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Selectivity of Grain Boundary Precipitation in Al Alloys

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AA6111 alloy (Al-Mg-Si-Cu), developed for automotive sheet application, shows extensive brittle grain boundary fracture depending on quenching rates. The aim of this study was to use the analytical scanning transmission electron microscope technique to evaluate the correlation between the grain boundary type and its chemistry in terms of the morphology and number of precipitates present under different cooling rates and heat treatments. The precipitation of the hexagonal quaternary Q phase within the matrix in Al6111 has been reported in details in terms of the crystal structure, composition, morphology and nucleation [1-5]. The Q lattice nucleates by plane strain deformation and grows as laths with a unique orientation relationship with the matrix: $[0001]_Q$ // $[001]_{Al}$ and $\{1120\}_Q$ // $[510]_{Al}$.

Grain boundary precipitates observed in this study were identified by selected area diffraction patterns and compositional analysis as Q phase reported in the literature.
Different grain boundary precipitate morphologies were classified depending on the boundary type as:

a) High-angle boundaries with a {100} grain boundary plane are covered with continuous precipitate “film-like” . Figures 1 (a, b) are such an example. A 700nm long precipitate with aspect ratio of ~30 is seen along the grain boundary.
b) CSL (coincidence site lattice) boundary type (Figures 2.a,b) demonstrate the faceted precipitates maintaining the <100> direction with one of the adjoining grains.
c) Figures 3 (a,b) show a low-angle boundary with densely populated precipitates again maintaining the preferred orientation relationship.

This results show clearly that the precipitation at grain boundaries occurs with a preferred orientation relationship, identical to the relationship of the matrix Q phase, with one of the two neighboring grains. Grain boundary character has a strong effect on the density and morphology of Q precipitates. In general, if the grain boundary plane contained a <100> direction, the precipitate grew with faceted morphology along that direction. If the grain boundary did not contain a <100> direction, the morphology of the Q phase was more equiaxed, but it still maintained the preferred orientation relationship with one of the two grains. More work characterizing the distribution of the grain boundary types in the alloy is underway.

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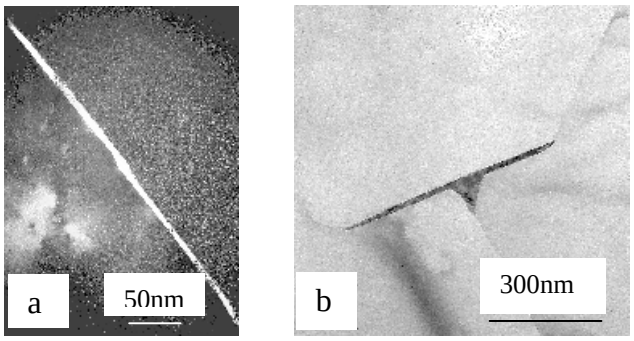

FIG 1.a. Dark-field- and b. Bright-field electron micrographs taken from “film- like” grain. boundary precipitates.

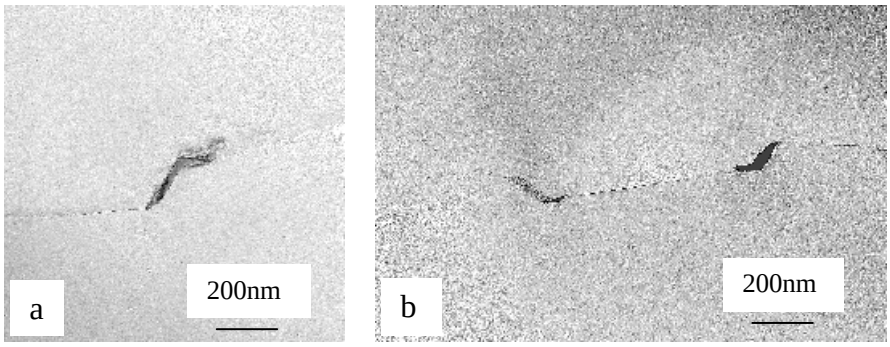

FIG 2. a,b. Bright-field electron micrographs of grain boundaries with faceted precipitates.

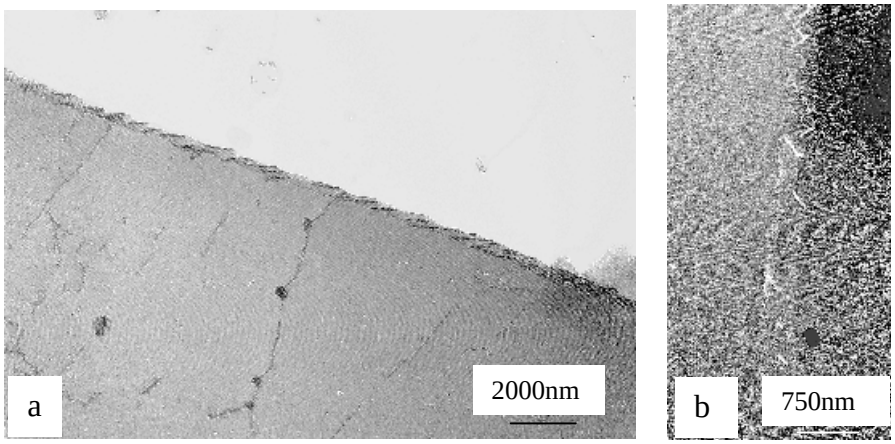

FIG 3. a. Bright-field- and b. Dark-field electron micrographs of precipitates present at low-angle grain boundaries.

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