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The Improvement of Solar Cell Output Power Using Cooling and Reflection from Mirror

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ABSTRACT

This paper explains the experimental investigation to improve the output power of solar cell using cooling and light reflection from mirrors. The results show that by adding mirror, the current and output power of solar cell increase but the open circuit voltage and maximum power voltage decrease due to heat. By adding cooling, the open circuit voltage and the maximum power voltage are improved, so the output power also increases.

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1. INTRODUCTION

Energy is the most important element for human being in the world to survive [1]. From morning until night, energy is involved in every life aspect. Overall, the sources of energy are divided into 2 which are renewable energy and non-renewable energy [2]. The renewable energy is energy that will not run out eventhough it is continuously used for long period while non-renewable energy is energy that will round out if it is continuously used for long period. Wind, water wave and solar energy are examples of renewable energy. Coal, oil and natural gas are examples of non-renewable energy. Compared to other energy sources, solar energy has many advantages. It is environmentally friendly, clean, abundant and free of noise pollution [3], [4]. Besides that, solar energy is unlimited energy which is available everywhere and free [5]. Solar energy must be converted into electrical energy so it can be used. The solar cell is a device that directly converts solar energy into electrical energy through photovoltaic process and the solar cell was firstly invented by Charles Fritts in 1883 using junction formed by coating selenium with gold but the efficiency was only 1 % [6]. Generally, solar cells are divided into 3 types, monocrystalline, polycrystalline and thin film where the monocrystalline solar cell has higher efficiency than polycrystalline and thin film solar cells [7], [8]. The combination of several solar cells form solar module and the combination of several solar modules form solar panel. Air-cooling, liquid-cooling and immersion are examples of methods to increase the efficiency of solar cell [9], [10], [11]. The purpose of this research is to increase the output power of solar cell using mirror reflection.

2. RESEARCH METHOD

Figure 1 shows the schematic picture of solar cell and solar module. The solar module is a combination of several solar cells parallelysor serially connected with bypass diodes or blocking diodes [12], [13]. The shadow from trees, building, cloud, dirt and leaves may decrease the output power [14].

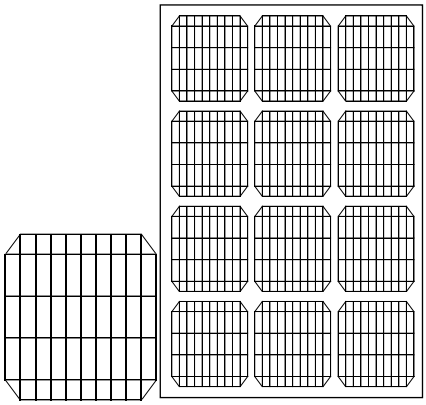

Figure 1. Schematic figure of (a) solar cell (b) solar module

Figure 2 shows the measurement of solar output power at the surface of earth using solarimeter. The unit is W/m^2.

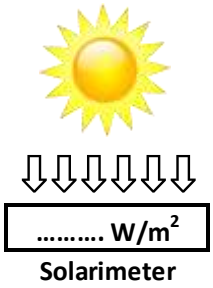

Figure 2. The measurement of solar output power

Figure 3 shows the measurement of I-V characteristic of the solar cell.

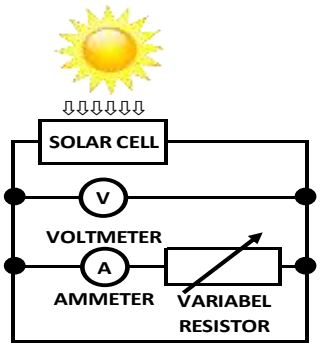

Figure 3. The measurement of solar cell

Figure 4 shows the equivalent circuit of a solar cell. I_{PH} is photocurrent. R_{SH} and R_S are shunt resistor and serial resistor respectively. The ideal value for RSH is infinity so there will no be path for current to flow, while the ideal value for RS is 0 so there will no a voltage drop before load [15]. The Equation for equivalent circuit of solar cell is given by Equation 1. Figure 5 shows the schematic to increase the solar cell output using reflection from mirror.

$$I = I_{PH} - I_S \exp\left[\frac{q(V+IR_S)}{nkT}\right] - \frac{V+IR_S}{R_{SH}} \quad (1)$$

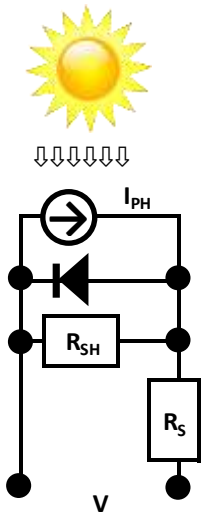

Figure 4. The equivalent circuit of solar cell

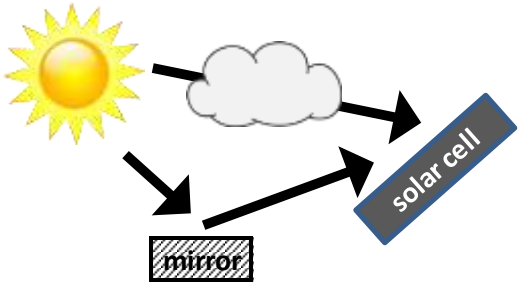

Figure 5. The reflection from mirror

3. RESULTS AND ANALYSIS

Figure 6 shows the solar output power by time. The horizontal and vertical axes represent time in hour and radiation in W/m^{2}respectivelly. Overall, the irradiance increased from around 20 W/m^2 at 2 am to around 900 W/m^2 at 12 pm and after that it decreased again to around 20 W/m^2 at 10 pm. The highest radiation was around 900 W/m^2.

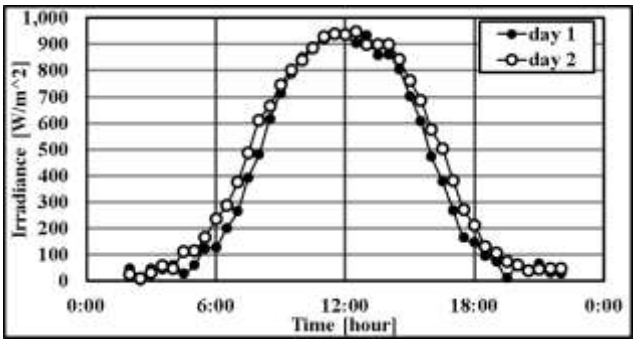

Figure 6. The solar irradiance by time

Figure 7 shows the temperature by time. The horizontal and vertical axes represent time and temperature respectively. Overall, the temperature increased from around 20 ^{o}C at 2 am to around 35 ^{o}C at 12 pm and after that it decreased to around 20 ^{o}C at 10 pm. The highest temperature was around 35^{o}C.

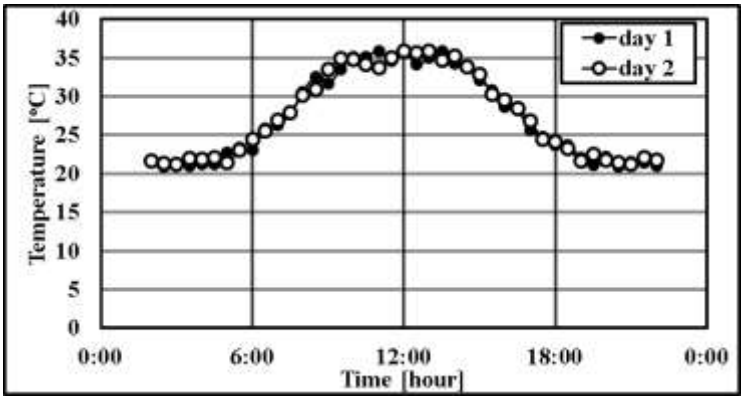

Figure 7. The temperature by time

Figure 8 shows the I-V curve of the solar cell. The horizontal and vertical axes represent voltage and current respectively. Figure 8 shows that the short circuit current (I_{SC}) increased from around 0.4 A to 0.6 A when there were mirrors reflecting sunlight to the solar cell. The maximum power current (I_{MP}) also increased from around 0.3 A to 0.5 A. However, due to heat, the open circuit voltage (V_{OC}) decreased from around 0.46 V to 0.4 V. The maximum power voltage also decreased from around 0.4 V to 0.3 V. I_{SC} is the current due to carriers generated by light flowing through solar cell when the voltage drop across the solar cell is 0 [16]. $V_{OC}$is the maximum voltage obtained by solar cell when the current is 0 [17]. I_{MP} and V_{MP} are points where the output power reaches maximum [18]. The efficiency of solar cell (η) is defined as ratio between the output power peak and the input power given by Equation 2, while the fill factor (FF) is given by Equation 3 [19], [20]. The current of solar cell is given by Equation 4 where I_{PH} is current generated by incoming light, $I_S$is saturation current, q is electron charge $1.6x10^{-19}$ C, k is Boltzman constant $1.38x10^{-23}$ J/K, T is temperature [21]. It is important to obtain solar energy near the maximum power point [22], [23].

$$\eta = \frac{V_{MP} \times I_{MP}}{P_{IN} \times A} \quad (2)$$

$$FF = \frac{V_{MP} \times I_{MP}}{V_{oc} \times I_{sc}} \quad (3)$$

$$I = I_{ph} - I_s \left(e^{\frac{qV}{kT}} - 1 \right) \quad (4)$$

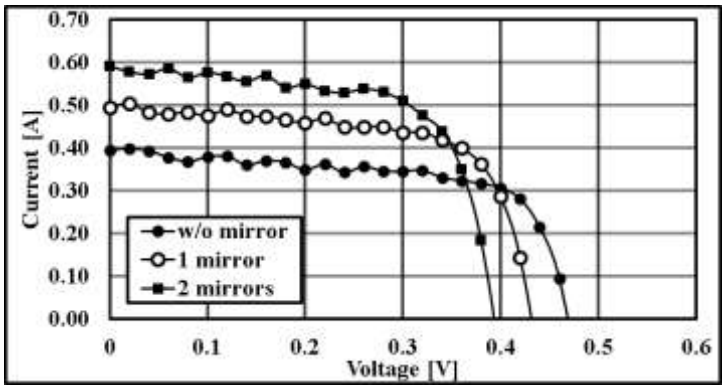

Figure 8. The I-V curve of solar cell with mirror and without cooling

Figure 9 shows the P-V curve of the solar cell. Figure 9 shows that the maximum power (P_{MP}) increased from around 0.12 W to 0.16 W when there were mirrors reflecting sunlight to the solar cell.

However, due to heat, the open circuit voltage (V_{OC}) decreased from around 0.46 V to 0.4 V. The maximum power voltage also decreased from around 0.4 V to 0.3 V.

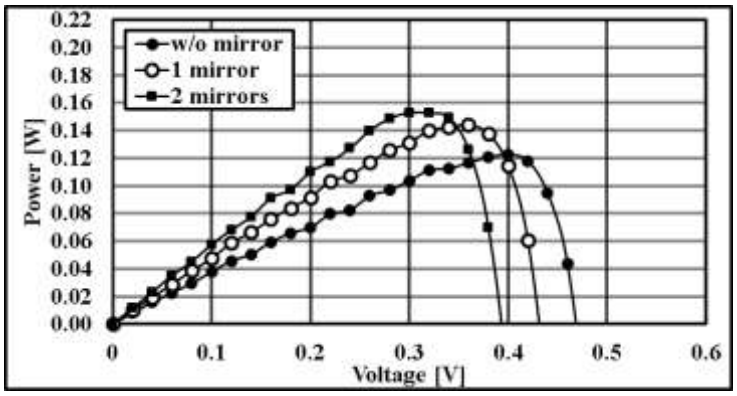

Figure 9. The P-V curve of solar cell with mirror and without cooling

Figure 10 shows the I-V curve of the solar cell with mirror and cooling. The horizontal and vertical axes represent voltage and current respectively. Figure 10 shows that compared to Figure 8, the V_{OC} increased to around 0.55 V by adding cooling. The maximum power voltage also increased to around 0.45 V.

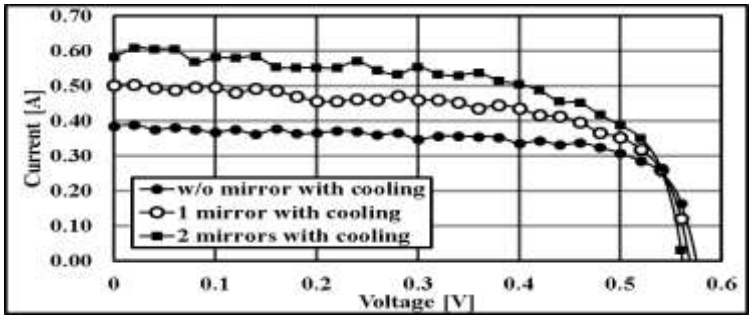

Figure 10. The I-V curve of solar cell with mirror and cooling

Figure 11 shows the P-V curve of the solar cell with mirror and cooling. The horizontal and vertical axes represent voltage and current respectively. Compared to Figure 8, by adding cooling, the V_{OC} and $V_{MP}$was improved to around 0.55 V and 0.45 V respectively. Figure 11 shows that compared to Figure 9, the maximum output power increased to 0.2 W.

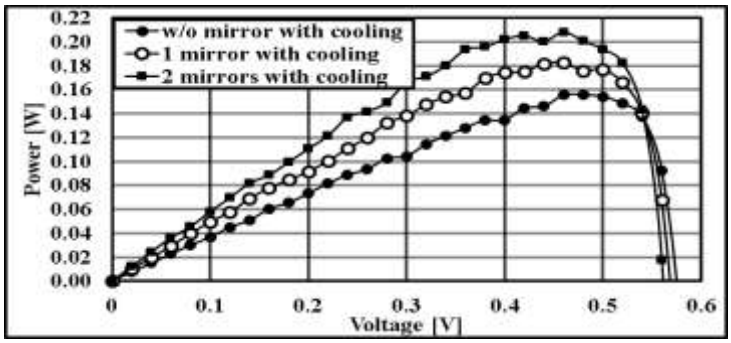

Figure 11. The P-V curve of solar cell with mirror and cooling

4. CONCLUSION

The effect of adding mirror and cooling to solar cell has been investigated. The results show that by adding mirror, the current and output power of solar cell increase but the open circuit voltage and maximum power voltage decrease due to heat. By adding cooling, the open circuit voltage and the maximum power voltage are improved, so the output power also increases.

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