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Preparation, durability and thermostability of hydrophobic antireflective coatings for solar glass covers

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Abstract

In this paper, SiO_2 coatings were prepared with sol–gel method based on base catalysis. The optical transmittance of the soda-lime glass was improved more than 7% by optimizing sol concentration and aging time while the refraction index and thickness of antireflective coatings (ARCs) were 1.227 and 107 nm, respectively. The surface modification of the coatings with Hexamethyldisilazane (HMDS) was investigated. The static contact angle values increase from 22° to 130° after the modification, while the average transmittance decreases slightly. The SEM images show agglomeration significantly reduced after modification while silica particle size and structure changed little. FT-IR spectra show $–CH_3$ in HMDS was covalently bonded to silica particles in the covalent reaction with Si-OH resulting in the improvement of hydrophobicity. The STA-IR analysis shows modified SiO_2 ought to be annealed at 300 °C to eliminate metal alkoxide and solvent. And the $–CH_3$ covalently bonded to silica particles began to be destroyed about 350 °C and severe damaged at 450 °C. Finally, brine pollution and corrosion resistance tests show that ARCs modified by HMDS have better self-cleaning ability and brine corrosion resistance than usual porous SiO_2 coatings.

Keywords: Antireflective coatings; Sol–gel; Hydrophobicity; Durability

1. Introduction

ARCs have been widely applied in the field of PV modules, solar thermal collectors, automobile windshield and architectural glass recently (Chabas et al., 2008; Helsch et al., 2010; Helsch and Deubener, 2012; Morimoto et al., 2001; Prado et al., 2010;), which can be prepared by several methods, such as sputtering, sol–gel and CVD (Nagel et al., 2001). The sol–gel method is most popular in industry for it is cost effective and suitable for large-scale production.

Two types of coatings could be prepared by sol–gel method based on either acid or base catalysis (Vincent et al., 2007). Under the acid environment, the ARCs demonstrated an excellent mechanical property but made a small contribution to antireflection due to its low-porosity and high refractive index. Contrarily, the ARCs prepared with base catalysis significantly increased transmittance but were very sensitive to humid condition due to its porous structure and active hydroxyl in it (Belleville and Floch, 1994; Thomas, 1992). Therefore, this kind of ARCs would not have a good performance on mechanical and weatherability, which is crucial for solar glass covers to withstand the outdoor environments. Post-treatment is a good way to enhance the weatherability and self-cleaning property of the coatings. ARCs initial treated with ammonia followed by hexamethyldisilazane (HMDS) vapor can reduce the tendency to absorb vapor

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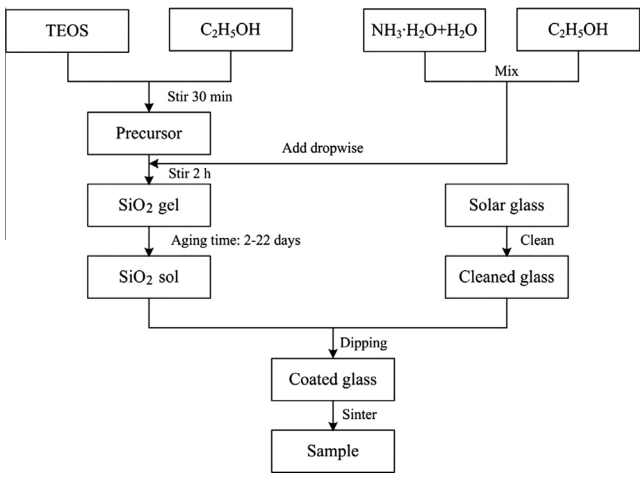

Fig. 1. Flow chart of the coating synthesis process.

contamination. The transmission efficiency of these coatings show much reduced loss in exposure tests at elevated temperature (Thomas et al., 1999). The effect of post-treatment on ordered mesoporous ARCs was also reported by Sun et al. (2014). Recently, combinations of antireflection with self-cleaning property have been achieved (Li et al., 2013; Xin et al., 2013; Ye et al., 2011; Zhang et al., 2013). However, the thermostability and weatherability of these coatings need further research.

In this study, coatings with high transmittance were prepared with sol–gel method based on base catalysis. The HMDS modification was followed to obtain hydrophobic ability. Coatings thickness and refractive index were controlled by varying solution concentration and aging time, in order to shift the reflectance to a minimum value. We also studied the mechanism of chemical modification and the influence on structure, morphology and optical properties in detail. Besides, the annealing process of modified coatings was first studied by STA-IR analysis.

The coatings modified by HMDS have stable hydrophobic and antireflective performance in the environment of strong ultraviolet radiation and low temperature (Dou et al., 2013). ARCs modified with hexamethyldisiloxane decreased the surface reactivity of porous silica antireflective films, hence reduced the effect of outdoor soiling and showing long-term durability (San Vicente et al., 2009, 2011). However outdoor solar glass covers are also long-term scoured by the rain, which contains a lot of salt. The salts will cover on the ARCs and reduce the transmittance as soon as the rain evaporates. At the same time, ARCs will be irreparably damaged if soaked in brine for a long time. In order to test the self-cleaning ability and

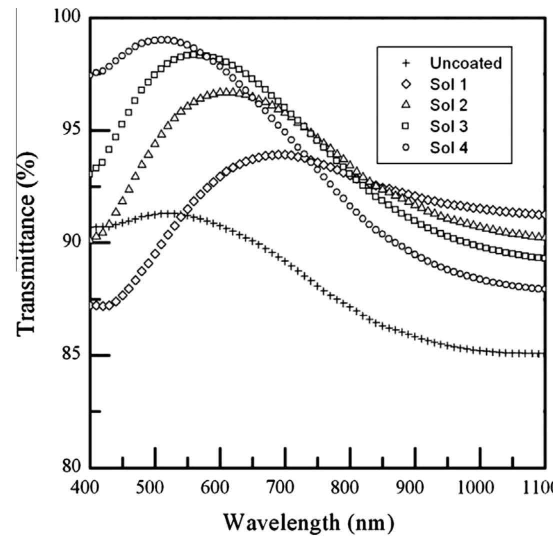

Fig. 3. Transmittance spectra of uncoated glass and coated samples with different concentrations of sols. The molar ratio of TEOS: EtOH was 1:18 (sol 1), 1:30 (sol 2), 1:38 (sol 3) and 1:45 (sol 4) respectively.

brine corrosion resistant of ARCs, we designed two simple and controllable tests: brine pollution test and brine corrosion resistance test.

Coatings prepared by this method showed good weatherability together with high transmittance, which has great potential in the application of outdoor environment.

2. Experimental procedures

ARCs prepared in this work were dip-coated by Stober sol–gel method (Stöber et al., 1968). Tetraethyl orthosilicate (TEOS), ethanol (EtOH) and water were mixed at a proper ratio as precursor to form a silica porous structure, ammonia was used as catalyst since the experiment need to be carried out under the base catalysis circumstance. The solution was stirred in sealed container for 2 h at 20 °C and then aging for 2–22 days before dip-coating. The coated sample was dried in a vacuum oven at 120 °C for 1 h and sintered in muffle furnace at 500 °C for another 1 h with a heating rate of 3 °C/min. The flow chart of the ARCs synthesis was shown in Fig. 1.

After coating process, soda-lime glass with ARCs was immersed in HMDS/hexane solution for the sake of surface modification, in which HMDS reacted with hydroxy to form organosilyl. The reaction between the HMDS and surface silanol groups was shown in Fig. 2.

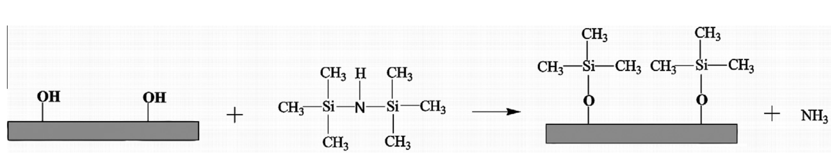

Fig. 2. Schematic representation of the reaction between HMDS and surface silanol groups.