Abstract. Organic solar cells of FTO/PEDOT: PSS/P3HT: PCBM/Al has been fabricated, and its performance has been tested in dark and under various illumination of light intensity 1000 W/m². The active materials used in this study are poly (3-hexylthiophene) (P3HT) and [6, 6]-phenyl-C₆₁-butyric acid methyl ester (PCBM). P3HT is the donor while PCBM acts as an acceptor. Variation of PCBM and P3HT are 1:1, 1:2, 1:3, 1:4 and 1:5. P3HT: PCBM was mixed by chlorobenzene solvents. The mixing was done by using the ultrasonic cleaner. The absorbance characterization using UV-Visible Spectrometer Lambda 25 instrument and I-V characterization has been tested using a set of 2602 A Keithley instrument. Absorbance characterization shows that two peaks are formed. The first peak in the range of 300 to 350 nm which is a range of PCBM and the second peak range from 450 to 600 nm which is a range of P3HT. As the mass ratio increases, the second peak of P3HT increases while the first peak does not change. The gap energy estimated by the Tauc method is 2.0 eV. I-V characterization of the efficiency was obtained. The efficiency of sample 1, 2, 3, 4, and 5 are 5.80 x10⁻²%; 6.46x10⁻²%; 7.72x10⁻²%; 8.25x10⁻²% and 9.81x10⁻²%, respectively. The highest value of efficiency was obtained at mass ratio 1:5.

1. Introduction
Important challenges in the field of organic photovoltaic are how to provide a viable alternative for the energy production at large scale including the development processes for up-scaling the fabrication of cells to modules [1]. Another benefit of organic polymeric solar cells is it allows molecular level modification, and the unlimited organic semiconductor materials [2]. The organic materials also can be extracted from some cultivated plants [2]. Another research on organic solar cells (OSC), which is being developed, is a bulk heterojunction (BHJ) device. The BHJ type becomes an option because it has a polymeric active material in a blend, roles as donor and acceptor [3-5]. Currently, the structure of a P3HT (poly(3-hexylthiophene)): PCBM
(6,6-phenyl-C61butyric acid methyl ester) bulk heterojunction (BHJ) cell, which may be considered as one of the most standard organic solar cell (OSC) devices.

An active material can work properly if the donor and acceptor have a proper HOMO (High Occupied Molecular Orbital) and LUMO (Lowest Unoccupied molecular Orbital) [6]. P3HT (Poly(3-hexylthiophene) and PCBM (Phenyl-C61-Butyric Acid Methyl Ester) polymer has HOMO 3 eV and 4 eV respectively, facilitating electron transfer from P3HT to PCBM [7]. Poly (3-hexylthiophene) or P3HT polymeric semiconductor has matching criteria as donor material and acts as a p-type. Poly (3-hexylthiophene) has a molecular weight of 65.5 g/mol and a high hole mobility of 3.8~3.9x10^{-4} cm²/Vs [8]. PCBM or C61-ButyricAcid Phenyl-Methyl Ester is derived from fullerenes. PCBM is typically used as a good acceptor material in organic solar cells. This causes the PCBM be a material uses in solar cell active ingredient compared to other fullerene-derived material [9].

2. Experimental procedure

P3HT and PCBM polymer were blended in the mass ratio of PCBM and P3HT (1:1; 1:2; 1:3; 1:4; and 1:5). P3HT and PCBM were mixed with a 1% concentration of chlorobenzene solvent. A solution of P3HT: PCBM was deposited on glass substrates. This deposition was performed by spin coater instrument at 2500 rpm angular velocity for 30 seconds [10]. The optical absorbance of samples were then analyzed by a UV-Vis Spectrometer (Lambda 25 instrument) with a wavelength ranging from 300-800 nm.

PEDOT: PSS layer was grown on FTO by spin coating method for 20 seconds at 2500 rpm of angular velocity. The method produces FTO / PEDOT: PSS [11]. The next process was growing a P3HT: PCBM active material by spin coater as well producing. FTO / PEDOT: PSS / P3HT: PCBM. The last process was metallization of Al by evaporator instrument. The organic solar cell devices were established with the structure of FTO / PEDOT: PSS/P3HT: PCBM/Al. The absorbance properties of the fabrication layers were then observed.

The current–voltage characteristic in dark at room temperature was analyzed by a 2602A Keithley instrument high voltage source. The measurement was performed under dark and under illumination to study the photosensitizing effect in the device. The device was illuminated by a visible light from xenon light source. The xenon light source was calibrated by adjusting the light intensity until 1000 W/m². The intensity was controlled by a solar power meter, meanwhile, the temperature was measured by the thermocouple. The illuminated cell area was 10 mm². The photosensitizing parameters of short circuit current density (I_s) and open circuit voltage (V_{oc}) were obtained from the intersection axis of current and voltage from the current-voltage curve under dark and illumination, respectively. Figure 1 shows the structure of organic solar cells of FTO/PEDOT: PSS/P3HT: PCBM/Al.

![Figure 1. The structure of organic solar cells of FTO/PEDOT: PSS/P3HT: PCBM/Al.](image)

3. Results and discussion

Figure 2 shows the absorption spectra of PCBM and P3HT film. The absorption spectra of PCBM shows that the material has the capability to absorb light at a wavelength of 350 nm,
which is in a UV range. The absorbance of P3HT is in the range of 450 to 600 nm, which is categorized as a visible light range.

**Figure 2.** (a) The Absorption spectrum of PCBM

**Figure 2.** (a) The Absorption spectrum of P3HT

Figure 3 shows the absorption spectra of PCBM and P3HT at various mass ratio (1:1; 1:2; 1:3; 1:4; and 1:5). The first peak is in the absorption region of PCBM and the second peak is in the absorption region of P3HT. The second peak increases as the increasing of the mass ratio of P3HT. Meanwhile, the first peak of the five samples has relatively similar intensities. It means that the addition of P3HT led to increasing the absorbance value of the second peak, which is in the range of visible light.

**Figure 3.** The absorbance spectrum of PCBM: P3HT at various mass ratio

The $I$-$V$ graph characteristic of organic solar cells was measured under dark and under illuminated condition using a 2602A Keithley instrument high voltage source. The $I$-$V$ graph characteristic was used to determine $V_{oc}$, $I_{sc}$, fill factor (FF) and the efficiency of organic solar cells. $V_{oc}$ is the voltage at zero current or in an open loop voltage condition. $I_{sc}$ is the current at zero voltage. The mass ratio of PCBM: P3HT are 1:1, 1:2, 1:3, 1:4 and 1:5, therefore, the $I$-$V$ graph characteristic of organic solar cells have five conditions. The study of $I$-$V$ characteristic of organic solar cells shown in figure 4 used xenon lamp for illumination with the intensity of 1000 W/m$^2$ and measurement area of 10 mm$^2$.

The best ratio of PCBM: P3HT is 1:5. The ratio produced high efficiency can be observed in figure 4(e). Figure 4(e) -shows the electrons can be produced more from P3HT due to its properties as an electron donor.
Figure 4. $I-V$ graph characteristic of organic solar cells PCBM:P3HT with the light intensity of 1000 W/m$^2$ (a) ratio 1:1 (b) 1:2 (c) 1:3 (d) 1:4 and (e) 1:5

Meanwhile, the I-V curves can not be observed when the solar cell was operated under dark condition.

The results in figure 4 show that the value of $I_{sc}$ increases, but the value of $V_{oc}$ decreases. $V_{max}$ is the maximum voltage produced by organic solar cells and $I_{max}$ is the maximum current. Table 1 shows the $I-V$ properties of organic solar cells characterization. Table 1 shows that the efficiency of organics solar cells were increased as the mass ratio of PCBM: P3HT. It is due to the ability of P3HT to be active in the wavelength range of visible light, and producing so more electrons.

**Table 1. I-V characterization of PCBM:P3HT**

| Ratio PCBM:P3HT | $I_{max}$ ($\times10^{-2}$ mA) | $V_{max}$ (V) | $I_{sc}$ ($\times10^{-2}$ mA) | $V_{oc}$ (V) | $FF$ | $Eff$ ($\times10^{3}$%) |
|-----------------|-------------------------------|--------------|-----------------------------|-------------|------|------------------------|
| 1:1             | 1.75                          | 0.32         | 0.98                        | 0.34        | 0.17 | 5.8                    |
| 1:2             | 2.59                          | 0.25         | 1.00                        | 0.29        | 0.21 | 6.4                    |
| 1:3             | 5.94                          | 0.13         | 1.03                        | 0.25        | 0.32 | 7.7                    |
| 1:4             | 5.14                          | 0.15         | 1.06                        | 0.24        | 0.35 | 8.2                    |
| 1:5             | 6.68                          | 0.14         | 1.07                        | 0.23        | 0.36 | 9.8                    |

Figure 5 shows that the values of $I_{sc}$ increases as the ratio of P3HT polymer increasing. It is due to the absorbance ability of P3HT is at the visible light range. This absorbance
influence on the number of photons, which are absorbed by the organic solar cells. The more photons absorbed, the more electrons can be generated. This result is in agreement with the results of the research of Khlyabich (2013) on the donor material.

![Mass ratio comparison graph of PCBM: P3HT to Isc, Voc, fill factor (FF) and efficiency](image)

**Figure 5.** Mass ratio comparison graph of PCBM: P3HT to Isc, Voc, fill factor (FF) and efficiency

Figure 5 shows that the fill factor value increases as the ratio of PCBM: P3HT. Higher fill factor indicates less recombination between holes and electrons because the transportation of free charge is running well. In addition, figure 5 also shows that the efficiency increased as the ratio of PCBM: P3HT increased as well as the value of $I_{sc}$.

4. Conclusion

The higher ratio of P3HT produces an absorbance peak the range of 450 to 650 nm. Meanwhile, the first peak (peak of PCBM) is in the range of 300 to 350 nm. The estimates gap energy is 2.0 eV. The highest efficiency is on the ratio of PCBM and P3HT 1: 5, i.e. 9.8x10$^{-2}$%.

Acknowledgement

The authors would like to acknowledge Kemeristek-Dikti Republik Indonesia for financial support in Penelitian Unggulan Perguruan Tinggi (PUPT 2015) of Sebelas Maret University (UNS), Indonesia.

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