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Simulation and Performance Assessment of OLED for Energy Efficient Communication Display Applications

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Abstract: OLEDs, known as organic light-emitting diodes, are a kind of technology with emitting light flat developed by inserting thin film of organic compound between two conductors, for example, a carbon dioxide on the principle of electro phosphorescence for converting electric energy into light energy in a very effective way. OLEDs technology, which is convenient for collecting more attraction of end users, is bright, lighter, thinner, more energy efficient and offers a higher contrast than liquid crystal displays. It deals with wide- angle OLEDs watches, faster response time, high contrast ratio and more saturation. The OLEDs is one of the bright lighting technologies, capable of delivering more efficient and better lighting compared to the incandescent bulbs of this fluorescent lamp. The primary goal of the work is to simulate and analyse the performance of OLEDs based on different structures and different layers, to analysis the performance of OLED by varying active layer material and to compare performance of the various OLEDs structures based on performance parameters.

Index Terms: Organic Light emitting diode (OLEDs), Multilayer, Energy Efficient, Display, Communication

I. INTRODUCTION

In the past two decades, OLED has been the most attractive research topic in the world [1]. The display of organic light emitting diodes (OLEDs) has many advantages over conventional display devices, such as high brightness, fast response time and high luminous efficiency, light weight, and most importantly low power consumption [2, 3]. An organic light emitting diode (OLED) is an electronic device consisting of one or more semiconducting organic layers interposed between two thin film conductive electrodes, one of which must be transparent. Carbon-based molecules are used in OLEDs that illuminate light as it passes through the organic layer. An OLED is an energy conversion device that converts electricity into light based on an electroluminescence phenomenon. Electroluminescence is a method of illuminating an organic material through which an electric current passes. The OLED consists of one or more semiconducting organic thin films interposed between two electrodes, one of which must be transparent. A typical OLED is shown in Figure 1. Indium tin oxide (ITO) is a high work function metal used as a cathode and is often used as a transparent anode. The device is fabricated by depositing an organic film in chronological order and then depositing a thin metal cathode defined by a shadow mask onto a transparent substrate, such as glass or flexible plastic. When an external bias is applied to the device into the organic semiconductor layer, holes and electrons are injected from the anode and the cathode, respectively. The holes and electrons in the organic layer move and recombine to form excitons. Finally, the excitons fail to illuminate and illuminate through the substrate state. "Heterogeneous structure" has become the standard practice of OLED design. Electrons and holes injected from the cathode and the anode, respectively, are collected at the heterojunction. The probability of electron-hole recombination at this organic/organic interface will increase, which results in a relatively high efficiency. This breakthrough has also attracted many chemists and engineers to focus on the further development of high-performance OLEDs. In the past two decades, efforts have been made to maximize device efficiency through the design of [4, 5] and the synthesis of new materials and device engineering [6, 8]. By using a highly efficient emitter in photoluminescence (PL), the internal quantum efficiency of the OLED is greatly increased. This work is also recognized as another milestone in the development of OLEDs. Organic light emitting diode (OLED) displays have many advantages over conventional display devices such as high brightness, high response time and high luminous efficiency, low power consumption and light weight. An organic light emitting diode (OLED) is an electronic device composed of one or more semiconductor organic layers sandwiched between two thin film conductive electrodes, one of which must be transparent. Carbon based molecules are used in OLEDs to illuminate when current is passed through them. An OLED is an energy conversion device that converts electricity into light based on an electroluminescence phenomenon [4]. Electroluminescence is a method of illuminating an organic material through which an electric current passes.

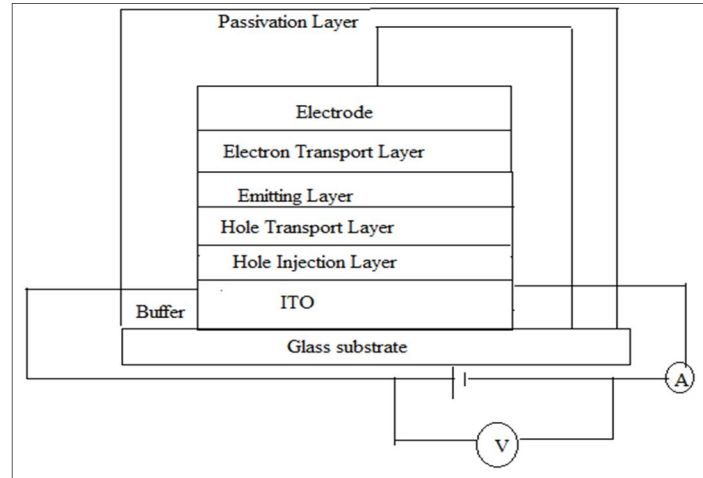


Fig 1: Multilayer OLED device structure

The following is a physical and mathematical description

$$\mu_n(E) = \mu_{n0} \exp\left(\frac{-\text{DELTAEN.PFMOB}}{KT_{\text{eff}}}\right) + \left(\frac{\text{BETAN.PFMOB}}{KT_{\text{eff}}} - \text{GAMMA.PFMOB}\right) \sqrt{|E|}$$

$$\mu_p(E) = \mu_{p0} \exp\left(\frac{-\text{DELTAEP.PFMOB}}{KT_{\text{eff}}}\right) + \left(\frac{\text{BETAP.PFMOP}}{KT_{\text{eff}}} - \text{GAMMP.PFMOP}\right) \sqrt{|E|}$$

where,

DELTAEN.PFMOB, DELTAEP.PFMOB = Activation energy at zero electric field for electrons and holes respectively.

$\mu_{n0}(E)$ = Field dependent mobility

μ_{n0} = Zero field mobility

E = Electric field

BETAN.PFMOB, BETAP.PFMOP = Electron and hole Poole-Frenkel factor respectively.

To forecast the results of OLEDs under proper boundary conditions, The Langevin recombination rate coefficient is given by

$$R_L(x, y, t) = A \text{ LANGEVIN} \frac{q[\mu_n(E) + \mu_p(E)]}{\epsilon_r \epsilon_o}$$

where,

R = rate of recombination

e = the charge of electron which is 1.6×10^{-19} ,

μ_e = Mobility of electron,

μ_h = Mobility of hole,

ϵ = Permittivity of material,

ϵ_o = Permittivity of air which is 8.85×10^{-12} F/cm.

If the logical parameter KOSTER is specified on the MODEL statement, the Langevin rate is given by:

$$R_L(x, y, t) = A \text{ LANGEVIN} \frac{q_{\min}(\mu_n \mu_p)}{\epsilon_r \epsilon_o}$$

The Langevin recombination rate is given by:

$$R_L n, p = r_L(x, y, t)(np - ni^2)$$

The fundamental equations consist of Poisson's equation, the continuity equations and the transport equations as follows

Poisson's Equation shows relation between variations in the electrostatic potential and local charge density of electrons and holes.

It is mathematically described by the following relation [7].

$$\begin{aligned} \nabla \cdot (\epsilon \nabla \psi) &= -\rho \\ \nabla \cdot (\epsilon \nabla \psi) &= -q(p - n + N_d^+ - N_a^-) \end{aligned}$$

Where, ψ = electrostatic potential

ρ = local space charge density

ϵ = local permittivity of the semiconductor (F/cm)

N_d^+ = ionized donor density(cm^{-3})

p = hole density (cm^{-3})

n = electron density (cm^{-3}) and

N_a^- = ionized acceptor density(cm^{-3}).

The reference potential is still considered to be the intrinsic Fermi potential for ATLAS simulation. To account for the trapped charge, Poisson's equations are modified by adding an additional term Q_T , representing trapped charge:

$$\nabla \cdot (\epsilon \nabla \psi) = -q (p - n + N_d^+ - N_a^-) - Q_T$$

Where $Q_T = q (N_{TD}^+ + N_{TA}^-)$. Here N_{TD}^+ and N_{TA}^- = ionized density of donor like traps and ionized density of acceptor like traps respectively. For electrons and holes, the continuity equations are defined as follows [7].

The area of the device is $10^8 \mu\text{m}^2$. Indium tin oxide (ITO) is used as anode for hole injection due to its high work function and transparency. The cathode used here is of LiF/Al as electron injection. The two-layer device contained a stack of 1-Naphdata and Alq₃ each, whereas the three-layer device consisted of a stack of 1-Naphdata, α -NPD, and Alq₃. The organic layers were inserted between ITO and LiF/Al electrodes.

II. DEVICE STRUCTURE

The proposed structures comprise of three layers stacked over one another; these layers are to be specific cathode layer, natural layer and anode layer and every one of these layers are mounted over a substrate which is utilized to help OLED. Cathode layer is stored on the highest point of dynamic layer and made up of having work 3.8 eV and it fill in as electron injection layer. Second layer is natural layer which is kept on anode and it separates as recombination layer where on use of voltage electrons from the cathode and openings from the anode recombines and in this manner prompts excitons arrangement, some of which rot radiative to the ground state by unconstrained light discharge. Proposed structure comprises of various natural layers for example (1-Naphdata)/(α -NPD)/Alq₃ Bottom most layer for example anode segment normally utilized is indium tin oxide ITO. This material is straightforward to noticeable light and is adequately conductor and has a high work (5.0 eV) which advances injection of openings into the HOMO dimension of the natural layer.

Table I. Parameters for bilayer oled

Usage	Material	Thickness(μm)
Cathode	LiF/Al	0.02
Hole Transport Layer	1-naphdata	0.06
Electron Transport Layer	Alq ₃	Variable (0.02/0.04)
Anode	ITO	0.02

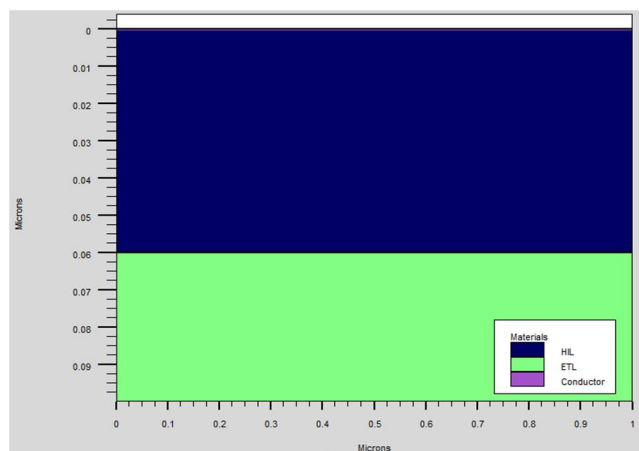


Fig. 2: Simulated structure of Device 2 (Bilayer OLED).

There are many layers in a multilayer OLED, but only one additional luminescent layer is introduced here, as shown in Fig.2. The EML layer used here is Alq3. An M1L layer is introduced in the middle of the OLED layer. In this layer, electron-hole pairs are recombined to produce photons [13]. By introducing various fluorescent and phosphorescent small molecules, the band gap energy between the HOMO and LUMO levels can be controlled [14]. The simulated structure of Device 3 is shown in Fig 3.

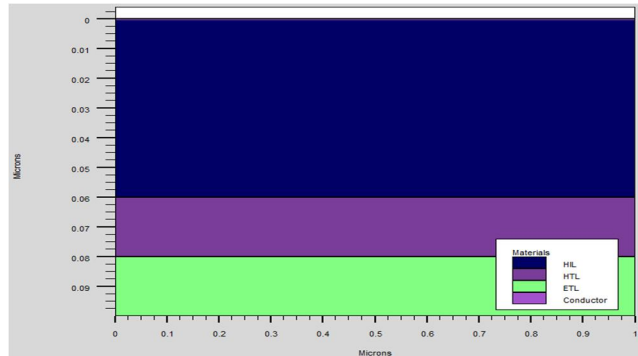


Fig.3. Simulated structure of Device 3 (Multilayer OLED)

To improve the efficiency of OLEDs the Langevin recombination model is used to predict the results under proper boundary conditions. This model visualizes the conduction due to field enhanced thermal excitation. Increase in biasing voltage improved the recombination rate.

III. SIMULATION AND RESULTS

Efficiency can be increased by adding EML (emitter layer). After manufacturing a single layer, the two-layer and three-layer OLED L-V characteristics of device structure 3 are superior to those of device 2. Due to the higher recombination rate, the three-layer structure has Low anode current but high luminescence power [10]. Higher recombination rate because the organic/organic interface reduces the energy barrier height and enhances carrier injection. The current depends on voltage and temperature. The current density should also follow The number of layers increases and increases. The rate of recombination depends on the mobility of the holes, electrons and the dielectric constant of the materials used. The recombination of carriers is the most important phenomenon in OLEDs because the light emission is completely dependent on it. By adding more layers of high dielectric constant, the recombination rate can be increased. The probability of recombination due to electrons and holes increases the likelihood of exciton formation. Therefore, the number of photons increases and the emission of light increases.

Table II. Comparative analysis of dimension of layer

Layer (OLEDs)	Luminescent Power(W/um)
Bilayer	0.008
Triple Layer @20nm	0.020
Triple Layer @40nm	0.018

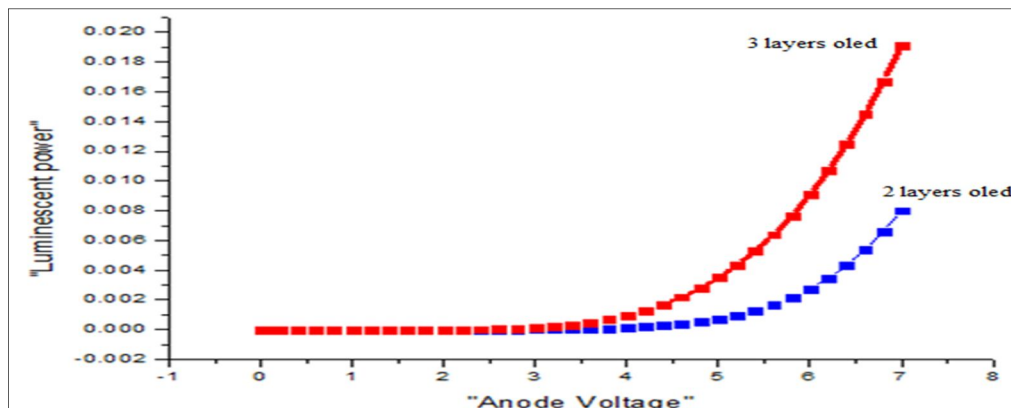


Fig 2: Comparative Analysis of Power

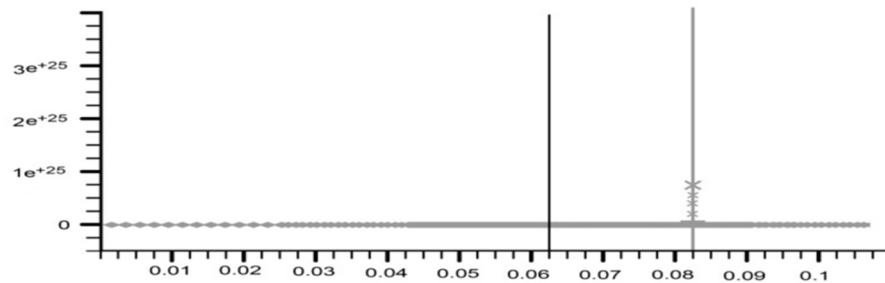


Fig 3: Comparative Analysis of Recombination rate of Device structures

In a two-layer OLED, an organic layer is interposed between the hole transport layer and the electron transport layer. ETL is added to the metal cathode and is responsible for transporting electrons from the cathode to the emissive layer (EML). The ETL used here is Alq3. The hole transport layer (HTL) used herein is 1-naphdata. The purpose of this layer is to transport holes from the luminescent layer to the anode. This must be the analog structure of the p-type semiconductor device 2 as shown.

IV. CONCLUSION

The general correlation of execution parameters communicates that the execution of proposed structure demonstrates more vitality proficient and have preferable quantum productivity over 2 layer oled. Execution assessment has been done on premise of four execution parameters which are anode current, luminescent power, effectiveness and Langevin recombination rate. It is obvious that the estimation of luminescent power of proposed multilayer oled is superior to that of structure 1. It is likewise clear that the expansion of luminescent power is conceivable because of higher estimation of Langevin recombination rate. It very well may be presumed that in spite of the estimation of anode current is higher in two layer organic LED. Because of quick increment in estimation of Langevin recombination rate the exhibitions of three layer structure have higher proficiency and higher luminescent power when contrasted with structure 1. Proposed gadget turns out to be reasonable possibility for application in foldable and adaptable hardware and advanced presentation applications because of polymer structure and better glowing effectiveness.

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