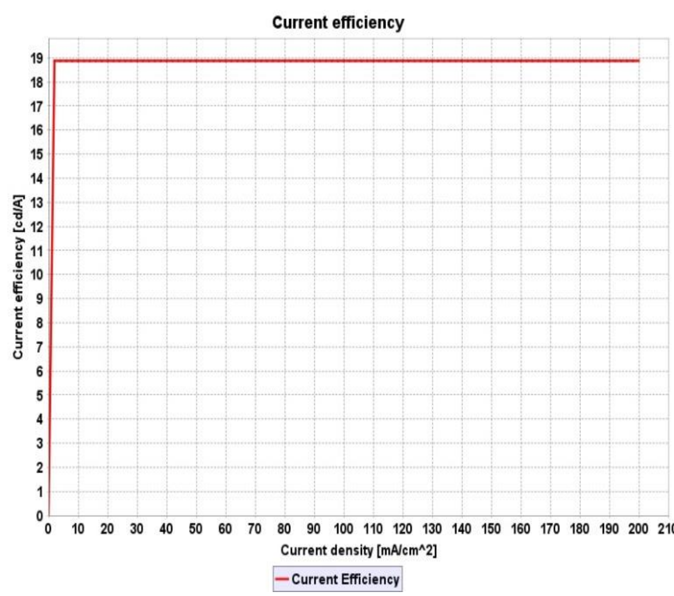

Fig.5: Current Efficiency of Device A

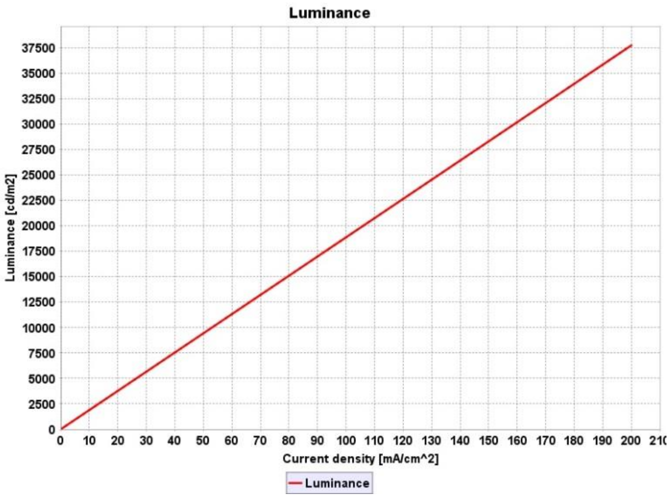

Fig.6: Luminance of Device A

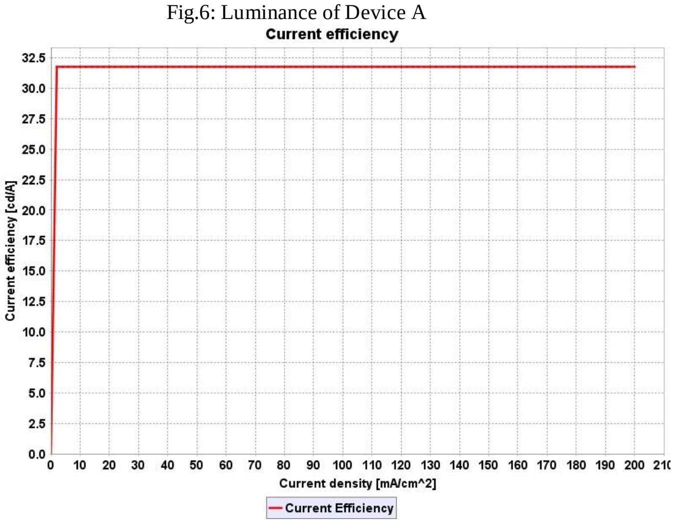

Fig.7: Current Efficiency of Device B

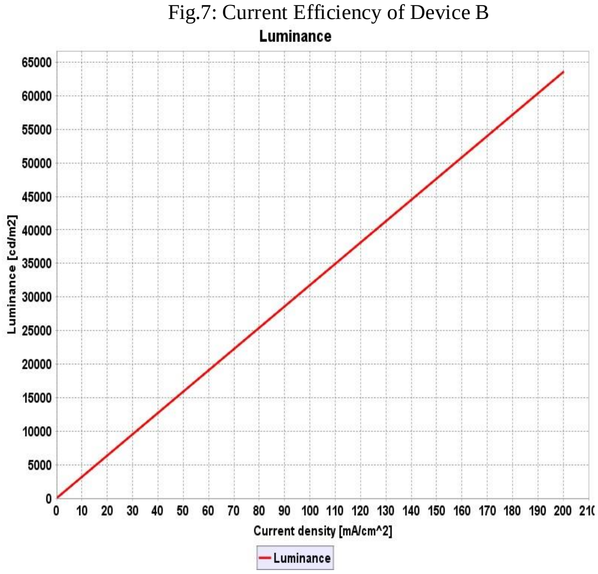

Fig.8: Luminance of Device B

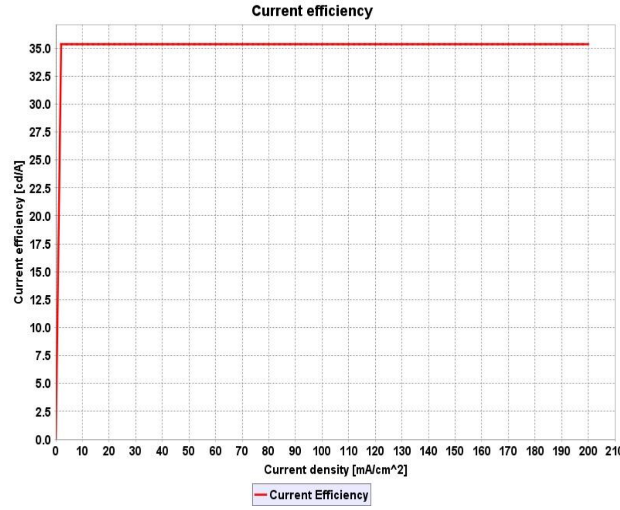

Fig.9: Current efficiency of device C

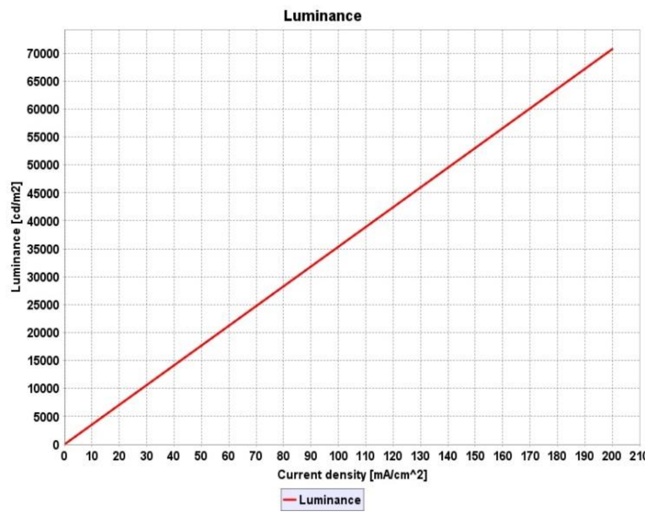

Fig.10: Luminance of device C

From the above graphs we can easily calculate the values of the current efficiency and luminance efficiency. The current efficiency of the Device A comes out to be 18.8726; Device A is the simple OLED structure having only one emissive layer. To further enhance this efficiency obtained by device A Tandem OLED structure (Device B) is used in which Al/Azo/Au (metal and metal oxide) structure is proposed as the CGL layer. Charge generation layer plays a vital role in the incrementation of the current efficiency in the tandem OLED and consists of p-doped layer and n-doped layer for the injection of the charge carriers.

The current efficiency of Device B is greater than that of the simple OLED structure; since two emissive units are used. But the current efficiency with this structure is coming out to be lesser than that of the heterojunction device because when a metal/metal oxide layers reacts with the negative charges present in the ETL layer they make complexes and thus deteriorates the performance of the structure.

Furthermore It is clear that the current efficiency of the Device C (heterojunction tandem OLED) is highest amongst the three proposed designs of OLED. This is because of the fact that the heterojunction do not make any type of complexes and provides a smooth flow of the charge carriers.

Table2: results obtained of different devices

Device	Current Efficiency (cd/A)	Luminance (lm/w)	EQE
A	18.8726	162.468	14.02%
B	31.7579	193.619	20.08%
C	35.3614	180.821	23.8%

VI. CONCLUSION

. In this paper, organic heterojunction of P3HT-PCBM is proposed as Charge generation layer . which is used to connect two electroluminescent units in the Tandem OLED. The role of the charge generation layer is to generate charges and transport these generated charges into the neighboring emissive units via the adjacent HTL and ETL which then combine with the charges generated by electrodes to form photons thus enhancing the device performance. The current efficiency and EQE of the proposed Tandem device is coming out to be 31.75 cd/A at 10 mA/cm^2 and 20.8% which is almost double as compared to the single emitter device having the current efficiency and External quantum efficiency of 18.87cd/A and 14.02% respectively.

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