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Thermodynamic and compositional assessment of Q-phase in Al–Si–Mg–Cu alloys using 3DAPT and in-situ TEM

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ABSTRACT

Quaternary Q-phase precipitates during aging of Al–Si–Mg–Cu alloys. From an uncertain and debated composition, to its relationship with similar phases such as the β′-phase, little has been understood of the Q-phase. The precipitation of the Q-phase is further complicated by its competition with the strengthening θ′-phase. The composition of the Q-phase has been explored in both wrought and cast aluminum alloys using 3-D atom-probe tomography (3DAPT) and has been found to vary with bulk alloy composition, specifically in regard to changes in both Cu and Mg content. This contradicts previous characterization studies that agree with the more commonly accepted stoichiometric compound $Al_5Cu_2Mg_8Si_6$ found in commercially available thermodynamic databases. Thermodynamic CALPHAD simulations, using a commercial database, show large disagreements not only with the composition of the Q-phase but also with the equilibrium phases present after long aging times as identified experimentally using both 3DAPT and TEM. After introducing an experimentally validated Cu:Mg sub-lattice into a custom thermodynamic database, thermodynamic simulations demonstrate close agreement of Q-phase compositional variations and equilibrium phase fractions of both the Q-phase and θ′-phase. Additionally, *in-situ* TEM aging studies demonstrate the competition between the Q-phase and θ′-phase and motivate further calibration at near solvus temperatures. Accurately predicting phase stability in pre-aging solution heat treatments is crucial in obtaining optimized precipitation strengthening.

KEYWORDS: aluminum alloys, Q-phase, CALPHAD, 3DAPT, TEM, characterization