# CURRENT-VOLTAGE CHARACTERISTICS OF SOLAR CELLS p-n JUNCTION ZnO AND $TiO_2$ PARALLEL ON $Cu_2O$ LAYER

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**ABSTRACT**

Current-Voltage Characteristics of solar cells p-n junction ZnO and $TiO_2$ parallel in the $Cu_2O$ layer has been determined using solar irradiation. Metal oxide has been used as a semiconductor material, such as ZnO and $TiO_2$ is an n-type semiconductor. The material has gap energy of 3.37 eV and 3.2 eV. Thermal oxidation is applied to commercial Cu plates for 60 minutes to produce $Cu_2O$ layers as p-type semiconductors. The process varies in temperature, namely 300, 400, and 500 °C. The process of thermal oxidation on Cu plates at a temperature of 300 °C increases the impurity in the $Cu_2O$ layer. The impurity layer is CuO. Then the CuO layer formed decreases with increasing temperature thermal oxidation. CuO layer increases the efficiency of solar cells p-n junction $TiO_2$-ZnO parallel in the layer $Cu_2O$. The results of measurements with sunlight showed that the $TiO_2$-ZnO/$Cu_2O$ (300) samples had the highest solar cell efficiency, which was 0.28 %.

**Keywords:** Current-Voltage Characteristic; ZnO; $TiO_2$; $Cu_2O$; Parallel; Solar Cells.

## Introduction

Solar radiation energy can be converted into electrical energy with solar cell devices through the photovoltaic effect. These days many semiconductor materials developed in material engineering technology related to its electrical properties. Metal oxides, such as $Cu_2O$, ZnO, and $TiO_2$, are semiconductor materials used in solar cells during the research stage. $Cu_2O$ layers can be produced from Cu sheets by no-vacuum techniques, such as thermal oxidation.[1] Zhu (2004) has conducted copper oxide kinetic studies in the temperature range of 350 ° C to 550 ° C for the formation of copper oxide.[2] In addition, at a temperature of 200 °C for 10 minutes in the air had started to form CuO copper to a temperature of 300 ° C to form $Cu_2O$.[3] $Cu_2O$ has a 2.1 eV energy band gap which is a promising p-type semiconductor material for solar cell applications with theoretical limits, energy conversion efficiency as high as 20% under AM1 solar lighting. This is very difficult to achieve high efficiency, because of the difficulty of obtaining n-type semiconductors and the stability of the $Cu_2O$ surface.[4] ZnO and $TiO_2$ are n-type semiconductor materials as negative electrodes have good optical properties.[5] ZnO has a bandgap energy of 3.37 eV. The energy band gap unable to absorb visible light, so it requires a moderate on ZnO semiconductor material to increase the absorption of visible light.[6] $TiO_2$ material has anatase, rutile, and brookite crystal structures. $TiO_2$ used in dye-sensitized solar cells (DSSC) has an energy band gap of 3.2 eV. Dyes or dyes are active ingredients to produce electrons, while $TiO_2$ material is an electron injection medium.[7] DSSC solar cell efficiency of 13% has been achieved using $TiO_2$ nanoparticles with dye porphyrin SM315.[8] DSSC does not use dyes on $TiO_2$ substrates which have low solar cell efficiency.[9]

Some studies using metal oxide materials are $TiO_2$/$Cu_2O$ all-oxide heterojunction solar cells produced by spray pyrolysis,[10] heterojunctions p-$Cu_2O$/ZnO-n solar cell fabricated by spark plasma sintering,[5] and interconnected $ZrO_2$ doped ZnO/$TiO_2$

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network photoanode for dye-sensitized solar cells.[11] Material engineering methods in the last two years of research require substantial investment. ZnO and $TiO_2$ parallel to the $Cu_2O$ layer for p-n junction solar cells, however, have not been studied in terms of Current-Voltage characteristics.

This article reports the Current-Voltage characteristics of solar cells p-n junction ZnO and $TiO_2$ parallel in the $Cu_2O$ layer. The efficiency of solar cells is generated from the Current-Voltage characteristic data. Study of the Current-Voltage characteristics of solar cells p-n junction ZnO and $TiO_2$ parallel in the $Cu_2O$ layer plate will broaden their analytical prospects.

## Methods

Commercial Cu sheets ware prepared with dimensions of 25 mm × 25 mm and thickness of 1 mm. The thermal oxidation process is applied for 60 minutes on a Cu plate to produce a $Cu_2O$ layer. Temperature variations were carried out on each of the Cu plates (300, 400, 500 °C). $TiO_2$ (anatase phase) and ZnO (zincite phase) ware used in powder form. PVA (Polyvinyl Alcohol) was used as a $TiO_2$ and ZnO adhesive in the ITO (Indium Thin Oxide) substrate. The ITO substrate was prepared with dimensions of 25 mm × 25 mm. Previously, PVA was mixed with distilled water at 80 °C for 30 minutes to produce PVA suspension as an adhesive.[12] $TiO_2$ paste was produced by mixing PVA suspension and $TiO_2$ powder in a ratio of 2:1. This was also done to produce ZnO paste with a ratio of 1:1. Then $TiO_2$ and ZnO paste was deposited on the ITO substrate by the doctor blade method.[13] ITO substrates that have been deposited in parallel $TiO_2$ and ZnO paste are dried at room temperature for 30 minutes. Furthermore, the substrate is attached to the $Cu_2O$ layer. The design of solar cells $TiO_2$ and ZnO parallel in the $Cu_2O$ layer is shown in Figure 1.

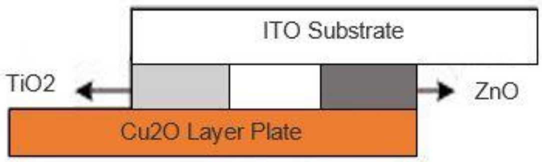



**Figure 1.** Schematic design of solar cells p-n junction ZnO and $TiO_2$ parallel in the $Cu_2O$ layer.

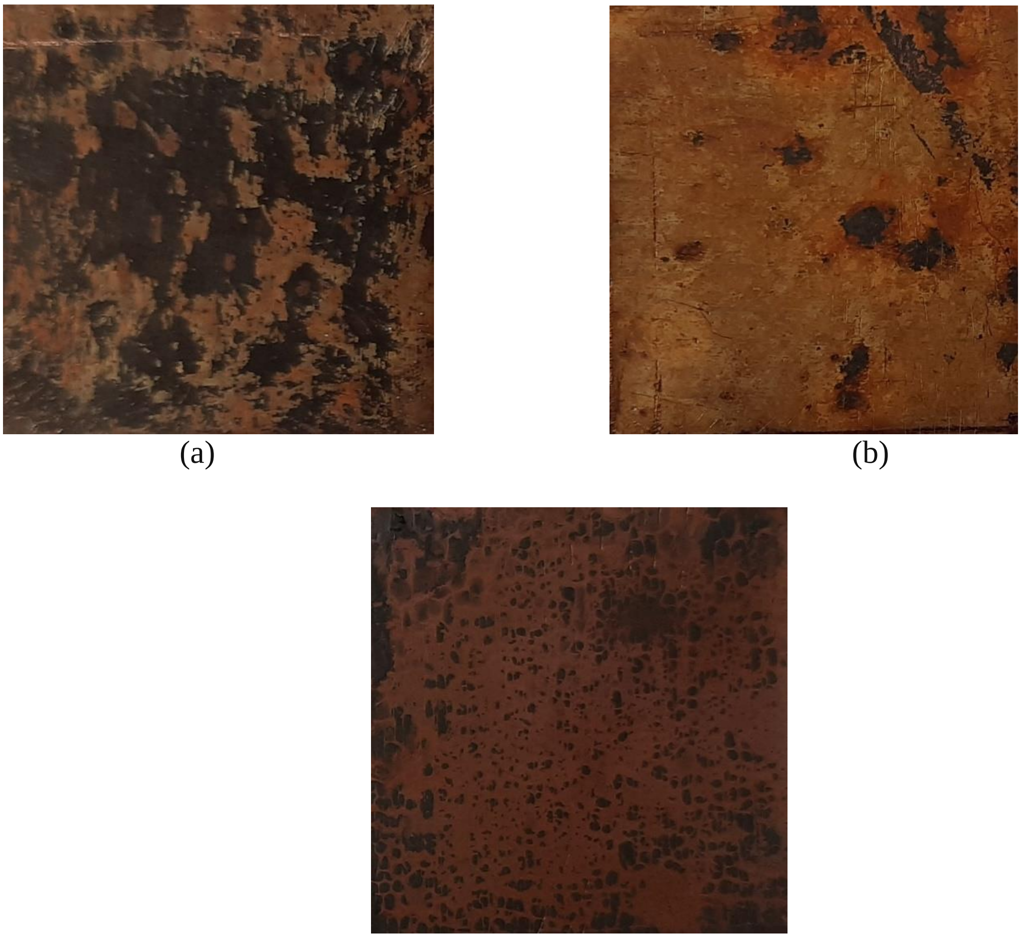
Measurement of solar cells is done by direct solar radiation for Current-Voltage characteristic data. Loading with a resistor made in the circuit for these measurements, which is 0-50 kΩ. The results of the Current-Voltage characteristic data are analyzed to obtain the efficiency ($\eta$) of solar cells using the equation[14, 15]:

$$\eta = \frac{P_{out}}{P_{in}} \qquad (2)$$

Where $P_{out}$ is the optimal electrical power of the cell/module from the Current-Voltage characteristic data. $P_{in}$ is the total incoming power of cell light/module radiation which is measured using an SM206 solar power meter.

## Result and Discussion

The results of the thermal oxidation process on Cu plates with temperature variations are shown in Figure 2. The observations showed that there was a change in colour on the Cu plate after the thermal oxidation process was carried out. This shows the formation of $Cu_2O$ layers. Cu plate with a thermal oxidation process at a temperature of 500 °C produces a more homogeneous $Cu_2O$ layer than at a temperature of 400 °C. Along with the reduction in the temperature of the thermal oxidation process, which is 300 °C, the $Cu_2O$ layer has more dominant impurities than at 400 °C. Furthermore, impurities begin to decrease at 500 °C. The impurity is black which identifies the formation of CuO layers.[16]



(a) (b)

(c)

**Figure 2.** Thermal oxidation on Cu plate for 60 minutes with temperature variations, a) 300 °C, b) 400 °C, and c) 550 °C

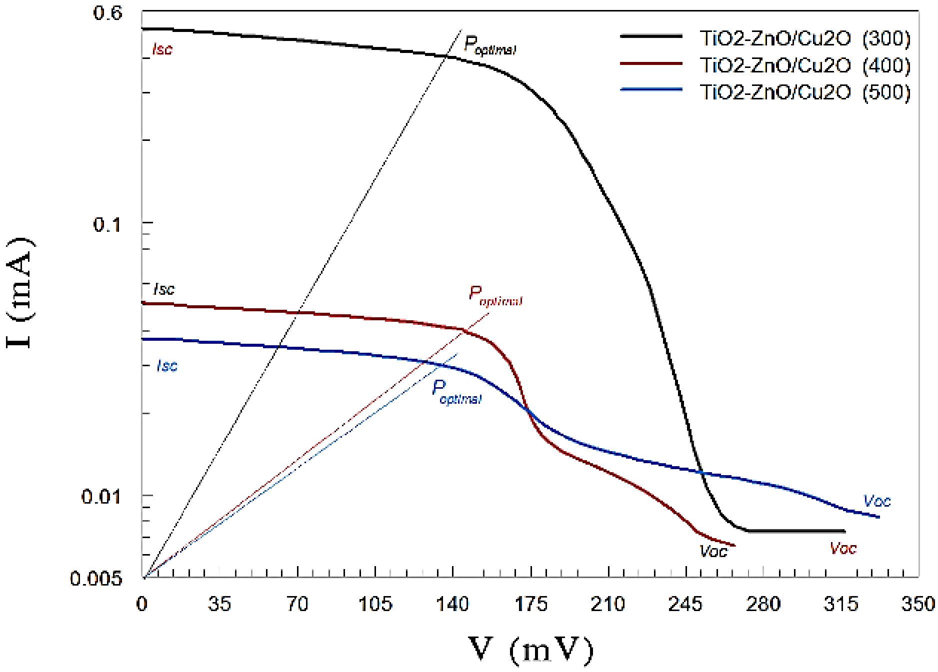



**Figure 3.** Current-Voltage characteristics of solar cells $TiO_2$ and ZnO parallel in $Cu_2O$ layer.

The graph of the Current-Voltage characteristics of solar cells $TiO_2$-ZnO parallel in the $Cu_2O$ layer is shown in Figure 3. The voltage at the $V_{oc}$ point increases when the Cu plate is thermally oxidized at 500 °C compared to the $TiO_2$-ZnO/$Cu_2O$ (300) sample. At this point, the decrease in the value of $V_{oc}$ in the sample is irregular with respect to the decrease in thermal oxidation temperature. This is caused by the transition of the CuO layer to $Cu_2O$ as shown in Figure 2. Shown in Figure 2b the CuO layer decreases with increasing thermal oxidation temperature. In addition, at 400 °C, the $Cu_2O$ layer begins to form and is more dominant at 500 ° C.[2] The open-circuit voltage ($V_{oc}$) values for each sample are completely listed in Table 1.

Measurement of solar cells applied variations in resistance ($R$) in the circuit, which is 0-50 kΩ. This causes the overall current value for all samples to increase with decreasing voltage. At the $I_{sc}$ point, the current value increases with the decrease in temperature in the thermal oxidation process of Cu plates. $TiO_2$-ZnO/$Cu_2O$ (300) samples have the highest current value compared to $TiO_2$-ZnO/$Cu_2O$ (400) and $TiO_2$-ZnO/$Cu_2O$ (500).

This is caused by the CuO layer formed which affects the value of $I_{sc}$ and $V_{oc}$. The value of $I_{sc}$ decreases and $V_{oc}$ increases as the CuO layer decreases. In addition, it is influenced by the gap energy value of each layer formed, which is 2.1 eV for $Cu_2O$,[4] and 1.2 eV for CuO.[16] Short current values ($I_{sc}$) of each sample are listed in Table 1.

Solar radiation power measured using an SM206 solar power meter has an average value of 830 W/m². Next, the power is divided by the effective area of the solar sample, which is 0.00025 m². The results of this division amounted to 120 mW. The power is used as the value of solar cell input power. The output power ($P_{out}$) of a solar cell is generated through the optimal power ($P_{opt}$) of the Current-Voltage characteristic data, so as to produce a fill factor value and solar cell efficiency.[15] The fill factor values and the efficiency of the solar cells for each sample are listed in Table 1.

**Table 1.** The results of the performance of solar cells $TiO_2$ and ZnO parallel in the $Cu_2O$ layer.

| Sample | $I_{sc}$ (mA) | $V_{sc}$ (mV) | Fill Factor | Efficiency (%) |
|---|---|---|---|---|
| $TiO_2$-ZnO/$Cu_2O$ (300) | 0.520 | 316 | 0.34 | 0.28 |
| $TiO_2$-ZnO/$Cu_2O$ (400) | 0.051 | 266 | 0.42 | 0.03 |
| $TiO_2$-ZnO/$Cu_2O$ (500) | 0.038 | 332 | 0.32 | 0.02 |

Based on Table 1, in general, the efficiency of solar cells increases with the decrease in temperature of the thermal oxidation process on the Cu plate. $TiO_2$-ZnO / Cu2O (300) samples have higher solar cell efficiency compared to $TiO_2$-ZnO/$Cu_2O$ (400) and $TiO_2$-ZnO/$Cu_2O$ (500). This is caused by the dominant CuO layer formed in the $TiO_2$-ZnO/$Cu_2O$ sample (300). The energy gap in CuO is lower than that of $Cu_2O$, so electrons diffuse more rapidly in solar cells. In addition, the formed CuO layer increases the current value of solar cells in the sample. The fill factor value increased in the $TiO_2$-ZnO/$Cu_2O$ sample with a thermal oxidation temperature of 400 °C, then decreased at a temperature of 500 °C. This shows that the formation of nanostructures in the $Cu_2O$ layer is not formed, thus reducing the value of the fill factor.[17]

## Conclusion

Impurity formed by the thermal oxidation process in the $Cu_2O$ layer increases the efficiency of solar cells. The impurity is the CuO layer. The highest efficiency of solar cells is owned by $TiO_2$-ZnO/$Cu_2O$ (300), which is 0.28%. Then the value decreases with the addition of temperatures (400 and 500 °C) to the thermal oxidation process of Cu plates. Each sample has a solar cell efficiency value, which is 0.03 % for $TiO_2$-

$ZnO/Cu_2O$ (400) and $TiO_2$-$ZnO/Cu_2O$ (500) is 0.02 %.

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