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An efficient way to prepare hydrophobic antireflective SiO_2 film by sol–gel method

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ABSTRACT

A single-layer hydrophobic antireflective SiO_2 film was prepared by sol–gel method. High transmittance (97%) and large static water contact angle (130.6°) were realized simultaneously through a simple and efficient way. Tetraethoxysilane (TEOS) was used as a precursor to prepare SiO_2 sol. A dip-pulling method was used to prepare the thin film. We controlled the film thickness by regulating pulling speed for making the transmittance of the film to reach a peak at about 550 nm. The surface of the film was covered with uniform particles of 20–30 nm and pores of 50–60 nm as shown in the SEM images. 1H, 1H, 2H, 2H-perfluorodecyltrichoxy silane (PFDS) was introduced to replace the hydroxyl (–OH) groups and decrease the surface energy of the film. The appropriate SiO_2 particle size and porosity in the film and low surface energy give the hydrophobic antireflective SiO_2 film with high transmittance and large static water contact angle.

1. Introduction

The wettability and transmittance of materials are two important performances which depend on microscopic structure of the surface and chemistry. Jiang et al. found that Water Striders could repel water and explained the role of micro–nano secondary structure to hydrophobicity [1]. Hao et al. reported an interesting liquid-infused film, which enhanced optical transmittance by the replacement of air pockets by liquid lubricant [2]. In the optical system of many fields like high power lasers, solar cells, solar collectors and so on, a large amount of energy can be lost because of the reflection on the glass surface [3,4]. The antireflective film on glass prepared by sol–gel method with many advantages like low reflection, high transmittance and high resistance to damage threshold have aroused wide spread attention and a lot of research [5–7]. However, on the process of forming antireflective film, the surface can be easily left many –OH groups, resulting in strong hydrophilicity, so that it tends to absorb water molecules in the air, and then bring down the transmittance [8]. In the humid marine environment, this phenomenon is particularly serious. By replacing the groups and controlling the surface morphology, the antireflective coating can achieve high transmittance and good hydrophobicity simultaneously in theory. Over the past decade, many efforts have been made to improve the transmittance or hydrophobicity, but few people could give consideration to both high transmittance and good hydrophobicity [9–12]. In our work, we presented a simple efficient approach to obtain an antireflective and hydrophobic surface by dip-coating a single-layer sol–gel film on glass and introducing PFDS to realize high transmittance and good hydrophobicity at the same time.

2. Experimental

Tetraethyl orthosilicate (TEOS), anhydrous ethanol (EtOH), ammonium hydroxide ($NH_3 \cdot H_2O$) and deionized water (H_2O) with volume ratio of 1:4:0.05:0.05 were mixed and stirred for 1 h, then aged for 7 days to get sol. The film was prepared on glass by dip-pulling method, heated to 500 °C and kept for 1 h. After that, the sample was dipped in the 1 vol% PFDS/ethanol solution for 10 s, and then heated at 120 °C for 1 h as the hydrophobic treatment. The surface morphology of the samples were determined by scanning electron microscopy (SEM, Hitachi S-4800) and atomic force microscope (AFM, Agilent 5400). The static water contact angle and transmittance were measured by contact angle instrument (JC2000C1) and ultraviolet–visible spectrophotometer (U-

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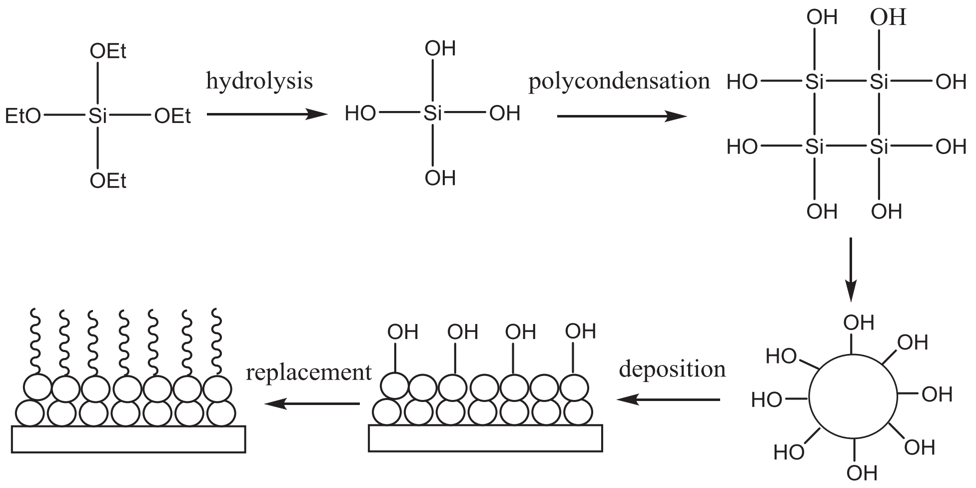

Fig. 1. The formation schematic of hydrophobic antireflective film.

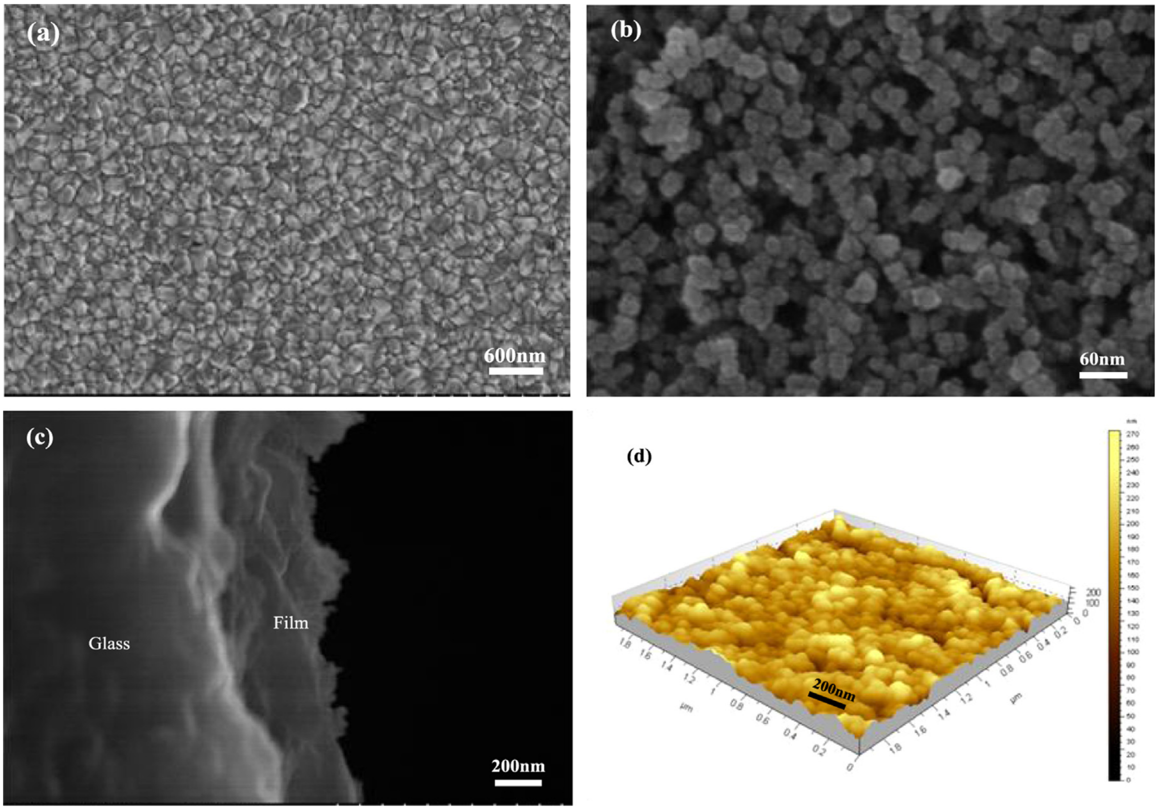

Fig. 2. The SEM and AFM images of the hydrophobic antireflective film (a) 20 K times magnified, (b) 150 K times magnified, (c) 50 K times magnified (cross-section) (d) Lateral view of AFM.

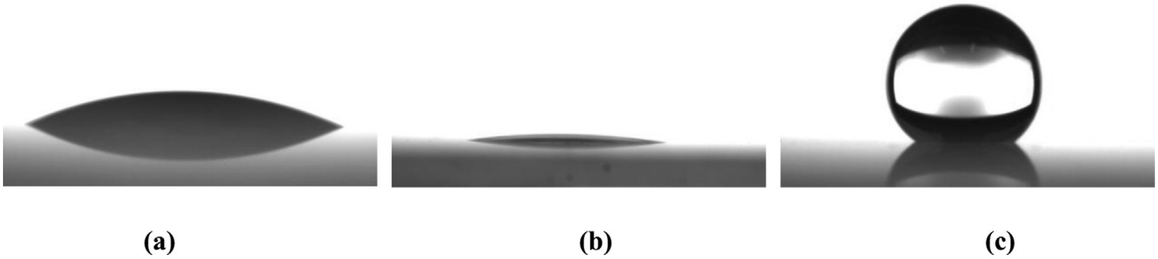

Fig. 3. The static water contact angle of (a) substrate, (b) antireflective film without hydrophobic treatment, (c) antireflective film after hydrophobic treatment.