Sudan University of Science and Technology

College of Graduate Studies

Efficiency of Solar Cell Made By Using Doped Gum Arabic Copper Oxide Nanostructured Thin Film

كفاءة الخلية الشمسية المصنعة من الصمغ العربى المطعم بشريحة أكسيد النحاس النانوية

Proposal for the fulfillment of Ph.D. in physics

By

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الآيــــــــة

قَالَ تَعَالَىٰ:

﴿وَيَسۡـَٔلُونَكَ عَنِ ٱلرُّوحِۖ قُلِ ٱلرُّوحُ مِنۡ أَمۡرِ رَبِّي وَمَآ أُوتِيتُم مِّنَ ٱلۡعِلۡمِ إِلَّا
قَلِيلٗا ٨٥﴾

الإسراء: ٨٥

Dedication

I dedicate to all those who contributed in education

Dedicate to my mother & my father

To my brothers and sister &

My teacher &

My colleagues

To all of you dedicate this modest effort

Researcher

Acknowledgements

Thank God first and foremost

Thank everyone who helped me in my career complete educational and completion of this research, and I especially thank my mother and

My father

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And thanks to my supervisor, Prof. Mubarak Dirar Abdallah yagub And thanks, Mr.Co- Supervisor:

D. Rawia Abdelgani Elobaid Mohammed

God bless all of us

Abstract

Gum Arabic doped with CuO based Dye Sensitized Solar Cells (DSSC) with five type of dye (Coumarin 500, Ecrchrom Black, Rhodamin B, DDTTCI and Nile blue) were fabricated on ITO glass and silver.5 additional samples were prepared also by exchanging gum and dye layers. Microstructure and cell performance of the solar cells with (ITO/Gum Arabic+CuO/dye/ITO+ graphite and Iodine) structures were investigated. Photovoltaic devices based on the Gum Arabic/dye hetrojunction structures provided photovoltaic properties under illumination. Absorption and energy gap measurement of the (Coumarin 500, Ecrchrom Black Rhodamin B, DDTTCI and Nile blue), were studied by using UV-VS mini 1240 spectrophotometer and light current-voltage characteristics. The five (ITO/Gum Arabic/dye/ITO+ graphite) solar cells were produced and characterized, which provided efficiency (η) and Energy gap are 4.92 % for Eg = 1.436 eV, 1.9 % for Eg = eV, 2.01, 0.44 % for Eg = 2.641 eV and 0.37 % for Eg = 4.197 it is very interesting to note that the efficiency increasy as the energy gap decreases, which agrees with and previous studies. However for Ecrchrom Black the efficiency is high for transparency. When the gum layer is replaced by dye layer the efficiencies for the samples gum/ Coumarin 500, gum/ DDTTCI, gum/Ecrchrom Black, gum/Rhodamin B, and gum/ Nile blue are 0.38, 5,15, 0.44, 1.9 and 3.29 respectively. This shows that in most cases the efficiency of the solar cells in which gum layer is above the dye is higher this may be attributed to the fact that the gum is more transparent than these dyes except Ecrchrom Black dye. For Ecrchrom Black the results are different. It was observed that its efficiency (0.44) is more than that of coumarin 500 (0.37) although its energy gap is (4.197 eV) is more than that of coumarin 500 (2.641 eV) this may be attributed to the fact that Ecrchrom Black, is more transparent than coumarin 500. Fortunate when gum is replaced by Ecrchrom Black to make Ecrchrom Black above gum the efficiency increase which means that Ecrchrom Black in more transparent than gum. This allows more photons is incident on gum layers this liberate more photons.

المستخلص

تم تصنيع 5 عينات من الصمغ المشوب بأكسيد النحاس المضاف إليه 5 صبغات هى (Coumarin 500, Ecrchrom Black Rhodamin B, DDTTCI and Nile blue) بترسيبها علي زجاج (ITO) مع الفضة تمت إضافة 5 عينات أخرى بإستبدال طبقة الصمغ بطبقة الصبغ. وتمت مناقشة التركيب الدقيق وآداء الخلايا(ITO/GumArabic+cuo/dye/ITO+graphite+iodine).هذه الخلايا الفوتوفولطائية لها خصائص إلكترونية عند تعرضها للضوء بإعتبارها متعددة الطبقات. تمت دراسة فجوة الطاقة للصبغات

(Coumarin 500, Ecrchrom Black Rhodamin B, DDTTCI and Nile blue)

بإستخدام جهاز UV –VS الطيفي بالرقم 1240 بالإضافة للخواص التيارية والجهدية(I–V). تمت صناعة الخلايا (ITO/gum Arabic/dye/ITO+graphity) وتحديد خصائصها، وتبين أن الكفاءات = η وفجوات الطاقة Eg هي (4.92 و 1.436 و 1.9 و 2.01 إ.ف). وإتضح أن الكفاءة تزيد بنقصان فجوة الطاقة مايتسق ذلك مع النظريات والدراسات السابقة. إلا أن كفاءة Ecrchrom أعلي بسبب النفاذية. وعند إستبدال طبقة الصمغ بطبقة الصبغ أصبحت كفاءات الخلايا و DDTTc /Gum و Gum/ Ecrchrom و Gum/ Rhodamin و Gum/ Nile هي(0.38 و 5.15 و 0.44 و 1.9 و 3.29%). ويبين هذا أن كفاءة الخلايا التي فيها طبقة الصمغ فوق طبقة الصبغ أعلي في معظم الاحيان. وهذا مرده يكون الصمغ شفاف اكثر من الصبغات فيما عدا صبغة Ecrchrom. بالنسبة ل Ecrchrom تكون النتيجة مختلفة. حيث لوحظ أن الكفاءة هي (0.44 إ.ف) وهي أعلي من كفاءة ال Coumarin (0.37 %) رغم أن فجوة طاقة Ecrchrom (4.197 إ.ف) أكبر من فجوة طاقة ال Coumarin (2.641 إ.ف) ويعزي هذا لأن صبغة ال Ecrchrom شفافة

أكثر من ال Coumarin. ولوحظ أن جعل الصمغ أسفل ال Ecrchrom يزيد من الكفاءة ممايعني أن ال Ecrchrom شفاف أكثر من الصمغ وهذا يؤدى لنفاذ فوتونات أكثر علي طبقة الصمغ لتحرير إلكترونات أكثر.

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Chapter One

Introduction

1.1 Solar energy

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].

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 [2].

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 [3].

1.2The 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 besides reducing the cost of producing of electricity and makes it available to remote places.

1.3 The Research Problem

The research problem is related to the non-availability of electricity in Remote areas it is also related to the low efficiency and high cost of silicon solar cells.

1.4 Aim of the Work

The aim of the work is to fabricate low cost high efficiency simple solar cell.

1.5Previous Studies

- Studying the properties of four Natural Dye -Sensitized Solar Cells Based on Solid State Electrolyte
- Ahmed Mohammed Hamid Mohammed1 and Mubarak Dirar Abdalla2

Abstract

The study aims at finding the properties of natural dye sensitized solar cells. Dye sensitized solar cells have been fabricated from four natural dyes. These dyes are Pomegranate, Mango, Cream and Orange. The cells were assembled using TiO_2 as semiconductor and Polyvinylpyrrolidone) PVP (polymer as solid electrolyte. The highest efficiency was obtained for the DSSC sensitized of Cream with efficiency 0.5904%. The absorption spectra of these dyes have been investigated by UV-VIS spectrophotometer. The parameters of these four fabricated cells such as short circuit current density(Jsc), open circuit voltage (Voc), fill factor (FF) and conversion efficiency(η) were calculated under 1000 W/m2 illumination.

Global journal of engineering science and researches the influence of transition metals on the solar cell efficiency.

Inaam Adam*1|, Mubarak Dirar2 Abdallah, Abdelrahman A.Elbadawi3 & Sawsan Ahmed Elhouri Ahmed.

Abstract

In this work the Nano solar cell were successfully designed by using a conducting polymer MEH-PPV as a positive Electrode and transition metals Al, Ag and Au as a negative electrode, the different dyes were concerned as a Sensitizer. The efficiency of the Nano solar cell was studied using the current – voltage characteristic. The results.

Show a good improvement in the efficiency which increasing from Al to Au gradually and this may due to the Atomic size and Fermi energy for that elements.

- Global journal of engineering science and researches the effect of optical energy gab=ps on the efficiency of zinc oxide solar cells doped by (Al, Cd, Co, Li and Mg)

  Shadia Tageldeen*1, Mubarak Dirar Abd Allah2, Abdalsakhi S. M.H3 & Sawsan Ahmed Elhouri.

  Abstract

  In this study, we investigated the effect of optical energy gaps on the efficiency of Zinc Oxide solar cells doped by

  (Al, Cd, Co, Li and Mg). The samples were prepared by chemical treatment using ITO glass at 70oC. The photo

  Conversion efficiency (η) values of the samples were (0.168 %, 0.191 %, 0.204 %, 0.205 % and 0.297 %)

  Respectively. While the energy gaps values were (3.699, 3.687, 3.685, 3.644 and 3.505) eV, both at 0.55 mW/cm2

  Light intensity and dark.

  - The Change of Zinc Oxide and Nile Blue Dye Solar Cells Efficiencies and Energy Gaps Due to the change of the Solvents P 1 PAsia .Gamareldawla eltayeb - P 2 PMubarak Dirar Abd-alla - P 3 PAbdalsakhi .S .M.H P 4 P Mohammed Idriss. Ahmed

    Abstract

    The effect of different solvents on Zinc Oxide based Dye Sensitized Solar Cells (DSSC) with Nile blue were studied. The performance of solar cells with (FTO/ ZnO/ Blue Nile dye /FTO+ graphite and Iodine) structures were investigated. Under the effect of different solvents, which and (Methanol, Ethanol, Acton m Chloroform and Benzene). Absorption and energy gap were found by using UV-VS mini 1240 spectrophotometer and light cu rrent-voltage characteristics and XRD. The five (FTO/ ZnO/ Blue Nile dye /FTO+ graphite) solar cells were produced and characterized. Their which provided efficiency (η) (0.40165,0.3968 ,0.3858 ,0.3719 and 0.3477).which decrease when the absorbance decreases taking values(Methanol = (2.005 a.u) ,Ethanol = (1.4819 a.u) ,Acton = (1.221 a.u) , Chloroform = (0.983 a.u) and Benzene = (0.532 a.u)) and the decrease of efficiency due to absorbance decrease may be attributed to the decrease of atoms number. Density which decreases with the name crystal size.

1.6 Thesis Layout

This the research contains four chapters Where In Chapter one is the introduction for solar cells and Literature Review, Chapter two is Theoretical Background, Chapter three is Material and Methods, Chapter four is Results and Discussion.

Chapter Two

Theoretical Background

2.1 Introduction

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 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 photon [7].

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 [8].

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 [9].

2.2 Solar Cells Properties

Solar cells 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 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 change 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 (showers, swimming pools, etc.).

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 [10].

2.3 Solar Cells (PV) Panels

The solar cells convert 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 are 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 [11].

2.4 Advantages of Solar Cells

Solar Cells has many features that make it a wonderful technology to use to solve many electrical needs. Although, like any technology, it has its drawbacks as well, some of the main advantages of solar cells all’s:

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 [12].

2.4.2 Low Operating Costs

Solar cells use the energy from sunlight to produce electricity the fuel is free. With no moving parts, the cells require little upkeep. This 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.

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).

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.

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 [13].

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.

2.5 disadvantages of Solar Cells

Here we will take in detail about the equality of the photovoltaic cells.

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.

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, winter for areas near the South 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 [14].

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.

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.

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 [15].

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, SiO_2) 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.

2.8.1Single 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)

Figure (2.1) Single crystal silicon (the Siemens modules on your roof are single Crystal silicon).

2.8.2 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.

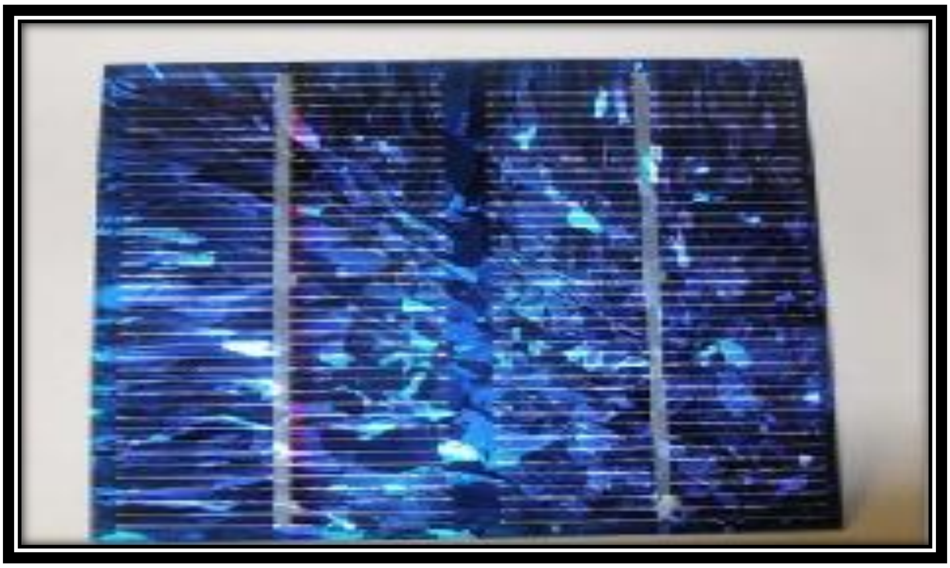

Figure (2.2) Polycrystalline Silicon solar cell

2.8.3 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 [16].

Figure (2.3) Amorphous Silicon solar cells

2.9 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.

2.9.1 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.

2.9.2 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.

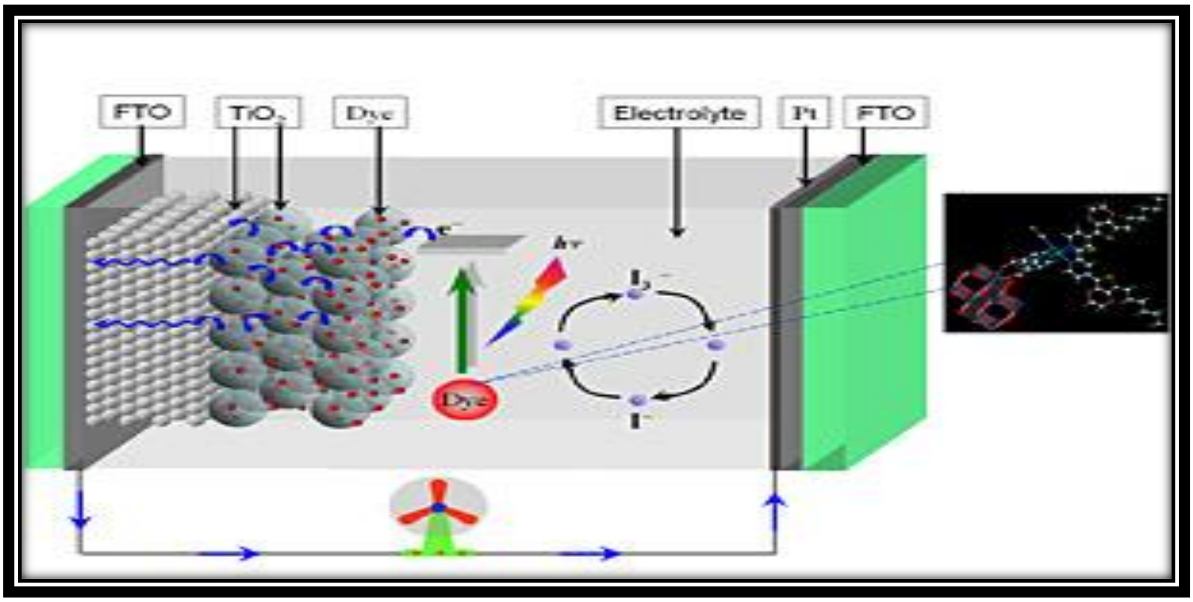

Figure (2.4) Dye sensitized solar cell diagram

Transparent conducting oxides (TCO) for both the conducting electrode and counter electrode TCO coated glass is used as substrate for the TiO_2 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 TiO_2 electrode is carried out at 450º C. 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.

TiO_2photo–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 TiO_2, have good chemical stability under visible irradiation in solution; additionally, they are nontoxic and inexpensive. The TiO_2 thin-film photo–electrode is prepared by a very simple process. TiO_2 colloidal solution (or paste) is coated on a TCO substrate and then sintered at 450 to 500°C, producing a TiO_2 film. The dye molecules (sensitizer) Dye molecules of proper molecules structure are used to sensitized wide band gab nanostructure photo electrode [17].

2.9.3 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.

2.9.3.1 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 TiO_2 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 TiO_2. A redox couple (I-/I3-) in an electrolyte.

Solution covering the whole TiO_2 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 asN_3 dyes), where L is a π-conjugated ligand with TiO_2

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 [18].
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 [19].

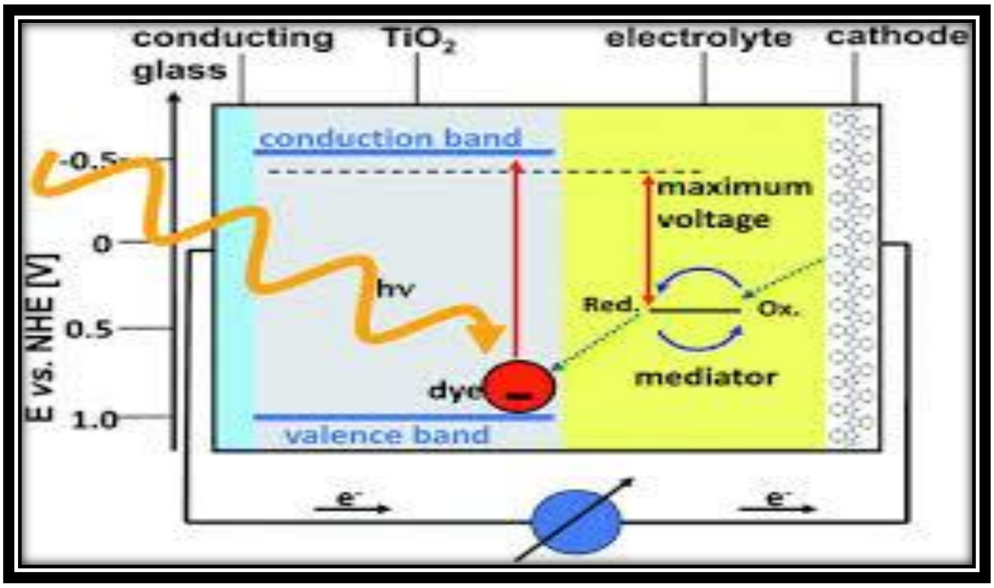

Figure (2.5) Schematic scheme of the traditional dye-Sensitized solar cell

2.9.3.2 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 [36]. 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 Figure (2.6) 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%.

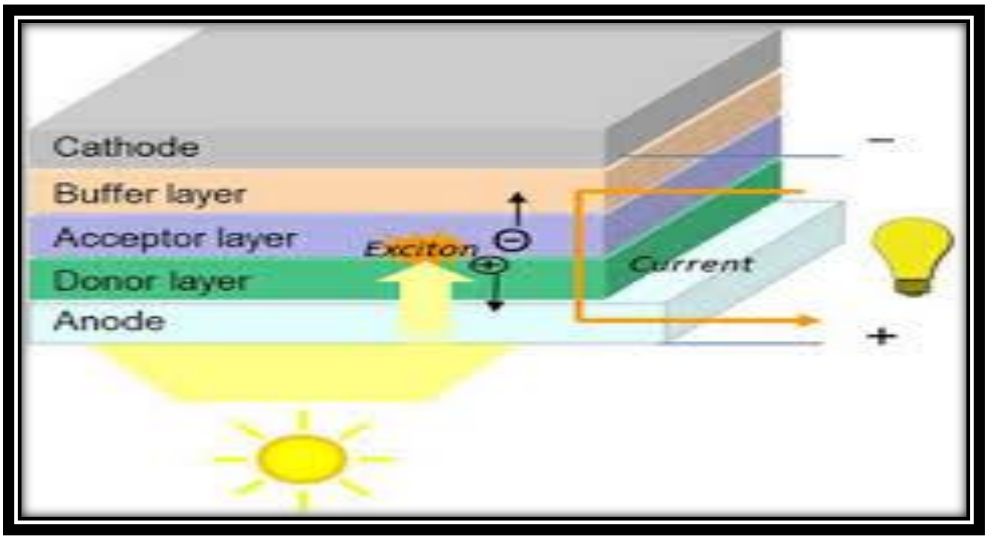

Figure (2.6) Polymer solar cells

2.9.3.3 Work of Polymer Solar Cells

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.

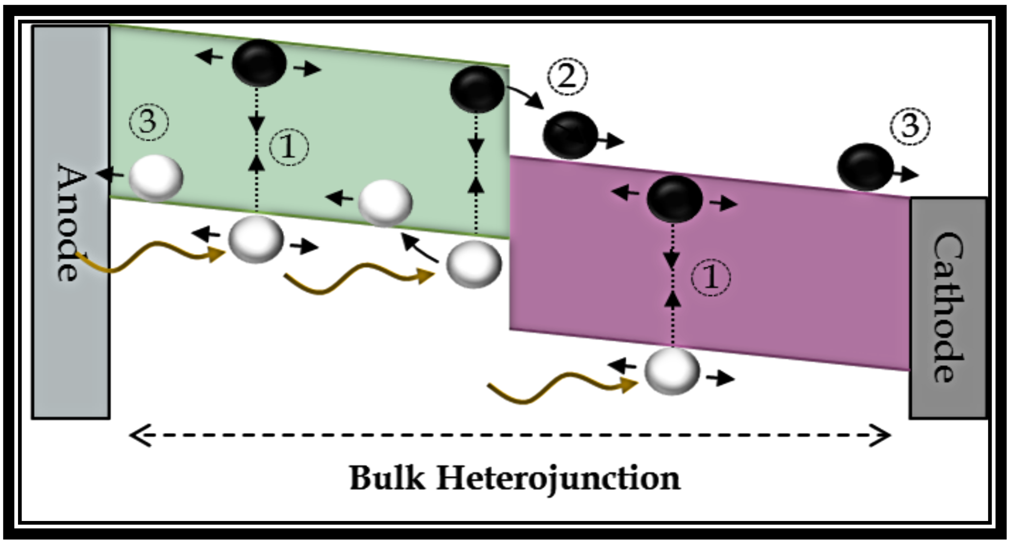

Figure (2.7) the working principle

The working principle of the solar cell, Light enters the cell through the transparent anode, and is absorbed in the bulk hetero junction layer through generation of excitons (1). The excitons diffuse in the bulk hetero junction 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) [20].

2.9.3.4 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 [21].

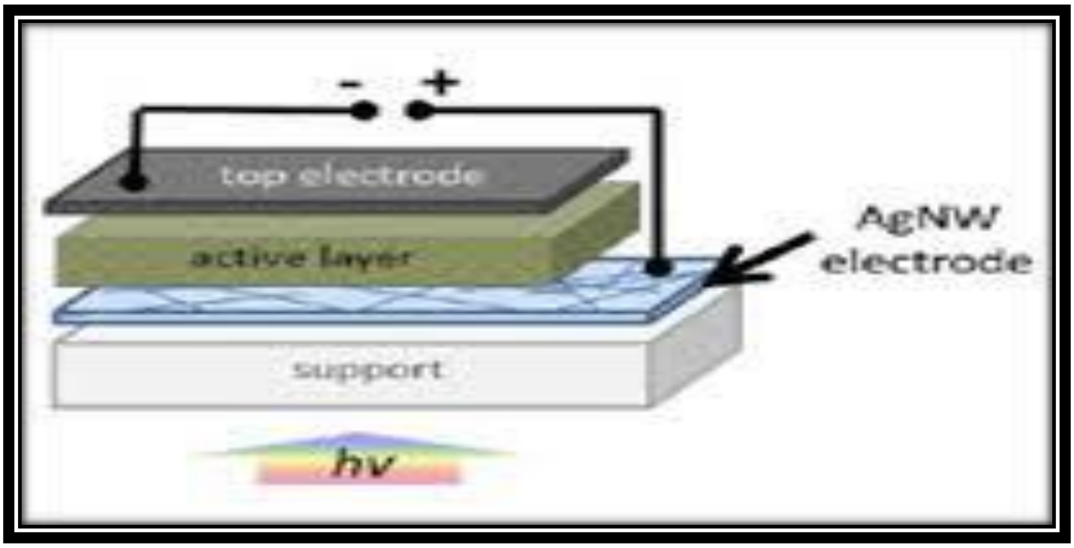

Figure (2.8) Consist of Polymer Solar Cell

2.10. 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.

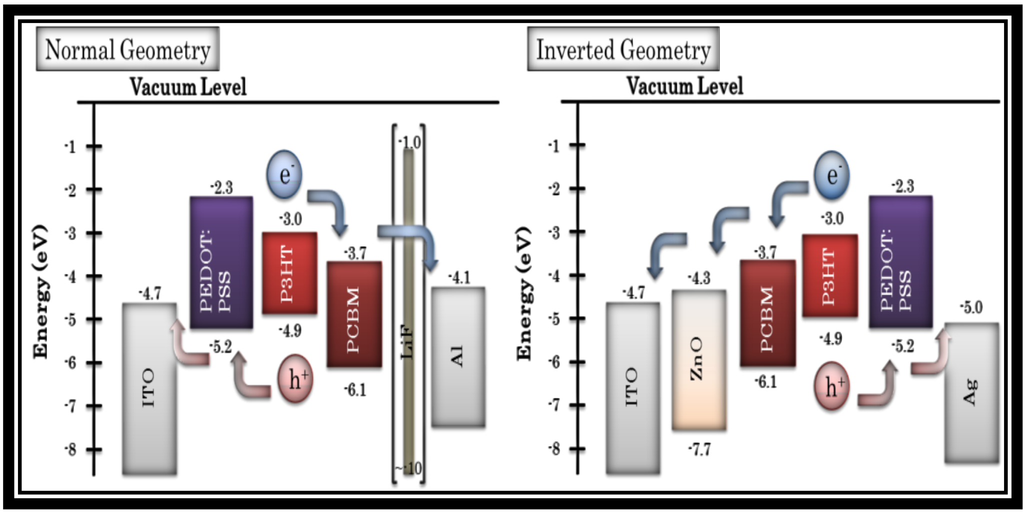

Figure (2.9) Energy levels for normal and inverted geometry solar cells

2.10.1 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 [21].

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[22].

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[23].

Chapter Three

Materials and Methods

3.1 Introduction

This chapter contains the materials used to build the solar cell, including ITO (Indium Tin Oxide) , gum Arabic, copper oxide, silver and dyes(Rhodamine B , Coumarin 500 , DDTTCI , Ecr - chrome Black T , Nile blue).

3.2 The Materials of a Gum Arabic Solar Cell

Gum Arabic (GA) is most important commercial polysaccharide and it is probably the oldest food hydro-colloid in current use. GA is naturally obtained from Acacia Senegal and seyal trees, which are known to grow in the sub-Sahara region of the Sudan.[1,2] GA is the dried, gummy exudation obtained from various species of Acacia trees of the Leguminosae family. About 500 species of Acacia are distributed over tropical areas of Africa, India, Australia, Central America and south west North America. The composition of GA is dependent to some extend on the location and age of the tree.[3,4[Even though there are over 1,100 Acacia species worldwide, A. Senegal and A. shall remain the most commercially exploited species.[5] GA is high molecular weight polymeric compounds, composed mainly of carbon core mixed in heterogeneous manner, including some materials in tonic forms as salts of macromolecules.[6-8] There are many studies carried out using GA, but most of them were focused on food, hydrocolloid and adhesive material. In this study, we will examine the structure and physical properties such as electrical and optical properties for two types of GA [24].

3.3 ITO

ITO (Indium Tin Oxide) is a transparent conductive material. It is a mixture of indium oxide (In_2O_3) and tin oxide (SnO_2). 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 [50].

3.4 Rhodamine B

Constitution 2-[6-(Diethyl amino)-3-(diethylimino)-3H-xanthen-9-yl] benzoic acid Rhodamine 610 - C28H31N2O_3Cl · MW: 479.02 Characteristics Lambda chrome® number: 6100 CAS registry number: 81-88-9 Appearance: 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.

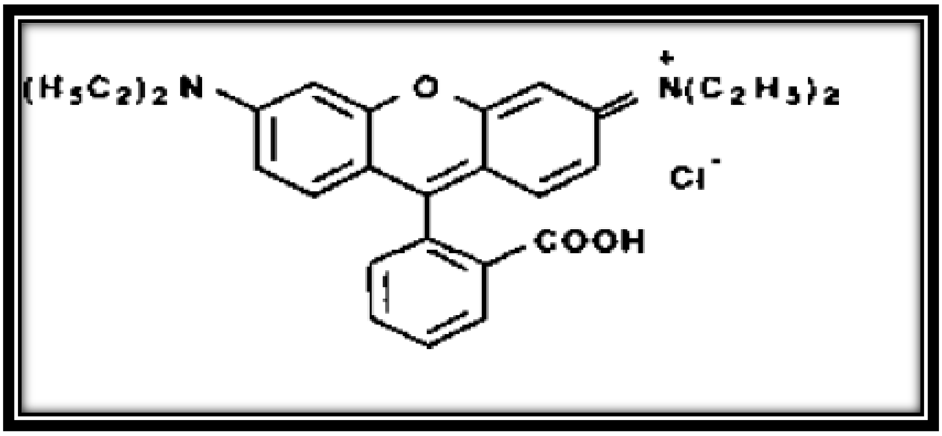

Figure (3.1) Rhodamine B

3.5 Coumarin 500

Constitution $C_{12}H_{10}NO_2F_3$ · MW: 257.21 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 [25].

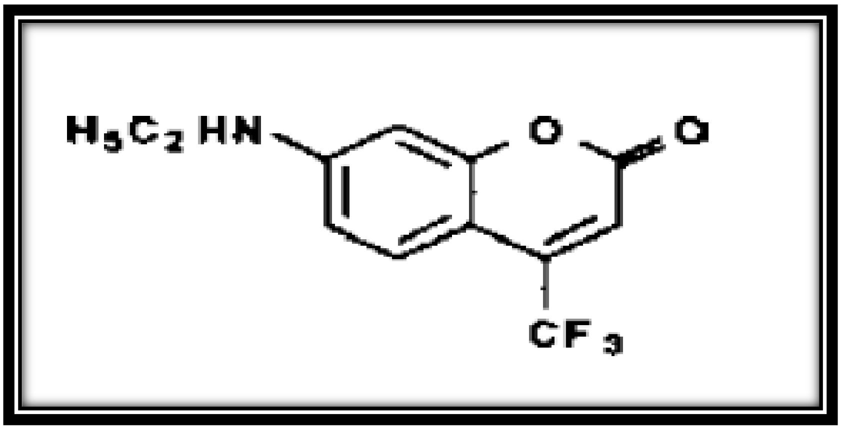

Figure (3.2) Coumarin 500 Characteristics

3.6 DDTTCI

Constitution3, 3'-Diethyl-4, 4', 5, and 5'-dibenzothiatricarbocyanine Iodide Hexadibenzocyaini 45C33H29N2S2I · MW: 644.43.Characteristics Lambda chrome® number: 9280CAS registry number Appearance: bronze colored, crystalline solid Absorption maximum (in ethanol): 798 nm Molar absorptivity: 19.6 x 10^4 L mol^{-1} cm^{-1}Fluorescence maximum: - For research and development purposes only.

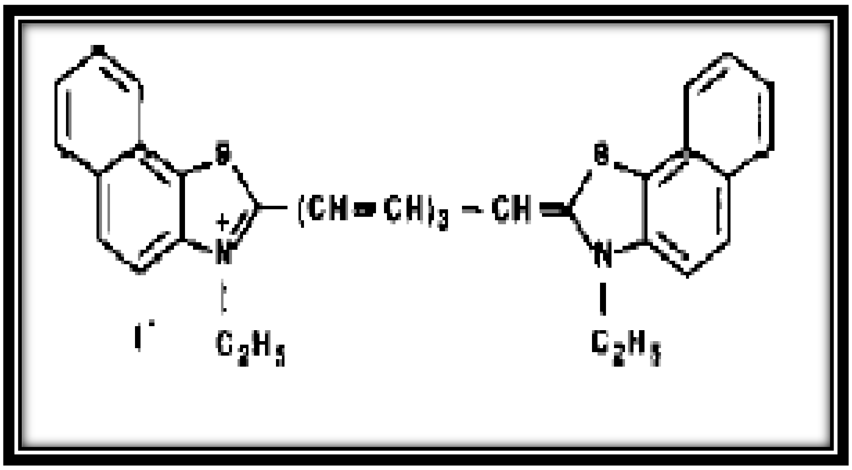

Figure (3.3) DDTTCI

3.7 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 complex metric indicator that is part of the complex metric titrations, e.g. in the water hardness determination process. It is an azo dye. Eriochromeis a trademark of Ciba-Geigy, in its protonated form, riochromeis Black T is blue. It turns red when it forms a complex with calcium, magnesium, or other metal ions [26].

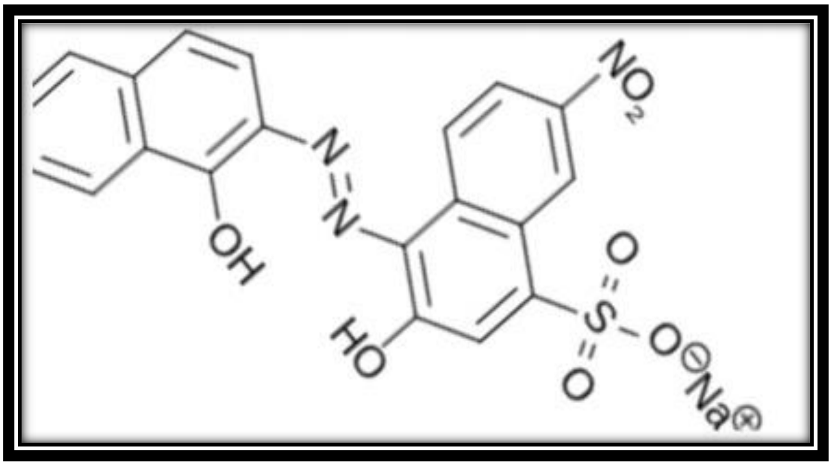

Figure (3.4) Ecr - chrome Black T structure

3.8 Nile blue

Constitution 5-Amino-9-diethyliminobenzo[a]phenoxazonium erchlorate $C_{20}H_{20}N_3O_5Cl$ · MW: 417.85 Characteristics ambdachrome® number: 6900 CAS registry number: 53340-16-2 Appearance: green, crystalline solid Absorption maximum (ethanol): 633 nm Molar absorptivity: 7.75×10^4 L mol^{-1} cm^{-1} Fluorescence maximum (in bas. ethanol): 672 nm [27].

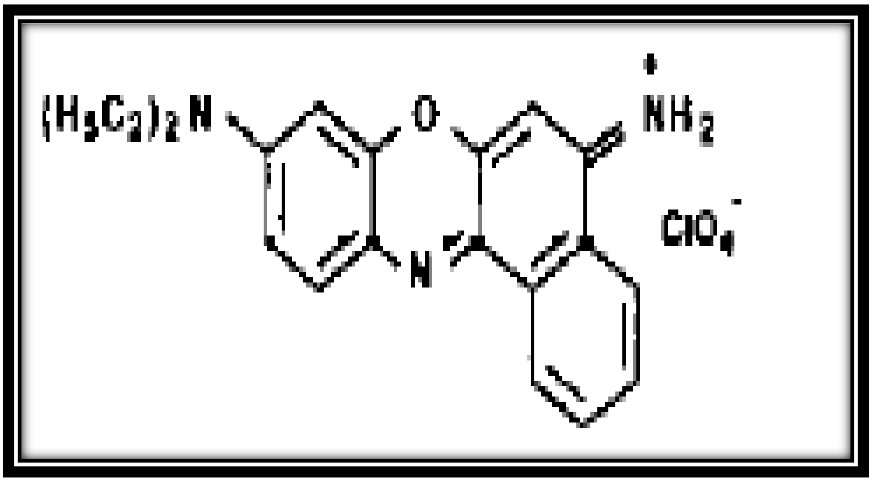

Figure (3.5) Nile blue structure

3.9 Methods

10 samples of Gum Arabic solar cells were made by depositing the solution of Day (Ecrchrom Black T, DDTTCI, Rhodamine B, Coumarin 500 and Blue Nile) on ITO and silver (Ag) by Spin Coating technic. Al was fabricated on the layers to silver (Ag) 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 Gum Arabic and the dye of interest then spin coated it indium tin oxide glass. Silver (Ag) electrode was used to complete the formation of Gum Arabic 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 performance. The solar cell was exposed to light and the current and voltages of the cell recorded were UV spectrometer was needed to display absorption spectrum. 10 samples were prepared.

The Gum Arabic solar cell was made on ITO glass. The ITO glasses were firstly cleaned by ethanol and distilled water. 10mg of Gum Arabic was dissolved into 0.5ml of chloroform and 3mg of dyes (Ecrchrom Black T, DDTTCI, Rhodamine B, Coumarin 500 and Blue Nile) dissolved into 0.5 of high pure chloroform was deposited on Gum Arabic .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 [28].

3.10 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 and then creates electron-hole pairs. These are separated by the intrinsic electric field in the barrier layer and can migrate in the reverse direction. Electrons migrate into the n-doped region, and the holes migrate into the p-doped region.

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

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

$$I = Isc(\Phi) - I_D(V) \qquad (3.1)$$

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

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

$$R_i = V_{oc}/I_{sc} \qquad (3.2)$$

The maximum power:

$$P_{max} = I_{max}.V_{max} \qquad (3.3)$$

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

$$FF = P_{max}/V_{oc}I_{sc} \quad (3.4)$$

FF is often called fill factor.

The efficiency η is given by:

$$\eta = I_{sc} \times FF \times V_{oc}/I_n \quad (3.5)$$

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 [29].

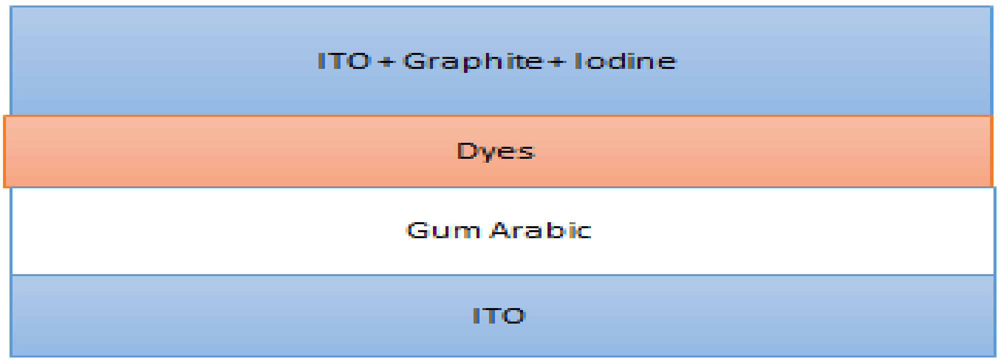

Fig (3.6) schematic structure of polymer solar cell formed with a single organic layer of MEH-PPV

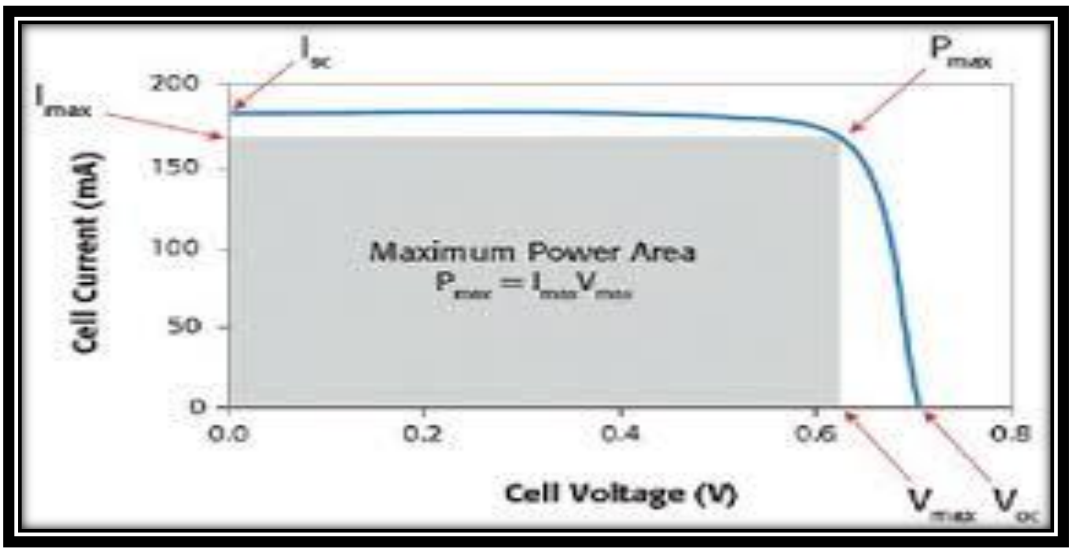

Fig (3.7) Current-voltage characteristic of a solar cell

Chapter Four

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. 2 Apparatus

10 type of Gum Arabic solar cell (2.5×2.5) cm^2 with different types of dyes , 1 plug-in board A4 576 764,1 set of ten bridging plugs 50148,1 pair of board holders 576771, 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 Gum Arabic solar cell by using ten samples with different types of dyes. The spin coating see Fig (4.7) 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 Gum Arabic 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 silver 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 has 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 (4.10).

Figure (4.1) spins coating

Figure (4.2) UV spectrometer device

4.3 Steps:

- The 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 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 $\times 10^{-11}$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.

4.4 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 [30].

4.5 Results

4.5.1 Introduction

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 I-V characterize to study the solar cell performance.

4.5.2 Results Samples of (Coumarin 500)

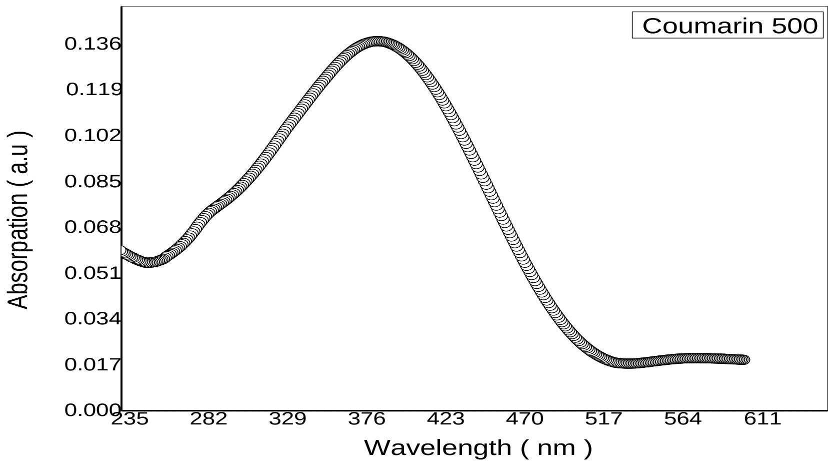

Figure (4.3) the relation between absorbance and wavelength of Coumarin 500

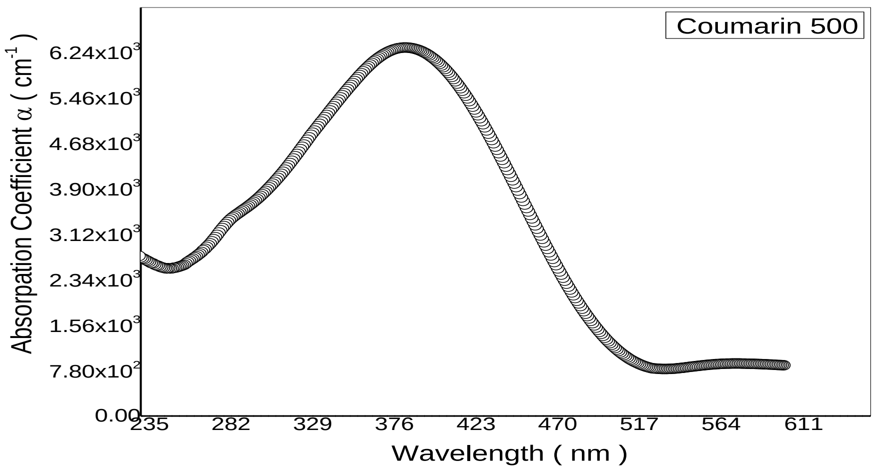

Figure (4.4) the relation between absorbance Coefficient and wavelength of Coumarin 500

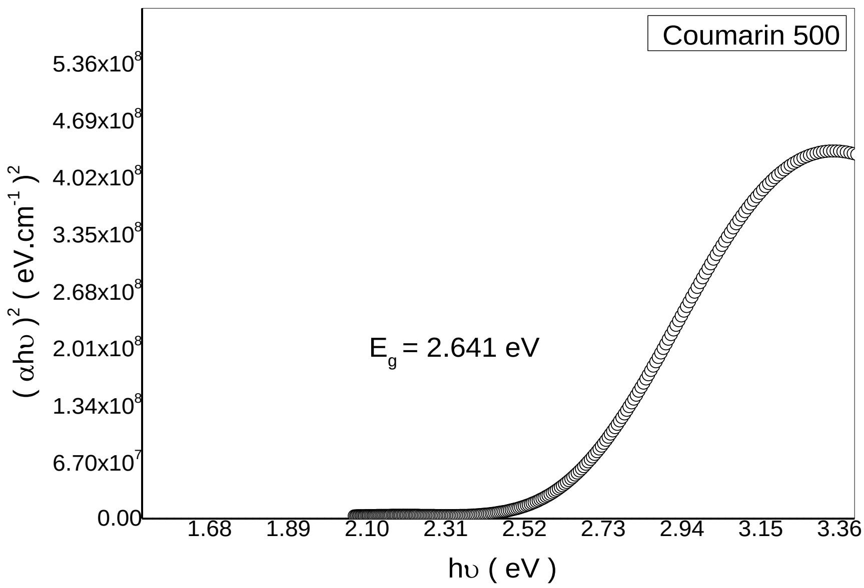

Figure (4.5) the optical energy gap (Eg) value of Coumarin 500

The optical energy gap (Eg) has been calculated by the relation $\boldsymbol{(\alpha h\upsilon)^2 = C(h\upsilon - Eg)}$ 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 2. 641 eV.

Table (4.1) I-V reaction for sample Gum Arabic doped with CuO_2 + Coumarin 500

Current (mA) ±0.001	Voltage (V) ±0.001
27.24975	0.01303
27.24883	0.01346
27.24915	0.01394
27.24975	0.01429
27.24975	0.01459
27.24975	0.01496
27.24883	0.0153
27.22014	0.01552
27.18116	0.01566
27.14246	0.01573

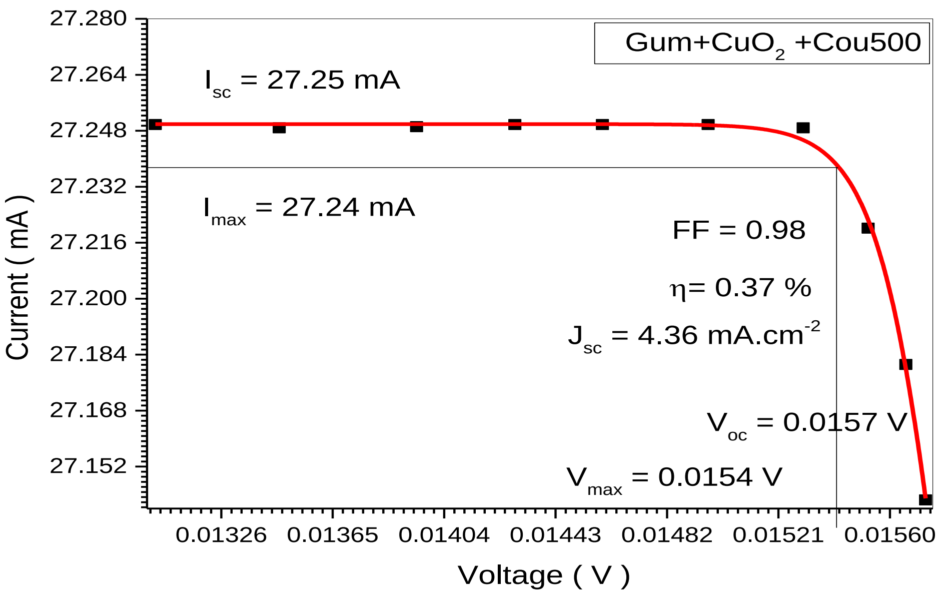

Figure (4.6) I-V graph for sample Gum Arabic doped with CuO_2 + Coumarin 500

Table (4.2) I-V reaction for sample Gum Arabic doped with CuO_2 + Coumarin 500

Current (mA) ±	Voltage (V) ±
27.30154	0.01442
27.30062	0.01468
27.29786	0.01502
27.2997	0.01523
27.2997	0.01546
27.27962	0.01571
27.23322	0.01582
27.15681	0.01588
27.05039	0.01595
26.98494	0.01599

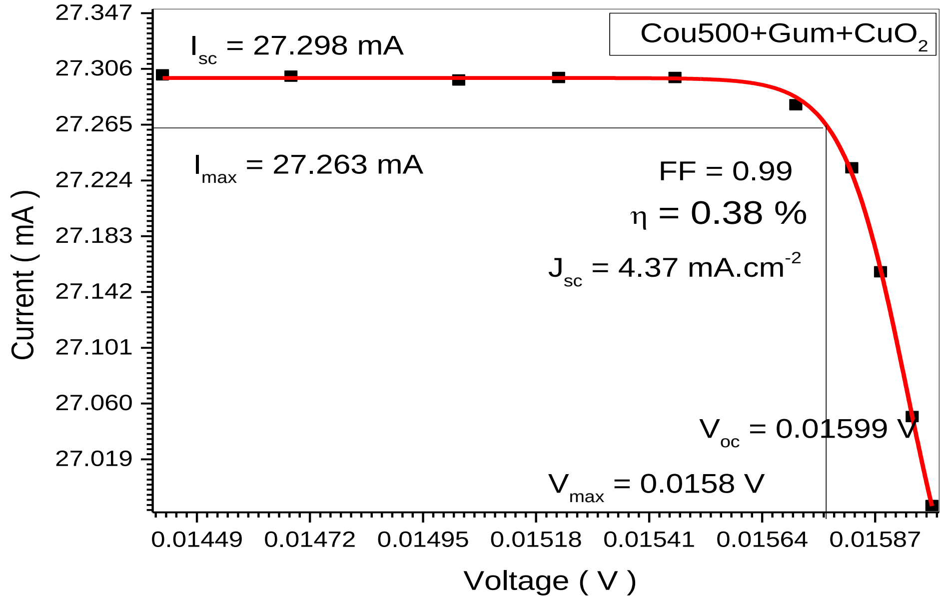

Figure (4.7) I-V graph for sample Coumarin 500 Gum Arabic doped with CuO_2

4.5.3 Results Samples of (DDTTCI)

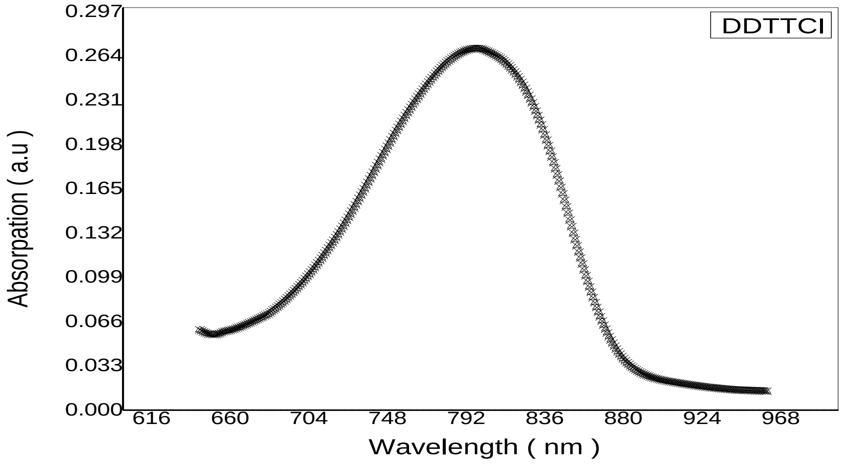

Figure (4.8) the relation between absorbance and wavelength of DDTTCI

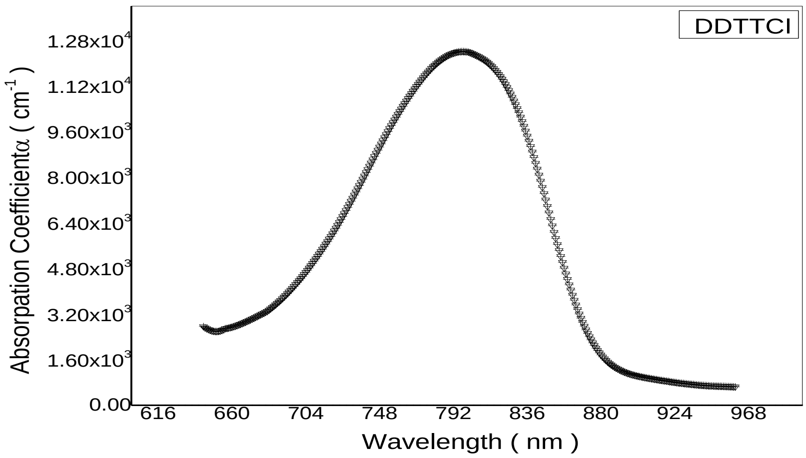

Figure (4.9) the relation between absorbance Coefficient and wavelength of DDTTCI

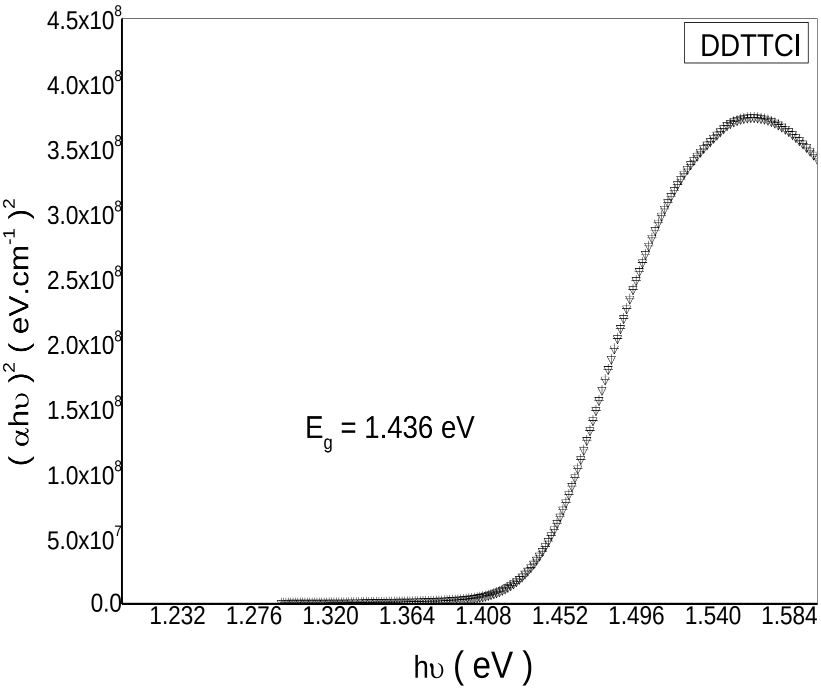

Figure (4.10) the optical energy gap (Eg) value of DDTTCI

The optical energy gap (Eg) has been calculated by the relation $\mathbf{(\alpha h\upsilon)^2 = C(h\upsilon - Eg)}$ 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 1. 436eV.

Table (4.3) I-V reaction for sample Gum Arabic doped with CuO_2 +DDTTCI

Current (mA) ±	Voltage (V) ±
26.11332	0.21462
26.29593	0.21358
26.45972	0.21224
26.61342	0.20943
26.66915	0.20485
26.67087	0.20308
26.66573	0.20087
26.6625	0.19797
26.66078	0.19568
26.64899	0.19296

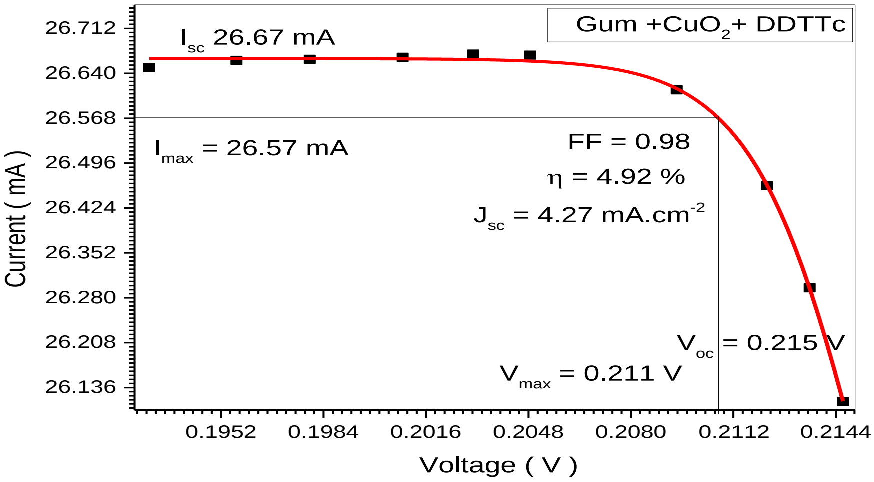

Figure (4.11) I-V graph for sample Gum Arabic doped with CuO_2 + DDTTCI

Table (4.4) I-V reaction for sample Gum Arabic doped with DDTTCI + CuO_2

Current (mA) ±	Voltage (V) ±
26.69982	0.20922
26.69787	0.21199
26.69837	0.21484
26.69932	0.21755
26.68352	0.22029
26.65044	0.2213
26.6243	0.22153
26.59072	0.22213
26.56403	0.22245
26.53439	0.22297

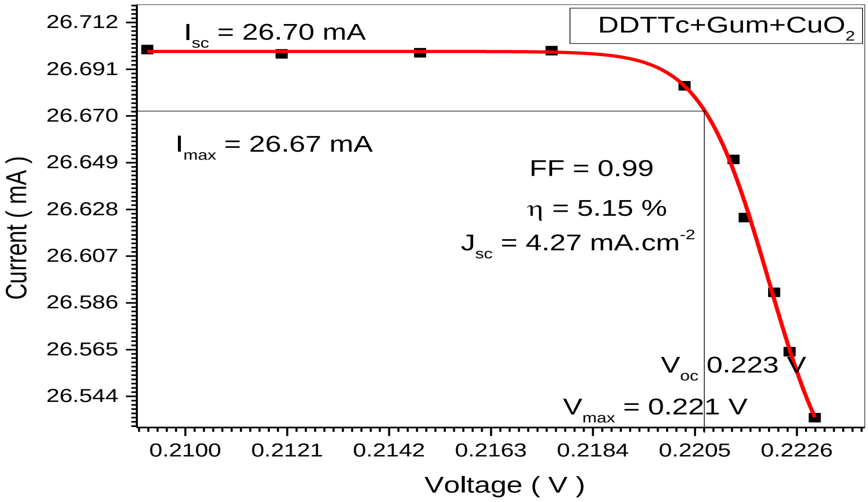

Figure (4.12) I-V graph for sample + DDTTCI Gum Arabic doped with CuO_2

4.5.4 Results Samples of (Ecr-chrome Black T)

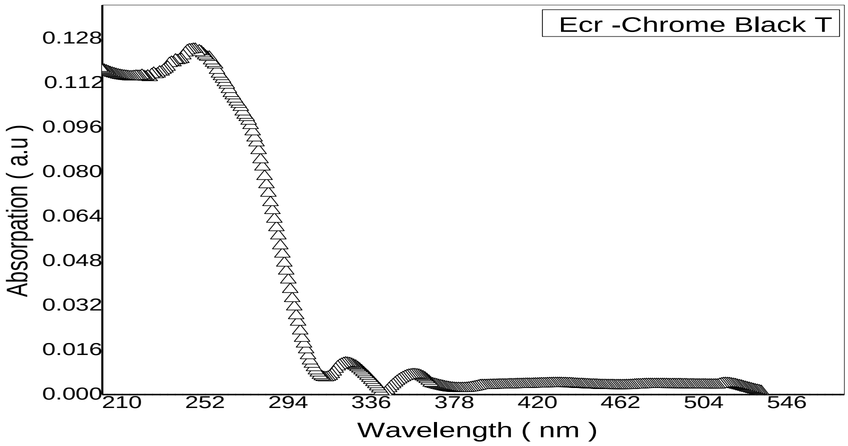

Figure (4.13) the relation between absorbance and wavelength of Ecr-chrome Black T

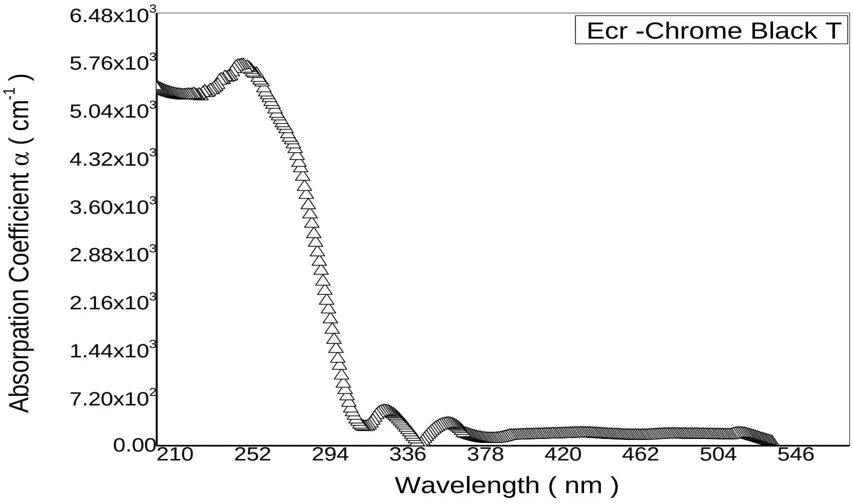

Figure (4.14) the relation between absorbance Coefficient and wavelength of Ecr-chrome Black T

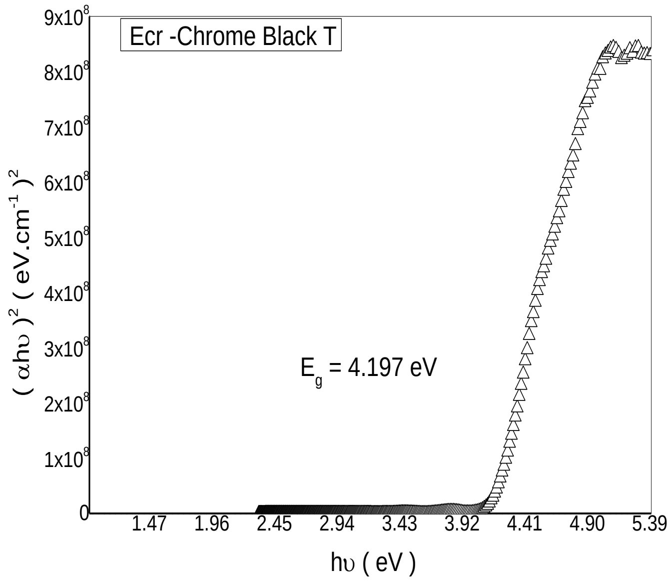

Fig (4.15) the optical energy gap (Eg) value of Ecrchrom Black T

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 (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 4.197 eV.

Table (4.5) I-V reaction for sample 8 Gum Arabic doped with Eriochrome Black T + CuO_2

Current (mA) ±	Voltage (V) ±
26.93856	0.00222
26.92382	0.04305
26.92632	0.09011
26.90909	0.13095
26.88184	0.17227
26.81261	0.20494
26.64969	0.21408
26.4548	0.22036
26.29438	0.2242
26.06474	0.22896

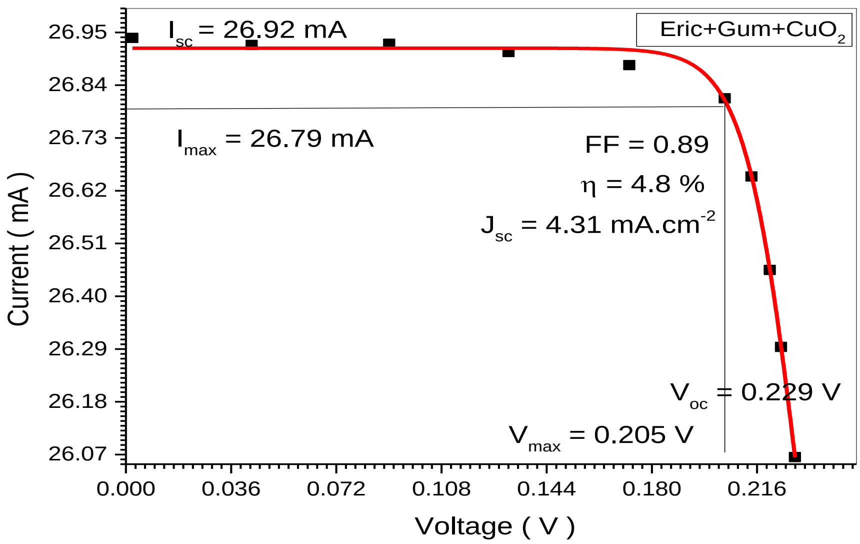

Figure (4.16) I-V graph for sample Eri o-chrome Black+ Gum Arabic doped with CuO_2

Table (4.6) I-V reaction for sample 7 Gum Arabic doped with CuO_2 + Erio -chrome Black T

Current (mA) ±	Voltage (V) ±
26.99601	0.01629
26.99693	0.0166
26.99878	0.0169
26.9997	0.01719
27	0.01809
26.97235	0.01832
26.95	0.01857
26.89328	0.01886
26.85	0.019
26.67582	0.01925

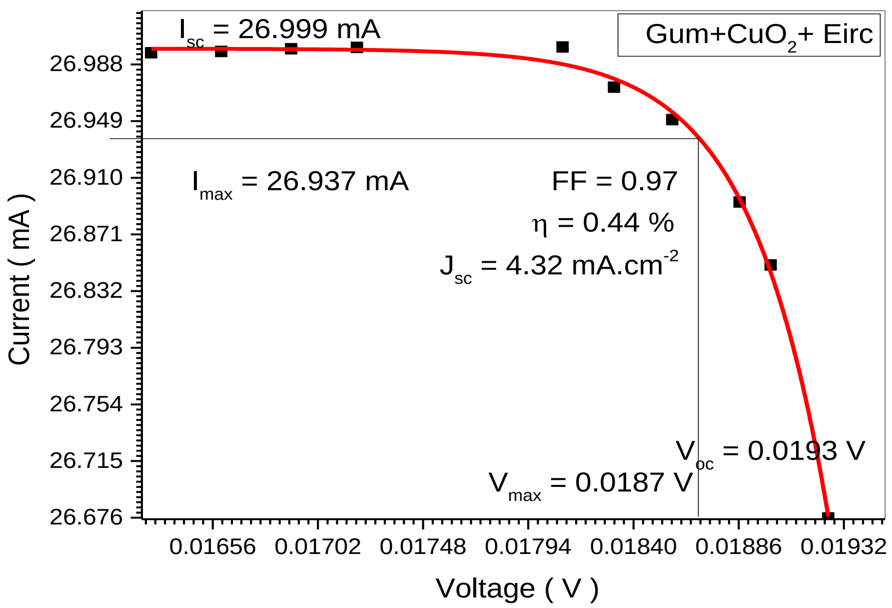

Figure (4.17) I-V graph for sample Gum Arabic doped with CuO_2 + Erio-chrome Black

4.5.5 Results Samples of (Rohadamin B)

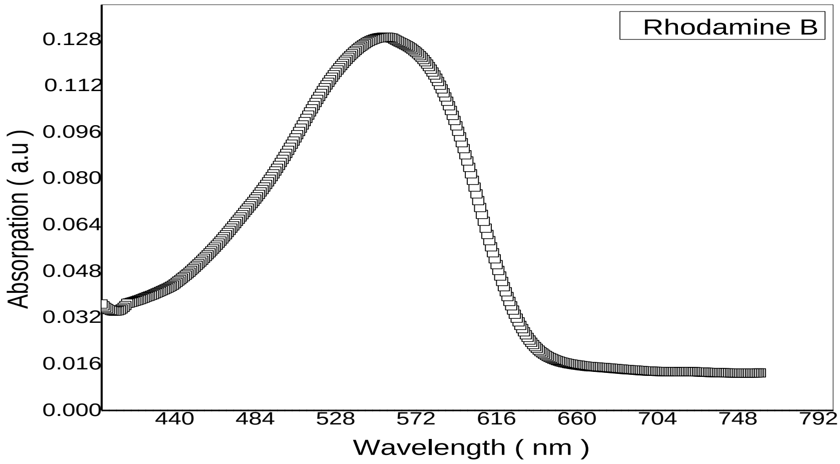

Figure (4.18) the relation between absorbance and wavelength of Rohadamin B

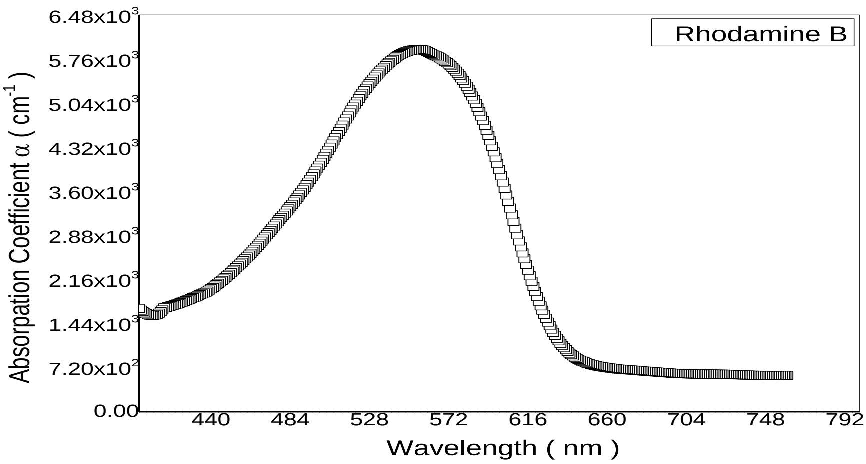

Figure (4.19) the relation between absorbance Coefficient and wavelength of Rhodamine B

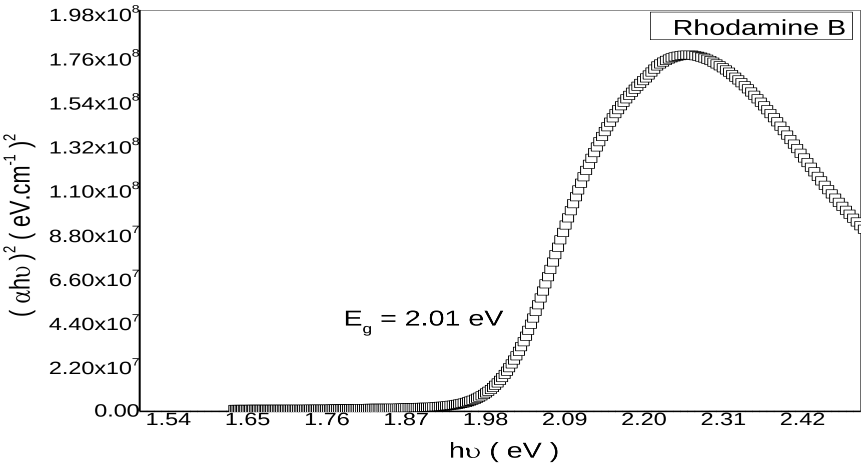

Figure (4.20) the optical energy gap (E_g) value of Rhodamine B.

The optical energy gap (E_g) has been calculated by the relation $\mathbf{(\alpha h\upsilon)^2 = C(h\upsilon - E_g)}$ 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 (E_g) obtained was 2.01 eV.

Table (4.7) I-V reaction for sample Gum Arabic doped with Rhodamine B+ CuO2

Current (mA) ±	Voltage (V) ±
27.63345	0.08113
27.68377	0.0805
27.75884	0.07282
27.79442	0.0562
27.79787	0.04729
27.79932	0.03714
27.79932	0.02852
27.79687	0.01655
27.79587	0.00855
27.7958	8.48118E-4

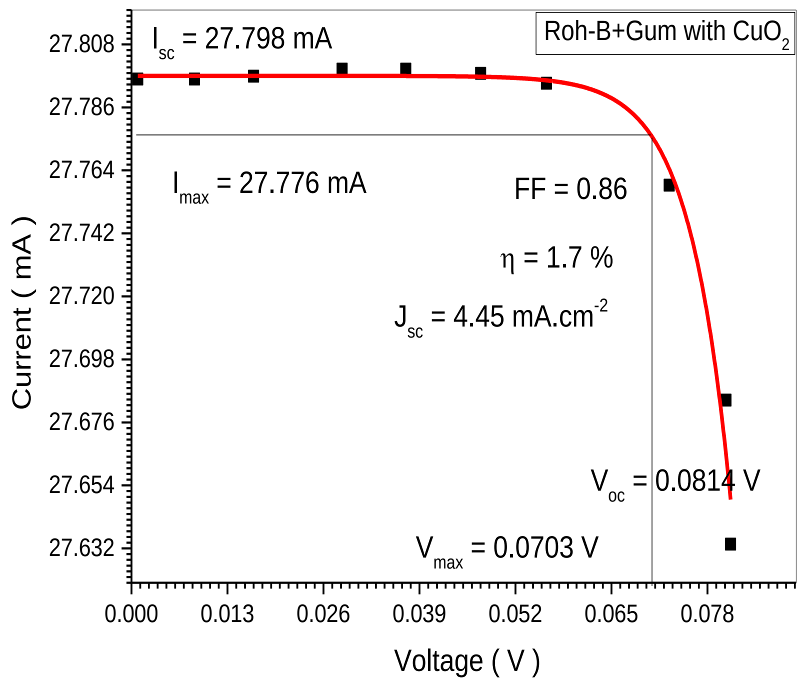

Figure (4.21) I-V graph for sample Gum Arabic doped with Rhodamine B+ CuO_2

Table (4.8) I-V reaction for sample Gum Arabic doped with CuO2 + Rhodamine B

Current (mA) ±	Voltage (V) ±
28.49303	0.05112
28.47736	0.06327
28.4709	0.07268
28.45	0.0829
28.40672	0.08854
28.29627	0.09192
28.11741	0.09393
27.97388	0.09562
27.8102	0.09742
27.71318	0.09826

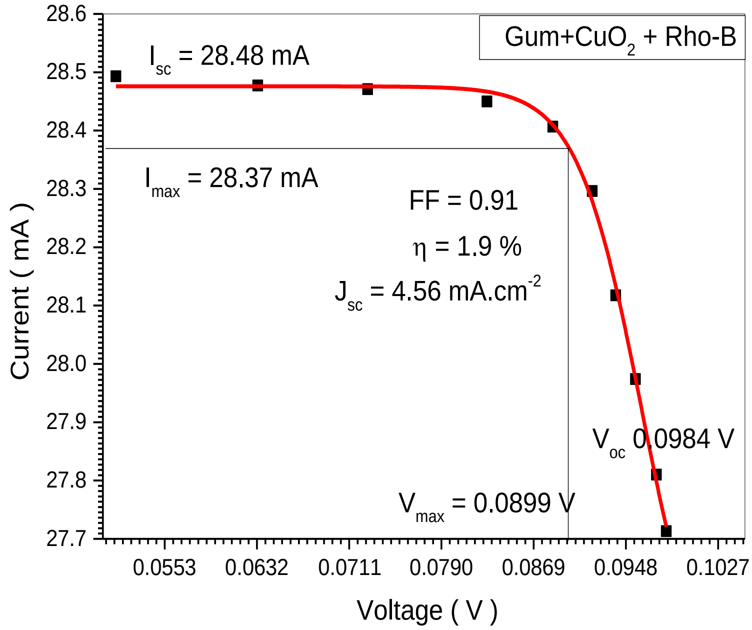

Figure (4.22) I-V graph for sample Gum Arabic doped with CuO_2 + Rhodamine B

4.5.6 Results Samples of (Nile blue)

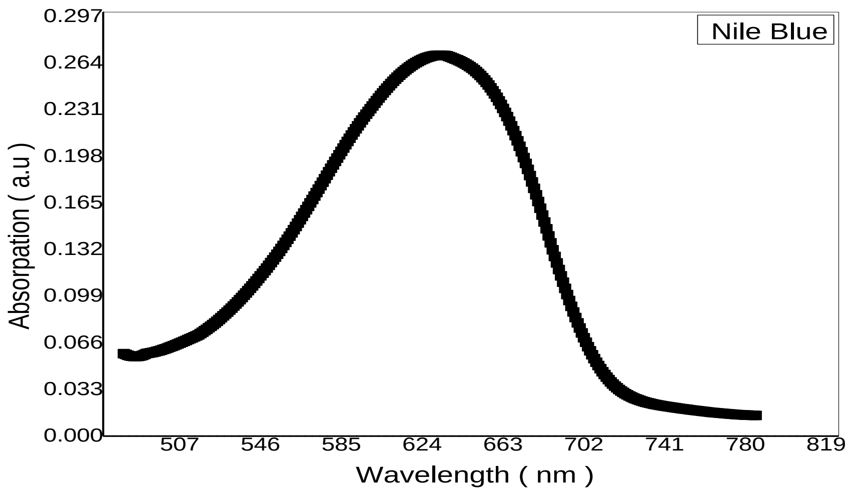

Figure (4.23) the relation between absorbance and wavelength of Nile blue

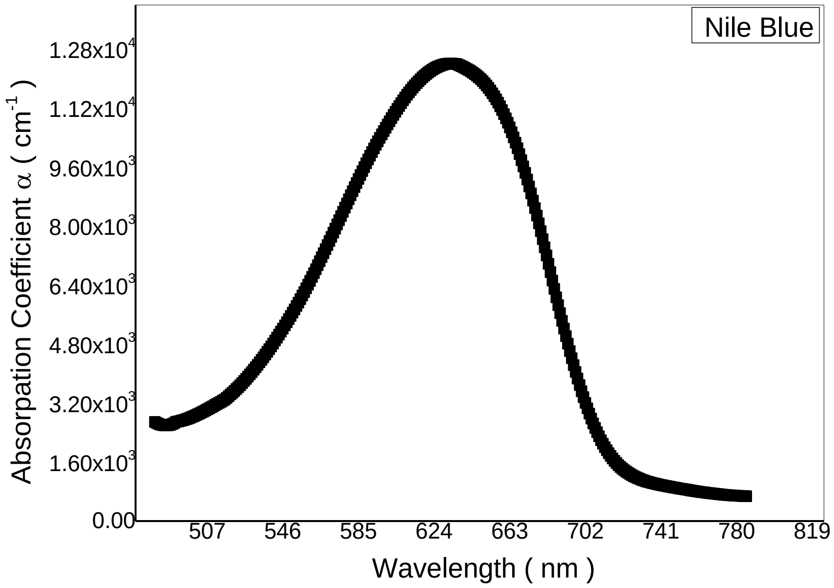

Figure (4.24) the relation between absorbance Coefficient and wavelength of Nile blue

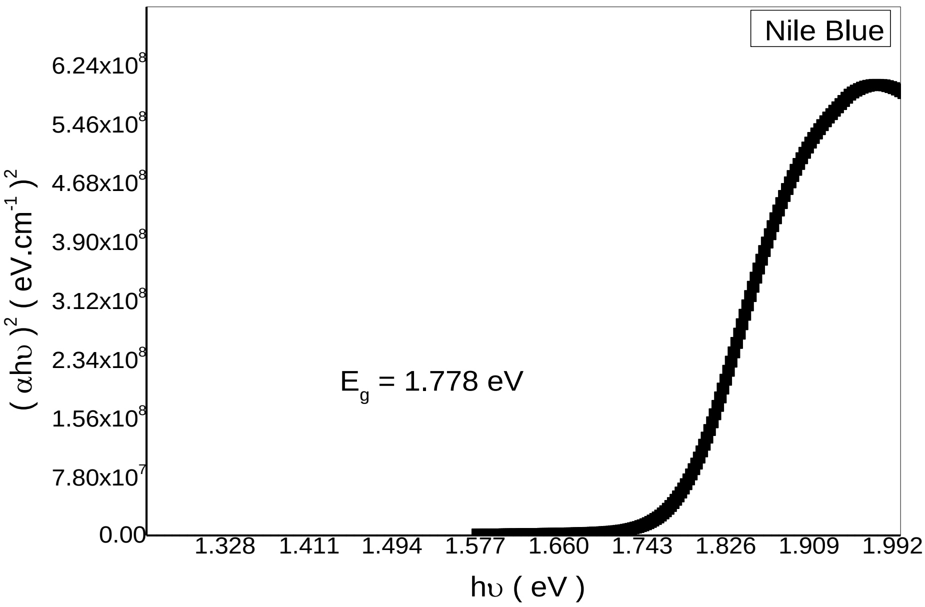

Figure (4.25) the optical energy gap (Eg) value of Nile blue.

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 1.778eV

Table (4.9) I-V reaction for sample Nile blue Gum Arabic doped with CuO_2

Current (mA) ±	Voltage (V) ±
27.49844	0.01291
27.5	0.01301
27.5	0.01312
27.5	0.01323
27.49778	0.01342
27.48615	0.01359
27.4653	0.01374
27.43091	0.01385
27.36528	0.01399
27.27954	0.01405

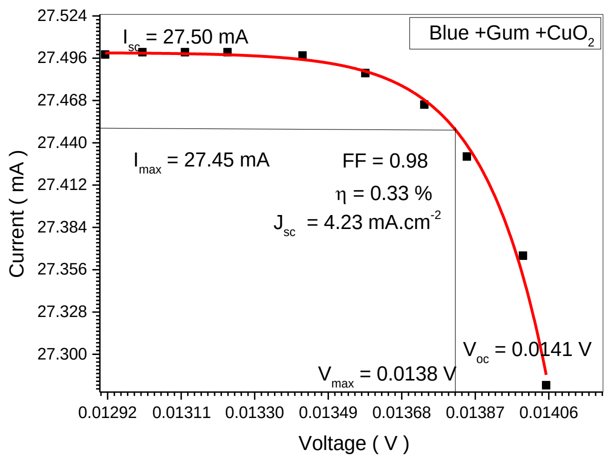

Figure (4.26) I-V graph for sample Nile blue + Gum Arabic doped with CuO_2

Table (4.10) I-V reaction for sample Gum Arabic doped with CuO_2 + Nile blue

Current (mA) ±	Voltage (V) ±
27.70056	0.12615
27.70056	0.12882
27.6999	0.13074
27.69215	0.13251
27.68249	0.13448
27.66391	0.13565
27.62125	0.13658
27.58409	0.13713
27.5	0.1378
27.47595	0.13794

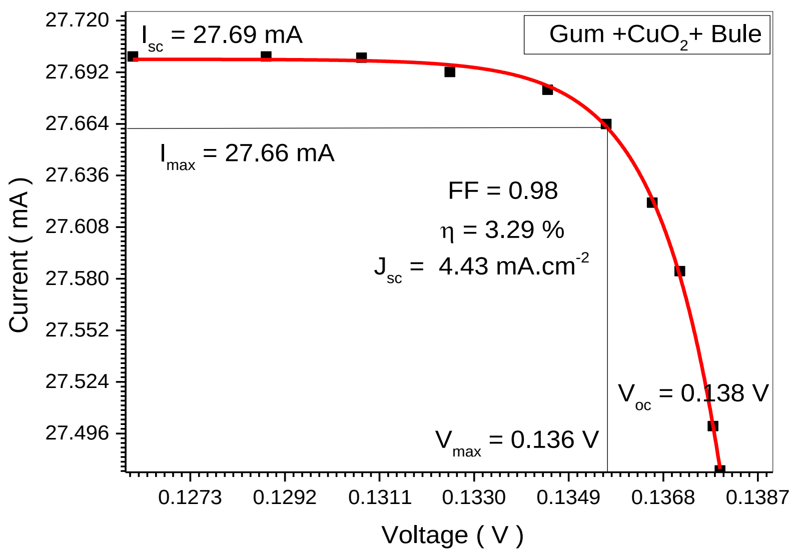

Fig (4.27) I-V graph for sample Gum Arabic doped with CuO_2 + Nile blue

Table (4.11) is Factors for characterization of Arabic Gum solar cells performance for three samples

Sample	I_{sc} mA	I_{max} mA	V_{oc} (V)	V_{max} (V)	J_{sc} mA.cm-2	F.F	η %	E_g	mλ
1C(F1)	27.25	27.24	0.0157	0.0154	4.36	0.98	0.37	2.641	376
2C(F2)	27.29	27.26	0.0159	0.0158	4.37	0.99	0.38	2.614	376
3D(F1)	26.67	26.57	0.215	0.211	4.27	0.98	4.92	1.436	792
4D(F2)	26.70	26.67	0.223	0.221	4.27	0.99	5.15	1.436	792
5E(F1)	26.92	26.79	0.229	0.205	4.31	0.89	0.48	4.197	252
6E(F2)	26.999	26.937	0.0193	0.0187	4.32	0.97	0.44	4.197	252
7R(F1)	27.798	27.776	0.0814	0.0703	4.45	0.96	1.7	2.01	550
8R(F2)	28.48	28.37	0.0984	0.0899	4.56	0.91	1.9	2.01	550
9N(F1)	27.50	27.45	0.0141	0.0138	4.23	0.98	3.3	1.778	630
10N(F2)	27.69	27.66	0.138	0.136	4.43	0.98	3.29	1.778	630

Where

F1≡ face1 dye up (dye/gum), F2≡ face2 gum up (gum /dye), C≡ Coumarin 500 dye, D≡ DDTTC dye, E≡ Ecro-chrome Black T dye, R≡ Rhodamine B dye and N≡ Nile blue dye.

In view of table (4.11) it is clear that in all cases for all 5dyes the efficiency is higher when the gum layer is above the dye layer which are denote it by F2(gum up, gum/dye), where it assumes the values (0.38, 5.15, 1.9,) for gum (2cf, DDTTC dye (4DF2) and Rhodamine B.

The efficiency is lower where the dye for Coumarin 500, DDTTC and Rhodamin B.

Is above gum layer (f1 dye/gum) where it assumes the values (0.37, 4.92, and 1.7) respectively.

This may be related to the fact that gum layer is ware Trans parent that the 3 dye layers.

It is very important to note that for Ecro-chrome Black T (5EF1) where dye is up the efficiency is (0.48) which is higher than where gum is up (6EF2) where it assumes that value (0.44) this means that Ecro-chrome Black T is more transparent than gum Arabic.

It is very interesting to note that this transparency of Ecro-chrome Black T.

May explain why the efficiency of Ecro-chrome Black T which in the range of (0.46) is Higher than that of Coumarin 500.

Which is about (0.37) although the energy gap of Ecro-chrome Black T is equal to (4.197) and layer than that of Coumarin 500 which is (2.641).

This means that the effect of transparency of dye more effective than the energy gap.

It is very interesting to note that the efficiency increases as the energy gap decreases for 4dyes. Where the efficiency for (f2) takes the values.

Table (4.12) the relation between the efficiency (η) and the energy gap (E_g)

η	5.15	3.29	1.9	0.38
(E_g)	1.436	1.778	2.01	2.614

For DDTTC dye (4DF2), Nile blue (10NF2), Rhodamin B (8RF2) and Coumarin 500 (2CF2) which have energy gap this may be are to the fact that the decreases of energy gap give change to more less energetic photons in the sun radiation spectrum to excite electrons to the conduction band.
This cause the number of free electrons to increase, which increases current density (J), where J≡ near.

4.6 Discussion

Here, each cell will be discussed separately as follows:

4.6.1Discussion Samples of (Coumarin 500)

Determination of the optical properties of Samples of (Coumarin 500). The optical absorption spectra in the (235 – 564) nm wavelength range for the (Coumarin 500) dye are depicted in Fig (4.3) the maximum absorption observed at wavelength (376 nm). The absorption edge of the (Coumarin 500) dye occurs at wavelength (376 nm) corresponding to photon energy (3.29eV). Fig (4.4) shows the relation between Absorption Coefficient and wavelengths, we had been found rapid decrease at 376 nm and sudden increase in 260 nm and it continuous with increase after that wavelength 517 nm, rated of (Coumarin 500) dye increase refers to the decrease in transparent value.

The energy band gap of these materials is determined using the absorption spectra. According to the absorption coefficient (α) for direct band gap material is given by the relation

$$\alpha h\nu = B(h\nu - E_g)^n \qquad (4.1)$$

Where (E_g) the energy gap, constant (B) is different for different transitions, (hv) 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 calculated. The value of (E_g) was (2.641 eV) as show in fig (4.5).

Curve (4.6) shows the current-voltage characteristics obtained from the measured values (see Table 4.1).this measurement was taken from solar cell of the structure (ITO/(Coumarin 500) dye / Gum Arabic /Ag), The short-circuit current (I_{sc}) is 27.25 mA, the open-circuit voltage (V_{oc}) is 0.0157 V, fill factor (FF) is 0.98, and the efficiency is 0.37%.

Curve (4.7) shows the current-voltage characteristics obtained from the measured values (see Table 4.2).this measurement was taken from solar cell of the structure (ITO/Gum Arabic / Coumarin 500 dye /Ag), The short-circuit current (I_{sc}) is 27.298 mA, the open-circuit voltage (V_{oc}) is 0.01599 V, fill factor (FF) is 0.99, and the efficiency is 0.38%.

4.6.2Discussion Samples of (DDTTCI)

Determination of the optical properties of Samples of (DDTTCI). The optical absorption spectra in the (660 – 924) nm wavelength range for the (DDTTCI) dye are depicted in Fig (4.8) the maximum absorption observed at wavelength (792 nm). The absorption edge of the (DDTTCI) dye occurs at wavelength (792 nm) corresponding to photon energy (0.18 eV). Fig (4.9) shows the relation between Absorption Coefficient and wavelengths, we had been found rapid decrease at 792 nm and sudden increase in 660 nm and it continuous with increase after that wavelength 924 nm, rated of (DDTTCI) dye increase refers to the decrease in transparent value.

The energy band gap of these materials is determined using the absorption spectra. According to the absorption coefficient (α) for direct band gap material is given by the relation:

$$\alpha h\nu = B(h\nu - E_g)^n \qquad (4.2)$$

Where E_g the energy gap, constant B is different for different transitions, (hv) 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 calculated. The value of (E_g) was (1.436 eV) as show in fig (4.10).

Curve (4.11) shows the current-voltage characteristics obtained from the measured values (see Table 4.3).this measurement was taken from solar cell of the structure (ITO/(DDTTCI) dye / Gum Arabic /Ag), The short-circuit current (I_{sc}) is 26.70 mA, the open-circuit voltage (V_{oc}) is 0.223 V, fill factor (FF) is 0.99, and the efficiency is 5.15%.

Curve (4.12) shows the current-voltage characteristics obtained from the measured values (see Table 4.2).this measurement was taken from solar cell of the structure (ITO/Gum Arabic / DDTTCI dye /Ag), The short-circuit current (I_{sc}) is 26.67 mA, the open-circuit voltage (V_{oc}) is 0.215 V, fill factor (FF) is 0.98, and the efficiency is 4.27%.

4.6.3Discussion Samples of (Ecro-chrome Black T)

Determination of the optical properties of Samples of (Ecro-chrome Black T). The optical absorption spectra in the (210 – 252) nm wavelength range for the (Ecro-chrome Black T) dye are depicted in Fig (4.13) the maximum absorption observed at wavelength (252 nm). The absorption edge of the (Ecro-chrome Black T) dye occurs at wavelength (252 nm) corresponding to photon energy (0.18 eV). Fig (4.14) shows the relation between Absorption Coefficient and wavelengths, we had been found rapid decrease at 210 nm and sudden increase in 660 nm and it continuous with increase after that wavelength 252 nm, rated of (Ecro-chrome Black T) dye increase refers to the decrease in transparent value.

The energy band gap of these materials is determined using the absorption spectra. According to the absorption coefficient (α) for direct band gap material is given by the relation.

$$\alpha h\nu = B(h\nu - E_g)^n \qquad (4.3)$$

Where E_g the energy gap, constant B is different for different transitions, (hv) 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 calculated. The value of (E_g) was (4.197 eV) as show in fig (4.15).

Curve (4.16) shows the current-voltage characteristics obtained from the measured values (see Table 4.5).this measurement was taken from solar cell of the structure (ITO/ Ecro-chrome Black T dye / Gum Arabic /Ag), The short-circuit current (I_{sc}) is 26.92 mA, the open-circuit voltage (V_{oc}) is 0.229 V, fill factor (FF) is 0.89, and the efficiency is 4.8%.

Curve (4.17) shows the current-voltage characteristics obtained from the measured values (see Table 4.6).this measurement was taken from solar cell of the structure (ITO/Gum Arabic / Ecro-chrome Black T /Ag), The short-circuit current (I_{sc}) is 26.999 mA, the open-circuit voltage (V_{oc}) is 0.0193 V, fill factor (FF) is 0.97, and the efficiency is 0.44%.

4.6.4Discussion Samples of (Rhodamine B)

Determination of the optical properties of Samples of (Rhodamine B). The optical absorption spectra in the (440 – 560) nm wavelength range for the (Rhodamine B) dye are depicted in Fig (4.18) the maximum absorption observed at wavelength (550 nm). The absorption edge of the (Rhodamine B) dye occurs at wavelength (550 nm) corresponding to photon energy (2.25 eV). Fig (4.19) shows the relation between Absorption Coefficient and wavelengths, we had been found rapid decrease at 572 nm and sudden increase in 660 nm and it continuous with increase after that wavelength 440 nm, rated of (Rhodamine B) dye increase refers to the decrease in transparent value.

The energy band gap of these materials is determined using the absorption spectra. According to the absorption coefficient (α) for direct band gap material is given by the relation

$$\alpha h\nu = B(h\nu - E_g)^n \qquad (4.4)$$

Where E_g the energy gap, constant B is different for different transitions, (hv) 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 calculated. The value of (E_g) was (2.01 eV) as show in fig (4.20).

Curve (4.21) shows the current-voltage characteristics obtained from the measured values (see Table 4.7).this measurement was taken from solar cell of the structure (ITO/ Rhodamine B dye / Gum Arabic /Ag), The short-circuit current (I_{sc}) is 27.798 mA, the open-circuit voltage (V_{oc}) is 0.0814 V, fill factor (FF) is 0.86, and the efficiency is 1.7%.

Curve (4.22) 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/Gum Arabic / Rhodamine B dye /Ag), The short-circuit current (I_{sc}) is 28.48 mA, the open-circuit voltage (V_{oc}) is 0.0984 V, fill factor (FF) is 0.91, and the efficiency is 1.9%.

4.6.5 Discussion Samples of (Nile blue)

Determination of the optical properties of Samples of (Nile blue). The optical absorption spectra in the (507 – 780) nm wavelength range for the (Nile blue) dye are depicted in Fig (4.23) the maximum absorption observed at wavelength (630 nm). The absorption edge of the (Nile blue) dye occurs at wavelength (630 nm) corresponding to photon energy (1.98 eV). Fig (4.24) shows the relation between Absorption Coefficient and wavelengths, we had been found rapid decrease at 630 nm and sudden increase in 507 nm and it continuous with increase after that wavelength 780 nm, rated of (Nile blue) dye increase refers to the decrease in transparent value.

The energy band gap of these materials is determined using the absorption spectra. According to the absorption coefficient (α) for direct band gap material is given by the relation

$$\alpha h\nu = B(h\nu - E_g)^n \qquad (4.5)$$

Where E_g the energy gap, constant B is different for different transitions, (hv) 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 calculated. The value of (E_g) was (1.77 eV) as show in fig (4.25).

Curve (4.26) shows the current-voltage characteristics obtained from the measured values (see Table 4.7).this measurement was taken from solar cell of the structure (ITO/ Nile Blue dye / Gum Arabic /Ag), The short-circuit current (I_{sc}) is 27.50 mA, the open-circuit voltage (V_{oc}) is 0.0141 V, fill factor (FF) is 0.98, and the efficiency is 0.33%.

Curve (4.27) 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/Gum Arabic / Nile Blue dye /Ag), The short-circuit current (I_{sc}) is 27.69 mA, the open-circuit voltage (V_{oc}) is 0.133 V, fill factor (FF) is 0.98, and the efficiency is 3.29 %.

4.7 Conclusion

- The gum Arabic doped with CuO and Ag can act as efficient solar cell.
- The efficient increases as the energy gap decreases.
- The efficiency is also affected when the gum layer is replaced by the dye layer.
- The efficiency increases when the gum layer became above dye layer.

4.8 Recommendation

1- Gum Arabic can be doped with other mineral oxides to see how the material affect performance.

2- The pressure effect on gum electrical characteristic needs also to be studied.

3- The effect of temperature and heating on the performance of such solar cells are also needed.

References

[1] Hino, Y., Kajii, H. & Ohmori, Y. 2006. Transient characteristics of polyfluorene-based polymer light-emitting diodes and their application for color tunable devices. Thin Solid Films, 499, pp.359-363.

[2] Spanggaard , H. & Krebs, F. C.(2004). A Brief history of the development of organic and polymeric photo-voltaic .Solar Energy Materials & Solar Cells.

[3] Hoke, E. T. Vandewal, K., Bartelt, J. A., Mateker, W. R., Douglas, J. D., Noriega, R., Graham, K. R., Fréchet, J. M., Salleo, A. & McGehee, M. D. Recombination in Polymer:Fullerene Solar Cells with Open-Circuit Voltages Approaching and Exceeding 1.0 V. Adv. Energy Mater. 3,220–230 (2013).

[4] Elektronikbutikken, Vesterbrogade, A. C. (2006). Solpanelercis. ttp://solkraft.dk

[5] Al-Assaf, S., Sakata, M., McKenna, C., Aoki, H., & Phillips, G. O. (2009). Molecular associations in acacia gums. Journal of Structural Chemistry, 20, 325–336.

[6] Hermann, W. & Simon, A. J. 2007. Global Climate and Energy Project. [Online]. [Accessed9th of June 2009]. Available form World Wide Web: http://gcep.stanford.edu/pdfs/GCEP_Exergy_Poster_web.pdf.

[7] Sakina Ibrahim Ali , Mubarak Dirar Abdallah, Sawsan Ahmed Elhouri Ahmed, Rawia Abdalgani, Amel Abdalla A, Abdalsakhi. S. M. H. international journal of engineering sciences and research technology. International Journal of Engineering Sciences & Research Technology. 5(8): (2016)

[8] L. A. Dobrzanski, L. Wosinka, B. Bolzanka, and A. Drygala, “Comparison of Electrical Characteristics of Silicon Solar Cells,” Journal of Achievements in Material and Manufacturing Engineering, vol. 18, pp. 215-218, 2006.

[9] M. Chegaar, Z. Ouennoughi, F. Guevhi, and H. Langueur, "Determination of Solar Cells Parameters under Illuminated Conditions," The Journal of Electron Device, vol. 2, pp. 17-22, 2003.

[10] J. D. Servaites, M. A. Ratner, and T. J. Marks, "Practical Efficiency Limits in Organic Photovoltaic Cells: Functional Dependence of Fill Factor and External Quantum Efficiency" Applied Physics Letters, vol. 95, no. 16, Article ID 163302, 3 pages, 2009.

[11] A. Subrahmanyan and N. Balasubramanian, "Studies of The Photovoltaic Behavior of Indium Tin Oxide (ITO)/Silicon Junctions Prepared by the Reactive Thermal Evaporation Technique," Semiconductor Science and Technology, vol. 7, no. 3, Article 07, pp. 324-327, 1992.

[12] Kinoshita, T. et al. (2015) Spectral splitting photovoltaics using perovskite and wideband dye-sensitized solar cells. Nat. Commun. 6, 8834.

[13] NimaParsiBenehkohal (2013) Innovations in Electrophoretic Deposition of Nanotitania-Based Photoanodes for Use in Dyesensitized Solar Cells, Ph. D Thesis McGill University Montreal, QC, Canada.

[14] Shadia Tageldeen*1, Mubarak Dirar Abd Allah2, Abdalsakhi S. M.H3 & Sawsan Ahmed Elhouri Ahmed4 - optical properties of zinc oxide doped by (Al, Cd, Co, Li and Mg) - global journal of engineering science and researches -[Tageldeen, 5(12): December2018] ISSN 2348 – 8034 DOI-10.5281/zenodo.2529394 Impact Factor- 5.070.

[15] M.B. Gongalsky, L.A. Osminkina, A. Pereira, A.A. Manankov, A.A. Fedorenko,

[16] A.N. Vasiliev, V.V. Solovyev, A.A. Kudryavtsev, M. Sentis, A.V. Kabashin,

[17] V.Y. Timoshenko, Sci. Rep. 6, 24732 (2016). https://doi.org/10.1038/srep24732

[18] M. Miyano, S. Endo, H. Takenouchi, S. Nakamura, Y. Iwabuti, O. Shiino, T. Nakanishi, Y. Hasegawa, J. Phys. Chem. C 118, 19778 (2014)

[19] N. A. Ragab*1, Sawsan Ahmed Elhouri Ahmed2, Ahmed Hassan Alfaki3, Abdalsakhi S. M. H4 & Mubarak I. S. Tagabo5 – the value of efficiency and energy gap for different dye solar cells – global journal of engineering science and reseaches -August 2018 - ISSN 2348 – 8034 DOI- 10.5281/zenodo.1343451 Impact Factor- 5.070

[20] B. O'Regan, M. Grätzel, "A low cost, high-efficiencysolar cell based on dye-sensitized colloidal TiO2films", Nature, Vol. 353, 1991, 737-740.

[21] R. T. Young, R. F. Wood, J. Narayan, C. W. White, and W. H. Christie. Pulsed laser techniques for solar cell processing. IEEE Transactions on Electron Devices 1980; 27: 807–815.

[22] R. Younkin, J. E. Carey, E. Mazur. Infrared absorption by conical silicon microstructures made in a variety ofbackground gases using femtosecond-laser pulses. J. Appl. Phys. 2003; 93: 2626–2629.

[23] C. H. crouch, J. E. carey, M. shen, E. mazur, F. Y. genin. Infrared absorption by sulfur-doped siliconformed by femtosecond laser irradiation. Appl. Phys. A 2004; 79: 1635–1641.

[24] Sh. T*1, Mubarak Dirar Abd Allah2, Abdalsakhi S. M.H3 & Sawsan Ahmed Elhouri Ahmed4 –the effect of optical energy gaps on the efficincy of zinc oxide solar cells doped by (Al, Cd, Co, Li and Mg) - global journal of engineering science and researches - [Tageldeen, 5(12): December2018] ISSN 2348 – 8034 DOI- 10.5281/zenodo.2529389 Impact Factor- 5.070

[25] M. A. Sheehy, Luke Winston, James E. Carey, Cynthia M. Friend, and Eric Mazur. Role of the Background Gas inthe Morphology and Optical Properties of Laser-Microstructured Silicon. Chem. Mater. 2005; 17: 3582–3586.

[26] A.M. El Sayed, G. Said, S. Taha, A. Ibrahim and, F. Yakuphanoglu, Influence of copper incorporation on the structural and optical properties of ZnO nanostructured thin films, Superlattices and Microstructures, (62), 2013, 47–58.

[27] M. K. Nazeeruddin, P. Réchy, T. Renouard, S. M. Zakeeruddin, R. Humphry-Baker, P.Comte, P. Liska, L. Vevey, E. Costa, V. Shklover, L. Spicca, G. B. Deacon, C. A.Bignozzi, M. Grätzel, J. Am. Chem. Soc. 2001, 123, 1613.

[28] U. Bach, D. Lupo, P. Comte, J. E. Moser, F. Weissörtel, J. Salbeck, H. Speitzer, M.Grätzel, Nature 1998, 395, 583.

[29] P. A. van Hal, M. P. T. Christiaans, M. M. Wienk, J. M. Kroon, R. A. J. Janssen, J. Phys.Chem. B 1999, 103, 4352.

[30] J. J. M. Halls, C. A. Walsh, N. C. Greenham, E. A. Marseglia, R. H. Friend, S. C. Maratti, A. B. Holmes, Nature 1995, 376, 498.