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The superhydrophobic aluminum surface prepared by different methods

Ruomei Wu [a,*], Guanghua Chao [a], Haiyun Jiang [a], Yang Hu [b], Anqiang Pan [b]

[a] School of Packaging & Materials Engineering, Hunan University of Technology, Zhuzhou 412007, Hunan, China
[b] School of Materials Science and Engineering, Central South University, Changsha 410083, Hunan, China

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ABSTRACT

Inspired by the biomimic lotus leaves, superhydrophobic aluminum alloy surfaces (SAAS) with modified nano-/micro-structures were prepared by different methods. Their surface morphology and hydrophobic properties were studied by using scanning electron microscopy (SEM) and contact angle meter, respectively. The results demonstrate the superhydrophobic surfaces irregular porous structures were successfully fabricated. Similar to lotus leaf surfaces, the depth and width of corrosion pits were in the range of 5–30 μm and 5–20 μm, respectively. The total thickness of the films was in the range of 5–30 μm. The water contact angles (WCAs) were larger than 150° and the water sliding angles (WSAs) were lower than 10°. The best superhydrophobicity was obtained by acid etching method, the stearic acid–ethanol coating was used to modify the irregular porous surfaces, with the average WCAs and WSAs of 166 ± 1.8° and 7°, respectively. The method is facile, the materials is inexpensive and is expected to be used widely.

1. Introduction

The surface properties of metals can be greatly modified when a superhydrophobic film was formed on metal substrates [1,2]. Recently, many methods have been used to fabricate superhydrophobic surfaces. In particular, the preparation of the SAAS has attracted extensive attention due to their promising applications [3]. Aluminum is widely used as an engineering material because of their inherent properties. Moreover, it is of great importance to fabricate superhydrophobic surfaces on aluminum alloys, which could inhibit the corrosion and oxidation of aluminum alloys [4,5]. It is well known that to obtain a superhydrophobic surface, two factors should be fulfilled [6–8], one is the geometric factor and the other one is the surface chemistry. The superhydrophobic properties can only be detected on a very rough surface or a rough surface coated with a low surface energy material. Therefore, the surface roughening is one key factor for aluminum alloy surface to obtain superhydrophobic property. In other words, a rough structure must be formed on the surface of aluminum alloy, which is crucial for the preparation of the SAAS. In order to provide the theoretical basis for fabricate superhydrophobic surfaces in metallic field and industrial development, the formulation of chemical treatment liquid and electrolyte solution was optimized and the process parameter was also explored [9,10]. In this article, various approaches, such as acid etching method, galvanic cell corrosion method, nitrate method, phosphoric acid-dichromate method and anodic oxidation method, were used to fabricate the micro-nano structure of the SAAS, and the morphology and characters of these fine structure surfaces were also studied.

2. Materials and methods

2.1. Materials

Aluminum alloy was obtained from Ruimin Aluminum Corporation of China. The alloy composition (designation 3003: Al-1.23Mn-0.51Fe-0.14Si-0.08Cu-0.05Zn-Mg0.008) was used as raw materials. All other reagents were of analytical grade and purchased from Tianjin Kermel Chemical Plant, China.

2.2. Synthesis of SAAS

The substrates used in the experiment were aluminum alloy plates (20 mm × 20 mm × 1 mm). Haven been polished with silica paper of Grade (Nos. 600, 800, 1200), the samples were ultrasonically cleaned successively in ethanol for 15 min and dried in air at room temperature. Afterwards, the cleaned aluminum alloy

* Corresponding author.
E-mail address: cailiaodian2004@126.com (R. Wu).

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plates were immersed in different electrolytic solutions, the details were shown in Table 1. The samples were then cleaned with deionized water and dried in a vacuum drying oven at 70 °C. And the dried aluminum alloy plates were then immersed in a stearic acid–ethanol solution (mass fraction of 1%) for 30 min, before being taken out from the solution and dried for 24 h in air at room temperature, superhydrophobic aluminum alloy sheets were finally obtained.

2.3. Characterization

Water contact angles were measured by an optical contact angle meter (OCA20) at room temperature. Water sliding angles were measured by tilting the sample stage slowly from 0° to higher angles until the droplet start to roll off the surface, the angle of the sample stage was recorded as the sliding angle. The morphologies of the surface were observed by a scanning electron microscope (SEM) (S-3000 N, Hitachi).

3. Results and discussion

Superhydrophobic structures were prepared on aluminum alloys through acid etching method, galvanic cell corrosion method, phosphoric acid-dichromate method and anodic oxidation method. To visually confirm the roughness of the surfaces, the morphology of the superhydrophobic surfaces were observed by SEM. As shown in Fig. 1, it can be clearly seen that the porous

Table 1
Different preparation methods of superhydrophobic surface processes.

Sample preparation method	Solution component	Concentration	Reaction time
Acid etching method	Oxalic acid	0.08 mol L^{-1}	15 h
	Hydrochloric acid	1 mol L^{-1}	
Galvanic cell corrosion method	Sodium chloride	0.5 mol L^{-1}	30 min
Phosphoric acid-dichromate method	Phosphoric acid	0.653 mol L^{-1}	
	Sodium fluoride	0.119 mol L^{-1}	10 min
	Chromic trioxide	0.1 mol L^{-1}	
Anodic oxidation method	Sulfuric acid	1.803 mol L^{-1}	
	Potassium dichromate	0.068 mol L^{-1}	30 min
	Oxalic acid	0.079 mol L^{-1}	under a current density
	Sodium chloride	0.257 mol L^{-1}	1.2 A dm^{-2}
	Glycerol	1.1 mol L^{-1}	

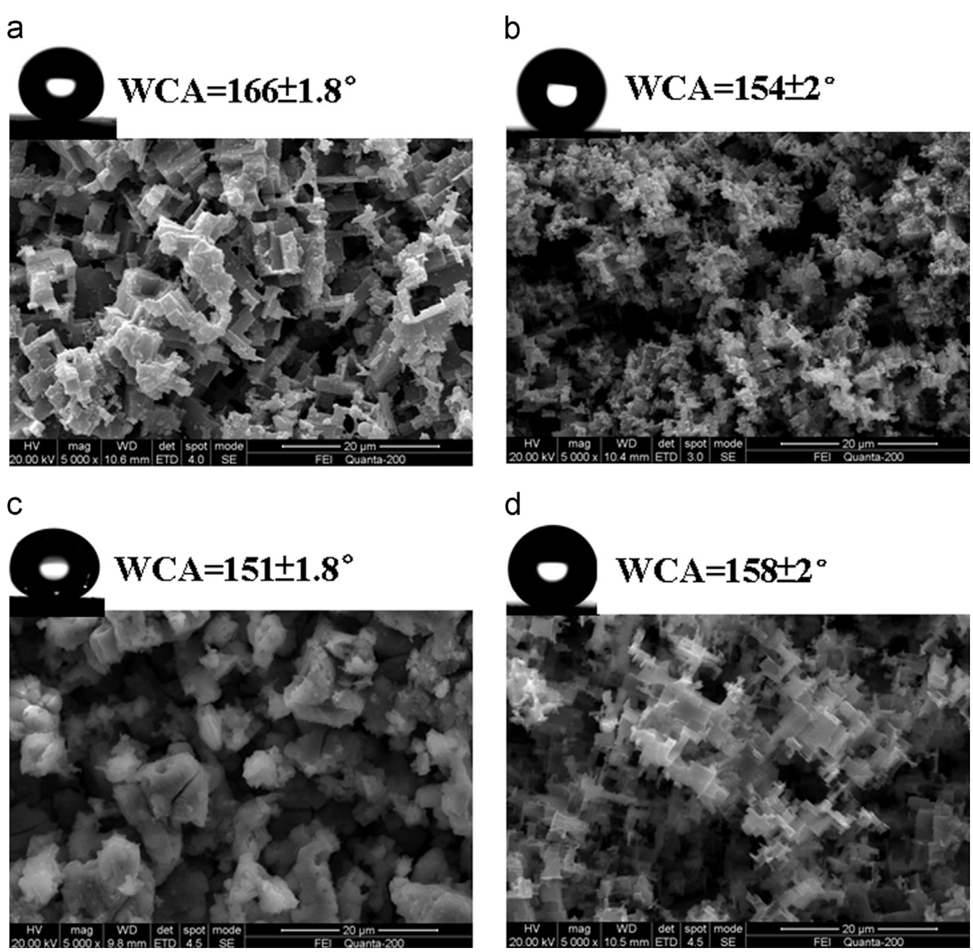

Fig. 1. Scanning electron microscopy (SEM) images of aluminum alloy surface by different fabrication methods: (a) acid etching, (b) galvanic cell corrosion, (c) phosphate-chromate, (d) anodic oxidation. (Inset in left is the WCA optical image of samples with stearic acid treatment).