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Poly Organic Polymer (3-Hexylthiophene) P3HT As Light Sensitivity In Prototype Dye-Sensitized Solar Cells (DSSC)

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ABSTRACT

This research aims to review the characteristic of the nature of electricity polymer material poly(3-hexylthiophene) P3HT against increasing efficiency solar cells based on dye-sensitized solar cells (DSSC). The testing sample has done electricity P3HT el-kahfi 100/ I-V meter. The optical properties use spectrophotometer UV visible 1601 PC and characterizing IV DSSC use keithley 2600 a type. The absorbance of P3HT polymer 1% has an absorption peak in the wavelength range of 300-650 nm. Thus the P3HT polymer material can absorb light in the visible wavelength range. The electrical properties of P3HT 1% indicate that the material has a response to light. In bright conditions, P3HT 1% shows a conductivity of $3.7 \times 10^{-3} \Omega^{-1} m^{-1}$ and in dark conditions $2.2 \times 10^{-3} \Omega^{-1} m^{-1}$. Meanwhile, Pt (Hexacloroplatinic IV) Platina as the opposing electrode can improve the performance of DSSC, which is because Pt (Hexacloroplatinic IV) functions as a catalyst to accelerate the redox reaction with electrolytes. The use of P3HT 1% can improve DSSC performance. DSSC using 1% P3HT and using Pt (Hexacloroplatinic IV) as the opposing electrode produced an efficiency value of 1.8×10^{-2}%.

Introduction

Energy is an essential requirement in fulfilling all life necessities globally, so that energy needs are increasing daily[1]. Therefore, the search for alternative energy sources that can be renewable (renewable), cheap, and environmentally friendly is a demand that cannot be postponed any longer today due to the significant reduction in fossil fuel reserves in recent years [2], as well as the effect of greenhouse and global warming caused during the process of their use. Therefore, the problem of increasing national energy consumption must resolve immediately. We need to understand that global energy demand will double per year in the next 30 years [3].

In the next 40 years, the demand will increase again to three times or the energy equivalent of 20 billion tons of petroleum. Indeed, according to the Energy Information Administration (EIA), it is estimated that energy use until 2025 will still dominate by fossil fuels, namely petroleum, natural gas, and coal. The problem is that according to data from the Ministry of Energy and Mineral Resources, the oil reserves in Indonesia are only sufficient for the next 18 years, while natural gas can still be sufficient for another 61 years. Then the coal reserves are estimated to be exhausted within 147 years [3].

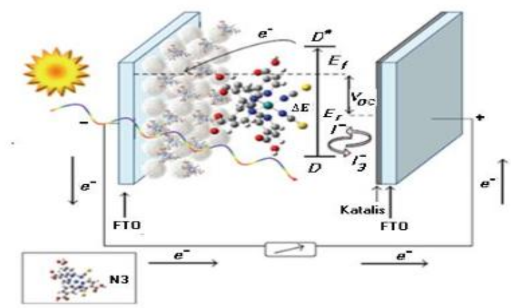

Figure 1. Dye-Sensitized Solar Cell Schema[4]

The DSSC structure in this research is TiO_2/ P3HT / Electrolyte / Pt (Hexachloroplatinic IV). FTO glass coated with TiO_2 functions as a working electrode, P3HT as the active material for solar cells, electrolytes as an oxidation-reduction reaction medium, and FTO coated with Pt (Hexachloroplatinic IV) as an opposing electrode [5].In the DSSC, dyes as sensitizers play a crucial role in absorbing photons from sunlight or lamps and converting them into electric current. Types of dyes such as metal, organic, and natural complexes usually use as sensitizers [1]. Metal complex absorbed on the TiO_2 nanocrystalline has reached an efficiency of 11-12%, where as the organic dye has reached an efficiency as high as 9.8%[6]. Efficiency becomes the global measure of the quality of solar cells. This research aims to review the characteristic of the nature of electricity polymer material poly(3-hexylthiophene) P3HT against increasing efficiency solar cells based on dye-sensitized solar cells (DSSC). Characterization is important to do, this aims to know the ability of the dye to deliver electrons in solar cells. The higher the efficiency of the resulting cells, the ability to dye or constituent materials of solar cells can be said to be very good. This efficiency value is a global measure in determining the quality of solar cell performance. Although DSSC achieves relatively high efficiencies, there are several drawbacks to using metals and organic complexes as sensitizers. One of the requirements for dye to function as a sensitizer, the material must be able to absorb the photons. One of the factors that is still a problem in the manufacture of DSSC solar cells is the use of electrolytes, both gels and solutions, which have an important role in converting light energy into those at the same time. generally in the form of a solution, many problems arise and are related to the use of electrolytes, such as leakage, evaporation, the possibility of corrosion of the counter-electrode, and so on. Most of the problems above are related to the issue of stability of cell performance in the long run. In addition, choosing the right type of electrolyte solution is one factor that is still being studied by many researchers.

Theory

A solar cell or Photovoltaic (PV) cell is a semiconductor device that has a large surface area and consists of a series of p and n types of diodes, which are capable of converting energy from sunlight into electrical energy. Photovoltaic is a study in the field of technology and research related to the application of solar cells as solar energy. Energy is a basic need in life in the world, so that energy needs in the world continue to increase. To meet these needs, it is necessary to develop various alternative energies, namely renewable energy[7]. Energy issues have been very much discussed recently because of the dwindling supply. Therefore, many experts are looking for ways to create alternative energy that can meet human needs, where the energy produced can be renewed, one of the solar energy.

Dye Sensitized Solar Cell was first discovered by Gratzel and Brian O'Regen in 1991 at Ecole Polytechnique Federale De Lausanne, Switzerland. Dye Sensitized Solar Cell (DSSC) is a photoelectrochemical solar cell that uses electrolytes as a transport medium [2] Solar cells or commonly called photovoltaic cells are devices that can convert solar radiation into electrical energy[8]. The DSSC is composed of a working electrode consisting of Flourine Tin Oxide (FTO) glass, Titanium Dioxide (TiO_2), natural dyes, an electrolyte consisting of a redox pair I^{-} / I^{3-} and a counter electrode consisting of graphite or carbon. DSSC works in the visible light region to a fraction of the infrared[9].

Dye-sensitized TiO2 nanocrystalline solar cells were developed as an alternative concept to conventional silicon-based photovoltaic devices. Dye-sensitized TiO2 solar cells consist of a layer of porous TiO2 nanocrystals as a photoanode, dye as a photosentizer, redox electrolyte and a counter electrode (cathode) coated with a catalyst layer.

The performance of Dye Sensitized Solar Cells (DSSC) based solar cells can be seen based on the efficiency of electrical energy conversion. Efficiency can be determined through the current-voltage (I-V) curve produced by the solar cell. Figure 2, shows the I-V curve of the solar cell.

Figure 2. shows the Maximum Power Point (MPP), and the voltage current on the MPP: Impp, Vmp. When the cell is in a short circuit, the maximum current or short circuit current (Isc) will be generated.

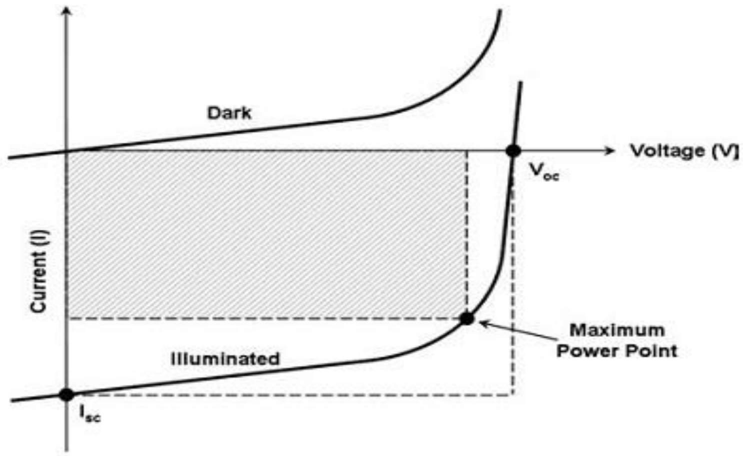

Figure 2. Dye Sensitized Solar Cell (DSSC) I-V Curve[10]

In an open circuit condition, the resulting current is zero, so that it will produce the maximum voltage or open circuit voltage (Voc). Pmaks is a point where the maximum power produced by a solar cell. Fill Factor (FF) is a quantitative measure of the quality of a solar cell, as well as the outer size of the I-V curve square, the Fill Factor can be obtained using Equation .1.

$$FF = \frac{V_{max} I_{max}}{V_{oc} I_{sc}} \tag{1}$$

By using the Fill Factor, the maximum power generated by solar cells can be obtained through Equation 2.

$$P_{max} = V_{oc} I_{sc} FF \tag{2}$$

So that the efficiency produced by solar cells is obtained through Equation 3.

$$\eta = \frac{P_{max}}{P_{in}} x100\% \tag{3}$$

This efficiency value is a global measure in determining the performance quality of a solar cell. The efficiency of the solar cell depends on the temperature of the cell and more importantly the quality of the illumination. For example, light intensity and spectrum intensity are distributed. Therefore, standard measurement conditions must be developed in line with solar cell testing in the laboratory[11]. Standard conditions that have been used to test solar cells are the light intensity of 1000 W/m^2, and the cell temperature is 25^{0}C. The power released by solar cells in this condition is normal power from the cell, or module, and is recorded as peak power (peak wattage)[12].

The amount of resistivity of a material can be measured using the two point probe method using the El kahfi 100 I-V Meter. In this method, there are two probes, one current probe and

one voltage probe. The first probe functions to conduct electric current and the other probe to measure the electric voltage when the probes are applied to the sample. From the variation of the change in voltage given, the measured current change will be obtained so that the amount of resistivity is based on the value of the voltage and current.
The amount of resistivity can be used to determine the conductivity of a material. Good conductor materials have high conductivity values, while for insulating materials the conductivity is low due to high resistivity. One thing that is very important in the current characteristics is the ability of solid materials to emit an electric current. Ohm's law which is proportional to current and voltage is shown in Equation 4

$$V = I.R \tag{4}$$

The electrical resistivity (ρ) is expressed in Equation 5

$$\rho = R.A / l \tag{5}$$

Electrical conductivity (σ) is used to classify the electrical characteristics of a material. In simple terms, electrical conductivity is the reciprocal of electrical resistivity (Equation 6). Conductivity indicates the ability of a material to generate an electric current.

$$\sigma = 1 / \rho \tag{6}$$

Solid materials show electrical conductivity reaching the order of 27. Classification of solid materials based on their ability to generate electric current is grouped into three groups, namely conductors, semiconductors and insulators. Metals are good conductors, having conductivity of approx. Order. The approximate very low conductivity material is an electrical property of the insulator. Materials with an approximate medium conductivity are called semiconductors [5].

Experimental Method

The first process before the research was carried out was the preparation process. This preparatory stage includes the preparation and service of tools for extraction and manufacture of TIO2 paste. The preparation process for extraction is carried out using a mortar, Flourine Tin Oxide (FTO) conductive glass, bottle, tip, beaker, dropper and spatula using an ultrasonic cleaner with ethanol solution so that it is free from materials that cannot be cleaned with air alone. The clean glass affects the test results of the sample to be superimposed on the glass substrate, then the cleaned glass is tested for resistance using a multimeter. The second process is the preparation process for extraction was carried by cleaning the tool using an ultrasonic cleaner with an ethanol solution free from materials that cannot clean with water alone. The TiO_2 used in this research is Titanium (IV) Oxide, Titanium dioxide powder anatase, 99.8% trace metals base. 3.5 grams of TiO2 powder mixed with 15 ml of ethanol, then stirred using a vortex stirrer at a speed of 200-300 rpm.

The deposition of Poly (3-hexylthiophene) P3HT used in this study is Poly (3-hexylthiophene-2,5-dyl) Regioregular, electronic grade, 99.95% trace metal base, an average of 15,000-54,000 Mn is the third step in the manufacture of DSSC. Furthermore, for the purposes of testing optical properties, the P3HT solution with each concentration is superimposed onto the glass preparatory using the spin coating method. Meanwhile, for the purposes of testing electrical properties, the P3HT solution with the respective concentrations is superimposed on the PCB. Spin coating speed used is 1500 rpm and time used is 10 seconds. P3HT polymer mixes with chlorobenzene solvent. Fluorine Tin Oxide (FTO) conductive glass measuring 2 x 2 cm. The conductive side of the FTO glass is tied using tape to form a deposition area in the center of 1 x 0.6 cm. Figure 3 shows a schematic of the TiO2 paste deposition area.

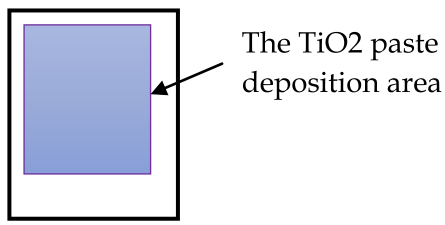

Figure 3. Schematic of TiO2 Paste Deposition Area

Solar cell assembly in this study uses a sandwich system. The working electrode is a layer of TiO_2, which deposit with 1% P3HT, then it is dripped with electrolyte from the redox pair I^- / I^{3-} and KI.

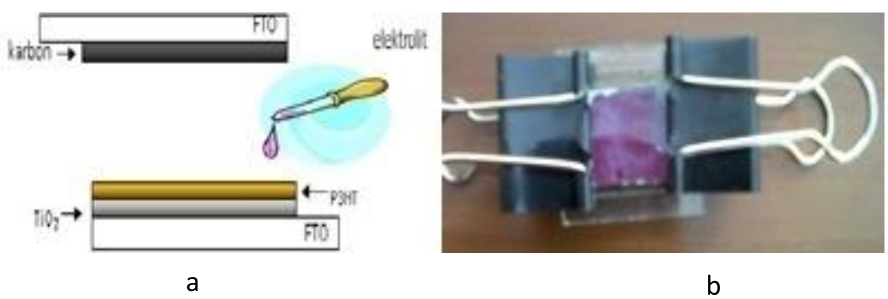

Figure. 4a. Illustration of DSSC based solar cell assembly. 4**b.** DSSC with P3HT dye is ready to test.

The opposing electrode stack on top of the working electrode has drip with electrolyte. Then, the two electrodes clamped using the clipboard, so they do not come off. A spacer of insulating material inserts between the two electrodes to prevent a short contact. Figures 4a and 4b show an illustration of solar cell assembly.

Characteristics testing with Keithley will result in two types of I-V curves: in dark and light conduction conditions that indicate a DSSC material's photoconductivity.

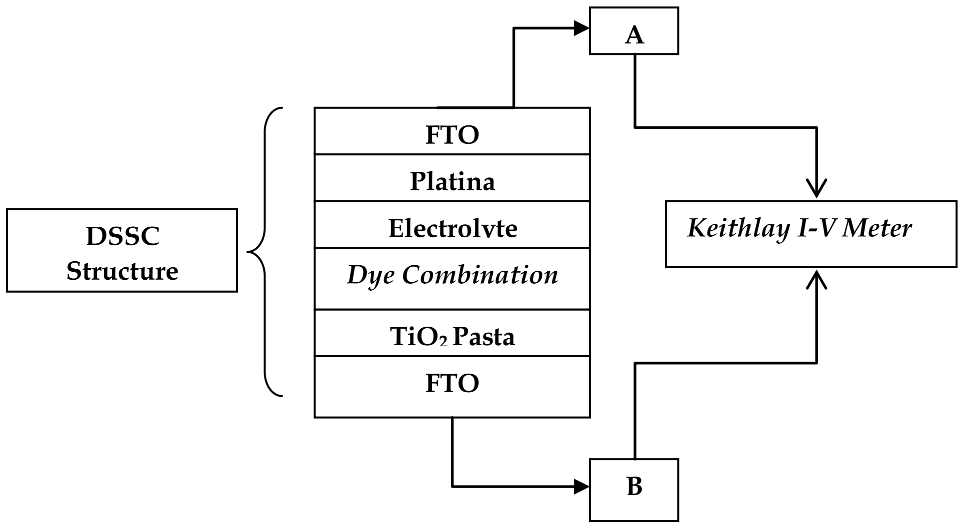

Figure.5. Calculation I-V DSSC Schema

Result and Discussion

This Dye-Sensitized Solar Cell (DSSC) uses the active material from the P3HT organic polymer characterized by currents and voltages to form an I-V meter curve. P3HT is first tested for its electrical properties to determine the material's characteristics and responsiveness to light. In general, optical properties refer to the response of a material to electromagnetic radiation and specifically to the visible light range. Some of the optical properties of the material are absorbance, reflection, and transmission. In this study, optical properties were limited only to the absorbance of P3HT. The absorbance of light occurs when the excitation of electrons from the valence band passes through the band gap to the conduction band, so a free-electron form in the conduction band and a hole in the valence band [5].

The absorbance of P3HT was measured using UV-Vis Spectroscopy Lambda 25, and it is in the wavelength range of 300-800 nm. Figure 6 shows the absorbance curve of P3HT with a concentration of 1%.

Based on the absorbance test, P3HT has a peak absorption wavelength of 300-650 nm. Studies [9]and [13] obtain the same results so that P3HT with a concentration of 1% can absorb light in the visible light wave range. This light absorption is photons' energy used to excite electrons from Higher Occupied Molecular Organic (HOMO) to Lower Uncopied Molecular Organic (LUMO) on the P3HT molecule. In line with this [9], in their research, obtained absorption peaks in the range of 450-650 nm with an energy gap of 1.9 eV.

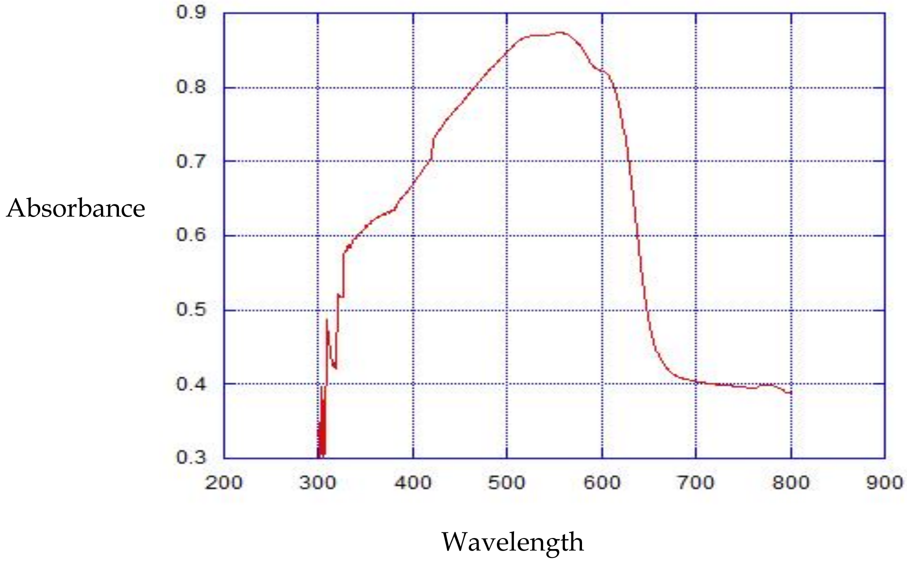

Figure 6. P3HT Absorbance Curve

In DSSC, TiO_2 functions as an electron trap from the P3HT conduction band. Besides, TiO_2 has an energy gap of ~ 3 eV [14]so it takes energy equal to or greater than ~ 3 eV so that electrons can be excited from the valence band to the TiO_2 conduction band. P3HT absorbs visible light at a wavelength of about 300-600 nm, able to excite electrons from HOMO to LUMO.

These electrons are injected into the TiO_2conduction band and then transferred to the external DSSC circuit. Therefore, P3HT is an electron donor while TiO_2 is an electron acceptor. The curve also shows that TiO_2 and P3HT with a concentration of 1% can absorb light. Following the Lambert-Beer Law, where the absorbance of light is directly proportional to the level of concentration [9]. Thus, it expects that the resulting current will also be more significant. The results obtained are maximal because the TiO_2 production is used at the nanoparticles' size to distribute the light absorption process among the TiO_2 molecules used.

Basically, for the maximum current to be obtained, the Triodide concentration must be small but with this small concentration it must be able to meet the needs in the process of electron recombination against the electrode counter used in the Pt (Hexacloroplatinic IV) layer. In addition, prevention of penetration of electrolytes out of the system must be taken. Thus the efficiency obtained will be maximized. Iodide is used because it is very strong and the recombination process is relatively long, so that its main function as the regeneration of electrons in cells against dye molecules can occur. Table 1 is the test results of the I-V characteristics of the electrolyte redox pair Iodine and Potassium Iodide under light and dark conditions.

Table 1. *I-V* The results of the comparison of electrolyte conductivity in dark and light conditions

Material	Dark Conductivity ($\Omega^{-1}m^{-1}$)	Bright Conductivity ($\Omega^{-1}m^{-1}$)	Δ Conductivity ($\Omega^{-1}m^{-1}$)
Electrolyte	3.5×10^{-3}	4.5×10^{-3}	5×10^{-4}

The value of electrolyte conductivity in dark conditions is $3.5 \times 10^{-3}\ \Omega^{-3}m^{-3}$ and increases $4,5 \times 10^{-3}\ \Omega^{-3}m^{-3}$ in bright conditions with a difference in conductivity of $5 \times 10^{-4}\ \Omega^{-3}m^{-3}$. The dark current is smaller than the bright current because, in the bright current, there is a photo flow (I_{Ph}) which is influenced by the size of the light intensity shining on the cell. The electrolytes' role in DSSC is as charge regeneration on dye molecules and charge transport in redox pairs [15].

The amount of conductivity expected to improve the work performance results on the DSSC. Due to the more remarkable the conductivity value of an electrolyte, the easier the electron donor ability of the dye will be and the more significant the change in the increase in the conductivity value when measured in dark and light conditions, the better this material can be applied as an active ingredient in solar cells [16].

Measurement of the conductivity of the solution is carried out by flowing current at the two electrodes. Measurements were made in dark conditions and under irradiation. Besides, it can also be seen that the photoconductivity value produced by the P3HT polymer is 5 x 10-4 Ω-1m-1. It indicates that P3HT dye can produce an excellent electric current. Conductivity indicates a material or material's ability to generate electric current [5]. The increase in the conductivity value occurs with irradiation and the addition of dye concentrations. The irradiation conditions and the addition of concentration will increase the ability of the P3HT dye to generate electric current.

Based on the I-V curve, it can be seen that P3HT appears to have a quadrant graphic in accordance with the characteristic graph of the DSSC, it can be seen that the I-V curve generated by DSSC using the Pt (Hexacloroplatinic) opposing electrode produces excellent Voc and Isc. This indicates that the use of Pt (Hexacloroplatinic) can improve the performance of DSSC, so that Pt (Hexacloroplatinic) can be used as a catalyst to accelerate the occurrence of redox reactions in electrolytes.

It can be seen that the DSSC with P3HT 1% appears to have a graph in quadrant IV that matches the characteristic graph of the DSSC. When a material with a donor-acceptor relationship is exposed to a light beam, it will increase the electron flow [17]. There will be a shift in the valence and conduction bands between the two P3HT layers, causing the current to flow.

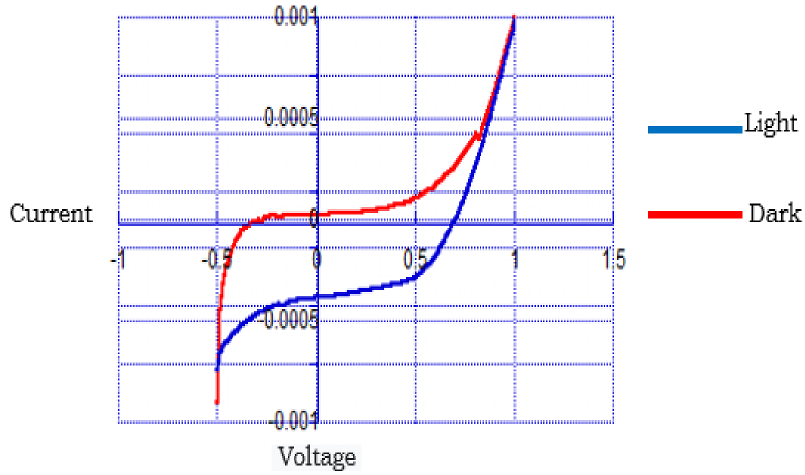

Figure 7. P3HT I-V Characteristic Curve

The amount of Isc strongly influences the value of the power conversion efficiency. The greater the Isc, the greater the resulting efficiency. If traced, Isc is the current density in a DSSC device when it is exposed to light without being given a forward or reverse bias voltage or is in quadrant IV [5].

Table .2 Optimization results for P3HT DSSC efficiency

Dye	*Vmax*(mV)	*I max*(mA)	*Isc*(mA)	*Voc*(mV)	*FF*	*Ef %*
P3HT	3.6x 10^{-1}	8.8 x 10^{-3}	5 x 10^{-4}	7.1x 10^{-1}	8.1 x 10^{1}	1.8x 10^{-1}

In table 2, based on the optimization results, the DSSC which uses a P3HT concentration of 1% with chlorobenzene solvent, results in characterization and uses Pt (Hexacloroplatinic) as the opposing electrode. In order to see the performance of the DSSC, characterization was carried out by measuring I-V in light and dark conditions. From graph IV made in Figure 7, it can be seen from the current when short circuit (short circuit) Isc gets 5 x 10^{-4} while for the open voltage (open circuit) Voc is 7.1x 10^{-1} and the resulting efficiency in the dssc manufacturing process 1.8x 10^{-1}.

The efficiency produced in this study is still relatively low. The organic material has low mobility, is easy to combine, and the amount of resistance that the injected electrons from P3HT must pass in the semiconductor layer. It will have a small impact on the number of electrons flowing into the outer circuit. For this reason, one of the ways to improve the performance of DSSC is by better dosing the material in order to obtain a broader absorption spectrum and increase the generation and mobility of the load [13]. Besides improving performance, it is necessary to improve each DSSC component's structure to obtain a better interface connection and reduce defects formed between the layers (interfaces).

Conclusion

Dye-Sensitized Solar Cells (DSSC) using P3HT polymer extraction materials have been fabricated. With the current and voltage generated in the manufacture of the DSSC with the area of the curve, it shows that the DSSC of the polymer material extract using the drop method produces an excellent I-V curve. The results of P3HT characterization showed an effect on the I-V characterization of solar cells. The opposing electrode is one of the critical components that are not usually released in the DSSC structure. Pt (Hexachloroplatinic) (IV) acid 10%) functions as a catalyst in accelerating redox reactions with electrolytes and using opposing electrodes from other materials that have better conductivity and catalytic properties and the use of a DSSC structure with a bulk heterojunction structure, where the two active organic DSSC materials are blended (mixed) before being deposited into solar cells.

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