TEM and Electrochemical Characterization of Three Experimental 6XXX Al Alloys

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The effects of copper concentration on the localized corrosion behavior of three experimental 6XXX aluminum alloys (0.0%, 0.68%, and 1.47%Cu) were investigated via potentiostatic electrochemical noise measurement and transmission electron microscopy (TEM). The TEM specimens were prepared by electropolishing in 30% nitric acid in methanol solution at –30 to –40^{o}C and examined in a Philips 420T TEM at 120 kV. Previous study revealed intergranular corrosion (IGC) was the dominant mode of attack for the copper-containing alloys in chloride-containing environments. TEM foils prepared by electropolishing were immersed in dilute HCl solution simulating the aggressive environment inside an active pit or IGC front, then examined under TEM. The goal of the on-going research is to correlate electrochemical corrosion performance with microstructure.

Initial TEM study revealed that the precipitates (PPT) in Al 6XXX (0.68%Cu) are about 250 nm in length and appear to be needle-like. They are most likely Q ($Al_WCu_XMg_YSi_Z$) and/or β (Mg_2Si) phases or precursors of both. No apparent precipitate-free-zones (PFZ) were observed. Some PPTs were observed right along grain boundaries (GB); however, the PPTs appear to be less densely populated in the vicinities of GB than the interior of the grain. Figure 1 is a bright field TEM image taken across the grain boundaries of Al 6XXX (0.68%Cu) showing PPTs in the proximity of the GB. Figure 2 is a dark field TEM image of Al 6XXX (0.68%Cu) showing the needle-like precipitates and a dispersoid tangled with dislocations at up-left corner. Present study also revealed that two types of Al-Fe-Mn-Si containing dispersoids exist in the copper-containing alloys and they appear to be either round or rod shaped. Aside from the round and rod shaped dispersoids, irregular block-shaped dispersoids also exist in the non-copper containing alloy. The apparent sizes of the rod shaped dispersoids in Al 6XXX (0.68%Cu) range from 30 x 110 nm to 300 x 950 nm. The diameters of the round dispersoids in Al 6XXX (0.68%Cu) range from 50 to 180 nm. The average sizes of the dispersoids in Al 6XXX (1.47%Cu) are 120 nm in diameter and 200 x 300 nm in apparent size for round and rod shaped, respectively. The apparent sizes of the rod dispersoids in non-copper containing alloy range from 10 x 45 nm to 150 x 950 nm and the diameters of the round dispersoids range from 10 nm to 1.7 μm. The maximum length of the irregular block-shaped dispersoid in non-copper containing alloy reaches 5 μm. EDX performed under TEM suggests that the round and rod-like dispersoids are similar in chemical compositions; both are Al, Fe, Mn, and Si containing. Correlation observed between electrochemical corrosion performance and microstructural features (as observed with TEM) will be presented and discussed.

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Figure 1-Bright field TEM image of Al 6XXX (0.68%Cu) across grain boundary (GB) showing thickness fringes and precipitates close to the GB.

Figure 2-Dark field TEM image of Al 6XXX (0.68%Cu) showing uniform distribution of needle-like precipitates and a dispersoid tangled with dislocations at up-left corner.