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Preparation and Characterization of Wavelength Selective Transmission Thin Films

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Optical films are currently used for a range of optical components. The aim of this research was to prepare wavelength selective transmission thin films which can improve the performance of solar cells. Radio frequency (RF) sputtering equipment was used for depositing the wavelength selective transmission thin film. Three kinds of targets were used, and set amounts of oxygen and argon gas were introduced into the chamber. Then an electrical discharge was produced by applying a high frequency voltage between the substrate and the targets. Thin films of set thickness were deposited on the substrate by the electrical discharge. The deposition of layers of various materials and of different thicknesses was carried out after simulation of the wavelength selective transmission thin film. The experimental wavelength selective transmission thin film was deposited on quartz glass, and the optical characteristics of the thin film were measured with a spectrophotometer. The transmission results showed that the designed wavelength selective transmission thin film was able to be made. The transmission range can be controlled by depositing layers of different materials and thicknesses.

Key words: Optical, RF sputtering, Wavelength selective transmission thin film, Simulation

1. INTRODUCTION

Currently, polycrystalline silicon solar cells are widely used in most houses and businesses because of abundant silicon reserves and high efficiency [1,2]. However, the drawback of these solar cells is that their conversion efficiency decreases as their temperature rises [3,4]. We think the infrared solar spectrum is one possible reason for this. The aim of this research was to use transmission films of TiO_2, Nb_2O_5 and SiO_2 to prepare wavelength selective transmission thin films. These thin films were designed to have a transmittance approaching zero in the near infrared solar spectrum and approaching 100% in the visible solar spectrum. The intention was to improve the conversion efficiency of solar cells by effectively absorbing solar radiation but preventing most temperature increase [5-8]. In the future, wavelength selective transmission thin films will be applied to solar cells as shown in Fig. 1.

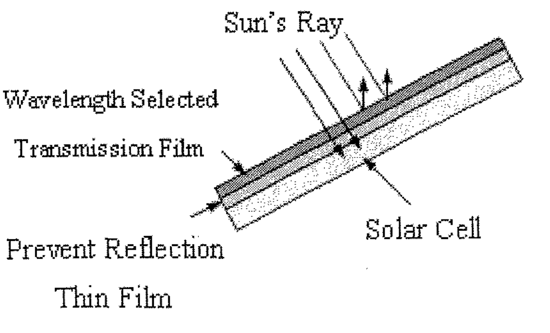


Fig. 1 Wavelength selective transmission thin films applied to a solar cell

The experimental sample was prepared by RF sputtering on a quartz glass substrate. The transmission properties of the sample were measured, and the results showed that we succeeded in preparing the designed wavelength selective transmission thin film. The wavelength selective transmission thin film we successfully prepared as an optical film that reflected only in the near infrared spectrum at about 1000-1400 nm. The reflection range was controlled by alternately depositing three different layers (TiO_2, Nb_2O_5 and SiO_2 films) and changing their thickness if necessary.

2. THE DESIGN AND EXPERIMENTAL PREPARATION OF WAVELENGTH SELECTIVE TRANSMISSION THIN FILMS

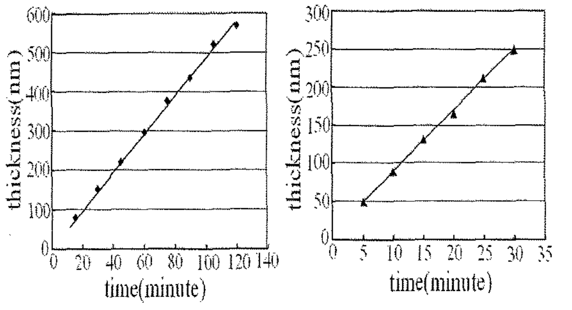
2.1 The simulation design of wavelength selective transmission thin films

We designed the wavelength selective transmission thin film using simulation software. The material, the number of layers, and the thickness of each layer can be changed, making a large number of possible combinations. After considering a number of designs, we chose the best multilayer combination. In the design we chose, the SiO_2 and Nb_2O_5 layers were deposited alternately at the thicknesses shown in Table Ⅰ.

Table Ⅰ The multilayer simulation design of a SiO_2/Nb_2O_5 wavelength selective transmission thin film

Layer Number	Material	Thickness (nm)
1	SiO_2	159.96
2	Nb_2O_5	12.52
3	SiO_2	176.60
4	Nb_2O_5	6.93
5	SiO_2	57.09
6	Nb_2O_5	140.23
...	...	...
...	...	...
19	SiO_2	213.82
20	Nb_2O_5	137.40

The deposition rates of these two materials are well known from previous research so it was possible to precisely control the thickness of each layer [3]. The change in thickness of these two materials with deposition time is shown in Fig. 2.



(a) Nb_2O_5 4.9 nm/min (b) SiO_2 8.5 nm/min

Fig. 2 The deposition rates of (a) Nb_2O_5 and (b) SiO_2

2.2 Equipment and Experimental

RF sputtering equipment was used for making the wavelength selective transmission thin film. Fig. 3 shows the chamber interior of the RF sputtering equipment. There were three targets (Ti, Nb, and Si) in the chamber, and during the experiment, the target could be changed freely under vacuum.

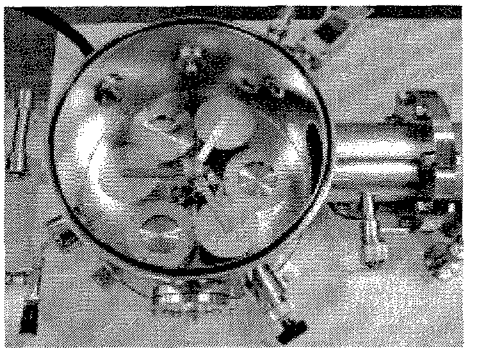


Fig. 3 The chamber interior of the RF sputtering equipment

The wavelength selective transmission thin film was prepared on a quartz glass substrate. Three kinds of targets were used, and a set amount of oxygen and argon gas was introduced into the chamber. Then a high frequency voltage causing an electrical discharge was applied between the substrate and targets. A thin film of set thickness was deposited on the substrate by the electrical discharge. It was deposited while changing the materials and thickness according to the simulation design of the wavelength selective transmission thin film.

2.3 Measurements

The optical characteristics of the wavelength selective transmission thin film were measured with a spectrophotometer (UV3150). The results showed that the designed wavelength selective transmission thin film was able to be made. The surface properties of the experimental thin film were observed with an atomic force microscope (AFM).

3. RESULTS AND DISCUSSION

Fig. 4 shows the transmittance of the simulation design. It was designed to achieve transmittance average 95% in the 400-1000 nm wavelength range and to efficiently absorb solar radiation in the visible range which is just about the sun's strongest radiation range. Furthermore, we successfully designed the transmittance to approach zero in the 1000-1400 nm wavelength range, which is the sensitive spectrum for solar cells. If solar cells absorb solar radiation in this range, the cell's temperature increases and efficiency decreases. The simulation 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.

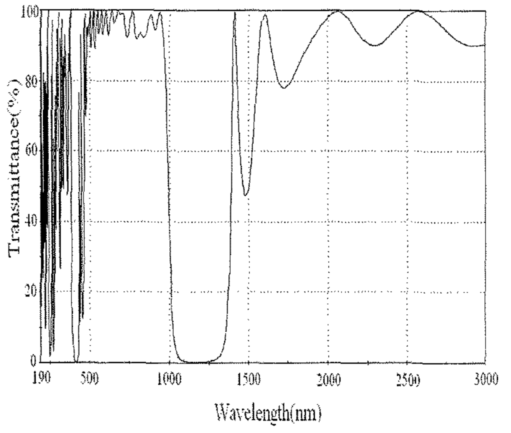


Fig. 4 The transmittance of the simulation design of wavelength selective transmission thin film

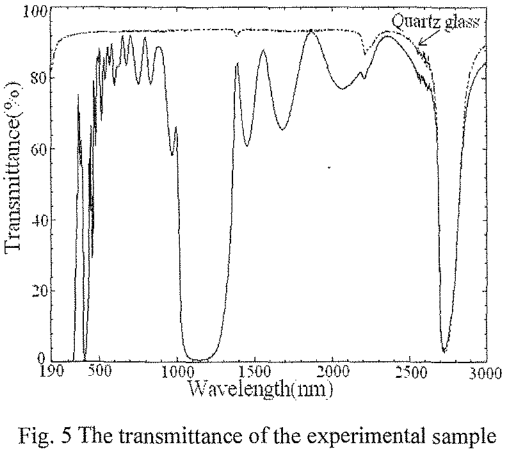


Fig. 5 The transmittance of the experimental sample

Fig. 5 shows the transmittance of the experimental sample. The experimental results are very similar to those of the simulation design, although the reflected range shifted a little to a longer wavelength. The transmittance of the experimental sample averaged 84%, just 8% lower than quartz glass from the 400nm to 1000nm, while the transmittance approached zero between 1000nm and 1400nm. These results show that we successfully made the designed wavelength selective transmission thin film. As expected, this sample should effectively absorb solar radiation in the visible range and reflect the main wavelengths which cause the temperature to increase.

Fig. 6 shows the AFM photograph of the experimental sample. The surface is smooth and it has no obvious defects, indicating a high surface crystallinity.

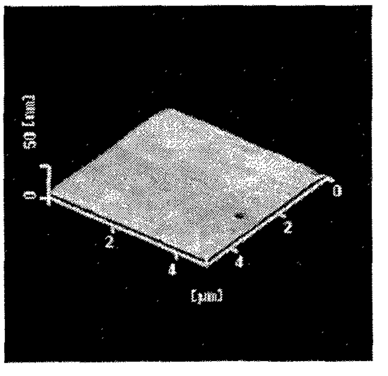


Fig. 6 The AFM photograph of the experimental sample

4. CONCLUSIONS

A wavelength selective transmission thin film was successfully designed and experimentally prepared. The transmission results showed that the experimental sample's transmittance approached zero in the near infrared spectrum and approached 84% in the visible spectrum. This means that it can efficiently absorb the main solar radiation as well as reflect the main spectral range which causes the temperature increase in solar cells. So it is likely that the wavelength selective transmission thin film will be applied to the solar cells and will improve their performance.

5. REFERENCES

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