Effect of Precipitation on the Electrochemical Behavior of Model Aluminum Alloys

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During production of aluminium sheet, the surface of the material is subjected to high shear strains leading to submicron grain sizes and a high dislocation density. Filiform corrosion behaviour of automobile aluminium alloys is predominently controlled by the presence of this surface deformed layer and the precipitation of fine intermetallic phases of impurity elements (eg. Fe, Si and Mn) at the surface during subsequent heat treatment. The effect is a consequence both of enhanced precipitation of intermetallic particles and depletion of noble alloying elements, particularly Mn, from the matrix. The intermetallic particles are cathodically active and are also pit initiation sites, and solute depletion enhances the anodic reactivity of the matrix.

This investigation is focussed on the electrochemical investigation of aluminium model alloys containing Fe, Si and Mn to understand the effect of intermetallic particles and changes in solid solution composition. The studies were carried out in de-aerated 5% NaCl at pH 3.0 and 11.5. Materials were solution heat treated (SHT) and annealed to generate microstructures with varying solid solution compositions and intermetallic particles. The effect of solid solution Mn content on the electrochemical behaviour was also investigated on a low silicon model alloy (Al-0.4Fe-0.05Si-1.0Mn) by isothermal annealing to different lengths of time. The solid solution composition of the alloys was determined using thermo-electric power measurements.

In general, annealed alloys containing Mn exhibited lower anodic activity and higher breakdown potentials (Figure 1) compared with alloys containing Si and Fe. The alloys showed different cathodic reactivity (Figure 2) owing to the presence of different intermetallic particles. The alloys containing Al_3Fe (Al-0.4Fe), AlFeSi (Al-0.4Fe-0.3Si), and $Al_{12}Si(Fe,Mn)$ (Al-0.4Fe-0.3Si-1.0Mn) particles showed higher activity than the one containing $Al_6(Fe,Mn)$ (Al-0.4Fe-0.05Si-1.0Mn). However in alkaline solution, alloys with silicon-containing particles exhibited lower cathodic reactivity.

Prolonged heat treatment of Al-0.4Fe-0.05Si-1.0Mn up to 48h significantly reduced the solid solution content of Mn. The lower Mn content in solid solution substantially reduced the open circuit corrosion potential and increased the anodic reactivity as shown in Figure 3.

Anodically polarized specimens showed crystallographic pitting in both pH 3.0 and pH 11.5 chloride solutions, indicative of acidic pitting above the breakdown potential while cathodically polarized specimens revealed alkaline grooving around intermetallic particles. The extent of grooving around the particles correlated with cathodic reactivity found with the polarization experiment.

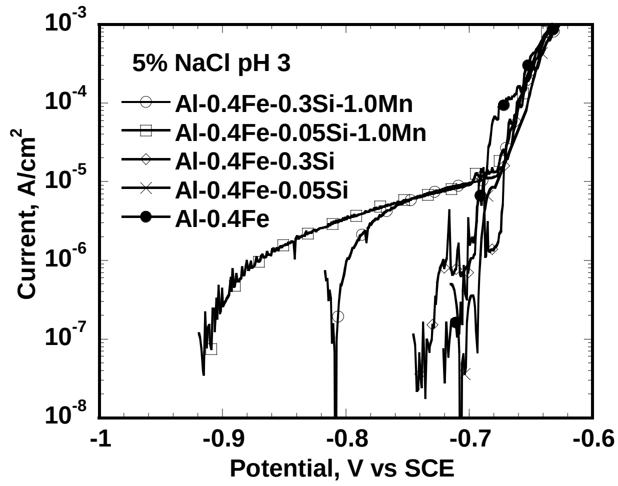

Figure 1. Anodic polarization curves for different alloys.

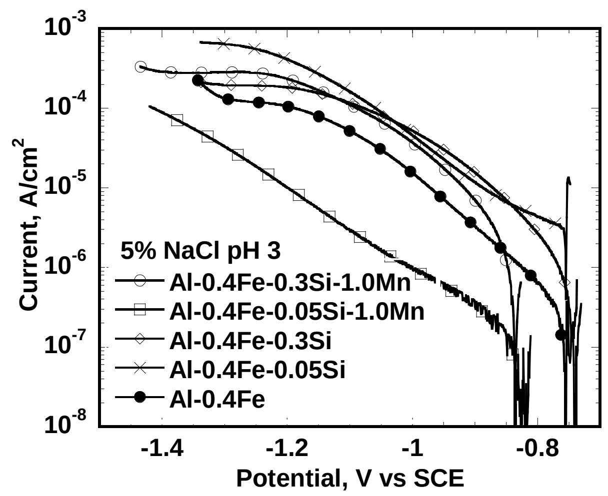

Figure 2. Cathodic polarization curves for different alloys

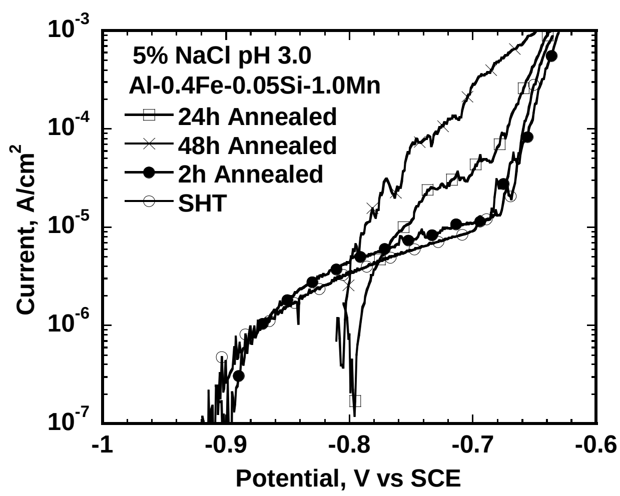

Figure 3. Anodic polarization curves for Al-0.4Fe-0.05Si-1.0Mn alloy annealed to different times.

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