Improve of Photovoltaic Performance of Dye-sensitized Solar Cell by Concentrating Sunlight

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ABSTRACT

Dye-sensitized solar cell (DSSC) that is the 3rd generation solar cell has low-cost of manufactures about 1/3~1/5 times compared with the silicon solar cell. Accordingly, the DSSC is constantly researched globally.

One of method that can be improved efficiency of solar cell is concentrating light. In this study, and was concentrated by Fresnel lens. High temperature heat on concentration can decrease efficiency of solar cell so as cooling radiator was installed. Maximum concentrating ratio was 26 times of 1sun (2.6W/cm2). When the solar energy of High density was illuminated on a DSSC, It was confirmed that temperature and concentrating ratio affect efficiency of DSSC.

When high density light is illuminated in the DSSC using concentrating lens, conversion efficiency is reached up to 16.11%. The enhancement in overall device efficiency is a result of increased open circuit potential and short circuit current. If coolant system is used, it can help guarantee of stable performance of a high efficiency of DSSC at 45℃.

Keywords: Dye-sensitized Solar Cell, Concentrating light, Fresnel lens, Surface temperature.

1 INTRODUCE

The use of a concentrator in solar cell devices is to reduce the price of the generated electric energy. Concentrator can lower the price of the entire device by decreasing the use area of expensive solar cells. On the other hand, the solar cell for concentration is very expensive although its efficiency is high. Thus, the price of solar cell per output ($/W) can be acceptable if high-density solar energy can be concentrated (>1000 suns). Ultimately, the key to price reduction is the efficiency of solar cell. The efficiency can be increased because the density of energy dispersed by the heat of concentrator increases in proportion to the concentration ratio.

Various factors influence the production of electricity from solar cells such as solar radiation, solar cell installation angle, direction, shade, solar cell module temperature. Among these, solar cell installation angle, direction, and shade have almost no influence on the system performance once the solar cell system is installed unless artificial external effects are given because they are determined when the solar cell system is designed and installed. After installation, the performance of a solar cell system varies greatly by the solar radiation reaching the module surface and the surface temperature. The higher the solar radiation, the higher the efficiency of the solar cell becomes. Due to the nature of the solar cell module, the power production increases in proportion to the solar radiation, and the power generation increases as the surface temperature of the solar cell module increases. Therefore, we can improve the performance of solar cell modules by compulsorily increasing the solar cell module temperature through solar concentration.

This study intended to develop solar cell module that can maximize the efficiency of unit cells of dye-sensitized solar cell (DSSC) by maximizing solar concentration and minimizing solar loss while analyzing and improving the factors that influence the efficiency of DSSC.

2 THEORETICAL BACKGROUND

2.1 DSSC principle and structure

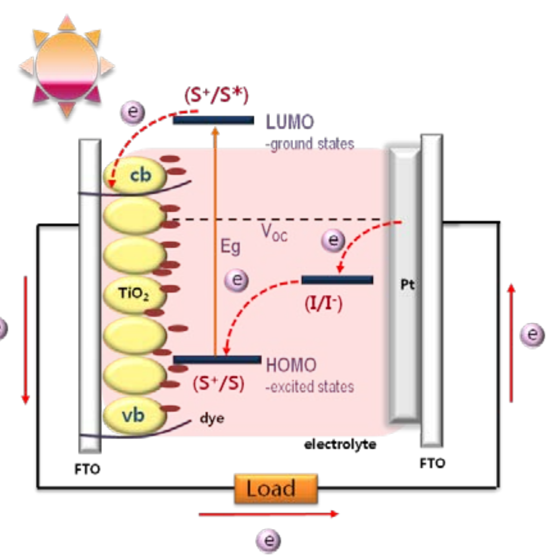

Fig. 1 A schematic representation of the construction of a DSSC

Figure.1 shows the operational principle and structure of dye sensitized cell. If visible rays are absorbed by n-type nano particles TiO_2 that dye molecules are chemically absorbed on the surface, the dye molecules generate electron-hole pairs, and the electron were injected into the conduction band of semiconductor's oxides. These electrons that are injected into the semiconductor's oxide electrode generate current through each nano particles' interfaces. The holes that are made from dye molecules are deoxidized by receiving electrons, thus causing the dye-sensitized cells begin to work [1].

2.2 Manufacturing DSSC

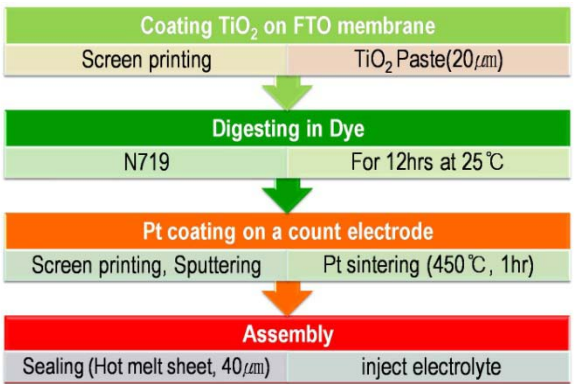

Fig. 2 Process of manufacturing DSSC

We applied screen printing method on FTO membrane to TiO_2 paste in 20 ㎛. Coated working electrode membrane was sintered at 450℃ and digested them into dye (N719) for about 12 hours.

Measurement

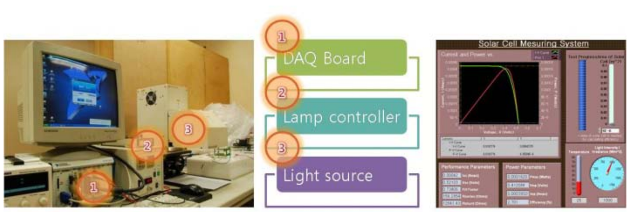

Fig. 3 Measurement system and program

In order to understand efficiency increase of solar cells due to coating method, we compared individual efficiencies using solar cell simulator. Measuring efficiency of solar cells had been progressed under AM (air mass) 1.5 conditions (1sun, 100mW/cm^2).

3 EXPERIMENTS

3.1 Evaluation of Solar Cell Performance by Changing Temperature

High temperature is generated when solar energy is concentrated to improve energy conversion efficiency. Performance drops due to sealing problems such as the leakage and evaporation of electrolytes resulting from the changes in the volume of volatile electrolytes and the increase of vapor tension [2]. To solve this problem, many efforts are being made to achieve performance reliability such as replacement of liquid electrolytes with solid electrolytes, development of new materials for sealing, and the performance of thermal stability tests [3]. Performance varies greatly by the surface temperature and the solar radiation that reaches the cell surface of a solar cell. The higher the solar radiation, the higher power production becomes, and the performance of a solar cell varies by surface temperature. In this study, the effects of the changing cell temperature on the efficiency of solar cells, and the optimum conditions for thermal stability in solar concentration and the production of solar cell module were investigated.

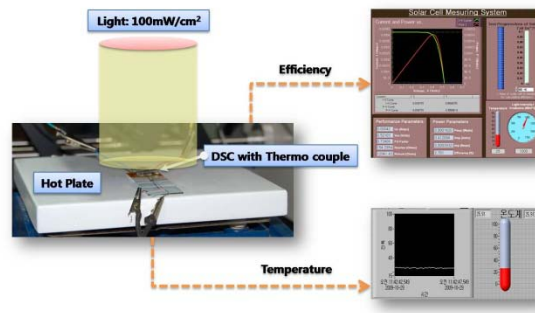

Fig. 4 Schematic design of measurements

Figure 4 shows a schematic diagram of a device for measuring the changes in the efficiency of DSSC according to changing temperature. A hot plate was used as a heat source, and a resin epoxy was used for sealing to prevent the leakage and evaporation of electrolytes due to exposure to high temperature. To examine the cell efficiency under changing temperature, a thermocouple for measuring temperature was attached to the DSSC. For this thermocouple, the K-type from Omega was used. The change in the efficiency of the solar cell was measured while the temperature was varied from 35℃ to 65℃ in 5℃ steps.

3.2 Performance evaluation of the solar cell by solar concentration rate

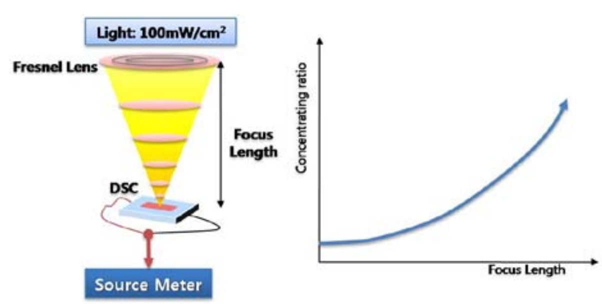

Fig. 5 Schematic of concentrating DSSC

The solar cell device was fabricated in such a way to obtain high efficiency by increasing the energy density through solar concentration. The lens for solar concentration was a Fresnel lens with the conventional curved surface of the lens replaced by concentric grooves, and fine patterns were formed on the thin, light plastic surface. Each groove has a refracting surface like a very small prism with a fixed focal distance and a low aberration. Because the lens is thin, it has a low loss from light absorption. A high groove density provides high image quality and a low groove density increases efficiency.

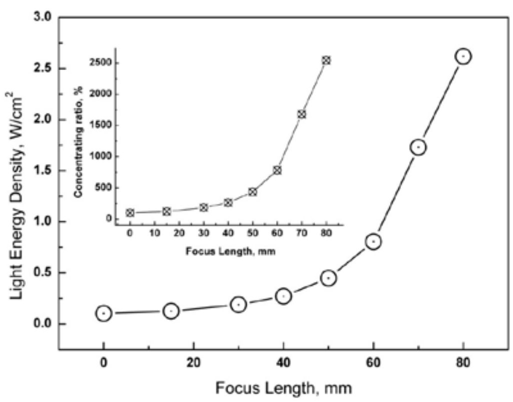

Fig. 6 Energy density due to focus length of Fresnel lens

The focal distances of the Fresnel lens were defined as 15, 30, 40, 50, 60, 70, and 80mm. A power meter was used to measure the concentrated energy density to determine the solar concentration rate for each focal distance. If was found that the energy density increased exponentially as the focal distance increased. As shown in Figure 6, the solar concentration rate at the highest focal distance was approx. 26 times (2.619W/㎠) the 1sun (100mW/㎠) condition.

4 RESULTS

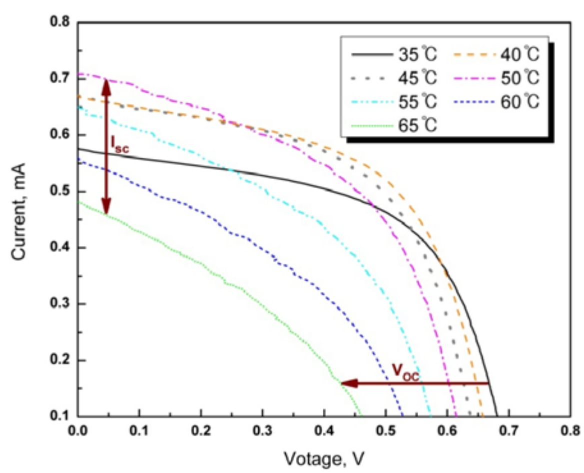

Fig. 7 Comparison of I-V curve due to temperature change

Figure 7 shows the results of the efficiency of the DSSC measured by different cell temperatures with the solar intensity of 1sun (AM 1.5, 100mW/㎠). The cell efficiency increased as the cell temperature increased and abruptly dropped from 45℃.

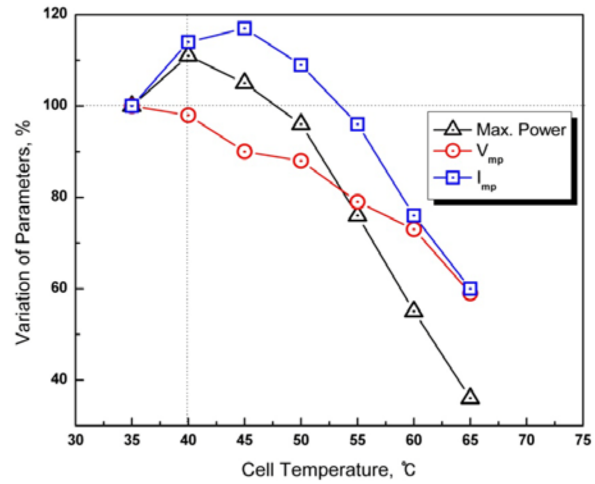

Fig. 8 Performance changes due to temperature change

Figure 8 shows the maximum output, maximum output current (I_{mp}) and voltage (V_{mp}) at various temperatures as percentages of the values at 35℃ to determine the factors influencing cell efficiency and output. It shows I-V line diagrams comparing the changes of I_{SC} and V_{OC} at different cell temperature. Isc increased as the cell temperature increased and dropped from 55℃ while V_{OC} decreased as the temperature increased.

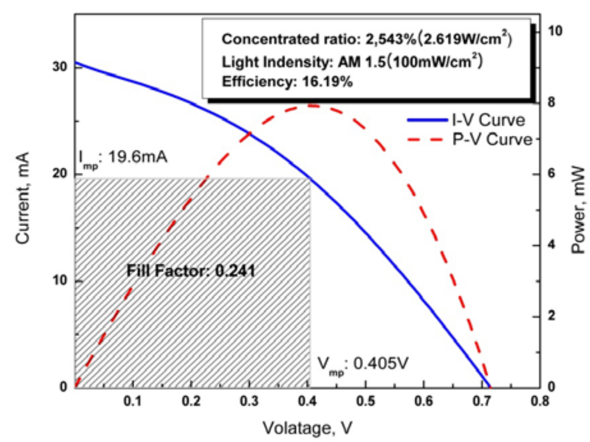

Fig. 9 I-V curves of DSC due to Focus length

The changing efficiency of the DSSC by solar concentration rate was measured at varying focal distances with the prepared lens and stage. Figure 9 shows the I-V line diagrams for each solar concentration rate. When the focal distance was 80mm and the solar concentration was at the maximum of 2,543%, the cell efficiency was 16.2%.

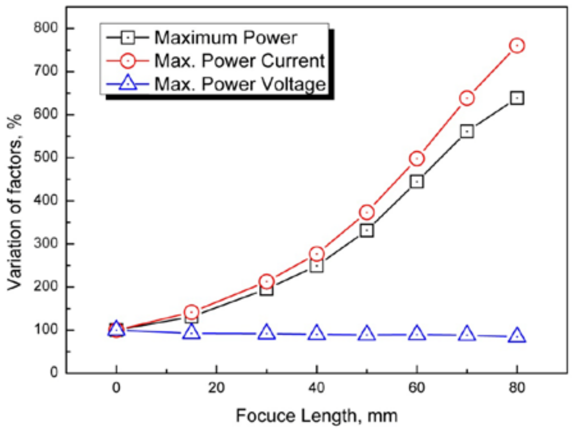

Fig. 10 Performance changes due to focus length

Figure 10 shows the maximum output for each focal distance and the voltage and current changes in percentages at the maximum output to determine the factors influencing efficiency improvement. The maximum output increased as the solar concentration rate increased, indicating cell efficiency improvement. It was found that the increase of current (I_{mp}) by solar concentration had a direct influence.

5 CONCLUSION

This study investigated the changes in efficiency when concentrated solar radiation with high energy density was applied to DSSC to determine the factors influencing efficiency.

- I_{mp} increased as the cell temperature increased and dropped from 45℃ while V_{mp} decreased as temperature increased.
- The efficiency of DSSC at changing temperatures was investigated when high heat was generated by solar concentration, and the highest efficiency was obtained at 45℃. As temperature increased over this value, the cell efficiency dropped sharply. Thus, a cooling device is essential when manufacturing a power generation system using solar concentration.
- The high energy density obtained by solar concentration increased the efficiency of DSSC by 6.4 times on average and up to 16.1% by absolute value. Because current density can be increased by solar concentration, it is possible to implement solar cells with a high output..

ACKNOWLEDGEMENT

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REFERENCE

[1] M. K. Nazeeruddin, A. Kay, I. Rodicio, R. Humphry-Baker, E. Mueller, P. Liska, N. Vlachopoulos, and M. Gratzel, “The improved performance of dye sensitized solar cells by bifunctional aminosilane modified dye sensitized photoanode”, J. Am. Chem. Soc. 115, 6382, 1993.
[2] J. H. Kim, “Dye-Sensitized Solar Cell”, News & Information for Chemical Engineers, 25, 4, 390, 2007.
[3] J. E. Fischer, H. Dai, A. Thess, R. Lee, N. M. Hanjani, D. L. Dehaas, R. E. Smalley, “Metallic resistivity in crystalline ropes of single-wall carbon nanotubes”, Phys. Rev. B55, 4921,1997.