Construction of Dye Sensitized Solar Cell with an Ethanol Based Anthocyanin Extraction of Grape Skin as Its Light Absorbing Material

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Abstract. As the use of renewable energy resources such as solar energy still leads to the augmentation of energy supply insufficiency, this study aimed to provide an alternative source of economical, time-efficient and environment-friendly solar cell as a powerful potential energy source using grape skin Dye-Sensitized Solar Cell. The experimental parameter was the concentration of anthocyanin. The anthocyanin was extracted by boiling the dried grape skin in the ethanol solution. The semiconductor paste was prepared by mixing Titanium Dioxide and very dilute Acetic Acid (0.1 mL acetic acid in 50 mL water), and was coated on the conductive side of the conductive glass through screen printing method. The Construction of DSSC was done layer by layer. It consisted of working electrode (TiO2 semiconductor-dye) and counter electrode with carbon applied on it. The construction time for the 5 dye-sensitized solar cells was approximately less than an hour. The measured voltages were 0.43V, 0.40V, 0.40V, 0.45V, and 0.41V respectively, while the measured short-circuit currents were: 41µA, 38µA, 35µA, 41µA, and 39µA respectively.

1. Introduction

The Philippines is very abundant in energy sources such as oil, coal, and natural gas. These sources are considered non-renewable as their natural supplies are not enough to keep up with the demand for consumption. As their environmental impact may become too severe to restore, the use of renewable energy resources like solar energy can also contribute to the augmentation of the possible energy supply insufficiency. Renewable energy, of which solar energy is a variant of, will become a viable way of augmenting the possible insufficiency of energy supply. The silicon-based solar cell, which is the solar cell technology often used in the solar market, is very costly because of the equipment used for the construction of the single panel. Moreover, its main component, Silicon, is not only toxic to humans, but also to the environment if improperly disposed. [1] Its by-products can also be lethal to nature when improperly handled.

Dye-Sensitized Solar Cell (DSSC) is another type of solar cell made of low-cost materials with a simpler construction process. It is composed of a semiconductor synthesized by a dye, an electrolyte, and an electrode. Its performance hugely depends on the dye used as a sensitizer. The absorption capacity of the dye- sensitized to the surface film of the semiconductor is an important factor in absorbing solar energy from light. When the sunlight strikes the PV cell, some of the light particles, or photons, are absorbed by the semiconductor material, which causes the electrons to flow that creates a direct electrical current. The anthocyanins belong to the group of natural dyes responsible for several colors in the red–blue range, found in fruits, flowers, and leaves of plants. Carbonyl and hydroxyl
groups present in the anthocyanin molecule can be bound to the surface of a porous TiO2 film. [2,3,4] This cell can serve as the alternative to the silicon-based solar cell due to its cheaper cost and flexibility to be customized, creating a powerful potential source of energy. [5,6]

The proposed grape skin Dye-Sensitized Solar Cell claims that grape skin functions as an effective alternative light-absorbing material for a dye-sensitized solar cell. When used, DSSC can make significant innovations in creating an economical resource of electrical energy. Its inexhaustible state generates the possibility of cheaper electricity cost, which can lead to massive electrical energy production across the country. [7,8] Furthermore, this study aims to promote recycling in creating renewable energy resources. Based on research, some grape-based wineries do not use grape skin even though it has a high amount of anthocyanin flavonoids. It also aims to present a more time-efficient process of creating a light-absorbing material, compared to the 2-day fabrication of a dye-sensitized solar cell. [9] The scope of this study centers on the manufacturing method of a grape skin-based dye-sensitized solar cell. Anthocyanin as its absorbent dye with amounts of dye, TiO2, and electrolyte were used as controlled variables. The researchers only used the method of anthocyanin extraction and did not tackle its rate and efficiency. The magnitude of the absorbance of anthocyanin was also not measured due to the inaccessibility of complex equipment needed to conduct the said test.

2. Methodology

The conceptual framework (Fig. 1) shows the chemical process of creating a dye-sensitized solar cell using an ethanol-based dye extraction.

Figure 1. Conceptual Framework for construction of DSSC.

Figure 2 shows the complete structure of DSSC. Under the illumination of lamp light energy, photons struck through conducive layer glass, while the Titanium Dioxide (TiO2) struck towards dye molecules which mounted on the surface of TiO2 particles. The photon excitation of the dye caused an injection of an electron into the conduction band of the TiO2 layer. These electrons circulated the external loop through the load. The dye molecules which lost electrons were restored by the electron donation from redox electrolyte (which contains iodide/triiodide), which in this experiment, was a mixture of Potassium Iodide (KI) and Iodine (I2). This process occurred very fast, which avoided any recombination of electrons rejected earlier. Under illumination, the voltage was generated through the potential difference between the Fermi level of TiO2 layer and redox electrolyte [10, 11].

Figure 2. Layers of the DSSC.

A border was created by making a frame out of tape. This tape was essential in making sure that there was an even layer of the paste after application. It was then applied on the conductive side of the glass
using the concept of screen-printing method. The paste was left to dry for about five minutes before the semiconductor was placed on a hot plate for the annealing process. In this procedure, the set temperature of the hot plate was 550 °C, conducted for about 15-20 minutes. After the semiconductor has cooled down, it was tainted by the grape dye by running it through the surface twice. Carbon was used as the counter electrode, which was obtained by burning the conductive side of the glass with a candle flame. The carbon was wiped off along the perimeter of the 3-side border of the semiconductor with a cotton swab. The DSSC was constructed by stacking both of the glasses face-to-face, and binder clips were used to clamp and hold it together. A drop of electrolyte (KI3 electrolyte solution consists of 0.5 M KI and 0.5 M I2 in anhydrous ethylene glycol) was added in between the glass and was made sure to run through the entire semiconductor. [12-16]. The multimeter clip (TiO2 coated as the cathode and the carbon-coated as the anode) were connected to each plate, and the voltage and current were measured using the open-circuit and short-circuit tests.

Figure 3. Workflow of the experiment.

2.1. Extraction of anthocyanin

2.1.1. A 100mL of ethanol was measured using a beaker, and the dried grape skin was placed until it reached 125mL.

2.1.2. The beaker was heated using a hotplate. The temperature was set to 100°C to let the ethanol evaporate to 50mL.

2.1.3. A thick cloth was used to hold the beaker. The dye was transferred to a pyrex media bottle while it was still hot. The media bottle was then covered and submerged into water to cool it off.

2.1.4. For storage, the dye was stored in a cool area to avoid vaporization.

Figure 4. Image of dried norton grape skin.  
Figure 5. Extracted Grape dye.
2.2. Preparation of titanium dioxide film to the glass

2.2.1. The conductive side of the glass was checked using the linearity test function of the digital multimeter (DMM). See Fig. 6 image (a).

2.2.2. A matte-finished, invisible tape was applied on the three sides of the glass to serve as its border. See Fig. 5 image (b).

2.2.3. The glass was wiped using a piece of cloth with ethanol to remove the fingerprints and dust.

2.2.4. The desired amount of titanium dioxide was placed in a watch glass. A syringe was then utilized to control the acetic acid solution. Furthermore, the TiO2 was mixed while adding droplets of the acetic acid solution until it turned into a paste. See Fig. 6 image (c).

2.2.5. The screen-printing method was conducted wherein the paste was applied on the glass, and a microscope slide was used to flatten the paste so its height will be equal to the height of the matte tape. In case there is no available microscope slide, any flat object can be used as an alternative.

2.2.6. Afterwards, the paste was dried. See Fig. 6 image (d).

2.2.7. The matte tape border was then carefully removed.

![Figure 6](image-url) Image of (a) Conductivity Testing, (b) Applying the matte-finished invisible tape, (c) Creating nanocrystalline TiO2 films, and (d) Screen-Printed TiO2.

2.3. Annealing the Semiconductors

2.3.1. After the matte tape was removed, the glass was placed on the hotplate and the temperature was set to 550°C.

2.3.2. The waiting time for the paste lasted for 15-20 minutes. And while waiting, it was noticeable that the paste turned into a brownish color. See Fig. 7.

![Figure 7](image-url) Image of Annealing Process at 550°C.
2.3.3. After 15-20 minutes, the glass was removed from the hotplate, and it was observed that upon cooling down, the brownish color turned into white again.

2.4. Tainting the semiconductor with grape dye

2.4.1. A syringe was used to easily control the amount of dye.

2.4.2. The dye was poured on the surface of the semiconductor to let it pass through. After the entire surface has been passed through, the ethanol evaporated, and it was noticeable that the color turned darker in the evaporation of the ethanol. See Fig. 8.

2.4.3. The dye found on the borders was wiped off.

![Figure 8](image.png)

**Figure 8.** Tainting process.

2.5. Preparation of carbon counter electrode

2.5.1. The conductive side of the glass was checked using the linearity test function of DMM. See Fig. 6 image (a).

2.5.2. Afterwards, the conductive side of the glass was burned using the candle flame. In this method, carbon was applied on the conductive side of the glass. See Fig. 9 images (a) and (b).

2.5.3. The carbon on the borders was wiped off, so the surface area of the semiconductor would be equal to the area of carbon. See Fig. 9 image (c).

![Figure 9](images.png)

**Figure 9.** Image of (a) Burning the Conductive Glass, (b) Cooling the Glass, and (c) Creating a Carbonless Border.

2.6. Assembling the Layers

2.6.1. The photoelectrode (glass with the semiconductor and dye) was placed face to face with the counter-electrode and with the carbon layer. See Fig. 10.
2.6.2. A binder clip was then used to bind and hold the two glasses together.

![Figure 10. Image of stacking the layers face-to-face.](image1)

2.7. Applying the electrolyte

2.7.1. The electrolyte was applied in between the glass, and the electrolyte ran through the entire semiconductor. See Fig. 11.

![Figure 11. Image of applying electrolyte.](image2)

2.8. Final Hardware Output

2.8.1. The multimeter clips were connected to each plate (TiO2 coated as the cathode and the carbon-coated as the anode). See Fig. 12.

2.8.2. The open-circuit voltage (Voc) and short-circuit current (Isc) were measured.

![Figure 12. Final hardware output.](image3)
3. Results and discussion

Table 1 presents the data obtained through an open-circuit test for voltage, and short-circuit test for the current under 1500 lux lamp light source. The researchers conducted five trials for data accuracy and repeatability. The measured open-circuit voltages for each trial were: 0.43V, 0.40V, 0.40V, 0.45V, and 0.41V respectively. The measured short-circuit currents were: 41µA, 38µA, 35µA, 41µA, and 39µA respectively. Trial 4 was found to be the best as it gained the highest measured voltage of 0.45V, and the highest measured current of 41µA among all the cells made. The construction time for 5 dye-sensitized solar cells was approximately less than an hour. At 99% degree of confidence, the mean open-circuit voltage and short-circuit current ranged from 0.3865V to 0.4495V, and 35.181µA to 42.419µA respectively.

| Trial | Voltage (V) | Current (µA) |
|-------|-------------|--------------|
| 1     | 0.43        | 41           |
| 2     | 0.40        | 38           |
| 3     | 0.40        | 35           |
| 4     | 0.45        | 41           |
| 5     | 0.41        | 39           |

4. Conclusion

Constructing a dye-sensitized solar cell using an ethanol based dye was proven effective having a range of voltages from 0.40V to 0.43V and range of currents from 35µA to 41µA under 1500 lux. Constructing a dye-sensitized solar cell using an ethanol-based dye was proven effective with a range of voltages from 0.40V to 0.43V, and range of currents from 35µA to 41µA under 1500 lux. The construction using ethanol-based dye was time-efficient since it took the researchers less than an hour to construct the cell, compared to the normal 2-day duration of a dye-sensitized cell construction [9].

5. References

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