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Study of Implementation of Broadband Antireflection Coating for Luminescent Solar Concentrators to Optimized the Efficiency

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Abstract

In this study, we study of luminescent solar concentrators comprise thick glass with broadband antireflection coating deposited on the top surfaces and inorganic phosphor layers contacted on the bottom surfaces. Solar cells are contacted to the lateral surfaces of the glass. Experimental results show the broadband antireflection coating increased the short-circuit current of the solar cell.

Key Word: *Solar Concentrators, Luminescent solar concentrator, broadband, antireflection, coating, short-circuit current.*

1. Introduction

Solar photovoltaics (PV) which create electricity directly from sunlight are clean sources of energy that have a much lower environmental impact than conventional energy technologies. However, the prices of PV modules are still too high and the PV modules are large and heavy, they must take up a lot of space to install the modules. Building integrated photovoltaics (BIPVs) are a promising solution and one of these BIPV elements is luminescent solar concentrators (LSCs), a transparent slab of plastic or glass that has an organic dye, quantum dots or nanostructure inorganic materials embedded or painted on it [1-2]. In this study, the LSC comprises a thick B270 glass with a broadband antireflection (AR) coating deposited on the top surface and an inorganic phosphor layer contacted on the bottom surface. The broadband AR coating composed of Ta_2O_5 and SiO_2 films ranged from 350nm to 950nm can allow more light to enter LSCs, resulting in more absorption of luminescent material and reemission of longer wavelength [3-4]. A large part of the emitted photons guide toward the edge of the LSC due to total internal reflection with the refractive index of the glass being higher than of air. A solar cell is contacted to the lateral surface of the thick glass [5-6]. The short-circuit current of the solar cell in the LSCs will be discussed in this paper with and without the broadband AR coating [7-8]. The design and fabrication of the broadband AR coating will also be discussed in this paper.

2. Experimental

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Thin films of Ta2O5, SiO2 were deposited on B270 glass substrates at a substrate temperature of 200 degrees C in an electron-beam evaporation system. The respective starting materials were Ta2O5 and SiO2. The 50 mm×50 mm B270 glass substrate had a thickness of 5 mm. Before evaporation, the deposition system was pumped down to a base pressure of under 3.2×10-5 torr using a rotary pump and turbo-molecular pump. The deposition rate, 0.1 nm/s, and film thickness were controlled with a quartz monitor. The deposition pressure with oxygen of 7 sccm as the reactive gas was 2.7×10-4 torr during deposition of Ta2O5, SiO2. All of the samples were analyzed using a Perkin-Elmer Lambda 900 spectrophotometer in transmission over a spectral range from 330 nm to 1000 nm. The optical constants and thickness of the films were determined using a J. A. Woollam M-2000U spectroscopic ellipsometer in the 330-1000 nm wavelength range. The short-circuit current of the solar cell in the LSC was measured when the LSC was illuminated under a flashing-mode solar simulator. The dependence of the short-circuit current on the incident angle of the sunlight can also be measured by rotating the LSC. The phosphor R630 (Intematix Cooperation) was used as the luminophore in the luminescent layer of the LSC [9-10].

3. Experimental results

Figure 1 demonstrates the transmittance spectra of the Ta2O5 films deposited on B270 glass substrates at 4, 6, 7, 8 and 10 sccm oxygen flow rates. The absorption of the Ta2O5 film deposited at 7 sccm oxygen flow rate was smallest among different oxygen flow rates due to nearest the transmittance of substrates, as shown in Fig. 1. Figures 2 and 3 display the refractive index and extinction coefficient determined by the spectroscopic ellipsometer for the Ta2O5 films as shown in Fig. 1. The extinction coefficient of the Ta2O5 film deposited at 7 sccm oxygen flow rate was smallest among different oxygen flow rates. This observation of the extinction coefficient was consistent with the results of transmittance. Figure 4 plots the measured transmittance spectrum of the Ta2O5 film deposited at 7 sccm oxygen flow rate and that calculated from the refractive index and extinction coefficient in Figs. 2 and 3. The strong agreement in Fig. 4 supports the refractive index and extinction coefficient in Figs. 2 and 3. Figure 5 illustrates the transmittance spectra of the broadband AR coating at the incidence angles of 0, 15, 30, 45 degrees. The design of the AR coating is B270 substrate/Ta2O5(14nm)/
SiO2(33nm)/Ta2O5(36nm)/SiO2(13nm)/Ta2O5(83nm)/SiO2(15nm)/Ta2O5(31nm)/SiO2(92nm)/Air. Figure 6 shows the short-circuit currents of the solar cell in the LSCs without and with the AR coating at the incidence angle of 0, 15, 30, 45 degrees. It can be seen in Fig. 6 that the LSCs with the AR coating increased the shortcircuit current of the solar cell and more light fell into the solar cell in the LSCs.

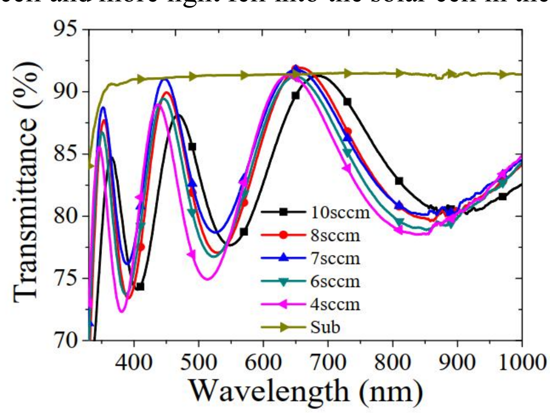

Figure 1. Transmittance spectra of the Ta2O5 films deposited at different oxygen flow rates.

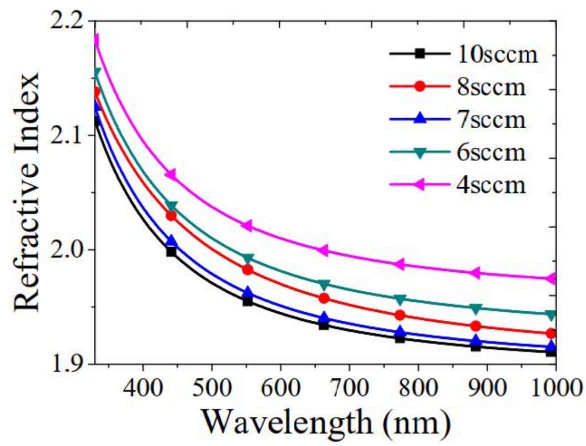

Figure 2. Refractive index versus wavelength for the Ta2O5 films deposited at different oxygen flow rates.

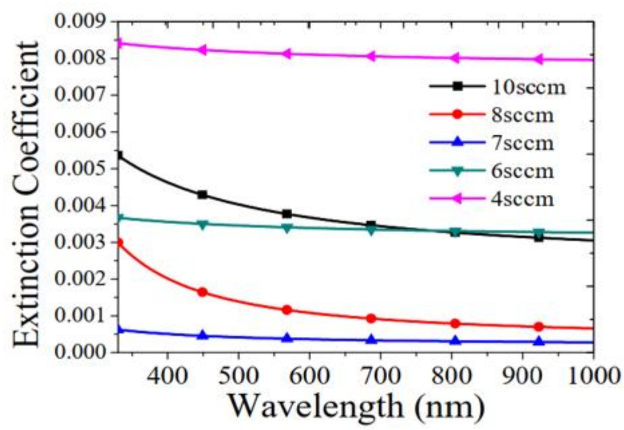

Figure 3. Extinction coefficient versus wavelength for the Ta2O5 films deposited at different oxygen flow rates

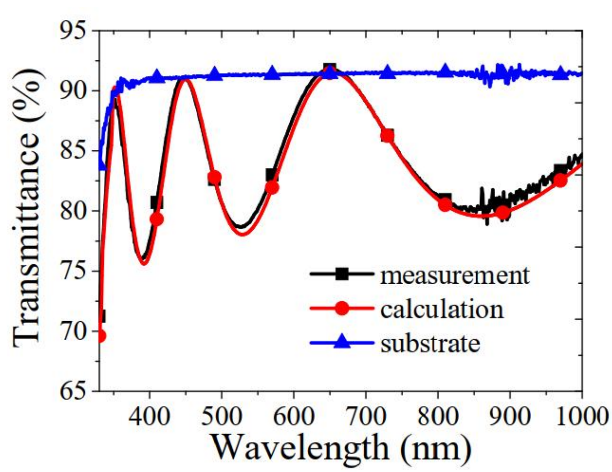

Figure 4. Measured transmittance spectrum of the Ta_2O_5 films deposited at 7 sccm oxygen flow rate, and spectrum calculated from constants in Figs. 2 and 3.

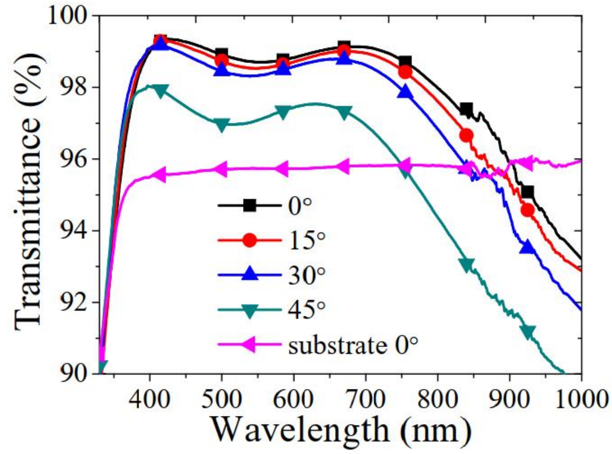

Figure 5. Transmittance spectra of the broadband AR coating at the incidence angles of 0, 15, 30, 45 degrees.

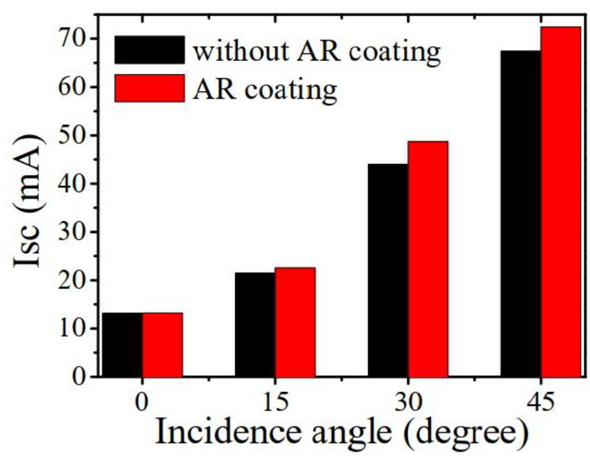

Figure 6. Short-circuit currents of the solar cell in the luminescent solar concentrators without and with the AR coating at incidence angles of 0, 15, 30, 45 degrees.

In the experiment result that show in Figure 1 to 6. The transmittance spectra of the Ta2O5 films deposited at different oxygen flow rates shown in Figure 1 that show the transmission is over 90 percent. However, Transmittance spectra of the broadband AR coating at the incidence angles of 0, 15, 30, 45 degrees are over 98%, that demonstrated the optimized the efficiency of coating have a high transmission.

4. Discussions and Conclusions

Effects of oxygen flow rate between 4 and 10 sccm on the optical property of the Ta_2O_5 films prepared by electron-beam evaporation at a substrate temperature of 200 degrees C have been investigated. The absorption and extinction coefficient of the Ta_2O_5 film deposited at 7 sccm oxygen flow rate were smallest among different oxygen flow rates. The 8-layer broadband AR coatings composed of Ta_2O_5 and SiO_2 films deposited on B270 glass substrates at 7 sccm oxygen flow rate have been successfully designed and fabricated. The LSCs with the AR coating increased the short-circuit current of the solar cell and more light fell into the solar cell in the LSCs.

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