# Chapter One

# Introduction

## 1.1 Solar Radiation:

Solar radiation is one of the alternatives available for the production of electrical power, that do not have traces or residues are injurious to the environment. They are convert incident light into electrical energy either by thermal conversion of the sun's energy in boilers solar and use the steam produced in the management of the turbine or by conversion light energy to electrical energy by solar cells [1, 2, 3].

Solar cell is tool semiconductor that converts solar energy into electrical energy. Silicon is the best semiconductor material used today in the manufacture of the solar cell the wide spread of it is due to high ratio of the abundance of the silicon in the land cost of production is also reasonable and the efficiency is high compared to other cells, however silicon cells suffer from the high cost and difficulty of manufacturing beside complexity associated with the formation of crystals of silicon [4, 5, 6].

This has led scientists to think in the manufacture of solar cells from other materials. So he veered scientists to mimic the way the plant do in converting the sun's energy across the chromosomes to useful energy. This resulted in their attempts for the manufacture of solar cells using polymers and dyes [7,8,9].

## 1.2 The Importance of Research:

The importance of this research comes from the fact that the use of solar energy in the production of electrical energy and reduces environmental pollution beside reducing the cost of producing of electricity and makes it available to remote places.

## 1.3 The Research Problem:

The research problem comes from the fact that there are many factors that affect the performance and efficiency of solar cell. There are also factors concerned with the cost and manufacturing. Thus there is an urgent need to know it.

## 1.4 Literature Review:

Solar energy is one of the most preferable neat source of energy .This is due the fact that solar energy does not create greenhouse gases as it generates electricity [10]. A greenhouse gas can absorb radiation in the infrared range which is the fundamental cause of the greenhouse effect, the main reason leading to global warming right now.

Solar energy is also easily available all around the world. Unlike wind power and hydro energy, solar energy spread out more evenly in the world, thus the geographical location of a country is not likely to prevent the countries from taking advantage of solar energy. The world solar energy potential clearly indicates that most part of the world could potentially utilize the solar energy as the primary energy resources, especially for countries near the equator.

NASA Map of the World Solar Energy Potential [10]. Thirdly, the solar energy is essentially inexhaustible because it is radiation from the sun and there is a large quantity of solar radiation accepted on the earth every day. The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3,850,000 exajoules (EJ) per year.  (Smil, 2006), only 0.01% of the solar energy, if used, could provide enough energy for primary energy use in 2005.

There are also more advantages of solar energy, such as minimum byproduct compared to other energies, no disposal method necessary, less space required and relative low cost and high efficiency [11]. From the reason above, solar energy

would be a prospective substitution of fossil fuels due to the reason of wide availability, relative low cost and renewable properties.

Other more advantages of solar energy, such as in the [12] (Using Gum Arabic in Making Solar Cells by Thin Films Instead Of Polymers ) by Abdalsakhi .S .M.H - Mubarak Dirar Abd-alla 2- , Rawia Abd Elgani3, Asma M.Elhussien4, Amel A.A. Alfaki5 (l Neenlen University – Faculty of Science and Technology Department of Physics 2,3,4,5 Sudan University of Science and Technology ) . Gum Arabic based solar cells with Rhodamine 6G were fabricated on indium tin oxide by a spin coater position. Microstructure and cell performance of the solar cells with ITO/ Rhodamine 6G/ Gum Arabic structures were investigated. Photovoltaic devices based on the Rhodamine 6G / Gum Arabic hetrojunction structures provided photovoltaic properties under illumination. Absorption and energy gap measurement of the Rhodamine 6G / Gum Arabic hetrojunction were studied by using UV-VS mini 1240 spectrophotometer and light current-voltage characteristics. The energy levels of the present solar cells were also discussed. The three ITO/Gum/Rhodamine/Au solar cells were produced and characterized, which provided efficiency ($\eta$) is (3.8 - 5.1 and 5.2) %. Fill factor (FF) is (0.964 - 0.9462 and 0.973), current density (Jsc) is (2.22 - 4.31 and 4.4) mAcm-2 and Open – circuit voltage (Voc) is (1.22 -1.25 and 1.209) V. This could be used at larger scale in promoting efficiency of solar cells.

Advantages of solar energy, such as the Thin Solid Films finally . A sub-micrometer-wide line of a conjugated polymer MEH-PPV [polyŽ2-methoxy-5-Ž2-ethyl hexyloxy.-$p$-phenylene vinylene.] was patterned using a scanning electron microscope ŽSEM The spin-coated thin MEH-PPV film was exposed to the electron beam in SEM, resulting in an increase in cross-linking, which reduced the solubility of the MEH-PPV film. The polymer was developed in $p$-xylene to dissolve the non-irradiated part of the polymer. The width, length and thickness of the active patterned current–voltage characteristics of the patterned MEH-PPV

line were measured as a function of temperature. The higher field data of the non-

## 1.5 The Aim of The Work:

linear *I–V* curves were fitted using the single carrier device model which considered the field and temperature dependent mobility with space charge limited conduction ŽSCLC.. The estimated zero-field hole mobility was of the order of $10^{-3}$ cm2/Vs with an activation energy of 0.038 eV [13].

Many reaches were made to fabricate Nano solar cells [14, 15,16,17,18, 19].

The research aims to determine the impact of change of electrodes material of dye solar cells on their performances and efficiency of the solar cell.

## 1.6 Thesis Layout:

The thesis consists of the five chapters. Chapter one is the Introduction and Chapter two is the theoretical background about solar cells. Chapter three the Literature Review. Chapter four consist of method, materials, Results and Analysis. Chapter five is concerned with Conclusion and Recommendations

# Chapter Two

## Theoretical Background

### 2.1 PV Cell:

1800's The "photovoltaic effect" was first described by the French physicist Edmond Becquerel in 1839. Becquerel found that certain materials would produce a small amount of electric current when exposed to light. During the latter part of the 19th century, research by Heinrich Hertz and others led to the development of selenium PV cells (sometimes called "solar" cells) that could convert light into electricity with efficiencies of 1-2%. Selenium was also used in light measuring devices for the burgeoning photography industry. Light meters are needed in photography to ensure that the correct shutter speed is used to achieve optimum exposure for the photo[20].

1900's In 1954, scientists at Bell Laboratories developed the first crystalline silicon PV cell. With efficiencies as high as 4%, it marked a significant improvement over selenium PV cells. The developing space program (1950's – 1970's) provided opportunities to utilize PV technology where a never-ending source of electricity was needed to power satellites and scientific instruments in space. The cost for this renewable energy technology was very high from the outset, but worthwhile for the space program due to the advantages of PV over other sources of electricity and their fuel requirements.

Through research and development in private, public, and university sectors, the cost of PV technology has declined steadily over the years. However, during the past 20 years, the effective cost (inflation-adjusted) of conventional electricity has actually declined. Consequently, PV-produced electricity is still an expensive option in many cases, especially if conventional electricity is readily available. However, for many specific types of applications (livestock watering, remote

roadway phones, wristwatches, calculators, etc.), it is the most cost effective way to satisfy the need for electricity.

## 2.2 Solar Cells Properties

Solar celles are physical systems that convert light energy into electricity. The term "photo" is a stem from the Greek "phos," which means "light.". The simplest systems power are small calculators and watches we use every day. More complicated systems provide electricity for pumping water, powering communications equipment, and even lighting our homes and running our appliances. Solar cells also used in satieties that revolve around the earth. The physics and chemistry behind PV technology are both very fascinating and exceedingly complex. This lesson will provide a very brief introduction to photovoltaic cells/modules and attempt to provide basic information in an understandable form. It is not meant to be comprehensive, but rather to give you some useful background information for understanding photovoltaic s and how they work. Topics are covered in more detail in accompanying materials in the notebook and through web sites listed throughout the text. There are two fundamentally different kinds of solar panels that can be commonly seen on rooftops throughout many parts of the United States – solar thermal and solar electric panels. Solar thermal panels take the sun's light energy and changes it to heat energy that is transferred to some other material for immediate use or storage for later use. The heat energy can be used to heat air in buildings or water for domestic use [21].

Solar electric panels, more commonly referred to as photovoltaic, or PV, panels, take sunlight and convert it directly into electricity. The electricity is used to run appliances and electrical devices or stored in batteries to be used later. The panels on your school are photovoltaic or solar electric panels.

## 2.3 Solar Cells (PV) Panels

The solar cells converts sunlight into electricity. Sunlight is composed of photons, or particles of solar energy. Imagine that these little particles of energy are microscopic "bullets" of light that literally "rain" on earth wherever sunlight is shining. Billions upon billions of these light bullets are hitting the earth every second. These photons contain various amounts of energy corresponding to the different colors of the solar spectrum. When photons strike a PV cell, they may be reflected, absorbed, or they may pass right through. Only the photons that are absorbed generate electricity. Which photons get absorbed is a function of their wavelength (what color they are in the solar spectrum) and the properties of the materials used in the PV cell (they are designed to absorb photons with a particular wavelength). When a photon is absorbed, the energy of the photon is transferred to an electron in an atom of the PV cell. With its newfound energy, the electron is able to escape from its "normal" position associated with that atom to become "free." The freed electron will move most easily along a conductor. The PV cell is really a semiconductor device (yes, similar to the semiconductors used in your computer!). Freed electrons move and become part of the current in an electrical circuit. As millions of photons strike the PV cell, millions of electrons are "freed" to move along the conducting wires. The freed electrons in the semiconductor become part of the current in an electrical circuit. The thin wires that you see in solar cells and modules are conducting wires for an electrical circuit. The PV cells have a built-in electric field to provide the voltage needed to drive the current through an external load (your radio, for example). Each cell produces a small amount of current. By connecting many cells together and placing them on larger panels, the electric current produced can be significant [22, 23].

## 2.4 PV Advantages and Disadvantages of Solar Cells

PV has many features that make it a wonderful technology to use to solve many electrical needs. Although, like any technology, it has it drawbacks as well. Some of the main advantages of solar cells all's[23].

### 2.4.1 High Reliability

Solar cells were originally developed for use in space, where repair is extremely expensive, if not impossible. So reliability has always been an important benefit of PV modules. PV still powers nearly every satellite circling the earth because it operates reliably for long periods of time with virtually no maintenance. PV modules have long useful operating lives on earth as well – typically 20-30 years. Some homeowners are connected to the electric utility grid and have a PV system (often with back-up battery pack for energy storage) at their home. When there is a utility power outage, they can simply turn on the PV system and have a reliable source of power ready to meet their needs[23].

### 2.4.2 Low Operating Costs

PV cells use the energy from sunlight to produce electricity the fuel is free. With no moving parts, the cells require little upkeep. These low-maintenance, cost-effective PV systems are ideal for supplying power to remote railway crossings, navigational buoys at sea, or homes far from utility power lines. PV systems are especially useful for mountaintop communication repeater stations or remote monitoring stations where using the electric grid is prohibitively expensive and environmentally damaging to extend. Compared to the difficulties faced by other potential power systems, such as the delivery of fuel for and maintenance of a diesel generator on a remote mountaintop with extremely harsh winter conditions, the low maintenance, high reliability of PV systems make them an attractive choice for these difficult to reach locations[23,24].

### 2.4.3 Environmental Benefits

Because they burn no fuel and have no moving parts, PV systems are clean and silent. This is especially important where the main alternatives for obtaining power and light are from diesel generators and kerosene lanterns. As we become more aware of "greenhouse gases" and their detrimental effects on our planet, clean energy alternatives like PV become more important than ever. The 2400 Watt PV system on your roof reduces greenhouse gases equivalent to not driving your car 6,700 miles this year (and every year the system operates) [24].

### 2.4.4 Modularity

A PV system can be constructed to virtually any size based on energy requirements. Furthermore, the owner of a PV system can enlarge it if his or her energy needs change. For instance, homeowners can add modules every few years as their energy usage and financial resources grow[23].

### 2.4.5 Portability

A PV system can be set up on a trailer and moved from location to location as needed. This is especially useful in seasonal applications such the Forest Service personnel, campground personnel, ranchers, boaters, etc.. Ranchers can use mobile trailer-mounted pumping systems to water cattle as the cattle are rotated to different fields. Portable PV systems can be used as a source of power following natural disasters that cripple the electric grid and our normal sources of electrical power [23].

### 2.4.6 Least Cost Alternative

In some cases, installing a PV system to meet the specific needs of an electrical load is cheaper than using conventional electricity sources i.e., bringing in the electric grid. PV powered emergency telephone call boxes or lighting for signs on remote stretches of highways are two examples where a PV system is more cost

effective than conventional electricity sources to solve a problem. In other instances, like putting in lighting on a traffic island at the entrance to a campground, it can be less expensive to install a PV lighting system than to dig up the roadway to bury electrical wires for the lighting system [24].

## 2.5 Some of The Main Disadvantages of PV Include:

### 2.5.1 Expensive Technology

The manufacturing process for making PV cells is still expensive in spite of great reductions in cost over the past 30 years. Depending on where you live in the U.S., it can be 2-5 times more expensive than electricity provided by electric utilities. If there is no electric grid available, the cost of paying to bring in the grid can be more expensive than installing a PV system. But, the grid is already available in most areas that people live in and, in those areas, PV systems are often more expensive than the grid[25].

### 2.5.2 Weather and Climate Dependent

While the PV cells themselves are fairly reliable, the sun's rays are not always a very predictable resource in some areas. PV modules need sunlight to produce electricity. Consequently, they do not produce electricity at night. Though PV modules can produce electricity on cloudy days, the amount of electricity produced will vary depending on the density of the cloud cover as it has a direct effect on the amount of sunlight striking the PV modules. Geographic areas that have cloudy climates or high humidity will require more PV modules to produce a given amount of electricity than in dry, sunny locations like New Mexico. Smog, dust, and other airborne particles can affect the amount of sunlight striking the PV modules and, hence, the amount of electricity produced .Geographic areas closer to the poles (North and South) have very long days in one season (summer for areas near the North Pole) and very short days during the opposite season. All of these are factors that can potentially prevent a PV system from being a reliable

source of electricity. Battery packs are often used to improve the reliability of PV systems. They add cost to the system, but help to provide a continuous source of power when needed [23 ,25].

### 2.5.3 Space Requirements

To provide enough electricity for an entire household, a good deal of the roof must be used, or equivalent space on the ground, and it must have good "solar access" free from shading effects of nearby trees, mountains, or buildings[25].

### 2.5.4 Other Necessary Equipment

Depending on the type of PV system and its intended use, there may be need for an inverter (device that converts DC electricity produced by the PV modules to AC electricity which is commonly used in homes and businesses) or for a battery pack or both. Either of these will add significant cost to a PV system[25].

### 2.6 Types of Materials Used in PV

There are a number of different semiconductor materials used and different manufacturing processes used in the production of solar cells. Some of the common materials include:

• Single-crystal silicon (Si)

• Polycrystalline silicon (Si)

• Amorphous silicon (a – Si)

These materials are chosen for a variety are their specialized effects or properties, such as:

• Electronic material properties

• Absorptivity

• Band Gap

• Cost

Some metals, such as copper, aluminum, platinum, gold and silver, are known as excellent conductors of electricity because their atoms hold their outer electrons loosely or with a weak attractive force. This means that they can be dislodged more easily than in other materials. Dislodged electrons move rapidly along a conductor and, in the case of a copper wire, can be made to follow a complete electric circuit. Most wires used in homes and businesses are copper, though aluminum is sometimes used. Copper costs more than aluminum, but it is a better conductor so smaller wires can be used. Aluminum is used by utilities for the transmission wires strung on high towers because it is lighter in weight than copper so it can handle the large spans between poles and it is more economical for the long transmission distances. Platinum, gold and silver are too expensive to use for these applications. Some materials, like plastic, rubber, wood, or glass hold their outer electrons tightly or with a strong attractive force. These materials are known as non-conductors because they do not readily conduct electricity. Other materials have conductive properties somewhere in between conductors and nonconductors. They are called semiconductors. Elements such as silicon (Si) and germanium (Ge) and compounds such as cadmium telluride (CdTe) and Cadmium Indium Diselinide (CuInSe2) are semiconductors used in photovoltaic s (though silicon is the most commonly used in commercial applications). There are two types of semiconductors: n-type and p-type. N-type semiconductors involve movement of negative charges – electrons. P-type semi-conductors involve positive charges (or absence of electrons commonly called "holes"). These two kinds of semiconductors are made into a "sandwich" in a PV cell. The area where they touch is called the p-n junction. So, solar cells are made up of both n-type and p-type semiconductors [25].

## 2.7 Comparison of Common Types of PV Modules

Silicon is a material commonly used in commercial PV modules. It is the second most abundant element in the Earth's crust, oxygen is the most abundant. Silicon occurs most frequently in nature as silicon dioxide (silica, SiO2) and as silicates (compounds containing silicon, oxygen, metals, and maybe hydrogen). Sand and quartz are two of its most common forms. However, sand is generally too impure to be processed into silicon. High-grade deposits of quartzite can be almost 99% pure silica, but will still be less than 90% silicon. The silica must be processed to become silicon. To become semiconductor grade silicon it must be processed and purified until it is 99.9999% pure silicon! This process, as you might expect, is very expensive. The computer industry uses purified silicon for manufacturing its computer chips [23].

## 2.7.1 Single crystal silicon (The Siemens Modules on Your Roof are Single Crystal Silicon)

❖ Advantages

• Well established and tested technology

• Stable conversion efficiencies over the life (20-30 years) of the module

• Highest efficiencies of silicon solar cells

❖ Disadvantages

• Expensive manufacturing process

• Uses expensive single crystal and other materials

• Round crystals have less packing density (single crystal silicon ingots are pulled from molten silicon as cylinders that are sawed into wafers)

Fig (2.1) Single crystal silicon (the Siemens modules on your roof are single crystal silicon)

## 2.7.2 Polycrystalline Silicon

❖ Advantages

• Well established and tested technology

• Stable conversion efficiencies over the life (20-30 years) of the module

• Square cells for better packing density

❖ Disadvantages

• Uses expensive materials (though less expensive than single crystal silicon)

• Expensive manufacturing process

• Slightly less efficient than single crystal silicon
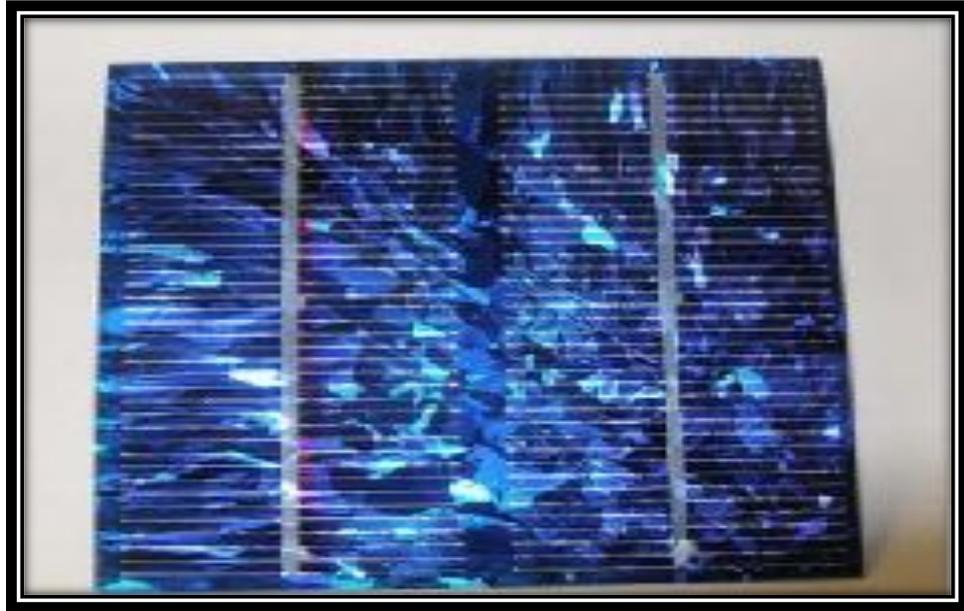
Fig (2.2) Polycrystalline Silicon solar cell

## 2.7.3 Amorphous Silicon

❖ Advantages

• Low material use because the films are microns thick

• Potential for automated production

• Potential for low cost

• Less affected by shading due to long, thin cells – harder to shade a single cell

• Thinness contributes to use in specialized applications, i.e. calculators and watches (where small amount of power is required)

• Can be incorporated into windows and roofing tiles or shingles in building-integrated PV systems (the electrical generation system is part of the building skin)

❖ Disadvantages

• Lower efficiencies than single and polycrystalline silicon

• Larger areas needed for same power output as single or polycrystalline silicon due to lower efficiencies the cost per unit area (cost/area) of silicon solar cells

increases with the size of the crystals. This means that a smaller area of single-crystal cells is required to generate 100 W of power. The cost of a panel that will generate a 100 W may be more constant than the size[26].



Fig (2.3) Amorphous Silicon solar cells

## 2.8 Other Materials for PV Cells

Other materials are being researched for both their electrical generation potential and commercial feasibility, including: Copper Indium Dieseline, Cadmium Telluride, and Gallium Arsenide. These compounds may become the PV material of choice in the future[26].

## 2.8.1 Dyes Solar Cell

The dye-sensitized solar cells (DSSC) provide a technically and economically credible alternative concept to present day p–n junction photovoltaic devices. These devices are based on the concept of charge separation at an interface of two materials of different conduction mechanism. To date this field has been dominated by solid-state junction devices, usually made of silicon, and profiting from the experience and material availability resulting from the semiconductor industry. The dominance of the photovoltaic field by inorganic solid-state junction devices is now being challenged by the emergence of a third generation of cells [27].

## 2.8.2 Structure of Dye Sensitized Solar Cell

The main parts of DSSCs systems is composed of five elements, the transparent conducting oxides, counter conducting electrodes, the nano-structured wide band gab semiconducting layer, the dye molecules (sensitizer), and the electrolyte
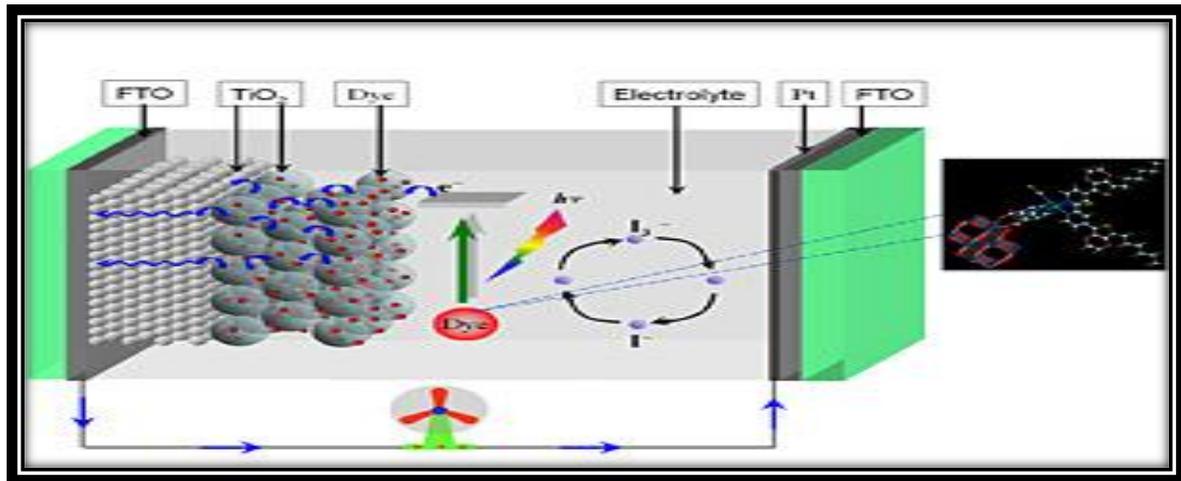


Fig (2.4) Dye sensitized solar cell diagram (source: Dyes sensitized solar cell images).

Transparent conducting oxides (TCO) for both the conducting electrode and counter electrode TCO coated glass is used as substrate for the TiO2 photo electrode. For high solar cell performance, the substrate must have low sheet resistance and high transparency. In addition, sheet resistance should be nearly independent of the temperature up to 500oC, because sintering of the TiO2 electrode is carried out at 450oC. Fluorine-doped tin oxide (FTO) coated glass is electrically conductive and ideal for use in a wide range of devices, including applications of thin film photo–voltaic devices, it has been recognized as a very promising material because it is relatively stable under atmospheric conditions, chemically inert, mechanically hard, Easily fabricated, has a high tolerance to physical abrasion and is less expensive than indium tin oxide [28].TiO2photo– electrode Photo–electrodes made of such materials as Si, Ga As, In P, and Cd S decompose under irradiation in solution owing to photo–corrosion. In contrast,

oxide semiconductor materials, especially TiO2, have good chemical stability under visible irradiation in solution; additionally, they are nontoxic and inexpensive. The TiO2 thin-film photo–electrode is prepared by a very simple process. TiO2 colloidal solution (or paste) is coated on a TCO substrate and then sintered at 450 to 500∘C, producing a TiO2 film [29]. The dye molecules (sensitizer) Dye molecules of proper molecules structure are used to sensitized wide band gab nanostructure photo electrode [30].

## 2.8.3 Types of Organic Solar Cells:

They are some types such as:

Dye sensitized solar cells:  Electrochemical cells.

Polymer solar cells:  Made by solution, low temperature processing.

## 2.8.3.1 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 $\pi$-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 liquid electrolyte. This liquid electrolyte is often related to its poor thermo-stability, and responsible for the corrosion of the Pt covered counter

electrode. For this reason alternatives for an electrolyte are being developed, 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 by the Grätzel group, is a solvent-free dye-sensitized solar cell based on an ionic liquid electrolyte and using Se CN-/ (Se CN)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 so called 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 [30].
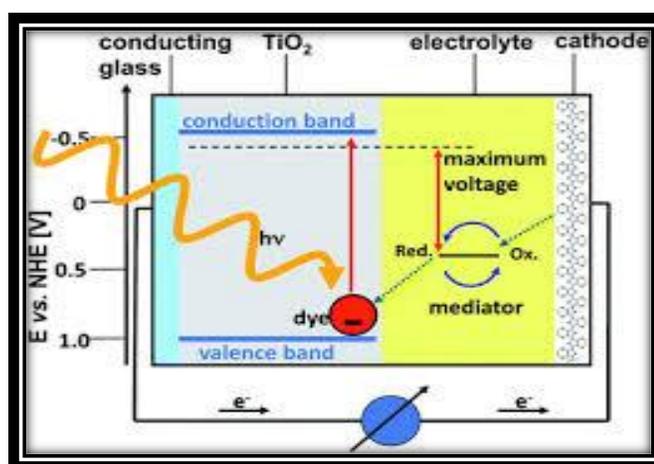


Fig (2.5) Schematic scheme of the traditional dye-Sensitized solar cell

## 2.8.3.2 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 [31]. 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% [32].
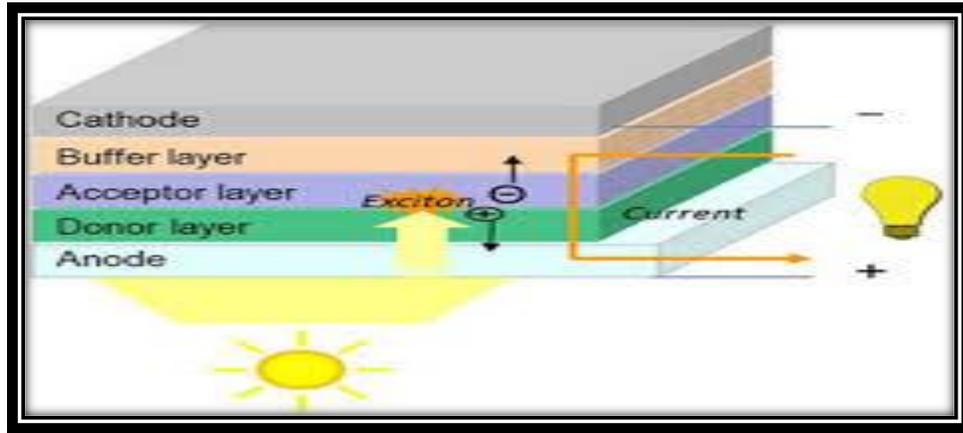
Fig (2.6) Polymer solar cells

## 2.8.3.3 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.

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.

The electron-hole pair is subsequently separated over a built-in gradient in the electrochemical potential of the solar cell.

Finally, the electron and hole is collected at opposite electrodes and led to recombine after being put to work in an external circuit [33].
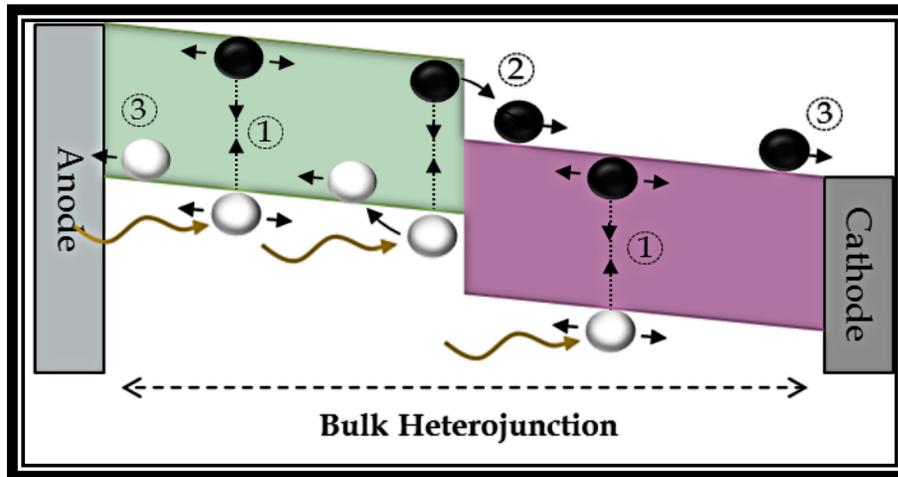
Figure (2.7). The working principle

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) [33, 34, 35].

## 2.8.3.4 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 [34, 36, 37,38, 39].
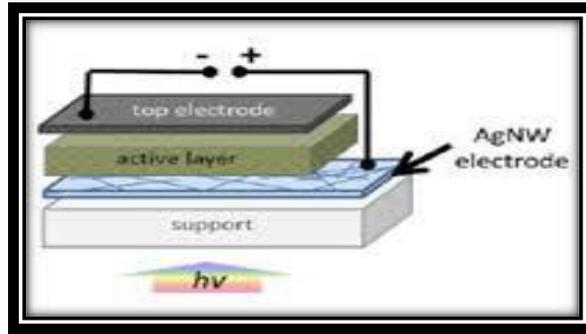
Fig (2.8) Consist of Polymer Solar Cell

## 2.9 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 [35].
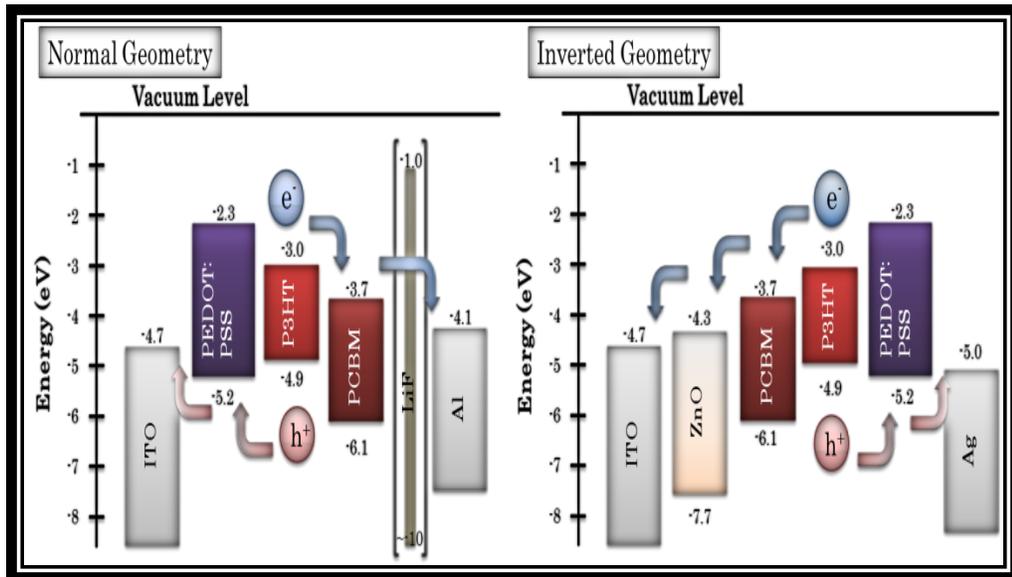
Fig (2.9) Energy levels for normal and inverted geometry solar cells

## 2.10 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 [35, 40, 41, 42].

## 2.11 Photovoltaic Terminology

A PV or solar cell (used interchangeably) is the smallest production unit of PV systems and it is the building block of larger systems. Common single crystal silicon (a typical type of semiconductor material used) solar cells produce about

0.5 Volts. A group of cells wired together form a module. With single crystal silicon, 36 solar cells are often grouped together and wired in series to produce 18 Volts. A number of modules grouped together and attached to a mounting frame form a PV panel or solar panel. A group of panels make up a PV or solar array. There many different materials used for PV modules and different ways of configuring modules. Consequently, there are many different sizes (Watts) and voltages available in commercial modules. Effective PV system design allows the user to meet a wide variety of electrical loads.

## 2.12 PV System Components

A PV power system consists of several components, though the exact list may vary with the application. A remote water pumping system may utilize a DC water pump and be designed to operate only during the day when there is sun and the components may be the PV array (or panel or module depending on size of the load), a controller to regulate current and voltage, and the water pump, or load. A grid-tied system, like the one at your school, consists of the following components:

• PV array

• Inverter – converts DC electricity generated by the PV array to AC electricity fed into a building electrical panel (or sub-panel) (Note: a controller is built into the inverter)

• Emergency disconnects – allows for the PV array or the inverter to be disconnected

• DAS – Data Acquisition System – monitoring instruments (anemometer, temperature thermistor, pyrometer, and AC watt-hour meter) that display readings real-time on classroom computer PV systems that are designed to provide useful energy even when the sun is not shining will have two additional components – a battery bank that stores the excess electricity produced until it is needed and a

charge controller that regulates the amount of current and voltage allowed to be fed into the battery bank[35].

## 2.13 Power Ratings of PV Modules

PV modules are tested and rated at Standard Test Conditions (STC) in a laboratory. NREL provides expert service to rate modules for a number of manufacturers. Standard Test Conditions include:

• Cell temperature of 25 °C

• Sun intensity of 1000 W/m2

• Spectral distribution at AM 1.5 (Air Mass 1.5)

Also, typically included in power ratings may be items such as the rated power of the module, current and voltage at typical load, short circuit current, open circuit voltage, and the dimensions of the module [35, 43].

# Chapter Three

## Literature Review

### 3.1 Introduction

The energy problem encourages scientists to search for cheap efficient solar cells. One of most promising ones are Nano solar cells.

In this chapter caught some of this all sample.

### 3.2 Using Gum Arabic in Making Solar Cells by Thin Films Instead Of Polymers

Gum Arabic based solar cells with Rhodamine 6G were fabricated on indium tin oxide by a spin coater position. Microstructure and cell performance of the solar cells with ITO/ Rhodamine 6G/ Gum Arabic structures were investigated. Photovoltaic devices based on the Rhodamine 6G / Gum Arabic hetrojunction structures provided photovoltaic properties under illumination. Absorption and energy gap measurement of the Rhodamine 6G / Gum Arabic hetrojunction were studied by using UV-VS mini 1240 spectrophotometer and light current-voltage characteristics. The energy levels of the present solar cells were also discussed.The three ITO/Gum/Rhodamine/Au solar cells were produced and characterized, which provided efficiency ($\eta$) is (3.8 - 5.1 and 5.2) %. Fill factor (FF) is (0.964 - 0.9462 and 0.973), current density (Jsc) is (2.22 - 4.31 and 4.4) mAcm-2 and Open – circuit voltage (Voc) is (1.22 -1.25 and 1.209) V. This could be used at larger scale in promoting efficiency of solar cells [12].

### 3.3 Performance Improvement of MEH-PPV: PCBM Solar Cells Using Bathocuproine and Bathophenanthroline as The Buffer Layers∗

A sub-micrometer-wide line of a conjugated polymer MEH-PPV [polyŽ2-methoxy-5-Ž2-ethyl hexyloxy.-*p*-phenylene vinylene.] was patterned using a

scanning electron microscope ŽSEM.. The spin-coated thin MEH-PPV film was exposed to the electron beam in SEM, resulting in an increase in cross-linking, which reduced the solubility of the MEH-PPV film. The polymer was developed in *p*-xylene to dissolve the non-irradiated part of the polymer. The width, length and thickness of the active patterned area, determined by the atomic ŽAF image, was 500, 200 and 20 nm, force microscopy M. respectively. The two-probe current–voltage characteristics of the patterned MEH-PPV line were measured as a function of temperature. The higher field data of the non-linear *I–V* curves were fitted using the single carrier device model which considered the field and temperature dependent mobility with space charge limited conduction ŽSCLC.. The estimated zero-field hole mobility was of the order of 10—3 cm2/Vs with an activation energy of 0.038 eV. © 2001 Elsevier Science B.V. All rights reserved[13].

## 3.4 Non-Linear I–V Characteristics of MEH-PPV Patterned on Sub-Micrometer Electrodes

In this work, bathocuproine (BCP) and bathophenanthroline (Bphen), commonly used in small-molecule organic solar cells (OSCs), are adopted as the buffer layers to improve the performance of the polymer solar cells (PSCs) based on poly(2-methoxy-5-(2-ethylhexyloxy)-1,4-phenylenevinylene)(MEH-PPV): [6,6]-phenyl-C61-butyric acid methyl ester (PCBM) bulk heterojunction. By inserting BCP or Bphen between the active layer and the top cathode, all the performance parameters are dramatically improved. The power conversion efficiency is increased by about 70% and 120% with 5-nm BCP and 12-nm Bphen layers, respectively, when compared with that of the devices without any buffer layer. The performance enhancement is attributed to BCP or Bphen (i) increasing the optical field, and hence the absorption in the active layer, (ii) effectively blocking the excitons generated in MEH-PPV from quenching at organic/aluminum (Al) interface due to the large band-gap of BCP or Bphen,

which results in a significant reduction in series resistance ($R$s ), and (iii) preventing damage to the active layer during the metal deposition. Compared with the traditional device using LiF as the buffer layer, the BCP-based devices show a comparable efficiency, while the Bphen-based devices show a much larger efficiency. This is due to the higher electron mobility in Bphen than that in BCP, which facilitates the electron transport and extraction through the buffer layer to the cathode [14].

## 3.5 Summary and Critique:

Dispute the flat that many researches to be made fabricate Nano solar and polymer cells [44 to 54].

But these don't study the effect of atomic number of electrodes and the energy gap of dyes on its efficiency.

# Chapter Four

## Experimental, Results and Discussion

## 4.1 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 different dyes were fabricated.

### 4.1.1 The Materials of an Organic Solar Cell

### 4.1.2 Polymer

Polymer is a Greek phrase which means many parts. Large molecules made of repeating units of smaller molecules. Small molecules are called "monomers" monomers link together like a chain resulting in new and exciting properties[55].

Conjugated polymers are organic macromolecules with alternating single and double bonds. Conjugated polymers are organic semiconductors, the semiconducting behavior being associated with the pi-molecular orbitals delocalized along the polymer chain. Due to the sp2 hybridization of the electron system, conjugated polymers are mostly planar, extended macromolecules. They combine the optical and electrical properties with the mechanical advantages for preparation of optoelectronic devices .There is one unpaired pz-electron per C-atom, which forms pi-pi* conduction and valence bands in the macromolecule due to the fact, that they describe a one-dimensional crystal[56] .

The Noble Prize in Chemistry 2000 was awarded jointly to Alan J. Heeger , Alan G. MacDiarmid and Hideki Shirakawa "for the discovery and development of conductive polymers", This discovery led, subsequently, to the discovery of electroluminescence in a poly(p-phenylenevinylene) (PPV) [32].In1990  The first

light-emitting products based on electroluminescence in conjugated polymers have already been launched at the consumer market by Philips (The Netherlands) in 2002, whereas light-emitting products based on conjugated molecules have been introduced by the joint venture of Kodak and Sanyo (Japan). Going from discovery to product within a little bit more than one decade truly holds a huge promise for the future of plastic electronics. Other emerging applications are coatings for electrostatic dissipation and electromagnetic-interference shielding [57].

Conjugated polymers and molecules have the immense advantage of facile, chemical tailoring to alter their properties, such as the band gap. Conjugated polymers combine the electronic properties known from the traditional semiconductors and conductors with the ease of processing and mechanical flexibility of plastics.

In this research we used poly (2-methoxy-5-(2'-ethyl-hexyloxy)-1.4 phenylene) (MEH-PPV) due to the corresponding internal quantum efficiency .The absorbed photons to electrons, is estimated to be nearly 100% in the short circuit case. The main limiting factor towards higher efficiencies is the spectral mismatch of the active layer absorption, with a maximum around 500 nm, to the terrestrial solar spectrum with a maximal photon flux between 600 and 800 nm [58]. Therefore, the use of low band gap {Eg~ 2.0 eV}. Polymers is a viable route to increase the amount of absorbed photons and consequently the power efficiency of solar cells [59].

Characterized polymers that can be turned into solids or semi-conductive for electricity as we mentioned earlier, and to make solar cells must first add a certain percentage of oxidizing substances or shorthand to become Article polymeric. Similar properties semiconductors inorganic and lead impurities to situations within the scope of the gap between the bands valance band conduction. has found that the energy gap of the  semiconductor in some polymers ranging from (1.5-3

ev) and thus wider than the gap in the energy inorganic materials that range where the energy gap between 0.1-2.2 eV in and fit so with photon energy in the visible range of the solar radiation [60].
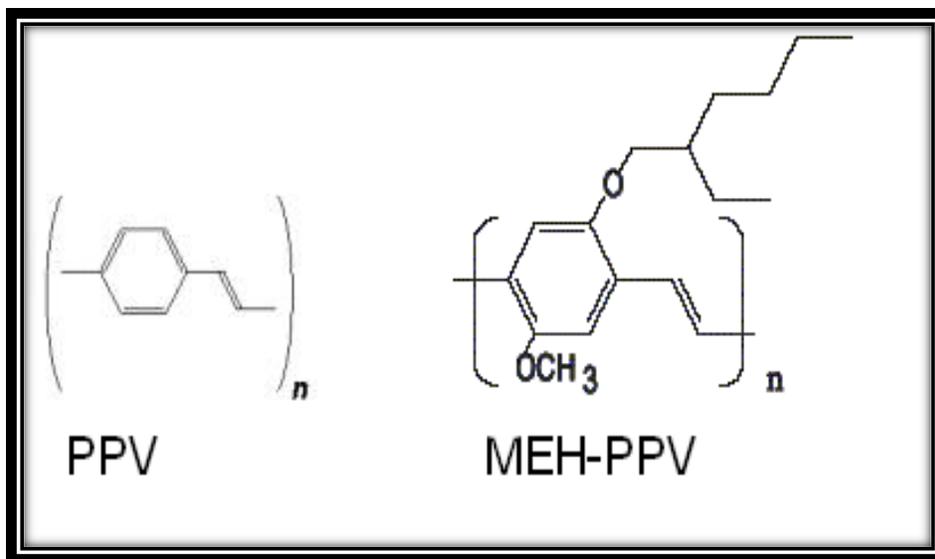


Fig (4.1) the two figures is the monomer of MEH-PPV (right) and the monomer of PPV (left)

## 4.1.3 ITO

ITO (Indium Tin Oxide) is a transparent conductive material. It is a mixture of indium oxide (In2O3) and tin oxide (SnO2). ITO is used as one of the electrodes in the solar cell .ITO can absorb light at the same wavelength as MEH-PPV. This is important because only the light absorbed by MEHPPV may result excitations[61].

## 4.1.4 Rhodamine B

Constitution 2-[6-(Diethylamino)-3-(diethylimino)-3H-xanthen-9-yl]  benzoic acid Rhodamine 610 - $C28H31N2O_3Cl \cdot$ MW: 479.02
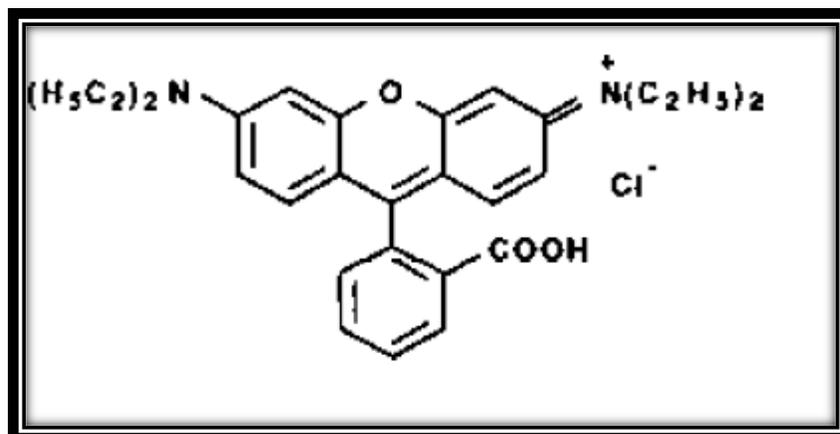
Fig (4.2) Rhodamine B

Characteristics Lambdachrome® number: 6100 CAS registry number: 81-88-9Appearance: green, crystalline solid Absorption maximum (in ethanol): 552 nm Molar absorptivity: 10.7 x $10^4$ L $mol^{-1}$ $cm^{-1}$ Fluorescence maximum (in ethanol):580 nm for research and development purposes only[62].

### 4.1.5 Coumarin 500

Constitution $C_{12}H_{10}NO_2F_3$ · MW: 257.21
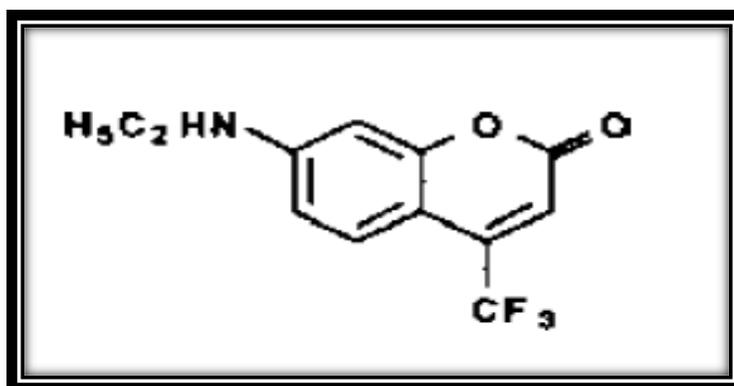


Fig (4.3) Coumarin 500

Characteristics

Lambda chrome® number: 5010 CAS registry number: - Appearance: yellow, crystalline solid Absorption maximum (in ethanol): 395 nm Molar absorptivity: 1.85 x $10^4$ L mol-1 $cm^{-1}$ Fluorescence maximum: - For research and development purposes only [60].

## 4.1.6 DDTTCI

Constitution3,3'-Diethyl-4,4',5,5'-dibenzothiatricarbocyanine Iodide

Hexadibenzocyaini 45C33H29N2S2I · MW: 644.43
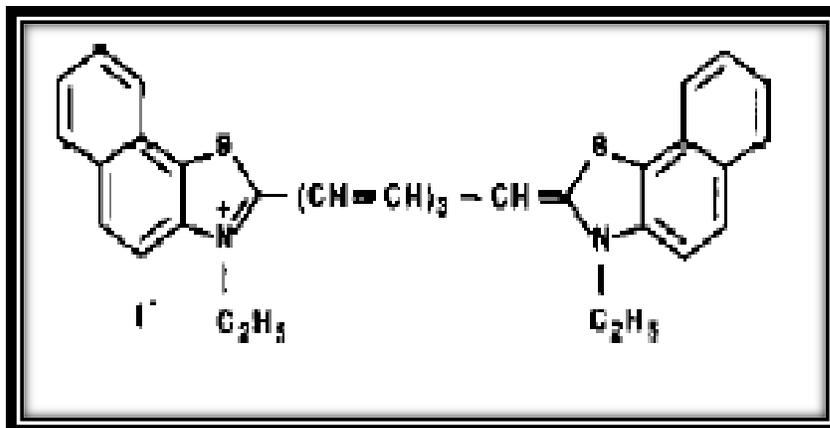


Fig (4.4) DDTTCI

Characteristics Lamb dachrome® number: 9280CAS registry number: -

Appearance: bronze colored, crystalline solid Absorption maximum (in ethanol):

798 nm Molar absorptivity: $19.6 \times 10^4$ L mol$^{-1}$ cm$^{-1}$Fluorescence maximum: -

For research and development purposes only [60].

## 4.1.7 Ecr - Chrome Black T:

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; Ecr-chrome 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 [62].
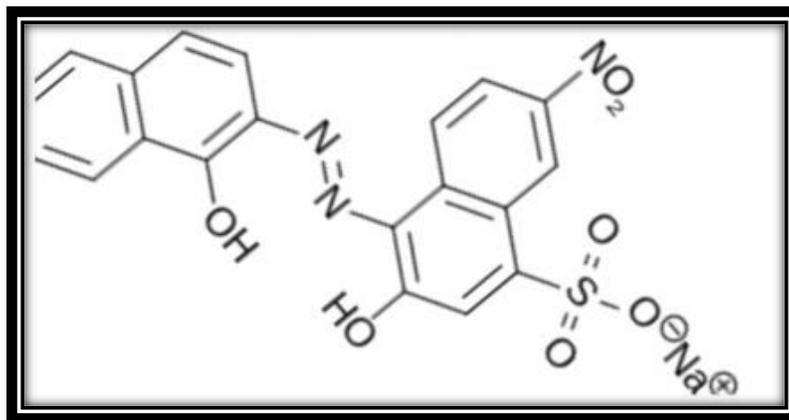
Fig (4.5) Ecr - chrome Black T structure

## 4.1.8 Methods

12 sample of solar cells were made by depositing the solution of Day (Ecrchrom Black T, DDTTC, Rohadamin B, Coumarin 500) on ITO and different electrodes (Aluminum ( Al ) , Gold (Au ) and silver ( Ag) )by Spin Coating technic, and another layer was deposited from dye on a layer of (MEH-PPV ) .Al was fabricated on the layers to actas anode and ITO Cathode. A clean glass plate with a thin layer of ITO (Indium Tin Oxide) is needed. The ITO acts as the first part of the solar cell, the first electrode. However a bit of the ITO has to be removed, to avoid short-circuiting For the purpose of the present study Day sensitized devices were made following the generally accepted methods. The fabrication process started by preparing the MEH-PPV and the dye of interest then spin coated it indium tin oxide glass. Aluminum electrode was used to complete the formation of organic dye sensitized solar cell. The formed cells were characterized by Ultra violet-visible spectroscopy. electrical circuit containing the (voltmeter and Ammeter and a light source Lamp with the intensity radiological" and a solar cell). Was need to study per formance .The solar cell was exposed to light and the current and voltages of the cell recorded the were UV spectrometer was need to display absorption spectrum. 12 samples were prepared .

For the purpose of the present study polymeric devices were made following the generally accepted methods. The fabrication process started by preparing the polymer and the dye of interest then spin coated on indium tin oxide glass. Silver electrode was used to complete the formation of organic polymer solar cell. The formed devices were characterized by Ultra violet-visible spectroscopy.

The polymer solar cell was made on ITO glass. The ITO glasses were firstly cleaned by ethanol and distilled water. 10mg of poly (2-methoxy-5-(2'-ethyl-hexyloxy)-1.4-phenylenevanillin) (MEH-PPV) was dissolved into 0.5ml of chloroform and 3mg of dyes dissolved into 0.5 of high pure chloroform was deposited on polymer .Been insert electrical circuit containing the (voltmeter and Ammeter and a light source "Lamp with the intensity radiological" and a solar cell).Cell was offered to light and fulfilled taking the results of the current and voltages.

## 4.1.9 Apparatus:

12 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. The spin coating see Fig (4.6) technique device was remove and surface was washed by distilled water and methanol, then rinsed with Acetone and dried, the ITO Glass was put in spin coating. The prepared of polymer (MEH–PPV) solution was spin coated on the ITO 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.

Measures absorbance, emission and permeability. The range from 190-1100nm range for registration -3.99-3.99.Named UV mini 1240 spectrophotometer made in a Japanese company called Shimadzu measures two types of fluids and can measure the solids in the form of slides. The device components are: light source – a cell sample – uniform wavelength – Scout – Screen. The working principle of the device .Each of the articles has a characteristic absorption of a specific wavelength. Any material have a certain extent of absorption to unchangeable but the material properties change works on the principle Ber -lambert based on assumptions:

*Absorbance is directly proportional to the concentration.

*Absorbance is directly proportional to the length of the optical path within the sample see fig (4.7).



Fig (4.6) spin coating

Fig (4.7) UV spectrometer device

## 4.1.10 Theory:

A polymer solar cell has p/n transition the radiation energy of incoming sun light is directly converted into electrical energy. Polymer Solar 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 4.8) 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[63 ,64 .65].

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 [35].

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 $\Phi$, and the current $I_D$ of the non-irradiated semiconductor diode in forward direction, which depend on the terminal voltage $(V)$:

$$I = I_{sc}(\Phi) - I_D(V) \tag{4.1}$$

In this way, the current-voltage characteristics typical of Solar cell are obtained (see Fig.3.10). 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.

$$R_i = V_{oc} / I_{sc} \tag{4.2}$$

The maximum power:

$$P_{max} = I_{max}.V_{max} \tag{4.3}$$

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

$$FF = P_{max}/V_{oc}I_{sc} \tag{4.4}$$

FF is often called Fill Factor.

The efficiency η is given by:

$$\eta = I_{sc} \times FF \times V_{oc} / I_n \qquad (4.5)$$

Where $I_n$ is the intensity of incident light. The short circuit Current density depends directly on the external quantum efficiency, the number of carriers collected/number of incident Photons [66].
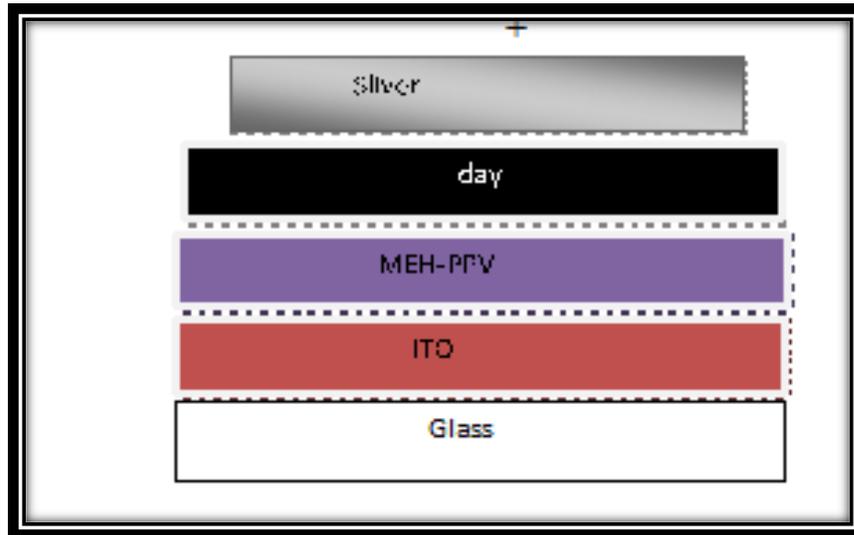


Fig (4.8) schematic structure of polymer solar cell formed with a single organic layer of MEH-PPV
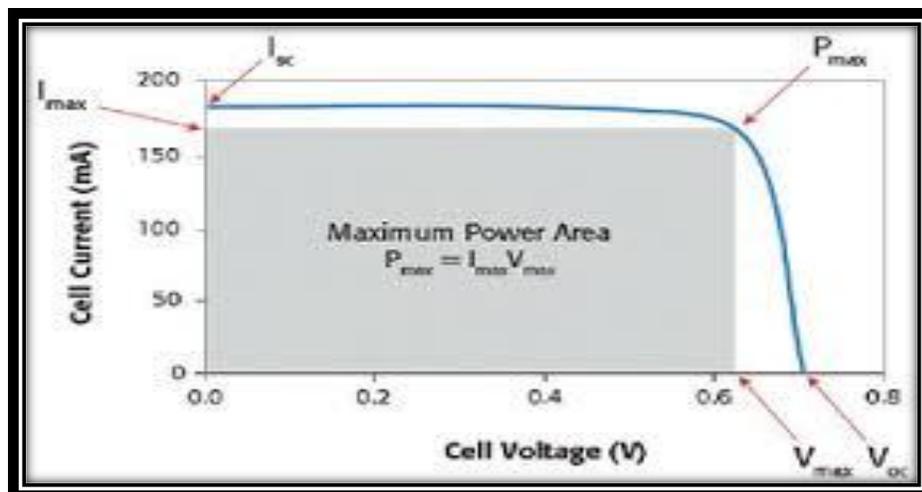


Fig (4.9) Current-voltage characteristic of a solar cell

## 4.1.11 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.

## 4.1.12 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.

## 4.2 Results

This section concerned with results and discussion. The results is can cared with samples characterization by Ultra violet-visible spectroscopy. Electrical circuit containing the I-V characters were studied by using (voltmeter, Ammeter and a light source Lamp) when connecting the solar cell to the circuit . Was need to study performance .The solar cell was exposed to light and the current and voltages of the cell were recorded then one use the T-V characterize to study the solar cell performance .

## 4.2.1 Results Samples of (DDTTC)
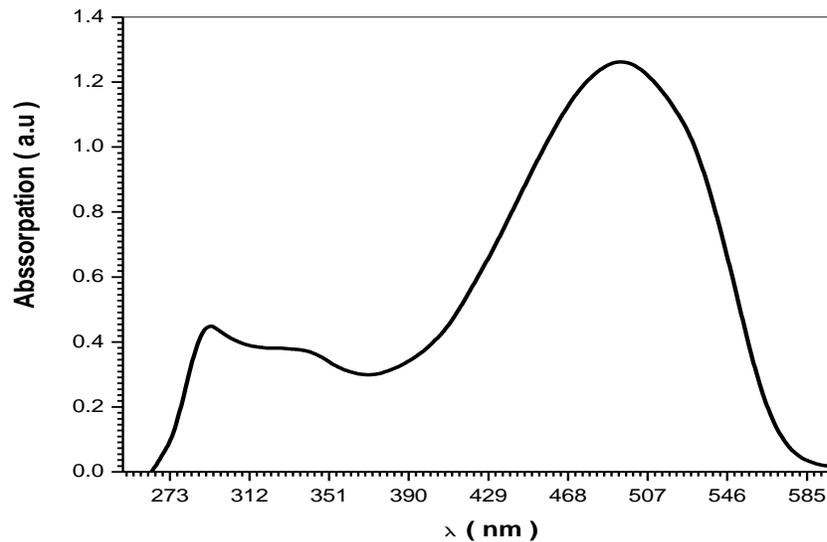
Fig (4.10) the relation between absorbance and wavelength of DDTTC
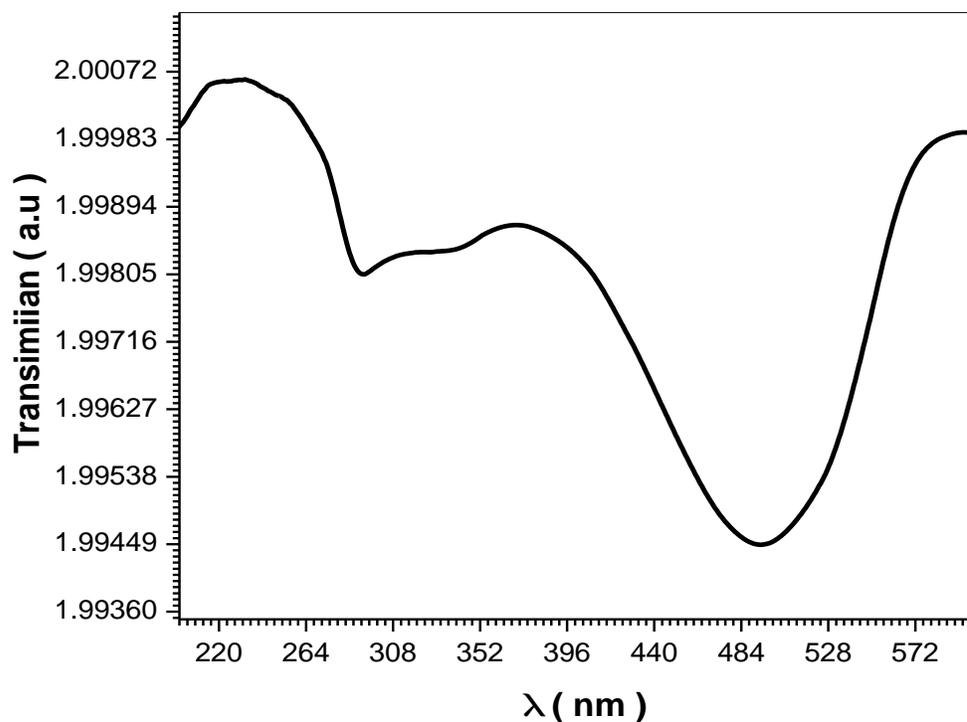
Fig (4.11) the relation between transparent and wavelength of DDTTC
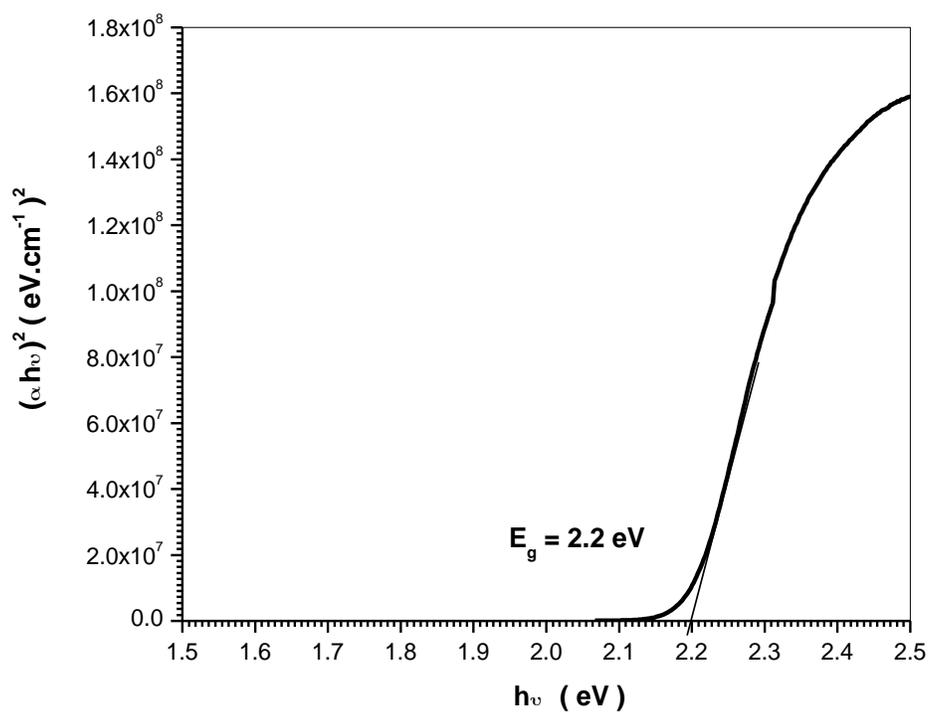


Fig(4.12) the optical energy gap (Eg) value of DDTTC. The optical energy gap (Eg) has been calculated by the relation $(\alpha h\upsilon)^2 = C(h\upsilon - Eg)$ where (C) is constant.

By plotting $(\alpha h\upsilon)^2$ vs photon energy ($h\upsilon$). And by extrapolating the straight thin portion of the curve to intercept the energy axis, the value of the energy gap has been calculated. The value of (Eg) obtained was 2. 2 eV.

Table (4.1) I-V reaction for sample 1( Ag)

| Voltage ( V ) | Current ( mA ) |
|---------------|----------------|
| 0.2078 | 59.09885 |
| 0.2124 | 59.09885 |
| 0.2169 | 59.09885 |
| 0.22387 | 59.09885 |
| 0.22836 | 58.98244 |
| 0.22996 | 58.78129 |
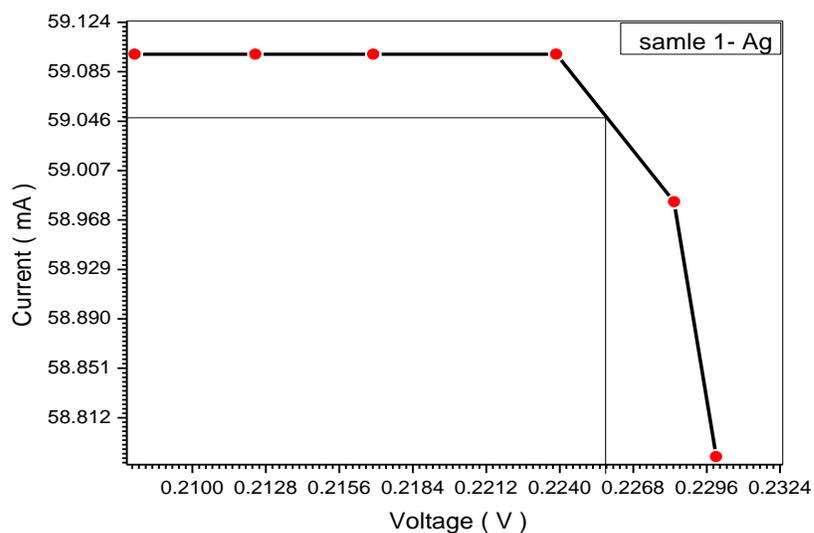
Fig (4.13) several factors for characterization of sample1 (Ag)

Table (4.2) I-V reaction for sample1 (Al)

| Voltage ( V ) | Current ( mA ) |
|---|---|
| 0.17117 | 59.60438 |
| 0.18462 | 59.60438 |
| 0.19505 | 59.60438 |
| 0.20677 | 59.60438 |
| 0.22046 | 59.60438 |
| 0.2309 | 59.21506 |
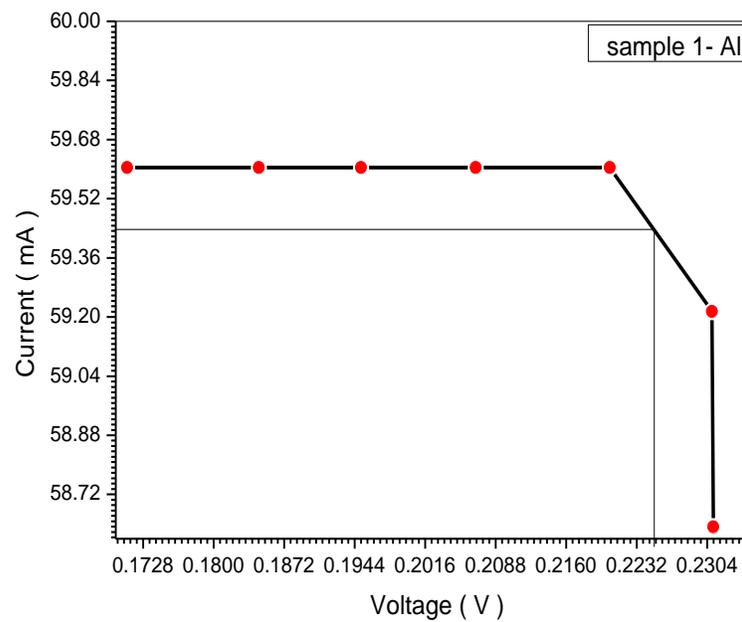


Fig (4.14) several factors for characterization of sample1 (Al)

Table (4.3) I-V reaction for sample1 (Au)

| Voltage ( V ) | Current ( mA ) |
|---|---|
| 0.13171 | 59.29775 |
| 0.15176 | 59.40309 |
| 0.17234 | 59.40309 |
| 0.19529 | 59.29775 |
| 0.21515 | 42.92837 |
| 0.21591 | 25.48455 |
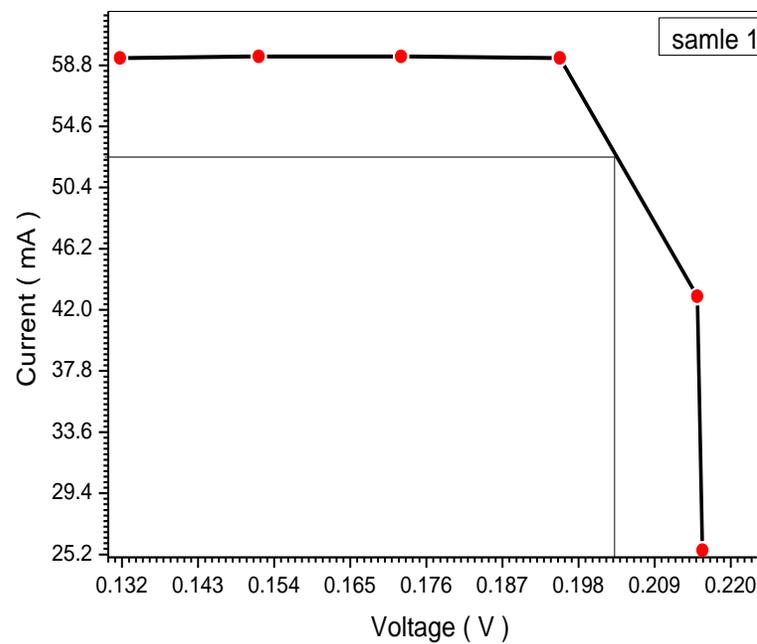


Fig (4.15) several factors for characterization of sample1 (Au)

Table (4.4) are Factors for characterization of performance DDTTC for three samples

| Number of sample | $I_{sc}$ (mA) | $I_{max}$ (mA) | $V_{oc}$ (V) | $V_{max}$ (V) | FF | $J_{sc}$ (mA.cm$^{-2}$) | Pmax | η % |
|---|---|---|---|---|---|---|---|---|
| Sample 1(Ag) | 59.10 | 59.05 | 0.2359 | 0.2299 | 0.9737 | 9.455 | 13.936 | 1.65 |
| Sample 1(AL) | 59.60 | 59.44 | 0.2310 | 0.2250 | 0.9714 | 9.536 | 13.374 | 1.62 |
| Sample 1(Au) | 59.29 | 52.49 | 0.2159 | 0.2031 | 0.8328 | 9.487 | 10.665 | 1.29 |

## 4.2.2 Results Samples of (Ecrchrom Black)
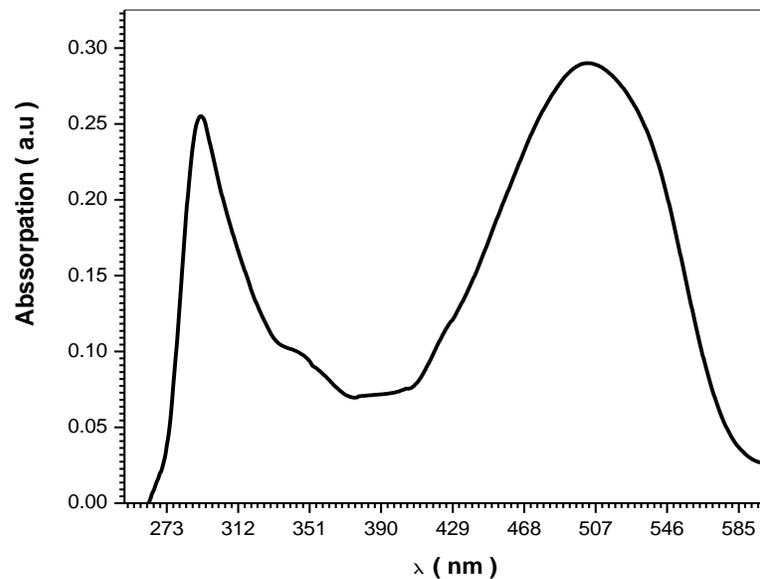


Fig (4.16) the relation between absorbance and wavelength of Ecrchrom Black.
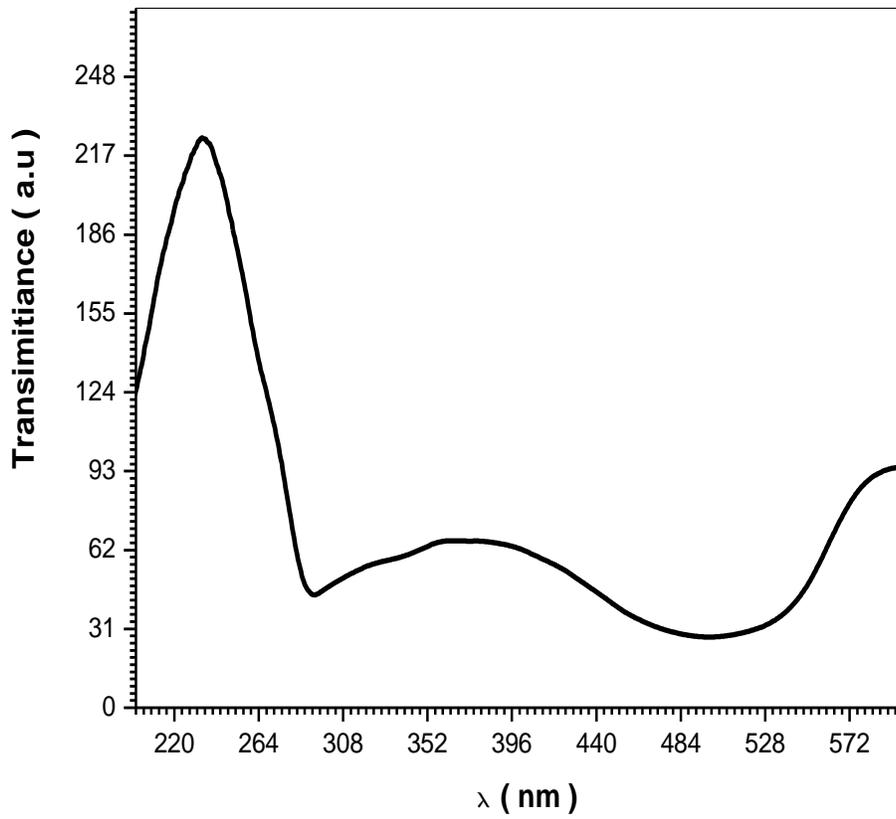
Fig (4.17) the relation between transparent and wavelength of Ecrchrom Black T.
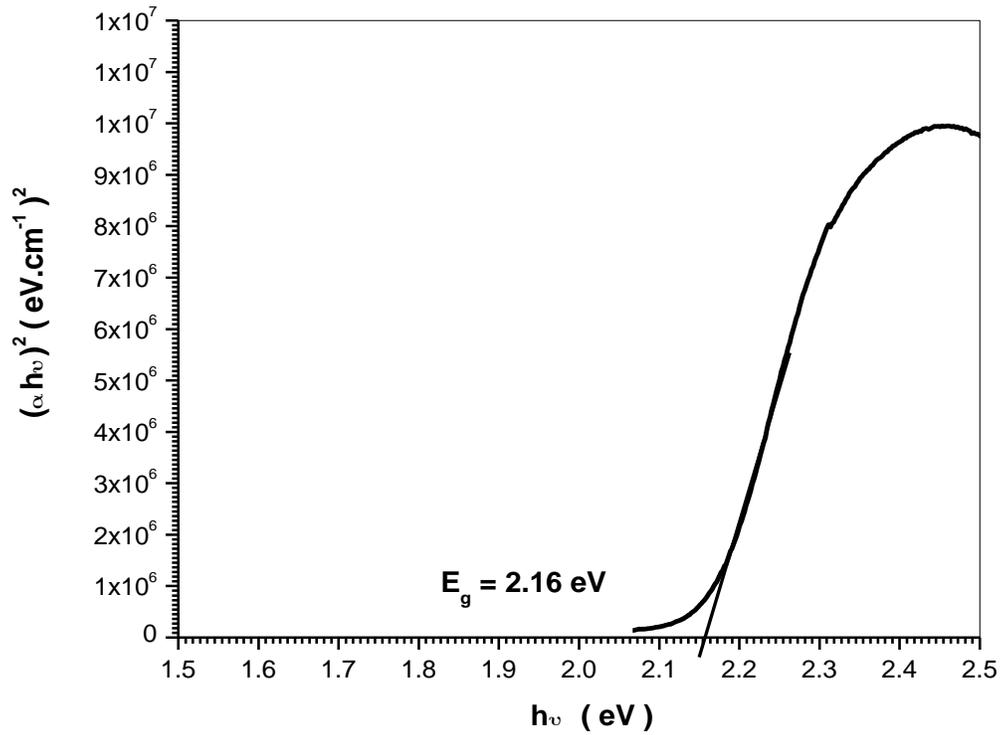
Fig(4.18) The optical energy gap (Eg) value of Ecrchrom Black T . The optical energy gap (Eg) has been calculated by the relation $(\alpha h\upsilon)^2 = C(h\upsilon - Eg)$ where (C) is constant. By plotting $(\alpha h\upsilon)^2$ vs photon energy $(h\upsilon)$. And by extrapolating the straight thin portion of the curve to intercept the energy axis, the value of the energy gap has been calculated. The value of (Eg) obtained was 2.16 eV.

Table (4.5) I-V reaction for sample2 (Ag)

| Voltage ( V ) | Current (mA) |
|---------------|--------------|
| 0.19558 | 59.60045 |
| 0.19886 | 59.60045 |
| 0.20307 | 59.60045 |
| 0.20967 | 59.60045 |
| 0.21539 | 59.60045 |
| 0.22188 | 59.50843 |
| 0.22476 | 59.28393 |
| 0.22501 | 59.06551 |
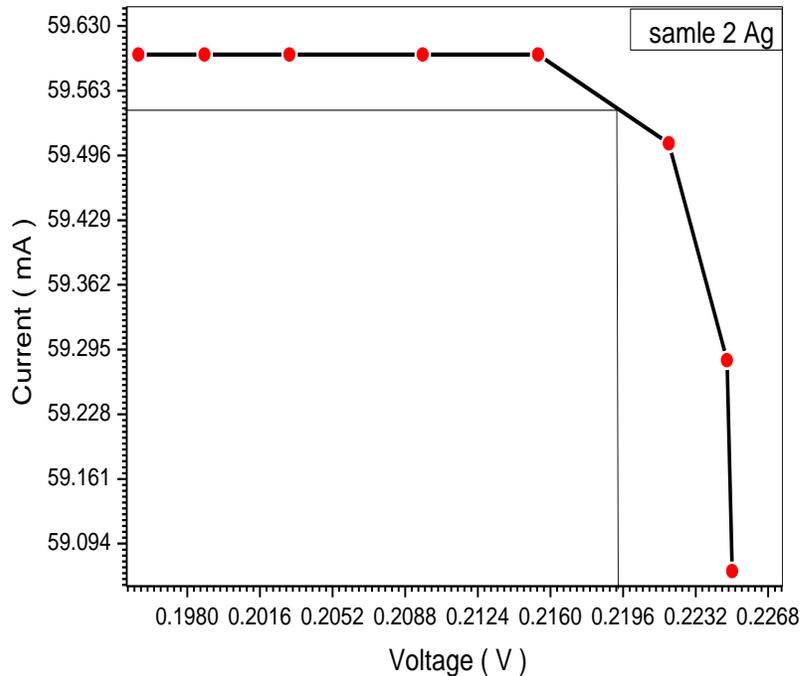


Fig

(4.19) several factors for characterization of sample2 (Ag)

49

Table (4.6) I-V reaction for sample2 (Al)

| Voltage ( V ) | Current (mA) |
|---|---|
| 0.10334 | 59.80562 |
| 0.13125 | 59.80562 |
| 0.15859 | 59.80562 |
| 0.18703 | 59.80562 |
| 0.21384 | 59.55197 |
| 0.22712 | 58.44101 |
| 0.23011 | 56.85815 |
| 0.10334 | 59.80562 |
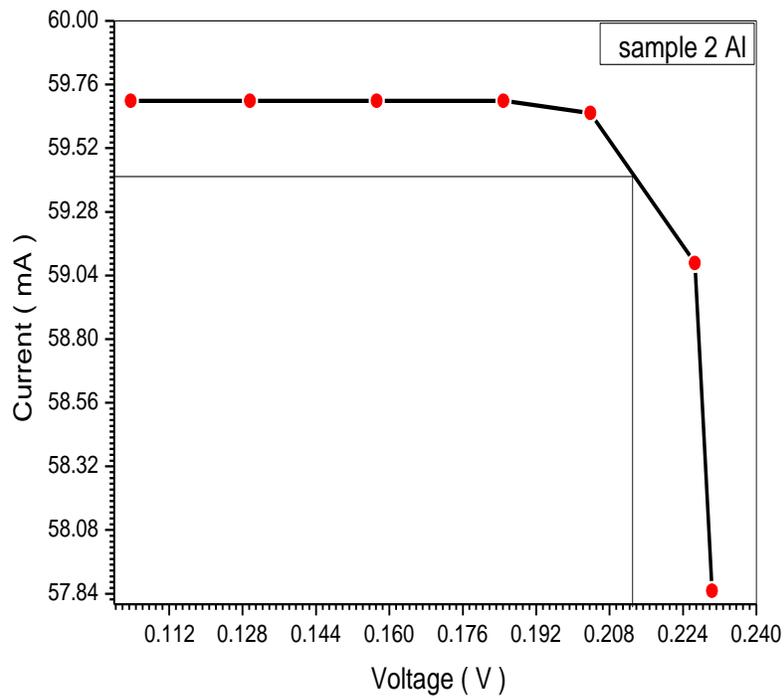
Fig (4.20) several factors for characterization of sample2(Al)

Table (4.7) I-V reaction for sample2 (Au)

| Voltage ( V ) | Current (mA) |
|---|---|
| 0.20289 | 59.29876 |
| 0.20704 | 59.30045 |
| 0.21289 | 59.30045 |
| 0.22012 | 59.30045 |
| 0.22577 | 59.11809 |
| 0.22662 | 58.76079 |
| 0.20289 | 59.29876 |
| 0.20704 | 59.30045 |
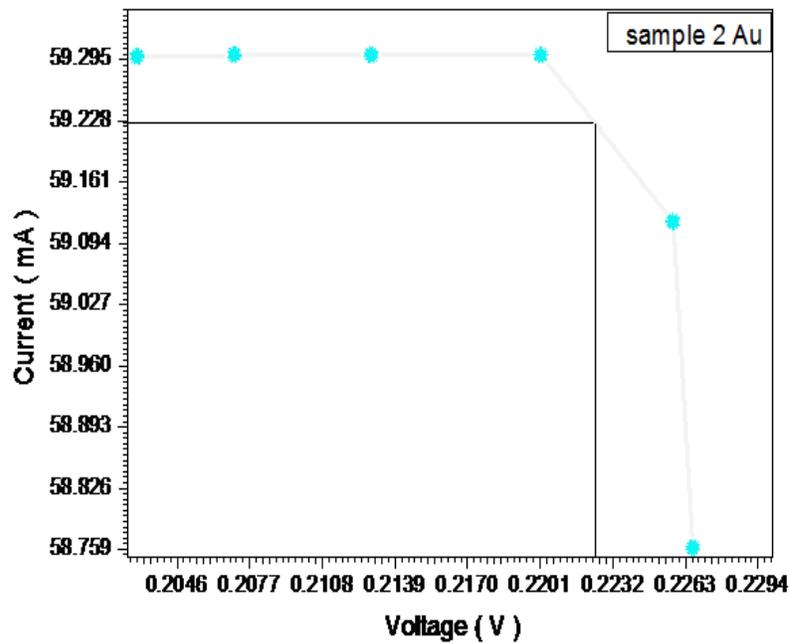


Fig (4.21) several factors for characterization of sample2 (Au)

Table (4.8) are Factors for characterization of performance Ecrchrom Black T. for three samples

| Number of sample | $I_{sc}$ (mA ) | $I_{max}$ ( mA) | $V_{oc}$ ( V ) | $V_{max}$ (V) | FF | $J_{sc}$ ( mA.cm$^{-2}$ ) | Pmax | $\eta$ % |
|---|---|---|---|---|---|---|---|---|
| Sample1(Ag) | 59.60 | 59.54 | 0.2250 | 0.2193 | 0.9738 | 9.5308 | 13.060 | 1.58 |
| Sample1(AL) | 59.69 | 59.41 | 0.2303 | 0.2130 | 0.9952 | 9.5517 | 13.685 | 1.66 |
| Sample1(Au) | 59.30 | 59.22 | 0.2266 | 0.2224 | 0.9816 | 9.4880 | 13.192 | 1.60 |

## 4.2.3 Results Samples of (Rohadamin B)
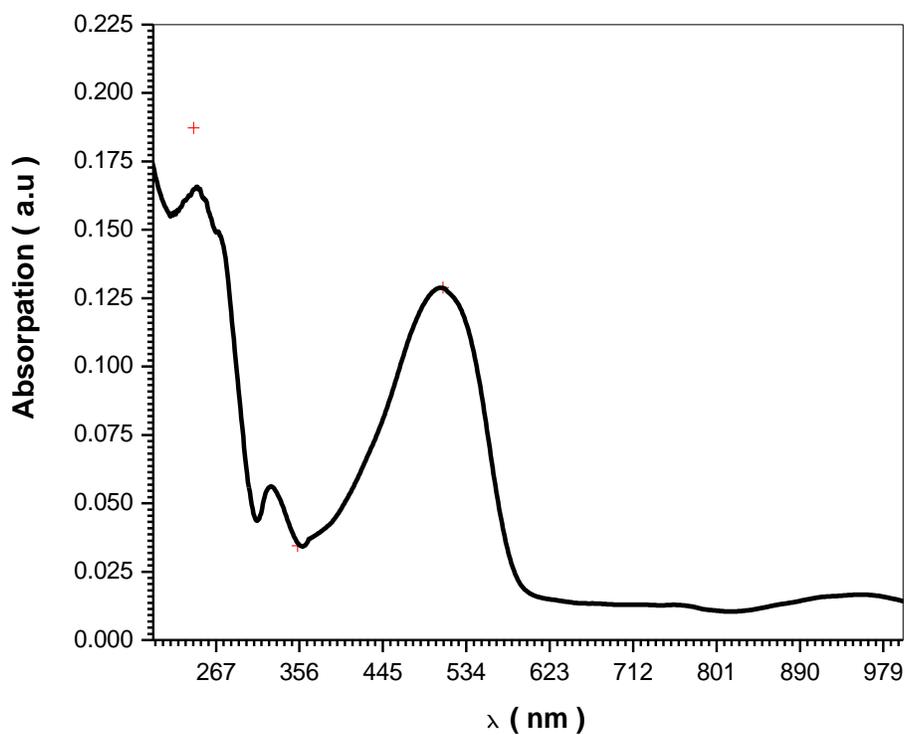


Fig (4.22) the relation between absorbance and wavelength of Rohadamin B
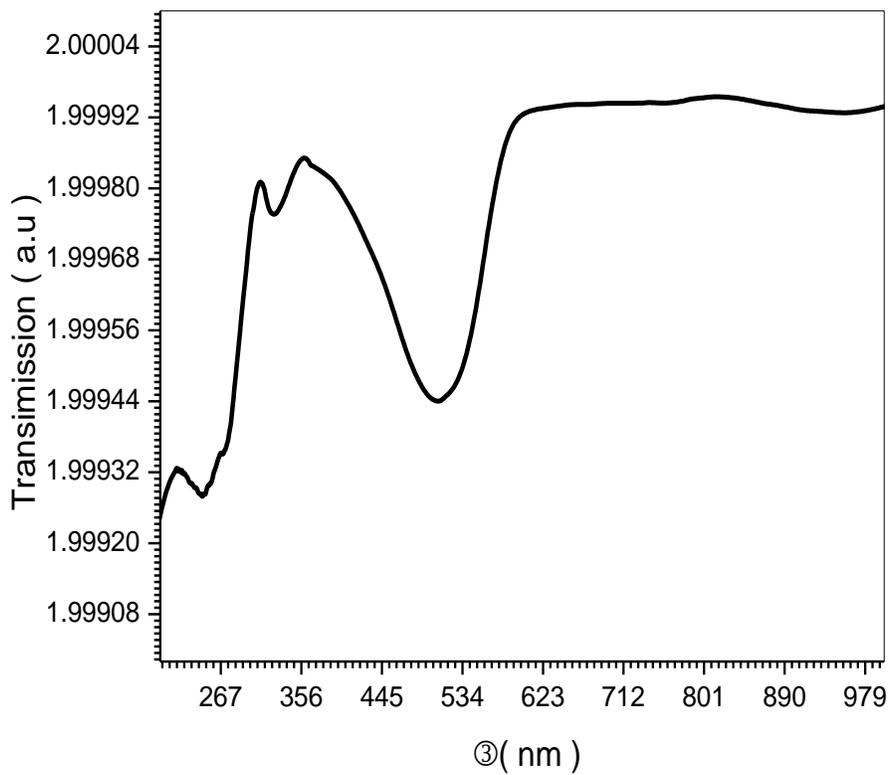
Fig (4.23) the relation between transparent and wavelength of Rohadamin B



$E_g = 3.27$ eV
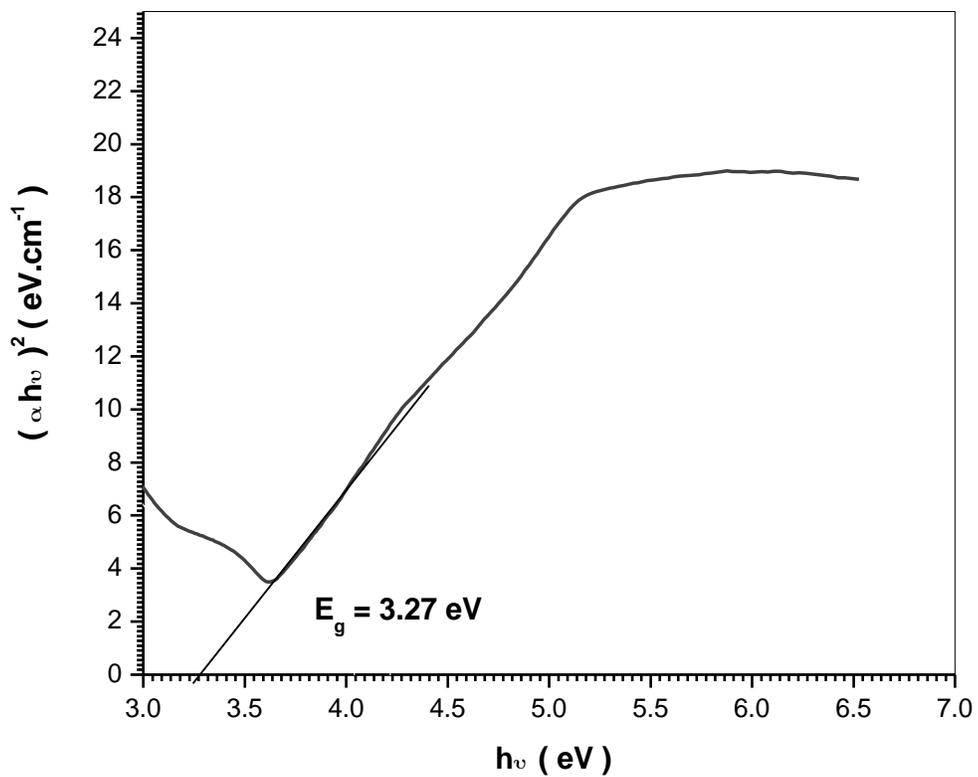
Fig(4.24) the optical energy gap (Eg) value of Rohadamin B. The optical energy gap (Eg) has been calculated by the relation $(\alpha h\upsilon)^2 = C(h\upsilon - Eg)$  where (C) is constant. By plotting $(\alpha h\upsilon)^2$vs photon energy (h$\upsilon$). And by extrapolating the straight thin portion of the curve to intercept the energy axis, the value of the energy gap has been calculated. The value of (Eg) obtained was 3.27 eV

Table (4.9) I-V reaction for sample3 (Ag)

| Voltage ( V ) | Current (mA) |
|---|---|
| 0.19427 | 58.82567 |
| 0.19872 | 58.82567 |
| 0.20199 | 58.82567 |
| 0.20500 | 58.82315 |
| 0.20798 | 58.78118 |
| 0.21030 | 58.51219 |
| 0.21096 | 58.01871 |
| 0.19427 | 58.82567 |
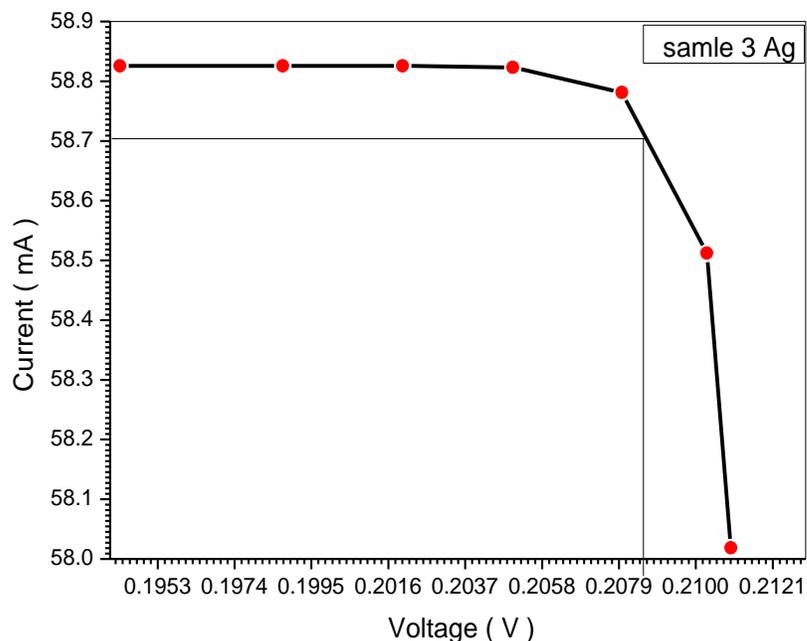


Fig (4.25) several factors for characterization of sample3 (Ag)

Table (4.10) I-V reaction for sample3 (Al)

| Voltage ( V ) | Current (mA) |
|---|---|
| 0.10334 | 59.80562 |
| 0.13125 | 59.80562 |
| 0.15859 | 59.80562 |
| 0.18703 | 59.80562 |
| 0.21384 | 59.55197 |
| 0.22712 | 58.44101 |
| 0.23011 | 56.85815 |
| 0.10334 | 59.80562 |
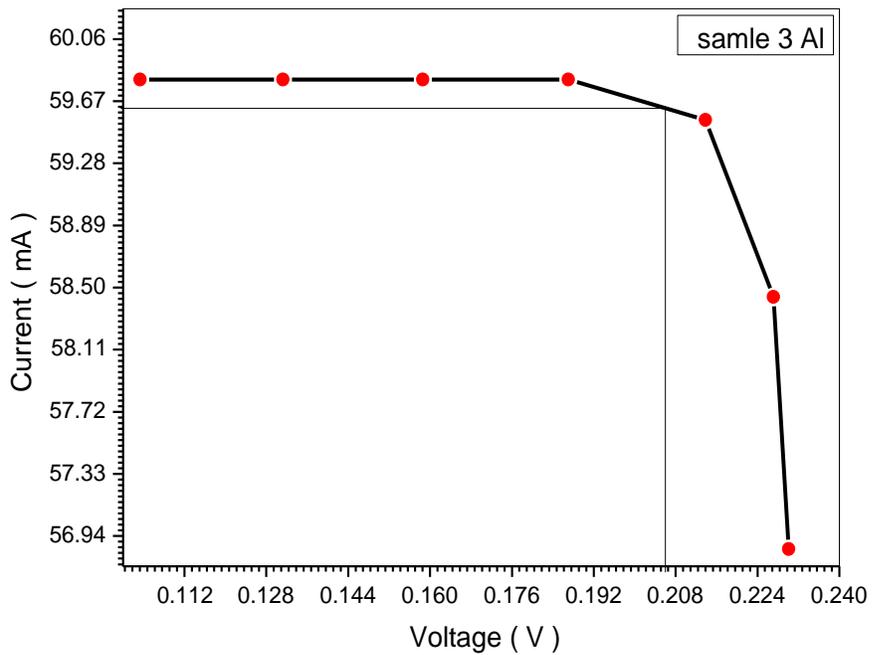


Fig (4.26) several factors for characterization of sample3 (Al)

Table (4.11) I-V reaction for sample3 (Au)

| Voltage ( V ) | Current (mA) |
|---|---|
| 0.11158 | 60.00899 |
| 0.12717 | 60.00126 |
| 0.1463 | 60.00899 |
| 0.17168 | 60.00126 |
| 0.1956 | 59.92247 |
| 0.21522 | 59.20098 |
| 0.22978 | 57.55716 |
| 0.11158 | 60.00899 |
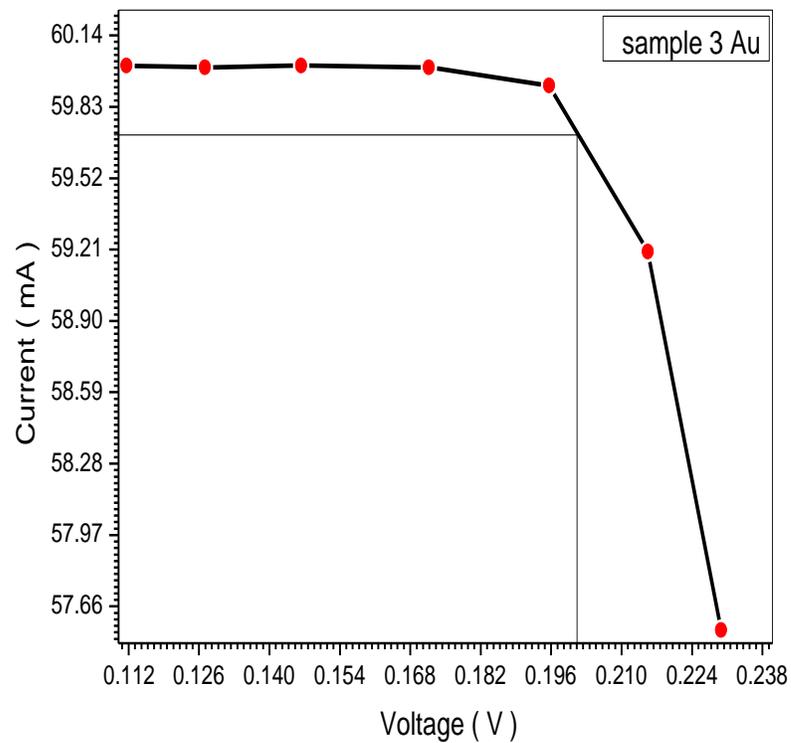


Fig (4.27) several factors for characterization of sample3 (Au)

Table (4.12) are Factors for characterization of performance Rohadamin B for three samples

| Number of sample | $I_{sc}$ (mA ) | $I_{max}$ ( mA) | $V_{oc}$ ( V ) | $V_{max}$ (V) | FF | $J_{sc}$ ( mA.cm$^{-2}$ ) | Pmax | η % |
|---|---|---|---|---|---|---|---|---|
| Sample1(Ag) | 58.85 | 58.70 | 0.2109 | 0.2085 | .9858 | 9.4168 | 12.2395 | 1.48s |
| Sample1(AL) | 59.80 | 59.62 | 0.2301 | 0.2059 | .8921 | 9.5688 | 12.2395 | 1.49 |
| Sample1(Au) | 60.00 | 59.70 | 0.2300 | 0.2011 | .8698 | 9.6012 | 12.0080 | 1.46 |

## 4.2.4 Results Samples of (Coumarin 500)
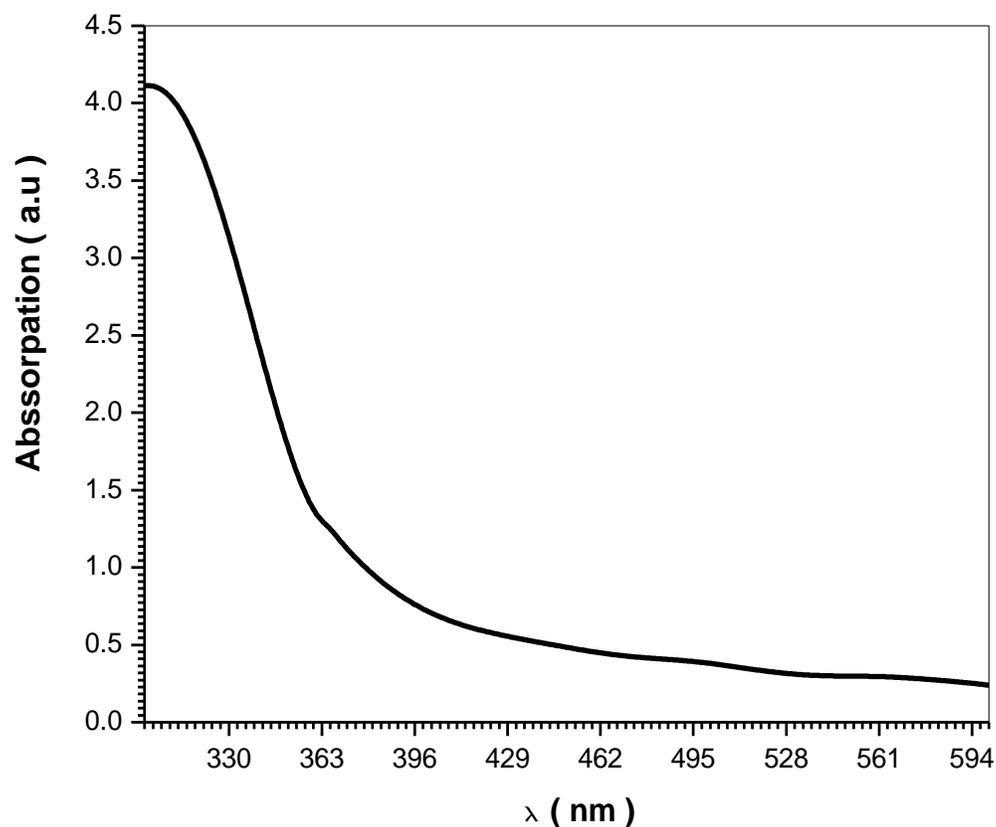


Fig (4.28) the relation between absorbance and wavelength of Coumarin 500

7
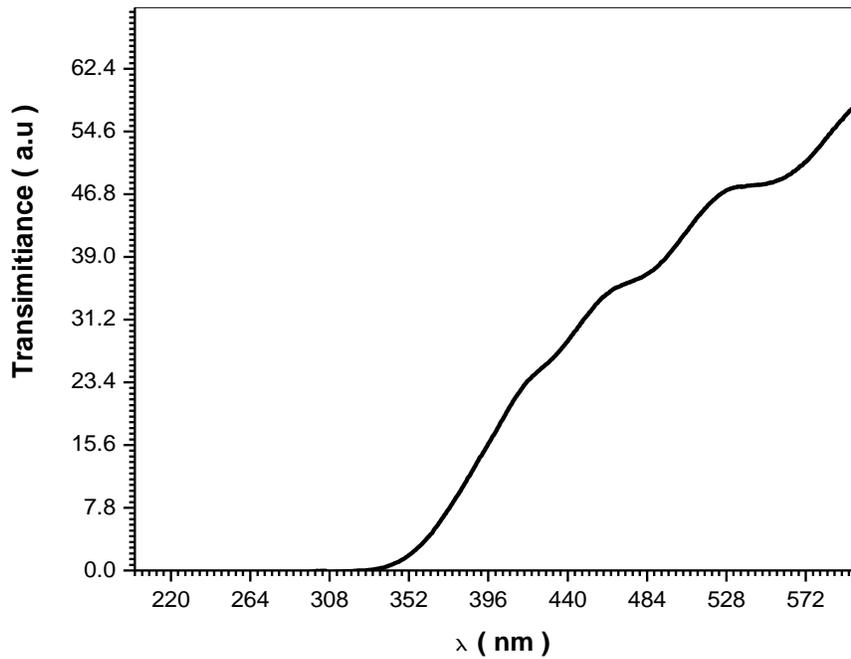


Fig (4.29) the relation between transparent and wavelength of Coumarin 500



$E_g = 3.6$ eV
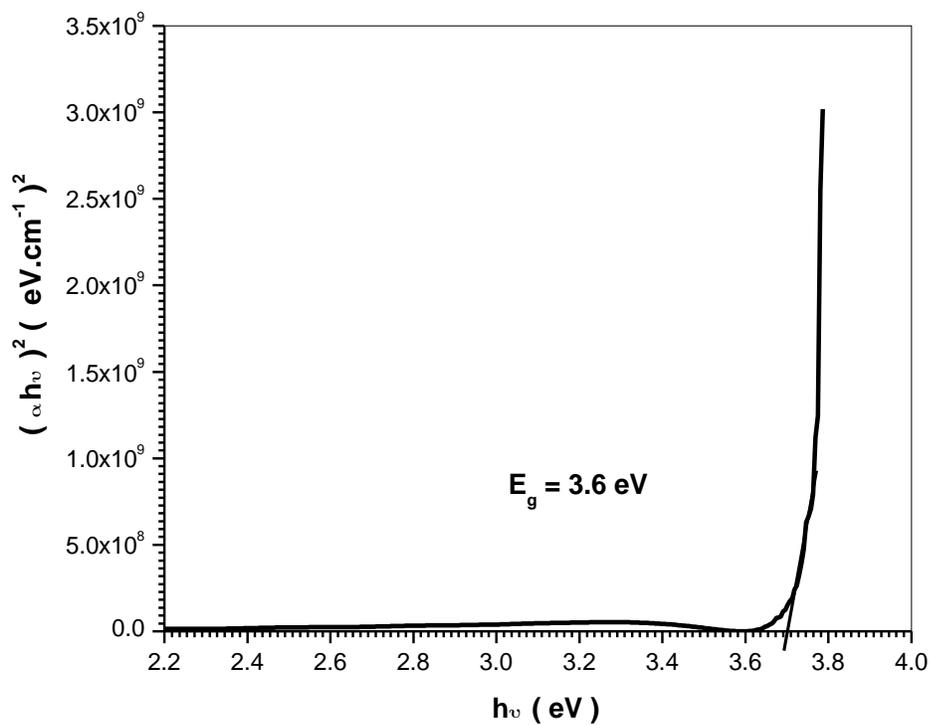
Fig(4.30) the optical energy gap (Eg) value ofCoumarin 500. The optical energy gap (Eg) has been calculated by the relation $(\alpha h\upsilon)^2 = C(h\upsilon - Eg)$  where (C) is constant. By plotting $(\alpha h\upsilon)^2$vs photon energy (hυ). And by extrapolating the

straight thin portion of the curve to intercept the energy axis, the value of the energy gap has been calculated. The value of (Eg) obtained was 3.6 eV

Table (4.13) I-V reaction for sample4 (Ag)

| Voltage ( V ) | Current (mA) |
|---------------|--------------|
| 0.10199 | 59.6977 |
| 0.11879 | 59.6977 |
| 0.13775 | 59.6977 |
| 0.16538 | 59.6977 |
| 0.19464 | 59.6977 |
| 0.22958 | 59.46489 |
| 0.23034 | 59.06612 |
| 0.10199 | 59.6977 |
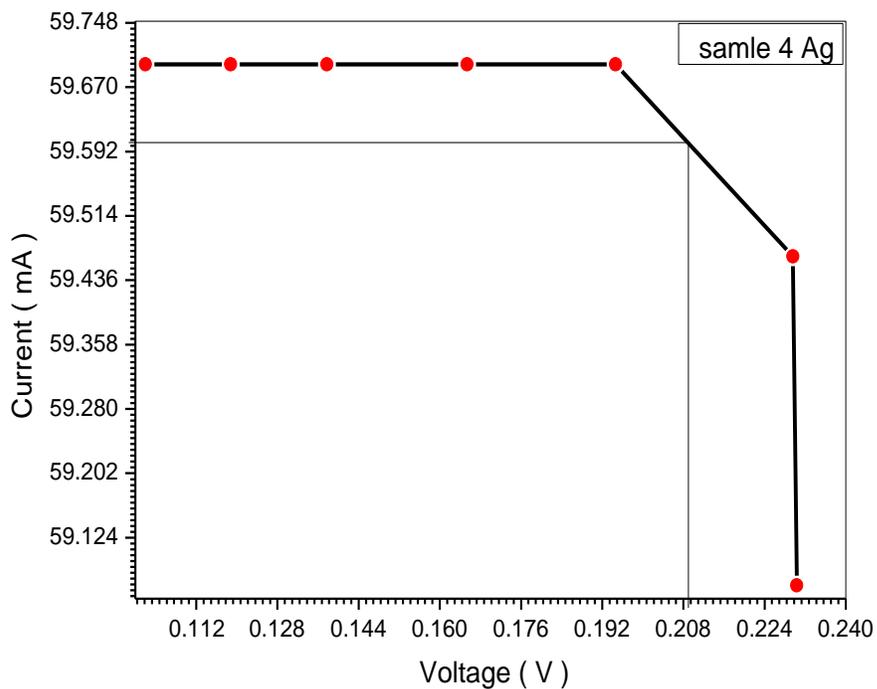
Fig (4.31) several factors for characterization of sampl4 (Ag)

Table (4.14) I-V reaction for sample4 (Al)

| Voltage ( V ) | Current (mA) |
|---|---|
| 0.11159 | 57.70045 |
| 0.12438 | 57.70045 |
| 0.13755 | 57.70045 |
| 0.15553 | 57.70045 |
| 0.17718 | 57.69573 |
| 0.20059 | 57.50562 |
| 0.20293 | 57.16247 |
| 0.11159 | 57.70045 |
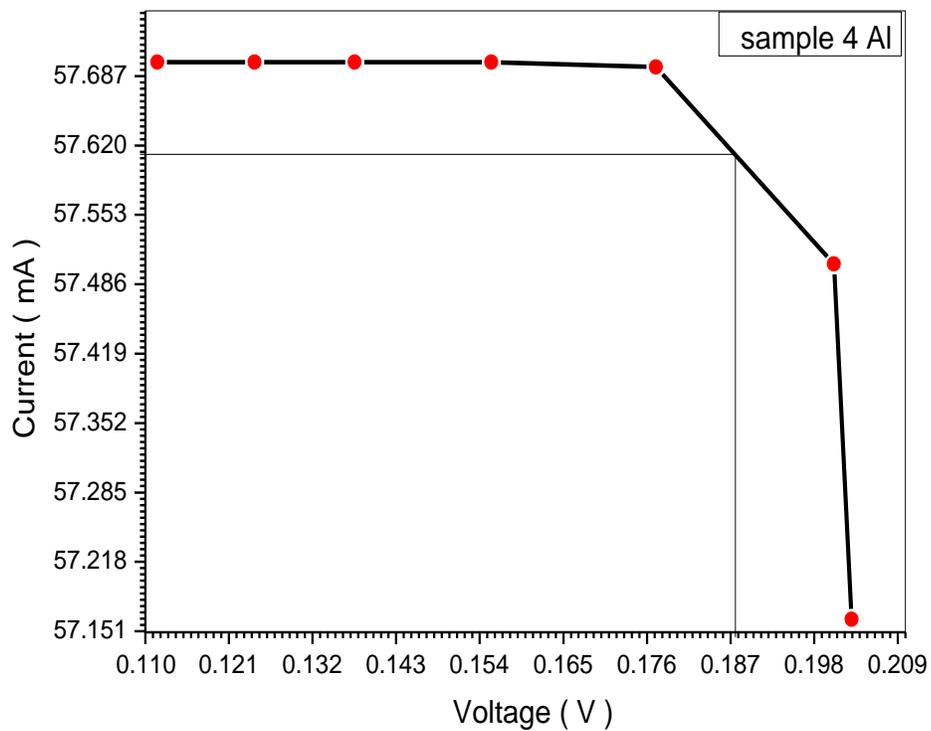


Fig (4.32) several factors for characterization of sample4 (AL)

Table (4.15) I-V reaction for sample4 (Au)

| Voltage ( V ) | Current (mA) |
|---|---|
| 0.19517 | 58.39989 |
| 0.19718 | 58.39989 |
| 0.19948 | 58.39989 |
| 0.20229 | 58.39989 |
| 0.20495 | 58.39534 |
| 0.20771 | 58.15416 |
| 0.20801 | 57.61871 |
| 0.19517 | 58.39989 |
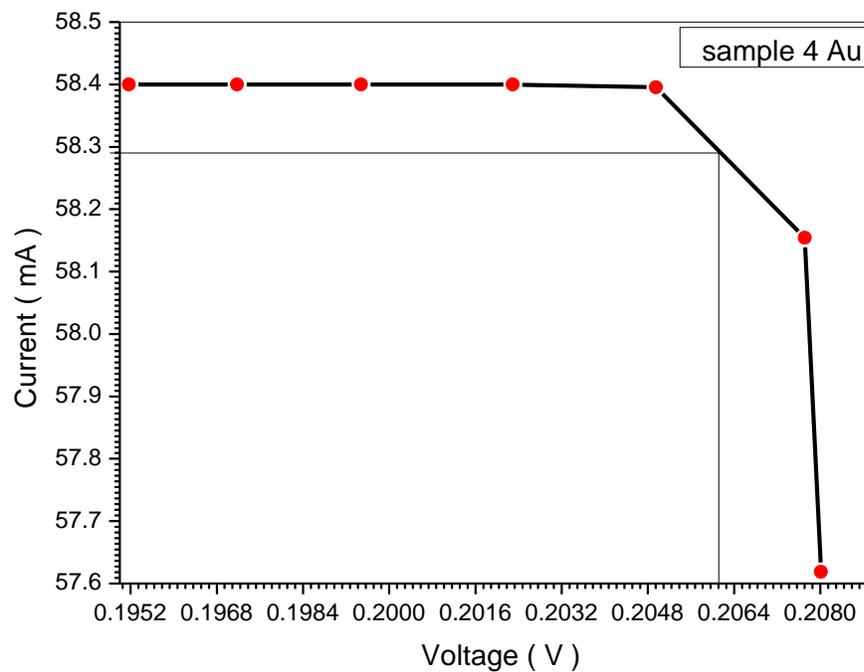


Fig (4.33) several factors for characterization of sample4 (Au)

Table (4.16) are Factors for characterization of performance Coumarin 500 for three samples

| Number of sample | $I_{sc}$ (mA ) | $I_{max}$ ( mA) | $V_{oc}$ ( V ) | $V_{max}$ (V) | FF | $J_{sc}$ ( mA.cm$^{-2}$ ) | Pmax | η % |
|---|---|---|---|---|---|---|---|---|
| Sample1(Ag) | 59.69 | 59.60 | 0.2306 | 0.2089 | .9043 | 9.5516 | 12.451 | 1.51 |
| Sample1(AL) | 57.70 | 57.61 | 0.2029 | 0.1876 | .9231 | 9.2323 | 10.809 | 1.31 |
| Sample1(Au) | 58.39 | 58.29 | 0.2080 | 0.2061 | .9885 | 9.3439 | 12.014 | 1.45 |

Table (4.17) sample 2performance and Energy gab for dyes

| Number of sample | η% | Energy gap eV |
|---|---|---|
| Sample1(AL) | 1.66 | 2.16 |
| Sample2(AL) | 1.62 | 2.20 |
| Sample3(AL) | 1.49 | 3.27 |
| Sample4(AL) | 1.31 | 3.60 |

Table (4.18) sample 2performance and Atomic number for electrodes

| Number of sample | η% | Atomic number |
|---|---|---|
| Sample3(Ag) | 1.49 | 13 |
| Sample3(AL) | 1.48 | 47 |
| Sample3(Au) | 1.46 | 79 |

## 4.3 Discussion:

The optical absorption spectra in the (273– 585) nm wavelength range for the (DDTTC) dye are depicted in Fig (4.10). The maximum absorption is observed at wavelength (507 nm). The absorption edge of the (DDTTC) dye occurs at wavelength (507 nm) corresponding to photon energy (2.45 eV). Fig (4.11) shows the relation between transmission and intensity wavelengths, one found rapid decrease at 220 nm and sudden increase at 507 nm with continuous increase after that wavelength.

The energy band gap of DDTTC is determined using the absorption spectra. According to the absorption coefficient ($\alpha$) for direct band gap material is given by the relation

$$\alpha h\nu = B(h\nu - E_g)^n \qquad (4.6.1)$$

Where $E_g$ the energy gap, constant $B$ is different for different transitions, ($h\nu$) is energy of photon and (n) is an index which assumes the values 1/2, 3/2, 2 and 3 depending on the nature of the electronic transition responsible for the reflection. And by extrapolating the straight thin portion of the curve to intercept the energy axis, the value of the energy gap has been to found be(2.2 eV) as show in fig (4.12). fig(4.13) shows the current-voltage characteristics obtained from the measured values (see Table 4.4).This measurement was taken from solar cell of the structure (ITO/(DDTTC) dye / MEH-PPV/Ag),  The short-circuit current ($I_{sc}$) is 59.10 mA, the open-circuit voltage ($V_{oc}$) is 0.2359 V, fill factor (FF) is 0.9737, and the efficiency is 1.65%.

fig(4.14) shows the current-voltage characteristics obtained from the measured values (see Table 4.4). This measurement was taken from solar cell of the structure (ITO/(DDTTC) dye / MEH-PPV/Al),  The short-circuit current ($I_{sc}$) is 59.60 mA,

the open-circuit voltage ($V_{oc}$) is 0.2310 V, fill factor (FF) is 0.9714, and the efficiency is 1.62%.

fig(4.15) shows the current-voltage characteristics obtained from the measured values (see Table 4.4).This measurement was taken from solar cell of the structure (ITO/(DDTTC) dye / MEH-PPV/Au), The short-circuit current ($I_{sc}$) is 59.90 mA, the open-circuit voltage ($V_{oc}$) is 0.2159 V, fill factor (FF) is 0.832, and the efficiency is 1.26%.

The optical absorption spectra in the (250– 570) nm wavelength range for the (Ecrchrom Black) dye are depicted in Fig (4.16) The maximum absorption is observed at wavelength (503 nm). The absorption edge of the (Ecrchrom Black) dye occurs at wavelength (507 nm) corresponding to photon energy (2.47 eV). Fig (4.17) shows the relation between transmission coefficient and wavelengths. One found rapid decrease at 220 nm and sudden increase in 503 nm with continuous increase after that wavelength.

The energy band gap of these materials is determined using the absorption spectra.

And equation (5.3.1)

The value of the energy gap has been found to be (2.16 eV) as fig (4.18). shows

fig (4.19) shows the current-voltage characteristics obtained from the measured values (see Table 4.8). This measurement was taken from solar cell of the structure (ITO/(Ecrchrom Black) dye / MEH-PPV/Ag), The short-circuit current ($I_{sc}$) is 59.60 mA, the open-circuit voltage ($V_{oc}$) is 0.2250 V, fill factor (FF) is 0.9738, and the efficiency is 1.58%.

Fig (4.20) shows the current-voltage characteristics obtained from the measured values (see Table 4.8).this measurement was taken from solar cell of the structure (ITO/(Ecrchrom Black) dye / MEH-PPV/Al), The short-circuit current ($I_{sc}$) is

59.69 mA, the open-circuit voltage ($V_{oc}$) is 0.2130 V, fill factor (FF) is 0.9952, and the efficiency is 1.66%.

Fig (4.21) shows the current-voltage characteristics obtained from the measured values (see Table 4.8).this measurement was taken from solar cell of the structure (ITO/(DDTTC) dye / MEH-PPV/Au), The short-circuit current ($I_{sc}$) is 59.30 mA, the open-circuit voltage ($V_{oc}$) is 0.2224 V, fill factor (FF) is 0.9816, and the efficiency is 1.6%.

The optical absorption spectra in the (240 - 625) nm wavelength range for the (Ecrchrom Black) dye are depicted in Fig (4.22). The maximum absorption observed is at wavelength (530 nm). The absorption edge of the (Rohadamin B) dye occurs at wavelength (530 nm) corresponding to photon energy (2.34 eV). Fig (4.23) shows the relation between transmission coefficient and wavelengths. One found rapid decrease at 356 nm and sudden increase at 534 nm with continuous with increase after that wavelength.

The energy band gap of these materials is determined using the absorption spectra (See Fig), The value of the energy gap has been calculated. Found to be (3.27 eV) as fig (4.24).

Shows fig (4.25) shows the current-voltage characteristics obtained from the measured values (see Table 4.12). This measurement was taken from solar cell of the structure (ITO/(Rohadamin B) dye / MEH-PPV/Ag), The short-circuit current ($I_{sc}$) is 58.85 mA, the open-circuit voltage ($V_{oc}$) is 0.2109 V, fill factor (FF) is 0.9858, and the efficiency is 1.48%.

Fig (4.26) shows the current-voltage characteristics obtained from the measured values (see Table 4.12). This measurement was taken from solar cell of the structure (ITO/(Rohadamin B) dye / MEH-PPV/Al), The short-circuit current ($I_{sc}$) is 59.90 mA, the open-circuit voltage ($V_{oc}$) is 0.2059 V, fill factor (FF) is 0.9210, and the efficiency is 1.49 %.

Fig (4.27) shows the current-voltage characteristics obtained from the measured values (see Table 4.12). This measurement was taken from solar cell of the structure (ITO/(Rohadamin B) dye / MEH-PPV/Au), The short-circuit current ($I_{sc}$) is 60.00 mA, the open-circuit voltage ($V_{oc}$) is 0.2011 V, fill factor (FF) is 0.9698, and the efficiency is1. 46%.

The optical absorption spectra in the (300 – 600) nm wavelength range for the (Coumarin 500) dye are depicted in Fig (4.28). The maximum absorption is observed at wavelength (320 nm). The absorption edge of the (Coumarin 500) dye occurs at wavelength (320 nm) corresponding to photon energy (3.875eV). Fig (4.29) shows the relation between transmission coefficient and wavelengths. One found rapid decrease at 220 nm and sudden increase at 352 nm with continuous increase after that wavelength.

The energy band gap of these materials is determined using the absorption spectra. (See fig), The value of the energy gap has been found to be (3.6 eV) as fig (4.30) shows fig (4.31) shows the current-voltage characteristics obtained from the measured values (see Table 4.15).this measurement was taken from solar cell of the structure (ITO/( Coumarin 500) dye / MEH-PPV/Ag), The short-circuit current ($I_{sc}$) is 59.69 mA, the open-circuit voltage ($V_{oc}$) is 0.2306 V, fill factor (FF) is 0.9043, and the efficiency is 1.51%.

Fig (4.32) shows the current-voltage characteristics obtained from the measured values (see Table 4.16). This measurement was taken from solar cell of the structure (ITO/( Coumarin 500) dye / MEH-PPV/Al), The short-circuit current ($I_{sc}$) is 57.70 mA, the open-circuit voltage ($V_{oc}$) is 0.2029 V, fill factor (FF) is 0.9231, and the efficiency is 1.31%.

Fig (4.33) shows the current-voltage characteristics obtained from the measured values (see Table 4.16). This measurement was taken from solar cell of the structure (ITO/( Coumarin 500) dye / MEH-PPV/Au), The short-circuit current

($I_{sc}$) is 58.39 mA, the open-circuit voltage ($V_{oc}$) is 0.2080 V, fill factor (FF) is 0.9885, and the efficiency is 1.45%.

The energy gap of solar cell effect on the efficiency it  is very interesting to note that table (4.17) indicates the decrease of energy gap and the increases of the solar cell efficiency in general. This is since the energy gap decrease enables electrons having lower excitation energy to become free electron in a conduction band thus increasing the electric solar current.

The electrodes atomic number also effect Solar Cells efficiency the results recorded in table (4.18) shows that increase of atomic number Z decreases efficiency. This can be under stood if one take into account the fact that according to Hydrogen difference between energy levels in the atom , which can represent the energy gap Eg is proportional to Z , $10^9$ Eg = E ; Z thus increase of Z increases Eg which decrease chances for electrons transfer from valence to conduction and which decrease in turn current and efficiency.

# Chapter Five

## Conclusion and Suggested Future Work

### 5.1 Conclusion:

This work shows that the electrode type affect polymer solar cell performance. This performance depend on the atomic number of the electrode.

The energy gap of the dyes used in dye sensitized solar cell affect the performance and efficiency of the solar cell.

The energy gab of the dyes also effect the performance and efficiency polymer Solar cells.

### 5.2 Suggested Future Work:

I am recommend further work in this area to enhance the dye structure and produce and adjust concentration to produce good performance  by finding a common solvent to the dye and the fullerene so that the solvent can be easily evaporated and yield efficient cells . The thickness of the cell must be decreased then become thinness for 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.

# Appendix (A)

**IJESRT**

## THE RELATIONSHIP BETWEEN ATOMIC NUMBER & EFFICIENCY AT DYE SOLAR CELLS

**Sakina Ibrahim Ali\*, Mubarak Dirar Abdallah, Sawsan Ahmed Elhouri Ahmed, Rawia Abdalgani, Amel Abdalla A, Abdalsakhi. S. M. H**

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International University of Africa- College of Science-Department of Physics & Sudan University of
Science & Technology-College of Science-Department of Physics- Khartoum-Sudan
University of Bahri- College of Applied & Industrial Sciences-Department of Physics- Khartoum - Sudan
Sudan University of Science & Technology-College of Science-Department of Physics-Khartoum-Sudan
Sudan University of Science & Technology-College of Science-Department of Physics-Khartoum-Sudan
Al Neenlen University – Faculty of Science and Technology Department of Physics

## ABSTRACT

In this work the effect of changing the anode of polymer solar cell on their performance was experimentally investigated .The cells were fabricated from ITO which act as a cathode beside MEH PPV, Ecrchrom Black T and Rohadamin B dyer . The anodes which c are AL, GL , AU with atomic number 13 , 47 and 79 were used . It was found that the efficiency of the solar cell of AL, GL , AU electrode for Ecrchrom dye are 1.66, 1.59 , and 1.58 Respectively the efficiency for Rohadamin , Ecrchrom Black T dye are 1.49, 1.48 and 1.46 respectively these results shows clearly that the efficiency increases as the atomic number decreases this conforms with the fact that energy gap increase with the atomic number.

**KEYWORDS**: Ecrchrom Black T , Rohadamin B, thin film, solar cell, photovoltaic property, optical property.

## INTRODUCTION

Human need energy so as to make life easier now a day petroleum fuels are the most wide spread energy which cause typ e[ 1] recently it was discovered that petroleum fuel cause air pollution which cause severe biological hazards' [2, 3] this forces scientists to search cheap free pollution energy forms [4,5] the most popular alternative that satisfies these needs is the solar energy [6] solar energy can be converted into many energy forms but the most preferable energy conversion is the electric energy conversion .[7] this is done by solar cells which converts solar radiation energy into electric energy [8,9] solar cells fabricated form silicone are the more commercially available solar cell types. Despite the fact that silicone solar cells are stable and live for a long time .but they suffer from some drawbacks first of all these cells are expensive and needs complex fabrication techniques. This encourages scientists to search for a new generation of cells. The direct conversion of light into electricity is done by solar cells. The usage of solar energy for heat has a long history but the origin of devices which produce electricity is much more recent. It is closely linked to modern solid-state electronics. Indeed, the first usable solar cell was invented at Bell Laboratories, the birthplace of the transistor - in the early 1950's. The first solar cells found a ready application in supplying electrical power to satellites. Terrestrial systems soon followed, these were what we would now call remote industrial or professional applications, providing small amounts of power in inaccessible and remote locations, needing little or no maintenance or attention. Examples of such applications include signal or monitoring equipment, or telecommunication and corrosion protection systems. Since then, numerous photovoltaic systems have been installed to provide electricity to the large number of people on our planet that do not have (nor, in the foreseeable future, are likely to have) access to mains electricity. The most popular wide spreaded cell [10] .Its characterized by long life time , chemical stability

and relatively a degut efficiency .However silicon solar cell suffers from noticeable setbacks It is efficiency is still low , it cannot exceed 25% . The fabrication of silicon solar cells is very complex, the made these cells expensive [11].

## MATERIALS & METHODS

Six samples were prepared by depositing **HEH-PPV** and using a different electrode **Al , Ag** and **Au** to act as an anode were prepared as shown in Fig(1) below .

The V- I curve for all solar cell sample were found by using electric circuit consisting of ammeter , volt meter and power supply as shown in fig (2)

| AL |
| --- |
| DYE |
| HEH-PPV |
| TTO |

*Fig (1): Polymer solar cell*

## RESULTS & DISCUSSION

The results and curves obtained by the Ultra-Violet device and curve.
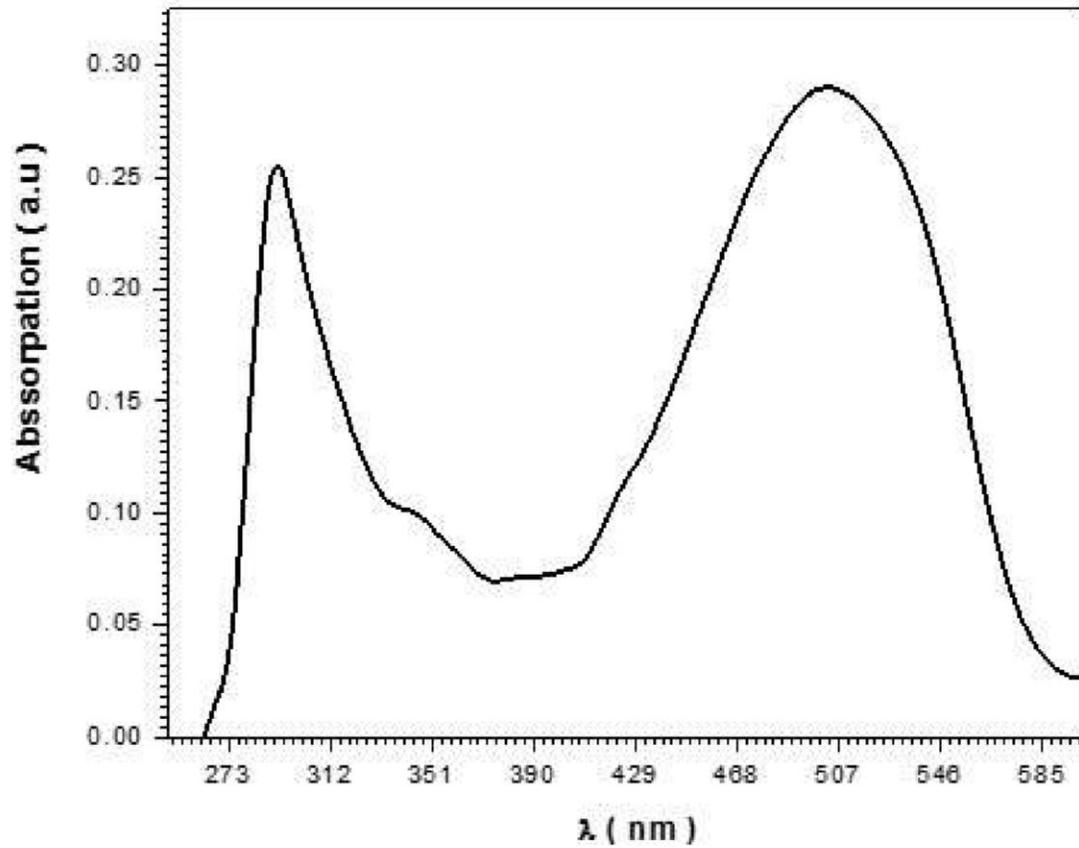
*Fig (3) shows the relation between absorbance and wavelength of Ecrchrom Black T.*
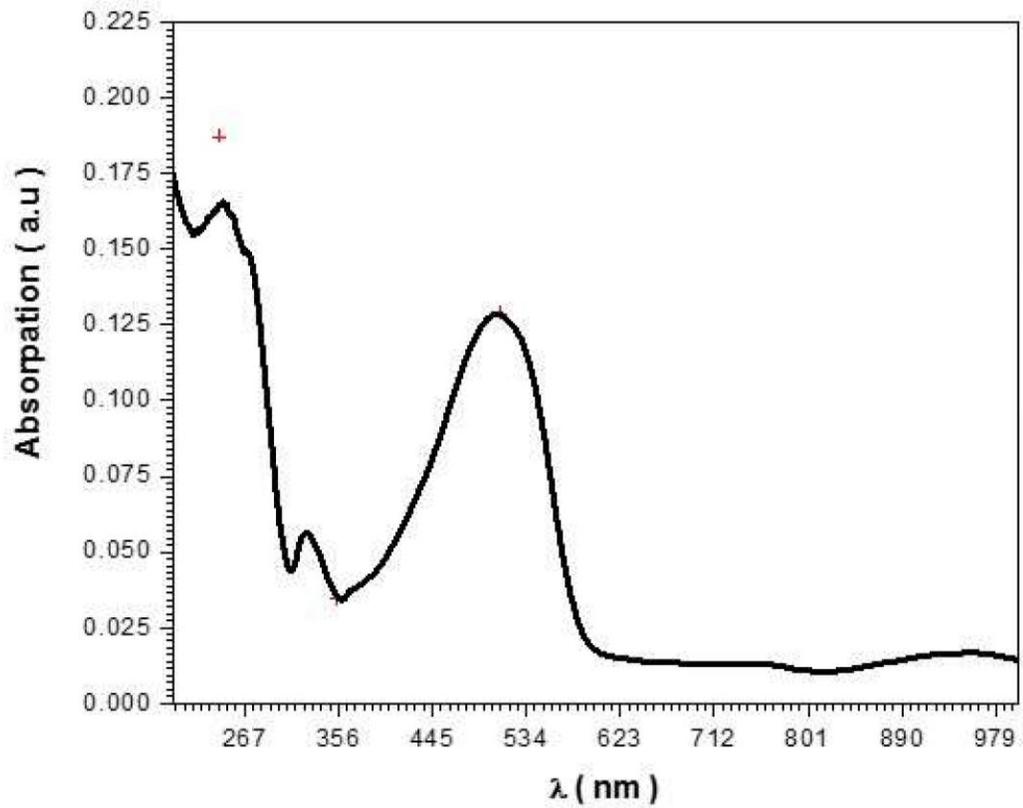
*Fig (4) shows the relation between absorbance and wavelength of Rohadamin*
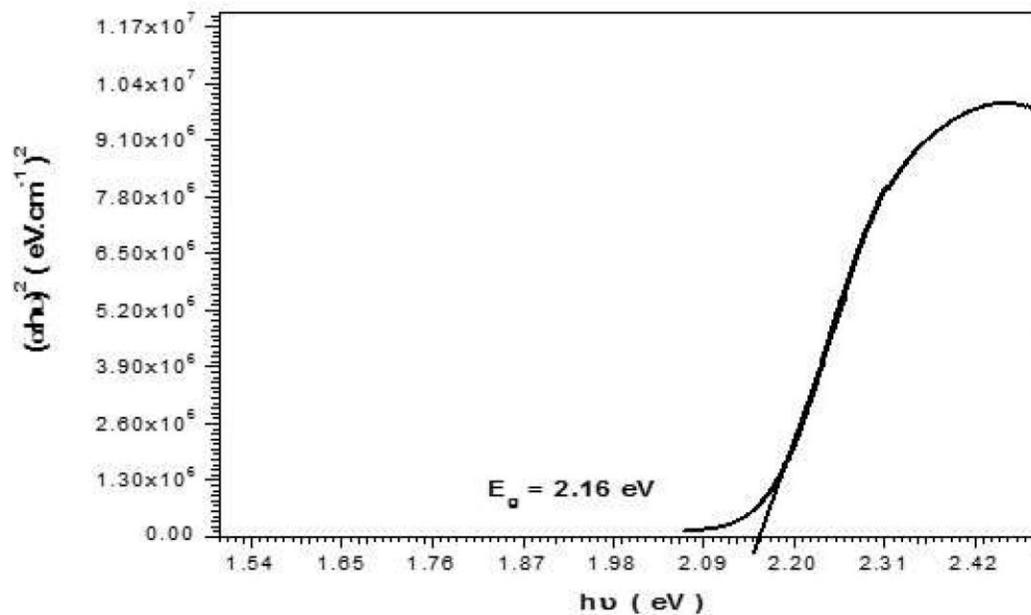


*Fig(5) The optical energy gap ($E_g$) value of Ecrchrom Black T*
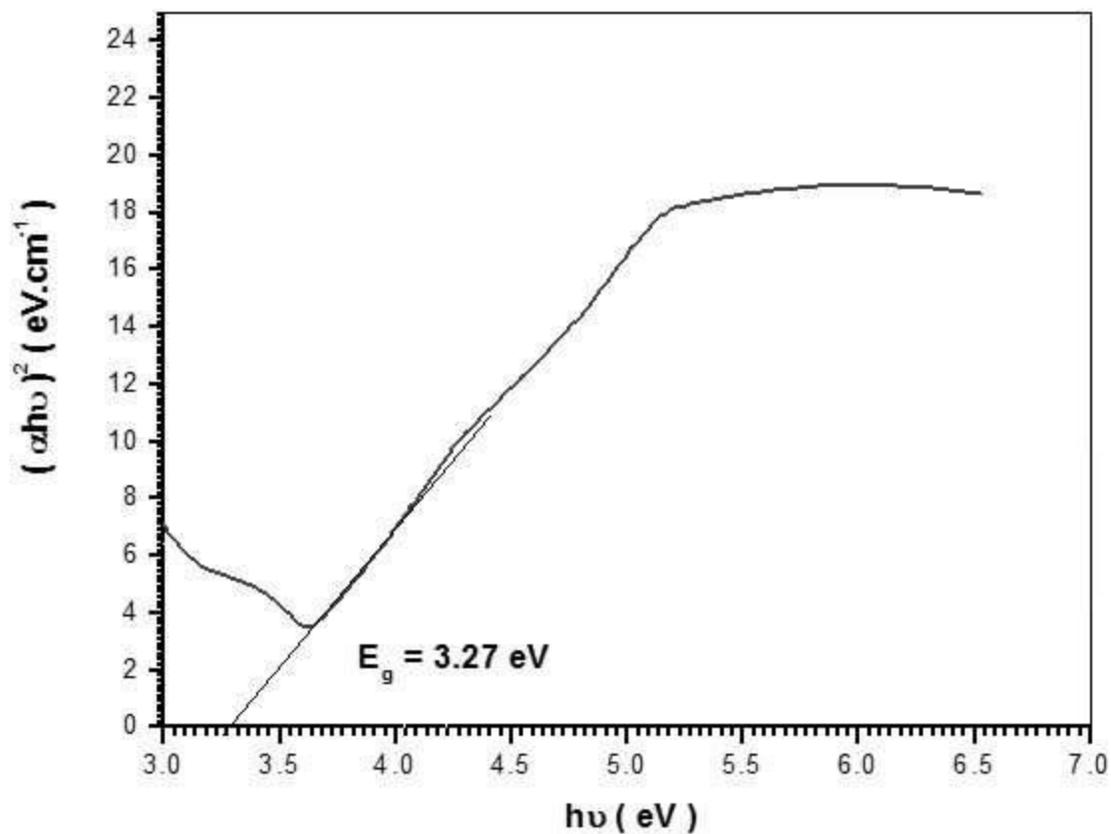


*Fig (6) the optical energy gap ($E_g$) value of Rohadamin B*
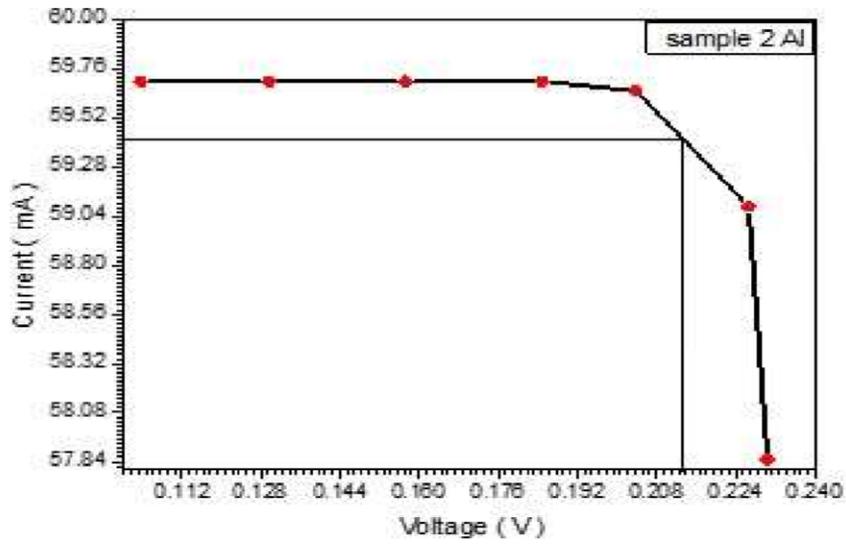
*Fig (7) several factors for characterization of sample 1(Al)*

*Table (1) I-V reaction for sample 1(Al)*

| V(V) | I(A) |
|---|---|
| 0.10334 | 59.80562 |
| 0.13125 | 59.80562 |
| 0.15859 | 59.80562 |
| 0.18703 | 59.80562 |
| 0.21384 | 59.55197 |
| 0.22712 | 58.44101 |
| 0.23011 | 56.85815 |

Voltage ( V )
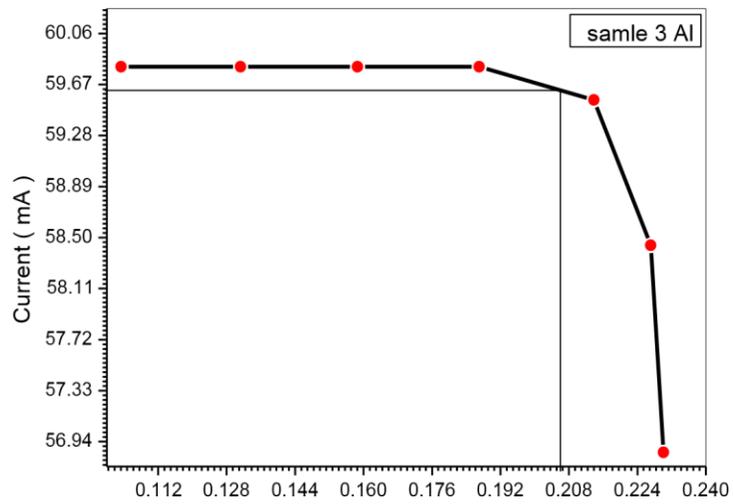


*Fig(8) several factors for characterization of sample 1(Al)*

*Table (2) I-V reaction for sample 1(Al)*

| V(V) | |
|------|------|
| 0.10334 | 59.80562 |
| 0.13125 | 59.80562 |
| 0.15859 | 59.80562 |
| 0.18703 | 59.80562 |
| 0.21384 | 59.55197 |
| 0.22712 | 58.44101 |
| 0.23011 | 56.85815 |
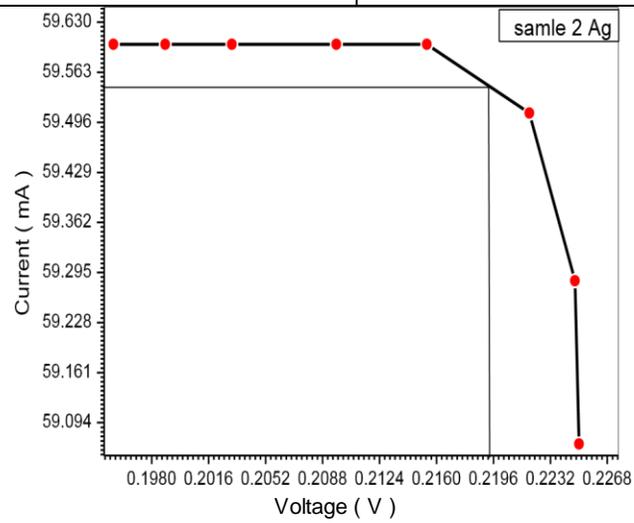


*Fig (9) several factors for characterization of sample 2(Ag)*

*Table (3) I-V reaction for sample 2(Ag)*

| V(V) | I(A) |
|------|------|
| 0.19558 | 59.60045 |
| 0.19886 | 59.60045 |
| 0.20307 | 59.60045 |
| 0.20967 | 59.60045 |
| 0.21539 | 59.60045 |
| 0.22188 | 59.50843 |
| 0.22476 | 59.28393 |
| 0.22501 | 59.06551 |

73
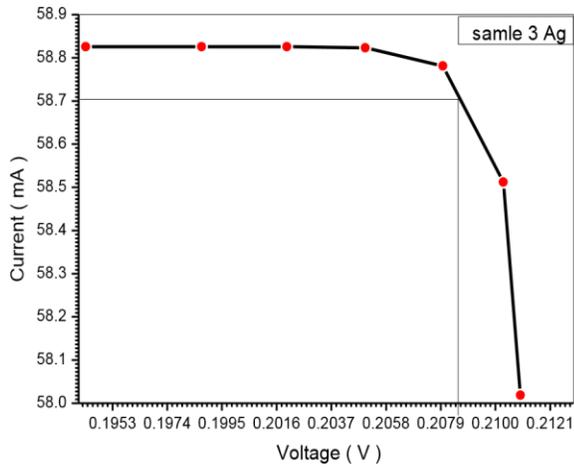
*Fig (10) several factors for characterization of sample 2 Ag*

*Table (4) I-V reaction for sample 2(Ag)*

| V(V) | I(A) |
|------|------|
| 0.19427 | 58.82567 |
| 0.19872 | 58.82567 |
| 0.20199 | 58.82567 |
| 0.20500 | 58.82315 |
| 0.20798 | 58.78118 |
| 0.21030 | 58.51219 |
| 0.21096 | 58.01871 |
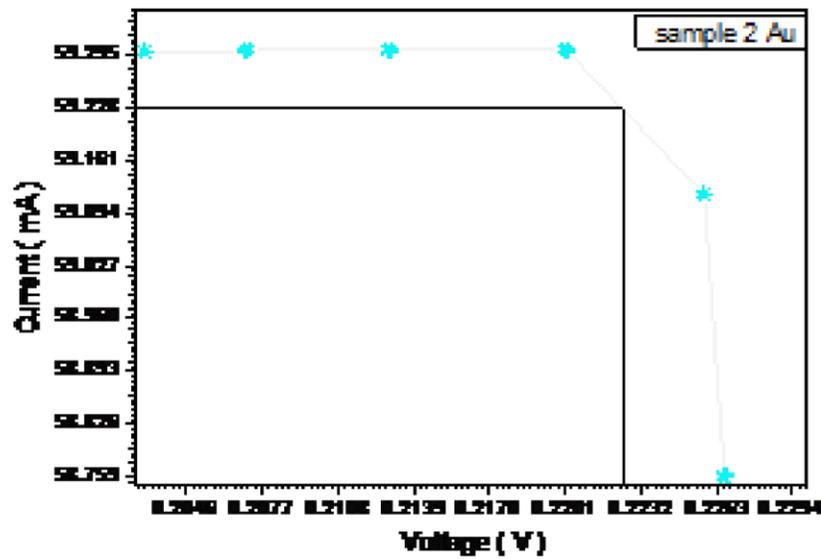


*Fig (11) several factors for characterization of sample 3(Au)*

*Table (5) I-V reaction for sample 3(Au)*

| V(V) | I(A) |
|---|---|
| 0.20289 | 59.29876 |
| 0.20704 | 59.30045 |
| 0.21289 | 59.30045 |
| 0.22012 | 59.30045 |
| 0.22577 | 59.11809 |
| 0.22662 | 58.76079 |
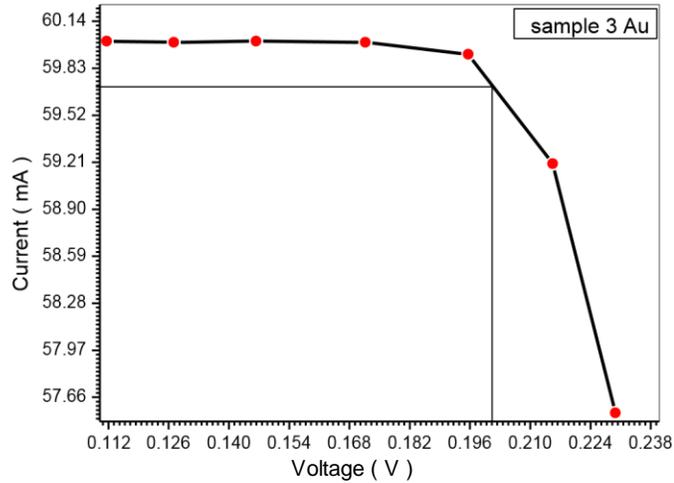


*Fig ( 12) several factors for characterization of sample 3(Au)*

*Table (6) I-V reaction for sample 3(Au)*

| V(V) | I(A) |
|---|---|
| 0.11158 | 60.00899 |
| 0.12717 | 60.00126 |
| 0.1463 | 60.00899 |
| 0.17168 | 60.00126 |
| 0.1956 | 59.92247 |
| 0.21522 | 59.20098 |
| 0.22978 | 57.55716 |

*Table (7)sample1 performance and Atomic number for electrodes*

| No of sample | Iscm A | I max mA | $V_{oc}$(V) | Vmax (V) | FF | Jscm $A/cm^2$ | Pmax | % $\eta$ | Atomic number |
|---|---|---|---|---|---|---|---|---|---|
| Sample (AL) | 59.69 | 59.41 | 0.2303 | 0.2130 | 0.9952 | 9.5517 | 13.685 | 1.66 | 13 |
| Sample (Ag) | 59.60 | 59.54 | 0.2250 | 0.2193 | 0.9738 | 9.5308 | 13.060 | 1.59 | 47 |
| Sample (Au) | 59.30 | 59.22 | 0.2266 | 0.2224 | 0.9816 | 9.4880 | 13.192 | 1.58 | 79 |

**Table (8)sample 2performance and Atomic number for electrodes**

| No of sample | Iscm A | I m ax mA | $V_{oc}(V)$ | Vmax (V) | FF | Jscm A/cm$^2$ | Pmax | % $\eta$ | **Atomic numbe** |
|---|---|---|---|---|---|---|---|---|---|
| Sample3(Ag) | 58.85 | 58.70 | 0.2109 | 0.2085 | .9858 | 9.4168 | 12.2395 | 1.48s | 13 |
| Sample3(AL) | 59.80 | 59.62 | 0.2301 | 0.2059 | .8921 | 9.5688 | 12.2395 | 1.49 | 47 |
| Sample3(Au) | 60.00 | 59.70 | 0.2300 | 0.2011 | .8698 | 9.6012 | 12.0080 | 1.46 | 79 |

## DISCUSSION

Fig (3) and to shows the optical energy gap (Eg) forEcrchromBlack T ,and Rohadamin $B$. The optical energy gap ($E_g$)hasbeencalculatedbythe relation $(\alpha h\upsilon)^2 = C(h\upsilon - E_g)$ where (C) is constant. By plotting $(\alpha h\upsilon)^2$ vs photon energy $(h\upsilon)$. And extrapolatingthestraightthinportionofthe curve to intercept the energy axis, of the energy gap has been obtaired. The value of ($E_g$) obtained was (EcrchromBlackT, and Rohadamin$B$.)

Fig s(6) to fig (12) were used to find ($I_{sc}$) , ($V_{oc}$) , ($I_{max}$) and ($V_{max}$) for all samples . parameters to were used calculate power conversion efficiency $\eta$ for the samples the dye sensitized solar cell(***EcrchromBlack, and RohadaminB***. ). These results for the samplesarerecordedin table (4) shows that increase of atomic number Z decreases effecting – this can be under stood it are take into account the fact that according to Hydrogen difference between energy levels in atom , which can represent the energy gap $E_g$ is proportional to Z , 109

$E_g = E$ ; Z thus increase of Z increases $E_g$ which decrease chances for electrons transfer from valence to conduction and which decrease in turn current and efficiency

## CONCLUSIONS

This work shows that the electrode type affect polymer solar cell performance. This performance dependontheatomicnumberoftheelectrode

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# Appendix (B)

## The Relationship Between Energy Gab & Efficiency in

## Dye Solar Cells

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**Abstract**—In this work dye sensitized solar cells made from: ***Ecrchrom Black T, DDTTC, Rohadamin B,and Coumarin 500,with Al and TTO electrodes*** were fabricated. The energy gab of these dyes were found using UV Spectrometer. The energy gap for**: *Ecrchrom Black T, DDTTC, Rohadamin B, and Coumarin 500*** ; were found 2.16 eV ,2.20 eV ,3.27 eV and 3,60 respectively .

The V- I characteristics for these cells and their performance were also found. The efficiency***: Ecrchrom Black T, DDTTC, Rohadamin B, Coumarin*** 500 were found 1.66,1.62, 1.49 and 1.31. It is realized that; the efficiency increased when energy gab decreased.

**Keywords—**Ecrchrom Black T, DDTTC, Rohadamin B, Coumarin 500, thin film, solar cells, photovoltaic property, optical property.

## INTRODUCTION

The direct conversion of light into electricity is done by solar cells. The usage of solar energy for heat has a long history but the origin of devices which produce electricity is much more recent. It is closely linked to modern solid-state electronics. Indeed, the first usable solar cell was invented at Bell Laboratories, the birthplace of the transistor in the early 1950's. The first solar cells found a ready application in supplying electrical power to satellites. Terrestrial systems soon followed, these were what we would now call remote industrial or professional applications, providing small amounts of power in inaccessible and remote locations, needing little or no maintenance or attention. Examples of such applications include signal or monitoring equipment, or telecommunication and corrosion protection systems. Since then, numerous photovoltaic systems have been installed to provide electricity to the large number of people on our planet that do not have (nor, in the foreseeable future, are likely to have) access to mains electricity [1, 2, 3, 4]. The most popular wide spreaded cell [5 ,6 ] .It is characterized by long life time , chemical stability and relatively a degut efficiency [7 ,8 ] .However silicon solar cell suffers from noticeable setbacks It is efficiency is still low , it cannot exceed 25% . The fabrication of silicon solar cells is very complex, The made these cells expensive [9] .These setbacks encourages researchers to search for new solar cell types that solves some of the afore noted defect [10 , 11 ] . Recently attention was played to polymer and dye sensitized solar cells. These cells were cheap and can be easily fabricated.

## MATERIALS AND METHODS

Four samples of (Ecrchrom Black T, DDTTC, Rohadamin B, Coumarin 500) solar cells were made by depositing the solution of Day sensitized on ITO Aluminum electrodes by Spin Coating technique and another layer was deposited from dye on a layer of (MEH-PPV ).Al was used on the layers to act as anode and ITO as Cathode. A clean glass plate with a thin layer of ITO (Indium Tin Oxide) was needed. The ITO acts as the first part of the solar cell, the first electrode. However a bit of the ITO has to be removed, to avoid short-circuiting. The fabrication process started by preparing the MEH-PPV and the dye of interest then spin coated it indium tin oxide glass. Aluminum electrode was used to complete the formation of organic dye sensitized solar cell. The formed cells were characterized by Ultra violet-visible spectroscopy. Electrical circuit containing the (voltmeter and Ammeter and a light source Lamp with the intensity radiological and a solar cell) were needed to study the performance. The solar cell was exposed to light and the current and voltages of the cell recorded UV spectrometer was need to display absorption spectrum.

## RESULTS & DISCUSSION

Engy gaps of : Ecrchrom Black T, DDTTC, Rohadamin B, and Coumarin 500 were found using UV spectrometer as shown in fig was (1), (2),(3) and (4)
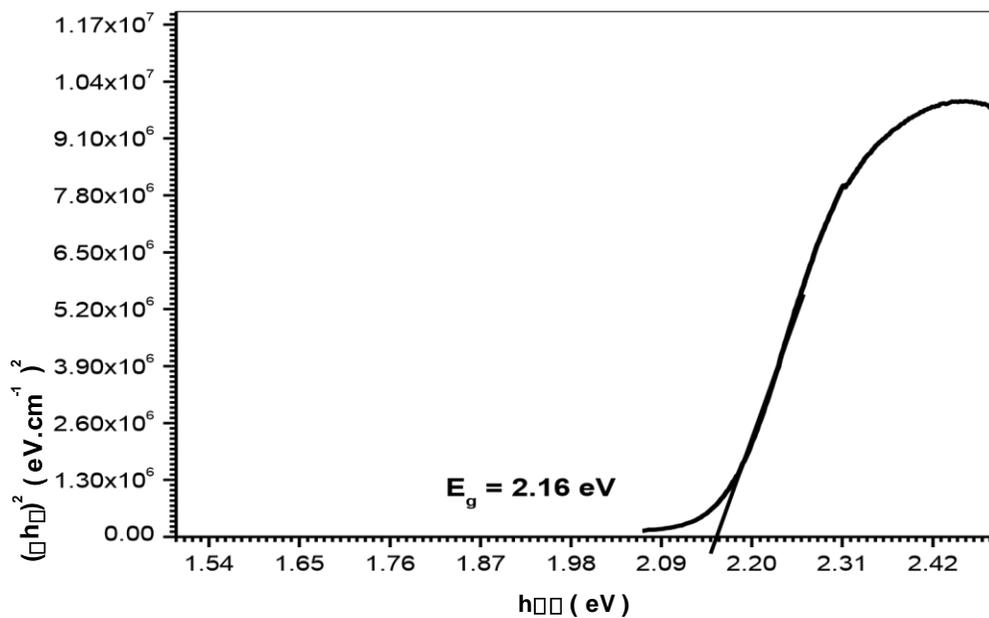


*Fig(1) The optical energy gap (Eg) value of Ecrchrom Black T*
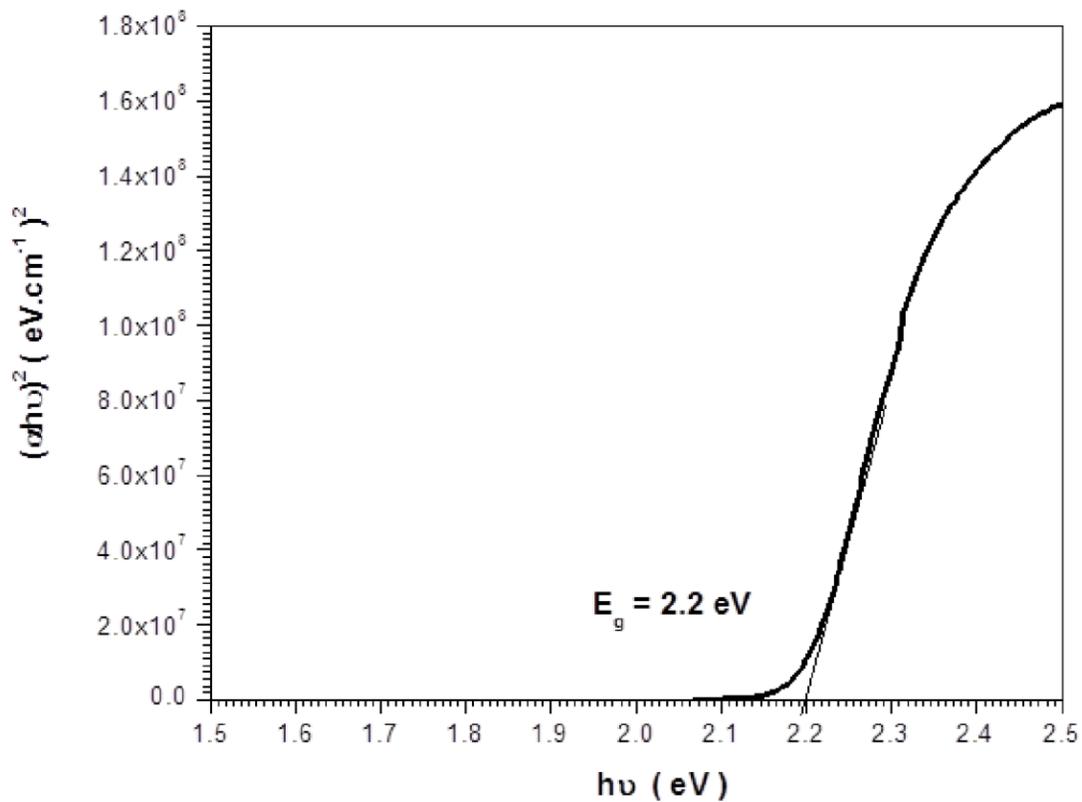
*Fig (2) the optical energy gap (E_g) value of DDTT*
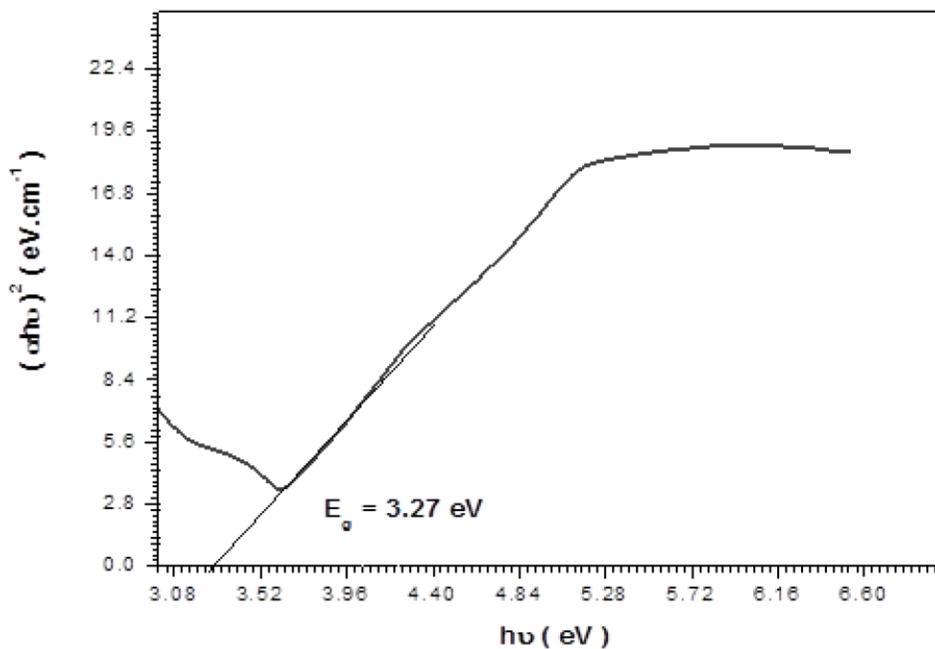


*Fig (3) the optical energy gap (E_g) value of Rohadamin B*

$E_g = 3.6$ eV

$(\square h \square)^2$ ( eV.cm$^{-1}$ )$^2$

h$\square$ ( eV )
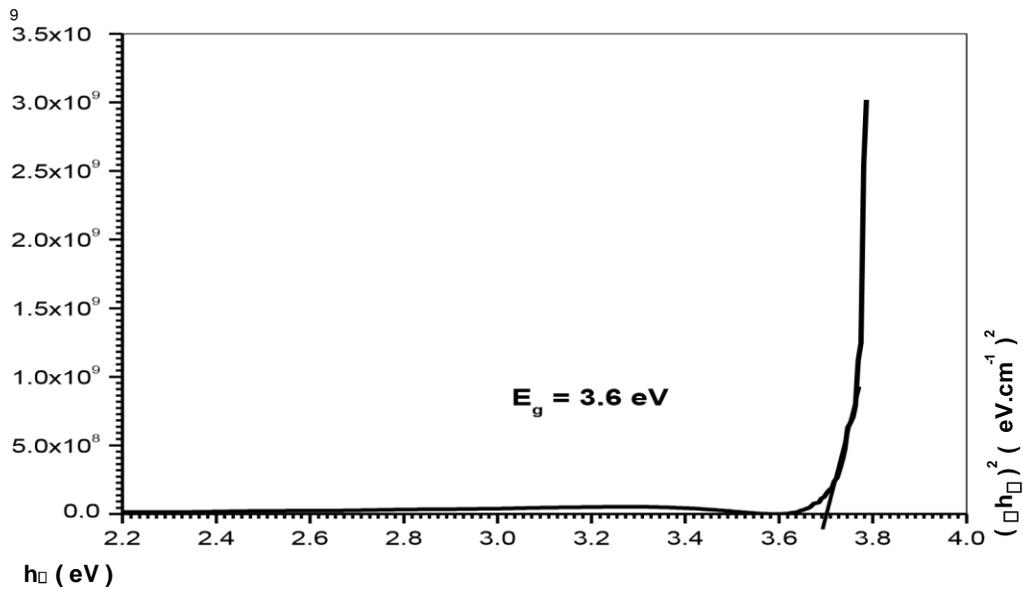
*Fig (4) the optical energy gap (E$_g$) value of Coumarin 500*

*The I-V readings for the samples fabricated are shown below*



sample 2 Al

Current ( mA )
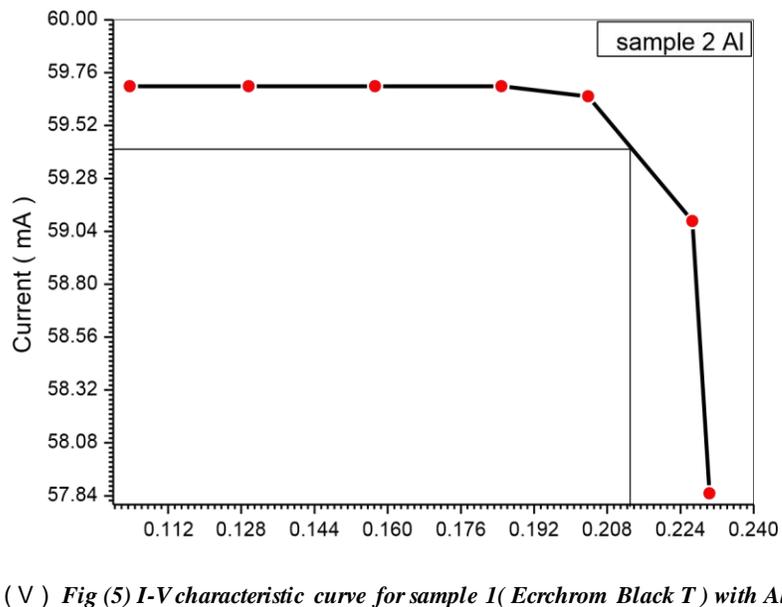
Voltage ( V )  *Fig (5) I-V characteristic curve for sample 1( Ecrchrom Black T ) with Al electrode*
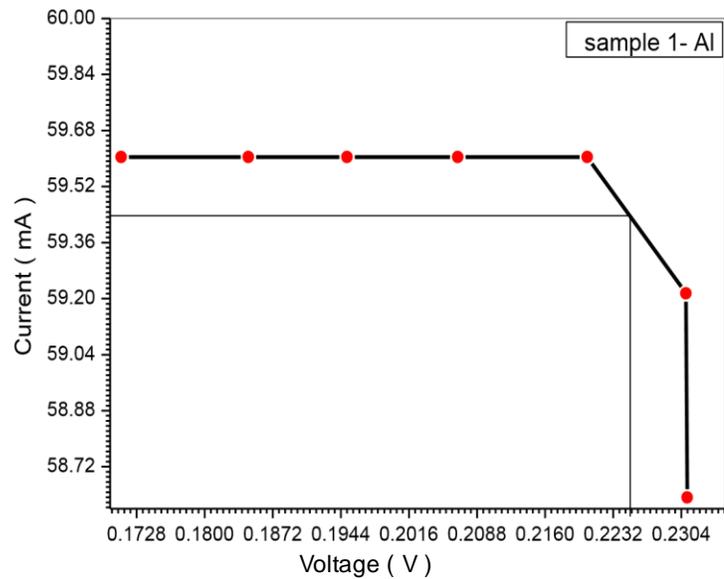
*Fig (6): I-V characteristic curve for sample 2 (DDTTC) with Al electrode*
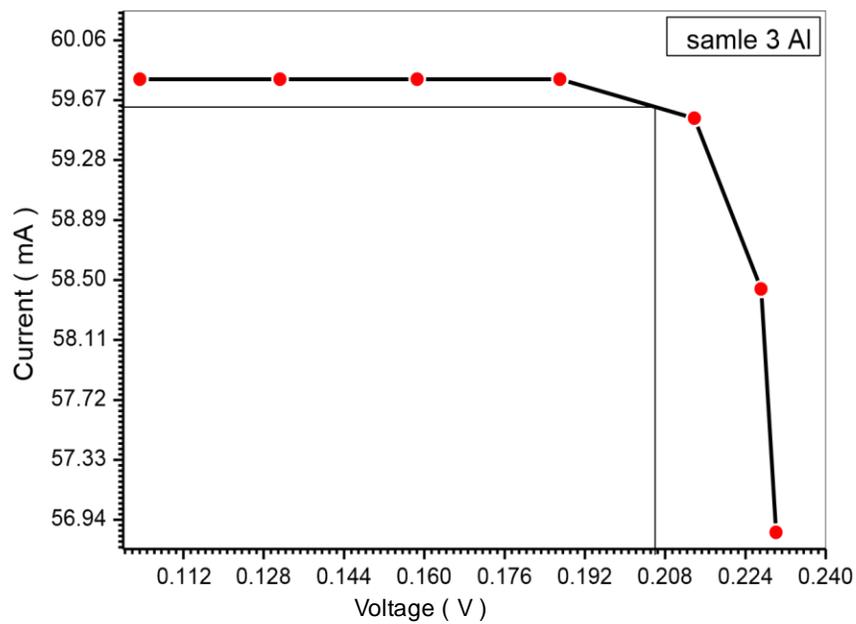


*Fig (7): I-V characteristic curve for sample 3(Rohadamin B ) with Al electrode*
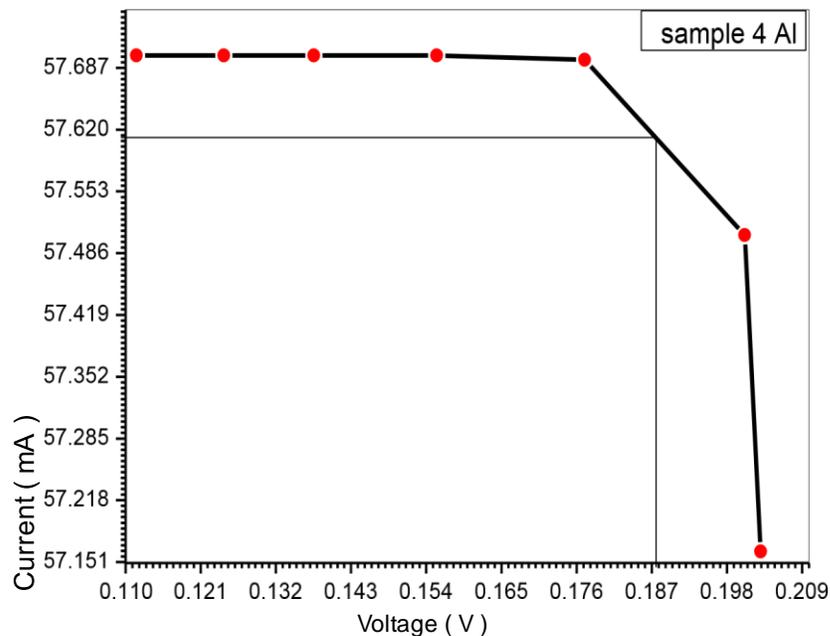
*Fig (8): I-V characteristic curve for sample 4( Coumarin 500) with Al electrode*

*I-V characteristics for samples:*

The following tables show Voltage (V) and current ( I ) relation for the four samples. all the samples have AL electrodes but were fabricated with the four dyes (Ecrchrom Black T, DDTTC, Rohadamin B, Coumarin 500)

*Table (1) I-V readings for sample1 (Ecrchrom Black T)*

| V/V | I/A |
|---|---|
| 0.10334 | 59.80562 |
| 0.13125 | 59.80562 |
| 0.15859 | 59.80562 |
| 0.18703 | 59.80562 |
| 0.21384 | 59.55197 |
| 0.22712 | 58.44101 |
| 0.23011 | 56.85815 |

*Table (2) I-V readings for sample 2(DDTTC)*

| V/V | I/A |
|---|---|
| 0.17117 | 59.60438 |
| 0.18462 | 59.60438 |
| 0.19505 | 59.60438 |
| 0.20677 | 59.60438 |
| 0.22046 | 59.60438 |
| 0.2309 | 59.21506 |
| 0.23103 | 58.63225 |

**Table (3) I-V readings for sample3( Rohadamin B)**

| V/V | I/A |
|-----|-----|
| 0.10334 | 59.80562 |
| 0.13125 | 59.80562 |
| 0.15859 | 59.80562 |
| 0.18703 | 59.80562 |
| 0.21384 | 59.55197 |
| 0.22712 | 58.44101 |
| 0.23011 | 56.85815 |

**Table (4) I-V readings for sample4(Coumarin 500)**

| V/V | I/A |
|-----|-----|
| 0.11159 | 57.70045 |
| 0.12438 | 57.70045 |
| 0.13755 | 57.70045 |
| 0.15553 | 57.70045 |
| 0.17718 | 57.69573 |
| 0.20059 | 57.50562 |
| 0.20293 | 57.16247 |

## DISCUSSION

Figs (1) to fig (4) show s the optical energy gap ($E_g$) for (Black T, DDTTC, Rohadamin B, Coumarin 500). The optical energy gap ($E_g$) has been calculated using the relation $(\alpha h\upsilon)^2 = C(h\upsilon - E_g)$ where (C) is constant. By plotting $(\alpha h\upsilon)^2$ Vs. photon energy ($h\upsilon$). And by extrapolating the straight portion of the curve to intercept the energy axis, the value of the energy gaps were found . The value of ($E_g$) obtained for Ecrchrom Black T, DDTTC, Rohadamin B, Coumarin 500 were found to be 2.16ev, 2.20ev, 3.27ev, 3.60ev respectively

Fig (5) to fig (8) is used to find ($I_{sc}$) , ($V_{oc}$) , ($I_{max}$) and ($V_{max}$) for all samples. The cells parameters were used to calculate power conversion efficiency η for the samples of the Day sensitized solar cells(Black T, DDTTC, Rohadamin B, Coumarin 500) . These results for the samples are recorded in table (5).

| No of sample | $I_{sc}$ (mA) | Imax (mA) | $V_{oc}$ (V) | V max (V) | FF | Jscm A/cm $^2$ | Pmax | η% | Energy gap eV |
|---|---|---|---|---|---|---|---|---|---|
| Sample1(AL) | 59.69 | 59.41 | 0.2303 | 0.2130 | 0.9952 | 9.5517 | 13.685 | 1.66 | 2.16 |
| Sample2(AL) | 59.60 | 59.44 | 0.2310 | 0.2250 | 0.9714 | 9.536 | 13.374 | 1.62 | 2.20 |
| Sample3(AL) | 59.80 | 59.62 | 0.2301 | 0.2059 | .8921 | 9.5688 | 12.2395 | 1.49 | 3.27 |
| Sample4(AL) | 57.70 | 57.61 | 0.2029 | 0.1876 | .9231 | 9.2323 | 10.809 | 1.31 | 3.60 |

**Table (5) performance of solar cells samples**

It is very interesting to note that table5 indicates that the decrease of energy gap and the increases of the solar cell efficiency in general.

This is since the energy gap decrease enables electrons having lower excitation energy to became free electron in a conduction band thus increasing the electric solar current .

## CONCLUSIONS

This work shows that the energy gap of the dyes used in dye sensitized solar cell affect the performance and efficiency of the solar cell.

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