



Preparation of Anti-reflective Coatings on Solar Glass†

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AJC-13335

Anti-reflective coatings have been applied on solar glass, which can increase the transmittance by 5 % or more and efficiently improve the conversion efficiency of solar cells. In this paper, there are three kinds of antireflective coatings *i.e.*, SiO₂ antireflective coatings, TiO₂ antireflective coatings and SiO₂/TiO₂ double-layer antireflective coatings by dipping slide glasses in the sols and being compared the three kinds of transmittance variation when they are prepared in different drawing speed.

Key Words: Solar glass, Anti-reflective coatings, Sol-gel, Transmittance.

INTRODUCTION

Solar glass as one kind of new clean energy is being taken great attention by people, Countries in the world have committed to the development and utilization of solar energy resources. Because the solar glass's low transmittance rate led to solar cells conversion inefficiency, which leads to the high cost of solar power, restricted the solar energy application pace. Therefore, high quality solar glass has become the most competitive products of the solar energy development and application¹. We prepared antireflective coating in solar glass surface in order to enhance the glass light transmittance. Anti-reflective coating also known as the semipermeable film, namely in optical components surface with an optical thin film, used to reduce optical components surface reflection, increase the light transmittance, so as to improve the work in wavelength or within the band performance.

There are many preparation methods of the film, such as a chemical vapour deposition, sputtering method, vacuum evaporation coating and making sol-gel. Chemical vapour deposition is a chemical gas phase of growth, hereinafter referred to as chemical vapour deposition technology. Sputtering method (sputtering) coating is a physical vapour deposition process. The main sputtering method, according to its characteristics, can be divided into three impacts *i.e.*, direct current (DC) sputtering, radio frequency (RF) sputtering, magnetron sputtering, *etc.* Vacuum evaporation coating is a kind of method that, in the vacuum chamber, the heating evaporation container can form a thin film of raw material, which leads to the atoms or molecules to escape from the surface

gasification and formed the steam flow, the incident to the substrate surface, condenses into solid film method²⁻⁵. These methods can though preparation out has a good uniformity and optical properties of antireflective coating, but the cost is expensive and not suitable for continuous mass production. And one of the most commonly used methods is making sol-gel, the biggest advantage of this method is low cost, it has the high economic value, the simple operation process which does not need to vacuum equipment, low cost. Therefore, in this study, the preparation method is (sol-gel) method.

EXPERIMENTAL

In this experiment, the preparation method of the film is making sol-gel, coating tiras immersion method in a clean glass slides both sides, the preparation of the film after heat treatment into samples are: TiO₂ single antireflective coating samples, SiO₂ single anti-reflective coating samples, TiO₂/SiO₂ double anti-reflective coating samples.

Experimental products: Titanium acid four butyl acetate (TPOP), ethyl silicate (TEOS), hydrochloric acid, anhydrous alcohol, KQ-50 type B ultrasonic cleaning machine, DGX-9243 BC-1 electric drum wind drying oven, 85-2 A digital display constant speed constant temperature magnetic blender. First, cleaning glass slides before film preparation, the process as follows: the essence that washed clean cleaning and soaked in nitric acid solution deionized water, rinse and ultrasonic cleaning 10 min, acetone ultrasonic cleaning 10 min and rinse deionized water and soaked in deionized water spare.

†Presented to the 6th China-Korea International Conference on Multi-functional Materials and Application, 22-24 November 2012, Daejeon, Korea

Single-layer film preparation of TiO₂: Put 10 mL titanium acid four butyl acetate soluble in 102 mL of anhydrous alcohol, the solution of stirring, stirring slowly 16 g edge to the concentration of 6.7 % of hydrochloric acid, in order to prevent to produce precipitation, stirring, about half an hour for a quick stable, even the milky, the titanium dioxide solution. Put cut good slides with titanium dioxide in vertical of their beaker, moving slowly upward and tiras. After the film coating, the sample under 150 °C in annealing 1 h, then with the furnace cooling, can the uniform, transparent titanium dioxide thin film. Made of sample Numbers: 1 # (tiras speed 0.97 mm/s), 2 # (tiras speed 1.46 mm/s), 3 # (tiras speed 1.04 mm/s).

Single-layer film preparation of SiO₂: Put 5 mL ethyl silicate without water soluble in 104 mL of ethanol, the solution of stirring, stirring slowly to join the 12.2 g density is 6.7 % hydrochloric acid, prevent precipitation produce, stirring, *ca.* 0.5 h, but stable, even and transparent silica sol. Cut good slides is placed vertically in a beaker of silica sol, then moving slowly upward and tiras. After the film coating, the sample under 150 °C in annealing 1 h, then with the furnace cooling, can the uniform, transparent silica films. The sample Numbers for: 4 # (tiras speed 1.13 mm/s), 5 # (tiras speed 2.04 mm/s).

Double-layer film preparation of TiO₂/SiO₂: Tiras method coating TiO₂ sol in 90 °C and heat treatment under 15 min-tiras method coating SiO₂ sol in 90 °C and the heat treatment in 150 °C and 15 min heat treatment 1 h-TiO₂/SiO₂ double membrane. Among them coated TiO₂ sol, such as the way of SiO₂ sol steps 1, 2 and the film samples: 6 # (tiras speed 0.84 mm/s), 7 # (tiras speed 1.7 mm/s), 8 # (tiras speed 0.98 mm/s).

By using fluorescence microscope to sample film coated glass microscopic surface of observation, which can clearly see the glass surface of the film that was studied. The results are as follows graphs in Fig. 1:

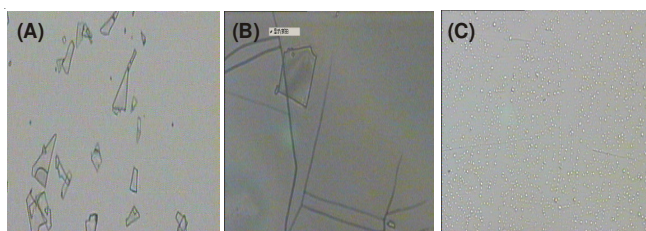


Fig. 1. Microscopic surface of (A) TiO₂, (B) TiO₂/SiO₂, (C) SiO₂ antireflective coatings sample

RESULTS AND DISCUSSION

Light transmittance test (test 300 nm -75 nm band range of light transmittance): Shown in the Fig. 2 is TiO₂ single-layer film in different wavelengths of through rate change trend, set in the slides wavelength of light through rate is 100 %, 2 # sample in glass slides of the formation of the surface film is the thinnest (tiras fastest), the transmission rate is the highest; 3 # samples and 1 # samples tiras speed are quite, so the film thickness is formed, but, because the 3 # samples tiras speed is slightly faster than 1# and 3 # samples of light through rate in most of the wavelength range (*ca.* 480 nm and 380 nm) is higher than 1 # samples. To see this experiment comprehensive made TiO₂ membrane minus

reflection didn't play a increase through, the effects of different thickness of the TiO₂ thin films are in the 480 nm wavelength place through rate reaches maximum and the smaller the thickness, the higher light transmittance.

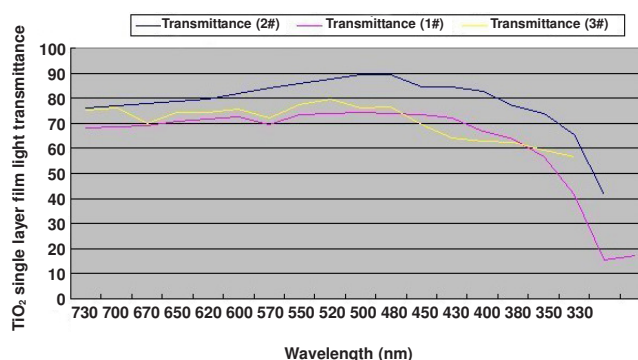


Fig. 2. Transmittance change trend of TiO₂ single-layer film in different wavelengths

Fig. 3 shows the transmittance change trend of SiO₂ single-layer film in different wavelengths, set in the slides wavelength of light transmittance was 100 %, the figure shows that two samples in the wavelength range for 750 to 450 nm, SiO₂ of single-layer film almost makes no influence to the light through rate and 4#, 5# samples in 430 nm of the low band transmittance are increasing rapidly, it achieved the purpose, so SiO₂ thin film is used in 430 nm low band to increase permeability.

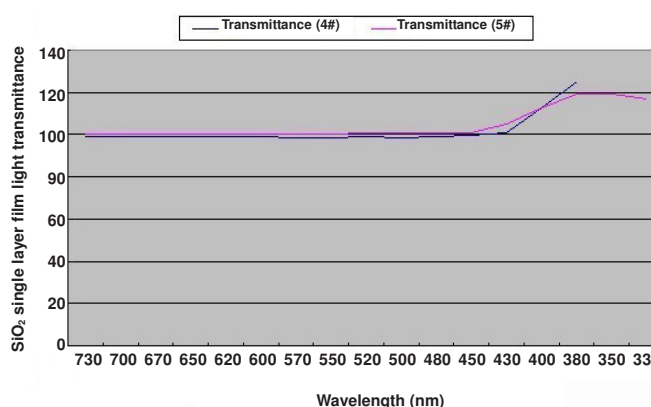


Fig. 3. Transmittance change trend of SiO₂ single-layer film

Fig. 4 shows the transmittance change trend of TiO₂/SiO₂ double membrane in different wavelengths, set in the slides wavelength of light through the rate was 100 %, we can see from the graph TiO₂/SiO₂ double membrane minus reflection effects were no better than TiO₂ single-layer film or SiO₂ single-layer film and compared to TiO₂ single-layer film or SiO₂ single-layer film, TiO₂/SiO₂ double minus reflection peak wavelength of membrane appear wide, which has good broad-band antireflective effects.

The results show that TiO₂/SiO₂ double anti-reflective coating didn't realize minus reflection effects and compared with the single anti-reflective coating of SiO₂ and TiO₂, double film through rate reduced. The main reasons are: (1) TiO₂/SiO₂ double minus reflection film appear cracked and destroy film structure. (2) TiO₂ film interface with SiO₂ was bad, which

impact of the double membrane of total transmittance. (3) There is no tiras machinery, can only carry on the manual tiras the membrane, so coating thickness is out-of-control and tiras direction uneven thickness. Therefore it is not according to the design of given instancing quarter- $\lambda/2$ W type double anti-reflective coating. (4) In this article, the electric drum wind machine was used to dry film heat treatment, its cooling and heating condition is very unstable, in the process of heat treatment film, it was easy to defect, which reduce the film through rate. (5) Other factors, such as the not cleaning glass substrate washing, the existing oil delay or introducing impurity, making gel process existing within the film porosity and so on.

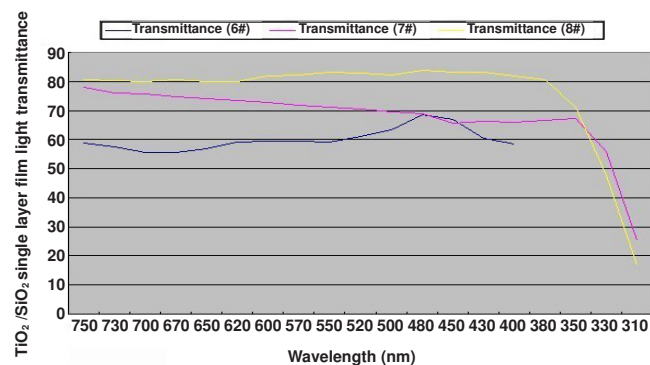


Fig. 4. Transmittance change trend of $\text{TiO}_2/\text{SiO}_2$ double membrane

Conclusion

Anti-reflective coating is a convenient and effective method to reduce solar glass exterior smooth reflection, to make solar

energy have higher through rate, to increase the output power of pv modules. Through the ultraviolet-visible spectrophotometer this study tested and compared SiO_2 single antireflective, $\text{TiO}_2/\text{SiO}_2$ double antireflective, TiO_2 single anti-reflective three film light transmittance, found antireflective effect of SiO_2 is good in the acidic catalysis, TiO_2 antireflective coating light transmittance is poorer. According to the literature, it is known that the film has photocatalytic titanium dioxide and photodegradation effect, therefore, putting TiO_2 and SiO_2 materials to cooperate to make the double function film, but the experiment sample made of $\text{TiO}_2/\text{SiO}_2$ double film showed no increase effect, it might because the thickness of the two membrane's design was not reasonable or processing conditions was not stable.

ACKNOWLEDGEMENTS

Thanks to the National Natural Science Foundation of China (51002002) funding.

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