JPEDAV (2008) 29:192–193
DOI: 10.1007/s11669-008-9262-7
1547-7037 ©ASM International

Al-Mg-Sc-Zr (Aluminum-Magnesium-Scandium-Zirconium)

V. Raghavan

Recent work on this quaternary system pertains to partial isothermal sections for Al-rich alloys at 500 and 430 °C [1992Fri, 2004Zen].

Binary and Ternary Subsystems

For brief descriptions of the phases in the Al-Mg, Al-Sc and Mg-Sc systems, see the Al-Mg-Sc update in this review. There are a number of intermediate phases in the Al-Zr system. The only phase of interest in the results on Al-rich alloys reviewed here is $ZrAl_3$ ($D0_{23}$-type tetragonal). There are no intermediate phases in the Mg-Zr and Sc-Zr systems.

Updates of the Al-Mg-Sc system appear in this issue and in [2007Rag]. [2004Zen] reviewed briefly the phase diagram data on the Al-Mg-Zr and Al-Sc-Zr systems.

Quaternary Phase Equilibria

[1991Rok] employed differential thermal analysis and a sedimentation method to determine the temperature profile of the liquidus surface at a constant 6 mass% Mg. Here, after equilibration of a liquid of known composition at a given temperature, a small quantity of the liquid was sucked out from the surface of the melt through a syringe. The agreement of the composition of this liquid with the known composition of the alloy indicated a single phase. A decrease in the Sc/Zr content indicated precipitation, as the precipitates sink to the bottom of the crucible. The liquidus temperatures were thus bracketed. An equation was obtained by [1991Rok] by regression analysis for the temperature T of the liquidus, as a function of Sc and Zr contents in mass% at a constant Mg of 6 mass%:

$$T(^\circ C) = 602.24 + 211.15[Sc] + 642.69[Zr] - 78.14[Sc]^2 - 697.43[Zr]^2$$

With starting metals of 99.99% Al, 99.96% Mg, 99.91% Sc and 99.90% Zr, [1992Fri] induction-melted about 40 alloy compositions with a constant Mg content of 6 mass%, Sc and Zr up to 3 and 4 mass% respectively. The alloys were annealed at 500 °C for 200 h and quenched in water. The phase equilibria were studied by metallography, x-ray powder diffraction (XRD) and x-ray spectral microanalysis. The isothermal section at 500 °C and at 6 mass% Mg shows that (Al) dissolves <0.1 mass% Sc or Mg and forms tie-lines with $ScAl_3$ and $ZrAl_3$. [1992Fri] found that the maximum solubility of Zr in $ScAl_3$ is 23 mass% and that of Sc in $ZrAl_3$ is 4 mass%.

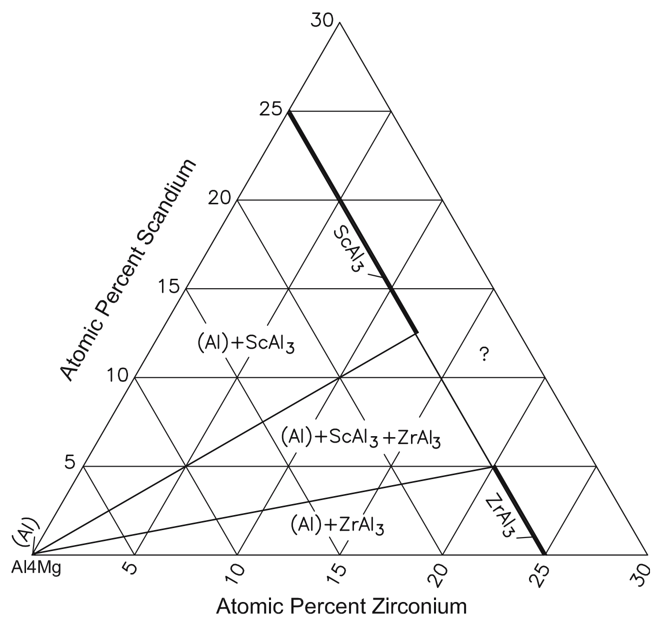

Fig. 1 Al-Mg-Sc-Zr isothermal section at 430 °C and at 4 at.% Mg [2004Zen]

With starting materials of 99.99% Al, 99.99% Mg, Al-1.77 mass% Sc, and Al-4.42 mass% Zr, [2004Zen] induction-melted under Ar atm 18 quaternary alloys with Sc and Zr up to 2.0 and 2.5 at.% respectively and a constant 4 at.% Mg. The alloys were annealed at 430 °C for 360 h and quenched in water. The phase equilibria were studied by optical and electron metallography, XRD and EPMA. The isothermal section at 430 °C and at 4 at.% Mg constructed by [2004Zen] is redrawn in Fig. 1 to comply with the binary data. It is similar to that found by [1992Fri] at 500 °C and 6 mass% Mg. The solubility limits of Zr and Sc in $ScAl_3$ and $ZrAl_3$ respectively are given by $Sc_{0.5}Zr_{0.5}Al_3$ and $Zr_{0.8}Sc_{0.2}Al_3$ [2004Zen].

References

1991Rok: L.L. Roklin, A.S. Fridman, T.V. Dobatkina, and D.G. Eskin, Formation of Grain Boundaries of a Single Phase Liquid Solution in the Al-Mg-Sc-Zr System, *Metally*, 1991, (6), p 158-160 in Russian; TR: *Russ. Metall.*, 1991, (6), p 146-148

1992Fri: A.S. Fridman, T.V. Dobatkina, and E.V. Muratova, Cross Section of Isothermal Tetrahedron of the Al-Mg-Sc-Zr System at

500 °C in the Aluminum-Rich Region, *Metally*, 1992, (1), p 234-236 in Russian; TR: *Russ. Metall*., 1992, (1), p 207-209

2004Zen: F. Zeng, C. Xia, and Y. Gu, The 430 °C Isothermal Section of the Al-4Mg-Sc-Zr Quaternary System in the Al-Rich Range, *J. Alloys Compd*., 2004, **363**, p 175-181

2007Rag: V. Raghavan, Al-Mg-Sc (Aluminum-Magnesium-Scandium), *J. Phase Equilb. Diffus*., 2007, **28**(5), p 471-472