Study on Making a Prototype Dye Sensitized Solar Cell (DSSC) as an Alternative Electric Energy Source

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Abstract. Sunlight as a potential renewable energy source is an ideal solution to meet the increasing electricity needs. Dye Sensitized Solar Cell (DSSC) is an environmentally friendly solar cell because it uses dye organic matter. The purpose of this study was to make a DSSC prototype and examine the effect of dye types and the concentration and thickness of TiO₂ layers on the DSSC voltage produced. Solar cells are devices that convert sunlight radiation into electrical energy. Solar cells use a photo-electric effect from semiconductor materials so they can collect solar radiation and convert it into electrical energy. Today, one of the solar cells developed is DSSC which uses electrolytes as an electron transportation medium. DSSC consists of TiO₂ nanopores, dye molecules adsorbed on the surface of TiO₂, and electrolyte solutions which are all deposited between two conductive glass. In this study, a prototype of DSSC was carried out using organic materials from the extraction of dragon fruit, orange fruits and darker colored mustard greens. Dye extract is adsorbed by TiO₂ nanopores which have been deposited into conductive glass (TCO). Carbon is used as a counter-electrode, then an electrolyte solution is added when both conductive glass has been assembled in the form of a sandwich. Based on the experimental results, the greater the concentration of TiO₂, the greater the power obtained. The greater the thickness of TiO₂, the greater the power obtained, and the variable type of dye that has been studied obtained greater power found in the type of dye from dragon fruit.
1. Introduction

The energy crisis is one of the biggest problems scientists currently need to solve. The availability of energy is getting less and less, one of which is the availability of sources of electrical energy which is inversely proportional to the need for electrical energy which continues to increase over time. So far, the source of electrical energy comes from conventional energy such as fossil fuels whose availability is decreasing over time [1]. Therefore, it is necessary to develop other alternative energy sources. One of the alternative energy sources used as a source of electrical energy is solar cells, which have been widely researched and developed by researchers in various countries [2]–[4].

The country of Indonesia is located on the equator and has a tropical climate that causes it to receive a large amount of sunlight. Sunlight is the main source of energy that will not run out if humans use it to meet their needs. In accordance with the working principle of solar cells, which can convert solar energy into electrical energy, Indonesia has a very large potential for solar power as an alternative energy source.

Solar cells work using solar energy by directly converting solar radiation into electricity. Solar cells that are widely used today are solar cells based on silicon technology which have high efficiency [5]. Although solar cells are now dominated by silicon materials, the high cost of producing silicon makes their consumption costs more expensive than fossil energy sources. Besides that, the disadvantage of solar cells made from silicon is the use of hazardous chemicals in the manufacturing process [6]. Therefore, other types of solar cells continue to be developed with environmentally friendly raw materials, an easy manufacturing process and a large enough efficiency. Until now, there are three generations of solar cells, namely solar cells made from silicon, solar cell thin film, and Dye-Sensitized Solar Cell (DSSC). In the process, the manufacture of solar cells made from silicon and thin layer solar cells requires a fairly expensive production cost. Therefore, currently there are solar cells made from organic materials, namely Dye-Sensitized Solar Cell (DSSC) which has the advantage of an easy and environmentally friendly manufacturing process [7].

Dye-Sensitized Solar Cell (DSSC) is a solar cell that is sensitized by TiO₂ nanocrystals using photo-excited molecules dye [8]. DSSC is one of the potential candidates for next-generation solar cells, this is because it does not require high purity materials so that the production process costs are relatively low. In contrast to conventional solar cells where all processes involve the silicon material itself, in DSSC light absorption and electric charge separation occur in separate processes. Light absorption is carried out by molecules dye and charge separation by inorganic semiconductor nanocrystals. One of the semiconductors that is often used is Titanium Dioxide (TiO₂). TiO₂ is commonly used because it is inert, harmless, and has good optical characteristics [9]. In this study, DSSC was made from dyes organic, namely pigments derived from plants. Therefore, the problem in this study is the effect of the 3 types of dye and the concentration and thickness of TiO₂ on the resulting DSSC stress.

2. Methodology

2.1 Materials

The main materials used in this study are polyvinyl alcohol and TiO₂ powder which are used to make TiO₂ paste. Both of these ingredients are purchased at a chemical shop in Semarang. Next, the ingredients used are dragon fruit, citrus fruit and mustard greens which are used as coloring agents. This material is purchased at the klipang market which is located in the Tembalang area, Semarang City.

2.2 Preparation of TiO₂ Paste

The first step is to prepare 10 ml of distilled water, then add 10% weight (1 gram) of Polyvinyl Alcohol (PVA) to distilled water, then stir at a temperature of 80°C. This suspension will function as a binder in making the paste. After that, add TiO₂ powder as much as 10% by weight to the suspension.
Then crushed by a mortar until it forms a good paste to coat. Adjust the volume of TiO2 according to a variable to get a paste with the best viscosity degree.

2.3 Solution Preparation Dye

Puree each variable, namely dragon fruit, citrus fruit, and mustard greens with 10 grams of mortar then add 10 ml of ethanol, let stand for 30 minutes. Then filtered using gauze paper.

2.4 Electrolyte Solution Preparation

Solution is obtained by mixing 0.8 grams (0.5 M) of potassium iodide (KI) into 10 ml of distilled water and then stirring. After that, add 0.127 grams (0.05 M) of iodine (I2) to the solution and then stir. Save the solution in a dark and closed bottle.

2.5 Carbon electrode Counter Preparation

Prepare 10 ml of distilled water, add 10% weight (1 gram) of Polyvinyl Alcohol (PVA) into distilled water, then stir at 80°C. Add 1 gram of carbon powder to the suspension. Then crushed by a mortar until it forms a good paste to coat. The carbon is superimposed on the TCO on the conductive part and then heated at a temperature of 400°C for 10 minutes so that the carbon forms good contact between carbon particles and with TCO.

2.6 Assembling the DSSC

After each DSSC component has been successfully assembled, the assembly is then carried out to form a solar cell by forming an area where TiO2 with a TCO of 5 x 4 cm and is positioned with the help of Scotch tape on the conductive glass section to form an area of 4.5 x 3 cm. Scotch tape also functions as a thickness regulator for TiO2 paste. Then the TiO2 paste is positioned over the area that has been made on the conductive glass with the help of a stirring rod to spread the paste. Then the layers are dried for about 15 minutes and heat at a temperature of 400°C for 30 minutes. Coat the TiO2 layer by dropping a drop of solution dye then let it sit for about 24 hours. In this process, pigment adsorption occurs on the TiO2 surface. The carbon counter-electrode is then placed on top of the TiO2 layer with a sandwich structure where at each end an offset of 0.5 cm is given for electrical contact. Then in order for the cell structure to be stable it is clamped with clips on both sides. The iodide / triiodide electrolyte solution is then dropped approximately 4-5 drops into the space between the two electrodes. And the solar cells are ready to be tested.

3. Solar Cell Testing

In this research, a current and voltage test is carried out in the solar cells that have been made. Two types of testing have been carried out in the assembled solar cell, namely direct testing of the measured voltage of the solar cell using a digital multimeter. The light source used is direct sunlight and current testing using a potentiometer as the resistance which is varied and the changes can be seen.

4. Results and Discussion

In the research that has been carried out, the DSSC device is connected in series with the ammeter and potentiometer and connected in parallel with a voltmeter which will then be tested using sunlight. The output data from these measurements are in the form of current and voltage values.

4.1 The Effect of TiO2 Layer Thickness on the Resulting DSSC Stress

In this Dye Sensitized Solar Cell, the TiO2 layer functions as an absorption site for dye molecules. The layer thickness is influenced by the number of TiO2 particles deposited on the
substrate [19]. At this stage, the thickness of the TiO₂ variables used were 45, 90 and 135 μm by using a TiO₂ concentration of 10% w and the type of dye derived from dragon fruit extract. Here are the results measurements during the study:

Figure 1. Graph of the Relationship Between TiO₂ Thickness with a Voltage on the Variable Thickness of TiO₂

Figure 2. Graph of the Relationship Between TiO₂ Thickness with a Flow on the Variable Thickness of TiO₂
The graph above shows the relationship of TiO\textsubscript{2} coating thickness with a current value and trades generated by the DSSC. The largest thickness was the TiO\textsubscript{2} layer thickness 135 μm while the lowest thickness was 45 μm. The results of current and voltage characterization for variations in the thickness of the TiO\textsubscript{2} layer, resulted in a voltage value of 33.2 mV and a current value of 3.9 μA for a layer thickness of 45 μm. In the second type of DSSC with a layer thickness of 90 μm, the voltage values are 47.1 mV and 5 μA. Furthermore, the voltage value is 52.4 mV with a current value of 5.1 μA for a layer thickness of 135 μm. From the voltage and current data that has been obtained, from there the value of the power generated from the maximum current and voltage can be obtained.

According to the opinion of previous studies, the thickness of the TiO\textsubscript{2} layer used in DSSC affects the photons that can be absorbed by the dye and the amount of dye that can be adsorbed [20]. This happens when the TiO\textsubscript{2} layer gets thicker, the more dye molecules will be adsorbed on the layer. The more dye, it will be possible to absorb more photons so that the higher the photoexitation of electrons [21]. The number of photons that can be absorbed by dye will increase the value of the voltage generated by the DSSC.

5. Conclusion

Based on the results of voltage and current measurements, it was found that the thickness of the TiO\textsubscript{2} layer on the DSSC had an effect on the power produced. The TiO\textsubscript{2} layer with a thickness of 135 μm is relatively better than the TiO\textsubscript{2} layer with a thickness of 45 μm and 90 μm with a maximum power value of 57.69 nW. In addition, the TiO\textsubscript{2} concentration in DSSC also affects the power that can be generated. The TiO\textsubscript{2} layer with a concentration of 20% w is relatively better than the TiO\textsubscript{2} layer with a concentration of 10% w or 15% w with a maximum power value of 117 nW.

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