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Trial Making and Evaluations of Solar Battery with Wavelength Selective Transmission Thin Films

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The conversion efficiency of light-electricity of the solar battery decreases when the temperature rises. To prevent this rise in temperature of the solar battery, wavelength selective transmission thin films that cut the 1000 nm–1400 nm wavelength range were developed. In this research, a solar battery provided with wavelength selective transmission thin films was made for trial purposes, and was compared to a past solar battery. When light was irradiated on the solar battery by using a source of light with heat rays, the rise of the surface temperature of the solar battery made for trial purposes was suppressed. The conversion efficiency of the solar battery was studied by using artificial sunlight, too. From the results, it was found that the new prototype of the solar battery is better than the old one. Therefore, it was understood that the wavelength selective transmission thin films were effective for improving the efficiency of the solar battery through suppressing the temperature as described above.

Key words: Wavelength selective transmission thin films, Solar battery, Conversion efficiency

1. INTRODUCTION

Currently, polycrystalline silicon solar cells are widely used in most houses and businesses because of their high efficiency and abundant silicon reserves [1]. However, one of the drawbacks of these solar cells is that the conversion efficiency of light-electricity of the solar battery decreases when the temperature rises, and we think it is caused by the sun light in the near infrared wavelength range.

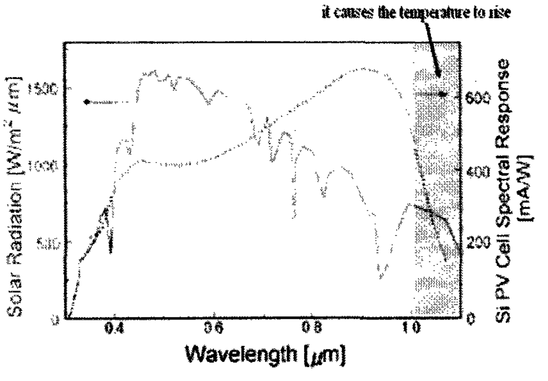

Fig. 1. Solar radiation curve and Si PV cell spectral response curve [2].

In this research, the authors prepared a wavelength selective transmission thin films which have a high transmittance in visible wavelength range to ensure the generation of electricity by the solar battery, but which has 0% transmittance in the 1000 nm to 1400 nm range to prevent the temperature rise of the solar battery as shown in Fig. 1. Then, the prepared thin films were applied to a solar battery, and surface temperatures, and conversions of solar battery with films and without films were measured, respectively.

2. SIMULATED DESIGNS AND PREPARATION OF WAVELENGTH SELECTIVE TRANSMISSION THIN FILMS

2.1 Simulated design and preparation of wavelength selective transmission thin films

At first, the authors designed the wavelength selective transmission thin films using the Essential Macleod simulation software. The wavelength selective transmission thin films were fabricated as shown in Fig. 2. SiO_2 and Nb_2O_5 layers were deposited on a quartz glass substrate alternately. The wavelength selective transmission thin films have the following configuration: air-LHLH···LHLH-quartz glass substrate. Where L and H are SiO_2 (with a low refractive index) layers and Nb_2O_5 (with a high refractive index) layers, respectively [3,4].

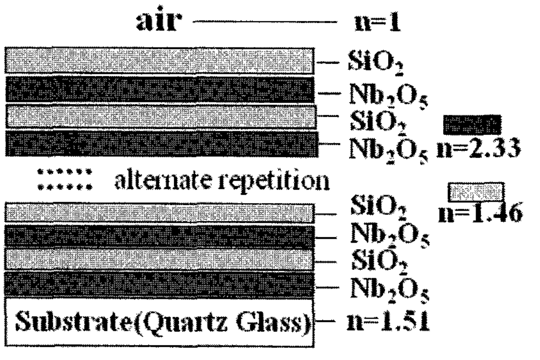

Fig. 2. The fabrication of SiO_2-Nb_2O_5 wavelength selective transmission thin films.

The series of Nb_2O_5 and SiO_2 single layer films was prepared and their thicknesses were measured preliminarily by auto-Ellipsometer as shown in Fig. 3. From the figure, the deposition rates of Nb_2O_5 and SiO_2 were 4.9 nm/min (100 W) and 8.5 nm/min (75 W), respectively. These results make it possible to precisely control the thickness of each layer of wavelength selective transmission multilayer films when they are deposited by RF sputtering equipment [5-7].

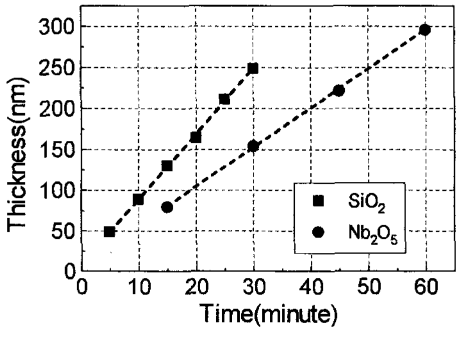

Fig. 3. Thickness changes of SiO_2 and Nb_2O_5 monolayer with sputtering time.

RF sputtering equipment(ULVAC, VTR-150M/SRF) was used for the preparation of the wavelength selective transmission thin films. The multilayer thin film was deposited on one side of a quartz glass substrate. Two kinds of targets were set, and prescribed flow rates of oxygen and argon gas were introduced in the chamber of the RF sputtering equipment. The multilayer film was deposited while controlling the materials and thickness under the simulated design. During the deposition of all films, the mass flow rates of argon gas in both the SiO_2 and Nb_2O_5 cathodes were held constant at 15 sccm (sccm denotes standard cubic centimeter per minute), and the flow rate of oxygen was maintained at 15 sccm with rf power of 75 W during deposition of SiO_2 and at 25 sccm with rf power of 100 W during deposition of Nb_2O_5, respectively.

2.2 Fabrication of solar battery

As shown in Fig. 4, there are four possible fabrications when the wavelength selective transmission thin films are applied to the solar battery. From the comparison of experimental results, the authors found that the best one is fabrication(c), the solar battery with the wavelength selective transmission thin films which were deposited on tempered glass directly. Therefore, in this research we applied the wavelength selective transmission thin films to the solar battery using the fabrication method of Fig. 4 (c).

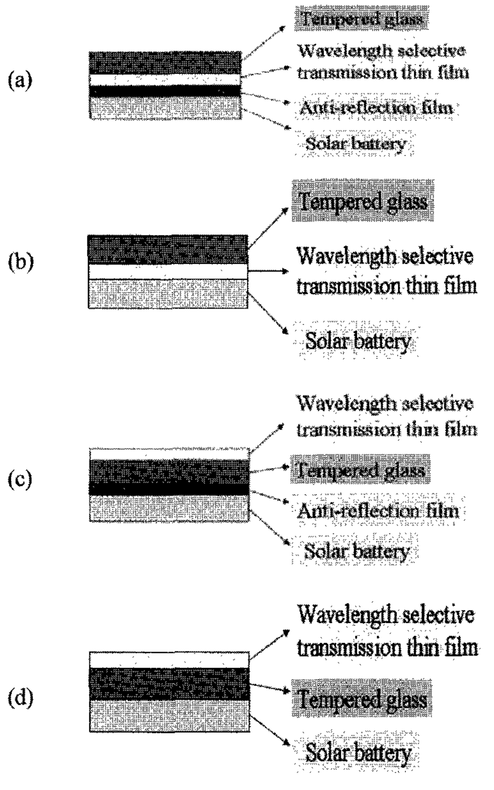

Fig. 4. Possible fabrications of solar batteries as wavelength selective transmission thin films are applied to them. (a) Wavelength selective transmission thin films deposited on anti-reflection thin film; (b) Wavelength selective transmission thin films replaced anti-reflection thin film; (c) Wavelength selective transmission thin films deposited on tempered glass; (d) Wavelength selective transmission thin films deposited on tempered glass without anti-reflection film.

2.3 Characteristics measurement of wavelength selective transmission thin films and solar batteries

Transmittance measurement of the films was carried out using a scanning spectrophotometer (Shimadzu, UV3150, wavelength range: 190–3200 nm). The surface properties of the quartz glass substrate and experimental sample of wavelength selective transmission thin films were measured with an atomic force microscope (AFM, Epolead Service, SPI 3800N). The thicknesses of monolayers deposited preliminarily were measured by an auto-Ellipsometer (ULVAC, ESM-1T/1AT). The authors measured IV (Current-Voltage) curves of solar batteries with wavelength selective transmission thin films and without thin films by using a solar simulator (Peccell Technologies, PEC-L11), and measured the thermo-images of the surfaces of the tempered glass of the solar batteries.

3. RESULTS AND DISCUSSION

3.1 The transmissions of the simulated and prepared wavelength selective transmission thin films

Fig. 5 shows the transmittance of the simulated design. It was designed to achieve a average transmittance of 96% in the 400–1000 nm wavelength range so that it can efficiently absorb solar radiation in the visible range, which is just about the sun's strongest radiation range as shown in Fig. 1. Furthermore, we designed the transmittance to approach zero in the 1000–1400 nm wavelength range successfully, which is the sensitive spectrum for solar cells. If solar cells absorb

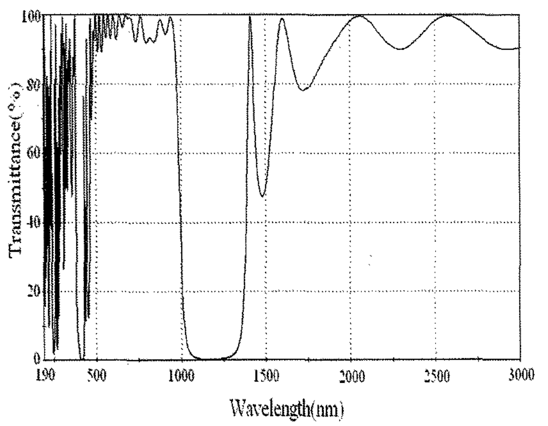

Fig. 5. Simulated transmittance spectrum of the wavelength selective transmission thin films.

solar radiation in this range, the temperature of solar cells increases while efficiency decreases. The simulated design succeeded in absorbing solar radiation in the visible range as well as reflecting the solar radiation in the near infrared solar spectrum. These design considerations will increase conversion efficiency by maximizing the absorption of solar radiation and preventing the increase of temperature.

Fig. 6 shows the transmittance of the prepared sample. The experimental results are very similar to those of the simulated design. The transmittance of the prepared sample averaged 87%, just 6% lower than quartz glass from 400 nm to 1000 nm, while the transmittance approached zero between 1000 nm and 1400 nm. These results show that the authors successfully prepared the wavelength selective transmission thin films as designed. As expected, this sample should effectively absorb solar radiation in the visible range and reflect the main wavelength that cause the temperature to increase.

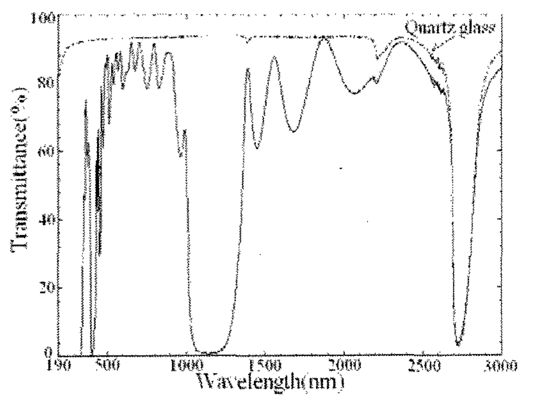

Fig. 6. The transmittance spectrum of the wavelength selective transmission thin films.

3.2 The AFM images of surfaces of the films

AFM images of the surface of quartz glass and experimental wavelength selective transmission thin films are shown in Fig. 7. Compared with the quartz glass, we can see that the surface of experimental wavelength selective transmission thin film is also smooth. And this means that the thin film will not cause unexpected dispersion and scattering when it is applied to a solar battery.

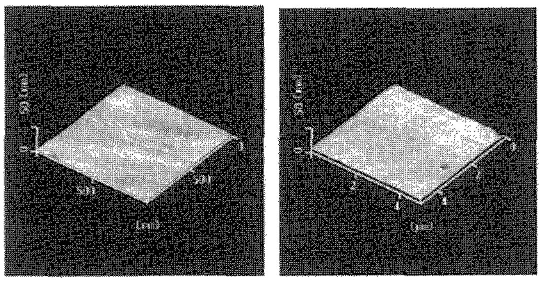

Fig. 7. AFM images of the surface of quartz glass and experimental wavelength selective transmission film.

3.3 Changes of the temperature and conversion efficiency of the solar battery

Fig. 8(in Manual of Solar Simulator) shows real solar spectral irradiance and artificial solar spectral irradiance. The two spectra have a little difference. The authors measured the conversion efficiency of the solar battery with artificial sunlight in this research.

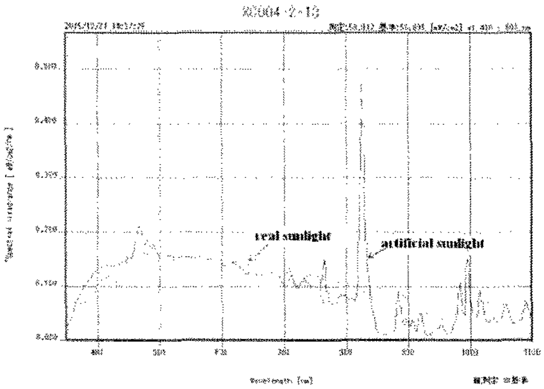

Fig. 8. Comparison with real spectral irradiance and artificial spectral irradiance.

The authors measured surface temperature and conversion efficiency of solar batteries as shown in Fig. 9. Because of the wavelength selective transmission thin films, the near infrared wavelength range was shut off; consequently the rise of temperature was prevented; and as a result, conversion efficiency of the solar battery was improved. Changes of surface temperature and conversion efficiency of solar batteries with films and without films are shown in Table I . From the table, we can see that conversion efficiencies of the solar battery with wavelength selective transmission thin films were lower than those without the films at low temperature. At high temperature, however, the efficiencies with the films were higher than those without the films. And it means that the wavelength selective transmission thin films can suppress the rise of temperature of solar battery.

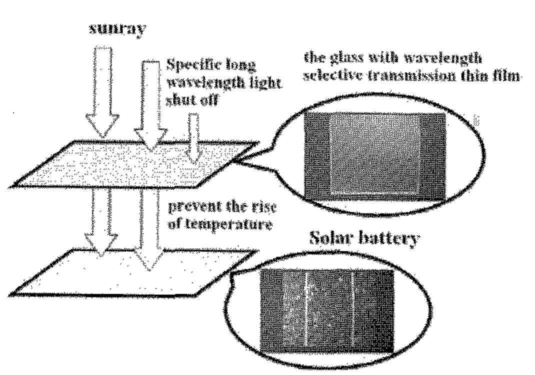

Fig. 9. Measurements of surface temperature and conversion efficiency of solar battery.

Table I Surface temperature and conversion efficiency of solar battery

	without wavelength selective transmission thin film		with wavelength selective transmission thin film	
heated time by heat source	temperature(℃)	efficiency(%)	temperature(℃)	efficiency(%)
0minute 0second	30.2	6.07	30.6	5.56
5minutes 37seconds	58.1	5.2	43.5	5.06
22minutes 26seconds	70.1	4.3	56	4.6
50minutes 0second	78.5	4.01	59.3	4.48

(Measuring Condition: Room temperature, Solar battery made by KYOCERA Corporation)

4. CONCLUSIONS

The aimed wavelength selective transmission thin films have been designed, prepared and then applied to a solar battery successfully. The results show that the film can suppress the rise of surface temperature of solar battery, and that is effective for improving the efficiency of solar battery. These conclusions mean that it is likely that the wavelength selective transmission thin films can be applied to solar batteries to improve their conversion efficiency by efficiently cutting off the heat rays of solar radiation.

5. REFERENCES

[1] F. Duerinckx, I. K. Filipek and K. V. Nieuwenhuysen, *IEEE Electron Device Lett.*, Vol. 27, Iss. 10, 837-39 (2006).
[2] Y. Kuwano, S. Nakano, Y. Kishi and M. Onishi, *Solar Cells and Their Applications*, M. Harada, Power Company, Tokyo, 40 (1994).
[3] X. R. Wang, H. Masumoto, Y. Someno and T. Hirai, *Appl. Phys. Lett.*, Vol. 72, No. 25, 3264-66 (1998).
[4] X. R. Wang, H. Masumoto, Y. Someno, L. D. Chen and T. Hirai, *Appl. Opt.*, Vol. 40, No. 22, 3746-52 (2001).
[5] J. Li and S. Fujita, *ICMR 2005 Akita*, 391-94 (2005).
[6] S. Fujita, *Vac. J. of Jap. Vac. Industry Asso.*, No. 99, 20-21 (2005).
[7] J. Li and S. Fujita, *MRS-Japan*, Vol. 31, No. 2, 291-94 (2006).

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