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Fabrication and Testing of a Dye-Sensitized Solar Cell Made from Dragon Fruit Dye

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Abstract – Dragon fruit coloration was made and utilized as sensitizer in the manufacture of DSSC. UV-Vis and FTIR technology examined the characteristics of dragon fruit colorings. A maximum of 535 nm is shown in the absorption spectra. Dragon fruit coloring reveals the intermolecular H-bond, C = O conjugate stretch and C-O-C esters, which is caused by anthocyanin component. On the other hand, the resistivity of TiO2 on ITO glass is also studied before it is utilized in the manufacture of DSSC. The resistivity of sheets increases from 1 layer = 22.1 = 2 layers = 369.6 = 2 layers. The TiO2 sheet is increased by 1 layer. Finally, a personalized approach was used to analyze and simulate the efficiency of assembling DSSC. The result reveals that, while halogen lamps present, the fill factor, Pmax and efficiency were 0.30, 13 µW, 0.22%. In order to prepare the environmentally friendly and cheap DSSC the DSSC has been shown effectively to be helpful with dragon fruit as a color sensitiviser.

Keywords – Dye-Sensitized Solar Cell, Natural Dyes, TiO2 Film

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INTRODUCTION

Dye-sensitized solar cell (DSSC) was created by O'Regan and Gratzel in 1991 as the third generation of solar cell. This basic assembly of solar cell (also known as a photovoltaic device) is based on a sensitisation of wide-band semiconductor, dyes and electrolyte, converting cheap photons from solar energy to electrical energy[2,3]. The advantages of DSSC include its flexible sheets, low cost of manufacturing sensitizing material, simplicity of manufacture, and low process temperature. Due to the lower cost of the total manufacture of DSSC, the DSSC kind of solar cell has been predicted to yield greater ROI than the silicone solar cell type (Si-SC). Depending on the sensitizer and wide bandgap material like TiO2, ZNO and Nb2O5, the performance of the DSSC is heavily reliant. The surface capacity of Material TiO2 is more preferred to resist the continuous electron transfer under the light of solar photograph (ultra-violet range). The performance of the dye absorption spectrum put on the surface of the TiO2 molecule is important for the determination of solar cell efficiency. Ruthenium Polypyridyl [4] is one of the most efficient sensitizers for heavy transition metal coordination. Due to its high load transmission (TL) absorption in the visible light spectrum, its good absorption, it's very efficient transmission of charge and long term excitement, the complex is widely used (MLCT).

However, it is highly costly and difficult to make the ruthenium based complex. There is, thus, a comparable feature alternative organic teint, like genuine teeth with high absorption coefficients [5], proposed. Natural dyes are ideal for their availability, are environmentally friendly and cost-effective. The sensitising ability of the natural colour is related to the characteristics of anthocyanins (5-6). It is responsible for showing kinds of colour pigments in visible Red-to-Blue spectrics in the anthocyanine molecule as carbonyl and hydroxyl that occurs in fruit, leaves and flowers naturally. Variable natural anthocyanin sources provide a range of sensitive results in the prior investigations. In this article DSSC is made from dragon fruits (Hylocereus costaricensis), which are employed as sensitizers, utilising natural fruit colouring. Because of its extensively available in local areas and cheap conservation costs, dragon fruit-based dye has been selected. It next examines the spectrum of colour absorption, electrical characteristics of the TiO2 and DSSC efficiency.

BASIC OPERATION OF DYE-SENSITIZED SOLAR CELL (DSSC)

DSSC's whole structure, Photons hit through conductive glass layer under lighting of Sunlight energy; Indium-doped tin oxide (ITO) towards dye molecules mounting on TiO2 particle surface. The photon excitement of the colour causes an electron to be injected into the TiO2 layer conduction band. These electrons flow through the load through the external loop. Meanwhile, the electron-donated tealing molecule (containing iodide/threiodide), which was lost in this experiment; a potassium iodide (KI) and iodine (I2) combination, will be regenerated by electron donations from redox electrolytes [3]. This method quickly avoids any previously rejected recombination of electrons. Under lighting, a possible difference of voltage between Fermi's TiO2 layer level and redox electrolytes is created.

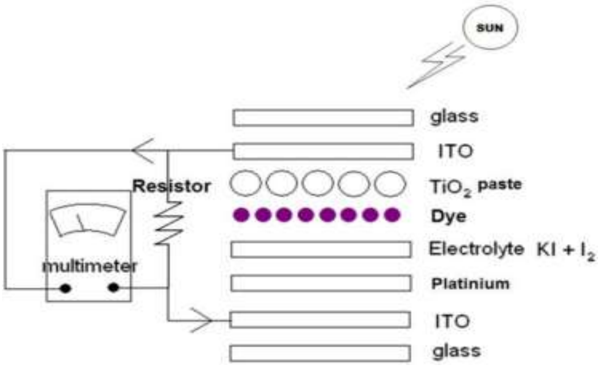


Figure 1: The cross section consists of ITO glass, TiO2 film, dragon fruit coloring, the electrolyte and the platinum layer on the ITO glass, organized to create a full solar cell sensitizing cycle.

Construction and working of DSSCs

Four important characteristics of a DSSC include the operating electrode, the sensitizers (faring), the redox mediator and the counter electrode. DSSC is a working electrode assembly that, by use of a heat melting tape, is soaking in the counter electrode and sealed to a counter electrode soaked in a fine electrolyte layer to avoid electrolyte leakage. Following are the components and the design and operation of DSSCs:

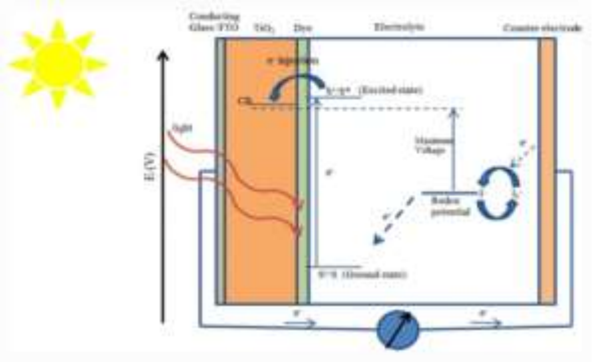


Figure2: construction and working principle of the dye-sensitized nanocrystalline solar cells

Transparent and Conductive Substrate

DSSCs are usually made of two sheets of transparently conductive materials, supporting the substratum for semiconductor and catalyst deposition and functioning as existing collectors [7]. The substrate is utilized in DSSC with two major characteristics: Firstly, the substratum requires more than 80% transparency in order to allow optimal sunlight to flow into the cell's effective region. Second, it should have excellent electrical conductivity for the effective transfer of charge and decreased energy loss in DSSCs. Topical use in DSSC's is typical for fluorine-doped tin oxide (FTO, SnO2:F) and indomodoped tin oxide (ITO, In2O3:Sn). These substrates are made of soda limestone, covered with indium doped tin oxide layers and fluorine doped tin oxide. The feeds are >80% and 18 pounds/cm2 of sheet resistance; the FTO films are 75% lower and the feeds resistance is 8.5 pounds/cm2 [8] in the visible region. [8]

Working Electrode (WE)

The working electrodes (WE) are manufactured by depositing a thin layer of semiconductive oxide, such as TiO2,Nb2O5, ZnO, SnO2(n) and NiO, on a clear, conducting glass panel consisting of ITO or Fto (P type). The width of oxide energy is 3–3,2 eV. Due to the high energy band gap of 3.2 eV the usage of allotropic anatase forms of TiO2 deserves DSSCs considerably more compared to rutile forms, while the rutile forms have a band gap of approximately 3 eV. TiO2 is mainly utilized as a semiconducting layer since it is untoxic, less costly and easier to use. However, only a tiny percentage of the light in the UV area absorbs those semiconducting layers. Consequently, these working electrodes are then submerged in a combination of a molecular sensitizer with a solvent. The dye is covalently connected to the surface of TiO2 upon soaking the film in the dye solution. Thanks to the extremely porous structure and the wide surface of the electrode, the nano-crystalline TIO2 surface is connected with a high number of dye molecules.

Different Ways to augment the efficiency of DSSCs

Researchers must concentrate on fundamental manufacturing processes and materials and the workings of these cells to improve the efficiency and stability of DSSCs. The following are some approaches for improving solar cell efficiency (SCs):

- The oxidized teal must be strongly reduced, following electron input, to improve the efficiency of DSSCs to its initial ground state. In other words, in comparison to the oxidation process of the dye, the regeneration procedure should be quick.
- Maximum dye absorption is carried out at W E by increasing the porosity of the TiO2 nanoparticles.
- Reduce or restrict dark current generation by placing the TiO2 nanoparticles on a conduction glass plate, using a uniform thin layer or under the layer. So, the electrolyte does not have a direct contact with the FTO or the back contact and therefore does not

reduce the generation of a dark current by the collector electrons.

- Prevents TBP molecules or electrolyte solvents from capturing the nanoporous TiO2 nanoparticles. A consistent awareness of the WE is therefore necessary from a sensitizer.

- Another approach to enhance the efficacy of DSSC is co-sensitization. Two or more sensitizing colors with differing ranges of absorption are combined together during co-sensitization. Expand the reaction range of the spectrum [9].

- by promoting the use of diverse materials in the manufacture of electrodes such as nanotubes, carbon nano wires and graphens; by using various electrolytes in place of a liquid such as gel electrolyte and virtually solid electrolyte; through various preparatory treatments for the working electrode such as anodization and TiCl4 therapy.

Limitations of devices

Comparable efficiency for DSSCs have been reported in the last several years, however because to the limits connected with these cells, they still need further changes. Stability failure in two separate classes may be defined as limited by I restricted external stability and (ii) limited internal stability. Due to the energy imbalance between the oxidized dye and an electrolyte, an enormous energy loss in the regeneration process occurs too. Thus, several electrolytes were created in the queue to improve the efficiency of these cells. In conjunction with a mix of TBP and Li [CF3SO2]2N hole conductor matrix, Grätzel et al. reported over 900mV ISC open circuit voltages and short circuit currents of up to 5.1mA resulting in an overall efficiency of 2.56 per cent at air mass 1.5(AM 1.5) lighting [10]. Furthermore the sheet resistance in the FTO glass sheet is around 10 pounds per square metre; this makes it difficult to scal the device and acts as an active cell area limiting factor of > 1 cm2. Therefore the short-circuiting of the solar cell is necessary, or the spacing should be increased between 25 and 50µm in small modules (where these modules consist of small strips of an active cell area of 1 cm2 and adjacent silver lines). Therefore, the resistance to plate should not simply increase the distance between working and counter electrode. As a consequence, in a 26.5 cm 2 submodule, the IPCE value for a cell of 1 cm2 decreased from 10.4% to 6.3%.

Silver fingers can be employed in order to increase cell performance, for the protection against electrolyte leakage, to collect the current and to utilize a sticky substance like a hotmelt tape. Although silver fingers are less practical due to the chemically aggressive nature of the electrolyte. And the risks of leakage are increasing owing to the tiny modules, resulting in 32 percent less active cell surface. The DSSC performance is influenced by the glass panel's conductivity. The conductivity of transparent leading oxide may be improved by combining highly conductive but less chemically stable Indium tin oxide (ITO) and Fluorine doped tin oxide (FTO) conductivity (FTO). The sheet strength of TCO glass was thus lowered to € 1.3/sq. [12].

OBJECTIVES OF THE STUDY

- To examine the use of dragon fruit dye as a sensitizer in the production of DSSC.

- To analyze UV-Vis and FTIR technology characteristics of dragon fruit dye

- To examine the resistivity of a TiO2 coating on ITO glass before using it to make DSSCs.

RESEARCH METHODOLOGY

MATERIAL AND METHODS

Preparation of natural dragon fruit dye

50 g of fresh dragon fruit at room temperature is combined in the 1:1 ratio. The mixture is blended for 10 minutes, or until the color is uniform. The cocktail is then centrifuged at 3000 rpm for 25 minutes at 25°C in a refrigerated centrifuge (HERMLE Z323K). A dropper will be used to gather dye pigment in the test tube's centre, which will be then used for UV-Vis and Fourier Transform Infrared Spectroscopy (FTIR) investigations.

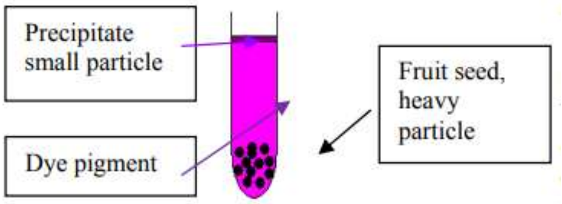


Figure 3: At 3000 rpm, at 30°C approx. 25 minutes, the tube portion after centrifugation.

Conductive ITO glass preparation

Farnell supplied the conductive ITO coated glass. Using a multimeter, the ITO glass initially shows a resistivity rating of 19/cm. Two pieces of conductive glass will be then mixed individually into two identical beakers holding 10 mL of 95wt. percent ethanol solution. Both beakers are subjected to a 25-minute ultrasonic bath in medium mode. After washing, the resistivity of ITO coated glass will be reduced to 17/cm.

Preparation of TiO2 paste and counter electrode

The technique published by Wongcharee et al., 2007, is used to make a porous film TiO2 paste. Age morter is used to combine 0.2g of commercial TiO2 nanoparticles and Triton X-100 of nitric acid solution (0.1M) and one drop of nitric surfactant (0.08g of TiO2 polyethylene glycol. The ultrasonic bath will be used to continue the blending process for another 30 minutes, until it formed a thick paste free of clots. On a metal sheet, a piece of conductive glass is chosen and inserted. On the conductive layer, Scotch tape will be utilised as a masking material on four sides to limit the thickness and area of the paste. Apply a thin layer to the directed area of a 1 cm x 1 cm hole with a glass rod. The glass is then sintered for 2 hours at 450°C in a thermal furnace module.

The coated glass is immersed in natural dye solution and left for 24 hours after the annealing process, when the temperature of the film paste lowers to 50–70°C. Anhydrous ethanol will be used to will beh away any remaining non-adsorbed colour. Sputtering deposition (JEOL 1601) with a Pt target at 40mA for 30 seconds on another conductive glass surface produces platinum (Pt) plated glass. Pt thin film has a thickness of around 20nm. In a solar cell, this layer is referred to as the counter electrode.

I-V characterization

Figures 3 and 4 illustrate the electrical current-voltage (I-V) curve properties of the TiO2 film coating. Figure 3 depicts a cross-section of the metal contact arrangement on TiO2 layer required for four-point probe measurement. The metal contact is created by sputter coating a Pt target onto a TiO2 layer with a thickness of roughly 20nm.

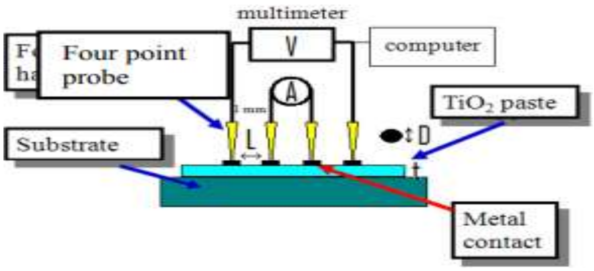


Fig. 4: Four-hand computerized diagram for characterizing TiO2 film with contact metal.

The voltage (V) and current (I) values of the TiO2 layer are measured using a computerized four-hand probe. Figure 4 depicts the four-point probe experiment's setup. The sheet resistivity, Rs, of the produced TiO2 film can be determined using the IV curve result, as given in equation.

$$R_s = (V / I) \text{ x } (A / L)$$

Where (V / I) denote resistance, A denotes area, which is defined as the diameter (D) of the metal contact multiplied by the film thickness (t), and L denotes the distance between metal contacts. The measurement is in centimeters. A surface profiler is used to determine the thickness of the TiO2 film over the formation layer.

Full assemble of DSSC and its analysis

The TiO2 film glass first will be immersed in the dragon fruit color for approximately 24 hours until the colour white of the TiO2 film became pale purple. The electrolyte solution is then made using a reference technique published between the dye coated TiO2 layer and the counter electrode material as a sandwich material. The solution is produced with electrolytes of 0.5M potassium jode (KI) and 0.05M iodine. The TiO2 material surface is treated with a small amount of magic tape dissolver. It creates trapped limits to prevent any electrolyte solution leakage in the solar cell. The liquid of the electrodes is introduced by capillary action between the electrodes. To hold electrodes together, binding clips are utilized. The Pt thin film will be covered by the second electrode's ITO-coated glass. Photocurrent-voltage (I-V) characterization curve solar power conversion efficiency consisting of modified digital Keithley multimeters will be obtained by lighting 50W halogen lamp (Osram.). It is a home-made solar simulation system, tested with the conventional silicone solar cell. The DSSC fill factor is computed from the resulting I-V graph as given in the equation.

$$FF = (I_{max} \text{ x } V_{max}) / (I_{sc} \text{ x } V_{oc}),$$

RESULTS AND DISCUSSION

Ultraviolet-visible spectroscopy (UV-Vis)

UV-Vis will be used to achieve the absorption spectrum of dragon fruit. The range from 400nm to 900nm lies on the wavelengths. Figure 6 shows the associated spectrum. The drachon fruit dye has been discovered to be 535 nm well absorbed. The fruit from dragon is well absorbed between 450nm and 600nm. It is understandable from the result that dragon dye absorbs light from the wavelengths 450nm to 600nm. A blend of red and blue colour (similar to violet) with under white light is displayed.

Fourier Transform Infrared Spectroscopy (FTIR)

The result from FTIR shows three main peak in absorbance wave numbers spectrum range from 4000 cm-1 to 600 cm-1.

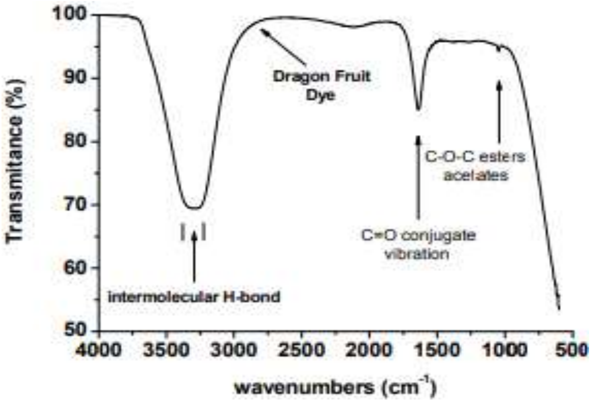


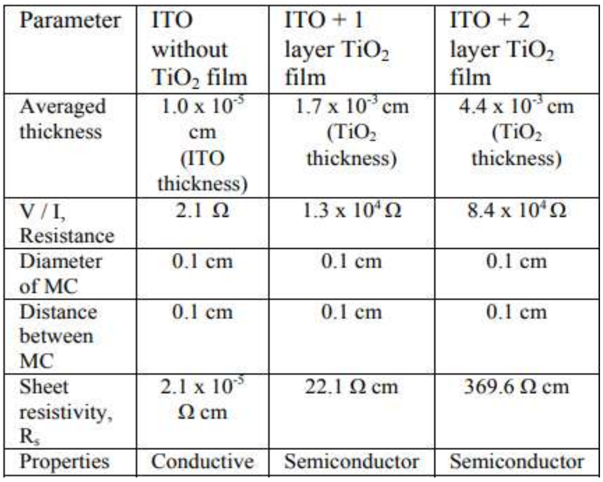
Figure 5: The FTIR dragon fruit coloration results 4000 cm-1 to 600 cm-1.

The result indicates that the chemical has intermolecular h-bonds between 3200 ~ 3400 cm-1 and the high absorption of the chemical between 1600 ~ 1700 cm-1 suggests that C = = O vibration of stretching is conjugated. This is the outcome. The C-O-C extending vibration of the ester acetates is the sharp pinnacle at 1030 ~ 1060 cm-1. Results of Figures 6 and 7 demonstrate the anthocyanin as core component for naturally occurring DSSC in the dragon fruit colouring. Dragoon fruit coloured carbonyl and hydroxyl groups may be bonded to the TiO2 film surface resulting in a photo-electric conversion. Further research will be undertaken in the future on the molecular structure of dragon fruit coloring.

TiO2 film resistivity

The sheet resistivity of 1 and 2 layers of TiO2 film may be derived using the equation. Table 1 shows the results. The ITO-film with a diameter of 1.0 x 10-5 cm will be utilised in this experiment. The three samples are composed of the ITO substrate without TiO2 movie, the ITO masks of single layer and the TiO2 film with a thin layer of rubber thickness: 2,1 x 10-5 x 1 cm, 22,1 x 22 cm and 369,6 x 1 cm, respectively. From the aforementioned result, it demonstrates that the sheet resistivity value increases concurrently as the thickness of the TiO2 film increases. It results in a shift in the electrical characteristics of the sample, as the thickness value increases, from conductor to semiconductor. To understand this scenario further research is required on the crystallinity owing to the influence of the grain boundaries.

Table 1: Thickness and resistivity over number of masking layer during TiO2 film preparation.



Parameter	ITO without TiO_2 film	ITO + 1 layer TiO_2 film	ITO + 2 layer TiO_2 film
Averaged thickness	1.0×10^{-5} cm (ITO thickness)	1.7×10^{-3} cm (TiO_2 thickness)	4.4×10^{-3} cm (TiO_2 thickness)
V / I, Resistance	2.1 Ω	1.3×10^{4} Ω	8.4×10^{4} Ω
Diameter of MC	0.1 cm	0.1 cm	0.1 cm
Distance between MC	0.1 cm	0.1 cm	0.1 cm
Sheet resistivity, R_s	2.1×10^{-5} Ω cm	22.1 Ω cm	369.6 Ω cm
Properties	Conductive	Semiconductor	Semiconductor

Efficiency of DSSC

Interestingly, the solar energy conversion efficiency is assessed by the entire DSSC assembly. Figure 8 illustrates the radiation of the halogen lamp into black boxes, with halogen lighting and the predicted greater efficiency curve, in three distinct circumstances measured between -600 mV and 600 mV without any halogen illumination.

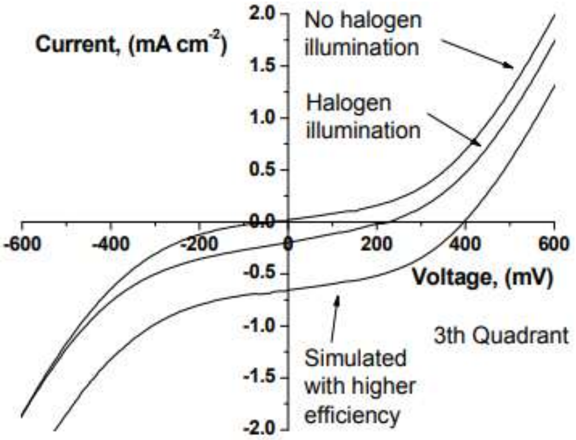


Figure 6: The DSSC conversion efficiency test for samples of halogen light with and without and simulates better efficiency reading.

When under handmade 5.8 mW/cm2 halogen light, solar cell properties may be evaluated. During the halogen lighting the I-V curve will move to the lower y-axis. The DSSC's greater efficiency is predicted to demonstrate a greater change in y-axis than in figure 8. This simulation curve is generated to illustrate that the solar cell has a greater efficiency. On the other hand, the curve intercepts the value of the origin when there is no halogen lighting present.

CONCLUSION

Dragon fruit coloration will be made and utilized as sensitizer in the manufacture of DSSC. The fruit shows good spectrum of absorption at a peak value of 535 nm between 450nm and 600nm. The TiO2 film preparations on ITO glass demonstrate that the receptiveness of sheets increases from 1 layer to 2 layer = 369.6 cm as the masking layer increases. Manufacture of full DSSC reveals the fill factor, Pmax, and halogen efficiency of 0.30,13 µW, and 0.22%. The natural color derived from the dragon fruits therefore offers potential for the generator of green energy It is proposed in future that TiO2 film from the paste type is used in a thin film, as the connection between TiO2 and dye is improved.

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