

## A Study of the Electrodeposition of Sol-Gel Coatings on Al 2024-T3

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### Introduction

Aluminum alloys are commonly used in the aerospace industry because of their mechanical properties. Unfortunately, aluminum alloys are susceptible to corrosion. In the past, chromate conversion coatings have been used to passivate alloys. Chromates are being phased out because of negative affects on health. The research to find replacements for chromate conversion coatings has been considerable in recent times. In this work, the electrodeposition of sol-gel coatings on aluminum 2024-T3 was investigated.

The electrodeposition of sol-gel coatings has been shown to be a promising technique for the corrosion protection of aluminum.[1] Electrodeposition of sol-gel coatings occurs in two steps.[2] A metal-alkoxide is added to an acidic solution where it undergoes hydrolysis to form a 'sol', but does not condensate into a thick coating. Then, a cathodic potential is applied to an electrode creating a region of high pH at the electrode surface. This high pH catalyzes condensation reactions at the surface forming a coating.

Al 2024-T3 is known to undergo localized corrosion at copper enriched particles. A coating must prevent attack at these particles to be effective. Recently, it was shown that the majority of redox activity on the surface of Al 2024 occurs through these particles.[3] This makes electrodeposition an especially attractive method, since the coating will, in theory, preferentially deposit on the particles because of their high redox activity.

### Experimental

Alkoxy silanes were added to a 0.5 M  $\text{KNO}_3$  solution with a pH of 4 to facilitate hydrolysis. The coating was deposited by applying a -1.2 V (vs. SCE) potential to an Al 2024-T3 sample. The coating progress was monitored by measuring the change in current during the coating procedure and periodically performing electrochemical impedance spectroscopy (EIS). The coatings were cured after the electrodeposition and characterized using vibrational spectroscopy, x-ray photoelectron spectroscopy, scanning electron microscopy and electrochemical methods.

### Results and Discussion

In order to investigate the coating mechanism, samples were subjected to the procedure without the alkoxy silane for the purpose of comparison. When an Al 2024-T3 sample is polarized -1.2 V (vs. SCE) in a 0.5 M  $\text{KNO}_3$  solution (without alkoxy silanes), the current increases over time (see Figure 1). The electrolyte solution becomes cloudy, suggesting that aluminum is being dissolved from the electrode. The polarization, at these potentials, is expected produce a basic region at the electrode surface that could dissolve the aluminum surface. The current measured on a sample when the alkoxy silane is in solution does not vary as much as the previous case. When the silane is included in the solution, the solution does not become cloudy. The aluminum that would otherwise be suspended in the solution is either incorporated in the coating or does not dissolve.

SEM images show that the coating is deposited in two forms, rod like structures and smooth coatings. It is apparent from the images, that the coating does not have a constant thickness over the surface.

During the formation of the coating, EIS initially indicates a decrease in polarization resistance followed by a slow increase with time. The Bode plot of impedance and frequency is shown in Figure 2. The low frequency impedance increases greatly after the coating is cured. This indicates increased corrosion resistance of the coating.

### Acknowledgements

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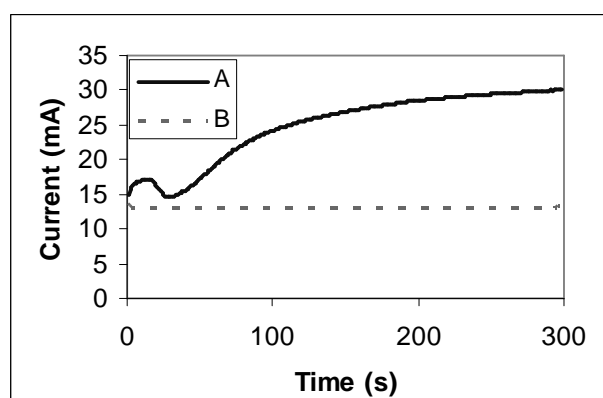


Figure 1. Current behavior of Al 2024-T3 at -1.2 V vs. SCE in A) 0.5 M  $\text{KNO}_3$  pH = 4, and B) 0.5 M  $\text{KNO}_3$  pH = 4 with alkoxy silane.

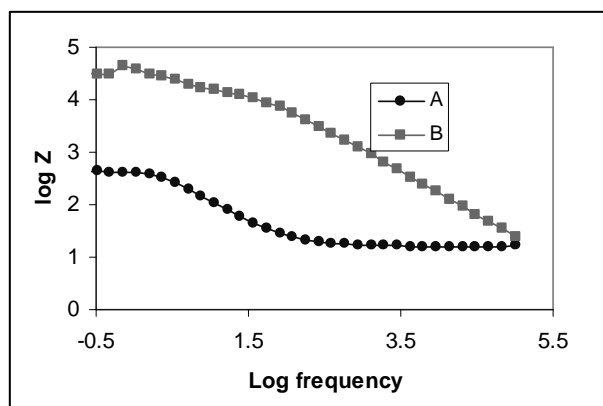


Figure 2. Bode plot of log impedance for A) non-cured coating and B) cured coating.

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