Wettability of Aluminum-alloys Surface with Various Surface Roughness and Thickness Coating

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ABSTRACT – Corrosion continues to be an obstacle in protecting electronic components. A coating with higher hydrophobicity is required to protect the electronic components. A surface with high roughness and thin film coating may improve the hydrophobicity of a surface. Thus, a study was conducted to explore the influence of roughness and coating thickness on the wettability of coated and uncoated Aluminum alloys. They were roughened by using silica carbide abrasive paper and coated with spray paint-polymer coating. It was found that roughness and coating thickness strongly influenced the wettability Al-alloys due to air trap and its geometrical structured (P-V, W and D).

1. INTRODUCTION

Electronic components are well known for its sensitivity to heat and humidity that can cause corrosion which affected its operability. Even minute signs of corrosion on, and in, semiconductor packaging may contribute to its failure of physical and chemical properties. Therefore, protecting electronic components from corrosive operating environments is an ongoing process. Higher hydrophobicity coatings may help counteracts corrosion by demonstrating its corrosive resistant qualities in many applications, including in the electronics industry.

The study of wettability usually quantified by the measurement of contact angle that indicates the degree of wetting when a solid and liquid interact. Contact angle that less than or equal to 90° is known as hydrophilic, while contact angle that larger than or equal to 90° is known as hydrophobic. Superhydrophobic is a special case of wetting which has larger contact angle (>>150°). Other than applying coating, the previous study has shown that the wetting behavior of liquid on a solid surface depends on the surface morphology (i.e. surface roughness) [1]. This could be explained by Wenzel and Cassie- Baxter theory that elaborate the phenomena of a water droplet on a rough surface [2].

This paper will demonstrate the influences of surface roughness and coating thickness on the hydrophobicity of coated and uncoated Al-alloys. The used of Al-alloy to present the surface because it is one of the common metals that founded in electronic components such as resistors, capacitor, and transducer of the materials.

2. METHODOLOGY

In this study, 9 samples of the Al-alloys were roughened directly with different silica carbides abrasive paper (SiC) at 180, 360 and 1200 by using Nano 2000T Grinder-Polisher. However, for grit 2000, another 3 samples of Al-alloys were grinded by using 180 grit sized sandpaper then followed with 600, 1200 and 2000 grit sizes. The polishing process was then performed by using 1µm, 3µm and 6µm DIAMAT of polycrystalline diamond until a mirror-like surface was achieved. After polishing, the samples were ultrasonicated for 10 minutes by using distilled water, acetone and isopropyl ethanol (IPA) before dried at room temperature. Two samples from each grit will be coated with two different thicknesses (one and two layers) respectively with the spray paint-polymer coating (SP) at 300mm vertically from the surface. After the samples were dried, the uncoated and coated Al-alloys were analyzed by self-fabricated contact angle tools and Profilometer Surfatest SJ-410 to measure the contact angle and surface roughness of the samples.

3. RESULTS AND DISCUSSION

The influence of roughness on the wetting properties has been evaluated by using contact angle measurement. Figure 1 shows the contact angle that measured after 2s dropped for each surface. Lowest contact angle but good wetting properties can be observed for the uncoated Al-alloys surface (AL/UC) with the contact angle of 86˚ ~ 63˚. Al-alloys coated with one-layer of spray paint-polymer coating (Al-1L/SP) shows the worst wettability with an average contact angle of 81˚~ 95˚ compared to two-layer of spray paint-polymer coating (AL-2L/SP) with a contact angle of 78˚-94˚.The phenomenon of contact angle can be explained through Wenzel and Cassie-Baxter model. Wenzel Model can be expressed as in Equation (1);

$$\cos\theta_w = R_f \cos\theta_o \qquad (1)$$

where θ_w is the contact angle on the rough surface, θ_o is the contact angle on the smooth surface and R_f is roughness factor. Based on Equation (1), the surface roughness can amplify the contact angle on the hydrophobic surface but reduce on the hydrophilic surface [2]. While Cassie-Baxter model describes the relation of contact angle and surface roughness with air trap and the model can be expressed as Equation (2);

$$\cos\theta_w = R_f\cos\theta_o - f_{LA}(R_f\cos\theta_o + 1) \quad (2)$$

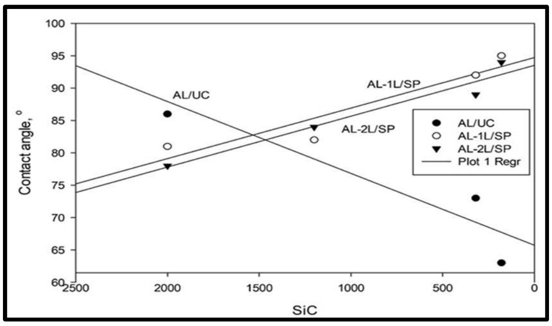
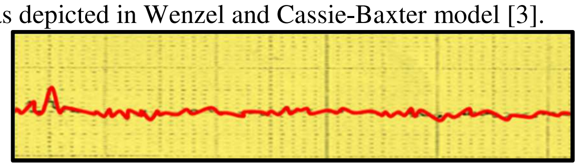
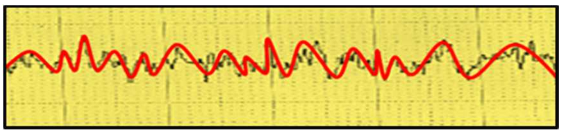


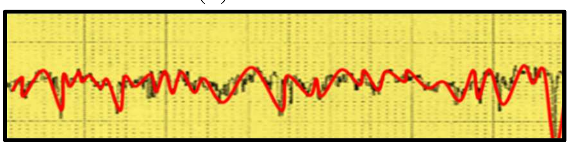
Figure 1 Contact angle at different SiC roughness

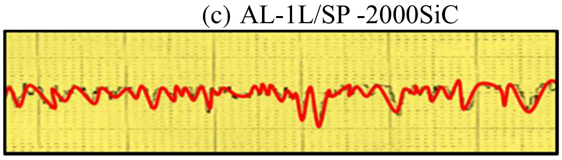
Where f_{LA} is the fractional flat geometrical area of the liquid-air interfaces under the droplet (air trap). The Cassie-Baxter model shows that the increase of f_{LA} between the rough surface will decrease the geometry areas of solid-liquid interfaces (f_{SL}) thus increase the θ_w of the surface [2]. Based on the results obtained, the contact angle of AL/UC shows compatibility with both models, while AL-1L/SP and AL-2L/SP were only compatible with the Cassie-Baxter model and not with the Wenzel model.

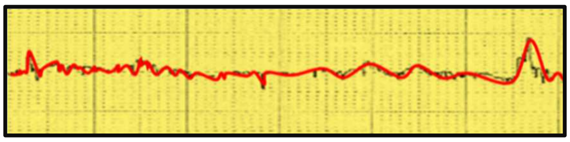
To understand the present occurrence, the geometrical structure of roughness on AL/UC, AL-1L/SP, and AL-2L/SP were display in 2D line scanning profile from 1200SiC to 180SiC after roughening as shown in Figure 2. The influenced of geometrical structure of roughness on contact angle could be explained in term of peak and valley (P-V) height, distance between peak to peak (D) and average roughness width (W) that change from smooth (1200SiC) to rough (180SiC) surfaces. From the 2D profile of AL/UC, the increase of P-V causes the roughness of the surface to increase however the increase of D and W caused the contact angle to decrease due to less air trap between the surface thus allowing the liquid to penetrate easily between the P-V as depicted in Wenzel and Cassie-Baxter model [3].


(a) AL/UC-2000SiC


(b) AL/UC-180SiC


(c) AL-1L/SP -2000SiC


(d) AL-2L/SP-180SiC


(e) AL-2L/SP -2000SiC

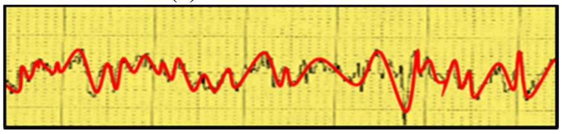

(f) AL-2L/SP-180SiC

Figure 2 2D line scanning periodic profile for (a)(b) AL/UC (c)(d) AL-1L/SP (e)(f) AL-2L/SP at 2000SiC and 180SiC

Meanwhile, Figure 2(c-e) reveals the geometrical structure of AL-1L/SP and AL-2L/SP surface from 1200SiC to 180SiC. The AL-1L/SP surface displays in Figure 2(c-d) shows decreasing in P-V, D, and W that increases the air trap between roughness but decrease the f_{SL} hence increase the contact angle. However, the increased of P-V with decrease of D and W of AL-2L/SP surface as shown in Figure 2(e-f) cause the f_{SL} to decrease but still higher than AL-1L/SP hence the contact angle increases but lower than AL-1L/SP. These results also indicate that the thicker the coating may reduce the hydrophobicity of surface due to the changes of its roughness and air trap as describe in Wenzel and Cassie-Baxter model [3].

4.0 CONCLUSIONS

From the presented investigations, the following conclusion can be concluded coating and thickness of coating influenced the hydrophobicity. Decrease the thickness, increase the contact angle. Besides, roughness also has a strong influence on the wettability of tested materials due to geometrical structured (P-V, W and D) and air trap which affects the water droplet on the surface. Increase the roughness, increase the contact angle. Thus, increase the roughness and apply thin coating may help to improve the hydrophobicity performance of surface to create a higher hydrophobicity coating for corrosive resistance especially in the electronic field.

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