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FABRICATION OF SUPER HYDROPHOBIC SURFACE ON ALUMINIUM 6061 ALLOY SUBSTRATE

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ABSTRACT

In view of developing of super hydrophobic film over substrate of Al 6061 alloy a systematic procedure is developed and proposed in this literature. The various stages of the process include ultrasonic cleaning, chemical etching, hot water treatment, solution immersion technique and heat treatment. In order to prepare the test specimens, the chemical etching and solution immersion time have been varied at five, three different levels respectively. In each category three samples are considered. The super hydrophobicity is measured in terms of Contact Angle (CA) and it is obtained upto 158^o with water. The roughness values of the substrate at various stages have been predicted and presented. In addition, the resulting surfaces exhibit excellent anticorrosion and self-cleaning properties and they were measured and reported.

Key words: Aluminium alloy 6061, Superhydrophobicity, Chemical etching, silicon coating, Water contact angle.

1. INTRODUCTION

The term hydrophobicity is measure of non-sticking property of water over surfaces. It is one of the desired properties in various engineering applications such as ship body building, aircraft structures, solar panels and automobile outer structures. Water droplets placed on a super hydrophobic surface act like soft balls with minimum contact with surface. Nature exhibits excellent super hydrophobic surfaces with a high contact angle (CA) of greater than 150^0 in certain plant leaves such as lotus leaves, rice leaves and butterfly wings, cicada wings. The term "lotus effect" is the property of repelling the water and other contaminants. The water does not adhere on lotus leaves because of multi-scale roughness (nano-micro level) and epicuticular wax (low surface energy). The hydrophilic is an antonym to hydrophobic and it means very less CA with water. When the contact angel of water or oil on a surface is almost 0°, it is called super hydrophilic or super oleophilic, respectively.

The hydrophobicity will be measured in terms of CA over the surfaces when water droplets are made to contact and it is also the measure of water repellent characteristics. As the CA value increases the surface is said to have higher hydrophobicity. If the CA is more than 150^o the surface is assumed to possess super hydrophobic property. In general, if the CA is less than 90^o the surface is said to be hydrophilic. The other desired properties usually expected along with hydrophobicity include anti-corrosion, anti-icing and self-cleaning properties.

The process of developing super hydrophobic surfaces on various substrates is carried out in two different methods. The first one is to produce rough surface on low surface energy material and reduce the surface free energy of roughened surface subsequent chemical treatment with silane or fluoro-containing polymers. Alternatively, a super hydrophobic surface can be generated via nano-structured surfaces fabricated on substrates, among different methods by chemical/ electrochemical deposition, chemical etching, anodization, self-assembly, laser surface texturing and sol-gel process followed by further surface modification with low surface energy materials. However most of the above techniques involved a tedious and multiple step procedure, which are impractical for fabrication of super hydrophobic surfaces on various substrates such as metals and non-metals for a large scale industrial application.

Aluminum alloys have been applied extensively in our daily life because of their good performance. Therefore, the fabrication of super hydrophilic and superhydrophobic surfaces on aluminum alloys is of importance. Since the natural wettability of aluminum alloys is hydrophilic, a facile method for fabricating a super hydrophilic surface on aluminum alloys is to enhance the surface roughness, while a suitable method for fabricating a super hydrophobic surface on aluminum alloys is to modify a rough surface by materials with low surface free energy. Some work has been reported on designing rough super hydrophobic surfaces on aluminum such a way of chemical etching, silica nano coating, sand blasting and anodization also produce the nano-pore structure film. After producing the rough surface it will be treated with low surface energy polymeric materials such as silane or fluoro-containing polymers etc.

Chemical etching is a simple and cost effective method to produce the micro scale roughness. Chemical Etching is unique in that the process does not change the internal structure or properties of the metal. The grain structure, hardness, and ductility of the materials are not affected. The etching can be done at various methods. The detailed methods are plasma etching, laser etching, chemical etching etc. These methods have been applied for the fabrication of the superhydrophobic surface. Micro fabrication method is also used to produce the micro scale roughness using laser machining, laser texture methods etc.

In this study, a facile and fast method for fabricating super-hydrophobic surfaces on aluminum alloy was reported. Hydrochloric acid solution was used to etch the cleaned aluminum surface and form micro-structures; through hot water treatment was adopted to generate a surface with micro/nano binary roughness.

2. LITERATURE REVIEW

Hui Wang et al. (2008) investigated super hydrophobic surfaces on aluminium substrates. Anodization process was conducted in the solution with phosphoric acid. After anodization, the specimens were put into the plasma reaction chamber to further modify the surface. The plasma treated specimens were dipped into trichlorooctadecyl-silane/hexane solution for 2 hours, and then washed thoroughly with hexane. After drying in an oven at 60 ^{0}C, the superhydrophobic films were obtained. The film surfaces were observed by FE-SEM. Contact angles on coating films were measured with a contact angle meter at room temperature.

Yanhua Wang et al. (2010) fabricated superhydrophobic film on magnesium by chemical etching method. The mg substrate was cleaned ultrasonically. The cleaned specimen was etched into acid bath. After etching, the specimen was immersed into stearic acid ethanol solution for one hour at room temperature. The superhydrophobic surface showed a static water contact angle of 154^0 with the sliding angle of about 18^0. With scanning electron microscope (SEM), energy dispersive spectroscopy (EDS) and Fourier-transform infrared (FT-IR) spectrometer, the microstructure and composition of the sample were analysed.

3. PROPOSED METHOD

3.1 Materials

Al 6061 alloy, Sodium hydroxide (NaOH), Hydrochloric acid (HCl), Stearic acid (STA) and Dimethylformamide (DMF). The other reagents acetone and ethanol were used.

3.2 Sample Preparation

The industrial grade aluminum alloy 6061 plates (30 mm×30 mm×3 mm) were first surface-polished with fine metallographic sandpaper (120#) to remove the surface oxidation layer and other impurities. The polished plates were washed with distilled water. And then they were cleaned ultrasonically with ethanol and de-ionized water bath each for 15 min, respectively. Finally the cleaned specimens were rubbed with wet acetone cloth.

3.3 Chemical etching

After that the surface cleaned plates were immersed into an aqueous solution of 2.5 mol/L sodium hydroxide and treated in an ultrasonic bath for 10 minutes. After they were fetched out, the plates were rinsed with de-ionized water and dried with air. After NaOH etching, the specimens were immersed in 20% of HCl solution for 2, 4, 6, 8 and 10 minutes respectively. Then, the aluminum plate was immediately rinsed ultrasonically with de-ionized water to remove any residual dust particles. The plates were rinsed with de-ionized water and dried with air and heated into the furnace at 70^{0}c for 20 minutes. Now the super hydrophilicity of aluminium alloy fabricated. The roughness values of the specimens were measured.

3.4Anodizing

Many method used for preparing the superhydro phobic surface are almost based on the two main method which are to create increase roughness and made low surface energy coating. The anodizing method create required roughness surface on aluminium alloy.

Anode	-	Aluminium Alloy
Cathode	-	Copper
Electrolyte	-	Sulphuric Acid
Power Source	-	Dc Power Supply

S.NO	VOLT	TIME(min)
1	5.5	45
2	10.5	55
3	12.5	65
4	15.5	75

Table:1 Anodizing process

3.5 Hot water treatment

The etched specimens were treated with hot water. The specimens were immersed into the hot water at 120 ^{0}C for 30 minutes. After that the substrate was rubbed with cotton cloth. The purpose of hot water treatment is to remove residual acids from the pores.

3.6 Immersion method

In our study, the solution immersion method was applied to adjust the microstructure to obtain an appropriate micro/nano structure and lower the surface energy. After hot water treatment, the samples were immersed in silicon, 3 hours, after being taken out from the solution, it was rinsed with distilled water and ethanol in order to remove any physical adsorbed impurities, and then dried for 24h in air at room temperature and heated into the furnace at 80^{0}c for 30 minutes, super hydrophobic aluminum alloy sheets were finally obtained.

4. RESULT AND DISCUSSION

4.1 Wettability of super-hydrophobic surface

Fig. 1 (a) and (b) shows the photographs of water droplets on untreated and etched Al6061 alloy substrate. They shows Fig. 1 (c)the water droplets on superhydrophobic treated Al6061 alloy substrate, which obviously demonstrates the change of wettability, after Al alloy substrate is coated with super-hydrophobic films. Aluminium is a type of hydrophilic material with a native oxidized layer, showing the contact angle is less than 90^0, while after super-hydrophobic treatment; the surface exhibits a high water contact angle about 158^0 with a low sliding angle.

(a)

(b)

(c)

Figure 1. Digital photographs of one water droplet on surfaces of (a) Al6061, (b) etched Al6061, (c) superhydrophobic surface with various CA.

Si No	Anodizing		Roughness Of substrate (μm)		Conduct angle (θ)
	Voltage(v)	Time(min)	Before Anodizing	After Anodizing	
1	5.5	45	0.28	1.78	142
2	10.5	55	0.29	2.47	148
3	12.5	65	0.28	2.98	151
4	15.5	75	0.27	4.78	158

4.2 Roughness

Roughness is plays on important role in wettability. Increasing the roughness of the surface and treated with low surface energy materials, the hydrophobicity was improved. The untreated aluminium specimen's roughness values are very less in the range of 0.26 to 0.29 micrometers

Table.1 Anodizing &Conduct angle

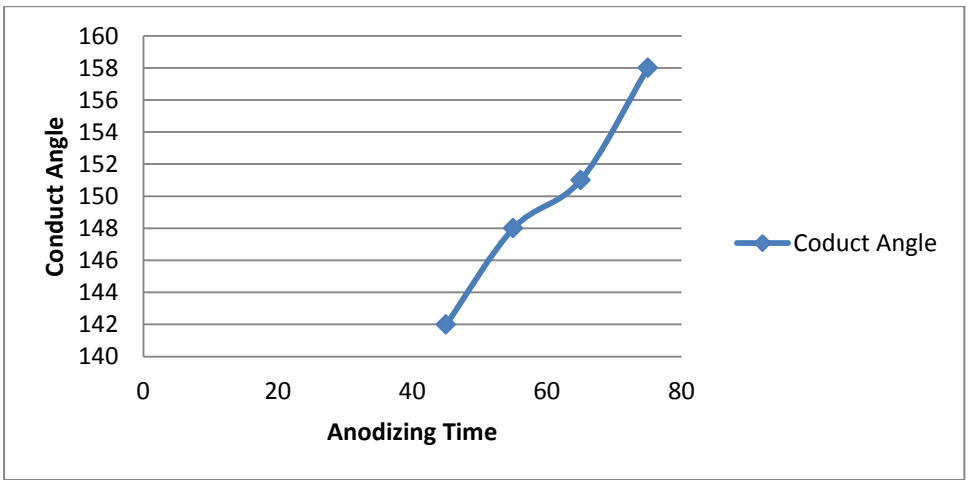

Figure 2 .Chart for anodizing Time&Conduct Angle

4.3 Self-cleaning ability

The self-cleaning ability of as-prepared super-hydrophobic surface on aluminium alloy was characterized. Similar to superhydrophobic lotus leaf, etched-immersed superhydrophobic rough surface is also able to get rid of various external contaminants and can self-clean dirt upon water droplet rolling. The superhydrophobic surface was dusted with fly ash, whose size is range from a few micros to a few hundred micros, and then super hydrophobic surface placed at a slope angle of under 30^0. Namely, when water is added drop-wise onto the superhydrophobic rough surface, the dust, ashes are easily removed from the surface by the rolling water droplets, which primarily demonstrate that as-prepared etched-immersed superhydrophobic rough surface has excellent self-cleaning ability.

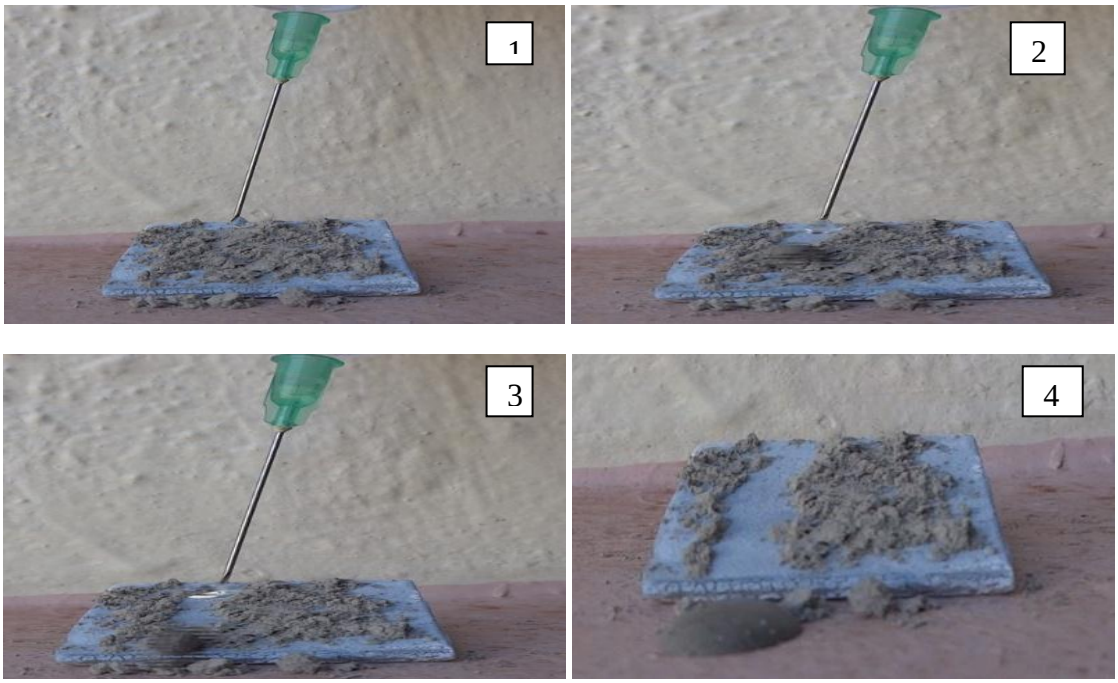

Figure 3. Self cleaning property showing dust particles cleaned at different stages

5. CONCLUSION

A super hydrophobic aluminium alloy surface is fabricated by treating in the boiling water and immersing in silicon solution. After immersion method the wet ability of the surface can be changed to super hydrophobic with Conduct Angles as high as $158^0$and a low sliding angles of <10. Meanwhile, both the etching and anodizing solution play important roles on the super hydrophobicity of the aluminium alloy, while the super hydrophobic aluminium alloy surface with water contact angle of 158^0. The present study puts forward a very simple and environment-friendly method for the fabrication of super hydrophobic surfaces.

REFERENCES

1. Hui Wang, Dan Dai, Xuedong Wu (2008) 'Fabrication of super hydrophobic surfaces on aluminum' Applied Surface Science, Vol. 254, pp. 5599–5601.

2. Yanhua Wang, Wei Wang, LianZhong, Jia Wang (2010) 'Super-hydrophobic surface on pure magnesium substrate by wet chemical Method' Applied Surface Science, Vol. 256, pp. 3837–3840.

3. Yanhua Wang, Wei Wang, Lian Zhong (2010) 'Super-hydrophobic surface on pure magnesium substrate by wet chemical method' Applied Surface Science, Vol. 256, pp. 3837–3840.

4. Long Yin, Yuanyi Wang, Jianfu Ding (2012) 'Water condensation on superhydrophobic aluminum surfaces with different low-surface-energy coatings' Applied Surface Science, Vol. 258, pp. 4063– 4068.

5. Min Ruan, Wen Li, Baoshan Wang (2012) 'Optimal conditions for the preparation of superhydrophobic surfaces on al substrates using a simple etching approach' Applied Surface Science, Vol. 258, pp. 7031– 7035.

6. Ana M. Escobar, Nuria lorca-Isern (2014) 'Superhydrophobic coating deposited directly on aluminum' Applied Surface Science, Vol. 305, pp. 774–782.

7. RuomeiWu, GuanghuaChao, HaiyunJiang (2015) 'The superhydrophobic aluminum surface prepared by different methods' Materials Letters, Vol. 142, pp. 176–179.