Effect of Activated Variations Carbon From Oil Palm Empty Fruit Bunch To Solar Cell Efficiency p-n Junction Layer Cu$_2$O-TiO$_2$

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I. Introduction

One source of energy that can be utilized to be converted into electrical energy is solar radiation energy. The potential of solar radiation energy in Indonesia is very large, especially in areas that are crossed by the equator. The intensity of solar radiation in the area averaged 4.8 kWh/m$^2$/day [1]. Solar cell devices can be used to convert solar radiation energy into electrical energy through the photovoltaic process. One of the metal oxide materials that can be used as a constituent of solar cells is Copper (I) Oxide (Cu$_2$O). Copper (I) Oxide (Cu$_2$O) has an energy gap of around 2.1 eV. The energy gap has an acceptable range of values for the conversion of solar radiation energy [2].

Nurhidayah in 2017 conducted research on the manufacture of TiO$_2$ composite solar cells/graphite rosella flower extract produced solar cells with the highest efficiency reaching 0.003% [3]. Fadlly in 2018 conducted research on the characteristics of I-V Cu/ Cu$_2$O solar cells using star fruit electrolytes, in that study the highest efficiency solar cells were found in Cu/Cu$_2$O-100 samples with efficiency values reaching 2.84% [4]. Based on these studies, this article will examine the effect of variations in activated carbon from on the efficiency of Cu$_2$O-TiO$_2$ p-n junction solar cells to broaden the analysis of solar cells in the hope of having high solar cell efficiency. The solar cell will be compared to a composite
comparison of TiO\textsubscript{2} with activated carbon from oil palm empty fruit bunch to get the best solar cell efficiency.

II. Method

A. Material Preparation

Cu\textsubscript{2}O coating plates will be produced from Cu plates with a size of 5 cm × 2.5 cm through a thermal oxidation process at 550 °C in 100 minutes [4]. While activated carbon from oil palm empty fruit bunch is produced through a chemical activation method, where the oil palm empty fruit bunch carbon is immersed using 3 M H\textsubscript{2}PO\textsubscript{4} solution for 24 hours. Then the results of the marinade are filtered using filter paper and a neutralization process is carried out using HCl and distilled water. The process produces activated carbon from oil palm empty fruit bunch [5].

B. Synthesis of TiO\textsubscript{2}/Activated Carbon Composite Paste from Oil Palm Empty Fruit Bunch

The manufacture of composite paste begins with the manufacture of polyvinyl alcohol (PVA) suspensions. In making a suspension, the PVA is stirred using a magnetic stirrer at a temperature of 80 °C for 30 minutes [6]. PVA functions as a binder in the manufacture of TiO\textsubscript{2}/activated carbon composites from oil palm empty fruit bunch. Furthermore, to obtain the best composite results, TiO\textsubscript{2} powder and activated carbon powder from oil palm empty fruit bunch variation in weight percentages as shown in table 1.

| No | Sample  | TiO\textsubscript{2} (w.t\%) | Activated Carbon (w.t\%) |
|----|---------|----------------|-------------------------|
| 1  | TiO\textsubscript{2}−C 0%    | 80       | 0                      |
| 2  | TiO\textsubscript{2}−C 10%   | 70       | 10                     |
| 3  | TiO\textsubscript{2}−C 15%   | 65       | 15                     |
| 4  | TiO\textsubscript{2}−C 20%   | 60       | 20                     |

After a comparison between TiO\textsubscript{2} and activated carbon crushed using a mortar survived 10 minutes. Addition of PVA to the composite using a ratio of 1:1. Then stir homogeneously so that a TiO\textsubscript{2}/activated carbon composite paste will form oil palm empty fruit bunch.

C. ITO Glass Coating

Homogeneous composite TiO\textsubscript{2}/activated carbon paste from oil palm empty fruit bunch was deposited on ITO glass with doctor blade technique to form a thin layer [7]. The area of the ITO glass to be deposited is 4.5 cm × 2.5 cm. The prototype design of solar cells that have been deposited with TiO\textsubscript{2}/activated carbon composites from oil palm empty fruit bunch is shown in Fig 1.
D. Data analysis method

TiO$_2$/activated carbon composites from oil palm empty fruit bunch will be analyzed using X-ray Diffraction (XRD) to identify the formation of a composite between TiO$_2$ and activated carbon from oil palm empty fruit bunch. Next, the Spectroscopy Fourier Transform Infrared (FTIR) test will be performed to support the XRD results. I-V characteristics of solar cells will be carried out using sun simulators and direct sunlight by measuring the parameters of the open circuit voltage ($V_{oc}$) and short circuit current ($I_{sc}$) with a resistance variation of 0-50 KΩ.

III. Results and Discussion

A. Analysis XRD and FTIR

The results of XRD analysis on TiO$_2$ powder identified rutile phase using Match software with PDF number 96-900-7532. The phase peaks which have TiO$_2$ are shown in Fig 2. In Fig 2 we see the peak intensity between carbon and TiO$_2$, no new peaks are found, so that between TiO$_2$ and activated carbon from oil palm empty fruit bunch can still be distinguished.

![Fig 2. Analysis XRD](image)

The results of the analysis of TiO$_2$/ activated carbon composites from oil palm empty fruit bunch using FTIR spectroscopy are shown in Fig 3. The range of wave numbers used in the process is 4000-400 cm$^{-1}$.

![Fig 3. The FTIR composite spectroscopy of TiO$_2$/activated carbon from oil palm empty fruit bunch.](image)

Based on the Fig 3, the infrared spectrum detected vibrations in bonds between atoms with their ideal state. At lines A, B, C, D E with wave numbers between 3760-3000 cm$^{-1}$ is an O-H stretching functional group originating from H$_2$O [8]. E line with wave number 2858 cm$^{-1}$ corresponds to group C–H. The C–H group is thought to originate from the impurity of organic compounds trapped in activated carbon.
The peak of the active carbon spectrum at wave numbers 2353 cm\(^{-1}\) and 1701 cm\(^{-1}\) shown at lines F and G are functional group bonds C=O, wave number 1134 at line H refers to bonds C–O [10]. While at line I with a wave number of 690 cm\(^{-1}\) is a functional group O–Ti–O [11]. Addition of activated carbon from oil palm empty fruit bunch 20% to TiO\(_2\) changes the peak of the spectrum. Based on the results of the FTIR graph, there is no functional group bond between TiO\(_2\) and activated carbon, so that it can be stated the formation of a composite.

B. Characteristics of Solar Cell I-V

Characteristics I-V are performed under direct sunlight conditions and using a sun simulator. Based on the measurement results of the open circuit voltage (V\(_{oc}\)) and short circuit current (I\(_{sc}\)), the maximum voltage (V\(_{maks}\)) and maximum current (I\(_{maks}\)) can be determined through the optimal power (P\(_{out}\)) of the current characteristic curve against the voltage (I-V). The characteristics of I-V solar cells using sun simulator and sunlight are shown in Fig 4.

![Curve I-V of solar cells](image)

Fig 4. Curve I-V of solar cells (a) using a sun simulator, (b) using a sunlight
Based on Fig 4 there is a change between current and voltage, where the highest $I_{sc}$ value is present when the solar cell is not given a load resistance. While the value of $V_{oc}$ increases with increasing load placed on solar cells. The increasing value of the efficiency of solar cells is also influenced by the addition of activated carbon to the TiO$_2$ composite. That is because activated carbon can help the absorption of electrons to solar cells to be more maximal [12].

| Sample       | $V_{oc}$ (mV) | $I_{sc}$ (mA) | $V_{maks}$ (mV) | $I_{maks}$ (mA) | $P_{in}$ (mW) | $P_{out}$ (mW) | FF (%) | H (%) |
|--------------|---------------|---------------|----------------|----------------|--------------|---------------|--------|-------|
| TiO$_2$−C 0%| 44.2          | 0.006         | 23             | 0.004          | 11.14        | 0.09          | 0.34   | 0.008 |
| TiO$_2$−C 10%| 70            | 0.014         | 37.5           | 0.006          | 11.14        | 0.22          | 0.22   | 0.020 |
| TiO$_2$−C 15%| 75            | 0.015         | 39             | 0.009          | 11.14        | 0.35          | 0.31   | 0.031 |
| TiO$_2$−C 20%| 82.5          | 0.17          | 43             | 0.011          | 11.14        | 0.47          | 0.35   | 0.043 |

The complete current and voltage values can be seen in Table 2 and Table 3. In Table 2 the highest efficiency of solar cells when using a sun simulator is found in the sample TiO$_2$−C 20% by 0.043%. In this sample the weight variation of 60% TiO$_2$ and 20% of oil palm empty fruit bunch activated carbon were used. Then the solar cells when using direct sunlight the highest efficiency values are also found in the sample TiO$_2$−C 20% by 0.0018% as shown in Table 3. The efficiency of solar cells using direct sunlight is much lower than the efficiency using the sun simulator test. This is due to the magnitude of the $P_{in}$ value generated from sunlight. The power produced by sunlight reaches 830 W/m$^2$, while the power from the sun simulator is 9.9 W/m$^2$ [4].

| Sample       | $V_{oc}$ (mV) | $I_{sc}$ (mA) | $V_{maks}$ (mV) | $I_{maks}$ (mA) | $P_{in}$ (mW) | $P_{out}$ (mW) | FF (%) | η (%) |
|--------------|---------------|---------------|----------------|----------------|--------------|---------------|--------|------|
| TiO$_2$−C 0%| 105           | 0.014         | 53             | 0.009          | 933          | 0.45          | 0.30   | 0.0004 |
| TiO$_2$−C 10%| 150           | 0.028         | 76             | 0.018          | 933          | 1.33          | 0.31   | 0.0012 |
| TiO$_2$−C 15%| 162           | 0.032         | 70             | 0.025          | 933          | 1.75          | 0.33   | 0.0016 |
| TiO$_2$−C 20%| 180           | 0.035         | 67             | 0.031          | 933          | 2.08          | 0.33   | 0.0018 |

IV. Conclusion

The results of the characteristics of I-V solar cells p-n junction layer of Cu$_2$O composite TiO$_2$/activated carbon from oil palm empty fruit bunch that has been implemented can be summarized as follows:
1. The XRD results identified the TiO$_2$ powder as a rutile phase and between the peak intensities of TiO$_2$ and activated carbon from oil palm empty fruit bunch can still be distinguished.
2. Based on the results of characteristic data of I-V, the highest efficiency value is obtained in solar cells with 20% active carbon variation.

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