High-Performance Materials Based on Organic Light-Emitting Transistor (OLET)

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Research Article

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Abstract

As per industrial environment the devices which made by the organic molecule based materials most preferred current time. Its behavior and OLET characteristics which are bi-functional in nature are fully related to the concerned materials which are utilizes for electrode, OSC, gate, as well as source and drain. These parameters are also defined how its cost should be minimize and made more and more flexible in nature. It will generate more commercialized devices that are too much demanding in current scenario. The OLET behavior are of bi-functional in nature, because its operations on two principles, the first one working as a transistor and the second one emission of light also. This paper also tells us that, the analysis of different types of high performing materials, their performances with the threshold voltages which are utilizing for designing of OLET layers. Our major concerned towards the material selections for designing of layer rather than structure of OLET. The reliability of materials which perform better in response and to improve the potentials of OLET is our main indication in this analysis.

Introduction

In last decades organic optoelectronic devices like organic light emitting diode (OLED) and organic light emitting transistor (OLET) are fully commercialized on the basis of its optical and magnetic materialistic properties, which were used for the manufacturing of devices. Similarly, another kind of organic electronic module like, organic field-effect transistors (OFETs)(1) is also working in the tentative as well as experimental phase. The OLET works on the two principal, first one is OFET and second one is OLED. The electrical switching part we will collect from OFET and the light emitting part from OLED. In case of OLED a too much thin emissive layer of 80-100 nm, where the electrons as well as holes materials are sandwiched in between their two separated electrodes, there-off electrically forced into the organic lasers (2-5). The OLET and OLED both have the potential to streamline the construction of the optoelectronic communications. Whereas in OLET devices, the source and drain electrodes inserted the electrons as well as holes which are recombine into the passes or transport channel which are nearly between 5–95 μm long. As per our requirements we have to utilize it as a electron transport layer (ETL) and holes transport layer (HTL) for getting highest recombination and emission of more and more light.

In case of ideal condition of light emission of organic semiconducting materials like, oligomers and polymers in general purpose tetracene and pentacene used for its designing, because they all have some exact value of energy, which is to reduce their charge injection-barrier where metal have contacts. The ambipolar, where high mobility rate of charge carrier certify that, the light should be emitted at the center point of the channel with high fluorescence (6-9). The OLED structures like Nano scale and micro cavities which operating at lower voltage and higher dielectric constant material, where photon conversion to attain sufficient number of excitons. These structures design should be further applied in OLETs. To achieve the sufficient number of conversion process of exciton-to-photon that are known as external quantum efficiency (EQE), where the optoelectronic processes should be stable on all of the above parameters.

Design And Working Strategy Of Olets

The first BGTC single layer field effect transistor device structure fabricated by Hepp and his co-workers in the year 2003 with the help of an oligomer molecule like tetracene (30). This devices of FET was p-type unipolar in nature with its hole mobility of 5.0×10^{-2} cm^2 /V s. Unipolar (10,11) it means that all electrodes made with the same type of materials. It was first time observed that, during operation the emission of light were originating towards the drain electrode, but now in current days with the help of doping we have to focus and centralize its a emission of light towards the center.

As per Vgs (gate to source voltage) and Vds (drain to source voltage) increased then the photocurrent should also be increased more and more. The maximum spectral emission bandwidth of tetracene's photoluminescence (12) for higher value of photocurrent getting was at 500.0 to 540.0 nm. The characteristics become fully saturated when we provide more negative voltages ie; over -50 Vds. When Vgs provide more and more positive voltages, then maximum number of holes should be generated from the source and passes through the channel of tetracene / pentacene (13-16) and recombined with the tunneled electrons, which ejected from the drain terminal and finally reach this emitted light in the recombination zone, which is illustrated in the Figure 1(a) and Tetracene or Pentacene which uses in the OSC channel, their images in Figure 1(b).

Multilayer Olets

Recently it's a challenging to design a extremely high emissive those materials which also implicit a great electrical properties. This problem can be eliminating by using Multilayer OLET devices. The P type and n type both fluorescent emission of light achieved in case of ambipolar (17-25) OLET. Ambipolar OLETs are those where all the electrodes made with different types of materials. Due to this a bulk hetero junction films achieved which is shown in the below Figure 2. also an extreme range of control in both their electroluminescent intensity and charge mobility(21). Sirringhaus and their co-workers proposed a design of lateral hetero structure, where the high ambipolar charge mobility with high tunable recombination zone was achieved (28). In these OLET their high EQE was 1.3% and nominal material degradation were achieved. In Multilayer devices each and every layer have a separate optimization level for their each components of charge injecting, charging transporting and its emission of fluorescent light illustrated in Figure 2. Bazan and co-workers designed multilayer OLET devices (29) selected a series of fluorescent polymers such as poly[2-methoxy5-(2'-ethyhexyloxy-1,4-phenylenevinylene)] (MEH-PPV) (30), super yellow (SY), and poly[9,9-di(ethylhexyl)fluorene] (PFO) as the emissive layers. Here all layers made with organic polymers and produce lesser rating of florescence than hydro materials.

Results And Discussion

(a) Higher EQE Rating

Now for getting higher values of florescence as well as recombination rate, we have to use hydro materials like MEH-PPV (organic) and aluminum (inorganic), the recombination rate of MEH-PPV with aluminum at 10 V anodes illustrated in the Figure 2.

To simplify the electron injection process, a conjugated PMMA with aluminum was inserted between the emissive layer and the source-drain electrodes. The relocation of ions and their dipoles are effectively modified and decreased the interfacial energy. Further, to certify a good charge transportation in OLET devices, a hole transport layer (HTL) was implanted between the emissive layer and the gate dielectric. Due to this the hole can be directly inserted into HOMO of PMMA and transported towards the drain electrode, where electron can be inserted into the LUMO of emissive layer. They are radiatively recombined to each other near drain electrode and emission of light observed.

The higher value of emission efficiency and their carrier mobility's are more efficient for effective way of light emission from the transistor, here PMMA have smaller concentration of holes than larger concentration of electrons in Aluminum, so that the EQE rating becomes 1.3%. If we equate the holes concentrations of PMMA exactly equals to the electrons concentrations of Aluminum then the value of EQE has to become just 3 times (3.6%) larger than the earlier. Such type of high recombination rate in terms of EQE and the images of tetracene and pentacene are illustrated in the Figure 3.

We have to get the values of Electron Quantum Efficiency (EQE) rating becomes higher one by one after using of higher doping concentration of holes (PMMA) into aluminum (in terms of thickness), which we have to discussed earlier. Its pie diagram and linear characteristic are depicted in Figure 4.(a) and (b).

(b) Material selection to improve the potential of OLETs

Because of metal drain electrode the emission of light provides a significant level of quenching effect. As per energy band diagram, there are two parameters ie;, HOMO and LUMO (21-27). Where, HOMO stands for highest occupied molecular orbit and LUMO stands for lowest unoccupied molecular orbit. In case of tetracene the HOMO which preferred for hole injection only, its value is (-5.20 eV) and the LUMO value becomes (-2.20 eV). Therefore in my analysis for OLET devices, the tetracene BGTC with single crystal layer provide much better responses than pentacene with ETL and HTL layers. Earlier for light emission we have to choose PMMA with Aluminum, but now for better transfer as well as output characteristics of OLET we have to choose the PMMA as a gate (G) electrode material and gold (Au) as a source (S) and drain (D) electrode materials. In spite of tetracene or pentacene by means of a OSC materials, there are two more layers that are HTL (Holes Transport Layer) and ETL (Electrons Transport Layer).

In case of organic light emitting transistors (OLETs) the contact effects can be examined by using parameter analysis and extraction are obtained by electrical characteristics of the device. The linear regime channel mobility in the bottom-gate top-contact (BGTC) pentacene (31-33) can be evaluated by its active layers of dissimilar thicknesses with contact-doped layers prepared by ETL and HTL of pentacene. The extracted parts of parameters suggested that the contact-doping trials give rise to becomes more prominent with enhancement in the channel mobility with their larger thickness of active-layer. Same experiments we have also performed with Tetracene OSC materials and to get its characteristics. Now to correlate these characteristics of OLET with pentacene and OLET with tetracene. Its behavioral design and their characteristics are depicted in figure 5 (a) (b) (c) and 6 (a) (b) (c).

The input characteristics states that the transistor operats at higher value of threshold voltage and its output characteristics is also predicting in about its non saturation level.

It is clear that tetracene channel performance is too much better than pentacene. The final analysis and extraction confirms in about our results and their proposed methodology. On this basis, we can investigate that, how the different types of organic materials used for better performance of OLET, their extraction of parameters and their various characteristics.

Experimental Section

As shown in the Figure 5.(a) (b) (c) and Figure 6.(a) (b) (c) the width of pentacene and tetracene are 400 nm. Gold (Au) width in both source and drain are 400 nm, ETL width is 50 nm and HTL width is 150 nm. Hole mobility (μ_h) is of 5.0×10^{-2} cm^2 /V s. EQE rating before doping is 1.3 % and after doping 3.6%. Between PMMA and Al, MEH-PPV was used as a HTL-ETL.

Conclusion

There has been made tremendous progress in previous ten to fifteen years in case of designing of OLETs. But still now some serious and necessities issues are also focused : (1) As compare to OLED, OLET have a lesser EQE value, (2) In case of Multilayer OLET electroluminescence mechanism are not clear.In the future work, the ambipolar multilayer cylindrical/ vertical OLET may overcome the restrictions of modern organic luminescent materials. Furthermore, the utilization of hybrid devices with high mobility of inorganic semiconductors material, like carbon nanotube (CNT), perovskite, or graphene, which work as the transporting layer may be it become a possible substitute and improve the OLET performance. In the meantime, the growth of proficient dielectrics with their high dielectric constant value may be minimizing their optical and electrical threshold voltages and in future it realize efficient low-power devices. The supplementary functional parts in OLETs may also excite in new era.

Declarations

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This work did not receive a financial support.

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 declare 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

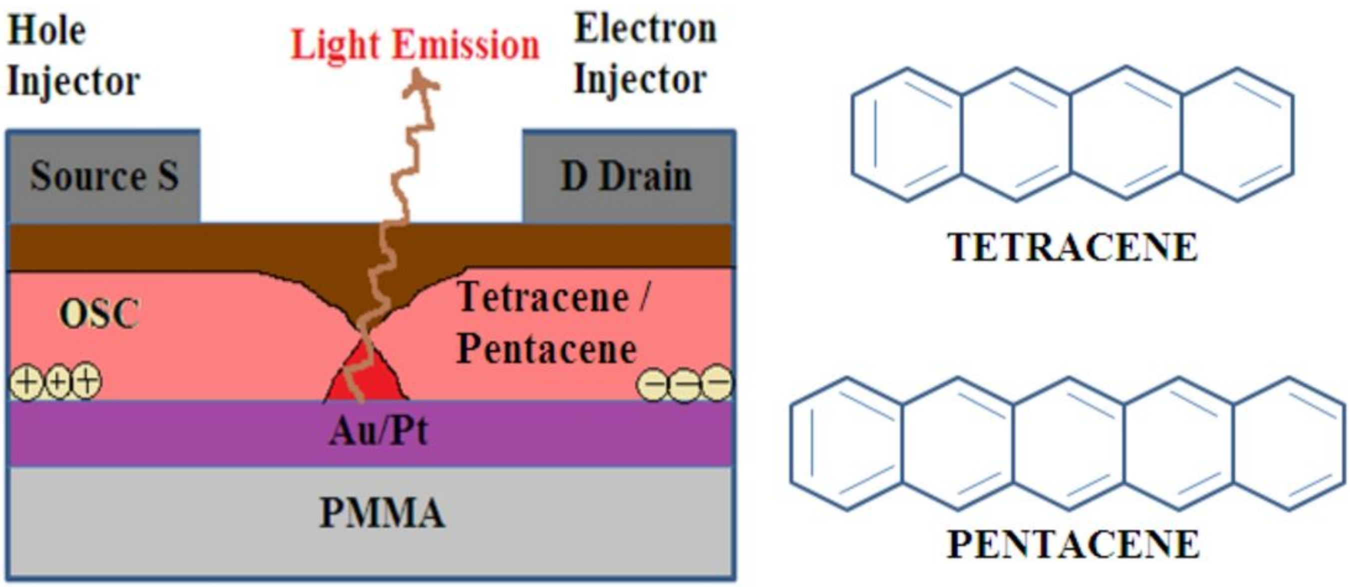


Figure 1

(a) Emission of light from the recombination zone (b) Tetracene and Pentacene Image

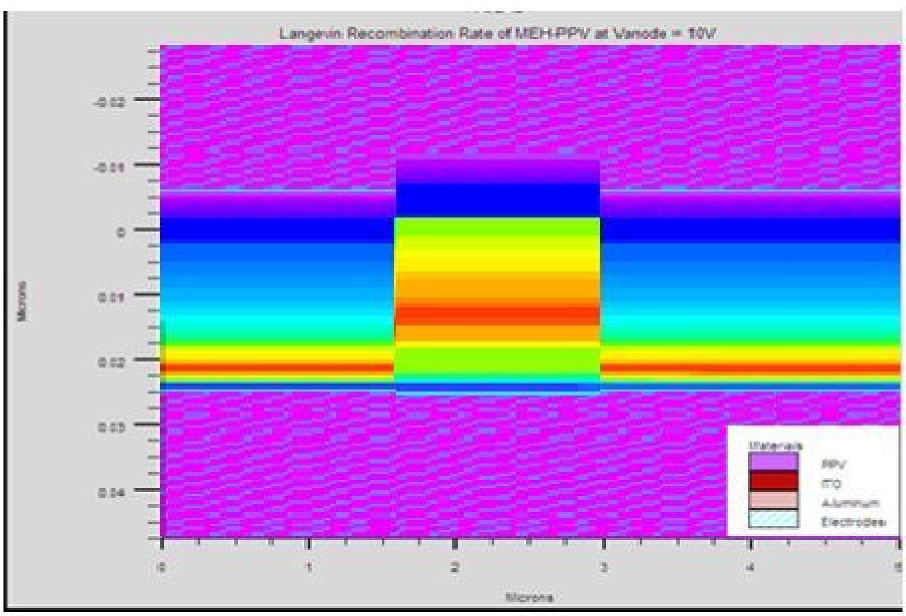


Figure 2

Highest recombination rate of MEH-PPV at midpoint which works as a ETL and HTL

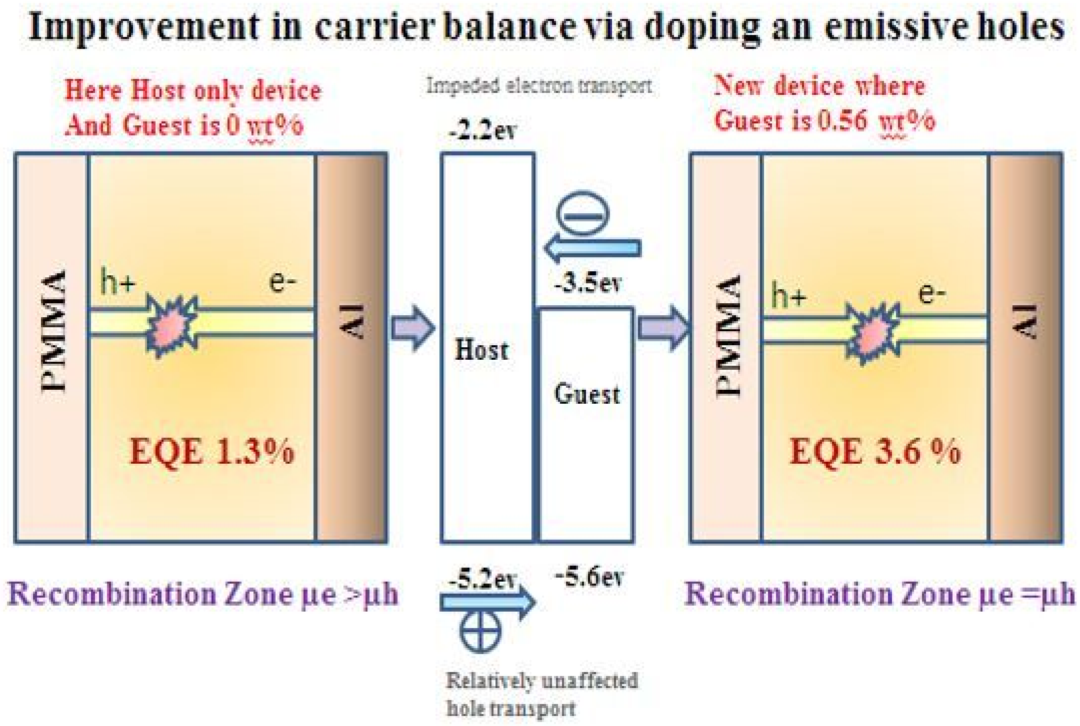
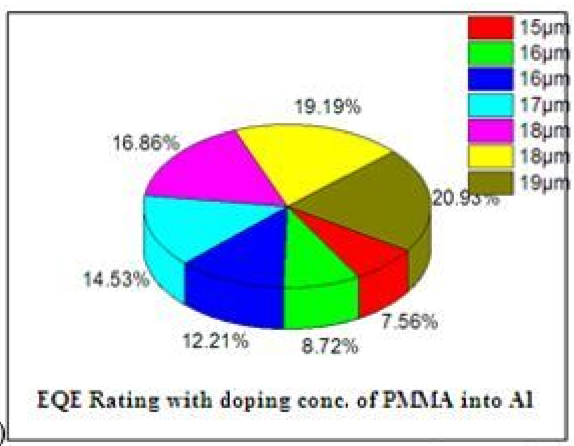


Figure 3

Improvement of recombination rate between two electrodes.

(a)



(b)

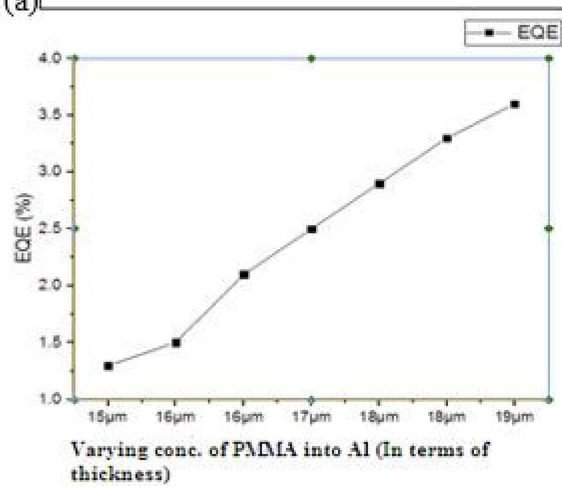


Figure 4

(a) Pie diagram of EQE Rating with doping conc. of PMMA into Al (b) Varying conc.of PMMA into Al (in terms of thickness)

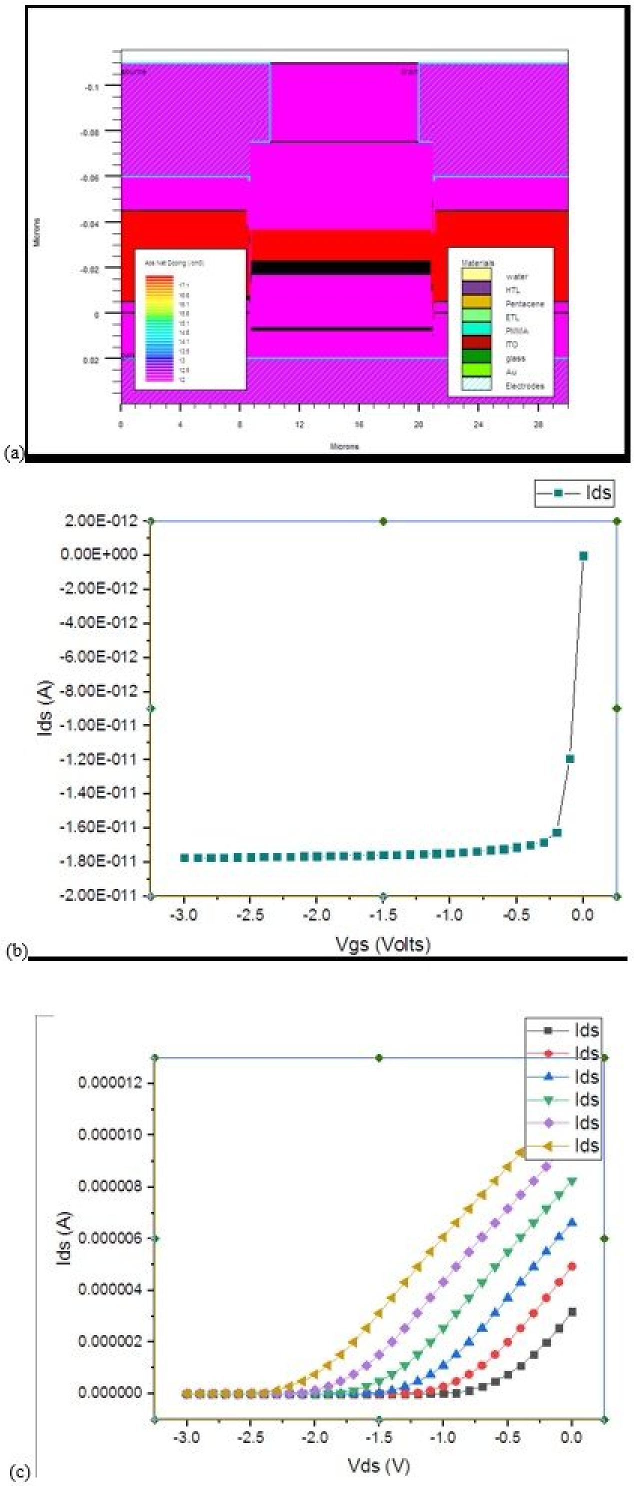


Figure 5

(a) OLET structure with Pentacene as a OSC materials (b) Vgs Vs Ids Characteristics (c) Vds Vs Ids Characteristics

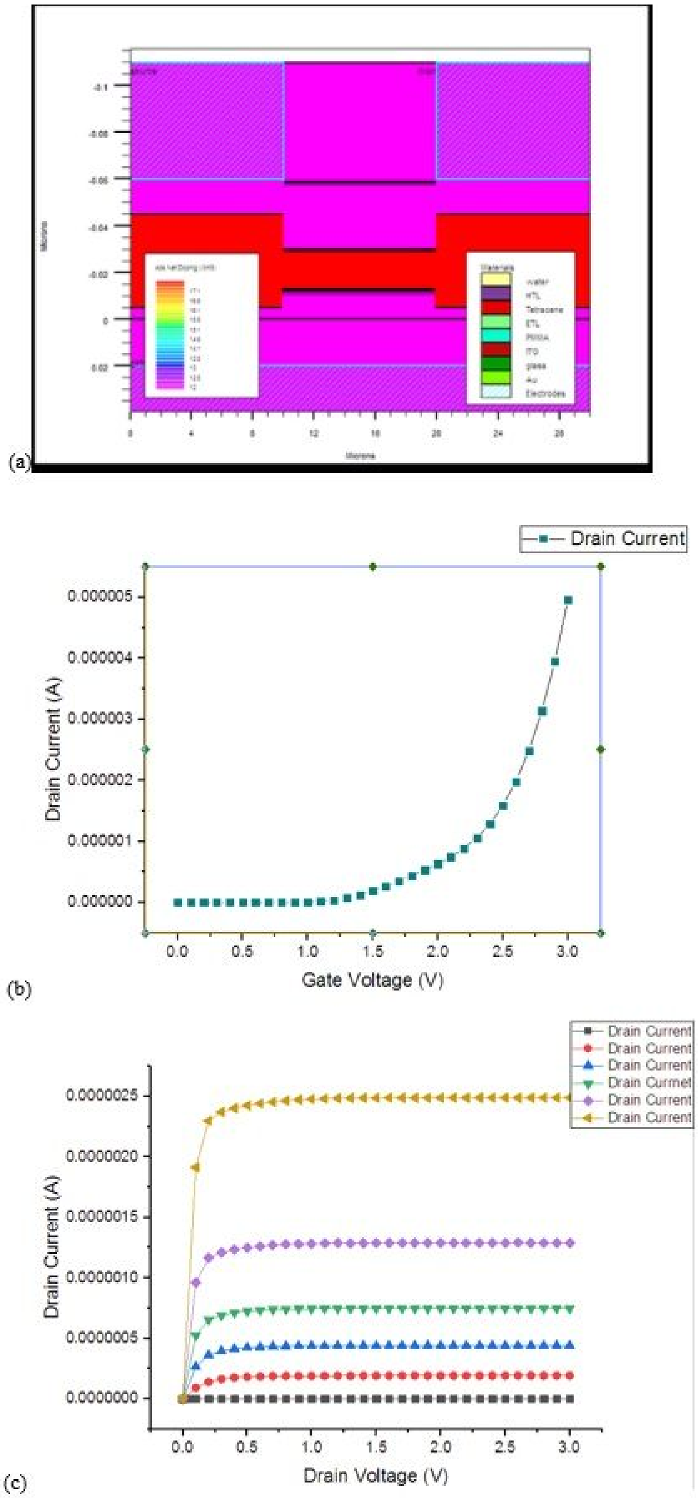


Figure 6

(a) OLET structure with Tetracene as a OSC materials (b) Vgs Vs Ids Characteristics (c) Vds Vs Ids Characteristics.

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