

Solar Cell Prototype with TiO_2 as an Electrode and Utilization of Dragon Fruit Peel as a Photosensitizer

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Abstract

Energy is important part in human life. However, energy sources in Indonesia are still dominated by non-renewable energy sources. The depletion of non-renewable energy sources, there is a shift to use renewable energy sources, one of which is solar cells. Dye Sensitized Solar Cell (DSSC) is a device that can convert light energy into electrical energy. DSSC is a third-generation solar cell consisting of TiO_2 semiconductors placed on a conductive glass substrate and immersed with dyestuffs. The dye as a sensitizer used comes from the skin of the red dragon fruit (*Hylocereus costaricensis*). DSSC is formed with a sandwich structure, there are five parts, namely ITO glass (Indium Tin Oxide) as a substrate, TiO_2 as a semiconductor material, dye (red dragon fruit skin) as an electron donor, gel electrolyte as electron transfer and active carbon as a catalyst in the comparison. This study aims to prove that organic compounds can be used as photosensitizers to produce solar-powered electric current. Researchers use descriptive methods with a quantitative approach. The test methods carried out are voltage tests, electric current tests, fill factors, power, and efficiency. Based on the tests carried out, the results of the voltage test of 199.3 mV, the electric current test of 199.3 mV, the Fill Factor of 1.379%, and the efficiency of $1.948 \times 10^{-5}\%$. This research successfully proved that DSSC with Dragon Fruit Skin as a photosensitizer can produce electrical current and voltage.

Keywords: Dye Sensitized Solar Cell (DSSC), Sun Energy, Dragon Fruit Peel, Solar Cell.

INTRODUCTION

Energy has an important role in every aspect of human life. The need for energy in Indonesia continues to increase due to infrastructure development, regional expansion, road construction, etc. (Hardani, 2019). This increasing need is inversely proportional to the amount of world energy supply which every year experiences a drastic decline, this results in a problem, namely the world energy crisis.

Energy use in Indonesia is still dominated by non-renewable energy derived from fossils, especially petroleum and coal (Azhar, 2018). Due to the depletion of energy sources, there has been a shift from the use of non-renewable energy sources to renewable energy sources.

Renewable energy sources are energy sources that can be used indefinitely and will never run out because they can be restored in a relatively short time (Darmayanto, 2007). Solar energy is the energy obtained by converting heat energy through certain equipment becomes a resource in another form (A. SMP, 2021). Solar energy is remarkable because it is not destructive, inexhaustible, trustworthy and does not buy (Mustari, 2019). The use of energy through solar cells is the most potential alternative to be applied in Indonesia (Widayana, 2012).

The most widely used solar cells today are silicon solar cells, as the first generation of solar cells. Solar cells are dominated by silicon materials, but the high cost of silicon production makes the cost of consuming solar cells more expensive than fossil energy sources. Inexpensive solar cells can be made from organic semiconductor materials. Organic semiconductor materials can be synthesized in large quantities. In addition, organic semiconductors can absorb color with the help of substrates (Vitriani, 2019).

Dye Sensitized Solar Cell (DSSC) is a third generations solar cell that was first developed by Professor Michael Gratzel in 1991 and serves to convert solar energy into electrical energy (Q. S. Musaff, 2018). DSSC is one of the potential candidates for future generations of solar cells because it is environmentally friendly, the production cost is cheap, dye is available in large quantities, it is easy to extract, and easily biodegradable in the environment and no further purification process is needed (Zhou, 2011).

DSSC has a sandwich like layered structure that generally consists of electrodes working, a layer of TiO_2 (Titanium dioxide), and an opposing electrode that has been coated with a catalyst (Israyanti, 2019). Each layer in a dye based solar cell is centrifified made by a sequential process. Substrate used as places for working photoelectrodes and opposing electrodes generally use ITO (Indium Tin Oxide) type glass or FTO (Fluorine-doped oxide) glass. TiO_2 paste is coated with dye or dye and an electrolyte solution is added on top of the dye layer to accelerate the reaction between sunlight and solar cells (Dharma, 2014).

TiO_2 has advantages, stable is used as an electrode in photoelectrochemical systems that work at extreme conditions (high temperatures), it is cheap, no toxic, and has good optical characteristics thus supporting the injection of electrons from excited dye in semiconductors (Narayan, 2012).

The natural organic matter used as a censitator on the DSSC must have the ability to absorb a wide spectrum of light and match the energy bands of inorganic semiconductors, in this case it is TiO_2 . In this study, the red dragon fruit peel (*Hylocereus costaricensis*) was chosen as the source of dye, which from its color is predicted to have the appropriate optical absorption.

The red dragon fruit (*Hylocereus costaricensis*) is a type of cactus. Dragon fruit has a skin proportion of 30-35% but is often only disposed of as garbage even though it contains a fairly high anthocyanin natural dye (Simangunsong, 2014). Anthocyanins are red dyes that are a natural dye. Anthocyanins have functional groups O-H which is the hydroxyl group that constitutes the anthocyanin structure. This hydroxyl group is useful as an adhesive between pigment compounds and the TiO₂ layer on FTO (Setiawan, 2015).

The use of red dragon fruit peel as a source of dye in this study, apart from its potential in optical absorption, also takes into account environmental aspects, namely in an effort to use organic waste to reduce waste production. To produce dye, the red dragon fruit peel is crushed, then extracted by maceration.

With energy needs that are increasingly important to meet, as well as environmental circumstances that have a lot of waste with a high anthocyanin content. The idea came up for the creation of waste-based organic solar cells for photosensitizers. The purpose of this study is to prove that organic compounds can be used as photosensitizers to produce solar powered electric current.

METHOD

This research was conducted at SMA Trensains Muhammadiyah Sragen on October until November 2022. The research method used is descriptive with a quantitative approach. The testing methods are Voltage Test, Electric Current Test, Fill Factor, and Efficiency.

Materials and tools

The materials used are TCO conductor glass type ITO 2.5x2.5 cm, TiO₂ powder, citric acid, iodine (I₂), aquades, dragon fruit peel, 8B pencil, wax, Potassium Iodide (KI), Polyethylene Glycol (PEG), Polyvinyl Alcohol (PVA). The tools used is a digital multimeter, magnetic stirrer, 50 ml and 100 ml beaker glass, pipette, digital scales, filter paper, and masking tape.

Steps for making solar cells

1. Manufacture of dye solution
 - a. Roast the red dragon fruit peel with temperature for 60 minutes in 100°C.
 - b. Destroyed the red dragon fruit peel.
 - c. Macerating the powder of red dragon fruit peel with 10% citric acid solvent and aquades in a ratio of 5:1.
 - d. Stirring for 60 minutes at a speed of 200 rpm using a magnetic stirrer at room temperature.
 - e. Soak for 24 hours and strain using filter paper.
2. TiO₂ Pasta Making
 - a. Mix 3.10 grams of polyvinyl alcohol (PVA) into 30 ml of aquades.
 - b. Stired it for 30 minutes at a temperature of 40°C using a magnetic stirrer.
 - c. Adding as much as 3.15grams of TiO₂ powder is added until a paste is formed.
3. Electrolyte manufacturing
 - a. Mixing Potassium Iodide (KI) as much as 0.8grams with 10 ml of polyethylene glycol (PEG).
 - b. Add Iodine (I₂) as much as 0.13 grams.
4. Carbon manufacturing
 - a. Shaded the 8B pencil on the conductive part of the ITO.
 - b. Burn the glass on the flame of the candle in the position of the shade facing the fire. Combustion is carried out until the soot of the fire covers the conductive surface of the ITO.

5. Creation of DSSC

- Form an area to position the TiO_2 paste in a 2.5x2.5 cm conductive glass measuring 2x1.5 cm using insulation.
- Place the TiO_2 paste then flatten it so that it forms a thin layer
- Dry by heating the glass along with TiO_2 paste for 10-20 minutes
- Soak the working electrode with dragon fruit peel extract for 30 minutes
- ITO glass rinse with aquades
- DSSC series stacking with sandwich structure
- Each end is given an offset of 0.5 cm for electrical contacts
- Pinch both sides of the ITO glass
- Drip electrolyte KI_3 on the space between the electrodes of the cell

Testing

Tests used include Voltage Testing, Electric Current Testing, Fill Factor, Electric Power and Efficiency

Voltage Test

The voltage is measured using a digital multimeter with clamp the alligator clip to the digital multimeter and attach it to each negative and positive electrical contact.

Electric Current Test

The current is measured using an Avometer by connecting an alligator clip to the Avometer and attaching it to each negative and positive electrical contact.

Electric Power Test

Electrical power is the rate of energy consumption in a circuit or electrical circuit. Electrical Power is measured by the equation:

$$P = V_m \times I_m$$

P = Power (W)

I_m = Current at the time of maximum power (A)

V_m = Voltage at maximum power (V)

Fill Factor

Fill factor is indicator of the quality of solar cell performance [4]. The fill factor is measured using the equation:

$$FF = \frac{V_m \cdot I_m}{V_{oc} \cdot I_{sc}} \times 100\%$$

V_m = Voltage at maximum power (V)

I_m = Current at the time of maximum power (A)

V_{oc} = Voltage at maximum resistance (V)

I_{sc} = Current when the resistance is minimal (A)

Efficiency

Efficiency is the percentage of maximality of the work of an object [1]. Efficiency can be measured by equations

$$\eta = \frac{V_m \cdot I_m}{P_{\text{sunlight}} \cdot A} \times 100\%$$

V_m = Voltage at maximum power (V)
 I_m = Current at the time of maximum power (A)
 P = Sunlight power
 A = DSSC surface area (m²)

RESULT AND DISCUSSION

RESULT

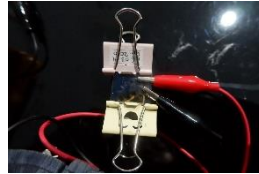


Figure 1. DSSC with dragon fruit peel extraction

In the application of TiO₂ paste as such is obtained the active area of solar cells 3cm² with a thickness of TiO₂ paste of 0.05 mm. The resulting color after soaking Dye for 30 minutes is reddish pink.



Figure 2. DSSC test scheme

Figure 2. Show a test scheme carried out using a digital multimeter and alligator clips in sunlight.

The test results are described in Table 1.

Table 1. Result of test

Quantitative	Value
V_{oc}	123.3 mV
I_{sc}	34.8 μA
V_m	199.3 mV
I_m	29.7 μA
FF	1,379 %
P_{max}	4,418 $\times 10^{-5}$ W
η	1,948 $\times 10^{-5}$ %

DISCUSSION

V_{oc} indicates the voltage at maximum resistance measured using a digital multimeter. I_{sc} indicates the current when the resistance is minimal. V_m and I_m indicate the maximum voltage and current measured by the measured average V_{oc} and I_{sc} . FF indicates the quality of cell performance. P (Power) indicates the power of the cell. η (Efficiency) indicates the effectiveness of solar cells.

From Table 1. values of the voltage, current, and effectiveness of the DSSC in converting the light energy of the sun into electrical energy. This proved that TiO₂-based solar cells and organic dyes

can produce electric current even if they are still with small values. DSSC does have a smaller effectiveness value than solar cells in general. This is due to several factor including the limitation of sensitization carried out by anthocyanin molecules from the skin of the dragon fruit to the conduction band TiO_2 . The excited dye electrons are in an unstable state so there is a possibility that the electrons injected into the TiO_2 band return to the ground state.

The efficiency of DSSC is also influenced by the intensity of the rays received by the conductor glass because not all rays can be absorbed and some of them are reflected, thus affecting the effectiveness of the DSSC. However further development of DSSC is necessary so that the resulting efficiency is close to that of conventional solar cells. DSSC is also considered more environmentally friendly, easy to manufacture and relatively cheaper than silicon solar cells, as well as the ability to absorb room light and low-intensity light.

CONCLUSION

From the research that has been carried out, the results of the voltage test of 199.3 mV for the electric current test of 199.3 mV and the Fill Factor of 1.379%, as well as the efficiency test of $1.948 \times 10^{-5}\%$. So, it can be concluded that this research has succeeded in proving that DSSC with dragon fruit peel as a photosensitizer can produce electric current and voltage. The test results are influenced by several factors such as anthocyanin content, the intensity of the rays received, and the injection of electrons at TiO_2 into the carbon electrode.

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