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Al-Cr-Si (Aluminum-Chromium-Silicon)

V. Raghavan

The early work on this ternary system was summarized by [1995Vil], who presented partial isothermal sections at 1300 and 550 °C, a partial liquidus projection at the Al-corner, and two vertical sections at 4 mass% Si and 5 mass% Cr, respectively. Several ternary phases were listed. The review of [1991Sch] presented a partial liquidus projection for the Al-rich region and two isothermal sections at 1300 and 500 °C. Recent studies of [2004Gup] and [2007Che] reported conflicting results on the stability and occurrence of ternary phases in this system.

Binary Systems

The Al-Cr phase diagram 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), $CrAl_4$ (hexagonal), 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]. Recent work by [2005Gru] confirmed the continuous nature of this region (denoted γ), separated into a high-temperature sub-region with the perfect γ-brass structure and a low-temperature sub-region with a distorted γ-brass structure. The Al-Si phase diagram is a simple eutectic system with the eutectic reaction at 577 °C and 12.2 at.% Si. The Cr-Si phase diagram [2000Du] depicts the following intermediate phases: Cr_3Si (22.4-25.3 at.% Si; *A*15-type cubic), βCr_5Si_3, αCr_5Si_3 ($D8_m$, W_5Si_3-type tetragonal), CrSi (*B*20, FeSi-type cubic), and $CrSi_2$ (*C*40-type hexagonal).

Ternary Phases

Early studies indicated two ternary compounds denoted as α and β in this system. The existence of α phase (redesignated as τ_1) was confirmed by [2007Che]. It occurs at the composition $Cr_4Al_{13}Si_4$ and belongs to the $F\bar{4}3m$ space group with the lattice parameter a = 1.09270 nm [2007Che]. Whereas the earlier studies indicated that α (τ_1) forms peritectically at 710 °C, [2007Che] found this phase to be stable at 800 °C. The second phase β is a solid solution based on $CrSi_2$.

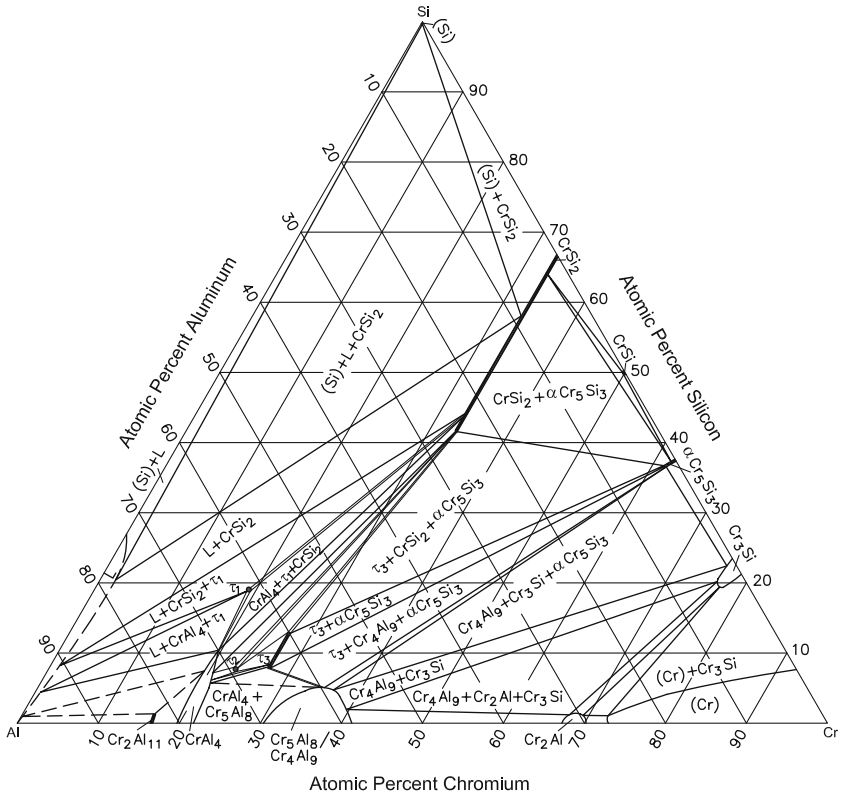

Fig. 1 Al-Cr-Si isothermal section at 800 °C [2007Che]

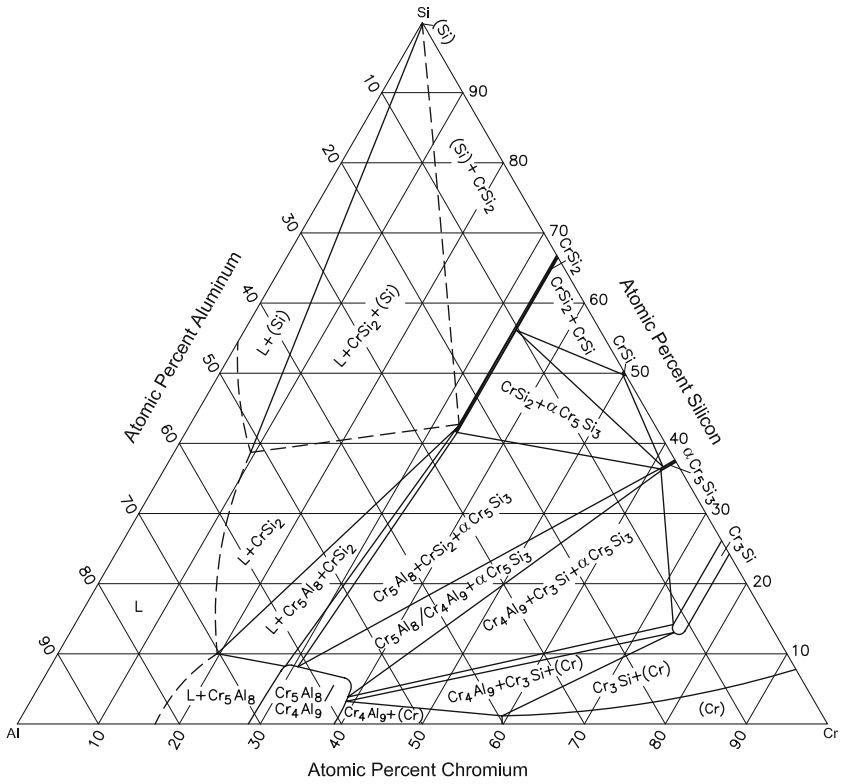

Fig. 2 Al-Cr-Si isothermal section at 1100 °C [2004Gup]

In their recent studies, [2007Che] found two more ternary phases at 800 °C, not reported in the earlier literature and designated them as τ_2 and τ_3. Cr_3Al_9Si (τ_2) is Mn_3Al_9Si-type hexagonal and has the lattice parameters of a = 0.75346 nm and c = 0.78393 nm. $Cr_4(Al,Si)_{11}$ (τ_3) is Mn_4Al_{11}-type triclinic. At $Cr_{27}Al_{63}Si_{10}$, it has the parameters a = 0.51260 nm, b = 0.89802 nm, c = 0.50472 nm, α = 89.775°, β = 100.71°, and γ = 106.605°.

Isothermal Sections

With starting metals of 99.99% Al, 99.99% Cr, and 99.9999% Si, [2007Che] arc-melted under Ar atm 36 ternary alloys. The samples were annealed at 800 °C for at least 2 weeks and quenched in water. The phase equilibria were studied by optical and scanning electron metallography and x-ray powder diffraction. Phase compositions were determined with energy dispersive x-ray analysis.

The isothermal section constructed by [2007Che] at 800 °C is shown in Fig. 1. All three ternary phases τ_1, τ_2, and τ_3 are present. Whereas τ_1 and τ_2 have a fixed composition, τ_3 has a range of 60-65 at.% Al and 13-8 at.% Si, at constant Cr content. Among the binary phases $CrSi_2$ dissolves up to 25 at.% Al at constant Cr content. Cr_5Si_3, CrSi, and Cr_3Si dissolve up to 1.8, ~0, and 4.1 at.% Al, respectively. Cr_2Al, Cr_5Al_8, and $CrAl_4$ dissolve 1.7, 5.6, and 10.4 at.% Si, respectively.

With starting metals of 99.999% Al, 99.99% Cr and 99.999% Si, [2004Gup] prepared diffusion couples of an Al-Si eutectic alloy and Cr. The diffusion couples were annealed at 1100, 1000, 900, and 800 °C for 1, 2, 4, and 16 h, respectively and quenched in ice-water mixture. It may be noted that, at the investigated temperatures, one member of the couple is in the liquid state. The phase equilibria were studied by optical metallography and electron probe microanalysis. The phase identification was based solely on microstructural observations and the measured phase composition. No structural studies were done. None of the isothermal sections constructed by [2004Gup] at 1100, 1000, 900, and 800 °C depicts a ternary compound. [2004Gup] cited the earlier literature, which showed that the ternary phase α (τ_1) forms at 710 °C. Thus the results of [2007Che] and [2004Gup] are contradictory. Figure 2 shows tentatively the isothermal section of [2004Gup] at 1100 °C, where we can expect that no ternary phase will be stable. The phases of Cr_5Al_8 and Cr_4Al_9 are shown as one region in Fig. 2.

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