Evaluation of the Corrosion Resistance of Anodized Aluminum Samples Using Electrochemical Impedance Spectroscopy (EIS)

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I. Introduction

The purpose of this study is to evaluate the corrosion resistance of anodized layers produced by new anodizing and sealing process using electrochemical impedance spectroscopy (EIS). The scanning electron microscope (SEM) was employed to determine the surface structure and the thickness of the anodized layers. The impedance spectra were analyzed using an appropriate equivalent circuit (EC). There was very little change in the impedance for all test samples during exposure period. The results of these tests suggest that anodized Al 6061 treated in the new processes was very corrosion resistant during extended exposure time periods.

![Anodized Aluminum Interface Model](image)

Anodized aluminum interface model

- $C_{\text{po}}$: Capacitance of the outer porous layer
- $C_{\text{b}}$: Capacitance of the inner barrier layer
- $Z_{\text{po}}$: Polarization resistance of the barrier layer
- $R_{\text{po}}$: Pore resistance
- $R_s$: Constant phase element (CPE) to account for the variations of properties of the pores

![Cross Section of the Anodized Layer](image)

II. Experimental Methods and Results

Impedance spectra were collected at the open-circuit potential (OCP) in a three-electrode cell. A stainless steel electrode was used as the counter electrode and a SCE as the reference electrode. The impedance spectra were obtained with a BSA-Zahner IM6 unit using a frequency range between 1 MHz to 1 mHz with an ac amplitude of 10 mV. The EIS data were analyzed using the ANODAL software of ANALEIS. The spectra for all test panels for a given treatment were almost identical and did not change much with exposure time (Fig. 1-3). The almost identical capacitance values at the highest and lowest frequencies suggest that the thickness of the outer porous layer and the inner barrier layer, respectively, are almost the same for the all tested samples. The SEM pictures revealed that the coating thickness was about 63 μm (Fig. 4). The capacitance of the porous layer $C_{\text{po}}$ for the all test samples was very stable during the entire exposure period (Fig. 5 and 6). The pore resistance $R_{\text{po}}$ had very high values for all test samples (Fig. 7 and 8). These results indicate that the anodizing process was very reproducible and that the sealing process was very effective.

![Bode Plots](image)

EIS Results

- Fig. 1. Bode-plots for the R&D tank mixed acid sample for an exposure period of 14 days
- Fig. 2. Bode-plots for the type III sample for an exposure period of 14 days
- Fig. 3. Bode-plots for the production tank sample for an exposure period of 365 days

III. Conclusions

- The impedance spectra for the samples that were anodized in the R&D tank mixed acid were very stable during 14 days exposure.
- The impedance spectra for the type III samples suggest that oxide layers are more complex than those for the other samples. The impedance spectra did not change significantly during the 14 days exposure time which suggests that these anodized surfaces were very corrosion resistant.
- The impedance spectra for the production tank samples were very stable for an exposure time of 365 days showing that these surfaces had very high corrosion resistance.
- The very high and stable values of the pore resistance $R_{\text{po}}$ for all three processes indicate that the newly developed anodizing and sealing processes were very effective.

![Time Dependence of $C_{\text{po}}$](image)

Fig. 5. Time dependence of $C_{\text{po}}$ for R&D tank mixed acid and type III samples

![Time Dependence of $R_{\text{po}}$](image)

Fig. 6. Time dependence of $R_{\text{po}}$ for production tank samples

![Time Dependence of $R_{\text{po}}$](image)

Fig. 7. Time dependence of $R_{\text{po}}$ for R&D tank mixed acid and type III samples

![Time Dependence of $R_{\text{po}}$](image)

Fig. 8. Time dependence of $R_{\text{po}}$ for production tank samples

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References

4. Dr. Hong Shih presentation.