

## Investigation on the effect of a bis-1,2-(triethoxysilyl) ethane film on the corrosion protection of AA2198-T8 aluminum-lithium alloy

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### *Abstract*

Aluminum-lithium alloys are highly susceptible to localized corrosion, mainly to a type known as severe localized corrosion of peculiar characteristics, such as, hydrogen evolution and fast penetration through its thickness related to the alloy microstructure. These type of alloys requires corrosion protection for their application. In this work, a surface coating composed of BTSE (bis-1,2-(triethoxysilyl) ethane) was applied on AA2198-T8 samples and its effect on corrosion resistance was investigated and compared with that of chromate layer formed in solution with hexavalent chromium ions. The corrosion resistance of BTSE coated samples was evaluated by immersion tests in sodium chloride solution (0.001 mol/L NaCl) and monitored by electrochemical impedance spectroscopy (EIS). The results were compared with that of the uncoated alloy and showed the BTSE coating led to a surface with corrosion resistance similar to that of the same alloy coated with a chromate conversion layer.

**Keywords:** Corrosion, Coating, Silane, AA2198-T8, BTSE.

### **Introduction**

The promising future of aluminum alloys are correlated to weight reduction and increase of elasticity modulus due to lithium addition (1). Al-Cu-Li alloys were developed with the aim of weight reduction to replace the conventional Al-Cu alloys largely used in the aircraft industry. However, high susceptibility to localized corrosion has been associated to T1 phase (Al<sub>2</sub>CuLi) in Al-Cu-Li alloys, which is preferably located in regions of high dislocation density, due to intense deformation according to preferential orientation (1),(2). The preferential location of this phase in some areas lead to severe localized corrosion whose mechanism was presented by Ma et al (2). According to these authors, the T1 phase is initially anodic relatively to the matrix, but due to lithium high reactivity resulting in its selective dissolution from T1 phase, copper enrichment and polarity reversal relatively to the matrix. (3)

In case of heterogeneous polycrystalline materials, anisotropy can result in different susceptibilities to corrosion, according to preferential orientation of grains. Severe localized corrosion proceeds into the material and can lead to an early failure (1), (2) and (3). Surface treatments based on hexavalent chromium were used for many decades and these are highly effective for corrosion protection of aluminum alloys, besides promoting good adherence to organic coatings, and their self-healing properties (4). However, in the last years the search for environmentally friendly surface treatments has been encouraged. (5) Silane films have

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been considered potential replacements for chromate coatings in the protection of aluminum alloys with the advantage of being friendly to environment (6), (7). The aim of this study is to investigate the effect of a silane based treatment for the corrosion protection of the AA2198-T8 under two conditions, polished or unpolished surfaces, and compare the results with that of similar surfaces with chromate conversion coating.

## Methodology

The AA2198-T8 alloy whose chemical composition is presented in Table 1 was used in this study. Some of the investigated samples from this alloy were polished with diamond paste until a finishing corresponding to 1  $\mu\text{m}$  whereas others were used as received (unpolished). All samples were degreased with ethanol and dried in air stream before use. The treatment named BTSE was carried out by immersion for 3 minutes in a solution with bis-1,2-(triethoxysilyl) ethane and then oven-dried at 100 °C for 30 minutes. Polished and unpolished samples were also coated with a chromate layer for comparison reasons. Immersion tests were carried out with coated and uncoated samples, either polished or unpolished, by exposure to  $10^{-3}$  mol/L NaCl solution for 24h.

**Table 1 - Nominal composition ( wt.%) of the AA2198-T8 used in this study.**

Cu	Li	Mg	Ag	Zr	Fe	Si	Zn	Mn	Al
2.9-3.5	0.8-1.1	0.25-0.80	0.10-0.50	0.04-0.18	0.10 max.	0.08 max.	0.35 max.	0.50 max.	Bal.

Source: Aluminium Association, 2015.

## Results and discussion

The samples surface before and after 24 h of test are shown in Figures 1 and 2, for polished and unpolished surfaces, respectively. The results show that both types of coatings protected the AA2198-T8 alloy surface against corrosion, either in polished (Figure 1) or unpolished (Figure 2) condition prior to surface coating. Comparison of the two types of coating tested show a more preserved silane coated surface than the chromate coating in the case of unpolished surface (as received). Figure 3 shows severe localized corrosion in the uncoated and polished surface whereas the untreated and unpolished surface shows a surface with larger areas affected by corrosion but with more superficial penetration compared with the polished ones.

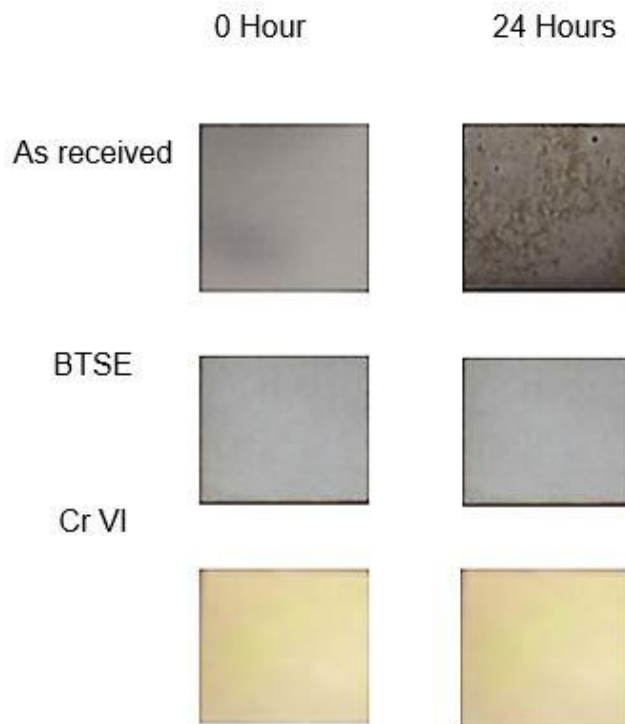


Figure 1 – Surface of polished AA2198-T8, either uncoated (as received) or coated with either BTSE or chromate, before and after 24 h immersion in  $10^{-3}$  mol L<sup>-1</sup> de NaCl.

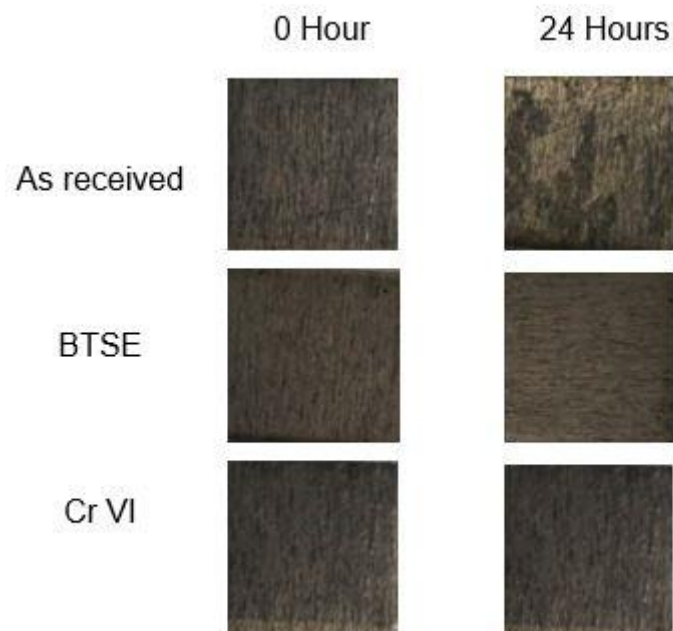
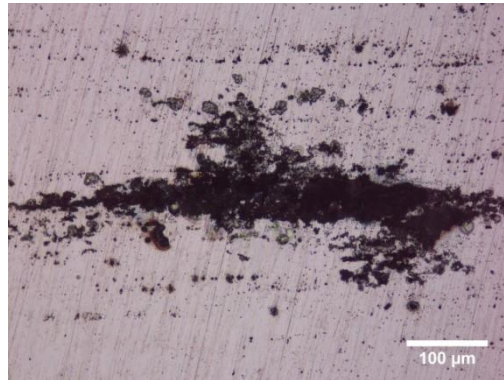


Figure 2 – Surface of unpolished AA2198-T8, either uncoated (as received) or coated with either BTSE or chromate, before and after 24 h immersion in  $10^{-3}$  mol L<sup>-1</sup> de NaCl.



**Figure 3 – Severe localized corrosion in the AA2198-T8 alloy after 24h immersion in 1 mM NaCl.**



**Figure 4 – Corrosion in the unpolished AA2198-T8 alloy after 24h immersion in 1 mM NaCl.**

EIS results compared the effects of both tested coatings, chromate and BTSE, on the corrosion resistance of the AA2198-T8 in  $0.1 \text{ mol L}^{-1}$  NaCl solution, Figure 5. It is important to notice that the stability of the BTSE coated interface was higher than that of the chromate coated samples. For this last type of samples, there was a decrease in impedance between 24h and 168h. Also higher impedances were associated to BTSE coated samples. Besides, the low frequency data indicated diffusion controlled processes associated to the BTSE coating while for the chromate coating the data at low frequencies indicate a charge transfer control. These results show that the mechanisms related to corrosion processes for both surface coatings were different.

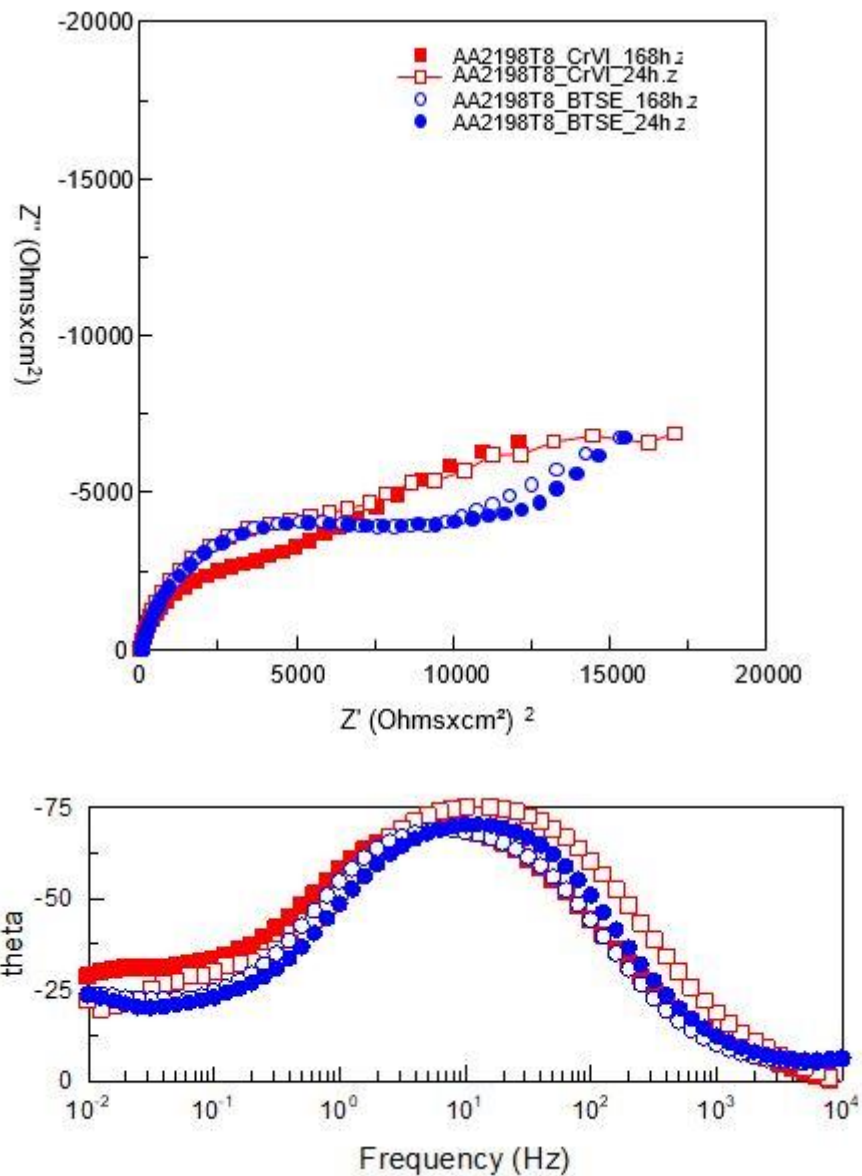


Fig 5 – Nyquist and Bode diagrams of AA2198-T8 alloy coated either with chromate (CrVI) or BTSE after 24h and 168h immersion in 0.1 M NaCl solution.

## Conclusions

The corrosion resistance of the BTSE coated samples of AA2198 T8 aluminum alloy, either polished and unpolished, was evaluated in this work. The results showed the silane coating used presented corrosion protection to the aluminum alloy slightly superior to that provided by a chromate layer formed in hexavalent chromium ions containing solution. The stability of the silane coated surface was also higher than that of the chromate coating. Results pointed out that the silane tested could be an alternative for replacing chromating treatments for aluminum alloys.

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