Chapter One

Solar cells

1.1 Introduction:

The basic idea of a solar cell is to convert light energy into electrical energy. The energy of light is transmitted by photons, small packets orquantum's of light, whose energy depends on the frequency, or color, of the light. The solar spectrum covers ultra violet to infrared wavelength ranges. Only 30% of incident light energy is in the visible light range, while over 50% is in the infrared range. The photons in ultra violet (UV) and visible range have enough energy to pump electrons in semiconducting material, and this can be effectively used for charge generation. However, infrared(IR) waves are too weak to generate electricity using conventional PV technology.

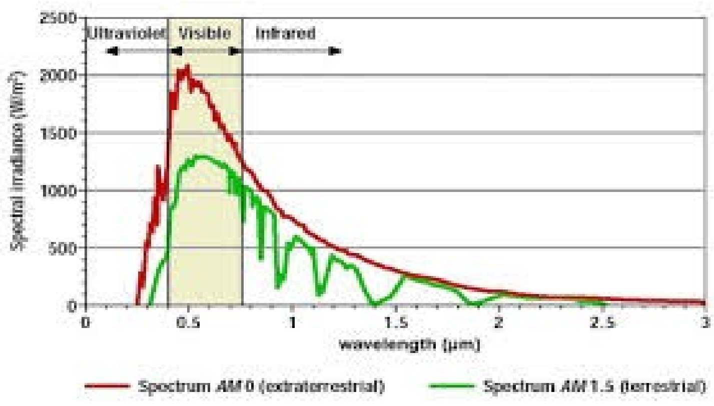


Figure (1.1) solar radiation spectrum

New photovoltaic (PV) energy technologies can contribute environmentally friendly, renewable energy production, and the reduction of the carbon dioxide emission associated with fossil fuels. Solar cells do not produce noise and they are totally silent, they require very little maintenance, they are long lasting sources of energy which can be used almost anywhere, They have long life time and biomass.

They are many applications of solar cell solar like solar pumps which are used for water supply, Domestic power supply for appliances include refrigeration, washing machine, television and lighting, Ocean navigation aids, Telecommunication systems and Electric power generation in space.

There are many types of solar cells, this research briefly introduces several types of solar cells covering silicon, polymer/organic based, and hybrid types like the dye-sensitized solar cell.

One new PV technology, plastic solar cell technology, is based on conjugated polymers and molecules. Polymer solar cells have attracted considerable attention in the past few years owing to their potential of providing environmentally safe, flexible, lightweight, inexpensive, efficient solar cells. Especially, bulk-hetero junction solar cells consisting of a mixture of a conjugated donor polymer with a methanofullerene acceptor are considered as a promising approach.

The mechanical flexibility of polymer materials is welcome for all PV applications onto curved surfaces for architectural integration. By casting semi-transparent polymer PV thin films between insulating window glass, large unused areas (the windows) can be employed for power generation in addition to the limited roof areas of crowded cities. Even the color of such PV elements can be varied by sacrificing some parts of the visible solar spectrum. An encouraging breakthrough in realizing higher efficiencies has been achieved by mixing electron ± donor-type polymers with suitable electron acceptors. The photo physics of conjugated polymer/fullerene solid composites has been particularly well investigated over the last eight years. An understanding of the photo physics in detail has allowed the realization of prototype PV devices with solar power conversion efficiencies of around 3 %, and this has in turn triggered enhanced emphasis from several groups worldwide [9].

1.2 Research problem:

Most commercial solar cells are made from a refined, highly purified siliconcrystal, similar to the material used in the manufacture of integrated circuits and computer chips (wafer silicon). The high cost of these silicon solar cells and their complex production process has generated interest in developing alternative photovoltaic technologies. Also there is other type of solar cell fabricated from polymer; most photovoltaic cells that have been fabricated have low efficiency and high coast. Thus there is a need to see how low cost and eare fabricated polymer solar cells can be commercially fabricated and used.

1.3 Research Significance:

Polymer solar cell technology is relatively new and is currently being very actively researched by universities, national laboratories, and companies around the world.

1.4 Research objective:

The aim of this research:

- To study relationship between efficiency of polymer solar cell and light intensity.
- To study efficiency of polymer solar cells by using different types of dyes (natural, chemical).
- To compare between natural dyes and chemical dyes.

1.5 Research Layout:

This research has come into four chapters. Chapter one is the introduction. Chapter two is theoretical backgrounds of the polymer solar cell. Chapter three is concerned with the experimental work and chapter four is the contribute.

Chapter Two

Polymer Solar Cell

2.1 Introduction

It is expected that the global energy demand will double within the next 50 years. Fossil fuels, however, are running out and are held responsible for the increased concentration of carbon dioxide in the earth’s atmosphere. Hence, developing environmentally friendly, renewable energy is one of the challenges to society in the 21st century. One of the renewable energy technologies is photovoltaic (PV), the technology that directly converts daylight into electricity. PV is one of the fastest growing of all the renewable energy technologies, in fact, it is one of the fastest growing industries at present.1Solar cell manufacturing based on the technology of crystalline, silicon devices is growing by approximately 40% per year and this growth rate is increasing.This has been realized mainly by special market implementation programs and other government grants to encourage a substantial use of the current PV technologies based on silicon. Unfortunately, financial support by governments is under constant pressure [9].

2.2 Silicon Solar Cell:

The sunlight is absorbed by a solar cell in a solar panel. The absorbed light causes electrons in the material to increase in energy. At the same time making they free to move around in the material. However, the electrons remain at this higher energy for only a short time before returning to their original lower energy position. Therefore, to collect the carriers before they lose the energy gained from the light, a PN junction is typically used. PN junction consists of two different regions of a semiconductor material (usually silicon), with one side called the p type region and the other the n-type region. During the incident of light energy, in p-type material, electrons can gain energy and move into the n-type region. Then they can no longer go back to their original low energy position and remain at a higher energy. The process of moving a light- generated carrier from p-type region to n-type region is called collection. These collections of carriers (electrons) can be either extracted from the device to give a current, or it can remain in the device and gives rise to a voltage. The electrons that leave the solar cell as current give up their energy to whatever is connected to the solar cell, and then re-enter the solar cell. Once back in the solar cell, the process begins again [12]:

- The mechanism of electricity production- Different stage:

Conduction band **High density**

Valence band **Low density**

Fig (2.1) p-n junction

The above diagram shows the formation of p-n junction in a solar cell. The valence band is a low-density band and conduction band is high-density band.

Stage-1

When light falls on the semiconductor surface, the electron from valence band promoted to conduction band

Conduction band **High density**

Valence band **Low density**

E

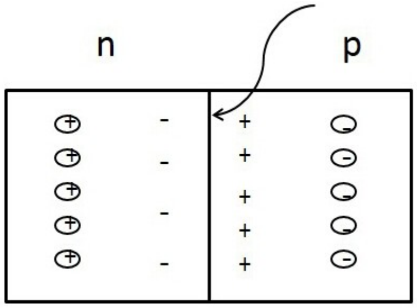


Fig (2.2) charge generation by light

Therefore, the hole (vacancy position left by the electron in the valence band) is generates. Hence, there is a formation of electron-hole pair on the sides of p-n junction. Where positive ions exist at n type negative ions exists at p type.

- ## Stage-*2*

In the stage 2, the electron and holes are diffuse across the p-n junction. Where positive ions at (n) type attracts electrons, while negative ions at (p) type attracts holes.

Conduction band **High density**

Valence band **Low density**

E

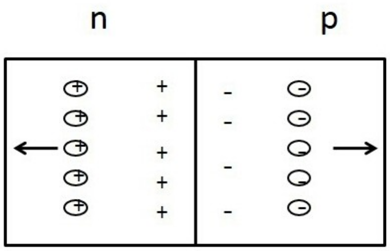


Fig (2.3): charge separation at p-n junction by ions

- ## Stage-3

In the stage 3, due to accumulation of high concentratedelectron build due to contraction gradient to the left side of the p-n junction. The same hold far holes, where they diffuse to the left from high concert region to low concentration region.

Conduction band **High density**

Valence band **Low density**

E

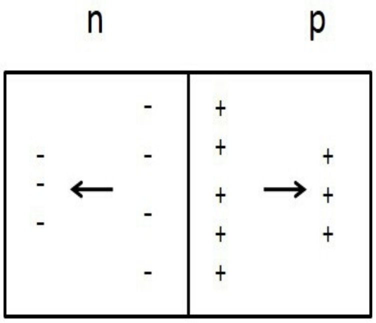


Fig (2.4): Diffusion of charge

- ## Stage-4

When the PN junction is connected with external circuit, the current flows

Conduction band **High density**

Valence band **Low density**

E

Power

Fig (2.5):PN junction is connected with external circuit

$$I = I0 \underset{¿}{\overset{e}{(¿¿\beta v-1)}}-Ip \qquad (2.1)$$

Where Io is the saturation current, v is the voltage and Ip is the photon current.The cells are characterized by many parameters, one of these parameter, is the short-current it is defined as the current that flows when the cells terminals are connected with resistant less wire. In this case v = 0 and I = Isc and equation (2.2.1) gives:

$$Isc = I0 \underset{¿}{\overset{e}{(¿¿0-1)}}-Ip = - Ip \qquad (2.2)$$

Isc = - Ip (2.3)

The other parameter is the so called open circuit voltage Voc it is defined as the volt, when no current flows. For open-circuit voltage:

At I = 0 V = Voc (2.4)

$$I = Io \quad \overset{e}{\underset{¿}{(¿¿\beta v-1)}}-Ip$$

$$0 = Io \quad \overset{e}{\underset{¿}{(¿¿\beta voc-1)}}-Ip$$

$$e^{\beta voc} = \frac{Io+I\,p}{Io} = 1+ \frac{I\,p}{Io}$$

$$Voc = \frac{1}{\beta} \ln (1+ \frac{I\,p}{Io}¿$$

(2.5)

$$FF = \frac{Vm\Im}{Voc\;Isc}$$

(2.6)

Where FF is the fill factor.

The power P is given by:

$$P = IV = VI0 \quad \overset{e}{\underset{¿}{(¿¿\beta v-1)}}-VIp$$

(2.7)

To find Vmax = Vm at which Pmax

$$\frac{dP}{dV} = 0 \qquad I+ \frac{VdI}{dV} = 0$$

(2.8)

I = Io $\overset{e}{\underset{\text{¿}}{(\text{¿¿}\beta v-1)}}-Ip$

$\frac{dI}{dV}$ = Io $\beta e^{\beta v}$

(2.9)

I + Vm (I0 $\beta e^{\beta vm}$) = 0

I0 $\overset{e}{\underset{\text{¿}}{(\text{¿¿}\beta vm)}}-\text{¿}$ Io – Ip + I0 $\beta Vm\, e^{\beta vm}$ = 0

(1 + β Vm) $e^{\beta vm}$ = $\frac{Io+I\,p}{Io}$ = 1+ $\frac{I\,p}{Io}$

β Vm = ln { (1+ $\frac{I\,p}{Io}$)/ (1 + β Vm) } ln (1+ $\frac{I\,p}{Io}$) – ln (1 + β Vm)

Vm + $\frac{1}{\beta}$ ln (1 + β Vm) = $\frac{1}{\beta}$ ln (1+ $\frac{I\,p}{Io}$) = Voc

Vm + $\frac{AkT}{q}$ ln (1+ $\frac{qvm}{AkT}$) = Voc (2.10)

To find Imax = Im at which

P = max P =VI

$$\frac{dP}{dI} = 0 \qquad V + \frac{IdV}{dI} = 0$$

(2.11)

But from (2.2.9):

$$\frac{dV}{dI} = \left(\frac{dI}{dV}\right)^{-1} = \frac{1}{\beta I0} e^{-\beta vm}$$

(2.12)

Thus inserting (2.2.12) in (2.2.11) and substituting (I = Im, V = Vm) yields

$$Vm + Im \frac{1}{\beta I0} e^{-\beta vm} = 0$$

$$\frac{\mathfrak{I}}{\beta I0} e^{-\beta vm} = -Vm$$

$$I_m = -\beta I0 Vm\, e^{-\beta vm} = -\frac{qvm\, I0}{AkT} e^{qvm/AkT}$$

$$I_{max} = I_m = -\frac{qvm\, I0}{AkT} e^{qvm/AkT}$$

(2.13)

Many different designs of this general p-i-n type silicon solar cell have been developed. Single crystalline and multi-crystalline cells nowadays reach 15-20% measured solar energy conversion efficiencies. In essence silicon is not the optimal material for solar cells, its band gap of 1.1 eV (Crystalline Si) is at the lower limit for optimal solar light harvesting. The requirements for an ideal solar cell are:

1. Band gap between 1.1 and 1.7 eV
2. Direct band structure
3. Non-toxic readily available materials
4. Easy reproducible deposition technique, suitable for large area
5. Good photovoltaic conversion efficiency
6. Long term stability.

Silicon also suffers from its disadvantage of being an indirect semiconductor; as a result it is only a weakly absorbing material. For a silicon film to absorb 90% of the light, at least a 100 μm thick film is needed. Using direct semiconductors, like GaAs, a 1 μm thin film is sufficient. Because the photo carriers have to reach the p-n junction for separation, the silicon has to be of very high purity and crystalline perfection. For this reason the production of crystalline silicon is far from easy and cheap, and much attention is paid to the development of multi-crystalline and amorphous silicon solar cells, promising high efficiencies at lower costs. Nonetheless single crystalline silicon solar cells still have a market share of 43%, versus 48% for multi-crystalline silicon and only 8% for amorphous silicon, leaving 1% for non-silicon based solar devices [1].

2.3 Organic Solar Cell:

An organic solar cell or plastic solar cell is a type of polymer solar cell that uses organic electronics, a branch of electronics that deals with conductive organic polymers or small organic molecules for light absorption and charge transport to produce electricity from sunlight by the photovoltaic effect [10].

The plastic used in organic solar cells has low production costs in high volumes. Combined with the flexibility of organic molecules, organic solar cells are potentially cost-effective for photovoltaic applications. Molecular engineering (e.g. changing the length and functional group of polymers) can change the energy gap, which allows chemical change in these materials. The optical absorption coefficient of organic molecules is high, so a large amount of light can be absorbed with a small amount of materials. The main disadvantages associated with organic photovoltaic cells are low efficiency, low stability and low strength compared to inorganic photovoltaic cells [10].

2.3.1 Basic Processes in an Organic Solar Cell:

Various architectures for organic solar cells have been investigated in recent years. In general, for a successful organic photovoltaic cell four important processes have to be optimized to obtain a high conversion efficiency of solar energy into electrical energy.

1. Absorption of light
2. Charge transfer and separation of the opposite charges
3. Charge transport
4. Charge collection

For an efficient collection of photons, the absorption spectrum of the photoactive organic layer should match the solar emission spectrum and the layer should be sufficiently thick to absorb all incident light. A better overlap with the solar emission spectrum is obtained by lowering the band gap of the organic material, but this will ultimately have some bearing on the open-circuit voltage. Increasing the layer thickness is advantageous for light absorption, but burdens the charge transport [10].

2.4 Types of Organic Solar Cells:

They are some types such as**:**

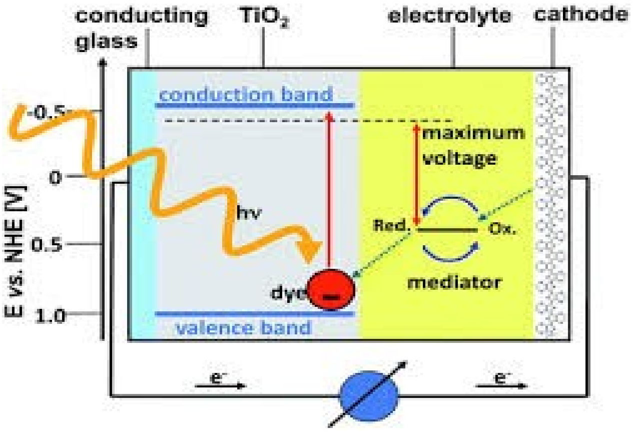
1. Dye sensitized solar cells: Electrochemical cells.
2. Polymer solar cells: Made by solution, low temperature processing.

2.4.1 Dye Sensitized Solar Cells:

In 1991 Brian O’Regan and Michael Grätzel introduced the dye sensitized solar cell (DSSC). This type of solar cell is considered as accost effective alternative for silicon solar cells. The heart of the DSSC is a high surface area TiO2 nano particulate electrode, covered with a monolayer of dye molecules. Upon photo excitation of the dye an electron is injected into the conduction band of the TiO2. A redox couple (I-/I3-) in an electrolyte.

Solution covering the whole TiO2 electrode regenerates the dye, and is itself in return regenerated at the counter electrode. The layout of the DSSC is shown in figure (2.6). Often, transition metal complexes are used as dyes, e.g. RuL2-(NCS)2 (known asN3 dyes), where L is a π-conjugated ligand with TiO2 anchoring groups. The best DSSCs reach efficiencies higher than 10% measured under AM1.5 solar irradiation. The main drawback of the traditional DSSC, hampering wide use, is the application of a liquidelectrolyte. This liquid electrolyte is often related to its poor thermo-stability, and responsible for thecorrosion of the Pt covered counter electrode. For this reason alternatives for an electrolyte are beingdeveloped, aiming at solid-state version of the DSSC. Current state of the art quasi-solid-state dye, Figure 2.6Schematic scheme of the traditional dye-sensitized solar cell.

Sensitized solar cells based on the iodide/triiodide redox couple, reach stable and > 6% efficient solar cells. Commercial application of this type of solar cells in consumer products is currently explored by Hitachi Maxell for application in a film-like lightweight solar battery. One recent result, also bytheGrätzel group, is a solvent-free dye-sensitized solar cell based on an ionic liquid electrolyte and using SeCN-/ (SeCN)3- as the redox couple, replacing the iodide/triiodide redox couple. This solar cell reaches measured AM1.5 efficiencies of 8%. Another elegant example of recent progress is the quasi solid-state tandem DSSC developed by Dürr and coworkers. The device layout and working Principles are shown in figure 2.8. Two separate dye-sensitized cells are connected in parallel and placed on top of each other. The cell first exposed to illumination contains a Red dye, the other a socalled black dye. This assures an effective absorption of the solar emission, leading to a high power conversion efficiency of 10.5%, measured under AM1.5 conditions [8].



Fig(2.6) Schematic scheme of the traditional dye-Sensitized solar cell

2.4.2 Polymer Solar Cells:

A polymer solar cell is a type of flexible solar cell made with polymers, large molecules with repeating structural units, that produce electricity from sunlight by the photovoltaic effect. Polymer solar cells include organic solar cells (also called "plastic solar cells"). They are one type of thin film solar cell, others include the currently more stable amorphous silicon solar cell [3]. Polymer solar cell technology is relatively new and is currently being very actively researched by universities, national laboratories, and companies around the world.

Compared to silicon-based devices, polymer solar cells are lightweight (which is important for small autonomous sensors), potentially disposable and inexpensive to fabricate (sometimes using printed electronics), flexible, and customizable on the molecular level, and they have lower potential for negative environmental impact. An example device is shown in Fig. 1. The disadvantages of polymer solar cells are also serious: they offer about 1/3 of the efficiency of hard materials, and they are relatively unstable toward photochemical degradation. For these reasons, despite continuing advances in semiconducting polymers, the vast majority of solar cells rely on inorganic materials.

Polymer solar cells currently suffer from a lack of enough efficiency for large scale applications and stability problems but their promise of extremely cheap production and eventually high efficiency values has led them to be one of the most popular fields in solar cell research. It is worth mentioning that state-of-the-art devices produced in academic labs – with the record currently held by Yang Yang’s group in UCLA – have reached certified efficiencies above 8% while devices produced which have remained unpublished – probably to maintain secrecy for industrial applications – are known to have already gone above 10% [12].

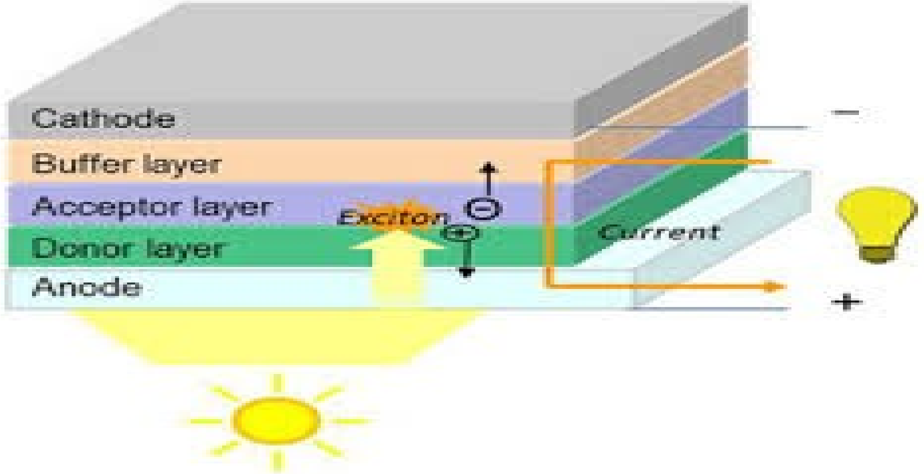


Figure 2.7Polymer solar cells

2.5 Polymer Solar Cells Work:

Like all solar cells, the polymer solar cell converts light into electricity, by converting a flux of photons (light) into a flux of charged particles (a current). This conversion process is made possible by the combination of several types of materials, all having distinct electrical and optical characteristics as described in the text presenting the polymer solar cell layer stack, but most importantly is the inclusion of semiconductors. explain how polymer solar cell is able to generate electricity, and will do so in three sections signifying the three main steps of the conversion process which can be summarized in brief.

1. A photon incident on a semiconductor, having an energy that exceeds the semiconductor band gap, excites an electron to an unoccupied state above band gap, creating an electron-hole (e-h) pair.

2. The electron-hole pair is subsequently separated over a built-in gradient in the electrochemical potential of the solar cell.
3. Finally, the electron and hole is collected at opposite electrodes and led to recombine after being put to work in an external circuit [10].

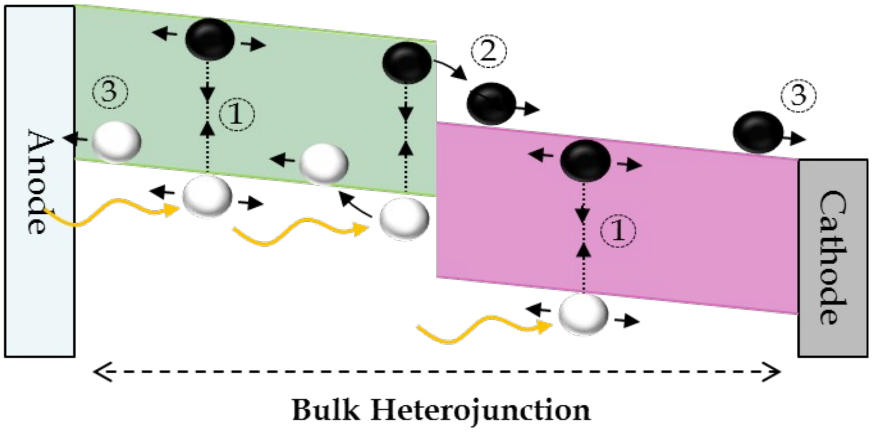
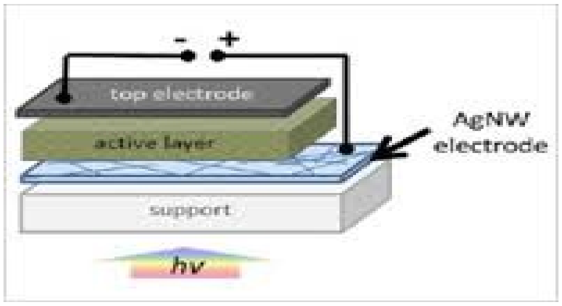


Figure (2.8). The working principle

The working principle of the solar cell. Light enters the cell through the transparent anode, and is absorbed in the bulk heterojunction layer through generation of excitons (1). The excitons diffuse in the bulk heterojunction until they either recombine or reach a donor-acceptor interface, where they separate into electrons (black) and holes (white) (2). The electrons and holes will then move to the respective anode and cathode, through the donor and acceptor material phase (3) [10].

2.6 Consist of Polymer Solar Cell:

Making a polymer solar cell is often done using polymers dissolved in organic solvents, which are transferred by printing or coating methods to a substrate. The materials are added in layers in a certain order to build a solar cell stack. The materials needed in the solar cell stack are; a central active (light absorbing) layer, which translate the impinging photons into separate electrons and holes, a selective charge transport layer on each side of the active layer, allowing only passage of either electrons (ETL) or holes (HTL), and finally two electrodes for extracting the charges from the solar cell, with at least one of the electrodes having a requirement of transparency such that the light can pass through and reach the active layer [9].



Figure(2.9)Consist of Polymer Solar Cell

2.6.1 Geometries:

Polymer solar cells are often divided into two groups based on the solar cell stack geometry. A normal and an inverted geometry.The definition of the two geometries lies within the direction of the charge flow. In a normal geometry solar cell the substrate and the transparent electrode on it is the positive electrode, with the light passing through the substrate and this electrode before being absorbed in the active layer. The top electrode is then the negative electrode. In the inverted geometry the two electrodes and the charge selective layers are switched around, such that the transparent electrode at the substrate is the negative electrode, with a ETL layer between it and the active layer, while the top electrode is the positive electrode with a HTL layer between it and the active layer [13].

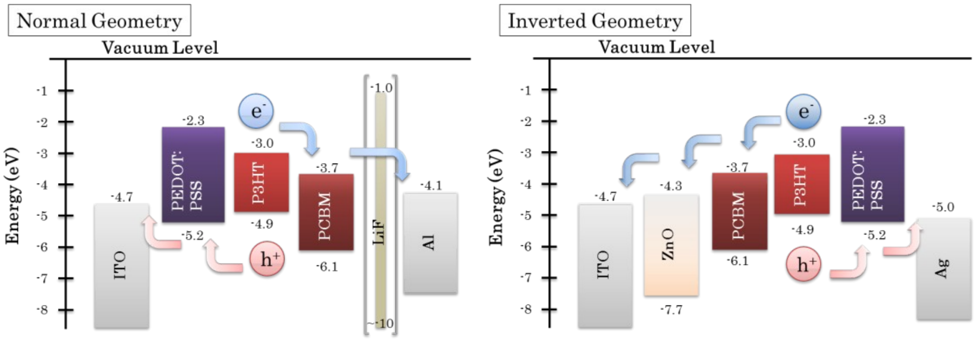


Figure (2.10) Energy levels for normal and inverted geometry solar cells

2.6.2 Active layer:

The active layer consists of two components in the polymer solar cells. A donor which absorbs the light and an acceptor which extracts the electron from the excitonic bound electron hole, resulting in an electron travelling in the acceptor phase of the active layer and a hole travelling in the donor phase. For this to occur successfully the low lifetime of an exciton in the donor materials necessitates a donor-acceptor boundary at which the exciton can be broken within approximately 10 nm. Furthermore, since the holes and electrons have to travel out of the active layer towards the electrodes, the domains of donor and acceptor needs to be connected in an interconnected network allowing both efficient dissociation of the excitons and efficient transport of the charge carriers to the respective electrodes. In this research used polymer with natural dye as active layer [13].

2.6.2.1 Polymer(MEH–PPV):

Poly [2-methyl-5-(2-ethyl-hexyloxy)-1, 4-phenylene vinylene] (MEH-PPV) is widely used in the fabrication of polymer light emitting diodes and as donor material in the fabrication of bulk-heterojunction photovoltaic cells because of its excellent processibility and favorable electronic and spectroscopic properties. It is very important to understand the relationship between the morphology and the processing conditions, and their influence on the electronic and photonic properties of polymer thin films [8].

2.6.2.2 Dyes:

In these polymer solar cells used four different types of dyes:

- **Ecerchrom**:

Preferred IUPAC name: Sodium 1-[1-Hydroxynaphthylazo]-6-nitro-2-naphthol-4-sulfonateSystematic name: Sodium 4-[2-(1-hydroxynaphthalen-2-yl)hydrazin-1-ylidene]-7-nitro-3-oxo-3,4-dihydronaphthalene-1-sulfonate Other names: Sodium4-[2-(1-hydroxynaphthalen-2-yl)hydrazin-1-ylidene]-7-noxonaphthalene-1-sulfonate; Solochrome Black T; ET-00Eriochrome Black T is a complexometric indicator that is part of the complexometric titrations, e.g. in the water hardness determination process. It is an azo dye. Eriochromeis a trademark of Ciba-Geigy. In its protonated form, Eriochrome Black T is blue. It turns red when it forms a complex with calcium, magnesium, or other metal ions [6].

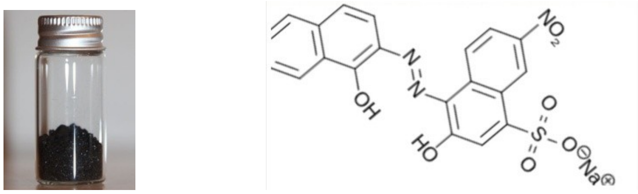


Figure (2.11) Ecerchrom structure

- ## Dray Ink:

Ink fluid containing pigment and chemical components and variety of molecules used in writing and printing on different sheets of paper or other scripts to show the different colorful graphics and designs. Inks compounds mixtures of chemical contents is not as simple as it contains the different types of solvents and oil and pigment particles chemical compounds intermingle and unite to give different properties in terms of density and flow of liquid and harmony and contrast colors in in different uses required . It does not cause acidity of the writing surface. Not much affected by light, affected by moisture and water [6].

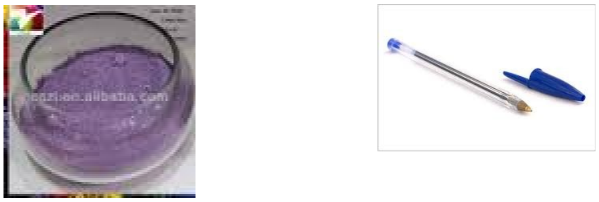


Figure (2.12) Dray Ink

Chrolorpheel:

In chloropheel the central ion is magnesium, and the large organic molecule is a porphyrin. The porphyrin contains four nitrogen atoms that form bonds to magnesium in a square planar arrangement. There are several forms of chloropheel. The structure of one form, chloropheel a, is shown. Chloropheel is one of the most important chelates in nature. It is capable of channelling the energy of sunlight into chemical energy through the process of photosynthesis [6].

Figure (2.13)Chloropheel structure

Fenugreek (Helba):

Binomial name: (Trigonellafoenum - graecum Fenugreek) is an annual plant in the family Fabaceae, with leaves consisting of three small obovate to oblong leaflets. It is cultivated worldwide as a semiarid crop, and its seeds are a common ingredient in dishes from the Indian Subcontinent.

The Fenugreek seed contion a yellow dye that is used for dyeing cloth and could be used for other coloring purposes,including possibly food and pharmaceucical products. This dye when mixed with copper sulphare,producesa fine permanentgreen(Fazli and Hardman,1968).theSame workersreport the use of fenugreek in the preparation of imotacion carmine [6].

Figure (2.14) Fenugreek (Helba)

2.6.3 Transport layers:

The transport layers are based on materials which have the capability of being able to primarily transfer either electrons or holes due to a suitable positioning of the energy levels [13].

2.6.4 Electrodes:

The main issue with choosing the electrodes is to find electrodes with a suitable energy level and with one of the electrodes being transparent to allow sufficient light to enter the solar cell.The most commonly used electrode material has been indium tin oxide (ITO), due to a high optical transmission combined with a low resistance; on glass a transmission of >85% at <10 Ohm/sq. is often seen. Another electrodeused in solar cell is Fluorine-doped tin oxide (FTO) coated glass is electrically conductive and ideal for use in a wide range of devices, including applications such as opto-electronics, touch screen displays, thin film photovoltaics, energy-saving windows, RFI/EMI shielding and other electro-optical and insulating applications. Fluorine doped tin oxide has been recognized as a very promising material because it is relatively stable under atmospheric conditions, chemically inert, mechanically hard, high-temperature resistant, has a high tolerance to physical abrasion and is less expensive than indium tin oxide(ITO) [13].

2.6.5 Substrates:

When making polymer solar cells the substrates used for supporting the layered solar cell stack, can be divided into two distinct groups: glass and plastics. The two most commonly used types being floated glass substrates with ITO transparent electrodes used [13].

Chapter Three
Experimental Method

3.1 Introduction:

This chapter is concerned with the experimental work. This includes sample preparation, apparatus, theory and the experimental work set up.In this work solar cell types with differentnatural dyes were fabricated.

3.2 Sample preparation:

The spin coating (see Fig (3.1)) technique device was remove and surface was washed by distilled water and methanol, then rinsed with Aceton and dried, the FTO Glass was put in spin coating. The prepared of polymer (MEH–PPV) solution was spin coated on the FTO glass substrate for 60 sec, and prepared of dye solution was spin coated on the polymer at about 600 rpm for 60 sec in order to yield a thin uniform film . Finally Aluminum strips were evaporated on top of the thin film.

3.3 Apparatus:

4 type of polymer solar cell (2×1) cm with different types,2 natural dyes,2 chemical dyes , 1 plug-in board A4 576 764,1 set of ten bridging plugs 501 48,1 pair of board holders 576 771 , 1 microvolt-DMM- voltmeter, KETHLEY-USA- 177 DC,1electrometer-ammeter, KETHLEY-USA- 642 DC, 1 halogen lamp housing, 12 V, 50/100 W 450 64 , rjoostat-Albert van der perk nv Rollerdom-No-464151-27Ω-5.2A, light OF intensity (scouts light, power of 1000 w),Connecting wires.

The purpose of this experiment is to find out the fill factor and efficiency of polymer solar cell by using Four samples with different types of dyes.

3.4Theory:

A polymer solar cell has p/n transition the radiation energy of incoming sun light is directly converted into electrical energy. PolymerSolar look like photodiode with a large surface area constructed so that the Light can penetrate the p/n transition through a thin n or p conducting layer (see Fig 3.2) and then creates electron-hole pairs. These are separated by the intrinsic electric field in the barrier layer and can migrate in the reverse direction. Electrons migrate into the n-doped region, and the holes migrate into the p-doped region.

If the external metal contacts are shorted, a short-circuit current I_{sc} flows in the reverse direction of the photodiode. This current is substantially proportional to the number of electron-hole pairs created per unit time, i.e. it is proportional to the irradiance of the incoming light and the surface area of the solar cell. If the metal contacts are open, this reverse current leads to a open-circuit voltage V_{oc}, which in turn leads to an equal diffusion current I_D in the forward direction of the diode so that no current flows at all. If a load with an arbitrary resistance R is connected, the current I flowing through the load depends on the resultant voltage V between the metal contacts [13].

In a simplified manner, in can be considered to be the difference between the current I_{sc} in the reverse direction, which depends on the irradiance Φ, and the current I_D of the non-irradiated semiconductor diode in forward direction, w hich depend on the terminal voltage (V):

$$I = I_{sc}(\Phi) - I_D(V)$$

(3 - 1)

In this way, the current-voltage characteristics typical of Solar cell are obtained (see Fig.3.3). In the case of small load resistances, the solar cell Behaves like a constant-current source as the forward current I_D can be neglected. In the case of greater load resistances, the behavior corresponds approximately to that of a constant-voltage source because then the current $I_D(V)$ increases quickly if the voltage changes slightly.

At a fixed irradiance, the power supplied by the solar cell Depends on the load resistance R. The solar cell reaches its maximum power P_{max} at a load Resistance R_{max} which, to a good approximation, is equal to the so-called internal resistance.

$$R_i = V_{oc} / I_{sc} \qquad (3 - 2)$$

The maximum power:

$$P_{max} = I_{max} . V_{max} \qquad (3 - 3)$$

This maximum power is smaller than the product of the open circuit voltage and the short-circuit current. The ratio:

$$FF = P_{max} / V_{oc} I_{sc} \qquad (3 - 4)$$

FF is often called fill factor.

The efficiency η is given by:

$$\eta = I_{sc} \times FF \times V_{oc} / I_n$$

(3 - 5)

Where I_n is the intensity of incident light. The short circuitCurrent density depends directly on the external quantum efficiency, the number of carriers collected/number of incident Photons.

3.5 Setup:

- The STE solar cell into the plug-in board was plugged, and the upper negative pole to the lower positive pole were connected using two bridging plugs (series connection of four solar cells).
- The STE potentiometer as a variable resistor was plugged, and connected it to the solar battery using bridging plugs.
- The ammeter was connected in series with the solar battery and the variable resistor. The measuring range was selected 100 10^{-11}A DC.
  - The micro voltmeter was connected in parallel to the solar cell.
- The scouts light lamp was connected to the transformer, and aligned it So that the solar cell is uniformly irradiated.

3.6 Carrying out of the experiment:

- The circuit was closed, first shorting the variable resistor with an additional bridging plug, and choose the distance of the halogen lamp so that the short circuit current was determined.
- The shorting bridging plug was removed, and increases the terminal voltage or decrease the current, respectively, step by step by changing the load resistance. For each step the current and the voltage were read, and take them down.
- Then interrupt the circuit, and measured the open-circuit voltage.
- repeat the series of measurements by change load resistance.

Fig (3.1)spin coating

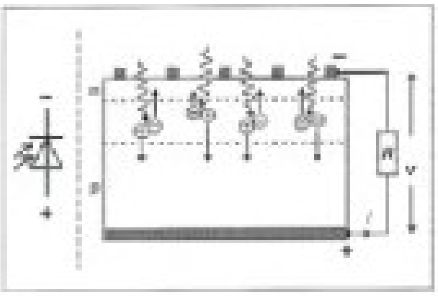


Fig (3.2)Principle of operation of a solar cell

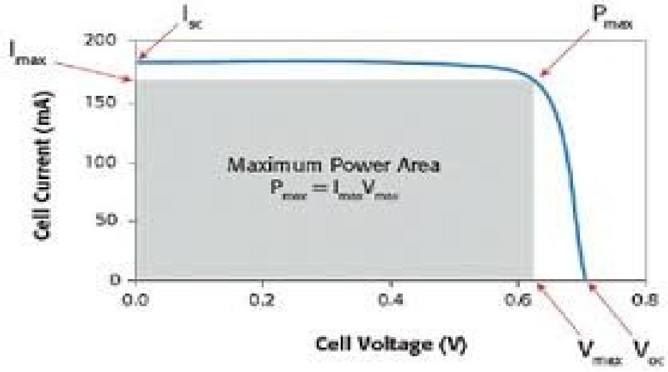


Fig (3.3) Current-voltage characteristic of a solar cell

Chapter Four
Results and Discussion

4.1 Introduction

This chapter concerned with results and discussion.The results consist ofFuor tables and three figures, each table and figure is for specific solar cell dye.

4.2 Results

Table (4.1): measured values of the terminal voltage *V* of the solar cell of the structure (FTO/Ecerchrom, MEH-PPV/CU) and the current *I* flowing through the load resistor.

V \ μv	I \ 10^{-13}A	V \ μv	I \ 10^{-13}A	V \ μv	I \ 10^{-13}A
3.84	30.30	3.66	34.08	3.15	36.74
3.84	30.80	3.65	34.48	3.12	36.77
3.81	30.52	3.62	34.89	3.09	36.74
3.71	30.50	3.61	35.40	3.07	36.74
3.67	30.55	3.62	35.70	3.03	36.80
3.66	30.75	3.60	35.93	3.00	36.72
3.65	31.01	3.59	36.31	2.99	36.77
3.65	31.21	3.56	36.52	2.99	36.82
3.65	31.31	3.47	36.69	2.96	36.82
3.65	31.41	3.43	36.74	2.94	36.84
3.65	31.51	3.66	34.08	2.91	36.84
3.65	31.74	3.65	34.48	2.87	36.90
3.65	31.87	3.62	34.89	2.83	36.90
3.66	32.02	3.61	35.40	2.79	36.95
3.66	32.23	3.43	36.74	2.74	36.95
3.66	32.40	3.39	36.72	2.70	36.97
3.66	32.53	3.36	36.77	2.67	37.02
3.67	32.76	3.32	36.77	2.62	37.05

Table (4.2): measured values of the terminal voltage *U* of the Solar cell of the structure (FTO/Dray Ink, MEH-PPV/CU), and the current *I* flowing through the load resistor

V \ µv	I \10^{-13}A	V \ µv	I \ 10^{-13}A	V \ µv	I \ 10^{-13}A
6.14	30	6.5	30	8.55	27.97
6.18	30	6.52	30	8.65	26.80
6.2	30	6.54	30	8.74	25.43
6.23	30	6.59	30	8.77	24.52
6.23	30	6.63	30	8.78	23.53
6.2	30	6.78	30	8.79	22.62
6.23	30	6.84	30	8.78	22.04
6.23	30	7	30	8..31	22
6.23	30	7.4	30	8.79	21.58
6.23	30	7.24	30	8.79	20.80
6.24	30	7.37	30	8.79	20.21
6.23	30	7.41	30	8.80	19.55
6.29	30	7.44	30	8.78	18.97
6.32	30	7.50	30	8.79	18.38
6.34	30	7.68	29.80	8.80	17.92
6.35	30	7.85	29.68	8.80	17.40
6.36	30	8.01	29.68	8.80	16.82
6.37	30	8.15	29.48	8.81	16.22

6.42	30	8.31	29.15	8.80	15.64
6.42	30	8.43	28.50	8.82	15.18

Table (4.3): measured values of the terminal voltage *U* of the Solar cell of the structure (FTO/Chrolorpheel, MEH-PPV/CU), and the current *I* flowing through the load resistor.

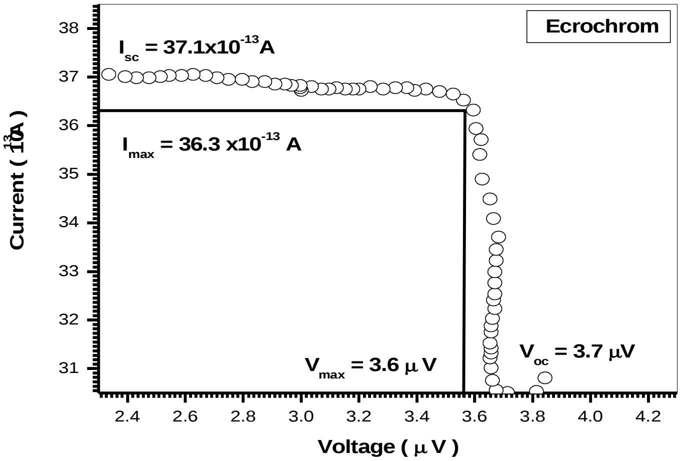
V \ µv	I \ 10^{-13}A	V \ µv	I \ 10^{-13}A	V \ µv	I \ 10^{-13}A
12.14	30	12.96	30	14.15	20.60
12.2	30	13.03	30.06	14.18	20.02
12.21	30	13.08	30.06	14.18	19.17
12.25	30	13.16	30.00	14.19	18.71
12.29	30	13.26	30.06	14.19	18.06
12.31	30	13.35	30.00	14.15	20.60
12.37	30	13.44	29.94	14.19	17.47
12.36	30	13.54	29.88	14.20	16.82
12.44	30	13.68	29.61	14.23	16.30

12.52	30	13.80	29.22	14.22	15.84
12.54	30	13.95	28.57	14.23	15.64
12.6	30	13.99	27.91	14.23	15.12
12.7	30	14.02	27.07	14.24	14.86
12.73	30	14.05	26.28	14.25	14.66
12.76	30	14.07	25.18	14.27	14.54
12.78	30	14.08	24.52	14.26	14.14
12.87	30	14.09	23.80	14.27	14.08

Table (4.4): measured values of the terminal voltage *U* of the Solar cell of the structure (FTO/Helba, MEH-PPV/CU), and the current *I* flowing through the load resistor.

V \ µv	I \ 10^{-13}A	V \ µv	I \ 10^{-13}A	V \ µv	I \ 10^{-13}A
9.68	30	10.32	30	10.77	30
9.79	30	10.34	30	10.74	30
9.86	30.08	10.41	29.95	10.74	30
9.91	30.08	10.52	30	10.78	30
9.96	30	10.51	30	10.76	30

9.98	30	10.47	29.95	10.75	30
10	30	10.56	30	10.85	30
10.04	30	10.61	30	10.89	29.25
10.06	30	10.64	30	10.94	28.31
10.07	30	10.64	30	10.97	27.37
10.09	30	10.69	30	10.98	25.60
10.12	30	10.7	30	10.99	24.18
10.14	30	10.72	30	11.00	23.35
10.17	30	10.73	30	11.00	22.65
10.22	30	10.76	30	11.00	21.47
10.24	30	10.77	30	11.00	20.66
10.28	29.84	10.74	30	11.01	19.47


Ecrochrom
I_{sc} = 37.1x10^{-13}A
I_{max} = 36.3 x10^{-13} A
V_{max} = 3.6 μ V
V_{oc} = 3.7 μV
Current (10^{-13}A)
Voltage (μ V)
38
37
36
35
34
33
32
31
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
4.2

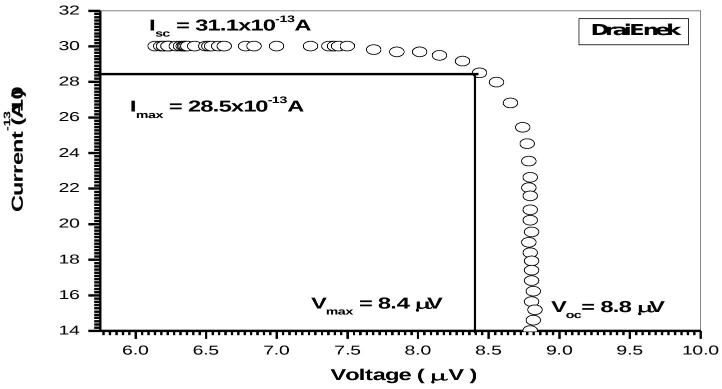


Fig.(4.1)

Current-voltage characteristics of the solar cell of the structure (FTO/Ecerchrom, MEH-PPV/CU) measured for constant values of the irradiance (see table 1).

Fig.(4.2) Current-voltage characteristics of the solar cell of the structure (FTO/Dray Ink, MEH-PPV/CU) measured for constant values of the irradiance (see table 2).

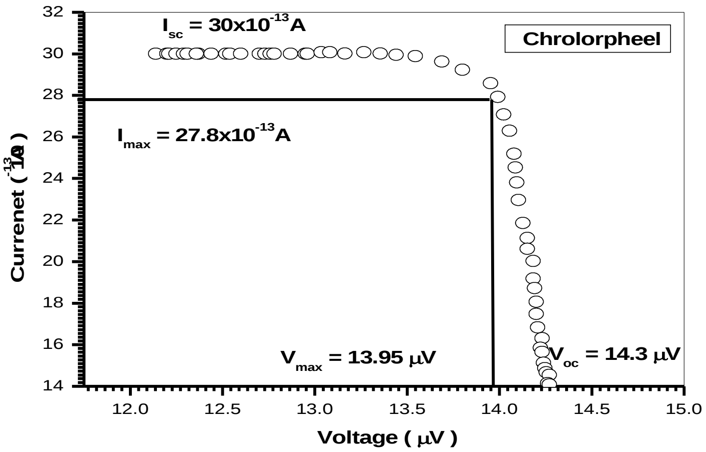


Fig.(4.3) Current-voltage characteristics of the solar cell of the structure ((FTO/Chrolorpheel, MEH-PPV/CU) measured for constant values of the irradiance (see table3).

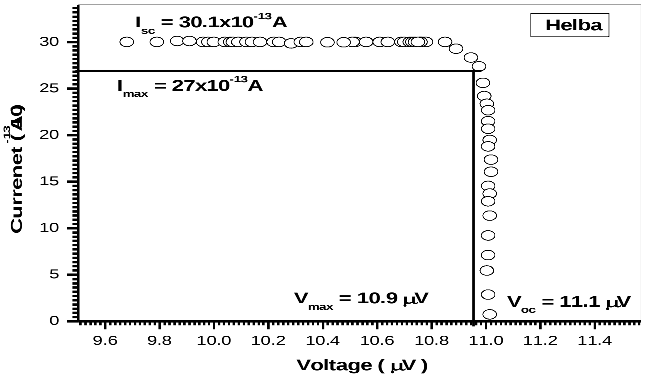


Fig.(4.4) Current-voltage characteristics of the solar cell of the structure ((FTO/Helba, MEH-PPV/CU) measured for constant values of the irradiance (see table 4).

Table (4.5): Efficiency and Fill Factor of the four polymer solar cell:

Dye	**V_{oc} / µv**	**I_{sc} /10^{-13}A**	**V_{max}/ µv**	**I_{max}/10^{-13}A**	**FF**	η

Ecerchrom	3.7	37.1	3.6	36.3	0.95	6%
Dray Ink	8.8	31.1	8.4	28.5	0.87	11%
Chrolorpheel	14.3	30	13.95	27.8	0.90	19%
Fenugreek (Helba)	11.1	30.1	10.9	27	0.88	14%

The Efficiency (η), Fill Factor (FF) carve calculated according to equation (3-5) and (3-4).

4.3 Discussion:

Curve (4.1) shows the current-voltage characteristics obtained from the measured values (see Table 1).this measurement was taken from solar cell of the structure (FTO/Ecerchrom, MEH-PPV/CU), The short-circuit current I_{sc} is $37*10^{-13}$ A, the open-circuit voltage V_{oc} is 3.7 μv, fill factor ff is 0.95, and the efficiency is 6%.

Curve(4.2) shows the current-voltage characteristics obtained from the measured values (see Table 2).this measurement was taken from solar cell of the structure (FTO/Dry Ink, MEH-PPV/CU),The short-circuit current I_{sc} is $31.1*10^{-13}$A, the open-circuit voltage V_{oc} is 8.8μv, fill factor ff is 0.87, and the efficiency is 11%.

Curve (4.3) shows the current-voltage characteristics obtained from the measured values (see Table 3).this measurement was taken from solar cell of the structure (FTO/Chrolorpheel, MEH-PPV/CU),The short-circuit current I_{sc} is $30*10^{-13}$A, the open-circuit voltage V_{oc} is 14.3μv, fill factor ff is 0.90, and the efficiency is 19%.

Curve (4.4) shows the current-voltage characteristics obtained from the measured values (see Table 4).this measurement was taken from solar cell of the structure (FTO/Helba, MEH-PPV/CU), The short-circuit current I_{sc} is $30.1*10^{-13}$ A, the open-circuit voltage V_{oc} is 11.1μv, fill factor ff is 0.88, and the efficiency is 14%.

Once the deficiency or increased distance between the severity of the luminosity and the cell that does not impair reading all of the current and voltage and batli does not impair cell efficiency.

4.4 Conclusion:

The conversion of light energy into electrical energy, The efficiency and fill factor of polymer solar cells where are fabricated from different types of dyes were calculated. We found that the relationship between light intensity and efficiency of polymer solar cell fixed. We found that the efficiency was changed when we used different types of dyes. The study ensure that the natural dyes (Chrolorpheel – Helba) has more voltage and efficiency than chemical dyes (Ecerchrom –Dry Ink).

4.5 Suggested Future Work:

We recommend further work in this area to enhance the dye structure and produce and adjust concentration in certain quality to produce good film by finding a common solvent to the dye and the fullerene so that the solvent can be easily evaporated and yield a good film. The hight of the cell must be decreased then become slim layer of glass and increased size of the cell lead to more efficiency. The temperature effect on the cells properties could be further investigated as well. Other dopant materials can be used to increase the dye photoconductivity.

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