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Mg segregation at coherent and semi-coherent Al/Al_3Sc interfaces

E.A. Marquis*, J.L. Riesterer*, D.N. Seidman**, and D.J. Larson***

* Sandia National Laboratory, PO Box 969, Livermore, CA 94550
** Materials Science and Engineering Department, Northwestern University, Evanston, IL 60208
*** Imago Scientific Instruments Corporation, 6300 Enterprise Lane, Madison, WI 53719

Aluminum alloys containing Sc are promising materials for high-temperature structural applications due to the high strengthening effect of the Al_3Sc ($L1_2$ structure) precipitates [1]. Further improvements in strength and nanostructural stability of Al-Sc based alloys are achieved by adding alloying elements, such as Mg, as solid-solution strengtheners. It is important to understand the effects of Mg in order to control not only the specific contribution of Mg to the properties of Al-Sc alloys (strengthening effect and creep resistance) but also the changes in the nanostructure.
From previous work, it is known that Mg tends to segregate to the coherent Al/Al_3Sc interface due to positive interactions between Mg and Sc atoms [2]. This paper reports measurements of Mg segregation at the Al/Al_3Sc interface and compares the segregation level between coherent and semi-coherent Al/Al_3Sc interfaces.

A cast Al-2 wt.% Mg-0.2 wt.% Sc alloy was annealed at 618°C in air for 24 hours, quenched into cold water, and then aged in air at 300°C for 24 hours. One sample was subsequently aged at 400°C for 240 hours. Three-dimensional atom probe (3DAP) microscopy tips were obtained by a double electro-polishing technique. Field evaporation was performed at 30 K with a pulse fraction of 20 % at a frequency of 200 kHz using a LEAP microscope. Transmission electron microscopy (TEM) imaging was performed on a JEOL 1200 microscope.

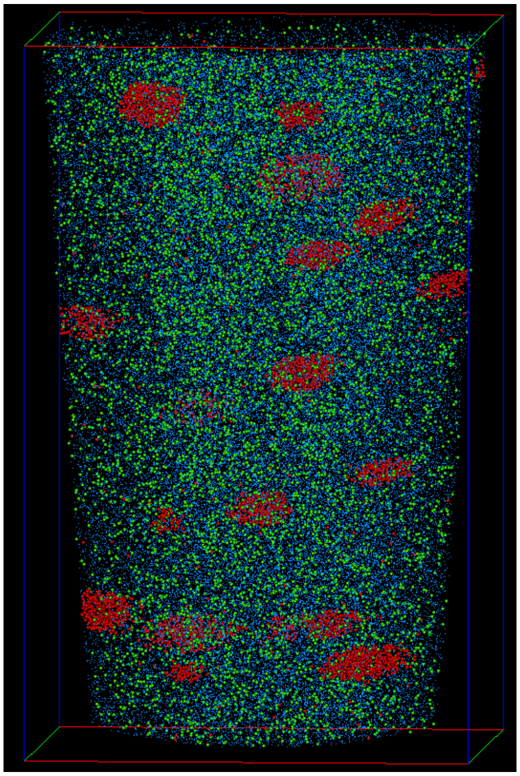
During aging at 300°C, Al_3Sc precipitates are formed with a high number density (~2 10^{22} precipitates/m^3), which is advantageous for random 3DAP microscope observations. The average radius of the precipitates is 2 nm and the interface is coherent (Fig. 1). After aging at 400°C, however, the average radius of the precipitates is ~19 nm and dislocations loops are observed at the matrix/precipitate interface. The number density of precipitates has also decreased dramatically (~10^{19} precipitates/m^3) and is no longer sufficient for random atom probe observations. Atom probe tips were therefore observed by TEM to confirm the semi-coherent nature of the Al/Al_3Sc interface and to determine the position of the precipitates with respect to the tip apex. Micro-polishing was used to position precipitates to within ~100 nm of the apex. A TEM image of a tip is shown in FIG.2. Al_3Sc precipitates are visible with dislocations at the matrix/precipitate interfaces.

Coherency loss may occur when the precipitate diameter is larger than the spacing between the misfit dislocations. This spacing is of the order of α/ε, where $\varepsilon = 0.62\%$ is the lattice parameter misfit between the α-Al matrix containing 2.2 at.% Mg and the Al_3Sc phase [3,4], and $\alpha = 0.20$ nm is the spacing between {200} planes. The calculated equilibrium dislocation spacing is therefore 32 nm, in good agreement with the presence of interfacial dislocations for precipitates with diameter of ~38 nm. Comparison is made between the segregation levels measured for coherent and semi-coherent interfaces. The role of the interfacial dislocations will be discussed.

References
[1] Toporova L.S., Eskin D.G., Kharakterova M.L., Dobatkina T.B. *Advanced aluminum alloys containing scandium*. Amsterdam: Gordon & Breach; 1998.
[2] Marquis E.A., Seidman D.N., Asta M., Woodward C., Ozolins V., *Phys. Rev. Letters* **91** (2003) 036101 1-3
[3] Hatch J.E. *Aluminum: properties and physical metallurgy*. Metals Park (OH): ASM; 1984.

[4] JCPDS – *International Centre for Diffraction Data*. v. 2.00, 1998.
[5] Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed-Martin Company, for the United States Department of Energy National Nuclear Security Administration under contract DE-AC04-94AL85000.

(a)



(b)

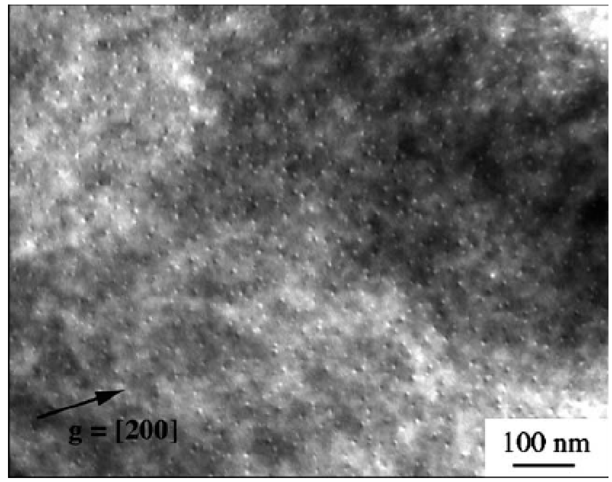


FIG. 1. Al–2.2 at.% Mg–0.12 at.% Sc alloy after aging at 300°C for 24 h: (a) 3DAP reconstruction showing Al_3Sc precipitates. Al atoms are represented in blue, Mg in green and Sc atoms in red. The volume is 54nmx54nmx89nm. (b) CTEM micrograph showing a high number density of Al_3Sc precipitates: dark-field image, exhibiting Ashby–Brown strain coherency contrast, obtained with a [200] reflection.

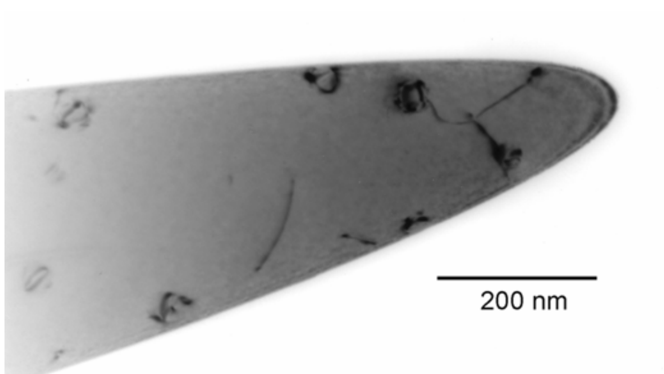


FIG. 2. Dark-field TEM image of an Al-Mg-Sc atom probe specimen containing semi-coherent Al_3Sc precipitates.

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