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Characterization of Mn Containing Precipitates Observed in 7XXX Series Al Alloys Using Aberration Corrected STEM

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Microstructural parameters such as precipitate volume fraction, size, shape, and spatial distribution determine the relative effectiveness of precipitation hardening achieved for hardenable metallic alloys. The ability to accurately measure these microstructural parameters provides quantitative inputs for predictive models. For 7xxx series Al alloys, intermetallic precipitates may have a marked effect on mechanical properties, and depending on thermomechanical history, the effect may be positive or negative [1]. As Mn intermetallics are believed to play an important role in enhancing 7XXX series Al alloy's strength, proper identification by STEM is critical for accurate microstructural characterization.

Modern scanning transmission electron microscopy (STEM) instruments with x-ray energy dispersive spectroscopy silicon-drift-detectors (XEDS-SDD) provide researchers a potent tool for phase identification of the various precipitates observed in Mn containing Al-alloys by probing the crystal structure and composition. Modern systems also provide the ability to directly image the lattice and interface to compare to image simulation and further improve predictive models.

While the microstructural evolution for intermetallic precipitate phases is thought to be well understood for the 7XXX series, when adding Mn to form Al-Zn-Mg-Mn alloys, unique identification of precipitates becomes challenging as two intermetallic precipitates are expected to grow with the addition of Mn; $Al_{57}Mn_{12}$ and Al_6Mn. Multiple researchers have previously determined orientation relationships for the Mn-containing precipitates by classical electron diffraction, however technological limitations restricted this to selected area diffraction without compositional data. This lack of compositional data requires assumptions by the researchers that the precipitate being characterized was indeed a Mn intermetallic. Due to trace elements this led to inconsistent results. Further complicating unique precipitate identification in Al alloys is the tendency for multiple precipitate phases to form concurrently, with multiple variants. While significant literature over the past 70 years has covered various Al-alloy systems, this has resulted in conflicting results due to the number of various phases that may form in a given alloy [2-5].

Typically, intermetallic precipitates need to remain small to provide positive strengthening benefits and this makes uniquely identifying the small intermetallic precipitates through experimental characterization challenging, to overcome this, concurrent imaging and phase identification of the various precipitate are required to correlate the observed two-dimensional cross section to the correct intermetallic precipitate. Necessary for (STEM) characterization of Al alloys are thin foils, and often the intermetallic precipitates occurring in Al alloys grow to a size that extends past the STEM foil thickness, resulting in cross sections from the same type of precipitates exhibiting quite different shapes due to the presence of multiple variants and making the unique identification of different precipitate phases from morphology difficult. Differentiating and uniquely identifying the small intermetallic precipitates is compounded due to difficulty in collecting quantifiable spectroscopy signals to confirm compositions. This work utilizes aberration corrected STEM, coupled with XEDS mapping, to provide unique identification of various intermetallic precipitates and correlates the observed atomic structure with image simulations to identify phase morphologies for distinct precipitates.

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