

Solar Cell Polymer Based Active Ingredients PPV and PCBM

H Hardeli*, H Sanjaya, R Resikarnila, R Nitami H

Chemistry Department, Universitas Negeri Padang, Indonesia

*hardeli1@yahoo.com

Abstract. A polymer solar cell is a solar cell based on a polymer bulk heterojunction structure using the method of thin film, which can convert solar energy into electrical energy. Absorption of light is carried by active material layer PPV: PCBM. This study aims to make solar cells tandem and know the value of converting solar energy into electrical energy and increase the value of efficiency generated through morphological control, ie annealing temperature and the ratio of active layer mixture. The active layer is positioned above the PEDOT:PSS layer on ITO glass substrate. The characterization results show the surface morphology of the PPV:PCBM active layer is quite evenly at annealing temperature of 165 ° C. The result of conversion of electrical energy with a UV light source in annealing samples with temperature 165 ° C is 0.03 mA and voltage of 4.085 V with an efficiency of 2.61% and mixed ratio variation was obtained in comparison of P3HT: PCBM is 1: 3

1. Introduction

Solar cell is very suitable to be developed in Indonesia considering the location is very strategic that is located on the equator, where the intensity of sunlight is quite large. Indonesia is classified as a rich source of solar energy with a total intensity of irradiation on average 4.5 kWh per square meter per day, compared with Japan whose total intensity of irradiation is only 150-180 Wh per square meter per day. In addition, as it lies on the equator, the sun in Indonesia shines about 2,000 hours per year (Suherdiana, 2008). The utilization of solar energy in Indonesia is only limited to natural benefits, so very much from the energy entering the surface of the earth re-reflected into outer space (Mairizwan, Hendro, 2015).

Solar cells work using solar energy by converting solar radiation directly into electricity. Today's most widely used solar cells are silicon which is the result of the rapid development of inorganic semiconductor technology. Although solar cells are now dominated by silicon materials, the high cost of production makes them more expensive than fossil energy sources. For that, cheap solar cells with high cell performance and organic solar cells or polymer solar cells can be a solution. These cells are easily made from organic material, inexpensive, lightweight, flexible and colorful (Soetrisno, 2009).

The P-Phenylene Vinylene (PPV) polymer is a conjugated conductive organic polymer having a single double bond in the form of a repeating unit of combined benzene rings and transacetylene bonds. This type of bond allows the electrons to be delocalized along the polymer chain, thereby providing the semiconductor properties of the polymer. PPV has a conductivity of 10⁻⁹-10⁻¹³ S / cm (Bradley 1987).

PPV is often used as a material model to obtain a basic understanding of photophysics conjugated polymers. PPV polymers readily dissolve in ordinary organic solvents and can be made in the form of films by spin-coating techniques (Bahtiar, A. 2009). The structure of PPV can be seen in figure 1.



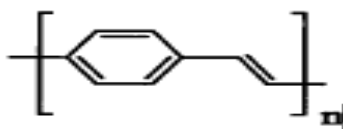


Figure 1. PPV Structure (Baskoroadi, G. 2011)

PPV has a ray absorption at a wavelength of 450-550 nm. The PPV material with wavelength absorption is likely to be solar cell material, since sunlight has the highest energy on the spectrum with a wavelength of 500 nm (Nurosyid, 2014). PPV polymeric materials are called electron donor materials (Aernouts 2006) and are also called p-type semiconductors. Orbital energy at -5.3 eV for HOMO (Highest Occupied Molecular Orbital) and LUMO (Lowest Unoccupied Molecular Orbital) at -3.2 eV (Oku et al., 2008).

The characteristics of photovoltaic effects of PPV solar cells with the addition of polymer [6,6] - phenyl C61 butyric acid methyl ester (PCBM) were also observed to obtain better organic solar cells. The PCBM polymer material was chosen because it has the same solvent as PPV and is acceptor (Aernouts, 2006) and also includes n-type semiconductors. PCBM has HOMO orbitals - 5.1 eV and LUMO - 3.7 eV (Zahlou et al., 2014). The structure of PCBM can be seen from Figure 2.



Figure 2. PCBM Structure (Bahtiar, A., et al. 2011).

Studies conducted on polymer solar cells typically use only one layer of polymer coating. therefore in this research will be done variation of PPV polymer coating amount: PCBM as effort to control morphology, that is 1,2, 3 and 4 coating. Thus, the expected polymer solar cells are capable of producing high efficiency.

2. Research Methodology.

A. Materials and Tools

Equipment used is XRD (X'Pert Powder PAN Alytical Pw 3060/40), FTIR (Perkinelmer type: FTIR Frontier Spectrometer), UV-VIS Agilent 8453, Digital Multimeter, 250 mL glass, measuring cylinder, dropper dropper, 5 and 10 mL, stirring rod, magnetic stirrer, spatula, petri dish, lumpang alu, tape, separating funnel, furnace and digital multimeter

The materials used are TiO₂ Degusa P-25, methanol pa, acetic acid pa, ethyl acetate pa, aquades, n-hexane pa, purple sweet potato, paper whatman, KI (potassium iodide), I₂ (iodine), acetonitrile pa, cetyl trimethyl ammonium bromide, pencil powder, ITO (Indium Tin Oxide) glass, and polyethylene glycol (PEG), PPV (poly [2-methoxy-5- (2-ethyl-hexyloxy) -1,4-phenylene] PCBM ([6,6] -phenyl-c61-butyric acid methyl ester), PEDOT (poly (styrenesulfonate), PSS (poly (3,4-ethylenedioxythiophene).

B. Experiments

1. ITO lithography

The ITO substrate prior to use should be in a clean and sterile state of the impurity particles then the substrate was washed glass substrate soaked in a glass of water containing soapy water, then wash thoroughly. The glass is immersed in 50 mL of methanol and disonikasi with ultrasonic cleaner for ± 120 minutes. Then the glass is cleaned with aquades and reconstituted in an ultrasonic cleaner for ± 120

minutes. Cleaned glass is stored in a bottle containing aquades for fat and dust free. Spray (spray) aquades onto the glass surface so no clumps of water are attached. Glass is dried in a vacuum oven at $\pm 110^\circ\text{C}$ for ± 60 minutes when it is to be used

2. Determining the Annealing Temperature of Making Polymer Thin Films

The ITO mask is worked on the part that will not be removed using adhesive tape while the part to be removed is immersed into 50% HCl for ± 15 min. 3 minutes. ± 3 minutes and water for $\pm$ Then the sample was dipped into 3 NaHCO₃ for After that the samples were dried by removing the mask from the sample and ultrasonic cleaning using water, IPA (isopropyl alcohol), and acetone for 10 minutes. $\pm$ Above the ITO layer is then superimposed PEDOT: PSS using screen printing techniques. The coating is then heated in a vacuum oven at 120°C for 60 minutes. PEDOT: PSS is used as a hole transporter and exciton blocker, and prevents ITO diffusion into the active coating polymer. then above the PEDOT layer: PSS is regenerated the active layer of P3HT polymer: PCBM. A total of 200mg of P3HT was dissolved into 10ml chlorobenzene and stirred until homogeneous solution, and also 200mg. PCBM dissolved into 10ml chlorobenzene is stirred until homogeneous solution. Using a pipette plastic, the two solutions are mixed into one bottle and stirred until homogeneous. Coating process using spin coating technique at 600rpm rotation speed for 30 seconds with active area of 2.6 cm². Furthermore, the polymer layer is left overnight in the nitrogen environment. After that the annealing process of the active layer at a temperature of 120°C and 150°C using a vacuum oven, then deposition metal contact Al. Al contact coating is done by thermal evaporation technique. Then the capsulation is done by covering the top surface of the cell with glass using a sealant as its adhesive medium and then heating at a temperature of 120°C for 10 minutes. To determine the I-V characteristic of polymer solar cells, measurements were made by irradiating the cells using a Xenon light source on a 60 mW / cm² light irradiation and a temperature of 25°C .



Figure 3. Flow chart of PCBM polymer solar cell research procedure: PPV

3. Conducting Morphological Control of Active Layers Through Annealing Treatment At Different Temperature Range

At sharing annealing temperatures SEM characterization was performed to obtain an active layer morphology image. Samples that are annealed at different temperatures will provide different surface morphologies. At this stage will be seen the surface of the annealing at what temperature is most homogeneous and evenly distributed

4. Preparation of mixture PPV: PCBM

Preparation of mixtue PPV: PCBM (3: 1)

A total of 30 mg of PPV was dissolved into 3 ml of chlorobenzene and stirred until homogeneous solution, and also 10 mg PCBM dissolved into 1 ml of chlorobenzene stirred until homogeneous solution. Both solutions are mixed and stirred until homogeneous (Pratiwi, Z. R. 2013).

5. Preparation of PEDOT: PSS

PEDOT: PSS weighed as much as 0.05 g, then dissolved in 1.5 mL of aquades, then stirred until a paste was formed

6. Preparation of Carbon Elektoda Counters

As the carbon source used graphite from pencil. The graphite is superimposed onto the ITO substrate on its conductive part and then heated at 450 ° C for 10 minutes to allow the graphite to form a good contact of carbon particles with the ITO substrate (Damayanti, Retno 2014)

7. Characterization of Thin Film on Glass Surface

a. SEM / EDAX

Characterization is done by using SEM / EDAX to see the surface morphology and elements present in thin films. The XRD characterization was performed to see the crystal structure of thin films on the glass surface as well as to determine the size of the crystals obtained. The size of the crystals in nanometer size will surely greatly help the production of the resulting solar cell. UV-Vis will be used to obtain the optical characteristics of the active layer of polymer solar cells

b. XRD

Characterization with XRD was performed to determine the crystal structure of the TiO₂ catalyst powder by knowing the sample peaks and comparing with the standard peaks of the Hanawalt index. The characterization was done in Physics Laboratory of FMIPA UNP, using Philips PW 1710 instrument equipped with PW channel control voltage 40 kV, current 30 mA and diffraction angle velocity $2\Phi = 200-1000$ with observation speed 2,40 / minute.

8. Solar Flow Testing of Solar Cells

In solar cells that have been assembled testing, namely direct testing of measured voltage and current from solar cells using a digital multimeter. Light source used is direct sunlight. From the value of the current and the voltage obtained can be calculated the efficiency value of the solar cell made.

3. Result and Discussion

1. Solar Cells Based on Polymer Blends PPV: PCBM

Solar cells based on polymer blends can be produced by growing the active layer on a glassed ITO substrate glass. Components of solar cells made of ITO substrate lithography, paste PEDOT:PSS, active layer PPV: PCBM and Carbon electrode counter.

The ITO substrate resistance used in this study is 100 Ω and PEDOT: PSS layer that has been made in the form of dark blue paste. The active layer created by mixing PPV with PCBM has a brownish red color. This solar cell uses a carbon electrode made by superimposing a pencil powder (graphite) on the ITO glass substrate surface.

Solar cell with PPV active layer: PCBM can produce electric current because PPV and PCBM are polymer or organic semiconductive materials. In PPV and PCBM there is a double bond that is conjugated, so that the more bonds π , the greater the current generated. PPV and PCBM are capable of absorbing light from UV lamps and generating electrons during UV light on the surface of solar cells, then electrons will flow through a pair of electrodes ie ITO as the cathode to the carbon anode so as to produce an electric current that will be read on a direct test with a multimeter.



Figure 4. The hybrid polymer solar cell device is in reverse structure

The solar cell device is encapsulated by clamping the structure of the solar cell with the binder clips on the off set on the left and right sides. This polymer solar cell is tested for its ability to convert UV light that serves to irradiate solar cells into electrical energy. UV rays are used with intensity 24 W and then characterized the active layer morphology of PPV polymer mixture: PCBM.

A. Characterization of PPV Active Layer: PCBM with SEM

Samples characterized by SEM were polymer active layer PPV:PCBM which has been deposited on glass substrate ITO. The result of SEM characterization in the form of morphological picture of sample surface can be seen in Figure 5 below. Characterization is done at magnification up to 40,000 times.

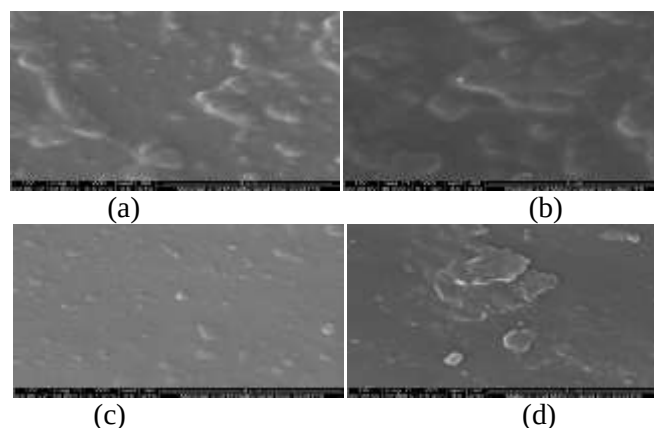


Figure 5. SEM results of PPV active layer: PCBM coating (a) 2 coatings, (b) 3 coatings, (c) 4 coatings and (d) 5 coatings.

The SEM results show the homogeneity of the surface of the active layer PCBM:PPV (3: 1) deposited above the thin layer of ITO, the most flat layer of the coating active layer 4 times, which only slightly holes appear.

The SEM results in the active coating of 2 and 3 coatings were obtained not too flat. In coating 2 and 3 coatings can be seen there is a stacking section. This is due to the incomplete growth of the coating during the spin coating process so that the polymer solution has not formed a flat layer. Another factor that causes incomplete layer is the rotational speed of the spin coating. In the coated 5-layer coating sample, there were more stacking parts compared to the active coating of 2, 3 and 4 coatings. This is because the thickness of the coating to get a layer that is not too flat.

B. Properties of Solar Cells Polymers

Polymer solar cells that have been successfully assembled then carried out direct testing, namely the ability to convert energy with the help of light sources used are UV lights. The irradiation performed with a large intensity of 24W / m². Polymer solar cells successfully convert into electrical energy which is indicated by the value of voltage and electric current.

Treatment of annealing to active layer PCBM: PPV is carried out at 120 ° C, 135 ° C, 150 ° C, 165 ° C and 180 ° C above the transition glass temperature, where the glass transition temperature for PPV is about 110 ° C. When the process of annealing active polymer molecules will be free to move in the film, so PCBM will relax and re-structure the process (Pratiwi, Z.R. 2013). The resulting voltage of the solar cell on the annealing treatment can be seen in Table 1.

Table 1 Results of voltage measurement on PCBM: PPV (1: 1)

Annealing Temperature	Voltage (V)	Current Power (mA)
120 °C	1,077	0,01
135 °C	1,081	0,01
150 °C	4,009	0,02
165 °C	4,032	0,02
180 °C	1,086	0,01

Table 1 shows that the optimum annealing temperature for polymer blends PCBM:PPV is 165 °C with the highest voltage of 4,032 V and a current current of 0.02 mA. The resulting voltage decreases

at temperatures above 165 °C, this is due to the effect of photon energy absorption on the active layer. Yunzhang lu, et al in Pratiwi, R.Z (2013) states that close to 200 °C the active layer will undergo a significant color change which states the polymer reaches its melting point.

The strength of the resulting current is still relatively small. Cocima, et al (2012) states that the current strength is influenced by the photon light source. Small photon sources will produce a small current because only a small amount of photon energy is absorbed by the active layer. The small amount of current generated is also caused by a hole or stack on the active layer of PCBM: PPV that can inhibit the absorption of photons.

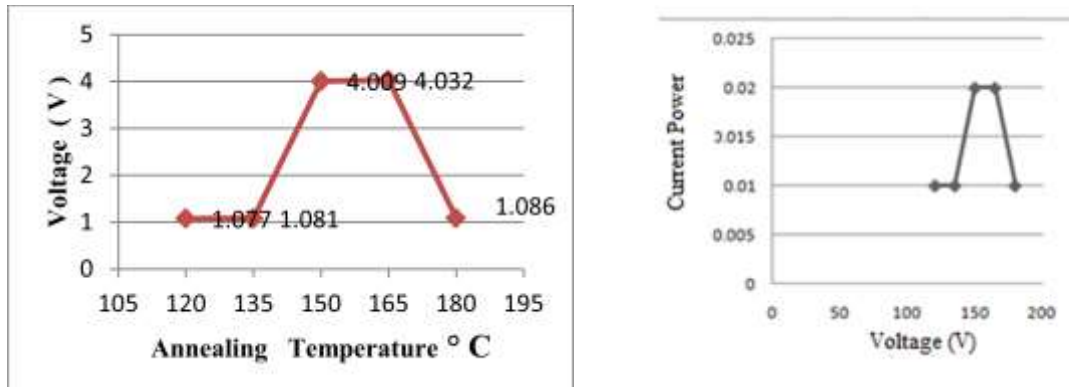


Figure 6. Annealing temperature comparison curve to (a) voltage (V) and (b) current strength

The annealing treatment is carried out to a temperature of 180 °C, Yunzhang Lu, et al in Pratiwi R.Z (2013) states that at temperatures close to 200°C there is a color change in the active layer which states that the active ingredient polymer reaches its melting point. Based on the measurement result, the current and voltage values obtained the highest efficiency at annealing temperature of 165 °C in Table 2

Table 2. Polymer solar cell parameters on PCBM: PPV (1: 1)

Temperature	Efficiency
120	0.23
135	0.23
150	1.71
165	1.72
180	0.25

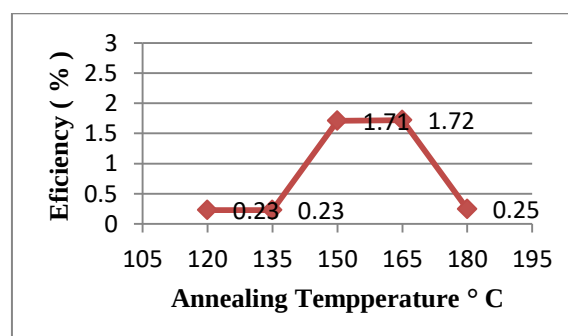


Figure 7. Annealing temperature comparison curve to the efficiency of solar cells

The highest efficiency value of solar cells was 1.72% using semiconductor polymer PCBM:PPV as the active layer, and shown in Figure 7 where it was obtained at 165°C with the highest efficiency. The

efficiency produced is relatively small, but higher than previous research conducted by Pratiwi, RZ (2013) using polymer P3HT:PCBM obtained 0.003% efficiency and also research conducted by Chotimah, Triyana, K and Kartini, I obtained maximum efficiency of 0.81%.

This study also conducted an increase in the number of particles of PCBM in active ingredients with a ratio of 2: 1 and 3: 1 to PPV. Annealing was done at a temperature of 165 ° C, because on PCBM: PPV (1: 1) obtained the highest efficiency there was a temperature of 165 ° C. Increasing the number of PCBM can increase the voltage and current strength of the solar cells, as in Table 3.

Table 3. Current and voltage measurement results at 165 ° C

[PCBM:PPV]	Voltage (V)	Current Power (mA)	Efficiency (%)
1:1	4,032	0,02	1.72
2:1	4,045	0,03	1,73
3:1	4,085	0,03	2,61

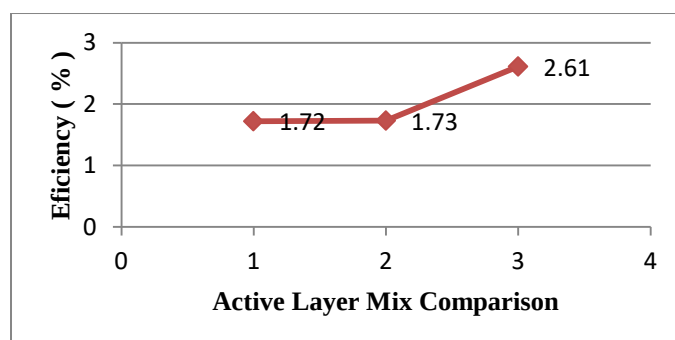


Figure 8. The ratio of the active ingredient mixture to the efficiency of the solar cell

Based on Table 3, it is seen that increasing the number of PCBM polymers in the active layer also improves the performance produced by the cells. PCBM in the active layer serves as an electron donor when UV irradiation is performed. Increasing the number of PCBM in the active layer is capable of producing the conversion of light to better electrical energy, as more and more photon energy can be absorbed so that more electron-holes are generated (Nurussaniya, et al., 2013).

Increasing the number of donor particles in the active layer will increase the amount of photon energy absorbed by the active layer. At annealing temperature 165 ° C resulted in higher efficiency at 3: 1 ratio that is 2,61%. This is because more of the photons are absorbed on the surface of the active layer. Widiastuti, Nanik, et al (2015) stated that increasing the number of particles in the active layer will increase the absorption of photon energy.

The efficiency improvement in the 3: 1 ratio is very small, as revealed by Mokarromah (2016) that the absorption of the photon is proportional to the rate at which electron-hole is formed. Electron excitation will lead to the semiconductor coding band. The electrons in the free conduction band move, but if the electron is too much it will inhibit the electron flow rate. This causes the electrons to flow through the outer circuit to the weaker electrode counter.

The results of this study are still relatively low when compared with the current solar cell efficiency, but better than the previous research conducted by Bakhtiar, Ayi et al (2011) which produced 0.5 x 10⁻³%. Chotimah, et al (2012) yielded 0.81% by varying the intensity of xenon lights.

The low efficiency of solar cells is influenced by some of them by the presence of solvents and water vapor trapped in the active layer in the spin coating process. When annealed solvent and water vapor will evaporate, thus creating a hole and creating an uneven morphology of the active layer. The presence of oxygen also affects the performance of the solar cells, since oxygen can bind to the ultimate carbon from the polymer double chains, then the bonds form a reaction that will interfere with the P3HT conjugation (Pratiwi, R.Z. 2013). The small energy source of the photon used also affects

solar cells, since the photon energy source is directly proportional to the performance of the solar cells (Chotimah, et al., 2013).

Conclusion

Based on the results of research and discussion, the following conclusions can be drawn:

1. The morphology of the more uniform and homogeneous active layer is produced at an annealing temperature of 165 ° C.
2. Highest current and voltage produced by solar cells using PCBM: PPV as active ingredient in a row is 0.02 mA and 4,032 V at annealing temperature of 165 ° C.
3. Efficiency of solar cells to the effect of annealing temperature obtained maximum at a temperature of 165 ° C that is 1.72%.
4. Efficiency of polymer solar cells increases with increasing amount of PCBM in coated active material, ie at 3: 1 at 2.61%.

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