ISSN : 0974 - 7486 Volume 9 Issue 12

Materials Science

Trade Science Inc.

An Indian Journal

Full Paper

MSAIJ, 9(12), 2013 [477-480]

Preparation of SiO_2 antireflective film on large area ultrawhite glass by roll coating method

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ABSTRACT

SiO_2 antireflective film was successfully coated on the large area ultrawhite glass (300 mm×300 mm) by roll coating method. The effect of the concentration of the SiO_2 and the annealing temperature on the photovoltaic transmittance of the film was studied and the hardness and the adhesion of the film were tested. The transparent antireflective film with the highest photovoltaic transmission of 95.7% was obtained.

KEYWORDS

Antireflective film;
SiO_2;
Roll coating;
Photovoltaic transmission;
Large area.

INTRODUCTION

Antireflective film for solar cells is deposited on the substrate to reduce the photovoltaic reflectivity and enhance the photovoltaic transmittance so that ultimately the photovoltaic conversion of solar cells can be enhanced. Currently, a wide variety of techniques have been employed to fabricate the antireflective film such as CVD[1-3], magnetron sputtering[4,5], chemically spray[6,7] and sol-gel[8-11]. In 1968, Stober W[12] has successfully prepared the monodisperse SiO_2 using sol-gel method. Since then sol-gel method is applied to coat the antireflective film extensively for its simple operation and low cost in the laboratory. However, few attempts were made of the coating antireflective film on the large area substrate due to the engineering amplification effect, in which the quality of the film cannot be guaranteed. In this paper, SiO_2 were prepared as the coating precursor using the sol-gel method. After that, antireflective coating was fabricated by roll painting the SiO_2 colloid on the large area ultrawhite glass (300 mm×300 mm) using roll coater designed by ourselves. The effect of the concentration of the SiO_2 and the annealing temperature on the photovoltaic transmittance of the film was studied and the hardness and the adhesion of the film were tested. The transparent antireflective film with the highest photovoltaic transmission of 95.7% was obtained.

EXPERIMENTAL

Chemicals

Tetraethoxysilane (TEOS), ethylalcohol, acetone and ammonia were purchased from Sinopharm Chemical Reagent Co. Ltd and used without further purification.

Synthesis procedure

In a typical synthesis procedure of SiO_2, TEOS, ethylalcoholm and ammonia were mixed according to a certain ratio. After stirring for 2 h at 30°C, the solution was sealed and aged for 4-7 days under the ambient temperature and the quasi-transparent SiO_2 colloid was obtained. The chemical equation was showed in Equation 1.

$$Si(OC_2H_5)_4 + 2H_2O \xrightarrow[25^\circ C]{NH_3 \cdot H_2O} SiO_2 + 4C_2H_5OH$$

Equation 1: Synthesis procedure of SiO_2

Fabrication procedure

The ultrawhite glass substrate was orderly washed by deionized water, ethylalcohol and acetone and was kept in the drying oven for further use. SiO_2 colloid was roll coated on the substrate by the roll coater displayed in Figure 1. After that, the antireflective film was annealed in the furnace for 2 h.

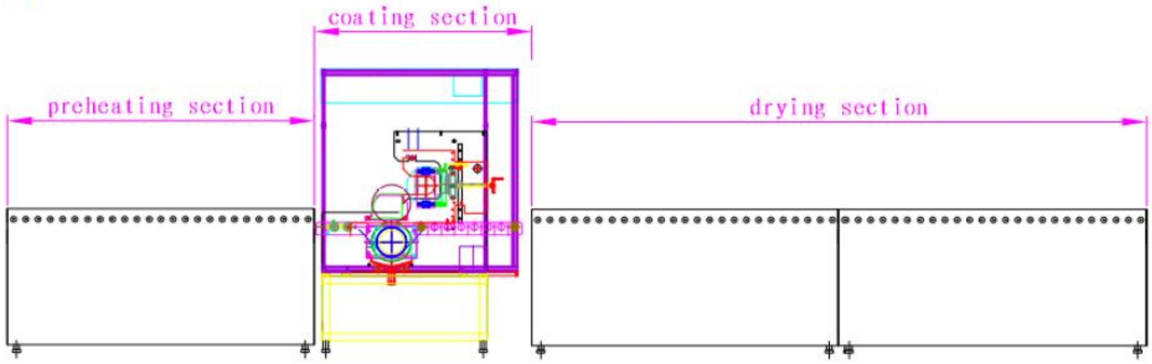

Figure 1: The drawing of the roll coater

Characterization

The morphology was observed using scanning electron microscopy (SEM, Nova NanoSEM450). The photovoltaic transmittance was studied by ultraviolet and visible spectrophotometer (Hitachi U3900). The hardness was tested by pencil hardness test apparatus (T-Machine JL3086) and the adhesion was tested using the transparent tape (3M Scotch 600).

RESULTS AND DISCUSSION

Effect of sio_2 concentration on the photovoltaic transmittance of antireflective film

Figure 2 showed the microscopy of SiO_2 with different concentrations. From the Figure 2 (a), it can be seen that SiO_2 colloide aggregates to form a big one which will decrease the transmittance of the film shown in Figure 3. From the Figure 2 (d), some cracks and small holes were observed which reduced the transmittance of the film. When the concentration of the film was 0.043 mol/L, the surface of the film was smooth and crack-free and the photovoltaic transmittance was up to 94.7%.

Effect of annealing temperature on the photovoltaic transmittance of antireflective film

Figure 4 showed the effect of annealing temperature on the photovoltaic transmittance of antireflective film. We simulate the large-scale tempered treatment on the glass, therefore the annealing temperature was above 400°C. When the temperature was reached at 450°C, the highest photovoltaic transmittance of 95.7% was obtained. After the temperature was increased, the photovoltaic transmittance was reduced. It can be concluded that when the temperature was relatively lower (400-450°C), increasing the temperature can effectively accelerate the dehydration of the $SiO_2 \cdot xH_2O$ which can increase the photovoltaic transmittance of the film due to the formation of porous SiO_2 and when the temperature was getting higher (450-500°C), the microstructure of the antireflective film might be destroyed which decreased the photovoltaic transmittance.

Hardness, adhesion and color difference measurement of the antireflective film

TABLE 1 showed the hardness measurement of the antireflective film. The hardness of the film was weighed by pencil hardness. Pencil hardness test apparatus was used to scratch on the glass and only one or less scratch was observed can confirm the sample was qualified. We randomly chose three samples and the test results showed that the hardness of the samples was over 4H which can meet the demand for solar cells outside.

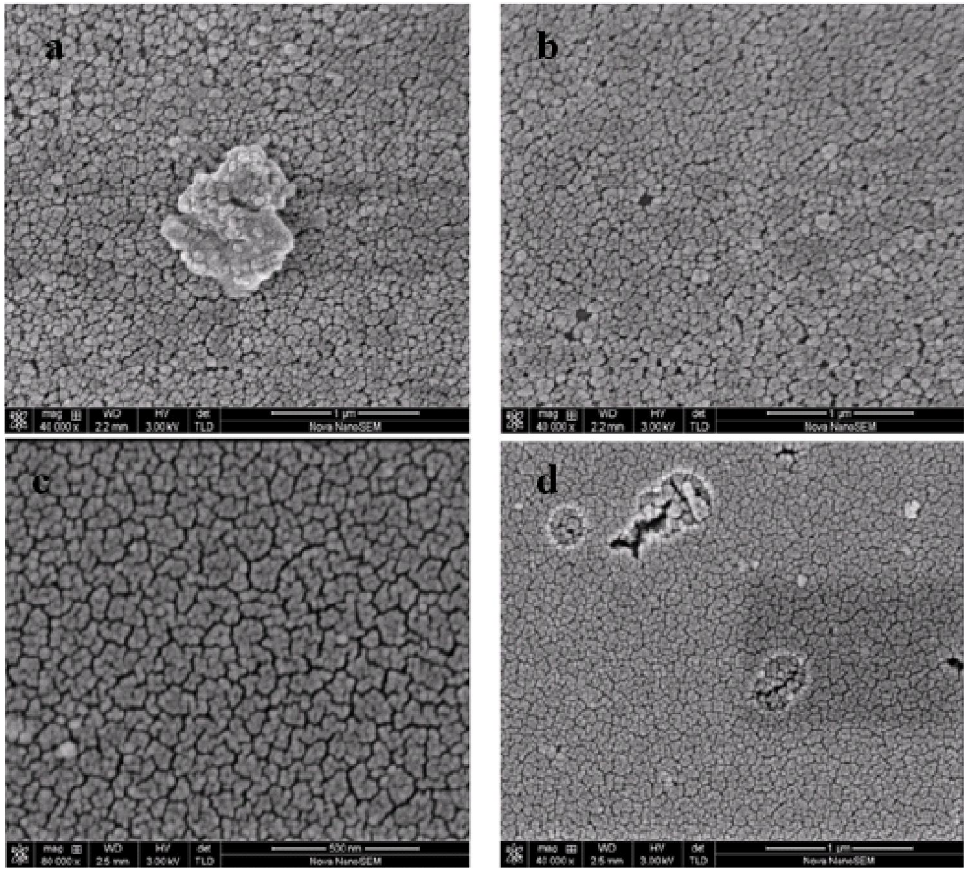

Figure 2 : The microscopy of SiO_2 with the concentration of (a): 0.050 mol/L; (b),(c): 0.043 mol/L; (d): 0.030 mol/L

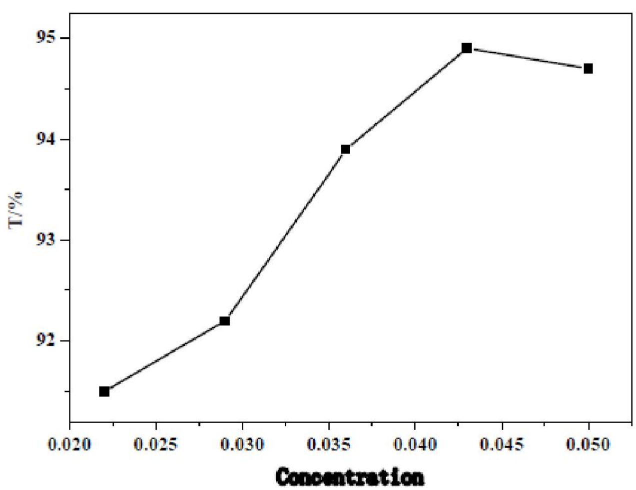

Figure 3: The photovoltaic transmittance of the antireflective film with different concentrations of SiO_2

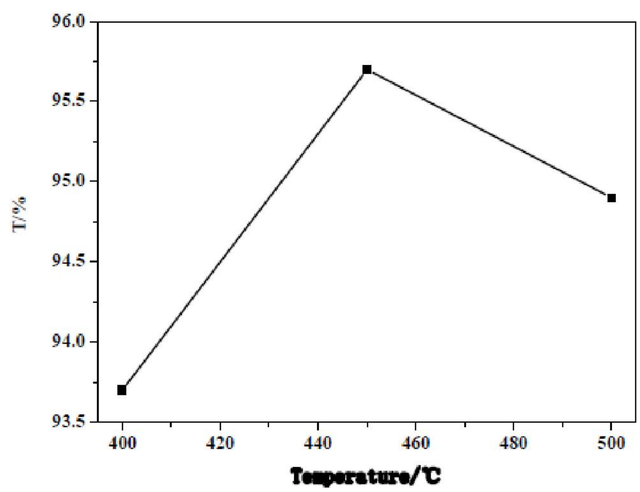

Figure 4: The photovoltaic transmittance of the antireflective film with different annealing temperature

TABLE 1: The pencil hardness of the antireflective films

Pencil hardness	6H	5H	4H
Sample 1	no scratch		
Sample 2	two scratches	no scratch	
Sample 3	five scratches	two scratches	no scratch

Adhesion measurement was implemented by using the transparent tape (3M Scotch 600) firmly attached to the surface of the film, and then the tape was quickly removed vertically. The same experiments were repeated for 200 times. There was no obvious film stripping and color difference phenomena found by macroscopic observation. More details can be found in supplementary information.

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CONCLUSION

We successfully coat the SiO_2 antireflective film on the large area ultrawhite glass (300 mm×300 mm) by roll coating method. The results showed that the transparent antireflective film with the highest photovoltaic transmission of 95.7% was obtained and the hardness was over 4H which can meet the demand for solar cells outside.

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