



## EFFECT OF LOW POTENTIAL ANODIZING OF AA 6061

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### ABSTRACT

The use of titanium as a cathode in the anodizing process AA 6061 proved to increase the mechanical strength and corrosion resistance. The surface morphology is tested by using scanning electron microscopy (SEM) and then the surface composition is tested by using Energy Dispersive X-ray (EDX). Hardness is tested using microvickers hardness tester the results showed that the increase in hardness after anodizing, while the porosity decreases with the increase of potential.

**Keywords:** aluminum alloy, anodicoxidation, hardness.

### INTRODUCTION

Aluminium and its alloys have been widely known to induce a diversity of functions, both at the household up to the construction industry (Bouchama, *et al*, 2013). Although this material has a fairly broad application compared to other metals, however the corrosion resistance can be improved because the natural protective layer on aluminum will not be stable when exposed to areas with fairly extreme acidity. There have been many ways used to increase the corrosion resistance on aluminum, either with passive coating (Turnbull, 1983), the polymer coating (Lin and Greene, 1992) as well as by anodizing (Mansfeld, *et al*, 1989). In general, the whole process is carried out to obtain a thicker film layer to improve the physical, mechanical, and chemical properties of aluminum (Gabe and Dowty, 1987).

Aluminum anodizing is an electrochemical process that converts the aluminum oxide layer by applying an external current in an electrolyte solution. This method has been widely capable of improving the corrosion resistance and abrasion (Zubillaga, *et al*, 2008). An electrolyte, which is generally used in the anodizing process, is an acid, such as sulfuric acid (Li, *et al.*, 2008), oxalic acid (Jessensky, *et al*, 1998) as well as phosphoric acid (Guo and An, 2005). In general, the morphology of the film layer formed characterized as hexagonal columns cells with a barrier layer on the base layer of the film, which has contributed to the corrosion resistance performance (Saedikhani, *et al.*, 2013).

In this paper, we study the mechanical properties, especially hardness and corrosion performance of the anodic film layer formed on phosphoric acid with anodizing process using titanium cathode. Surface morphology was examined using scanning electron microscopy (SEM) and the composition formed on the surface and on the porous was tested using Energy Dispersive X-ray (EDX). Hardness was obtained by microhardness testing.

### METHOD

The experiment was performed with AA6061 with the following composition (wt %): Mg 1.01%, Si0.88%, Fe 0.2%, Cu 0.21 %, Zn0.08%, Ti 0.08%, Mn1.01%, Cr 0.05%, Al balance. The specimen was manufactured using

this following pretreatment steps. Titanium was used as the counter cathode with a composition (% Wt) 2.6% P, 2.43% Ca, 0.54% Fe, 92.2% Ti, 0.29% Ni, 0.14% Zn, 0.90% Tm.

The pretreatment process included smoothing the entire sample by rubbing with the grit paper and then rinsing with distilled water. The process of pretreatment included degreasing in sulphuric acid at 55 °C for 10 min, alkaline cleaning by using sodium hydroxide at 60 °C for 10 min, followed by desmutting at nitrit acid at 25 °C for 5 min. Next, the sample was anodized using a titanium cathode.

Following aluminum pretreatment, the sample was connected to the anode power supply and then immersed in an electrolysis bath containing the electrolyte solution in the form of 1 M phosphoric acid mixture with pure water at a temperature maintained between 0 and 5°C. On the cathode side, the power supply was connected to a titanium plate with a distance of 5 cm. 15-30 V power supply was used to supply the potential. After the power supply was turned on, the processing time was 60 minutes. Hardness testing was done using Time Micro Vickers Hardness Tester (China) with a given load is 1kgfata time indents for 15 seconds. Hardness number were taken three times on the surface with a random sampling location in the surface of the specimen. Analysis of surface morphology was done using Phenom Scanning Electron Microscopy (SEM) and chemical composition analysis was performed using Energy Dispersive X-ray (EDX).

### RESULTS AND DISCUSSIONS

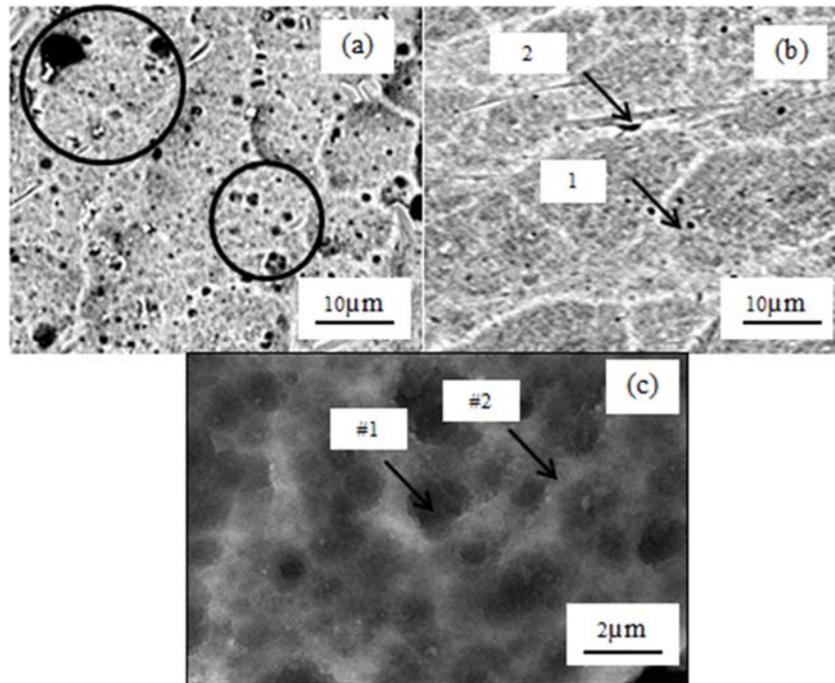
The surface morphology as shown in Figure-1 (a) presents a cross section specimen surface without anodizing and 1 (b) after anodizing process. It can be seen that both specimen surface morphology has much in common in the appearance of several micro-sized pores, basins and microfractures. On the other hand, it indicates that the specimens which are not undergoing anodizing process appear to have similar pore formed in size, ranging from 3.98 to 9.76 µm and do not spread evenly, but at some level, they appear with different sizes concentrated pores (marked with circles 1 and 2). There are also many pores connected to the specimens that do not undergo the process of anodizing compared with the



ones after anodizing process. While in the specimens that have undergone the process, it can be seen also that the size of the pores formed has relatively similar in size from 1.09 to 3.87  $\mu\text{m}$  and are dispersed relatively and evenly on the surface of the specimens (marked with arrows No. 1). The literature states that the pore formed by the oxide melts and the gas bubbles coming out (Saeedikhani, *et al.*, 2013). Whereas microcracks (marked with arrows No. 2) rise due to thermal potential during the procedure of rapid solidification of oxide boiled in a cold electrolyte solution.

Research that has been done previously (Wheeler, *et al.*, 2012) states that the reaction rate is influenced by potential. When the potential increases, the thickness of the barrier layer will also increase, resulting an increase in the distance between the pores. As shown in Figure-1 (b), it shows a decrease in porosity along with the increased potential.

Moreover, the zone formed as shown in Figure-1(c) was analyzed by using EDX to determine the composition of the region, as tabulated in Table-1.



**Figure-1.** The surface morphology (a) a substrate (b) anodized (c) the sampling point of EDX on the specimen surface after anodized.

**Table-1.** The chemical composition of figure 1(c) using EDX (% Wt).

Point	C	O	P	Mg	Al	Ti
1	16.35	27.63	01.49	01.02	53.38	00.13
2	11.94	19.02	02.01	01.00	65.67	00.35

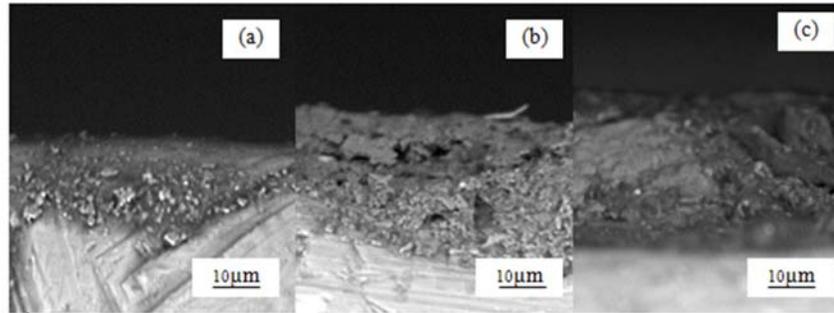
From Table-3 it can be seen that the titanium detected in the pore (# 1) and the surface (# 2) specimen after anodized. These results in dictate that titanium coating to migrate through the electrolyte films. Setyarini *et al.* (2015) explained that titanium also penetrate into the substrate. During the process of anodizing, titanium actively decays and will stick to the blend immediately in conjunction with the thickening layer of the film (LI, *et al.*, 2008) as shown in Figure-2. Figure-2 (a) shows the  $\text{Al}_2\text{O}_3$  layer that forms naturally on the surface of the aluminum substrate. It formed relatively thin layer with a thickness ranging from 1.48  $\mu\text{m}$ . Meanwhile, after the anodizing process with a potential of 15V, coating thickness increased to approximately 4.93  $\mu\text{m}$  as shown in Figure-

2(b). Increased thickness turned out to be coupled with increased porosity in the coating formed. Porosity was reduced in the coating as shown in Figure-(c) which is the result of an odizing at a potential of 25V. The thickness of the coating also increased about approximately four times when compared to the substrate be 8.64  $\mu\text{m}$ .

It was generally known that the porosity depends on the magnitude of a given potential. The higher the potential applied, the porosity that is formed will be smaller. Jessensky *et al.* (1998) explained that during the anodizing process, the aluminium has reacted with oxygen and formed  $\text{Al}_2\text{O}_3$  oxide that cause volume expansion which forms at the interface potential in the aluminum/oxide (Wang and Xia, 2013). The potential increase would



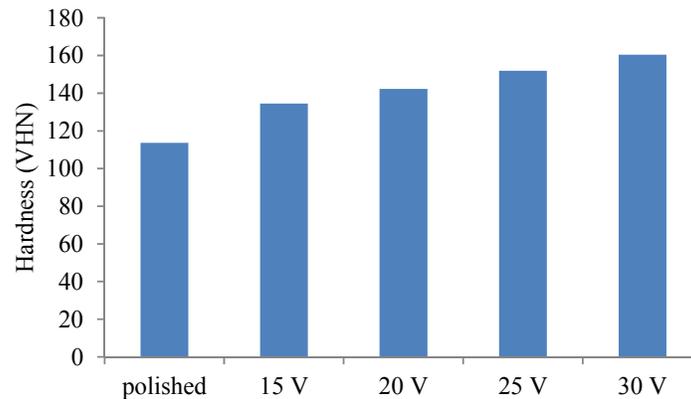
increase the surface tension so that the thickness of the barrier layer increases and reduces the porosity.



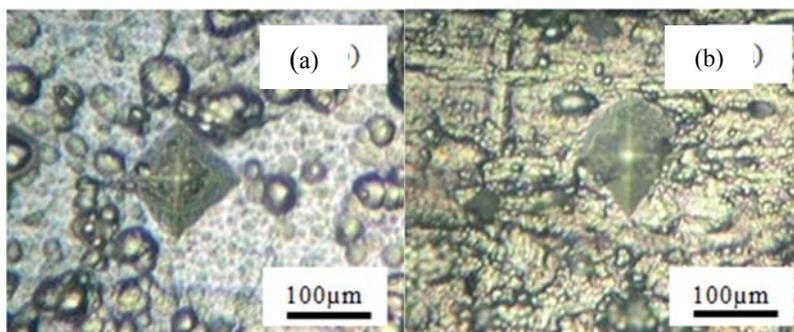
**Figure-2.** Film of  $\text{Al}_2\text{O}_3$  (a) Substrate (b) anodizing 15 V (c) anodizing 25 V.

We also examined the relationship between porosity and hardness as shown in Figure-3, wherein Vicker hardness testing method is the method used for testing the surface coating. Hardness testing is generally used loading 1kg for higher (Guo and An, 2005). Figure-2 shows the hardness of the substrate 6061 and 6061 after anodized with different potentials. It can be seen that the substrate hardness, increased by 14% after anodizing process. Increasing the value of hardness can

occur because of the influence of pore size and porosity were obtained in the anodizing process, in which aluminium reacts with oxygen to form aluminium oxide, which causes the amount of oxides will increase causing internal stress on the interface of the aluminum/oxide. The porosity also leads to differences in results when loading given in the indentation hardness testing, as shown in Figure-4. In Figure-4(a) it appears that the indentation traces much deeper than in Figure-4(b).



**Figure-3.** Microhardness of 6061 substrate and after anodizing with different potential.



**Figure-4.** Indentation of (a) substrate (b) after anodized 30V.

**CONCLUSIONS**

This study examined the relationship stress, porosity, hardness and corrosion resistance of the anodizing process AA6061 in an electrolyte solution of  $1\text{M H}_3\text{PO}_4$  using titanium cathode. By using this process it will form an oxide layer consisting of Al and Ti in line with the increase in the potential of 15V-30V. Retrieved decrease pore size and increased thickness by 60% when compared with specimens that are not anodized. Meanwhile hardness also increased in the range of 20VHN higher than the substrate. It can be said that potentially affect the anodizing process.

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