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Fabrication & Measurement of Characteristics and Stability of Solar Cell with Pomegranate

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Abstract:- **Dye sensitized solar cells are gaining importance due to their low cost. Further the use of natural pigments as sensitizing dye for the conversion of solar energy to electricity is interesting because on one hand it enhances the economical aspect and on the other it has significant benefits from environmental point of view.**

This work presents a Pomegranate as natural days in DSSCs. The parameters of interest were efficiency and stability. DSSCs were fabricated and V-I characteristics were studied on the first, day second and the tenth day. It gives higher efficiency.

Keywords— **Solar Cell, DSSC, Pomegranate, TiO_2, acetic acid, Silicon Plate**

I. INTRODUCTION

A dye-sensitized solar cell (**DSSC**, **DSC** or **DYSC**) is a low-cost solar cell that belongs to the group of thin film solar cells. It is based on a semiconductor formed between a photo-sensitized anode and an electrolyte, a photo electrochemical system. The DSSC has a number of attractive features. It is simple to make using conventional roll-printing techniques, semi-flexible and semi-transparent which offers a variety of uses not applicable to glass-based systems and most of the materials used are at low-cost.

A Modern DSSC is composed of a porous layer of titanium dioxide nano particles, covered with a molecular dye that absorbs sunlight, like the chlorophyll in green leaves. The titanium dioxide is immersed under an electrolyte sol ution, above which these is a platinum-based catalyst.

DSSCs are currently the most efficient third-generation solar technology available. Other thin-film technologies are typically between 5% to 13% and traditional low-cost commercial silicon panels operate between 14% and 17%.

The use of natural pigments as sensitizing dye for the conversion of solar energy in electricity is interesting because on one hand it enhances the economical aspect and on the other it has significant benefits from the environmental point of view. Natural pigments extracted from fruits and vegetables, such as chlorophyll and anthocyanins, have been extensively investigated as sensitizers for DSSCs. This work investigates the use of pomegranate as natural pigment.

II. OBJECTIVE OF THE SYSTEM

The main aim of the green generators or converters of energy is to replace the conventional (fossil) energy sources, hence reducing further accumulation of the Green House Gasses GHGs. Conventional silicon and III-V semiconductor solar cell based on crystalline bulk, quantum well and quantum dots structure or amorphous and thin film structures provides a feasible solution. However, Natural Dye Sensitized Solar Cells NDSSC are a promising class of photovoltaic cells with the capability of generating green energy at low production cost since no vacuum systems or expensive equipment are required in their fabrication. Natural dyes are also abundant, safe and easily extracted. In NDSSC, once dye molecules exposed to light they become oxidized and transfer electrons to a nano structured layer of wide bandgap semiconductors such as TiO2.

The generated electrons are drawn outside from the cell through ohmic contact to a load. In these papers we review the structure and operation principles of the dye sensitized solar cell DSSC. It discuses preparation procedures, optical and electrical characterization of the NDSSC using local dyes extracted from Henna (Lawsonia inermis L.), pomegranate, cherries and Bahraini raspberries (Rubus spp.). These natural organic dyes are potential candidates to replace some of the man-made dyes used as sensitizer in many commercialized photo electrochemical cells. Factors limiting the operation of the DSSC are discussed. NDSSCs are expected to be a favored choice in the Building-Integrated Photo Voltaic (BIPV) due to their robustness.

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Therefore, there is no requirement of special shielding from natural events such as tree strikes or hails.[1]

III. Solar Cell Terminology

Organic Solar Cell Terminology

Dye: A chemical pigment molecule or compound that will absorb light.

Electrode: A solid that makes contact with the electrolyte in a electrochemical cell so that current may flow.

Nano: A SI prefix meaning 10' of a unit. One nanometer is one billionth of a meter.

Nanocrystalline: A material made up of minute Photovoltaic Effect: regions that are each in the range of 1-100 billionths of a meter in dimension.

Nonrenewable Energy Sources: Resources that are depleted faster than they are replenished. Examples: wood, oil, natural gas and coal.

Organic: Pertaining to living organisms, compounds or molecules formed by living organisms and to the chemistry of compounds containing the element carbon.

Photovoltaic Cell: A device that converts radiant energy (photons or light) into electricity. Photo stands for photon and voltaic stands for the voltage produced from the photons. The flow of electrons from a substance by the action of light (or photons). Photo comes from the Greek work for light and voltaic stands for the voltage produced from the photons.

Tin Dioxide (SnO_2): An oxide of the metal tin (Sn) which has the useful property of being both electrically conductive and optically transparent.

Titanium Dioxide (TiO_2): The oxide of the metal titanium used as the white pigment in paint. It is found in nature as the minerals rutile and anatase. Titanium metal is used in the production of steels and corrosion resistant metal alloys of high strength.

Parameters of Solar Cell

- Short Circuit Current (Isc):- The short-circuit current is due to the generation and collection of light generated carriers.

- Open Circuit Voltage (Voc):- When load is connected to the PV cell current flows through the circuit and the voltage goes down.

- Maximum Power (Pm):- Power out of solar cell increases with voltage, reaches maximum (Pm) and decreases again.

$$P_{max} = V_{max} \times I_{max}$$

- Fill Factor (FF):- The FF is defined as the maximum power from actual solar cell to the maximum power from ideal solar cell.

$$FF = \frac{V_{max} \times I_{max}}{V_{oc} \times I_{oc}}$$

- Efficiency (η):-Efficiency is defined as ratio of energy output from solar cell to input energy from sun.

$$\eta = \frac{\text{Max cell power}}{\text{Incident light intensity}} = \frac{V_{max} \times I_{max}}{P_{in}} = \frac{V_{oc} I_{sc} FF}{P_{in}} \times 100$$

The efficiency is most commonly used parameter to compare the performance of one solar cell to another. Efficiency depends on solar spectrum, intensity of halogen and the temperature of solar cell.

IV. The Nanocrystalline Dye Sensitized Solar Cell

The story of the nanocrystalline solar cell started in the late 19th century within the principles of photography. It was discovered that certain colored organic dye molecules allowed silver chloride based photographic film to respond a wider range of visible wavelengths than it otherwise could. Modern photography is based on sensitization of silver halides (the group to which chlorine belongs) using days. The mechanism for this sensitization in modern photography involves the electron transfer from the organic molecule to the semiconducting, silver halide panicles in the photographic film a process known as electron injection.

In contrast to conventional solar cells, the nanocrystalline dye sensitized solar cell is a photo electrochemical cell. It resembles natural photosynthesis in two respects: I) It uses an organic dye like chlorophyll to absorb light and produce a flow of electrons, and 2) It uses multiple layer to enhance both the light absorption and electron collection efficiency. Like photosynthesis, it is a molecular machine that is one of the first devices to go beyond microelectronics technology.

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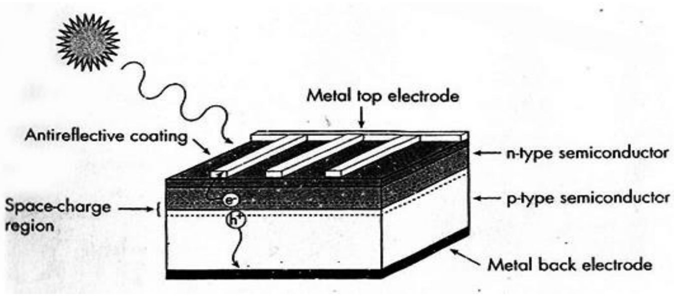

Fig. 1 Typical Silicon Solar Cell

To create the nanocrystalline solar cell, a suspension of nanometer size particles of *titanium dioxide,* TiO_2, is distributed uniformly on a glass (SiO_2) slide which has previously been coated with a thin conductive and transparent layer of *tin dioxide,* SnO_2. The TiO_2 film is dried and then heated on the glass to form a porous, high surface area TiO_2 film. When magnified, it looks like a thin sponge or membrane.

The TiO_2 film on the glass slide is dipped into a solution of a dye such as an organometallic complex or a green chlorophyll derivative. Many natural dyes can be utilized, but they must possess a chemical group that can attach *(adsorb)* to the TiO_2 surface, and they must have *energy* levels at the proper positions necessary for electron injection and sensitization.

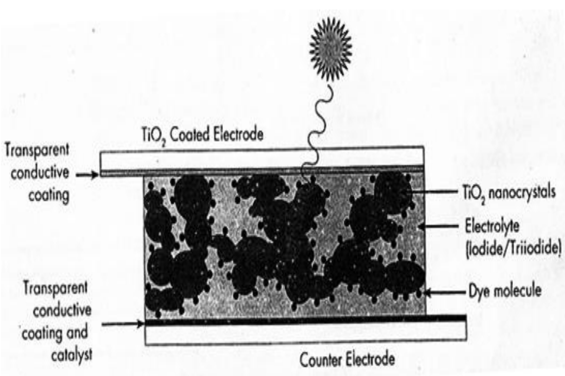

Fig 2 A single layer of dye (shown as black dots) adsorbing to the titanium dioxide (TiO_2) nanocrystals in the nanocrystalline dye sensitized solar cell

Even with these limitations, calculations that consider the spectrum of the light utilized by the dye indicate that nanocrystalline solar cells of at least 10% efficiency which may be competitive with conventional electricity generation. These cost estimates illustrate the promise of the new devices, but further research and development is needed to find ways to seal the cell and allow it to withstand the test of time so that it can be used in large-area commercial solar cells.

V. CREATING A SOLAR CELL

➢ **Background:-**

Conventional solar cells convert light into electricity by exploiting the photovoltaic effect that exists in semiconductors, the semiconductor in a typical solar cell is a single *crystal* of silicon that performs two processes simultaneously:

Absorption of light and separation of the electric charges, negatively charged electrons and positively charged holes, are formed when light absorption excites electrons in the crystal to higher energy levels. The silicon used in conventional solar cells must be highly pure and defect-free.

The nanocrystalline solar cell works on a different principle in which the processes of *light absorption* and charge separation are themselves separated. As shown in Figure 3, light absorption is performed by a single layer of dye (usually a metal organic compound or a metal complex) that is chemically attached to the rough surface of a layer of interconnected titanium dioxide (TiO_2) particles on conductive transparent glass. The minute particles of TiO_2 are single crystals, ranging between 10 and 50 billionths- of a meter in size are called nanocrystalline.

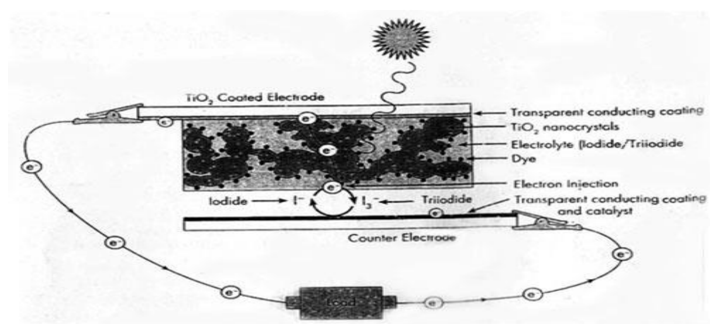

Fig. 3. Nanocrystalline dye sensitized solar cell

Electrons flow from the TiO_2 coated electrode of the nanocrystalline solar cell through the load and back to the counter electrode of the nanocrystalline solar cell when the solar cell is excited by light (photons), the colored dye is able to transfer an electron to the semiconducting TiO2 layer. This process is called electron injection or sensitization. This electron transfer is actually similar to the process used in color photography.

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- **Objectives of the Experimental Procedure**

This procedure will demonstrate the operating principles of the nanocrystalline solar cell and photosynthesis. The objectives of the experiment are: (a) to extract the natural dye (b) to deposit the TiO_2 nanocrystalline ceramic I film on conductive glass (c) to determine how the physical and the electronic coupling of an organic compound to an oxide semiconductor can occur via complexation and chelation and (d) to determine the current-voltage and power output to the chemical processes occurring in photosynthesis in green plants.

VI. STEPS FOR THIS SYSTEM

- **Equipment and Materials List:-**

- Conductive, tin dioxide coated, transparent glass slides per cell (2.54' cm X 2.54' cm) (included).
- 6 g colloidal titanium dioxide powder (per suspension batch) (included).
- Copper foil tape: 3M No. 1181 with pressure sensitive conductive adhesive (included).
- Iodide electrolyte solution in a dropper bottle (included): 0.5 M potassium iodide mixed with 0.05 M iodine in water-free ethylene glycol or a suitable organic solvent.
- Soft graphite pencil (HB woodless graphite pencil) (included). Graphite pencils can be purchased from any art supply store. Alternatively, an artist's charcoal pencil, a cleaned carbon rod taken from an alkaline battery or soot from a candle flame can be used
- Binder clips (included). Two clips are used per cell. The binder clips should be bent so that the pressure they exert may not too great. The jaws should be partially opened.
- Glassine envelopes for storing glass slides (included)
- Dropper bottle for TiO2 suspension (included)
- Surfactant (such as Triton X 100) or clear dishwashing detergent
- Light source: halogen lamp
- Heat Source
- Ceramic top hotplate (must be able to reach ~450 °C)
- Nitric or acetic acid solution (10 mL of pH 3-4 in deionized water < 0.001 M HNO3; < 0.057 M CH,COOH) or 0.2 mL acetyl acetone
- Polycarbonate (Lexan) plastic plate (2.5 cm X 2.5 cm)
- Ethanol and deionized water in wash bottles
- Pomegranate seeds for organic dye
- Multimeter (2 digital multimeters are best)
- Alligator dips (large, they should exert a large pressure when ciosed)
- Hookup wire (black and red)
- Pipettes (or auto pipette)
- Mortar and pestle
- Clamps, ring stand and ring for positioning solar cell in light source
- Tweezers or forceps
- Tongs
- Petri dish or beaker
- Transparent tape
- Glass stirring rod
- Absorbent tissue paper
- Cotton swabs
- Filter paper and glassware for filtration
- Protective gloves and tight fitting

- **Preparing the TiO_2 Suspension (Day One, Part One)**

- In 1-mL increments, add 9 mL of nitric or acetic acid solution (pH 3-4 in deionized water) to 6 g of colloidal Degussa P25 TiO_2 powder in a mortar and pestle while grinding. The grinding process mechanically separates the aggregated TiO_2 particles due to the high share forces generated. Add each 1 mL addition of the dilute acid solution only when the previous maixing and grinding has produced a uniform and lump–free suspension with a consistency of a thick paint. The grinding process requires approximately 30 minutes and it should be performed in a ventilated hood.
- To the TiO_2 paste, add a drop of a surfactant (such as clear dish detergent or Triton X100) in 1 mL of water. This allows the final suspension to more uniformly coat the glass slides in the steps described below. So as not to produce roam, the TiO_2 suspension should not be ground or agitated after the surfactant is added.

Fig. 4 Grind of nanocrystalline titanium dioxide in a mortar and pestle & A few drops of Triton X-100 surfactant.

- Store the TiO_2 suspension in a small capped bottle (use provided dropper bottle) and allow it to equilibrate for at least 15 minutes for best results

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- **Deposition of the TiO_2 film (Day one, Part two)**

1. Obtain and clean two glass conductive slides by rinsing them in ethanol and then drying with a soft tissue, use the same technique as with cleaning a pair of eyeglasses.
2. Use a multimeter set to ohms to check which side of the glass is conductive; the reading should be between 10 and 30 ohms

Fig 5 Identify the conducting side of glasses

3. Orient one glass slide conductive side up. This slide will be coated with the TiO_2 suspension
4. Apply two 6-7 cm pieces of Scotch (3M) adhesive tape to the top faces of the glass slides to mask a strip not more than 1 mm wide on the two longer edges.
5. Apply another piece of adhesive tape along with the top of the glass to be coated with a mask 4-5 millimeter strip.

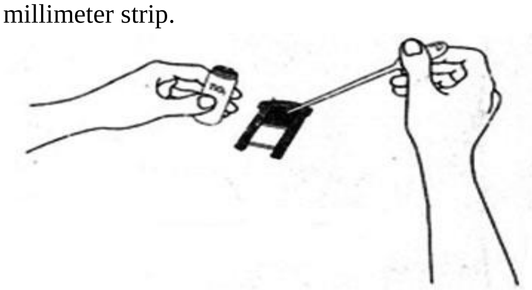

Fig. 6 Orientation of conductive glass slides, masking of slides and application of TiO_2 to the surface of the conductive slide

This tape has a controlled thickness and will form a 40-50 micron deep mold or channel into which the TiO_2 suspension can flow.

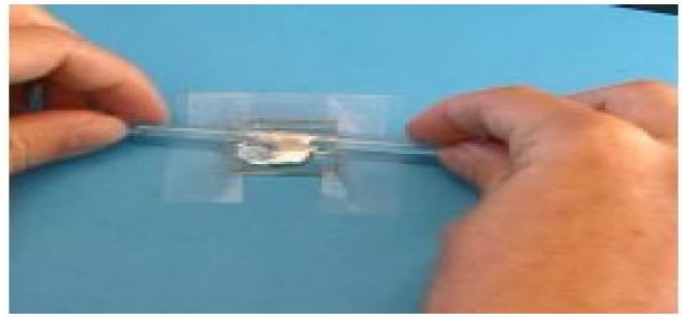

Fig. 7 The titanium dioxide paste and spread using a glass rod

6. To coat the glass, a thin line of the TiO_2 suspension is uniformly applied to the edge of the slide near the tape using the dropper bottle or a pipet. The amount or solution utilized is approximately 5 microliters per square centimeter ($\mu L/cm^2$).

7. Within five seconds after application of the TiO_2 suspension, slide a clean glass stirring rod (held horizontally) over the slide to spread and distribute the material (see Figure 8)

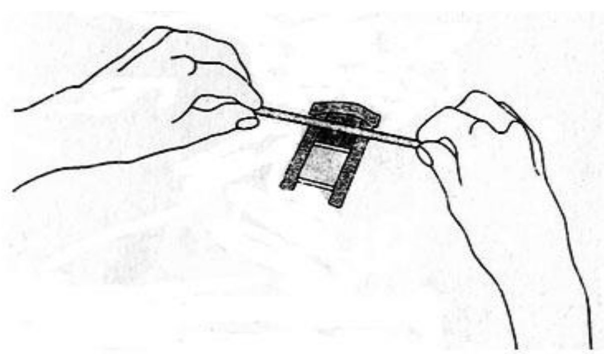

Fig. 8 A rapid sweeping motion with the glass rod is used to coat the titanium suspension (or paste) on the masked conductive glass slide

8. After deposition of the suspension, remove the tape carefully. Place the slide in a petri dish and cover it. Allow the TiO_2 film to dry for one minute. Wash clean the glass rod and dry the slide that was conductive side down.

9. Anneal the TiO_2 film on the conductive glass Heat the glass slide by using a ceramic top hotplate in a hood.

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Fig 9 Heat the glass on a hotplate in a hood

Note: the hotplate must be able to reach a temperature of ~450^0 C. place the glass slide (titanium dioxide film up) on top of the hotplate set on high. Heat for 10-20 minutes.

10. During heating, the film may turn light brown and then back to white. After the annealing is completed, allow the TiO2 coated conductive glass to cool the room temperature slowly. This will take approximately fifteen minutes.

Staining the TiO2 with Anthocyanins Dye (Day Two, Part One)

1.Crush same fresh Pomegranate Seeds, in 2 mL ionized water and filter. The filtered solution is an anthocyanin dye solution.

Fig. 10 Immerse the coating in a source of anthocyanins such as pomegranate

2. Place the anthocyanin solution in a beaker or petri dish and place the TiO_2 coated film in the solution fare down. Soak the TiO_2 coated glass slide for 10 minutes in the filtered berry solution

3. Wash the film (which is stained a dark purple) in water and then in ethanol or isopropanol.

4. Gently blot dries the TiO_2 film with a tissue.

VII. RESULT

The completed solar cell or light detector can be taken outside and measured under illumination by sunlight. In order to protect the cell from damage by excessive UV light, a polycarbonate plastic cover should be placed over the cell. Light enters the glass "sandwich" through the TiO_2 coated glass slide. Measurements can be taken with a multimeter to determine if the procedure was successful. Maximum current and voltage output can easily be determined by attaching a multimeter directly to the two sides of the cell using wires with alligator clips attached to their ends.

- **Output characteristics of solar cell when Pomegranate is used as a natural dye**

- **Day one**

1.	Name of organic dye	Pomegranate seeds
2.	Quantity of Dye	20 ml
3.	Light Intensity	600*10 lux
4.	Active Area of Solar cell	4cm^2

TABLE 1:- INPUT PARAMETERS OF SOLAR CELL

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S.No	Current(mA)	Voltage(V)
1	0	0.36
2	0.1	0.33
3	0.2	0.30
4	0.3	0.28
5	0.4	0.26
6	0.5	0.25
7	0.6	0.24
8	0.7	0.23
9	0.8	0.21
10	0.9	0.18
11	1.0	0.15
12	1.5	0.12
13	1.8	0.06
14	1.9	0

TABLE 2 OBSERVATION TABLE

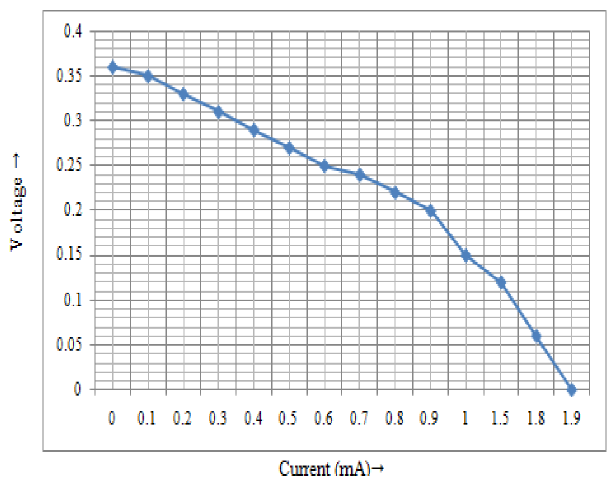

Fig. 11 Graph showing between current and voltage

The output characteristics of solar cell on day one are shown in fig. 11. The graph shown & between current & voltage. The current is on x-axis and voltage is y-axis calculated the value of I_{max} and V_{max} using the graphs. The results are shown in table 3.

S.No	Parameters	Value
1	I_{sc}	1.9 mA
2	V_{oc}	0.36 V
3	I_{max}	0.97 mA
4	V_{max}	0.208 V
5	P_{max}	0.189 mW
6	F.F	29.49%
7	η	5.75 %

Table 3 Output Characteristic Of Solar Cell

As shown in table 2, the efficiency on day one is 5.75%.

- **Day 2**

S.No	Parameters	Value
1	I_{sc}	1.8 mA
2	V_{oc}	0.34 V
3	I_{max}	0.8 mA
4	V_{max}	0.23 V
5	P_{max}	0.184 mW
6	F.F	30%
7	η	5.25 %

The efficiency on day two is 5.25%.

- **Day 10**

S.No	Parameters	Value
1	I_{sc}	1.5 mA
2	V_{oc}	0.26 V
3	I_{max}	0.85 mA
4	V_{max}	0.15 V
5	P_{max}	0.1275 mW
6	F.F	32.69%
7	η	3.63 %

The efficiency on day ten is 3.63%.

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VIII. CONCLUSION

Dye sensitized solar cells were fabricated using Pomegranate as a natural dyes. Output characteristics were measured on day one, day two and day ten for each. When Pomegranate is used as natural dye it was found that on **day one**, Voc=0.36V, I_{sc}=1.9mA, FF=29.49% and $\eta =$5.75%. On **day two** V_{oc}=0.34V, I_{sc}=1.8mA, FF=30.0% and $\eta =$5.25%. On **day ten** Voc= 0.26 V, I_{sc}=1.5 mA, FF = 32.69% and $\eta =$3.63 % .

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