LOW COST DYE- SENSITIZED SOLAR CELL BY USING SCREEN PRINTING DEPOSITION METHOD

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ABSTRACT

Looking for the green sources of energy have been the subject for research activities for last decade. For years we have been using various kinds of energy sources to fulfill energy requirement. In order to reduce further accumulation of greenhouse gases GHGs, green generator or converter of energy has been designed to replace the conventional (fossil) energy sources. A new technology had been developed that is known as Natural Dye Sensitized Solar Cells (NDSSC), NDSSC consists of a group of photovoltaic cells that produce green energy at low cost of sensitization material production since no vacuum systems or low cost equipment are usedin fabrication process.Besides natural dyes from flowers, leaves, fruits can be easily obtained,non toxic and easily extracted. In NDSSC, when dye molecules exposed to light source, they became oxidized and the electrons will be transfered to nanostructured layer of wide bandgap semiconductor for example TiO_2. Next,the electrons created and produced outside the cell through ohmic contact to a load. This paper reviews the structure and working principles of dye sensitized solar cell DSCC. Discussing preparation procedures , optical and electrical characterization of the types of natural dyes, raspberry and blueberry. Nowadays, these type of natural organic dyes are explored and used as a sensitizer .This is due to replace number of the man- made dyes used as sensitizer in many commercialized photoelectrochemical cells.Dye sensitized solar cell with dimension 2.5 cm x 2.5 cm is fabricated by using screen printing method with thickness 10µm of titanium dioxide (TiO_2) by putting it on indium tin oxide (ITO) coated glass.Then, the solar cell is tested under sunlight. Dye extracted from raspberry with TiO_2 viscosity 1.0 g is the best natural dye were used, has value Isc (0.0367 mA), Voc (474mV) , FF (0.818), Pmax (0.0000142) and η(0.0568).

ABSTRAK

Sejak suku abad lepas, aktiviti penyelidikan bagi mencari sumber tenaga hijau telah dilaksanakan.Setiap tahun kita telah menggunakan pelbagai jenis sumber tenaga untuk memenuhi keperluan tenaga.Untuk mengurangkan pengumpulan gas rumah hijau (GHGs). penjana hijau atau penukar tenaga telah direka untuk menggantikan konvensional (fosil). Satu teknologi baru telah dibangunkan yang dikenali sebagai sel suria terpeka pewarna semula jadi (NDSSC), NDSSC terdiri daripada sekumpulan sel-sel fotovoltaik yang menghasilkan tenaga hijau pada kos yang rendah pengeluaran bahan pemekaan kerana tiada sistem vakum atau peralatan kos peralatan yang rendah yang digunakan dalam proses fabrikasi. Dalam NDSSC, apabila molekul pewarna terdedah kepada sumber cahaya, ia akan teroksida dan elektron akan dipindahkan ke lapisan nanostruktur yang mempunyai nilai jurang tenaga yang luas contohnya TiO_2. Seterusnya, sentuhan ohmik elektron yang terhasil akan dikeluarkan dari sel dan terus ke beban. Dalam kajian ini,kami mengkaji semula struktur dan prinsip sebuah sel suria terpeka pewarna DSCC.Kami membincangkan prosidur penyediaan, pencirian optik dan elektrik sebuah NDSSC menggunakan pewarna semula jadi, raspberi dan blueberry. Pada masa kini, pewarna organik semula jadi yang diterokai telah digunakan sebagai pemeka..Sel suria terpeka pewarna semula jadi dengan dimensi 2.5 cm x 2.5 cm adalah digunakan dan dengan menggunakan kaedah percetakan skrin dengan 10µm ketebalan titanium dioksida (TiO_2) dengan meletakkannya pada oksida timah indium (ITO) bersalut kaca.Selepas itu , sel solar diuji di bawah cahaya matahari. Pewarna yang diekstrak daripada raspberi dengan kelikatan TiO_2 1.0 g adalah pewarna semulajadi yang terbaik telah digunakan, mempunyai nilai Isc (0,0367 mA), VLT (474mV), FF (0,818), Pmax (0,0000142) dan η (0,0568).

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LIST OF ABBREVIATIONS

CDTE	-	Copper Indium Sulphide
CSI	-	Copper Indium Sulphide
CIGS	-	Copper Indium Gallium Selenide
DSSC	-	Dye Sensitized Solar Cell
FF	-	Fill Factor
ISC	-	Short Circuit Current (mA)
ITO	-	Indium Doped Tin Oxide
HOMO	-	Highest Occupied Molecular Orbital
LUMO	-	Lowest Unoccupied Molecular Orbital
NIR	-	Near Infrared
η	-	Efficiency
UV	-	Ultra Violet
VOC	-	Open Circuit Voltage (mV)
XRD	-	X – Ray Diffraction

CHAPTER 1

INTRODUCTION

1.1 Background

Solar cells have gone through a number of years and a number of phases. Their development can be described according to their construction principles .A solar cell is a photonic device that changes photons together with particular wavelengths to electricity. Alexandre Edmond Becquerel (French physicist) found out this photoelectrochemical (photovoltaic) impact in 1839 (Becquerel,1839) while he was investigating and analyzing the effect of light on metal electrodes absorbed through electrolyte, analyze in this area extended as well as technologies produce many different types and also structures of the materials presently used in photovoltaic (PV) technology. Most of photovoltaic industry uses wafer of single crystal and poly-crystal silicon as material for photovoltaic (PV) modules. However, the cost of these modules is high due to material and processing cost [1]

The first and the second generations of photovoltaic cells are generally mainly made of semiconductors which include crystalline silicon, III-V compounds, cadmium telluride, and copper indium selenide/sulfide [2,3].However, solar energy produces a limited application that directly related to its expensive cost to generate electricity per watt. At present, technology of solar cells determined by crystalline silicon is usually coping with a problem involving silicon-based raw materials. Consequently, low cost alternatives and new varieties of low cost solar cells is surely an urgent issue and have absolutely recently been the subject of the research work for the last three decade.

The name DSSC stands for “dye sensitized solar cell". A dye-sensitized solar cells (DSSC) is the latest technology of solar cells. It belongs to the group of thin film solar cell that have attracted considerable attention because of their low cost of production along with the environmental friendliness. Dye sensitized solar cell (DSCC) is a group in the third generation of solar cell that was found by O'Regan and Gratzel in 1991.

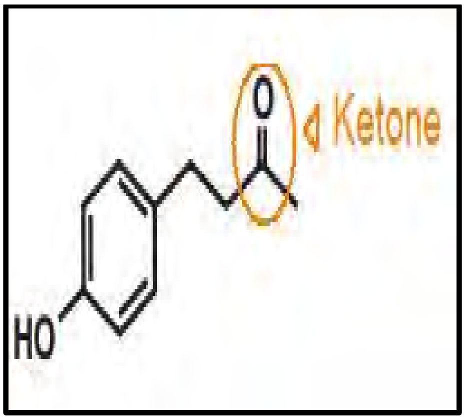
The simple assemble of solar cell (also referred to as photovoltaic device) operates by renovating affordable photon from solar energy to electrical energy according to sensitization of wide bandgap semiconductor, dyes and also electrolyte [4,]. The performance of dye absorption in DSSC is dependent on the sensitizer dye and wide bandgap material such as TiO_2 , ZnO_2 and Nb_2O_5 [5].Material TiO_2 always be chosen because its ability to the surface and to avoid the move of electron which take place under illumination solar photon. One of the ways to determine the efficiency of solar cell depends on the performance of dye absorption spectrum that is coated on the surface of TiO_2 [5,6]. The most efficient sensitizer, ruthenium polypyridyl complexcan be created from heavy transition metal coordination compound. This type of this sensitizer used widely because great charge - transfer (CT) absorption in the visible light spectrum and good absorption [8].On the other hand, high cost of ruthenium and hard to prepare highlights the need to identify low-cost, efficient sensitizers. Natural dyes are well known for their high absorption coefficient, cheap and easy availability, non-toxic and renewable reservoir to materials for many applications. Besides that, natural dyes compare to semiconductor solar cell are promising alternative sensitizers for DSSC because they are only available, easy to prepare, cheap and eco-friendly.

Natural dye extracted namely, raspberry and blueberry were prepared and characterized. This thesis discussing DSSC efficiency, optical and electrical characterization of the dye sensitized solar cells using dyes extracted.

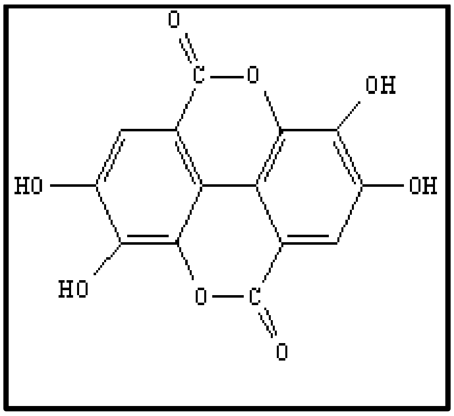
The raspberry would be edible fruit of a multitude of plant species in the genus Rubus of the rose family, majority of this fruits from the subgenus Idaeobatus Raspberries usually are perennial with woody stems. Rubus idaeus (raspberry, also known as red raspberry or occasionally as European raspberry to distinguish that from other raspberries) is usually a red-fruited species of Rubus native to Europe and northern Asia. This fruit is red in color, edible, and also sweet yet tart-flavored.

Figure 1-1: Red-fruited raspberry hybrids

Raspberries contain significant amounts of polyphenol antioxidants like anthocyanin pigments linked to potential health protection against several human diseases. Raspberries is a famous fruit and one of the top of all fruits for antioxidant strength, particularly due to their dense contents of ellgic acid (from ellagotannins), quercetin, garlic acid, and anthocyanin. Blueberries contain multiple nutrients, phytonutrients, polyphenols, salicylic acid, caratenoids, fiber, folate, vitamin C, vitamin E, manganese, iron, riboflavin, niacin and phytoesterogens. Research studies have shown that blueberries are one of the richest sources of antioxidant phyto-nutrients, with higher levels of anthocyanin and phenolic contents than other fruit or vegetable. Anthocyanins are powerful antioxidants which gives red, blue and purple colour to blueberry fruit. The darker, deeper blue and red fruits have the highest anthocyanin content; therefore they contribute the most potent antioxidant source.



(a)



(b)

Figure 1-2: Structure of raspberry (a) raspberry (b) anthocyanin raspberry dye

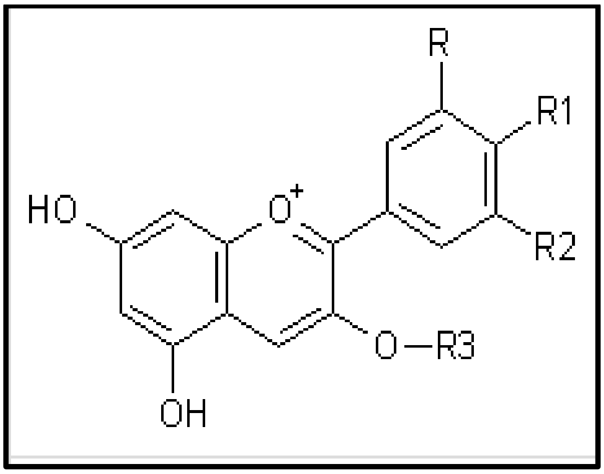


Figure 1-3: Chemical Structure of anthocyanin

1.2 Objective

This study concentrates on dye- sensitized solar cells (DDSC), which represent the third generation of photovoltaics. Crystalline silicon is being the first, and thin film technologies such as cadmium telluride (CdTe), copper-indium-gallium selenide (CIGS), copper-indium sulphide (CIS) and amorphous silicon (*a*-Si) being examples of the second generation. Introduced in the early 1990. DSSC is a photoelectrochemical device which operating principle mimics the photosynthesis reaction of the green plants. There are many advantages for (DSSC), for example it its simple and energy-efficient manufacturing, for the most part low cost, non-toxic and recyclable materials, and suitability for wide variety of end-user products. Also, as the DSC works better with low light intensities it is especially practical in indoor applications. The best DDSC efficiencies measured in the laboratory exceed already 10-11 % at the moment with carefully optimized cell configuration [9,10] which is comparable to the values typical for thin film technologies, which is comparable to the values typical for thin film technologies (5 – 13%) but still lack behind the crystalline silicon values which are already almost 20% .

This thesis is experimental by nature and there are some objectives of this final year project that need to be achieved due to following aspect below:

1. To review the structure and operation principles of dye sensitized solar cell DSSC.

2. To analyze the optical and electrical characterization of the natural dye sensitized solar cell using raspberry and blueberry.

3. To produce low cost fabrication of dye sensitize solar cell by using screen printing method.

1.3 Problem Statement

Energy plays a role of primary importance in our society, but the constraint of fossil fuel reserves along with issue related to pollution are resulting in an enhance the efficiency of energy processes in addition to reducing their losses and promoting renewable energy sources. One of the most interesting renewable energy from is Photovoltaic. Solar radiation, widely available all over the world, free and also inexhaustible, is used to produce electricity. However, despite its relatively high power density, the related cost of energy production is significantly higher compared to traditional energy sources. As a result, a new technology have been develop that is known as dye sensitized solar cells (DSSC), DSSC consists of group of photovoltaic cells that produces green energy at low cost of sensitization material production since no vacuum systems or low cost equipment are needed in their fabrication, in addition to being capable of working in the absence of direct light. Although, the principle of functioning is not complete clear yet, DSSC might represent a very competitive technology.

1.4 Scope of project

The scope of this thesis revolves around the understanding of solar cell physics and properties. It is important to know the dye sensitized solar cell performance, the effect of titanium dioxide (TiO_2) and natural dyes from fruits used as a sensitize and also know the chemical properties of TiO_2 for DSSC fabrication. In this thesis, the dye sensitized solar cell (DSSC) is fabricated by using screen printing method. The use of dyes and titanium dioxide ($Ti0_2$) is one of the most promising approaches to obtain both high performances at low cost. Finally, the important parameters of the DSSC such as short circuit current (Isc), open circuit voltage (Voc), fill factor (FF) and efficiency (η) are known.

CHAPTER 2

LITERATURE REVIEW

The purpose of this chapter is to provide a review of past research about the solar cell. This part also describe about dye- sensitized solar cell (DSSC).

2.1 Brief History

Solar cells are a device that directly converts the energy of sunlight into electricity through the process of the photovoltaic. Solar cells have gone through number of years and usually divided into the main categories called generations. The first generation of solar cells are expensive to produce and high efficiency. Second generations are usually called thin film solar cells that have an even lower efficiency, low cost of production, such that the cost per watt is lower than compare to first generation cells. The latest technology, third generation the cells that are very efficient.

First Generation Solar Cells is the earliest and the mostly common used technology type due to high efficiencies made from silicon. To increase power of solar cell, the solar modules which consist of many cells are used. Monocrystalline and Polycrystalline is one of group from crystalline silicon and this type of solar cell represents traditional technology for solar panel.

Monocrystalline Silicon Cells is one of the solar cell that made from thin wafer of silicon and good efficient solar cell.This wafer needs careful attention because the cells are sliced from large single crystal. The cells monocrystalline show a higher efficiency compare to other of cell (up to 24.2%), that means more electricity is get from the area of given panel.

Polycrystalline cells are produced from the same silicon material but not being implanted in a single crystal, they are melted and poured directly into molds. After that, the cell forms a square block. Next, the cell are cut into square wafer with a smaller amount waste of space or even material than round single-crystal wafers. When the material cools, it crystallizes in a way that is not perfect, forming random crystal boundaries. Energy conversion efficiency is slightly lower. The size of the finished module is slightly greater than the per-watt module that most single crystals. The particular cells likewise appear various compare to single crystal cells and surface features look regularly in many variations of the color blue.

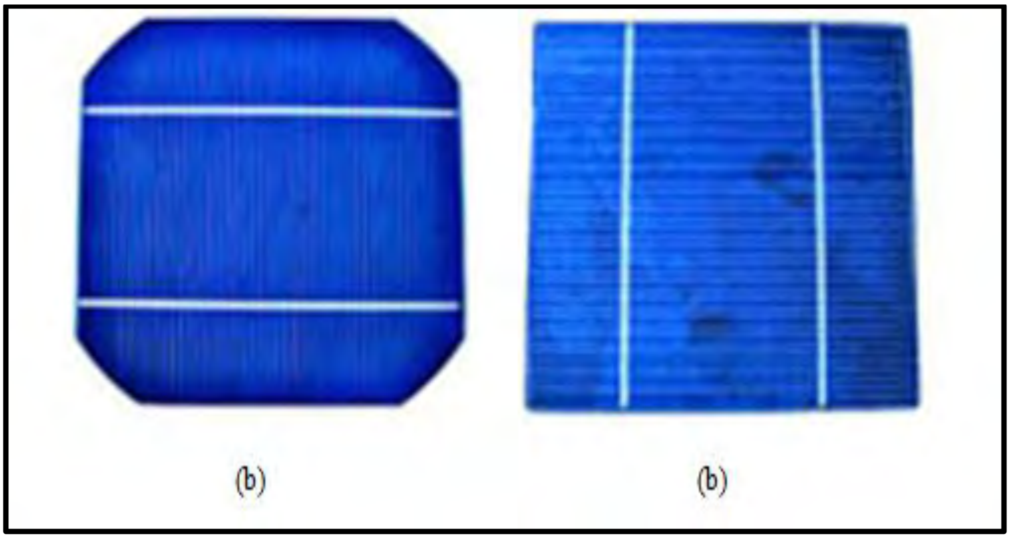


Figure 2-1 : (a) Monocrystalline Silicon Cells and (b) Polycrystalline cells

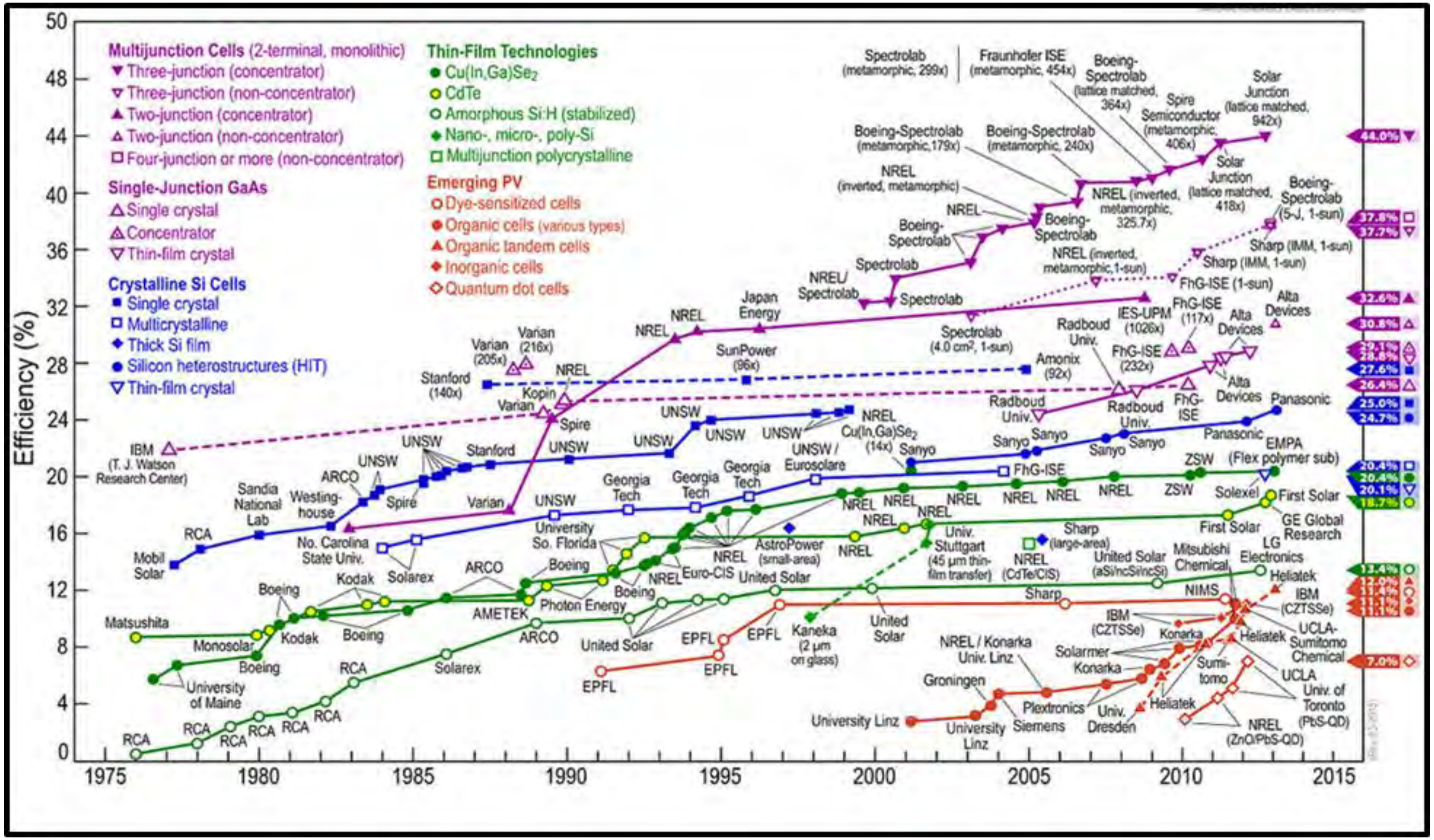


Figure 2.2: Reported best research cell efficiencies

Second generation of solar cell are usually called thin film solar cell. The cell from this group made from layer of semiconductor material only a few micrometer thick. Solar panel from this group is classified as a low cost of production because the materials use for manufacturing process is less. Based on figure 2-2, the second generation of PV cells shown by the green lines use photolithography to deposit layers of materials on a base material known as a substrate. Photolithography is like stenciling and is also used to make semiconductor devices. In 1976, David Carlson and Christopher Wronski of RCA Laboratories created the first amorphous silicon PV cell with an efficiency of 1.1%.Example of solar cells in this category, amorphous Si (a-Si) based thin films solar cells, Cadmium Telluride/Cadmium Sulfide (CdTe/CdS) solar cells and Copper Indium Gallium Selenide (CIGS) solar cells and so on.

Cadmium telluride (CdTe) also enable high volume, low cost production of solar modules with an automated process that requires using 98% much semiconductor materials, less energy and water. CdTe show the highest efficiency is about 18.5% by First Solar who seem to be leaders in the technology. CIGS is often tetrahedrally bonded semiconductor, with all the chalcopyrite crystal structure along with a bandgap varying consistenly having afrom about 1.0 eV (for copper indium selenide) to about 1.7 eV (for copper gallium selenide). CIGS also known as an alternate solar cell material in thin-film solar cells and have a good efficiency. Besides that, CIGS a leader among alternative cell materials.There are many advantages of CIGS, for example, produce flexible and lightweight solar panel. CIGS also can be deposited on flexible substrate materials

Third Generation Solar Cells is very different from the previous semiconductor device and contains a wide range of potential solar cells. This type of solar cell from this group including nanocrystalline cells, organic solar cell and dye sensitized solar cells. Dye sensitized solar cell (DSSC), which are latest technology in solar cells, was found by Gratzel and O‟Regan in 1991. DSSC are based on dye molecules between electrodes. Electron hole pairs occur in dye molecules and transported through TiO2 nanoparticles. Their production is easy with respect to other technologies and environmental friendly. The advantages of DSSC are low cost regarding sensitization material production, easier manufacturing as well as low process of temperature. In figure 2-1, reported best research cell efficiencies (Source:

National Center for Photovoltaics (NREL) has published an impressive chart that shows all solar cell record efficiencies since 1975.Redline on chart includes solar inks using conventional printing press technologies, conductive plastics and solar dyes. The Chart also shows that research into dye sensitized solids began in 1991 and research into organic cells began in 2001. Mitsubishi Chemical"s 2006, surprise that thin-film organic solar cell had an efficiency of 4.9%.By 2012, Mitsubishi had increased the efficiency to 11%. Moreover, they are presently working on how to improve efficiency by creating organic cells with multiple layers.

2.2 Structure of dye sensitized solar cell (DSSC)

The dye sensitized solar cell contains several components such as transparent conducting and counter conducting electrodes, the nanostructured wide bandgap semiconducting layer, the dye molecules (sensitizer), and the electrolyte.The schematic structure of the dye sensitized solar cell is show in figure 2-3.

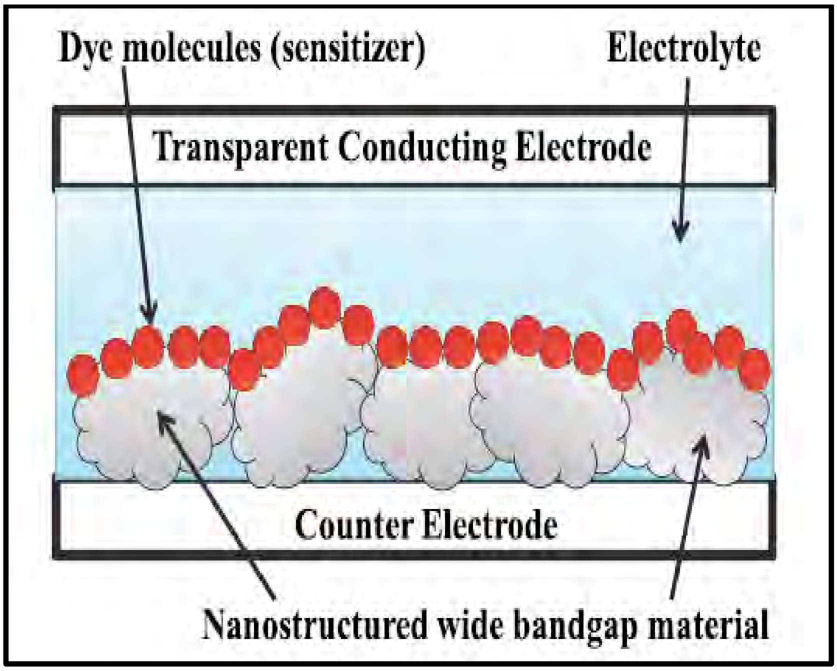


Figure 2-3 : Structure of the dye sensitized solar cell