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Al-Cr-Ni (Aluminum-Chromium-Nickel)

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The earlier reviews of this ternary system were those of [1984Mer], [1991Rog], and [1995Vil]. [2004Vel] updated the data reviewed by [1991Rog]. An update by [2006Rag] presented a computed liquidus projection, compared several isothermal sections of [1999Hua] and [2001Dup] and gave vertical sections along the NiAl-Cr and Ni_3Al-'Ni_3Cr' joins. An isothermal section at 1150 °C for Al-lean alloys determined by [2006Kit] was reviewed briefly by [2008Rag]. A recent update on this system by [2009Rag] reviewed the new experimental data of [2008Gru1] and [2008Wei] and presented isothermal sections at 1150, 1025, 1000, 900 and 700 °C and a liquidus projection, all for Al-rich alloys. The present update will be limited to the extension by [2009Gru] of the study of [2008Gru1] to 800 and 700 °C.

Binary Systems

The Al-rich end of the Al-Cr phase diagram was investigated recently by [2008Gru2]. The intermediate phases in the system are: $CrAl_7$ (V_7Al_{45}-type monoclinic, denoted θ), Cr_2Al_{11} ($CrAl_5$-type monoclinic, denoted η), $CrAl_4$ (hexagonal, $P6_3/mmc$, denoted μ), $CrAl_3$ (ν), Cr_2Al ($MoSi_2$-type tetragonal) and an unconfirmed low-temperature phase X at 75 at.% Cr. Between 30 and 41 at.% Cr, the high-temperature phase denoted γ_1 (Cu_5Zn_8-type, cubic) transforms on cooling via a second-order transition to γ_2(Cr_5Al_8-type, rhombohedral). The Al-Ni phase diagram [1993Oka] shows five intermediate phases: $NiAl_3$ (Fe_3C-type orthorhombic), Ni_2Al_3 ($D5_{13}$-type hexagonal, denoted δ), NiAl ($B2$, CsCl-type cubic, denoted β), Ni_5Al_3 (Ga_3Pt_5-type orthorhombic), and Ni_3Al ($L1_2$, $AuCu_3$-type cubic, denoted γ′). The Cr-Ni phase diagram [Massalski2] is of the simple eutectic type, with Ni dissolving up to ~50 at.% Cr and Cr dissolving up to ~32 at.% Ni.

Ternary Isothermal Sections

With starting metals of unspecified purity, [2009Gru] induction-melted 28 Al-rich ternary alloys under Ar atm. The alloys were annealed at 800 °C up to 1320 h or at

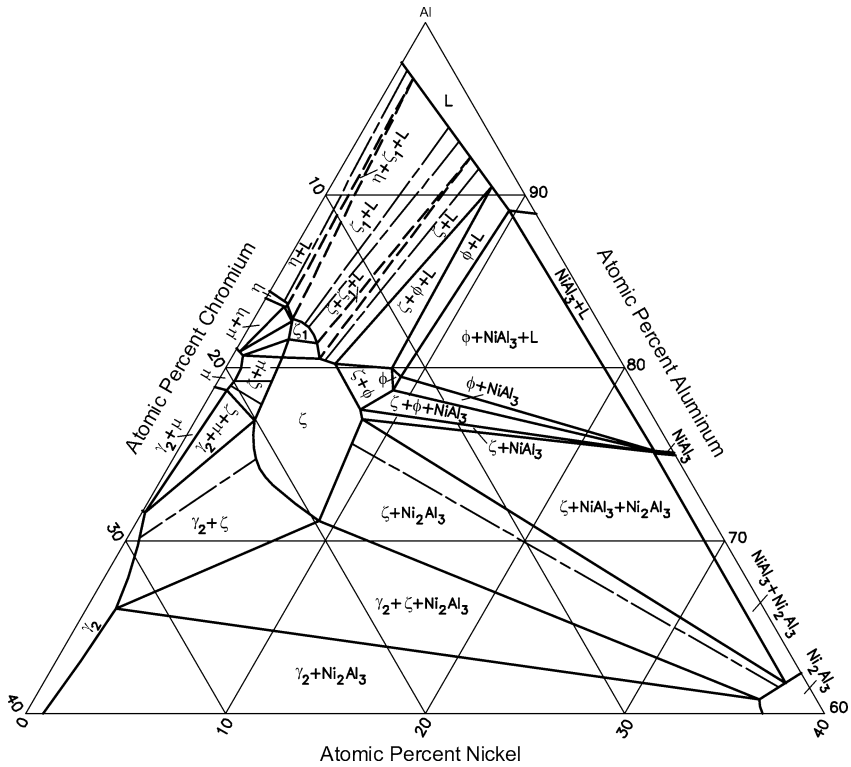

Fig. 1 Al-Cr-Ni isothermal section at 800 °C for Al-rich alloys [2009Gru]

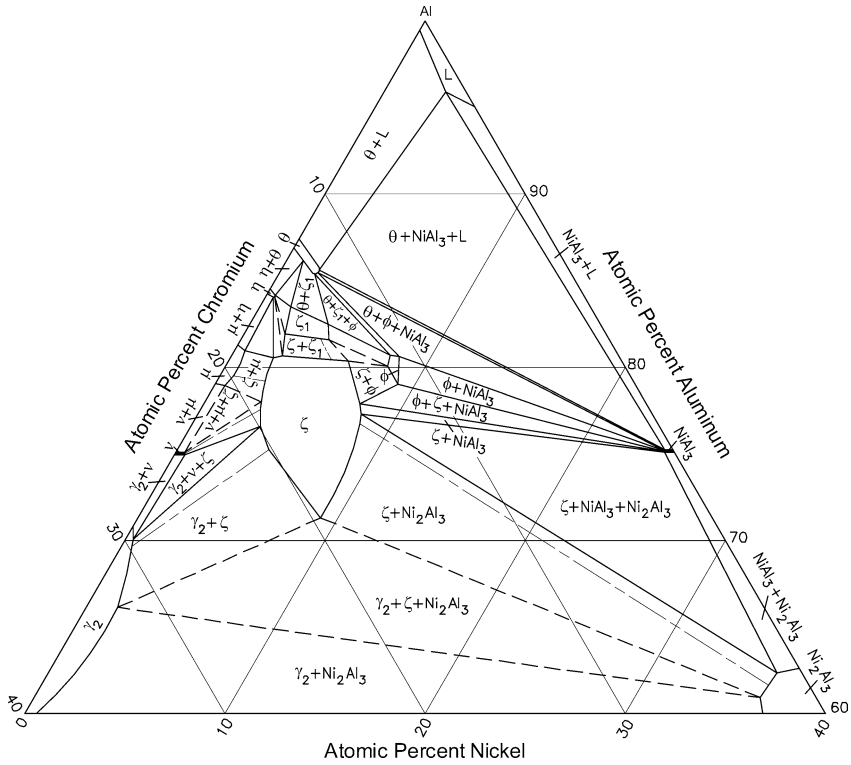

Fig. 2 Al-Cr-Ni isothermal section at 700 °C for Al-rich alloys [2009Gru]

700 °C up to 1703 h and quenched in water. The phase equilibria were studied with x-ray powder diffraction and by scanning and transmission electron microscopy. The local phase compositions were determined by energy dispersive x-ray analysis. Differential thermal analysis was carried out on selected samples at heating/cooling rates of 10-50°C/min.

The isothermal sections constructed by [2009Gru] at 800 and 700 °C are shown in Fig. 1 and 2. Three ternary phases are present at these temperatures. The previously known phase ζ (denoted as τ_1 by [2008Wei]; hexagonal, space group $P6_3/m$) has a homogeneity range approximately the same as found at 900 °C [2008Gru1]. The structurally related phase ζ_1 (labeled τ_3 by [2008Wei]) exhibited superstructure reflections. It has rhombohedral symmetry, $R3$ or $R\bar{3}$, with hexagonal parameters of a = 1.77 nm and c = 8.04 nm [2009Gru]. It is a separate phase around the composition $Al_{82}Ni_3Cr_{15}$, forming tie-lines with ζ [2009Gru]. The third ternary phase ϕ found earlier at 700 °C by [2008Wei] was labeled τ_2, without resolving the crystal structure. It forms below 835 °C and has a composition around $Al_{80}Ni_9Cr_{11}$. It has monoclinic symmetry ($P2_1$ or $P2_1/m$; a = 1.34 nm, b = 1.255 nm, c = 1.255 nm and $\beta \approx 100°$) [2009Gru]. At 800 °C (Fig. 1), the ternary solubility in the Al-Cr binary compounds and $NiAl_3$ is about 1 at.%. Ni_2Al_3 (δ) dissolves up to ~3 at.% Cr [2009Gru]. At 700 °C (Fig. 2), in addition to the phases found at 800 °C, $CrAl_7$ (θ) and $CrAl_3$ (ν) are present. The θ phase dissolves 2 at.% Ni.

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