Study and Performance Analysis of Organic Light Emitting Diode

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Abstract: *The objective of the chapter is to study the basic structure of organic light emitting diode. Various material technologies used in OLED has been discussed along with its principle of working. Further, various types of OLED are discussed in brief accompanied with their method of fabrication. Thereafter, the structure of OLED has been simulated and their performance characteristics have been observed using the Atlas-2D Silvaco simulation tool.*

1. INTRODUCTION

With the development in technology Organic light emitting diode is achieving great heights in the new display all over the world. Merits and De-merits of OLEDs as compare to conventional technologies are done as follows :

- Due to the ease of fabrication and also due to lighter weight, thinner devices as compared with cathode ray tube (CRT) display technology.
- It has various merits over other display as with the case of liquid crystal (LCD) displays. We can view OLEDS with different angles and it does not require backlight. Also in OLED consumption of power and drive voltage are lower [1].

In OLED devices, organic materials are incorporated between two electrodes. When electrical current is applied, the organic layers give off light (electroluminescence).

2. MATERIAL TECHNOLOGIES

For achieving emission in the spectrum for the blue region, developments for new materials are essential. For this organic light-emitting devices are the focus of strong research all over the world. For OLED device, scientists have urbanized a new class of materials that display excellent promises that used as electron transport materials within an OLED device. With the growth of practical blue OLED device results in good response of OLED technology in both display devices.

2.1 Small molecules based OLED

In the beginning, at Eastman Kodak, OLED technology was urbanized. Dr. Ching W. Tang has developed this technology with the use of small molecules. With the use of vacuum deposition involvement of small molecules display occur. Due to this production process becomes expensive for other processing techniques. This process is done on glass substrates, but the flexibility of display has not been achieved. But this limitation is not in the case with small-molecule organic materials. SMOLED is another name for OLED devices. Organo-metallic chelates are the mostly used molecules for OLED. For instant Alq_3, is first organic light-emitting device that has been used. In recent times hybrid light-emitting layer has been urbanized which uses nonconductive polymers doped with light-emitting, conductive molecules. Without concerning about the mechanical merits and production cost, the optical characteristics of polymer has been considered. SM OLEDs have equal longevity as compare with the small molecules.

2.2 Polymer based OLED

Another name of Polymer light-emitting diodes (PLED) is known as light-emitting polymers (LEP), due to which involvement of electroluminescent polymer which is conductive in nature emits light that can be connected with a voltage source connected externally. For displaying colors this are used as a thin film which requires less quantity of power from which light can be produced. From the method of inkjet printing, emissive materials can be applied but vacuum is not required. Flexible substrate is used for this purpose like PET. PLED are flexible displays and is also known as flexible OLED (FOLED), and they are not expensive. Distinctive polymers that are used for PLED displays take account of derivatives of poly (p-phenylene vinylene) and polyfluorene. Replacement of side chains onto the polymer spine may resolve the shade of emitted light or the constancy and solubility of the polymer for recital and ease of dispensation.

3. OLED STRUCTURE

An OLED consists of the following parts :

1. **Substrate** (clear plastic, glass, foil) - The substrate supports the OLED.
2. **Anode** (transparent) - The anode removes electrons (adds electron "holes") when a current flows through the device.
3. **Organic layers** - These layers are made of organic molecules or polymers.
   a. **Conducting layer** - This layer is made of organic plastic molecules that transport "holes" from the anode. One conducting polymer used in OLEDs is polyaniline.
   b. **Emissive layer** - This layer is made of organic plastic molecules (different ones from the conducting layer) that transport electrons from the cathode;this is where light is made. One polymer used in the emissive layer is polyfluorene.
4. **Cathode** (may or may not be transparent depending on the type of OLED) - The cathode injects electrons when a current flows through the device.

4. PRINCIPLE OF WORKING

Across the OLED voltage is applied in a manner so that cathode should be negative in respect of anode. This creates the flowing of charge from electrodes across terminals from anode to cathode. From cathode electrons are given at different layer such as emissive. From anode it withdraws electrons from the conductive layer; so that holes from anode can be given at conductive layer [2].

Now the negatively charged layer is emissive where as conductive layer consists of positively charged holes. Due to the electrostatic nature of force, attraction occurs between electrons and the holes and they start combining. Combination occurs closer to emission layer as it can be seen that in organic semiconductors holes are more than electrons. But due to the recombination there is decrease in energy level for electrons due to which accompanies with the emission of radiation. That's the reason why frequency is visible in this area. So this layer is called emissive.

5. Fabrication methods for OLED

There are generally two methods to fabricate OLEDs which are most widely used :

5.1 Thermal evaporation of the organic small molecules

This process is done in vacuum. Pressure of vacuum is about 10^{-6} torr or better. [6] with deposition molecules, it is also done for deposition of cathode materials. Various merits are there of using thermal evaporation. Fabrication makes the thickness of layer to monitor easily as compare to spin coating. In the semiconductor industry, vacuum equipment are easy to fabricated.

5.2 Spin-coating polymer layers

In polymer-based LEDs spin coating is used. In the solution polymer layers can be deposited directly, but during deposition thickness cannot be monitored.

6. Simulation Setup

6.1 Device Study and Structure

The OLED device has been made and simulated using Atlas-2D Silvaco simulator. In this section study, it is demonstrated that the characteristics of the organic light-emitting diode based upon MEH-PPV [more fully known as poly(2-methoxy,5-(2'-ethyl-hexoxy)-1,4-phenylene-vinylene)] are determined by tunneling of both the holes and the electrons through interface barriers caused by the band offset between the polymer and the electrodes. It is shown that manipulating these offsets can control the useful operating voltage of the device as well as its efficiency. A model is developed that clearly explains the device characteristics of a wide range of diodes based upon MEH-PPV. The turn-on voltage for an ideal device is shown to be equal to the band gap, i.e., 2.1 eV for MEH-PPV, and is slightly lower at 1.8 eV for an indium-tin oxide/MEH-PPV/Ca device. If there is a significant difference in the barrier height, the smaller of the two barriers controls the *I–V* characteristics, while the larger barrier determines the device efficiency. In indium-tin-oxide/MEH-PPV/Ca devices, the barrier to hole injection is 0.2 eV and the barrier to electron injection is only 0.1 eV. This combination of electrodes is close to optimal for MEH-PPV, but lowering the hole barrier can still lead to a doubling of the device efficiency.

The various parameters which affect the OLED performance are Bandgap of the conductance and valence band for OLED conduction. The temperature for OLED operation is at standard, i.e. 300 K. the affinity is sufficiently high so as to gather more and more charge carriers. The work function of the ITO layer is sufficiently high to excite the holes to its conductance band. And most importantly, we can see that the hole mobility is greater as compared to that of the electron mobility. The exciton lifetime is tha amount of time for which the excited charge carriers stays on that much longer so that it can provide sufficient energy to emit the light. The exciton diffusion length is the maximum length of the range to which the luminescence of the OLED can be visualized. The relative permittivity allows the permeability to the charge carries so as to produce more and more conduction and thus emission of light.

The various electrical and optical parameters used in the study are tabulated as follows :

Table 1. Device Parameters used in simulation

Parameter	Magnitude	Units
Bandgap, *Eg*	2.1	eV
Temperature, *T*	300	K
Affinity	2.8	eV
ITO Work Function	4.7	eV
Hole Mobility, μp	0.5e-4	cm^2/Vs
Electron Mobility, μn	0.5e-5	cm^2/Vs
Exciton Lifetime, *t*	1e-9	S
Exciton Diffusion Length, L_D	1e-6	Cm
Relative Permittivity, ε_r	3.0	Unitless

Simulating the single OLED using all of the above mentioned parameters provided in the table, the following device structure is obtained as shown in Figure.

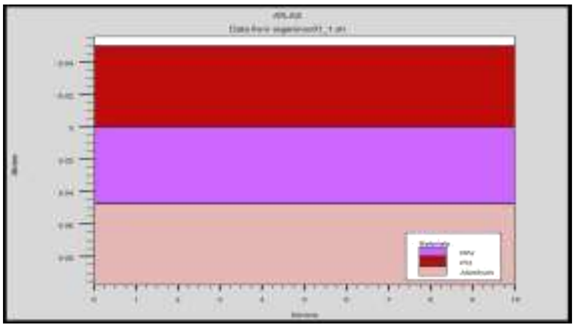
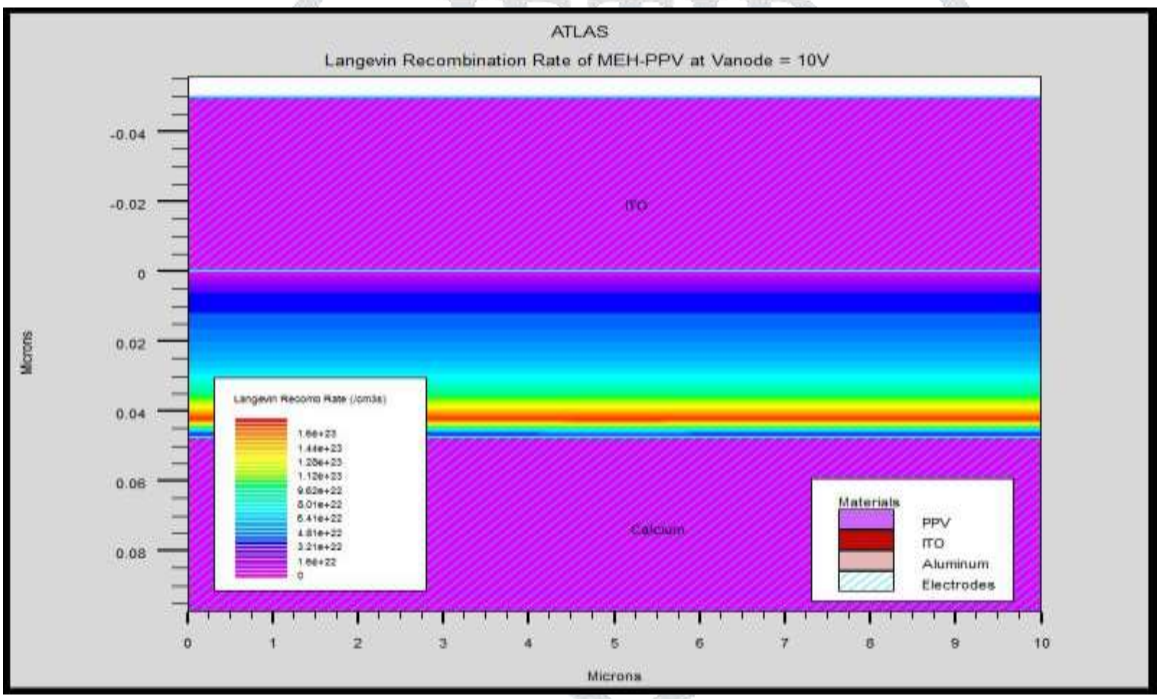
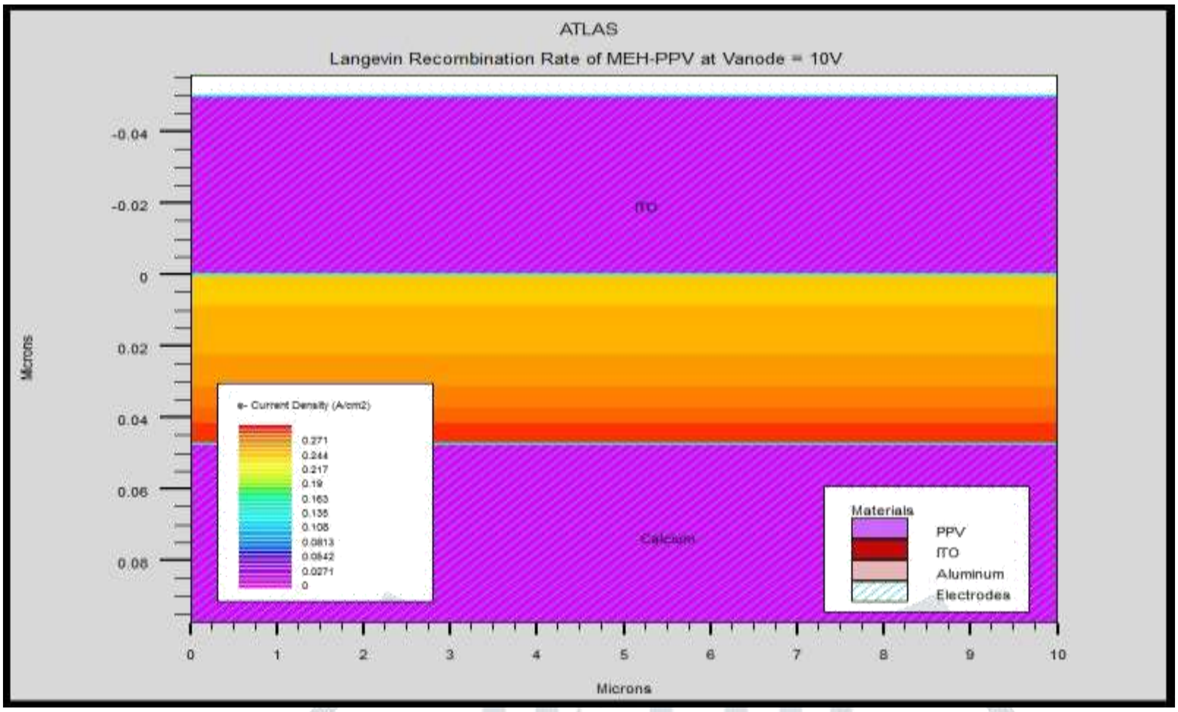


Fig. 1. Device structure of organic light emitting diode

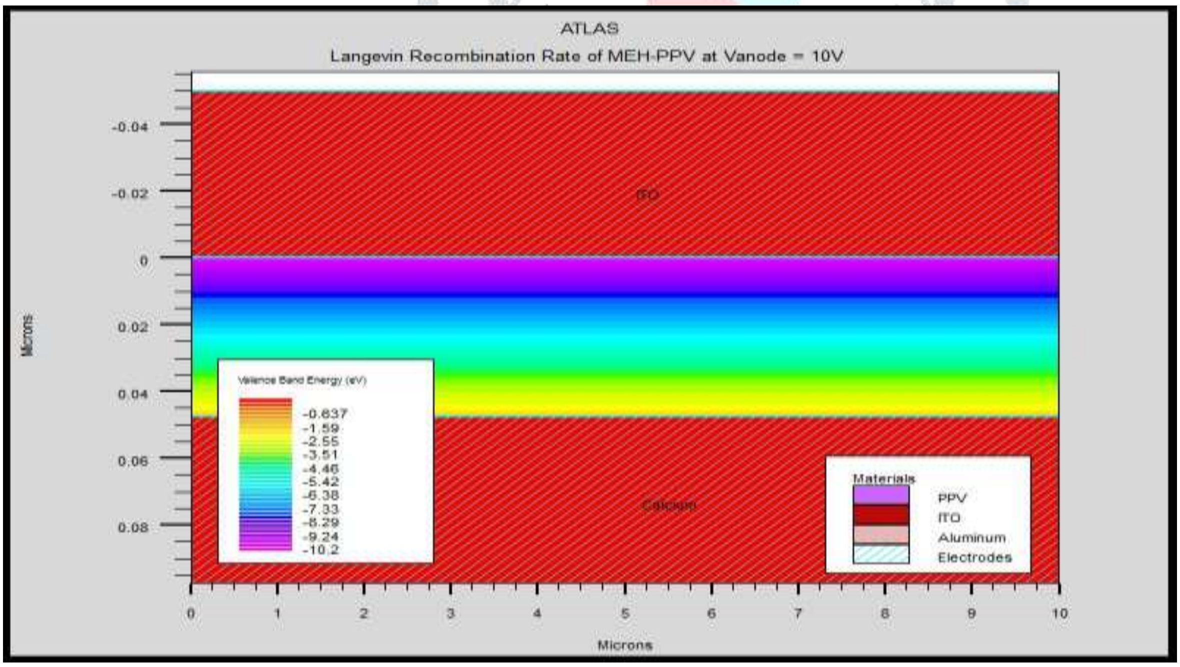
The various zone formation is further shown in Fig. 4.7 (a) for the langevin recombination rate of the organic material MEH-PPV at the anode voltage of 10V. Recombination in low mobility semiconductors can be described by Langevin recombination in the form R=knp, where k is the recombination prefactor and n/p are the free carrier concentrations.



(a)



(b)



(c)

Fig 2.(a) OLED langevin recombination zone (2-D Plot) (b) OLED electron density zone (c) OLED valence band energy zone.

The above shows that the electron current density is larger at the cathode end leading to the larger excitons formed near the conducting channel. Figure (c) shows that the energy is produced at the valence band of the electrodes leading to the greater luminescence produced by Organic LED.

7. Organic LED Device Simulation and Results

This section undergoes various simulation results of the MEH-PPV material based OLED. Applying the anode voltage, the current at the anode terminal can be observed. Thereby, an electric field is produced leading to the larger anode current density. When the amount of electric current generated is sufficiently high, the recombination of electrons from the cathode and holes from the anode takes place, which leads to the emission of light whose intensity is denoted by its luminescence produced at the terminals.

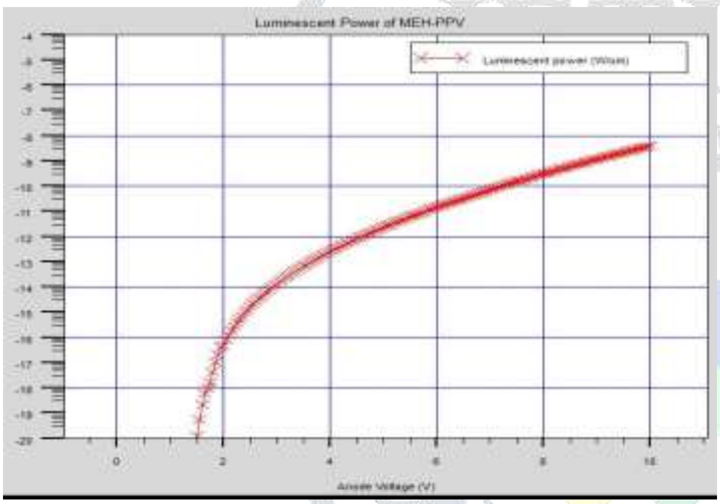


Fig. 3. Luminescent power with respect to the anode voltage.

Luminescence emission occurs after an appropriate material has absorbed energy from a source such as ultraviolet or X-ray radiation, electron beams, chemical reactions, and so on. The energy lifts the atoms of the material into an excited state, and then, because excited states are unstable, the material undergoes another transition, back to its unexcited ground state, and the absorbed energy is liberated in the form of either light or heat or both (all discrete energy states, including the ground state, of an atom are defined as quantum states). The excitation involves only the outermost electrons orbiting around the nuclei of the atoms. Luminescence efficiency depends on the degree of transformation of excitation energy into light, and there are relatively few materials that have sufficient luminescence efficiency to be of practical value.

Further, it can also be shown that the increasing anode voltage can generate the larger anode current after some fixed amount of voltage level. For small voltage values, the anode current remains unchanged but an exponential increase is observed for the further increased anode voltages as depicted in Figure.

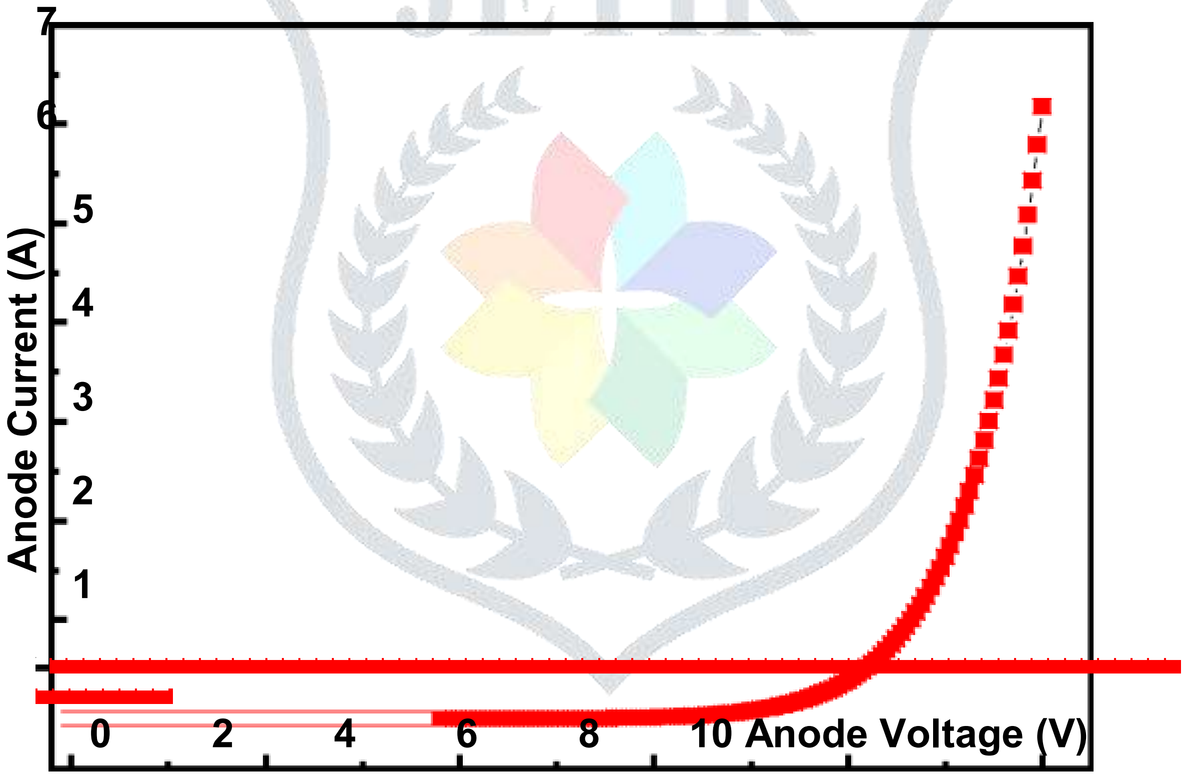


Fig. 4. Variation of Anode Current with Anode Voltage

Furthermore, the current density depicted by the amount of the electric current per unit of cross sectional area is also depicted in Fig. 4.10.

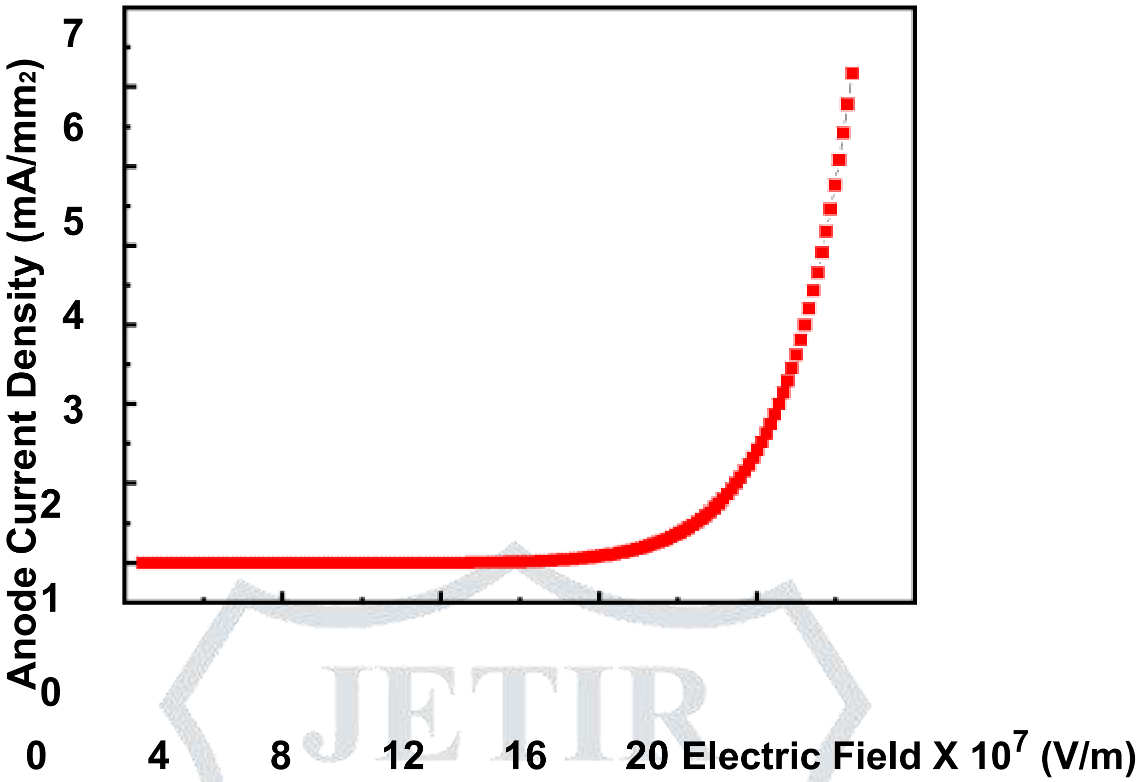


Fig. 5. Variation of anode current density with respect to the electric field.

8. Summary and Outlook

The chapter provides a brief description of all the desired profile for an efficient Organic Light Emitting Diode. Large area, flat light sources with surface brightness have potential applications such as space lighting, back lighting or advertising displays. Organic light emitting devices (OLEDs) offer the potential for such a source. OLEDs promise a cheap, light weight source which potentially can be made any size and on to a range of substrates (including flexible plastic). The important advantages which make OLED to be used more efficiently are as follows : Very thin panel, Low power consumption, High brightness, High contrast, Wide visibility, Quick response time, Viewer order wide angle, Self luminous, Thinner than LCD, No environmental drawbacks, No power intake when turned off. Despite outstanding properties of organic materials regarding usage in display technologies, their potential is by far not realized yet. Still present disadvantages of state of the art organic LED make competition with established principles difficult. Low driving voltages below 5V are needed to be compatible with typical integrated electronics used for passive addressed matrix displays. Unwanted voltage drops are partially due to the low conductivity of organic materials and interface barriers typically encountered in organic devices. Surprisingly enough, the doping concepts fundamental for the triumph of classical semiconductors have not been employed for organic devices. Organic Light Emitting Diodes are evolving as the next generation of light sources. Organic full-color displays may eventually replace liquid crystal displays for use with laptop and even desktop computers. Research is going on this subject and it is sure that OLED will emerge as future solid state light source. One of the future visions is to roll out OLEDs or to stick them up like post-it notes. Another vision is the transparent windows which would function like a regular window by day. At night it could be switched on and become a light source. This could be possible because OLED allows transparent displays and light sources.

9. REFERENCES

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