Coulomb Blockade Effects by Single Electron Tunneling Methods in Cylindrical Dual Gate OLET Configuration

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Research Article

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Abstract

In the field of nano electronics some nano-structure applications such as quantum dots (QDs), wires, wells and bulks must have distinctive potentials. These crystal structures emerged by an inorganic organic hybrid halide materials which processes in tremendous optoelectronic applications like electroluminescence, photoluminescence quantum yield (93.2%). There is a need of coupling to their surroundings by these structures which can either add or subtract electrons from the electrodes. As per state of the art the significant research efforts in about an isolated quantum dot coupling through tunneling of two leads that is source lead for supply of electrons and a drain lead for removes of electrons and their performances will be offered and discussed in the view for the realization of possible between Dual Gate Cylindrical Organic Light Emitting Transistor (OLET) architectures. In this article we examined the optical as well as electrical characteristics operation of cylindrical Dual Gate OLET (CDGOLET). Last year perovskite quantum dot (PQD) most preferred for the purpose of light-emitting transistors with high brightness of up to 1.432×10^{4} cd m^{-2}, high electron mobility's of up to 14.052 cm^{2} v^{-1} s^{-1}, and their external quantum efficiencies (EQE) of up to 1.85% operating at a source drain operating potential of 50 V.

1. Introduction

In case of an isolated quantum dot coupling method a direct current I flow with the applied voltage source drain voltage (Vds) where the electrons should be tunneled into and out of the quantum dot, which is depicted in the Fig 1.

After the applied voltage Vds in the circuit a direct current I flow in the circuit by the procedure of electron tunneling , which have a track from source electrode to quantum dot and from quantum dot to drain electrode, thus as per ohm's law we have to get the value of R (resistance) in the circuit.

As per ohm's law V = I R

COULOMB BLOCKADE EFFECT

The transportation of electrons is blocked at very low voltages in case of quantum dot single tunneling electron analysis. This situation is called as coulomb blockade effects. It means that the value of resistance R is not regulating in the circuits. Now to regulate the resistance value across the circuit, one of an additional circuit should be imposed within the circuit, which is termed as two capacitor coupled gate-terminal, where each have a applied potential is Vg, which is shown below in the Fig 2 [1-5].The major function of the gate electrode to controlling or regulating the value of resistance R across the circuit for the active region of the quantum dot and consequently opened the blockade effects of the circuit thus the current I flow between the source and the drain terminals [6].

This device as per named as the dual gate voltage controlled transistor. Here both of Cg with Vg is known as capacitor coupled gate terminal voltage. Thus the values of capacitor depend upon the dimension or

shape of their quantum dot. For examples the spherical as well as the disk shaped quantum dots whose radius is r each have a different capacitances, which are as follows,

C= 4 π €0 r [€ / €0] ——[for sphere] (1)

C= 8 €0 r [€ / €0] ———[for disk] (2)

Where €0 = 8.854 × 10^{-12} F/m is the dielectric constant of free space and [€ / €0] is the unit less parameter of dielectric constant of the dissimilar semiconducting material that are utilize in the formation of quantum dot. For example the spherical shape quantum dot material GaAs have a very small Capacitance value C = 1.47 × 10^{-18} r F whose dimension-less dielectric constant for GaAs is [€ / €0] = 13.2.When a single electron is either added or subtracted, then the electrostatic energy E for a spherical capacitor whose charge Q should be changed by the amount of ΔE = eQ/C, so the changing value of the potential

$\Delta V = \Delta E/Q$

Since we know that ΔE = eQ/C, then

$\Delta V = e/C = 0.109$ Volts (3)

In case of one by one tunneling of electrons this value of ΔV is quite enough. So, that the charge transfer of the single valued electron to a quantum dot, where to observing its distinct nature, two quantum state must be fulfilled [7,8].

1. By the product of the time constant □ = RTC with capacitor energy $e^2/2C$ which requiredfor changing the capacitor value, the Heisenberg uncertainty principles must be fulfilled for

ΔE . Δt = ($e^2/2C$) (RTC) □ h (4)

Where RT is the tunneling resistance during blockade potential barrier.

2. The charging energy of single electron capacitor should be $e^2/2C$ □ kBT ; kBT is ThermalEnergy which acquired from arbitrary vibration of the atoms.

Thus these two conditions combindly may be written as

$e^2/2C$ □ □ kBT (5)

RT □ □ h/e^2 (6)

1.2 V-I CHARACTERISTICS OF SINGLE ELECTRON TUNNELING

By this value of equation (3), its define that the value of current increases as the value of Voltage changes, which is illustrated in the Fig 3.

This graph between I/V is called as the coulomb blockade, the reason behind this are the electrons should become blocked from tunneling apart from the distinct voltage change positions. In the characteristics of Figure 3 the A graph is measured by single tunneling microscope (STM) [9] method and B,C graph is measured by theoretical simulation. The I-V graph (3) is called as coulomb staircase because of concerning in a coulomb charging energy ie:, $e^2/2C$ which is depicted in equation (5). Au55 nanoparticle which arranged in a FCC having diameter 1.432 nm are the best example of single electron tunneling. An insulating coating of cluster 55 gold atoms is called a ligand shell whose thickness is only 0.712 nm [10]. The feasibility of single electron tunneling are possible between any of these two Au55 ligand shell when they are contact in a cluster. That is illustrated in Fig 4 below.

As per Figure 4 it is defined that there are one to six numbers of ligand shell which are working as a quantum dot, where every part have their inter-particle resistance RT =100 MΩ and inter- particle capacitance Cmicro = 10^{-8} F was estimated.

2. Transportation Via Quantum Dots And Osc Channel In Single Gate And Dual Gate Cylindrical Olet

In case of single gate cylindrical OLET the feasibility of single electron tunneling with the help of quantum dots should be possible in one channel only, but in case of dual gate cylindrical OLET the feasibility of single electron tunneling with the help of quantum dots should be possible in more than one channel [11,12]. In spite of this in both of the cases we can design extra channel of OSC for the transportation of holes and electrons, which is depicted below in Fig 5 (a) and (b). It will operated more faster and feasible than the fabrication with only single channel of OSC. Single electron tunneling methods are more suitable and little bit compact, which we can design it with OSC channel in the future [13-16]. This is my new research part in this paper.

2.1 ANALYTICAL MODELING AND CHARACTERISTICS OF DUAL GATE CYLINDRICALOLET

The dual gate cylindrical OLET architecture has been defined by Figure 6, which also explains in about the greater area of recombination zone, from where light should be emitted after reacting of holes and electrons via two channels of quantum dots layer and OSC layer. The analytical modeling of Dual Gate Cylindrical OLET has been derived by firstly considering a cross section of it, which is illustrated in the Fig 6 here, where one of its side of cross section are clearly shown in the dual gate cylindrical OLET [17-22].

The inner gate radius is a and diameter is 2a The outer gate radius is b and diameter is 2b The drain width is d

The thickness of source and drain is t

The length of the channel of quantum dots as well as OSC both are L

$C2 = €2 / b \ln (b/a)$

; a = inner gate radius or inner insulator radius b = outer gate radius or outer insulator radius

€2 = Dielectric permittivity = 3 €0

€0 = 8.854×10^{-12} F/m^2

Channel width Z = 2πd Channel length = L

Now by derivation we calculate the linear drain current are as follows- $Id\ lin = (Z\mu C2 / L) [(Vgb-Vga-Vth) Vd - 1/2\ Vd^2]$

$Id\ lin = [2\pi d\ \mu €2 / bL \ln (b/a)] [(Vgb-Vga-Vth) Vd - 1/2\ Vd^2]$

$Id\ lin = [2\pi d\ \mu €2 / bL \ln (b/a)] [(Vgb-Vga-Vth) (Vd-Rs \times Id) - 1/2 (Vd-Rs \times Id)^2]$

; Vgb–Vga = Difference between outer and inner gate voltage, Vd = Drain voltage,

Vth = Threshold voltage,

μ = Mobility of the materials, Rs = contact resistance

The value of saturation drain current are as follows- $Id\ sat = (Z\mu C2 / L) [(Vgb-Vga-Vth)]^2$

3. Result And Discussion

Firstly we have to design to one of the OLED which have a different electrode as well as dielectric materials with TCAD simulation method and to find out their output characteristics, Recombination Rate, light emitting luminescent power and their current density on behalf of electric fields and doping for uniformity. Now on the same patterns we have to design and consideration of our OLET with dissimilar materials. The characteristics of the dual gate cylindrical OLET describes that, as the value of drain voltage Vds becomes more and more positive or increase then on the same aspect the value of drain current Ids should also become more positive or increase. After certain increment of Vds now the value of Ids should become on saturation level ie:, called as a Ids sat with rating in μA. The output characteristics of dual gate cylindrical OLET are illustrated in the Fig 7 below.

As per simulation patterns we have to change the thickness of MEH-PPV, ITO etc materials and we have to get the proper simulation value of OLED as well as OLET. On behalf of TCAD simulation programming we have to plot these four appropriate characteristics of recombination rate of different materials in Fig 8, output characteristics between Ids and Vds in Fig 9, light luminescent emitting power from the

recombination zone in Fig 10, current density Vs electric field of MEH-PPV in the Fig 11and lastly donor state energy Vs donor state density Fig 12. These all are shown below.

As per quantum dot analysis the single electron should be tunneled one by one through the channel of dual gate cylindrical OLET. Another channel is also there, that one is OSC channel. So by these two channels we can transport our electrons and holes with smoothly and efficiently. To avoidance the coulomb blockade effects, we should always take the enhanced value of drain voltage i.e. more positive, due to this it produce more drain current Ids through our cylindrical OLET. We have described these all matter in our characteristics of MEH-PPV which we have used for making of cylindrical DGOLET. Since there are two channels of transportations so, there should be also two numbers of recombination zones, where electrons and holes after reacted should be emitted more amount of light. For proper smoothness in reactions the quantum dots should be arranged in a ligand shell form. Here quantum dots utilized as an Au55 nanoparticle which arranged in a FCC form. These two channels of quantum dots and OSC are creating more and more recombination zone for the criteria of electroluminescence, so that more light should be glow from there as per OLED simulation prescription and in spite of that also describes the transfer characteristics of the dual gate cylindrical OLET. In future the dots can be also converted in wire, wells or bulks form of designing.

4. Conclusion

We conclude that the two basic things, first one to obey coulomb blockade effects principles for efficient operation of cylindrical DGOLET transistor with proper transportation, recombination, producing higher drain current and emitting more amount of light from the dual channels of recombination zones. Second things the compact designing of a single gate with the help of simulation, to get its proper output characteristics, recombination rate as well as luminescent emitting power and these all of the qualities we have to constructed for dual gate cylindrical OLET. As per our knowledge such type of quantum dots as an emissive layer first time constitutes in OLET application. Optimized value of one of perovskite QD OLETs material like Alq3 produced high brightness of up to 1.432×10^{4} cd m^{-2} , high value of electron mobility i.e.; up to 14.052 cm^{2} v^{-1} s^{-1}, and EQEs of up to 1.85% at 50 V (Vds) source drain voltage.

Declarations

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contribution

Authors have made substantial contributions to the conception and design, or acquisition of data, or analysis and interpretation of data; have been involved in drafting the manuscript or revising it critically for important intellectual content; and have given final approval of the version to be published. Author has participated sufficiently in the work to take public responsibility for appropriate portions of the content. Author read and approved the final manuscript.

Availability of data and material

The data and material are available within the manuscript.

Compliance with ethical standards

The author declares that all procedures followed were in accordance with the ethical standards.

Consent to participate

Author declare their consent to participate in this research article.

Consent for Publication

Author declare their consent for publication of the article on acceptance.

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Figures

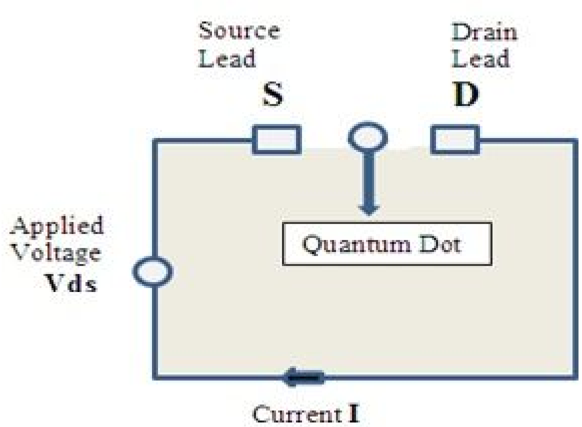

Figure 1

External Circuit of Quantum dot coupling through source and drain leads

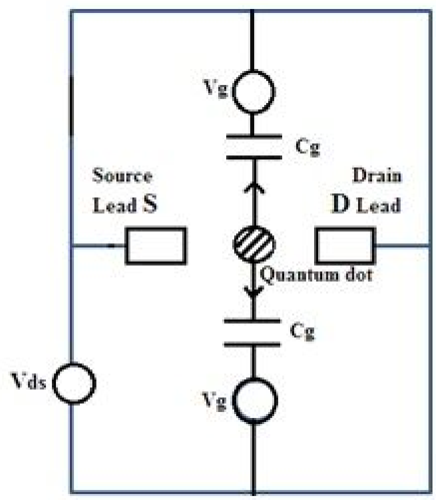

Figure 2

Quantum dot coupling transistor with two additional capacitor coupled gate terminal

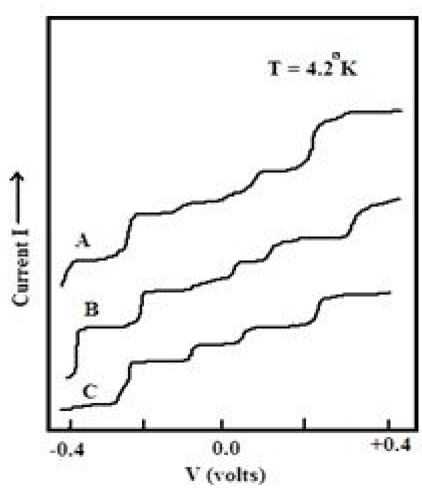

Figure 3

Coulomb Staircase containing by single electron tunneling in a V-I Characteristics plot.

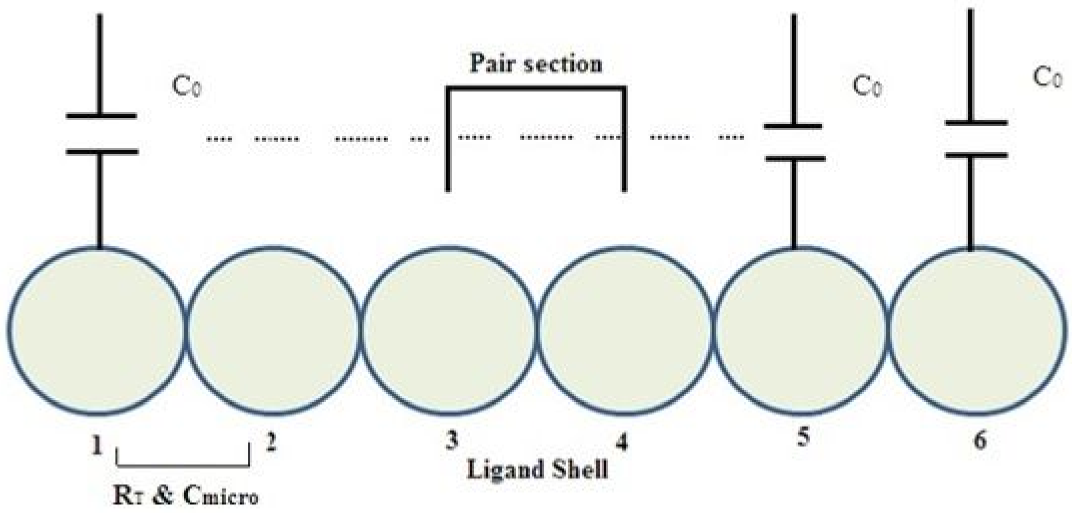

Figure 4

Au55 ligand stabilization with inter particle resistance RT with inter particle capacitance Cmicro and self-capacitances C0

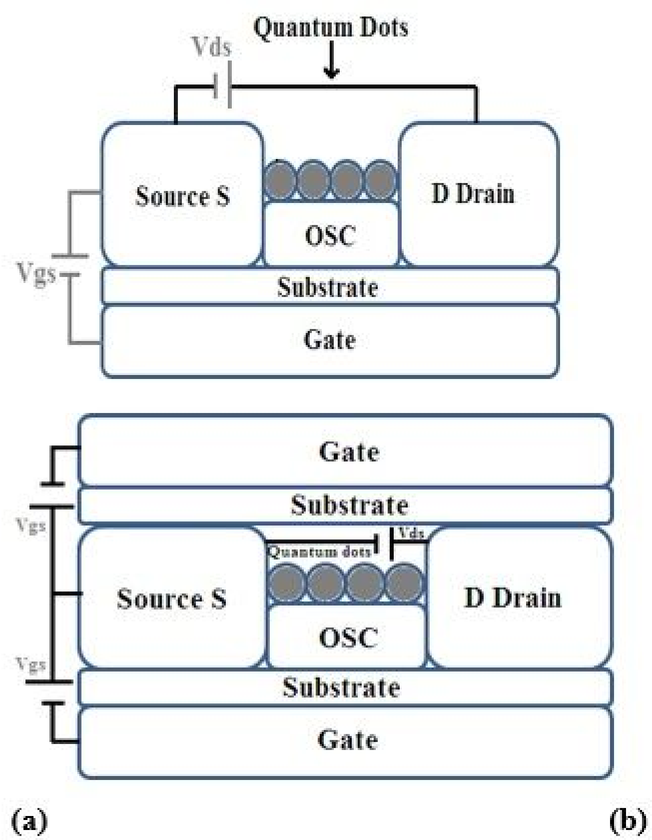

Figure 5

Transportation of holes and electrons Via Quantum Dots and OSC Channel in (a) single Gate and (b) Dual Gate Cylindrical OLET

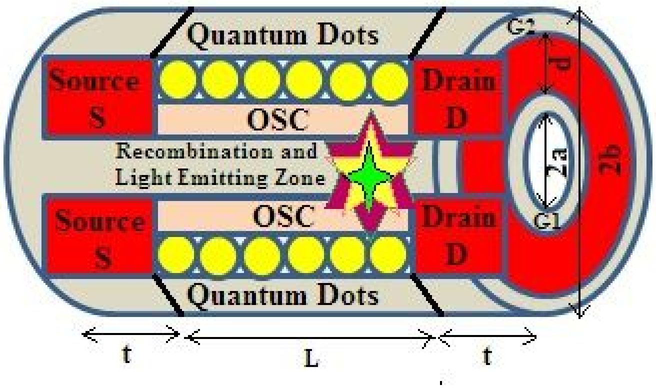

Figure 6

Cross sectional as well as graphical view of Dual Gate Cylindrical OLET Suppose the outer gate capacitance defined by C2.

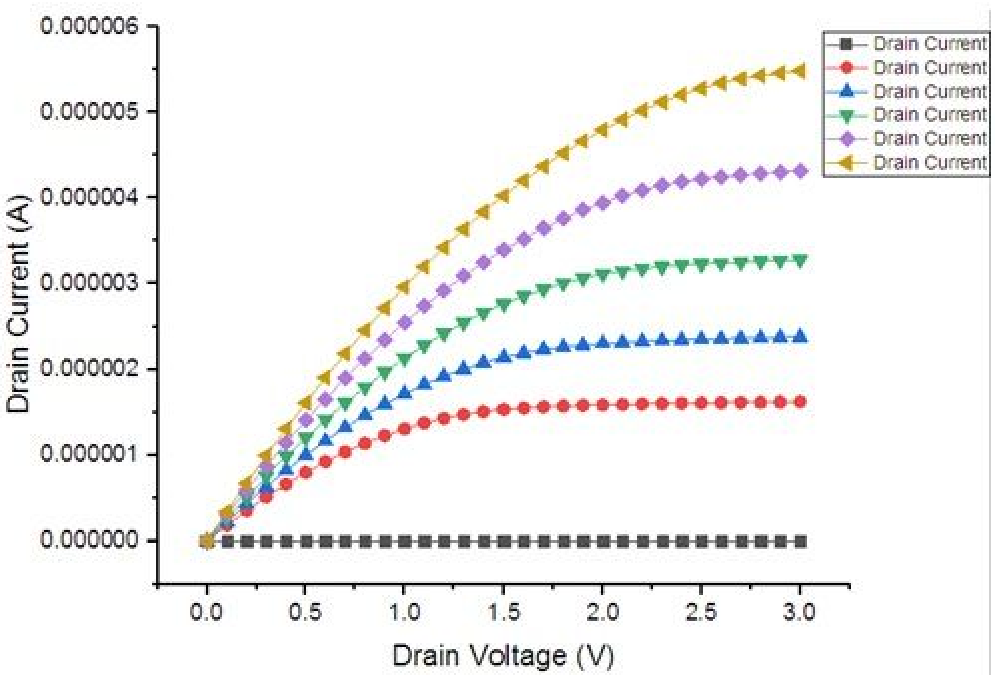

Figure 7

Output characteristics of dual gate cylindrical OLET

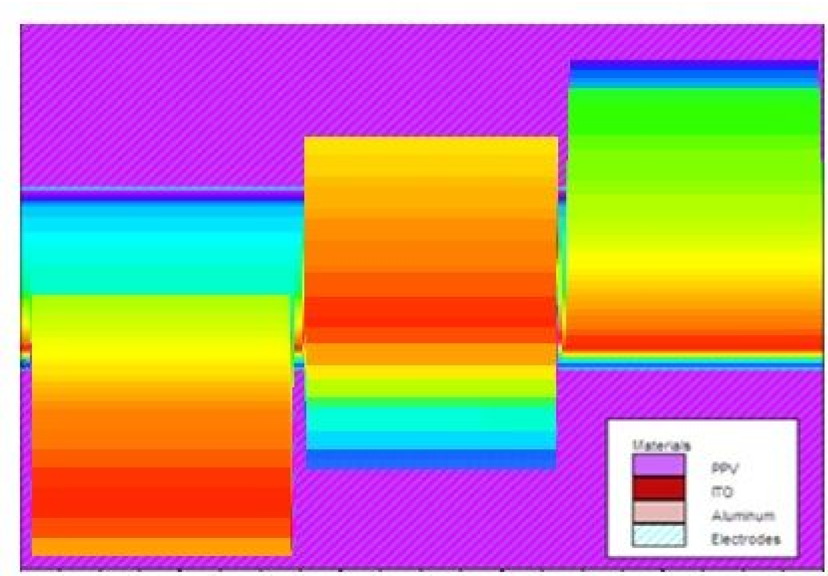

Figure 8

Recombination Rate of MEH-PPV at 10V Anode voltage

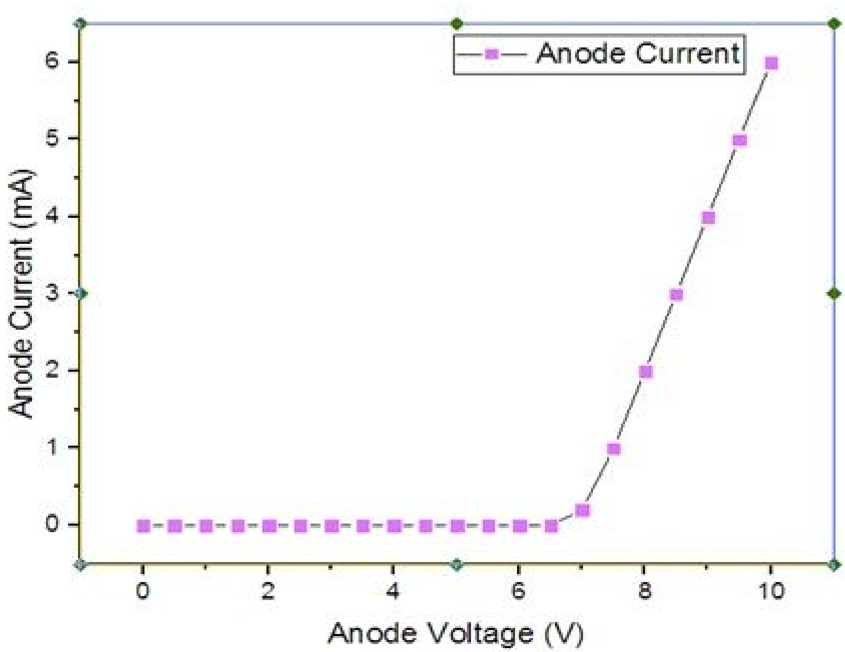

Figure 9

Output Characteristics of MEH-PPV (Anode Biasing VS Anode Current)

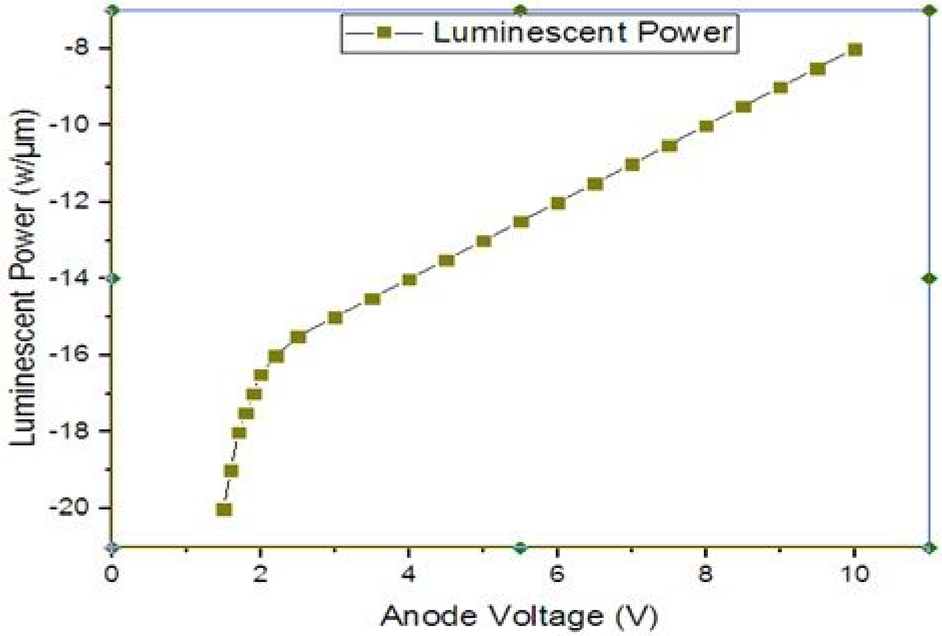

Figure 10

Light Emitting Luminescent Power of MEH-PPV

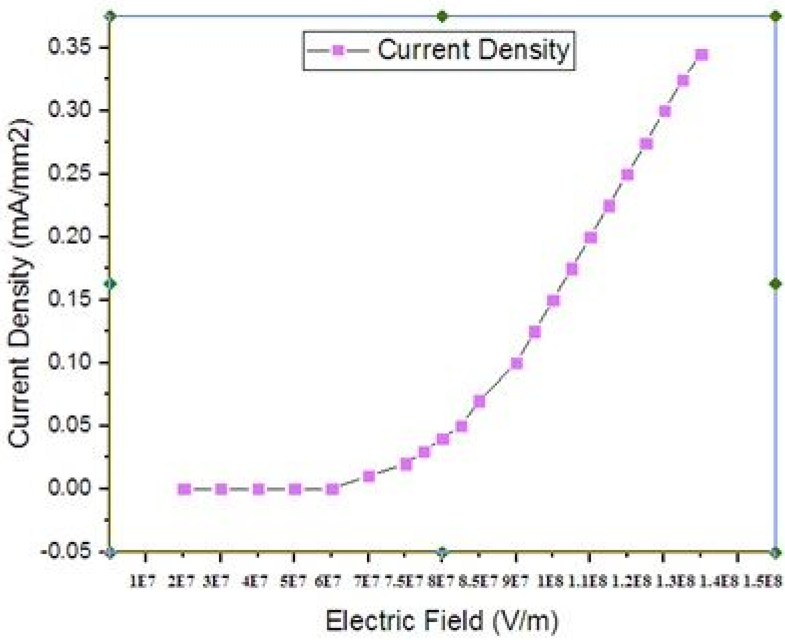

Figure 11

Current Density Vs Electric Field Characteristics of MEH-PPV

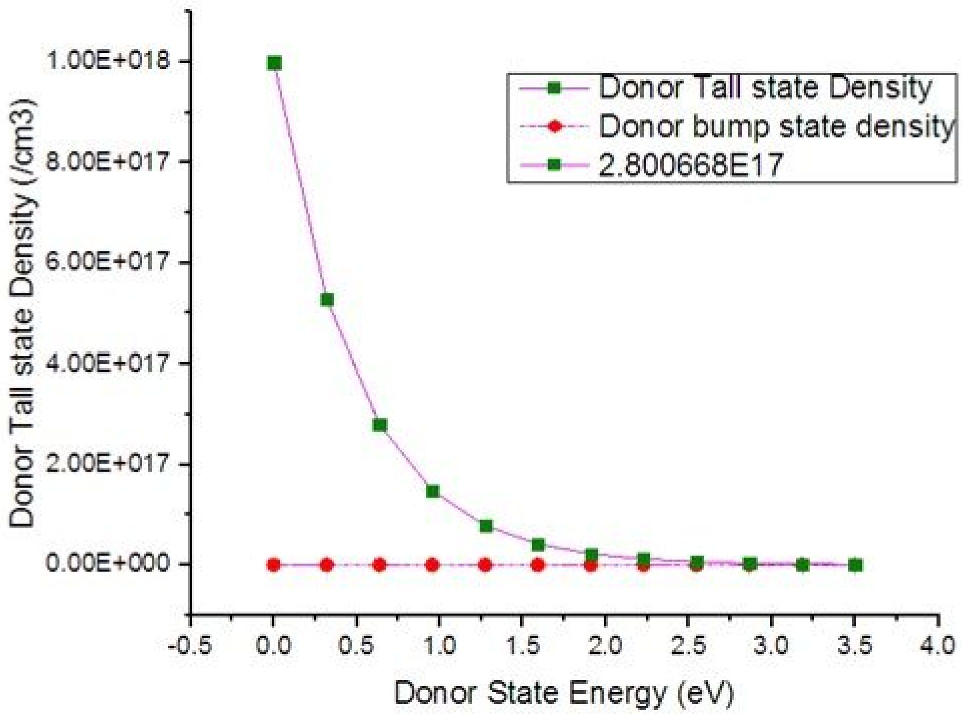

Figure 12

Donor State Energy Vs Donor State Density of MEH-PPV