B. TECH. PROJECT REPORT

On

Design and Development of OLEDs

BY

MERGU SURYA TEJA

DISCIPLINE OF ELECTRICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY INDORE
December 2016

Design and Development of OLEDs

A PROJECT REPORT

Submitted in partial fulfillment of the
requirements for the award of the degrees

of
BACHELOR OF TECHNOLOGY
in

ELECTRICAL ENGINEERING

Submitted by:
MERGU SURYA TEJA

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(Associate Professor, IIT INDORE)

INDIAN INSTITUTE OF TECHNOLOGY INDORE
December 2016

CANDIDATE’S DECLARATION

I hereby declare that the project entitled **“Design and Development of OLEDs”** submitted in partial fulfillment for the award of the degree of Bachelor of Technology in ‘Electrical Engineering’ completed under the supervision of **Dr. Vipul Singh, Associate Professor, Electrical Engineering,** IIT Indore is an authentic work.

Further, I declare that I have not submitted this work for the award of any other degree elsewhere.

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(130002022)

CERTIFICATE by BTP Guide(s)

It is certified that the above statement made by the student is correct to the best of my knowledge.

Dr. Vipul Singh,

Associate Professor,

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Preface

This report on “Design and Development of OLEDs" is prepared under the guidance of Dr. Vipul Singh.

Through this report, I have tried to give a detailed description of characteristics of OLEDs under different conditions. I have characterized thin films of different solutions to achieve optimized characteristics and better charge transport within the device.

I have also studied the effect of different annealing temperatures on these thin films, thus figuring out the best combination to choose for the fabrication of organic light emitting diodes. Reading and graphs at all steps have been added to make the report more comprehensive and illustrative.

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Acknowledgements

My efforts bore fruit with the successful completion of this project. I acknowledge the cooperation, encouragement and austerity of my project guide, Dr. Vipul Singh, whose guidance did half the magic of keeping me thrilled throughout this project. As a student, I respected his authority, yet felt comfortable enough to share ideas, ask questions, and discuss. That’s an environment that only few students get to truly experience.

However, there are many others who share the reward of this effort simply because it would never have been this good without their help. Having said that, I would like to express my heartfelt gratitude to Dr. Kshitij Bhargava and other PhD students who have provided ideas, advice and the good atmosphere that made working in the Molecular and Nano electronics Research group worthwhile.

My special thanks to my parents for their support and understanding, and of course for bearing with me when I was all too busy with the project.

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Abstract

The fast-growing organic electronics field has received the attention of a lot of researchers because of its wide applicability in the consumer electronics, photovoltaics and biotechnology. Along with this trend, high performance organic materials with cost-efficient fabrication processes and specific features such as thin, light weight, bendable, and low power consumption are required. Organic light-emitting diodes (OLEDs) show promise of revolutionizing display technologies. Hence, these devices and the materials that render them functional are the focus of intense scientific and technological interest. The multilayer OLED hetero structure introduces numerous chemical and physical challenges to the development of efficient and robust devices.

An understanding of thin film growth is crucial to tailor surface morphologies and organic film properties suitable for specific applications. The electro-optical behavior of organic light emitting diode devices (OLEDs) is greatly influenced by the morphology of the films. A major parameter is due to the important role that the morphology of the active organic thin films plays in the phenomena that lead to light emission. In this study, I have first investigated changes seen in optical properties of thin films due to different annealing temperatures prepared from different solvents. Results indicated that superior morphology was obtained for thin films which are annealed at 100°C. UV-Vis measurements showed a decrease in band gap energy as annealing temperature was increased. However, this was not entirely true in case of all the four solvents used.

Polymer light emitting diodes with hetero junction structures were fabricated using the light emitting polymer MDMO PPV in different solvents. The solvents used are Dichlorobenzene, Chlorobenzene, Toluene and Chloroform. UV and PL Spectra measurements were taken to measure the optical properties of the device prepared in different solvents. Finally, dependency of electric current on the voltage applied was undertaken for different samples prepared to measure the I-V characteristics of diode. Results indicated that the device gave best performance while using Dichlorobenzene as solvent and setting the annealing temperature to 100°C.

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List of Abbreviations

OLED	Organic Light emitting diode
HOMO	Highest occupied molecular orbital
LUMO	Lowest unoccupied molecular orbital
MDMO PPV	Poly[2-methoxy-5-(3’,7’-dimethyloctyloxy)-1,4-phenylenevinylene]
PEDOT: PSS	Poly(3,4-ethylenedioxythiophene)-polystyrene sulfonate
UV-Vis	Ultraviolet - Visible
PL	Photoluminescence
HMDS	Hexamethyldisilazane

Chapter 1 – Introduction

1.1 Organic electronics

Organic electronics is a field of interdisciplinary field of science concerning the design, synthesis, characterization and application of organic small molecules or polymers as active thin layers. The basis of organic electronics is predicted on the ability of a class of functional organic molecules known as organic semiconductors to actively transport charge, emit light, or to absorb light under appropriate conditions. Transistors, light emitting diodes, and photovoltaic cells are some of the examples of devices comprising of these organic materials.

Organic electronic devices are more energy-efficient and otherwise "eco-friendly" than today's electronics, contributing to a more sustainable electronic world. Organic electronic devices can be manufactured using more resource-friendly and energy efficient processes than today's methods, further contributing to a more sustainable electronic world.

From the fabrication point of view these materials can be classified into two categories namely that of solution processable and processable via thermal evaporation. While pi conjugated polymers clearly belong to the solution processable category, small molecule based organic compounds can be functionalized to belong to either group.

1.2 Organic materials as conducting polymers

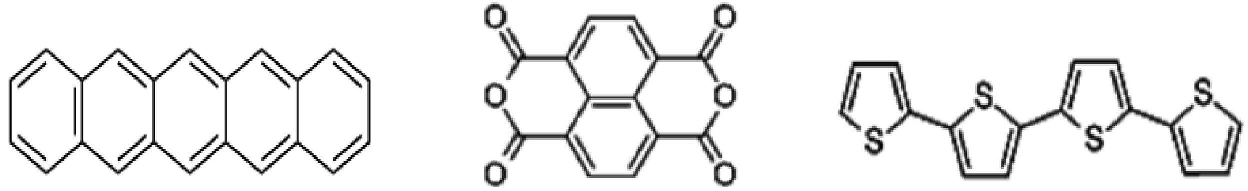
Initially the organic materials were believed to be insulating in nature but later it was discovered that these organic materials exhibit electrical conduction. Their electrical conductivity can be tuned from insulator to metal through various doping processes.

In conjugated polymers the electronic configuration is fundamentally different. The chemical bonding leads to the formation of one unpaired electron (π-electron) per Carbon atom. Moreover, the Carbon orbitals are in the sp^2p_z hybridized configuration which creates overlapping of orbitals of successive carbon atoms leading to electron delocalization along the polymer backbone. This electronic delocalization provides the highway for charge carrier movement resulting in conduction of electricity through these materials.

1.3 Small molecules and Conjugated polymers

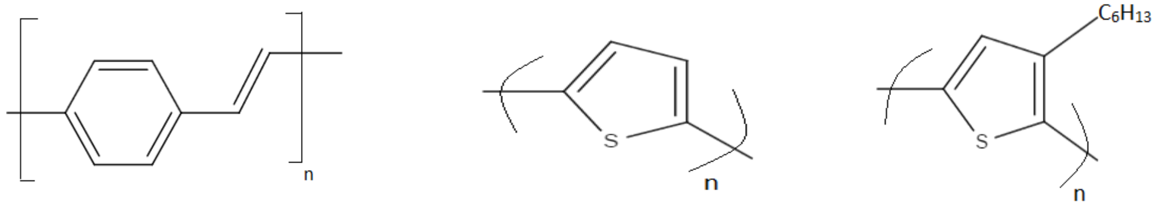
The organic semiconductors can be broadly classified on the basis of their molecular weights as small molecules and conjugated polymers. The small molecules have monomer units less than `10' and have lower molecular weights while conjugated polymers have monomer units greater than `20' in numbers and have comparatively higher molecular weights. The small molecules can be further divided into linear fused ring compounds, two-dimensional (2-D) fused ring compounds and heterocyclic oligomers while polymers can be homocyclic and heterocyclic in nature.

(a)Small molecules



Pentacene Napthalene dianhydride Quaterthiophene

(b) Conjugated Polymers



Poly(p-phenylenevinylene) Polythiophene Polyhexylthophene

Figure 1.1 Classification of organic semiconductors as (a) small-molecules (b) conjugated polymers.

The advantage of small molecules is the more facile control of charge transport by modification of various molecular parameters due to their ability to form a well-organized polycrystalline films leading to higher mobility in comparison to conjugated polymers. Small molecules are generally thermally evaporated which makes them less suitable for large area fabrication of organic device array. Polymeric semiconductors on the other hand are soluble in organic solvents making them a lucrative option for large area deposition of thin films but these films are highly disordered in nature yielding several orders of inferior mobility. In both these classes of organic semiconductors the presence of alternating single and double bonds (conjugated π-electron system) are responsible for their semiconducting properties.

1.4 Exciton in conjugated polymers

An exciton is a bound state of an electron and a hole in an insulator or semiconductor. It is also referred as an elementary excitation, or a quasiparticle inside a solid. The bound electron and hole pairs (excitons) provide a means to transport energy without transporting the net charge. A vivid picture of excitons formation is as follows: a photon enters is incident upon the organic semiconductor, exciting an electron from the HOMO into the LUMO. The missing electron in the HOMO leaves a hole (of opposite electric charge) behind, to which the electron is attracted (bounded) by the Coulomb force. The exciton results from the binding of the electron with its hole. As a result, the exciton has slightly less energy than the unbound electron and hole.

1.5 Light emission via exciton recombination in Conjugated polymers

After their creation, followed by their diffusion the excitons either recombine or dissociate. The recombination of excitons can occur either radiatively or non radiatively. While radiative recombination causes emission of light as in OLEDs, Non radiative recombination proceeds via phonon vibrations and does not result in the any radiations. In the case of OLEDs, the excitons are generated due the injection of electrons and holes into the bulk of the respective semiconducting layers. Such a charge injection usually leads to 25% singlet and 75% triplet excitons. The inter system crossing results in the formation of triplet excitons. Singlet excitons lead to fluorescence and thus it was thought that the maximum limit of the OLED efficiency is limited to the singlet excitons. However, later it was showed that even the triplet states can be utilized in efficient emission of light by the use of suitable phosphorescent molecules. This concept made white light emission possible from a single layer PLED.

Despite many applications of organic electronics, it is only the OLEDs that has shifted from the research and development phase to the scale up phase. In the year 2007 Sony launched an 11- inch television based on OLED technology, whose salient features include a 3-mm thick panel and a 178o viewing angle. In the display arena OLED technology promises to compete with the existing Liquid Crystal and Plasma technologies. OLEDs unique attributes including its ultra-brilliant colors, low power consumption and wider viewing angle make it a highly desirable technology for future display development. Thus in all we would like to conclude that the new and emerging field of organic electronics helps us gain better insight into material properties at the molecular level. While Displays based on OLEDs have already hit the market and are likely to replace the existing display technologies. A host of other applications involving organic materials as well are catching up fast.

Chapter 2 – Theory and Design

An OLED is a solid-state light emitting device based on organic materials. An OLED consists of thin organic films sandwiched in between the two electrodes. The typical architecture of an OLED comprises a transparent electrode on top of a substrate, followed by several layers of organic materials stacked on top of each other and finally capped with a highly reflective metal electrode.

2.1 OLED Device architecture

OLEDs presently exist under a variety of different geometries and compositions. The simplest of these is a single organic layer sandwiched between two electrodes as is shown in the Fig. The other geometry of these devices is bilayered device. Multilayered OLEDs have also been reported and extensively researched over the last few years. However, the addition of each layer increases the cost of the device and the display based on these devices as a whole, simultaneously increasing the complexity of their design.

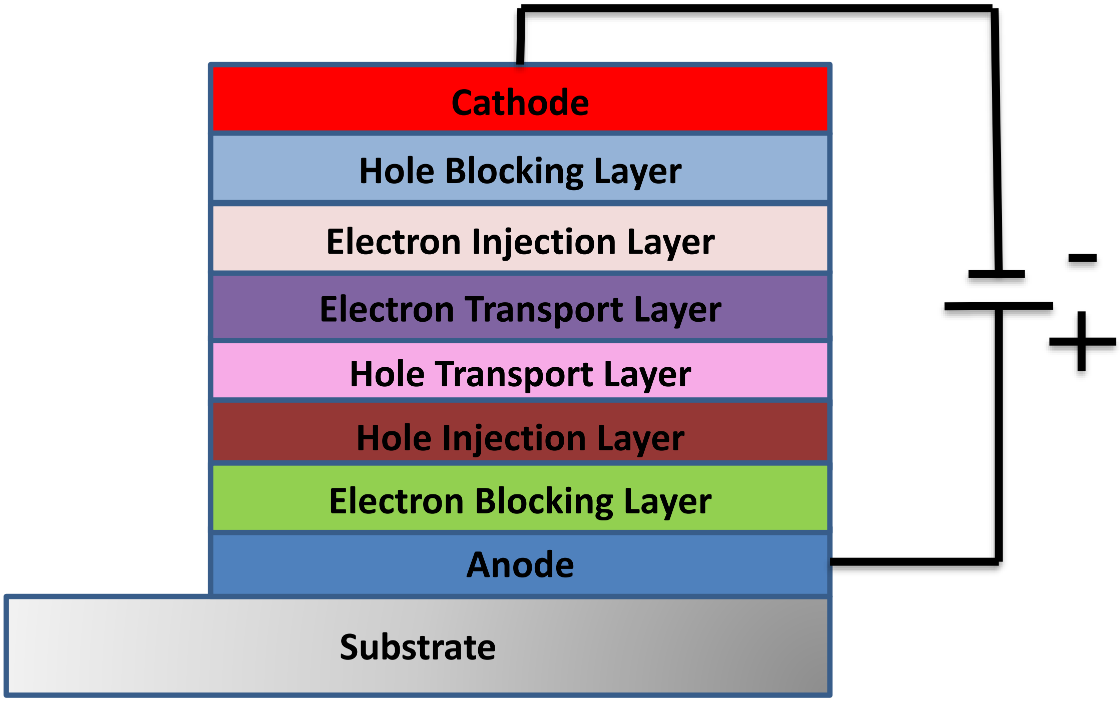


Figure 2.1 Typical Device architecture of an OLED

In a single layer device, the organic material must perform all the three functions: hole transport, electron transport and photon emission via electron-hole radiative recombination. In this case the injection rates of holes from the anode into the HOMO and electrons from the cathode into the LUMO must be roughly equal or efficient. Otherwise excess carriers of one sign will just pass through the organic layer without radiative recombination, contributing to the current in the external circuit but not to the emission.

Later a major technological breakthrough was achieved by the use of two layers of organic materials. In this approach one material (that adjacent to anode) can be selected for good hole injection and transport, while that adjacent to the cathode permits good injection and transport of electrons. Emission may occur from either or both materials. The interface between the two organic layers can have two additional effects on the operation of the bilayer device. First is that the energy level offsets may present a barrier for electrons entering the hole transport layer, and vice versa. This tends to prevent the loss of efficiency caused by the passage of charge from one electrode to the other without recombination. Secondly, because of the high density of carriers on each side of the organic interface, i.e. holes in the hole transport layer (HTL) and electrons in the electron transport layer (ETL), recombination is most likely to occur near the interface and well away from the metallic electrodes. This reduces the probability of exciton quenching by dissociation near the electrode. The exact nature of recombination and emission depends on the energetics of holes, electrons and excitons in each material.

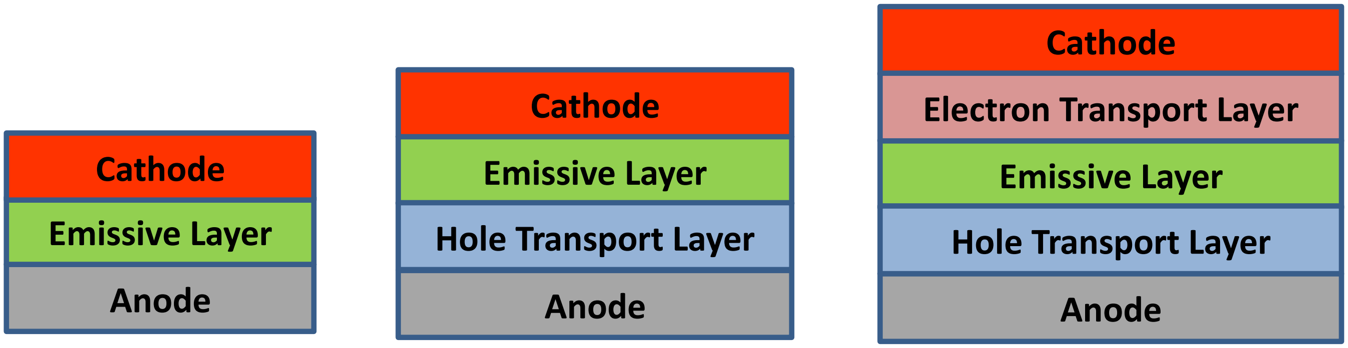


Fig 2.2 Different device structures of OLEDs

Besides the bilayered structures the trilayer structures offer additional possibility of selecting the emissive material, independent of its transport properties. Additional layers have also been added to accomplish various other benefits, tailoring the energy profiles and mobilities across the entire organic stack. Splitting the transport layers into two separate layers permits the optimization of injection into the layer nearest to the electrode (sometimes called the injection layer), and the transport in the farther layer. Layers of insulator (Charge confinement layers) have also been used in an attempt to control the motion of the charges and ensure recombination of the desired region.

The purpose of different layers is as follows. The electron/hole injection layer (EIL/HIL) has the function of facilitating electron/hole injection into the bulk of the emissive layer. The Electron Transport Layer (ETL) and Hole Transport Layer (HTL) perform the function of transporting the electron and hole respectively from cathode and anode. Whenever the recombination zone is located within an ETL, the ETL behaves as an emissive layer (EML). When the recombination occurs within the HTL, on the other hand, the HTL behaves as an EML. The hole blocking layer (HBL) and the electron blocking (EBL) layer have the function of blocking the holes and electrons to the either side respectively.

When a voltage is applied to the electrodes the charges start moving in the device under the influence of the electric field. Electrons leave the cathode and holes move from the anode in opposite direction. The recombination of this charges leads to the creation of a photon with a frequency given by the energy gap ($E = h\nu$) between the LUMO and HOMO levels of the emitting molecules. Therefore, the electrical power applied to the electrodes is transformed into light.

2.2 Materials Used

The following materials have been used in the fabrication of OLEDs

Substrate: Glass

The substrate supports the OLED. It can be flexible too. Alternate materials include metal foil, plastic.

Anode: Indium Tin Oxide(ITO)

The anode supplies the holes when current flows through the device. Other materials which can be used as anode are Aluminum Zinc Oxide(AZO), ZnO: Ga(GZO)

Hole Transport layer: PEDOT: PSS

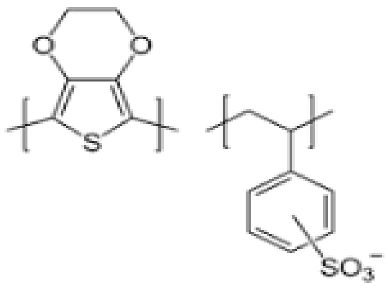


Fig 2.3 Chemical Structure of PEDOT: PSS

The hole transport layer performs the function of transporting holes from the anode. Other materials: m-MTDATA,1,2-TNANA, TFATA, CuPc

Emissive layer: MDMO PPV

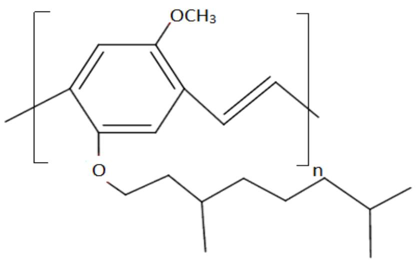


Fig 2.4 Chemical Structure of MDMO PPV

This is the region where electrons and holes recombine to form excitons. The excitons decay radiatively and release energy in the form of light. Other materials: PPV Derivatives and many other organic polymers

Cathode: Aluminum

The cathode supplies the electrons when current flows through the device. Other materials which can be used as anode are low work function metals and even noble metals such as silver.

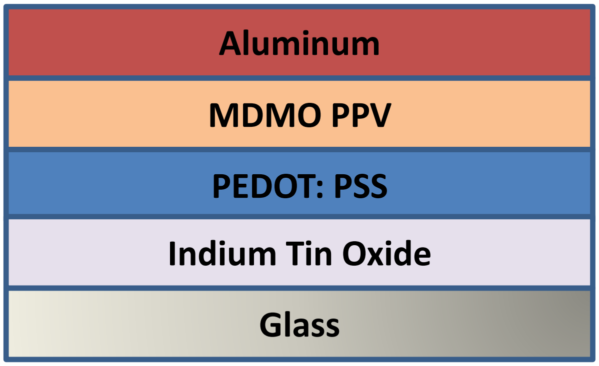


Fig 2.5 Final Device Structure

Chapter 3 – Experimental Procedure

This chapter presents the various experimental methods used for the fabrication of organic thin films and organic light emitting diodes. The general steps involved in the fabrication of thin films and organic electronic devices has been given in the form of a flow diagram in the beginning of this chapter. A brief description of various methods involved in the fabrication of thin films and device has also been discussed.

The factors that were changed to achieve optimum characteristics were:

1.) Choice of solvent
2.) Annealing temperature of the substrates

(Caution: Some of the materials used in the lab can be corrosive or harmful to your body. Make sure that you use safety goggles, rubber gloves, and masks whenever necessary to ensure your safety.)

The following steps were taken for making thin films:

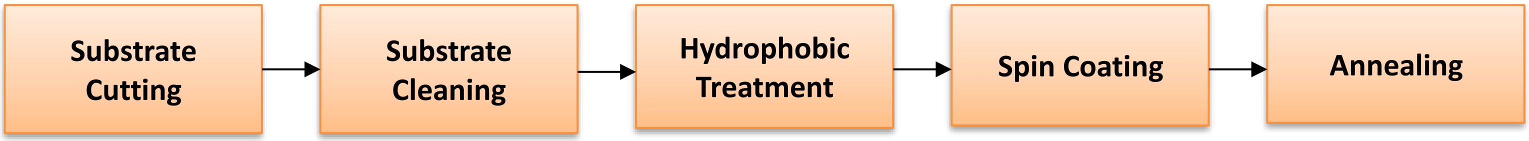


Fig 3.1 Flow diagram showing steps involved in thin film fabrication

The following steps were taken for fabricating organic light emitting diodes:

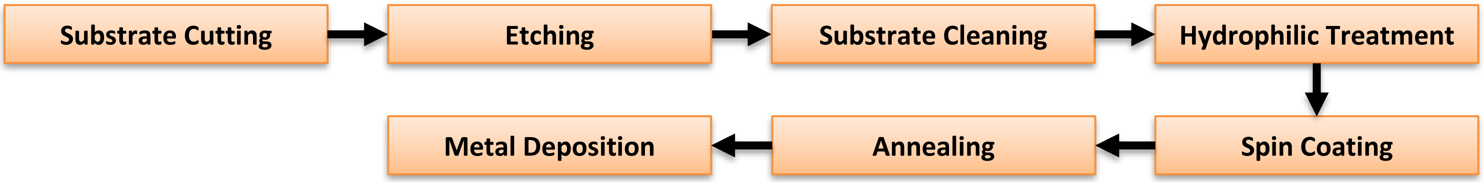


Fig 3.2 Flow diagram showing steps involved in organic device fabrication.

3.1 Substrate cutting

The glass substrates and ITO coated glass of required dimensions were cut using a diamond tip glass cutter. The dimension of both type of substrates used were 1.5cm × 1.5 cm. While glass substrates were used for optical characterization of thin films, ITO coated glass substrates were used to fabricate the OLED devices.

3.2 Etching of ITO coated glass

Etching was only done in case of ITO coated glass substrates. The substrates were covered with Scotch tape, and it is the region defined by the scotch tape that decided the dimensions of the ITO electrode later. It must be noted that region of the substrate not covered by Scotch tape is etched away. Etching was done using a dilute HCl solution in a petridish. While Zn turning are gradually added. It is known that Zn and HCl react with each other as

$Zn + 2HCl \rightarrow ZnCl_2 + 2[H]$

It is the nascent Hydrogen that evolves almost immediately and leads to the etching of ITO electrode, leaving behind the ITO covered with scotch tape. Besides this there exists another method of etching samples using aquaregia solution. However, this method is more severe and many times leads to damage of the scotch tape itself.

3.3 Cleaning procedure

The next stage involves cleaning the substrates. The substrates were cleaned for inorganic impurities clinging to the surface of these substrates by using the ultrasonic bath. Substrates were subsequently cleaned in Iso-propanol and Acetone solutions for 10 mins each.

3.4 Hydrophobic Treatment

In order to ensure good adhesion between organic semiconductor layer and substrate, surface treatment of substrate's surface is usually required to convert its nature from hydrophilic to hydrophobic. For this purpose, some silanizing agents like Hexa (1,1,1,3,3,3) methyldisilazane (HMDS), Octadecyltrichlorosilane (OTS), Octlytrichlorosilane (OTS-8) etc. are used.

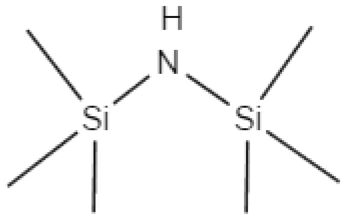


Figure 3.3 Chemical structure of HMDS

Generally, the glass and SiO2 surfaces are hydrophilic in nature while organic materials are known to be hydrophobic in nature hence in order to reduce the surface energy mismatch between substrate surface and organic material and thereby improving the smoothness of thin film these silanizing agents are used. These silanizing agents have both hydrophobic and hydrophilic ends attached to them, thus they act as some kind of a buffer layer which ensures the superior morphology of organic thin films coated over the silanized substrates. Such a treatment is particularly required for obtaining smooth active layer in OLED devices critical for their performance. In this work HMDS has been used for surface treatment glass substrates

3.5 Spin Coating

Spin coating is a well-established technique for depositing polymeric semiconductors and the resulting thin film is having homogenous coverage over the large area of the substrates. The necessary requirement of this technique is that the polymer should have good solubility in the solvents. However, the resulting spin coated films are highly disordered in nature mainly owing to the high speed rotation of the substrate hindering the molecules to attain energetically most favorable position. The settings are set to 1500 rpm for 20 seconds, and thin films are created.

3.6 Annealing

Annealing is a heat treatment that alters the physical and chemical properties of a material. In a qualitative way, annealing modifies the surface morphology of materials with temperature and time.

3.7 Metal Deposition

Metal deposition is done to make electrodes for electrical characterization of the device. The choice of metal to be deposited may vary depending upon the type of device functionality required and the HOMO/ LUMO levels of the organic semiconductor. Generally, Sputtering and Physical Vapor Deposition (PVD) techniques are used for depositing metal electrodes. In this work PVD technique has been used, a brief description of the method is as follows.

Physical vapor deposition

Physical Vapor Deposition (PVD) a technique of depositing thin films by the condensation of vaporized form of the material onto various surfaces (e.g. semiconductor wafers) the coating method usually involves purely physical processes such as high temperature vacuum evaporation. Usually the metal to be deposited is heated to a high vapor pressure by electrically resistive heating in low vacuum. This technique is superior than the Sputtering, as very thin metal films can be deposited. Besides, PVD provides a better control over the deposition of metal. Even the edges are sharply defined thus it is particularly well suited for deposition metal electrodes for various organic electronic devices viz OFETs, OLEDs and PIMDs.

After all these steps, the final samples look as shown in the below figure

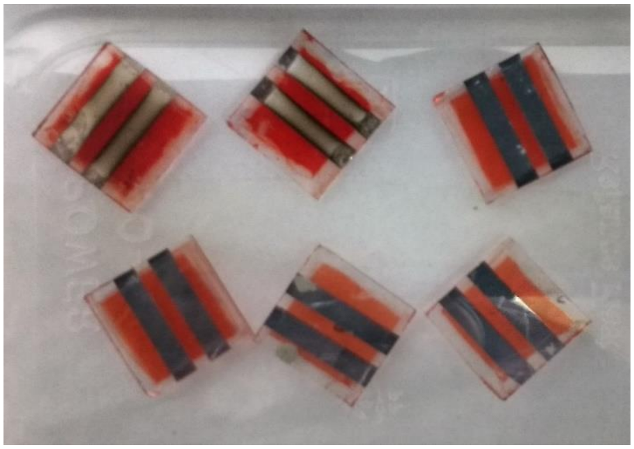


Fig 3.4 Final Prepared samples

Chapter 4 – Analysis, Discussion and Results

4.1 Light absorption in Conjugated polymers

When light either in the visible or ultraviolet is absorbed by the valence electrons in organic molecules, and these electrons are then promoted from their normal ground states to the higher energy states. The energies of the orbitals involved in the electronic transitions have fixed values. Because the energy is quantized, it can be safely assumed that the absorption peaks in the UV/Visible spectrum will be sharp peaks. However, this is rarely the case. Instead the commonly observed spectrum of π-conjugated dyes/polymers the spectrum consists of broad peaks. This is because there are also vibrational and rotational energy levels available. The exact energy differences between the orbitals varies. In organic molecules double bonds which are next to each other can conjugate join together and delocalize the electrons over all of the atoms. This lowers the energy to promote the outer electrons.

The π electrons on the backbone of π-conjugated polymers do not interact with one another and move on a straight line path which extends up to the length of the molecule or a single polymer chain

4.2 Spectroscopy

Spectroscopy usually means experimental charting of the energy level structure of physical systems. It is often used for the analysis of various types of radiation, electromagnetic or particle emission. Spectroscopic investigations can be of fundamental or an applied nature. Most fundamental spectroscopic techniques can be used to determine energy levels, transition probabilities etc., experimentally. Spectroscopic methods are also employed for understanding of the studied systems using adequate theory and models. Usually, certain primary quantities viz. wavelength, intensities, etc. are measured in spectroscopic investigations.

The spectroscopic information can be used for various kinds of analysis for instance, optical absorption and emission spectroscopy is used for both qualitative and quantitative chemical analysis. It can also be used to determine the electronic arrangement of various materials. Thus, spectroscopic techniques are one of the most powerful tools for a great variety of molecular structure studies.

4.3 Absorption Spectroscopy

The nature of excited state and the processes of absorption and emission of light are central ideas in the modern spectroscopy. Absorption spectroscopy refers to the interaction (absorption) of electromagnetic radiation (160

− 780nm) by matter. In common cases most chemical species molecules or compounds are made up of electrons. The electrons in turn located in different orbitals which are associated with different energies. When light of sufficient energy falls on an electron in the ground state, the electron absorbs some of the energy and gets excited to the higher energy level. These energy levels are typically known as HOMO and LUMO respectively.

4.4 Photoluminescence spectroscopy

Photoluminescence (PL) is the spontaneous emission of light from materials under optical excitation. The excitation energy and intensity are chosen to probe different regions and excitation concentrations in the sample. PL based investigations can be used to characterize a variety of material parameters [66, 67]. PL spectroscopy is a selective and extremely sensitive probe of discrete electronic states and its emission spectra can be used to identify surfaces, interfaces and impurity levels. It is a nondestructive technique that requires minimal sample manipulation and since the technique is based on optical excitation, highly resistive materials pose no practical difficulty. Although there is a fundamental limitation of PL analysis and it relies on radiative events therefore, materials with poor radiative efficiency, such as low quality indirect band gap semiconductors are difficult to study via ordinary PL. The principle of PL measurement can be described as follows. When a light of sufficient energy is incident on a material, photons are absorbed and electronic excitations are created. These excitations or quasiparticles are the bound state of an electron and its quasiparticle hole, usually occurring in an insulator or semiconductor. Since, they are bounded coulombically therefore their energy is less than that of free electron hole pairs. These excitons provide a means to transport energy without transporting the net charge. Eventually these excitons relax to the ground state and if the relaxation (recombination) is radiative it results in PL emission. This emitted light can be collected and analyzed to yield a wealth of information about the photo excited material. PL spectrum is indicative of transition energies, which in turn determine the electronic energy levels. The PL intensity gives a measure of the relative rates of radiative and nonradiative recombination.

4.5 Explanation of UV & PL Spectra

There are many observations we can make from UV-Vis Absorption Spectra and PL Spectra.

The following below parameters are of our primary interest:

1. Optical Band Gap
2. Conformational Disorders

3. Extent of length of π conjugation
4. π – π stacking
5. Narrow/ Broader Spectrum

Red shifted spectra refer to spectra which is shifted towards longer wavelength and less energetic. Blue shifted spectra refers to spectra which is shifted towards shorter wavelength and more energetic.We need higher extent of π conjugation so that there is more electrical conduction in the device. Extent of effective π conjugation is higher in case of thin films with lower optical band gap, less conformational disorders and more π – π stacking.

Optical band gap is measured from the UV-VIS absorption spectra. Lower optical band gaps are more favorable due to higher charge conduction in the device. It was observed that red shifted spectra have lower optical band gap energies hence they are more favorable. More conformational disorders result in less effective length of π conjugation which was observed in case of blue shifted spectra. Also π – π stacking is less in case of blue shifted spectra. Broader spectra mean that the thin films prepared are not morphologically stable. Hence red shifted and narrow spectra are more favorable than blue shifted and broader spectra.

The UV and PL spectra that are measured for the given samples are graphed, and compared to figure out which combination of solvent choice and annealing temperatures gives the best UV and PL characteristics. The graphs for all of these are shown below

4.6 UV and PL Spectra

A) Dichlorobenzene

UV Spectra

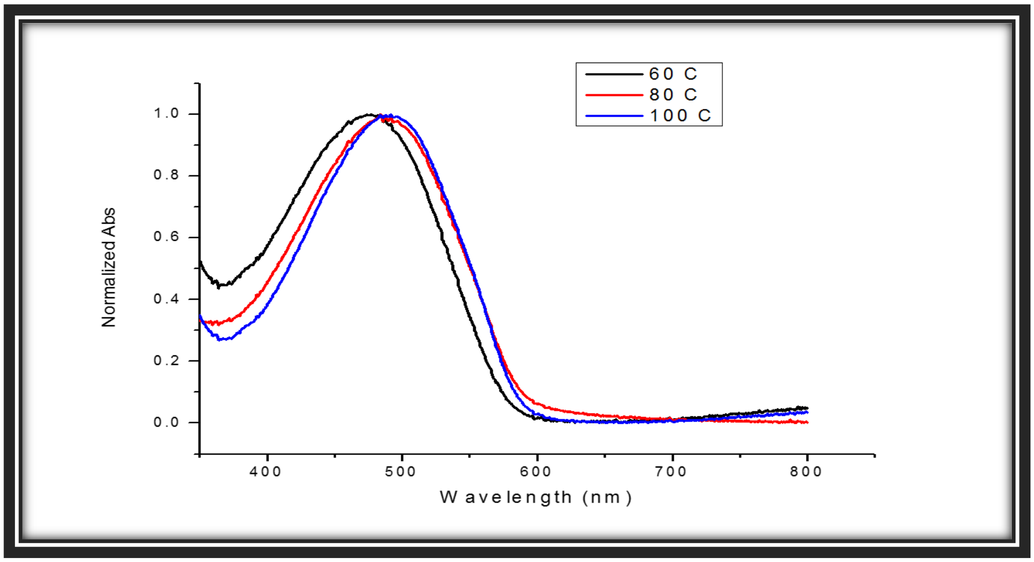


Fig 4.1: UV Spectra of MDMO PPV in dichlorobenzene at 60,80,100°C

PL Spectra

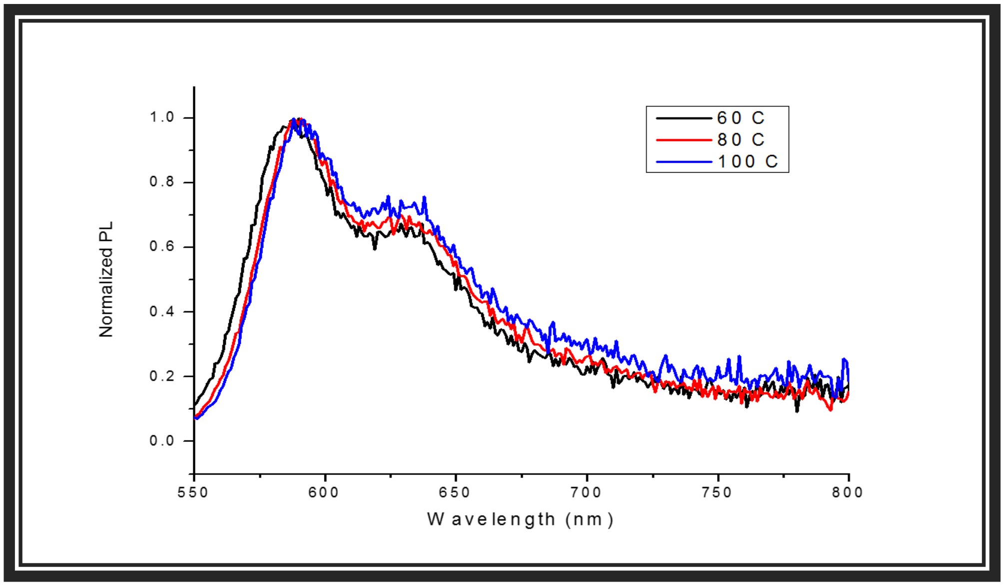


Fig 4.2: PL Spectra of MDMO PPV in dichlorobenzene at 60,80,100° C

As per the reasons mentioned in section 4.5 order of preference would be

100°C > 80°C > 60°C

B) Chlorobenzene

UV Spectra

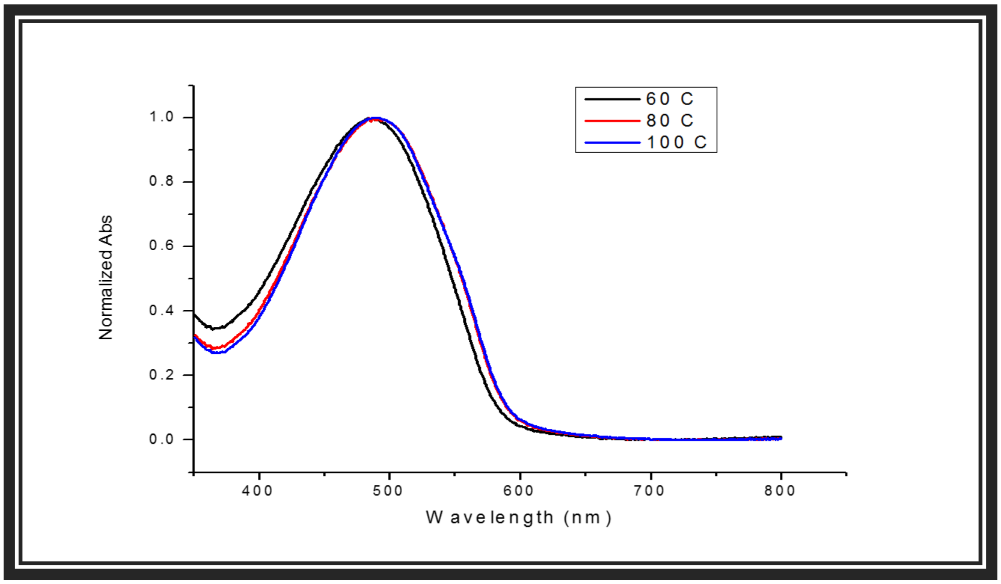


Fig 4.3: UV Spectra of MDMO PPV in Chlorobenzene at 60,80,100°C

PL Spectra

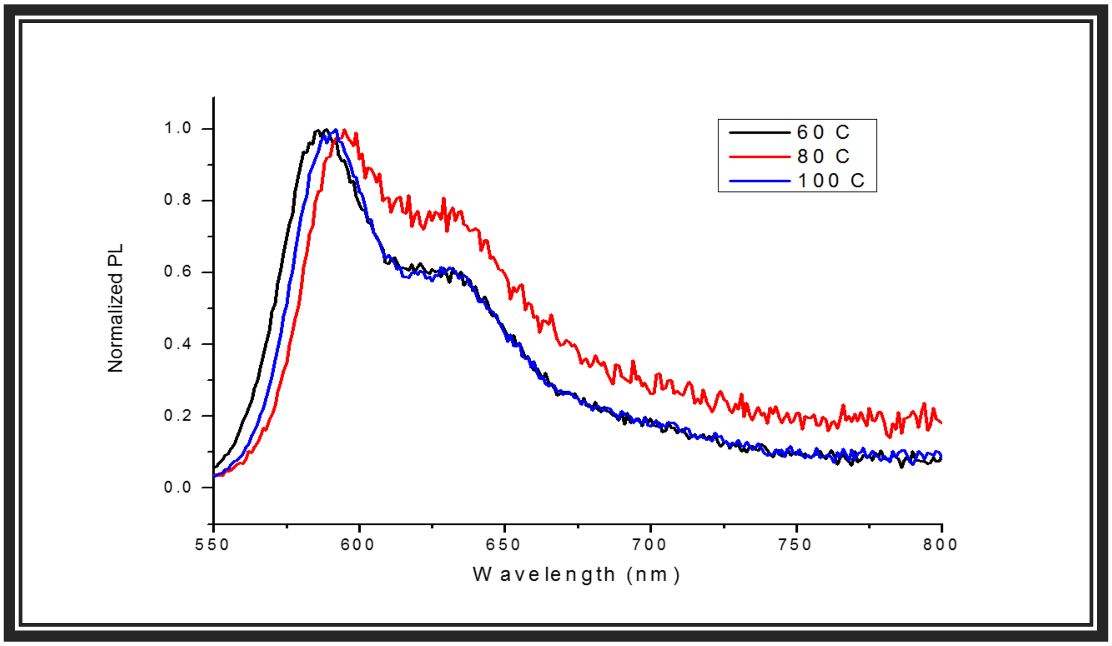


Fig 4.4: PL Spectra of MDMO PPV in Chlorobenzene at 60,80,100°C

As per the reasons mentioned in section 4.5 order of preference would be

80°C > 100°C > 60°C

C) Chloroform

UV Spectra

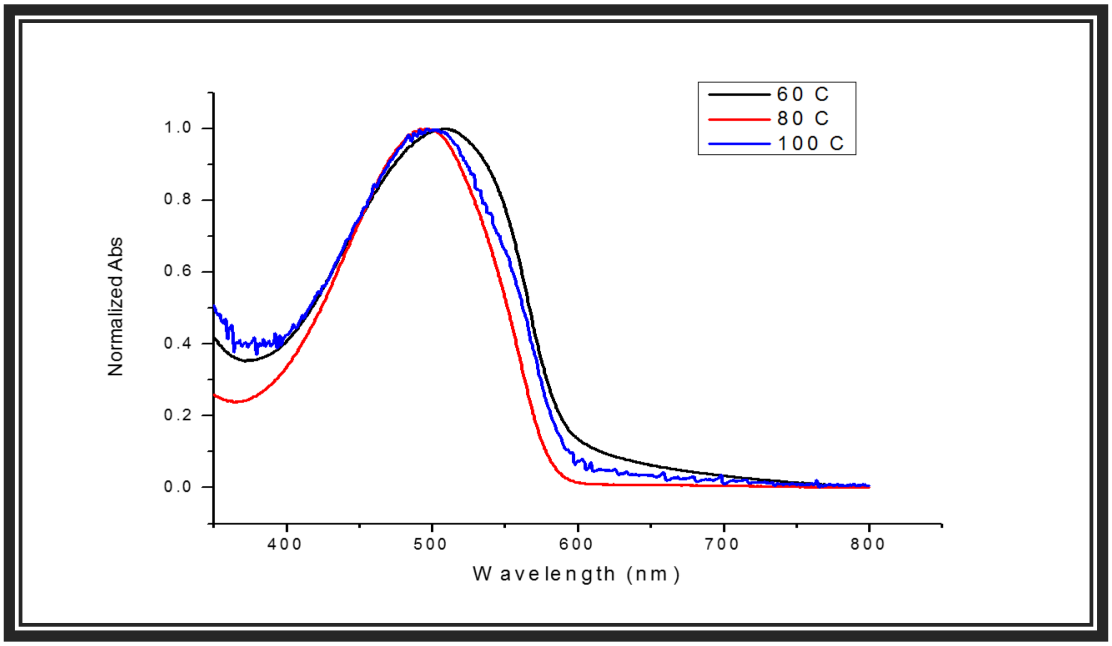


Fig 4.5: UV Spectra of MDMO PPV in Chloroform at 60,80,100°C

PL Spectra

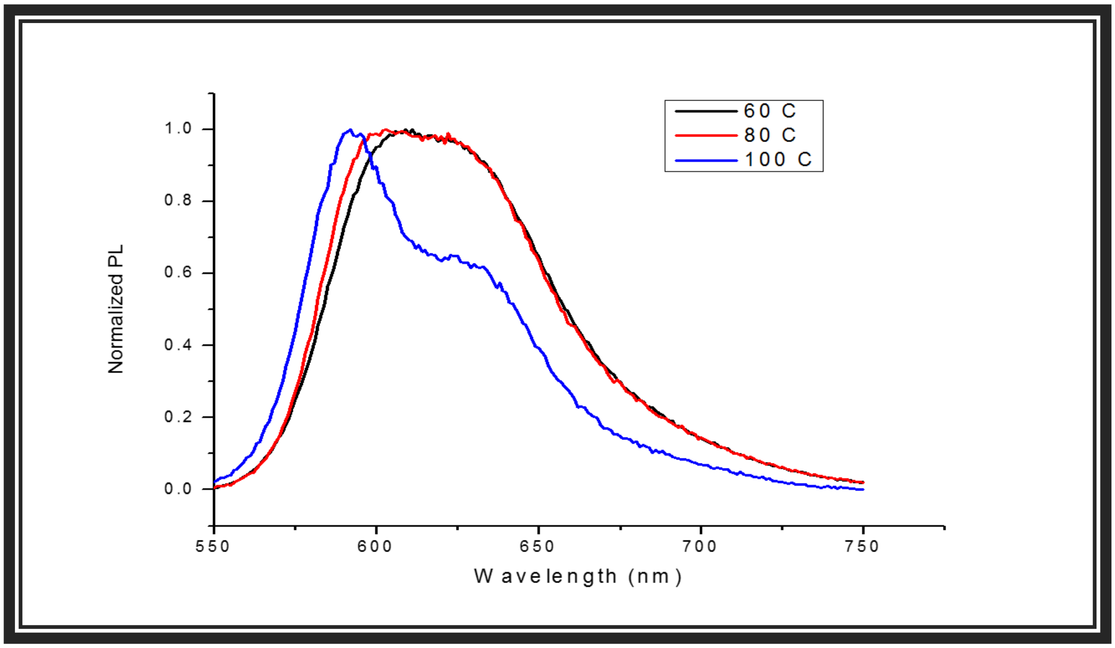


Fig 4.6: PL Spectra of MDMO PPV in Chloroform at 60,80,100°C

As per the reasons mentioned in section 4.5 order of preference would be

100°C > 60°C > 80°C

D) Toluene

UV Spectra

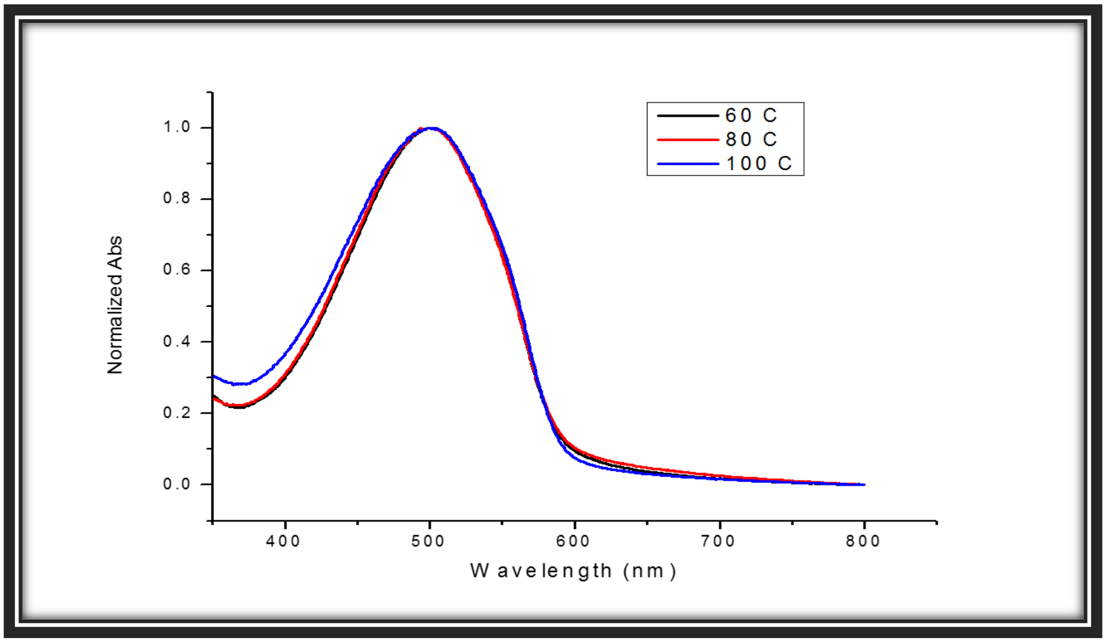


Fig 4.7: UV Spectra of MDMO PPV in Toluene at 60,80,100°C

PL Spectra

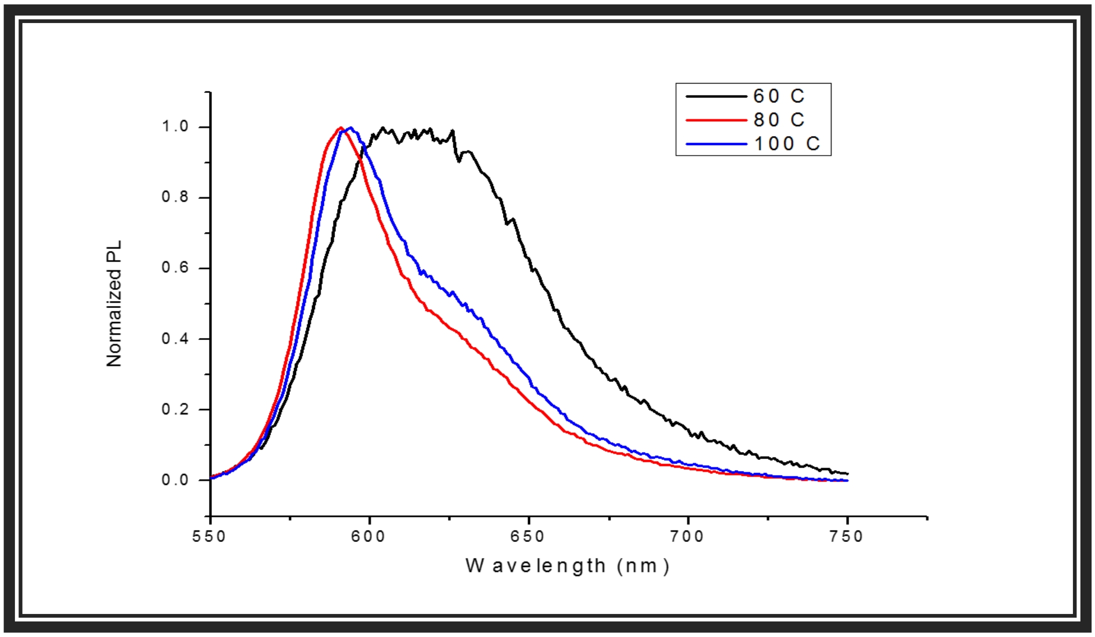


Fig 4.8: PL Spectra of MDMO PPV in Toluene at 60,80,100°C

As per the reasons mentioned in section 4.5 order of preference would be

100°C > 80°C > 60°C

Hence, 100°C is taken as the annealing temperature for the fabrication of organic light emitting diodes.

Comparison of UV Spectra in different solvents

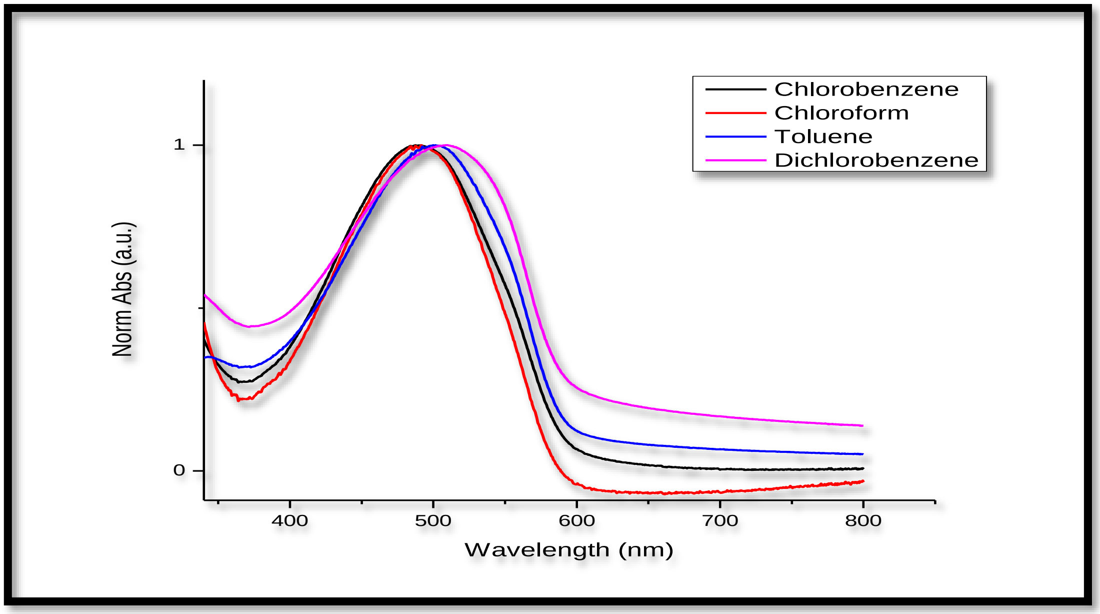


Fig 4.9: UV Spectra of MDMO PPV in different solvents at 100°C annealing temperature

Comparison of PL Spectra in different solvents

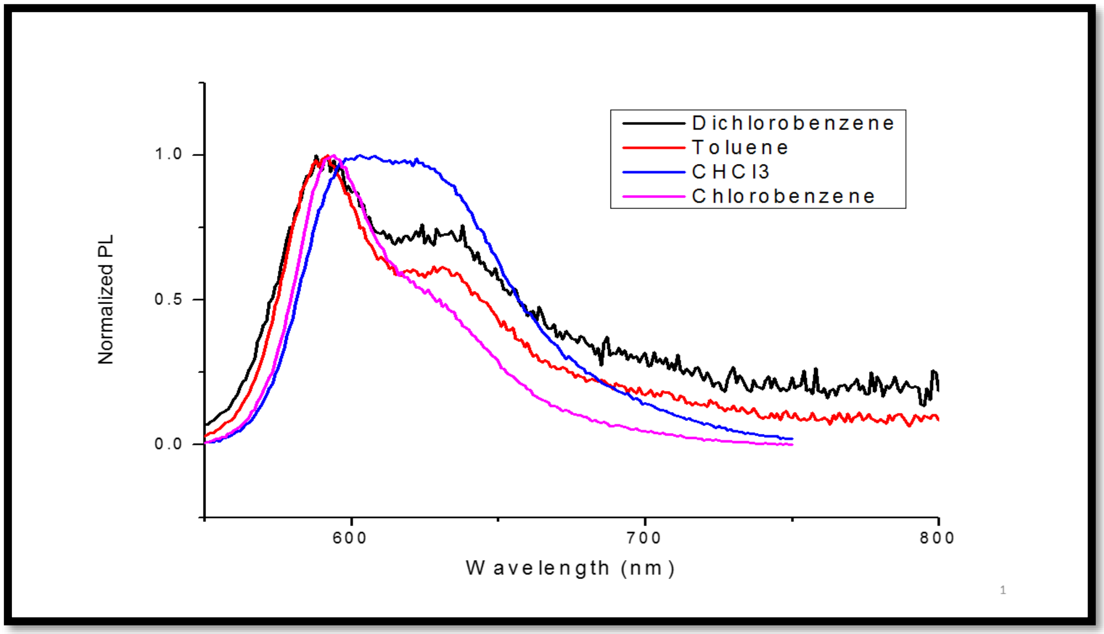


Fig 4.10: PL Spectra of MDMO PPV in different solvents at 100°C annealing temperature

As per the reasons mentioned in section 4.5 order of preference would be

Dichlorobenzene > Toluene > Chlorobenzene > Chloroform

Hence, while measuring the I-V characteristics of diode we must obtain the best performance for dichlorobenzene followed by toluene, chlorobenzene and chloroform respectively.

4.7 I-V Characteristics

The IV measurement was done to evaluate the performance of organic diodes. In order to perform IV measurement Keithley source meter was employed.

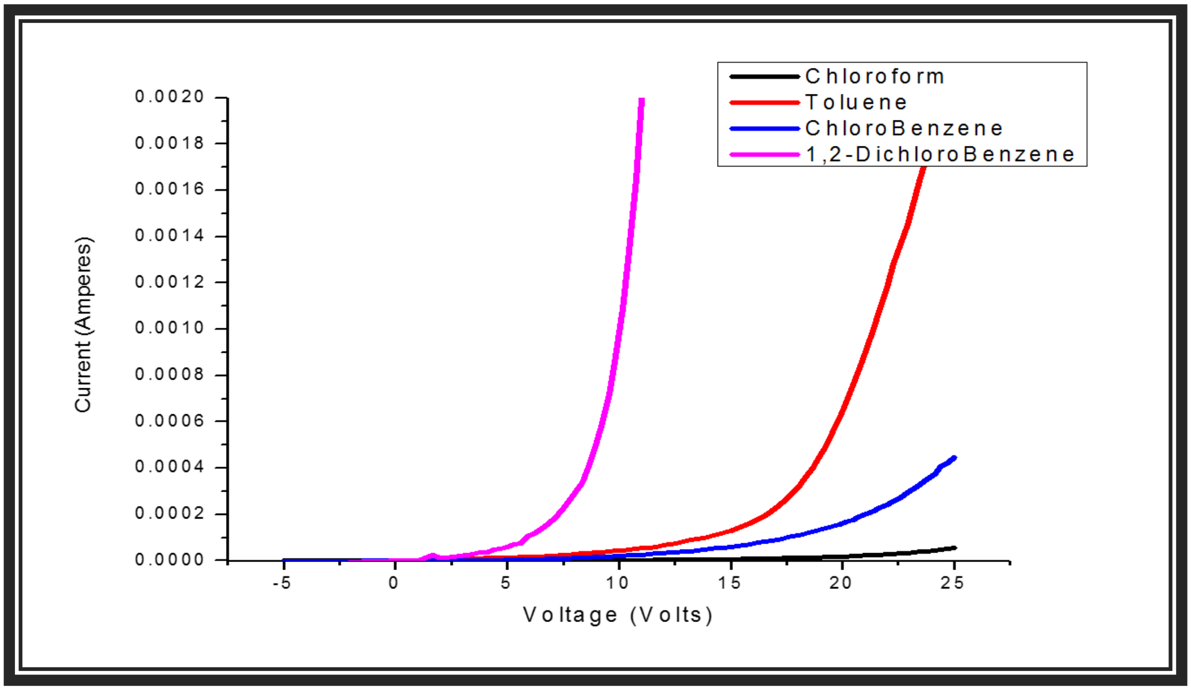


Fig 4.11: I-V characteristics of diode prepared from different solvents

As we can have inferred from section 4.5 and 4.6 the order of better charge conduction here is

MDMO PPV in Dichlorobenzene >MDMO PPV in Toluene >MDMO PPV in Chlorobenzene > MDMO PPV in Chloroform

Chapter 5 – Future Scope and Applications

In this work organic light emitting diodes were fabricated using conjugated polymers. They were made by varying the solvent used and at different annealing temperatures. The increase in annealing temperature led to good morphological state of the thin film which leads to better charge transport across the device.

Conducting polymers do not dissolve equally in different organic solvents, and show different UV and PL characteristics for different solvents and varied annealing temperatures. By studying the effects of varying these parameters on the standards of measurements, thin films can be optimized. Charge transport in an OLED can be improved by changing and improving the surface characteristics of the thin films being coated on top of the substrates. Experiments can also be carried out to measure the electroluminescence at each organic layer of the device by varying the solvent used and at different annealing temperatures.

Organic electronics are the technology of the future. The number of advantages and opportunities that organic electronics provide to modern technology can be exploited in numerous ways, and can only be limited by imagination. Organic semiconductors are a lot cheaper than their inorganic counterparts, which will play a huge role in bringing down the price of expensive technology. They are light in weight, compared to inorganic semiconductors which are often bulky and take a lot of space. Inorganic semiconductors need extreme fabrication test conditions, with clean rooms and temperatures of over a 1000 °C. Organic electronics can be fabricated in moderate conditions like at room temperatures.

Due to these reasons, organic semiconductor based electronics find use in a lot of technological advancements and futuristic applications. Some of this technology has already reached market maturity, and is used efficiently with OLEDs, leading to technology like flexible display films. These flexible display films are transparent when turned off, which means that foldable televisions could soon be a reality.

Also one of the key benefit is the substrate of an OLED can be flexible instead of rigid. These flexible OLEDs can be implanted in the body for various medical applications. They can thus be used as implantable patches for monitoring wound healing, for use in diagnosis or spectroscopy, or to control the delivery of drugs triggered by light in photodynamic drug therapy. In a field like organic electronics, new breakthroughs are happening every day, and endless innovations are possible. Keeping in view of sustainability production, we can definitely say that the future of lighting is organic!

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