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ABSTRACT:

Influence of hydrogen on the diffusion of substitutional elements in Al alloys

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Hydrogen exhibits a very low equilibrium solubility in pure aluminum (below 1 ppm at RT under 1 atm H_2) and a high mobility (typical diffusion coefficient at RT near 10^{-11} m^2/s). Using chemical or electrochemical charging methods, it is however possible to significantly increase the concentration of H, up to few hundreds ppm. Due to strong interactions with crystalline defects, H atoms quickly segregate to vacancies, dislocations and grain boundaries. Nevertheless, it has also been demonstrated that hydrogen may also significantly reduce the formation energy of vacancies. In precipitate hardening Al alloys, the precipitation kinetic is connected to the atomic mobility of substitutional alloying elements that is driven by a vacancy mechanism. Thus, we have hypothesized that hydrogen should affect the mechanisms of such transformations and we have experimentally investigated the influence of hydrogen on precipitation in two binary model Al alloys (Al-5Cu and Al-0.2Zr). Materials were solution treated and aged at various temperatures to nucleate precipitates that give rise to hardening. The influence of hydrogen was explored using chemical charging in NaOH solution or under high hydrogen pressure prior to aging. The precipitation kinetics were followed by transmission electron microscopy and atom probe tomography with a special emphasis on precipitate size, number density and distribution. Hydrogen trapping sites were also identified using thermal desorption spectroscopy. In the Al-Zr alloy, aging under high pressure of H_2 significantly accelerates the precipitate growth kinetic. The diffusion coefficient of Zr is increased by a factor of 2 which can be attributed to an enhanced vacancy concentration. In the Al-Cu alloy however, both the kinetic of natural aging and of the early stage of artificial aging are significantly reduced in hydrogen-charged samples. This feature clearly illustrates the complex hydrogen-solute-defect interactions in metallic alloys that may promote or reduce the atomic mobility of alloying elements.