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Al-Ca-Mg-Sr (Aluminum-Calcium-Magnesium-Strontium)

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Addition of Ca and Sr to Al-Mg alloys is often done in industrial practice to improve their mechanical properties. The combined effect of these chemically similar additives cannot be described adequately by clubbing them together as (Ca + Sr) in specifying the alloy composition. Recently, [2009Jan2] presented a thermodynamic description of this quaternary system, supplemented by a limited number of key experiments. Earlier, [2007Suz] studied the effect of Sr additions on the microstructure and strength of Al-Ca-Mg ternary alloys.

Ternary Subsystems

The Al-Ca-Sr and Ca-Mg-Sr ternary systems are updated in this issue on the basis of the results of [2009Jan1]. The Al-Ca-Mg system was updated by [2009Rag], based on the results of [2009Jan3]. The Al-Mg-Sr was by updated by [2007Rag] from the results of [2007Jan].

Quaternary Phase Equilibria

The presence of a true quaternary compound or phase was discounted by [2009Jan2]. Preliminary calculations extrapolated from ternary descriptions were used by [2009Jan2] to identify the invariant reactions in the quaternary system. The temperatures of such reactions are among the most decisive data for experimental validation. The centroid composition of an invariant reaction, which *fully* converts the reacting phases to the product phases and thereby yields the maximum heat effect, can also be found by calculation. As many as 22 transition-type reactions and two eutectic reactions were found in the quaternary region. Among these, only six involve both liquid and (Mg). Omitting reactions that are degenerate from the six, only two reactions were found suitable for investigation. The transition reaction U_8: L + $Mg_{17}Sr_2$ ↔ *C*15 + (Mg) + Al_4Sr at 505 °C corresponds to the centroid composition $Mg_{65.8}Al_{19.4}Ca_{5.1}Sr_{9.7}$ and the quaternary eutectic reaction E_1: L ↔ $Mg_{17}Sr_2$ + *C*14 + *C*36 + (Mg) at 508 °C

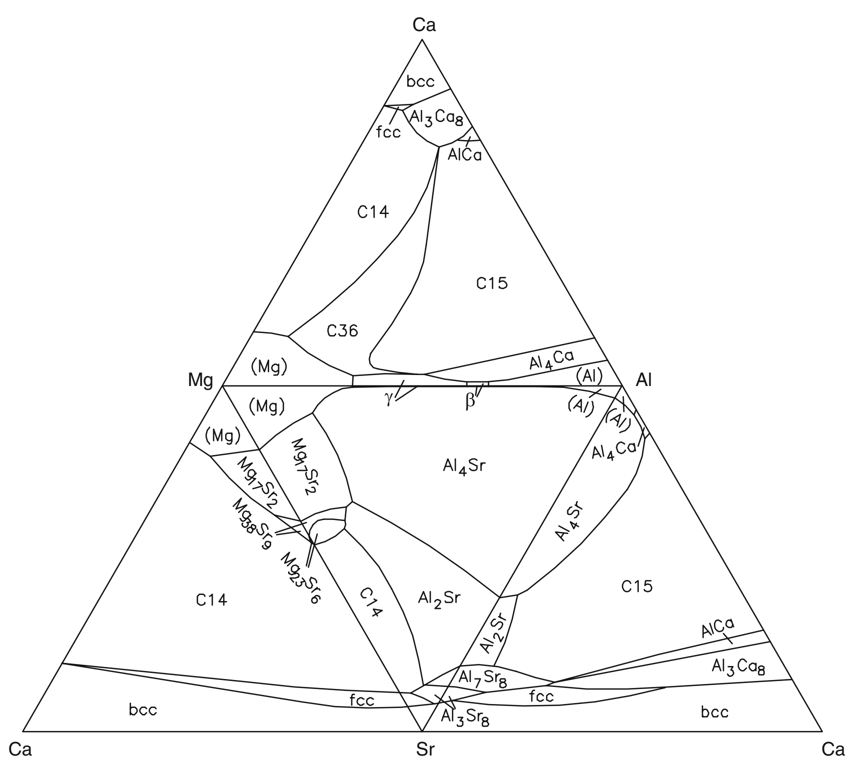

Fig. 1 Al-Ca-Mg-Sr computed liquidus projections of the ternary subsystems [2009Jan2]

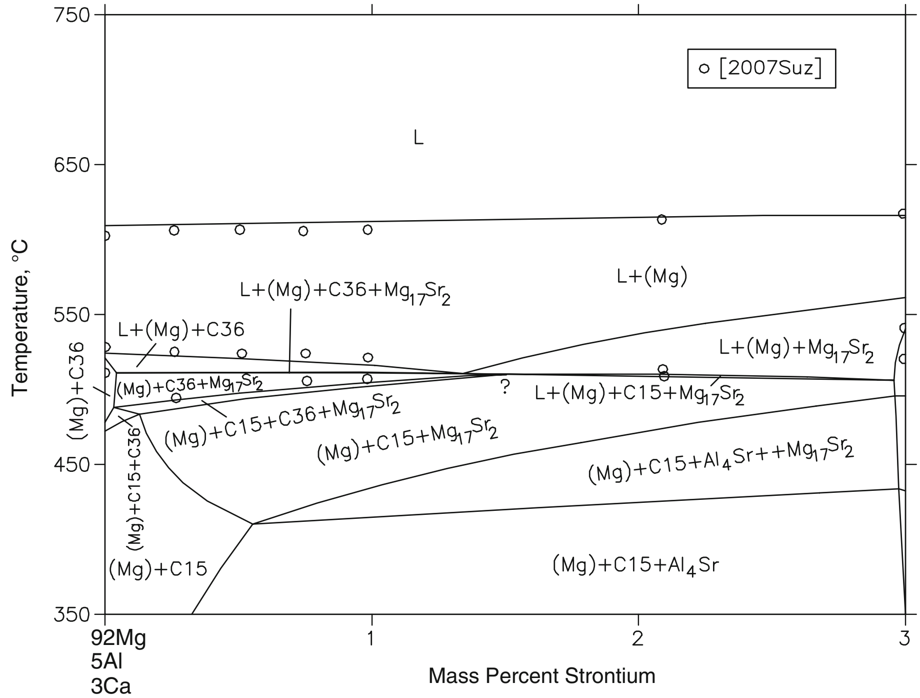

Fig. 2 Al-Ca-Mg-Sr computed vertical section at constant 92Mg-5Al (mass%) [2009Jan2]

corresponds to the composition $Mg_{91.6}Al_{4.8}Ca_{3.2}Sr_{0.4}$. Thermal analysis by [2009Jan2] on these two alloy compositions showed arrests at the computed invariant reaction temperatures of U_8 and E_1.

In addition, [2009Jan2] computed liquidus projections and isothermal sections at 700, 500, and 400 °C for all the four ternary subsystems and depicted them on an opened-out tetrahedron. As an example, the liquidus projections for the four ternary subsystems are shown in Fig. 1. Folding up the three Ca-containing ternaries to form the Ca apex will yield the tetrahedron, with the calculated data lying on all the four faces of the tetrahedron but none inside. Such partial information is still useful as a first step in understanding the quaternary phase equilibria. Approximate interpolations can be visualized if no quaternary phases are present. However, the exact volume over which a phase extends into the tetrahedron from adjacent faces cannot be derived from such data.

A vertical section computed by [2009Jan2] along the $Mg_{92}Al_5Ca_3$-$Mg_{92}Al_5Sr_3$ join (mass percent) is shown in Fig. 2. Satisfactory agreement is seen with the thermal arrests determined by [2007Suz]. In addition, graphs were presented by [2009Jan2] for the calculated fraction of phases as a function of temperature under equilibrium as well as Scheil conditions of cooling.

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