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Al-Cr-Sc (Aluminum-Chromium-Scandium)

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An isothermal section at 500 °C was determined for this ternary system by [1989Sok]. Recently, Rokhlin et al. [2006Rok, 2007Rok] reported an isothermal section at 640 °C, two vertical sections and a liquidus projection, all for Al-rich compositions.

Binary Systems

The Al-Cr phase diagram by [2000Mah] depicts a number of intermediate phases with significant ranges of homogeneity: $CrAl_7$ (V_7Al_{45}-type monoclinic), Cr_2Al_{11} ($CrAl_5$-type monoclinic), $CrAl_4$ ($CrAl_4$-type monoclinic), Cr_2Al ($MoSi_2$-type tetragonal), and an unconfirmed low-temperature phase X at 75 at.% Cr. Between 30 and 41 at.% Cr, five phases have been reported: αCr_4Al_9, βCr_4Al_9, γCr_4Al_9, αCr_5Al_8 and βCr_5Al_8, with no well-established phase boundaries between them [2000Mah]. The Al-Sc phase diagram [1999Cac] depicts the following intermediate compounds: $ScAl_3$ ($L1_2$, $AuCu_3$-type cubic), $ScAl_2$ ($C15$, $MgCu_2$-type cubic), ScAl ($B2$, CsCl-type cubic), and Sc_2Al ($B8_2$, Ni_2In-type hexagonal). There are no intermediate phases in the Cr-Sc system. (Cr) and (βSc) solidify as a eutectic mixture at 1090 °C [Massalski2].

Ternary Phase Equilibria

[1989Sok] melted about 65 alloys in an arc furnace under Ar atm with the alloy compositions lying mainly in the Al-rich region. The samples were annealed at 500 °C for 720 h and quenched in water. The phase equilibria were studied by metallography, hardness measurements, and x-ray powder diffraction. The isothermal section at 500 °C constructed by [1989Sok] is shown in Fig. 1. No ternary phases were found in the system. The third component solubility in the binary compounds is generally small. The solubility limits were determined by [1989Sok] from breaks in plots of lattice parameter versus composition. Without presenting such a plot, [1989Sok] reported a solubility of 11 at.% Cr in $ScAl_3$. [2007Rok], however, found this solubility to be about 0.3 at.% Cr. Figure 1 has been modified to reflect this lower value. A number of changes (some of them arbitrary) were found necessary in redrawing Fig. 1, for consistency with

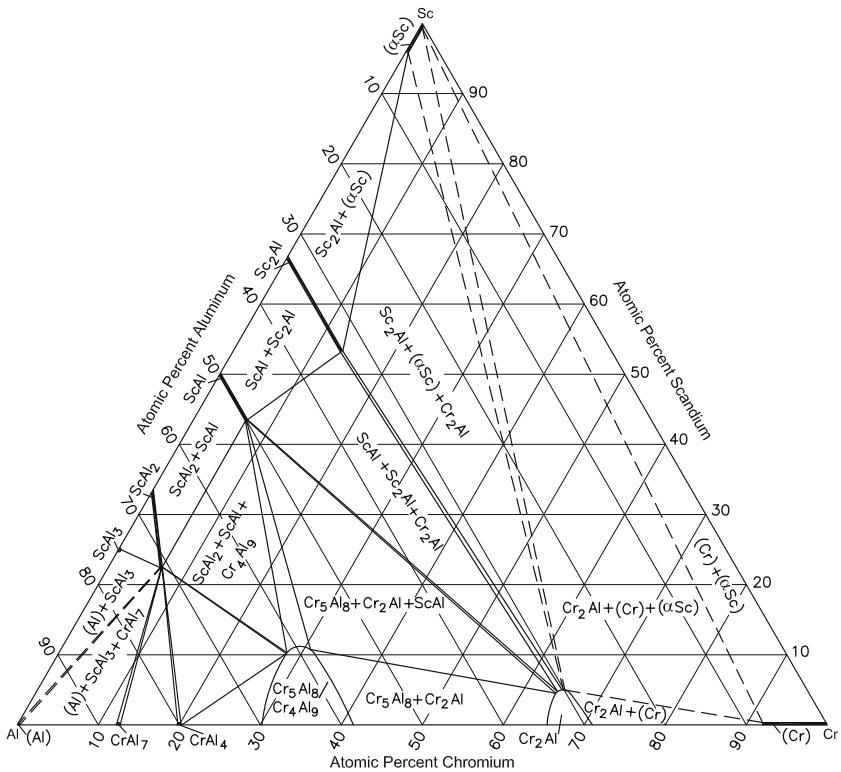

Fig. 1 Al-Cr-Sc isothermal section at 500 °C [1989Sok]

the accepted binary systems. The figure may, therefore, be considered tentative.

With starting metals of 99.99% Al, 99.96% Cr, and 99.86% Sc, [2006Rok] and [2007Rok] prepared master alloys with Sc and Cr contents up to 3.12 and 2.5 mass%, respectively. The master alloys and the final alloys were melted in an arc furnace under Ar atm. The phase equilibria were studied by electrical resistivity measurements, metallography, x-ray diffraction, and electron probe microanalysis. Differential thermal analysis (DTA) was carried out at a heating/cooling rate of 3 °C per min. For isothermal studies, the alloys were annealed at 640 °C for 10 h or at 600 °C for 25 h and quenched in water. The partial isothermal section constructed by [2006Rok] at 640 °C for Al-rich alloys is shown in Fig. 2. The (Al) solid solution in three-phase equilibrium of (Al) + $ScAl_3$ + $CrAl_7$ contains 0.23 mass%

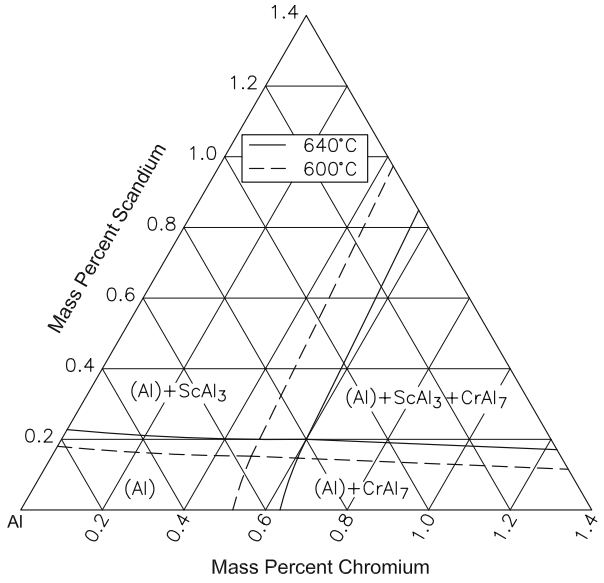

Fig. 2 Al-Cr-Sc partial isothermal sections for Al-rich alloys [2006Rok]

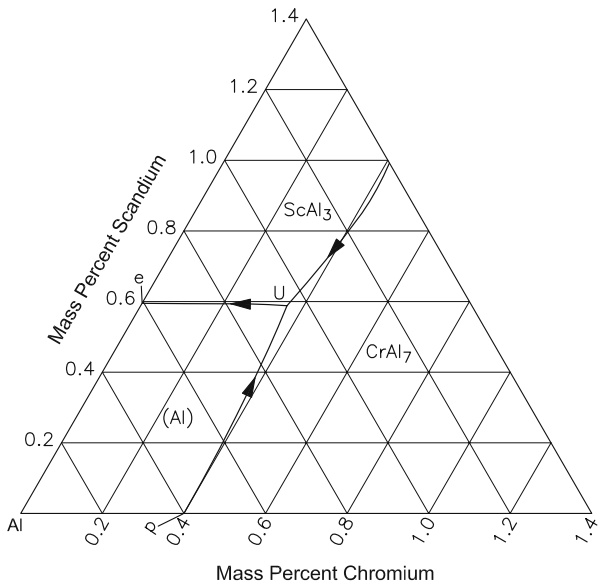

Fig. 3 Al-Cr-Sc partial liquidus projection for Al-rich alloys [2007Rok]

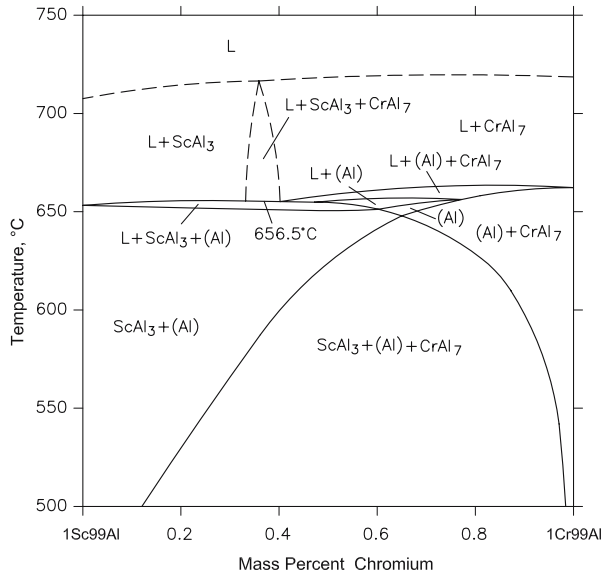

Fig. 4 Al-Cr-Sc vertical section along the 1Sc99Al-1Cr99Al (mass%) join [2007Rok]

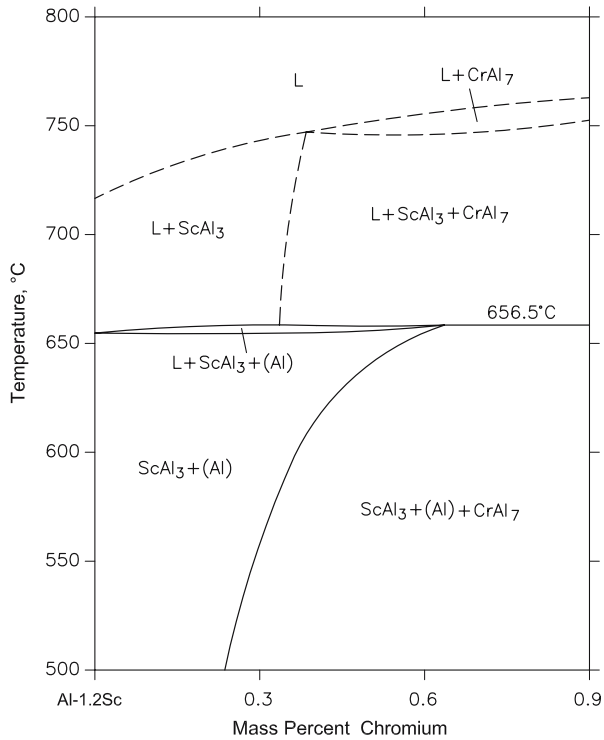

Fig. 5 Al-Cr-Sc vertical section at a constant Sc content of 1.2 mass% [2007Rok]

Sc and 0.58 mass% Cr. The isothermal section at 600 °C (not drawn by [2006Rok]) is shown tentatively by dotted lines. The liquidus projection for Al-rich alloys is given in Fig. 3 [2007Rok]. The transition reaction U: $L + CrAl_7 \leftrightarrow (Al) + ScAl_3$ occurs at 656.5 °C. The vertical sections along the 1%Sc99%Al-1%Cr99%Al join and at a constant Sc content of 1.2 mass% are shown in Fig. 4 and 5, respectively [2007Rok].

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