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One-step Hydrothermal Method to Fabricate Drag-reduction Superhydrophobic Surface on Aluminum Foil

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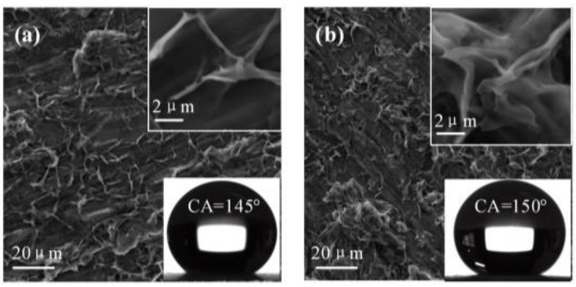
ABSTRACT

Inspired from the natural phenomenon that the lotus left is not dyed out of the sludge and the water strider can walk on the water, researchers have found the superhydrophobic effect. The superhydrophobic phenomenon is defined as the surface having a contact angle bigger than 150° and a sliding angle less than 5°. Generally, there are two methods for the preparation of super hydrophobic surface,the first way is to create a suitable roughness on the hydrophobic surface, the second way is to fabricate superhydrophilic surface with micro-nano structures and then use chemical reagent modifying the sample to obtain lower surface energy. In the recent years, various methods to fabricate superhydrophobic surface has attracted considerable attention [1,2], such as chemical etching, laser micromachining, electrodeposition method, etc. But the fabrication methods have some deficiencies more or less, such as tedious fabrication, high requirements for the equipment, and environment unfriendly.

In this paper, we present a novel, environment-friendly and one-step method to fabricate a superhydrophobic surface on an aluminum substrate. The aluminum substrate was immersed in a mixed solution containing aluminum oxide (Al_2O_3), perfluorotetradecanoic acid ($CF_3(CF_2)_{12}COOH$), deionized water and ethanol. After hydrothermal reaction in a high pressure autoclave at 150°C, a superhydrophobic surface was obtained. The morphologies and chemical compositions of the as-prepared sample were characterized by scanning electron microscopy (SEM), X-ray photoelectron spectroscopy (XPS) and energy-dispersive spectroscopy (EDS). Figure 1 shows the SEM images of aluminum samples after hydrothermal reaction for different time. As the duration of the hydrothermal reaction increases, more of the lamellar structures are formed on aluminum surface. When the reaction time reaches to 1h, the as-prepared sample exhibits a well superhydrophobic property with the contact angle (CA) of 158° ± 2° and the sliding angle (SA) of 3.5° ± 0.5°. Figure 2 shows the distribution of elements on the substrate after hydrothermal reaction for 1h. The lamellar structures consist of four elements about Al, C, O and F, and each element is evenly distributed on the substrate. Figure 3 shows the XPS results of the as-prepared sample. There are four signals: Al2p, C1s, O1s and F1s. The Al2p spectrum of the as-prepared sample is divided into two components: the signal at around 75.5eV is Al3+, which indicates the occurrence of hydrolysis reaction on the aluminum substrate [3]. The C1s spectrum of the as-prepared sample is shown in figure 3 (c). The peaks at around 284.6eV, 289.8eV, 291.6eV and 293.7eV are assigned to C-C, C=O, $-CF_2$ and $-CF_3$, respectively [4,5]. Therefore, the lamellar structures film is formed on the aluminum surface through two step reactions: the first is hydrolysis reaction of Al and Al_2O_3 to generate AlOOH and $Al(OH)_3$, the second neutralization reaction to generate $Al[CF_3(CF_2)_{12}COO]_3$ with low surface energy.



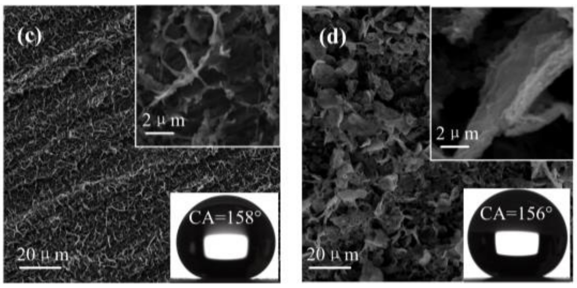


Figure 1 SEM images of aluminum samples after hydrothermal reaction. (a) reaction for 20min, (b) reaction for 40min, (c) reaction for 1h, (d) reaction for 2h.

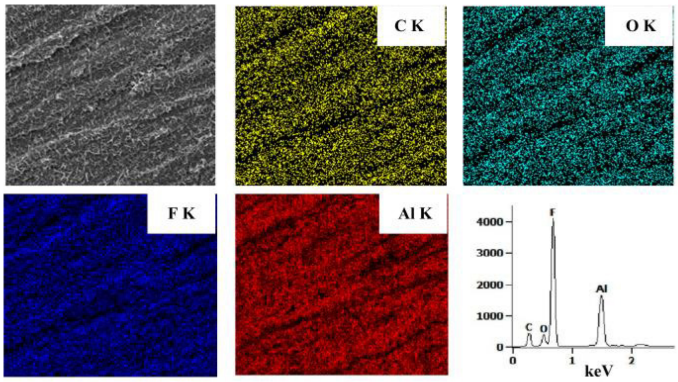


Figure 2 Distribution of elements on the substrate after hydrothermal reaction for 1h.

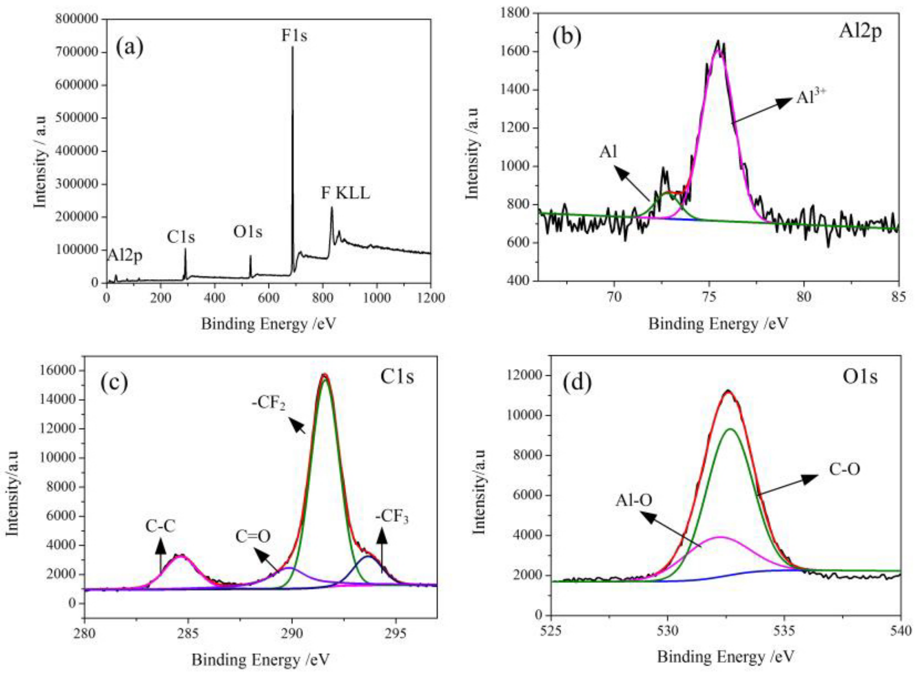


Figure 3 XPS results of aluminum sample after hydrothermal synthesis for 1h. (a) survey spectra, (b) Al2p spectra, (c) C1s spectra and (d) O1s spectra.

Furthermore, the superhydrophobic surface has self-cleaning and drag-reduction properties [6]. Figure 4 shows the self-cleaning property of the superhydrophobic surface. In the figure 4 (a), the left side of the as-prepared sample is untreated aluminum surface and the right side is superhydrophobic surface. When the sample has a tilting angle, the powdered dirt on the right side can be easily removed by the rolling water droplets, but the powdered dirt on the left side can not be removed. The drag-reduction property is tested by a self-designed liquid/solid friction measurement setup. As shown in Figure 5 (a), the testing setup is mainly composed of a cantilever, two strain gauges and data collection system. Figure 5 (b) shows that the friction resistance of untreated aluminum and superhydrophobic surface, which indicates that the drag-reduction radio for the superhydrophobic surface is about 20~30% at the velocity of 2~5m/s. Therefore, we believe this superhydrophobic surface has a great prospect in self-cleaning and drag-reduction applications.

Figure 4 Self-cleaning property of the superhydrophobic surface.

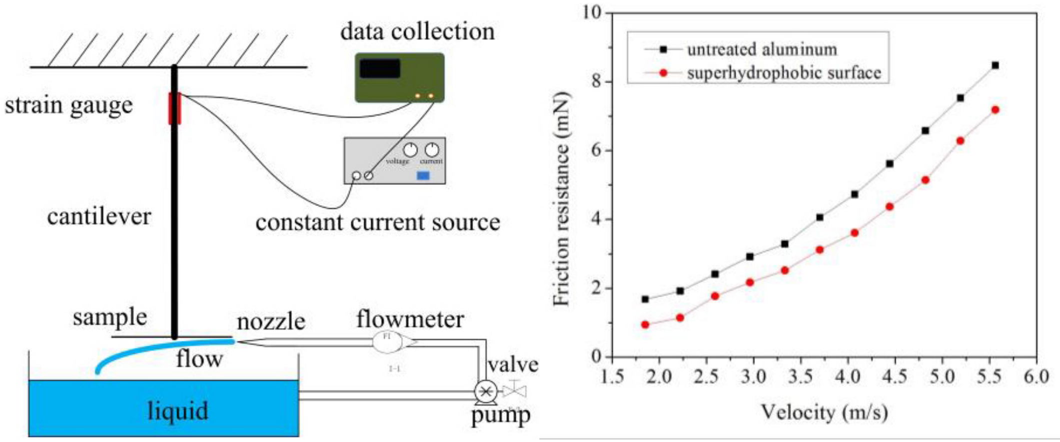


Figure 5 (a) Testing setup of friction resistance, (b) Friction resistance of untreated aluminum and superhydrophobic surface.

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