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Al-Cu-Mg-Si (Aluminum-Copper-Magnesium-Silicon)

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[1993Mur] calculated the phase equilibria in Al-rich alloys of this quaternary system and compared the computed projections, sections and perspective views with the early literature data. In a series of papers, Chang et al. [2001Yan, 2004Cha1, 2006Cha] presented the computed phase equilibria of Al-rich alloys, which included calculations of the type and fraction of phases expected under industrial cooling conditions. [1998Cha, 2002Cha, 2004Cha2] studied the phase equilibria in commercial compositions, emphasizing the precipitation aspects and the role of the quaternary phase Q.

Binary Systems

For brief descriptions of the Al-Cu, Al-Mg and Cu-Mg systems, see the Al-Cu-Mg update in this issue. For Al-Si and Mg-Si binaries, see the Al-Mg-Si update. The Cu-Si phase diagram is briefly described under the Al-Cu-Si update.

Ternary Systems

Updates on the Al-Cu-Mg, Al-Cu-Si and Al-Mg-Si ternary systems appear in this issue. For the Cu-Mg-Si system, [1995Vil] presented partial liquidus projections near the Cu and Mg corners, isothermal sections at 450 and 25 °C and a vertical section at 33.3 at.% Mg.

Quaternary Phase Equilibria

A quaternary phase $Al_5Cu_2Mg_8Si_6$ denoted Q is known in this system. It has hexagonal symmetry, space group $P\bar{6}$, Pearson symbol $hP21$, and lattice parameters a = 1.03932 nm and c = 0.40173 nm [Pearson3]. [2001Wol] proposed a composition of $Al_3Cu_2Mg_9Si_7$ for Q on the basis of energy calculations.

[2001Yan], [2004Cha1], and [2006Cha] employed the aluminum thermodynamic database PanAluminum [1998Pan] and the multicomponent phase diagram calculation software PANDAT [2000Pan] for computing the phase equilibria of this quaternary system. The liquidus projection for Al-rich alloys computed by [2006Cha] is shown in Fig. 1 and 2. Figure 1 shows the liquidus lines on the three ternaries only. The quaternary liquidus lines are shown in addition in Fig. 2. There are six five-phase invariant reactions in the Al-rich region: $\boldsymbol{E}_1$, $\boldsymbol{E}_2$, $\boldsymbol{E}_3$. $\boldsymbol{U}_1$,$\boldsymbol{U}_2$, and $\boldsymbol{U}_3$ occurring at 509, 502, 448, 541, 511 and 467 °C, respectively. [2004Cha1] and [2006Cha] listed the computed compositions of the phases participating in the quaternary invariant reactions.

A partial reaction sequence written by [2006Cha], shown in Fig. 3, gives the relationships between the ternary and quaternary invariant reactions in this region. The quaternary invariant reactions are labeled in bold italics. The origin of the four-phase equilibria in broken boxes is not known. The all-solid phase mixtures (products of the quaternary reactions) are underlined in Fig. 3 and are expected to be stable down to room temperature. The schematic view of the stable

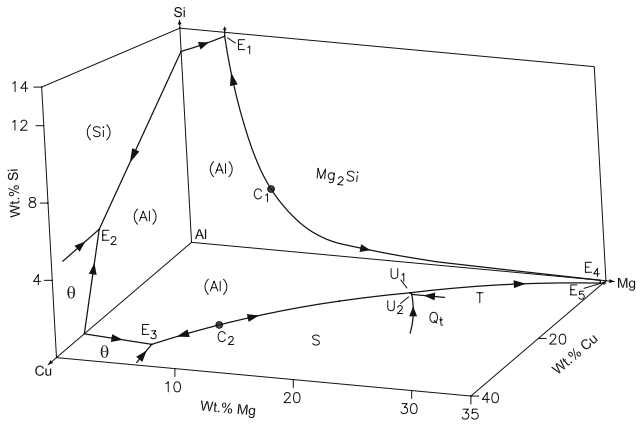

Fig. 1 Al-Cu-Mg-Si partial liquidus projection depicting ternary liquidus lines only [2006Cha]

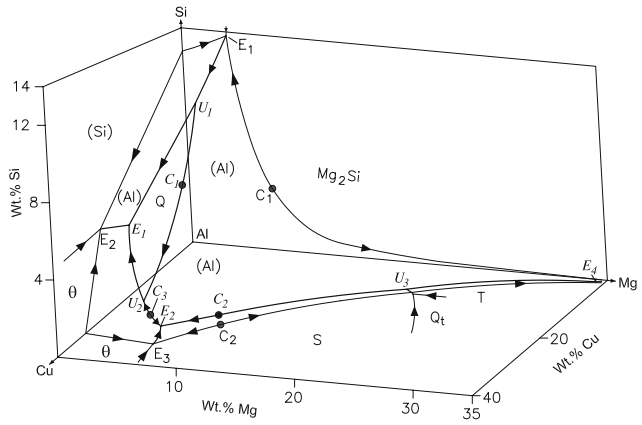

Fig. 2 Al-Cu-Mg-Si partial liquidus projection depicting ternary and quaternary liquidus lines [2006Cha]

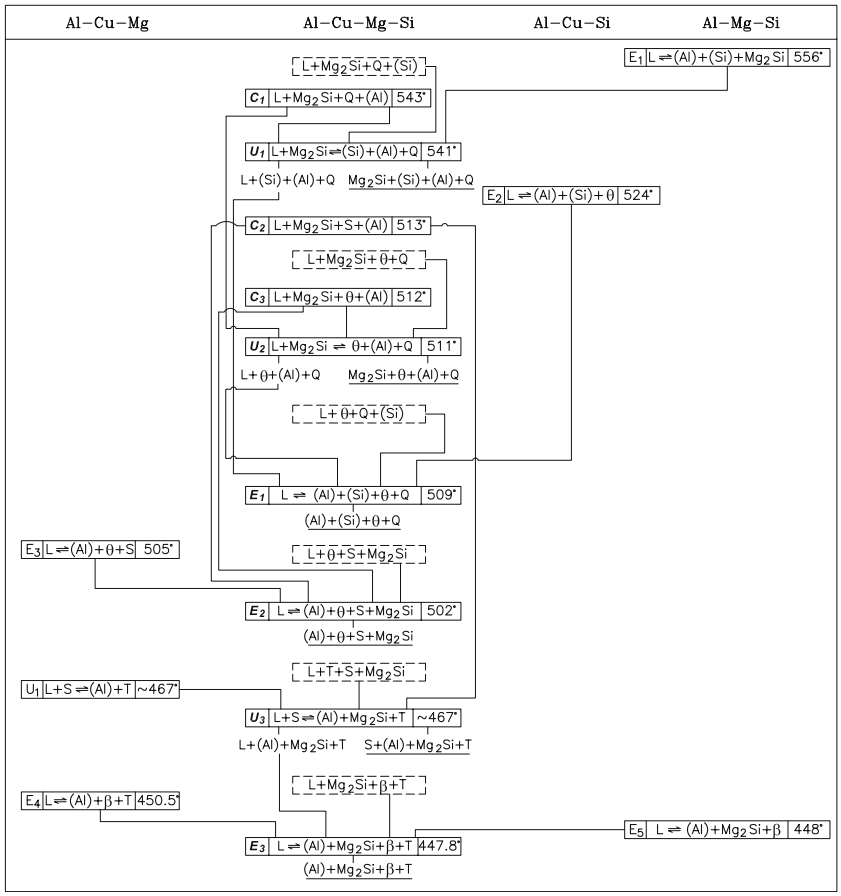

Fig. 3 Al-Cu-Mg-Si computed partial reaction sequence for Al-rich alloys [2006Cha]

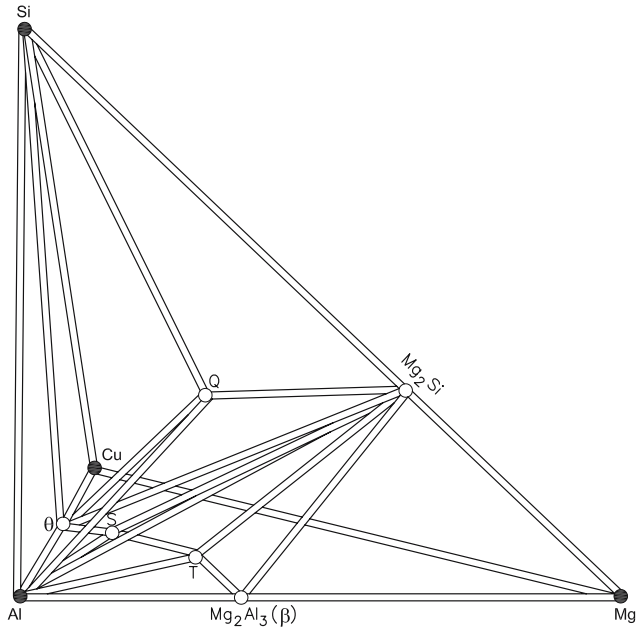

Fig. 4 Al-Cu-Mg-Si schematic view of the stable phase fields in Al-rich alloys at room temperature [2004Cha2]

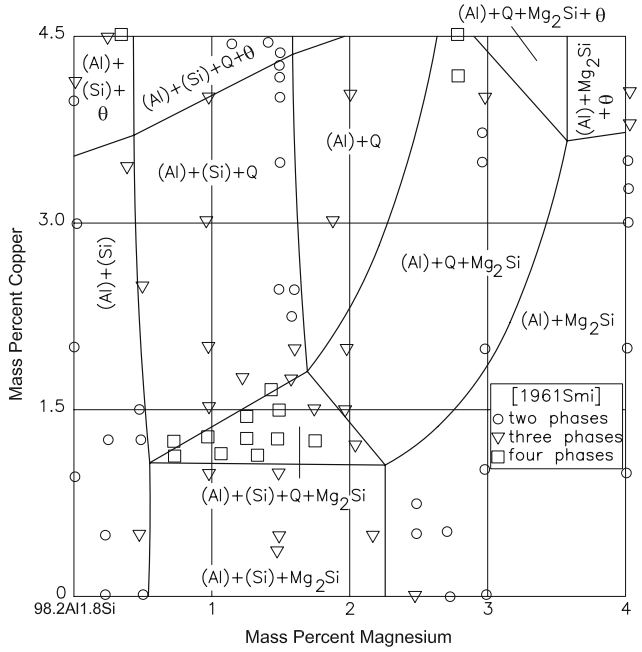

Fig. 5 Al-Cu-Mg-Si computed isothermal section at 1.8 mass% Si and at 500 °C [2001Yan]

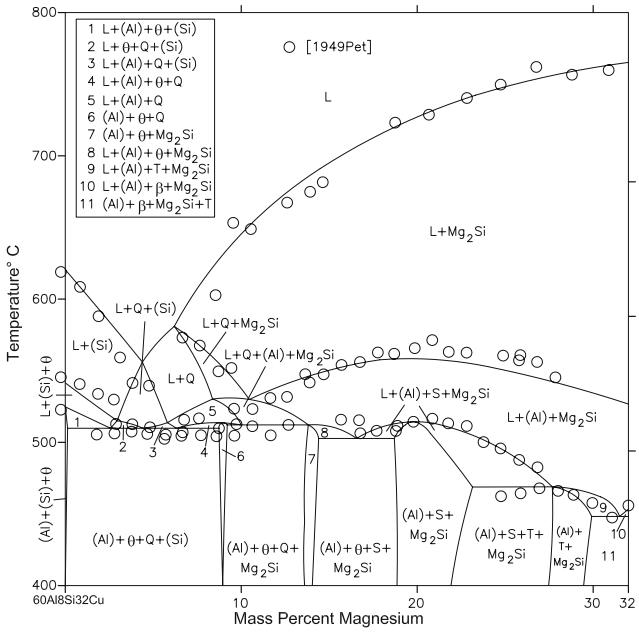

Fig. 6 Al-Cu-Mg-Si computed vertical section at 60 mass% Al and 8 mass% Si [2001Yan]

phase fields at room temperature given by [2004Cha2] is shown in Fig. 4. It confirms the six all-solid phase fields underlined in the reaction table (Fig. 3). [2004Cha2] pointed out that, for commercial Al alloys with Mg/Si mass ratio greater than ~1, the coexisting phases are (Al) + Q + θ + Mg_2Si. When Mg/Si mass ratio <1, the stable equilibrium is (Al) + Q + θ + (Si). When the Cu content in the alloy is low (less than 0.2-0.5 mass%), the equilibrium of (Al) + Q + (Si) + Mg_2Si prevails.

In Fig. 5, an isothermal section at 1.8 mass% Si and at 500 °C computed by [2001Yan] is compared with the experimental results of [1961Smi]. The agreement is satisfactory. A computed vertical section at 60 mass % Al and 8 mass % Si is shown in Fig. 6 [2001Yan]. The agreement with the thermal analysis data of [1949Pet] is good.

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