JPEDAV (2007) 28:471–472
DOI: 10.1007/s11669-007-9143-5
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Al-Mg-Sc (Aluminum-Magnesium-Scandium)

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The early work on this ternary system was summarized by [1995Vil], who presented an isothermal section at 400 °C for compositions up to 33.3 at.% Sc from [1989Odi, 1991Odi] and two vertical sections from [1976Tur]. Recently, [1999Gro] performed some key experiments and used the new results in conjunction with recent binary descriptions to calculate the phase equilibria of this system.

Binary Systems

The Al-Mg phase diagram [1998Lia] has the following intermediate phases: Mg_2Al_3 (cubic, labeled β), R or ε (rhombohedral), and $Mg_{17}Al_{12}$ (*A*12, αMn-type cubic, denoted γ). The Al-Sc phase diagram [1999Cac] depicts the following intermediate compounds: $ScAl_3$ ($L1_2$, $AuCu_3$-type cubic), $ScAl_2$ (*C*15, $MgCu_2$-type cubic), ScAl (*B*2, CsCl-type cubic), and Sc_2Al ($B8_2$, Ni_2In-type hexagonal). The Mg-Sc phase diagram [1998Pis] has one intermediate phase MgSc (CsCl-type cubic).

Ternary Phase Equilibria

With starting metals of 99.999% Al, 99.99% Mg, and 99.99% Sc, [1999Gro] prepared 23 ternary alloys by induction melting or electron-beam melting under high vacuum. A few samples were prepared by solid-sate reaction between an Al-Sc master alloy and Mg. For the isothermal study, the samples were annealed at 350 °C for 1-2 months and quenched in water. Differential scanning calorimetry (DSC) and differential thermal analysis (DTA) were carried out at a heating/cooling rate of 10 °C per min.

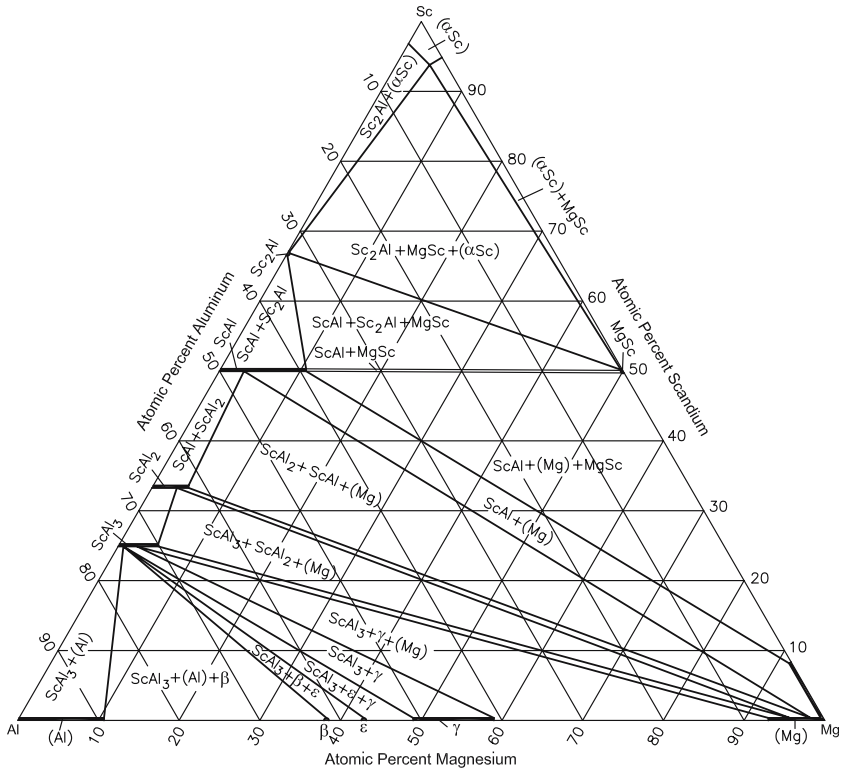

Fig. 1 Al-Mg-Sc computed isothermal section at 350 °C [1999Gro]

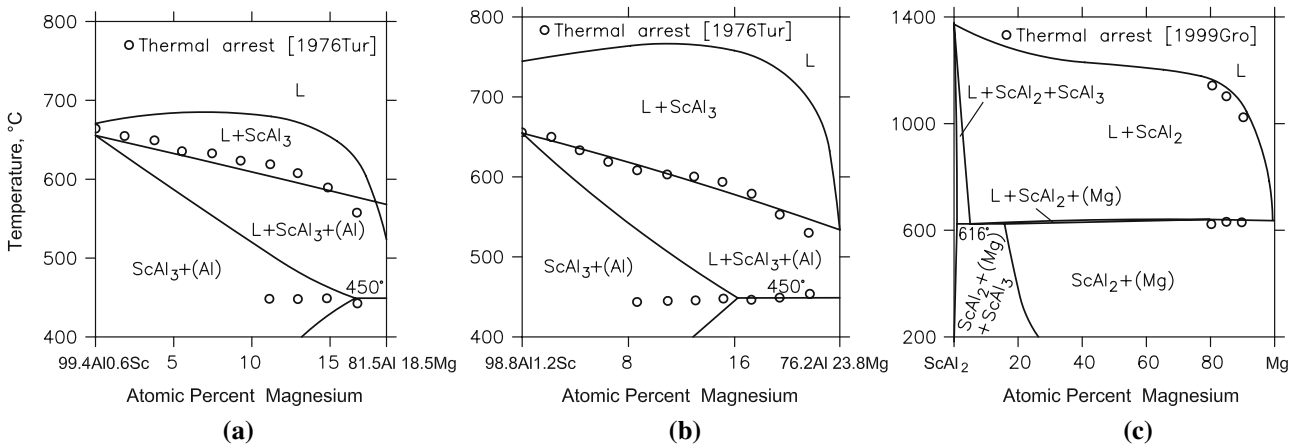

Fig. 2 Al-Mg-Sc computed vertical sections along (a) 99.4Al0.6Sc-81.5Al18.5Mg, (b) 98.8Al1.2Sc-76.2Al23.8Mg, and (c) $ScAl_2$-Mg joins [1999Gro]

Optical and scanning electron microscopy, energy dispersive x-ray analysis and x-ray powder diffraction techniques were used to study the phase equilibria.

The experimental results were used in the thermodynamic optimization. The binary descriptions of [1998Lia] (Al-Mg), [1999Cac] (Al-Sc) and [1998Pis] (Mg-Sc) were adopted. The ternary solubility in $ScAl_3$, $ScAl_2$, and ScAl was taken into account, assuming that Mg substitutes for Al at constant Sc content. Sc_2Al and MgSc were taken to be stoichiometric compounds with no ternary solubility. There are no ternary compounds in this system. The computed isothermal section at 350 °C is shown in Fig. 1 [1999Gro]. Four vertical sections were computed by [1999Gro] along 99.4Al0.6Sc-81.5Al18.5Mg, 98.8Al1.2Sc-76.2Al23.8Mg, and $ScAl_2$-Mg joins and at a constant 36 at.% Mg, respectively. Among these, the first three sections are redrawn in Fig. 2. The first two are compared with the thermal arrests determined by [1976Tur] and the third with DTA points of [1999Gro]. The agreement is satisfactory.

Using the binary extrapolations alone, a closed liquid miscibility gap is predicted in this system at high temperatures. Using their optimized parameters, [1999Gro] computed a liquidus projection and three isothermal sections at 1210, 1200 and 1160 °C to demonstrate the presence of the liquid miscibility gap, which vanishes below 1144 °C and above 1320 °C. [1999Gro] pointed out that a direct observation of two liquids experimentally is difficult in this system.

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