

Corrosion behavior of copper-rich model alloys

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In aluminum alloys, coarse intermetallic particles can lead to localized corrosion because of galvanic coupling between the matrix, the particles and the bordering zones. The intermetallics reactivity might be explained by a difference in the properties of the passive films grown on these metallurgical phases by comparison to the passive film grown on the aluminum matrix. So, to understand the corrosion behavior of copper-rich alloys, the corrosion behavior of model alloys representative of the intermetallics was studied and the passive films grown on these materials analyzed.

Model alloys of the metallurgical phases characteristic of copper-rich aluminum alloys (i.e. copper-rich intermetallic particles and aluminum matrix) were prepared using physical vapor deposition. They consisted in thin films, of about 150 to 400 nm for the thickness, developed on an aluminum substrate. Their compositions were Al-4%at Cu, Al-35%at Cu-10%at Fe and Al-55%at Cu-10%at Mg.

The model alloys as received and after polarization were observed by TEM [Fig 1 and Fig 2] and chemically analyzed [Fig 3]. Their corrosion behavior was investigated by plotting polarization curves in a 0.1 M Na₂SO₄ solution and compared to that of 2024 aluminum alloy. The corrosion treatment for passive film growth consisted in an 1hr polarization at 1V/SCE in a 0.1 M Na₂SO₄ solution.

Figure 4 shows that the corrosion behavior of 2024 alloy in the cathodic range is significantly influenced by the presence of intermetallic particles that promote oxygen reduction. In the anodic range, 2024 alloy behavior was similar to that of Al-4%at Cu model alloy. Galvanic coupling tests were also performed. Al-Cu-Fe alloy was found to be cathodic by comparison with Al-Cu alloy. For Al-Cu-Mg alloy, a more complex behavior was observed: Al-Cu-Mg alloy was first anodic, then cathodic by comparison with Al-Cu alloy. This experiment corroborates the results obtained in a previous study concerning the corrosion behavior of 2024 alloy in nitrate solutions [1].

TEM observations showed that the passive film grown on the Al-4%at Cu model alloys was about 20 nm thin whereas a thickness of about 150nm was measured for the model alloys characteristic of the intermetallics. EELS analysis showed significant differences in the chemical composition of the passive films.

Calculations were also performed using the density functional theory to study the influence of copper incorporation in aluminum alloys. Copper incorporation was detrimental for the oxide film growth.

[1]. C. Blanc, S. Gastaud and G. Mankowski, J. Electrochem. Soc., 150 (2003) B396

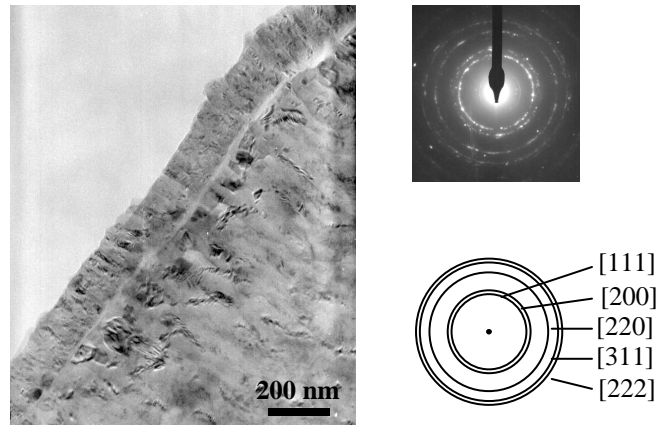


Fig. 1 : TEM micrograph of an Al-4%at Cu alloy on a 2017 aluminum alloy substrate. Electronic diffraction diagram.

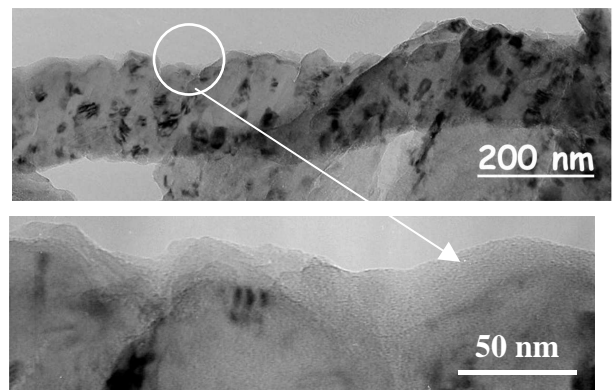


Fig 2. Passive film grown on the Al-4%at Cu alloy polarized for 1hr at 1V/SCE in 0.1M sulfate solution

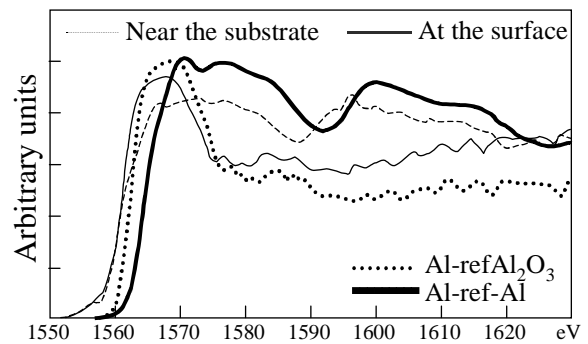


Fig 3. EELS analysis in the aluminum range for the AlCu4%at model alloy polarized in 0.1M sulfate solution at 1V/SCE for one hour.

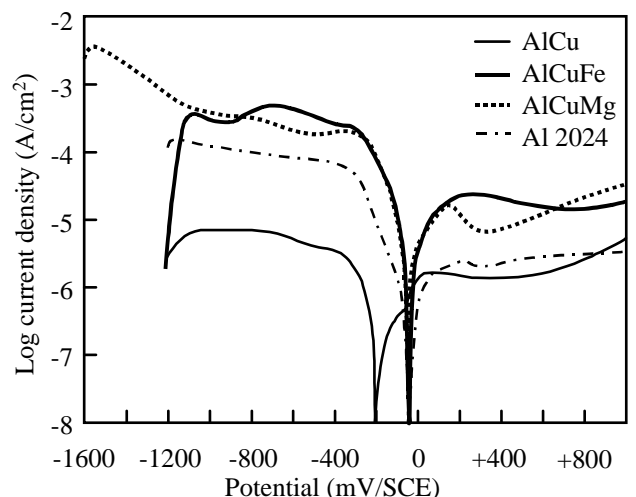


Fig 4. Potentiokinetic curves plotted for the three model alloys in 0.1M sulfate solution. Scan rate = 15 mV.min⁻¹