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

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The report of [1956Tay] on this quaternary system depicts pseudoternary sections on the Ni_3Al-'Ni_3Cr'-Ni_3Ti plane and perspective views of the composition tetrahedron at 1000 and 750 °C. Recently, [2004Pic] reported new experimental data on Ni-rich alloys.

Binary Systems

For brief descriptions of the Al-Cr, Al-Ti, and Cr-Ti phase diagrams, see the Al-Cr-Ti update by [2005Rag1]. See [2005Rag2] for a description of the Al-Ni and Ni-Ti diagrams. The Cr-Ni phase diagram is of the simple eutectic type. An ordering reaction occurs in (Ni) at 590 °C around the Ni_2Cr composition.

Ternary Systems

The compilation of [1995Vil] on the Al-Cr-Ni system presents a partial liquidus projection and 11 isothermal sections between 1527 and 750 °C. For updates of the Al-Cr-Ti and Al-Ni-Ti systems, see [2005Rag1] and [2005Rag2], respectively. [1956Tay] gave partial isothermal sections at 1000 and 750 °C for Ni-rich alloys of the Cr-Ni-Ti system.

Quaternary Phase Equilibria

Using starting metals of 99.995% Al, 99.65% Cr, 99.95% Ni, and 99.9% Ti, [1956Tay] induction- or arc-melted about 45 Ni-rich quaternary alloys. The alloys were annealed at 1000 °C for 24 h or at 750 °C for 4 days and quenched in water. The phase equilibria were studied by metallography and x-ray powder diffraction. The pseudoternary sections on the Ni_3Al-'Ni_3Cr'-Ni_3Ti plane determined by [1956Tay] at 1000 and 750 °C are shown in Fig. 1. The lower boundary of the ($\gamma + \gamma' + Ni_3Ti$) region was found to be slightly curved, as the sections are not strictly pseudoternary. The $L1_2$-type cubic phase Ni_3Al (γ') dissolves more than 15 at.% Ti, which substitutes for Al. Ni_3Ti ($D0_{24}$-type hexagonal compound denoted η by [1956Tay]) is stoichiometric and shows no solubility for Al or Cr. Perspective views of the quaternary phase relationships at 1000 and 750 °C are shown in Fig. 2 [1956Tay]. In addition to the γ' and Ni_3Ti phases, NiAl and NiTi (both $B2$-type cubic) and Ni_2AlTi ($L2_1$-type cubic) are present. Not all tie-lines and three-phase regions are seen in Fig. 2. The only tie-tetrahedron ($\gamma + \gamma' + Ni_3Ti + Ni_2TiAl$) identified by [1956Tay] is indicated in Fig. 2(b).

Using pure metals, [2004Pic] prepared eight quaternary alloys. Four of these had a Ni content of ~76.5 at.%. The other four had ~71.5 at.% Ni. The Al, Cr, and Ti contents were in the ranges of 4-10, 5-14, and 5-19 at.%, respectively. The alloys were annealed at 1100 for 16 h or at 1000 °C for 112 h and quenched in water. The phase equilibria were studied with scanning and transmission electron microscopy and energy dispersive x-ray spectroscopy. The phases identified are γ (fcc), γ'($L1_2$ type cubic), Ni_3Ti ($D0_{24}$ type hexagonal), and body-centered cubic (bcc, denoted α by [2004Pic]). The experimental data were used to compute the phase equilibria by the CALPHAD method at 1100 and 1000 °C. The computed equilibria showed some additional phases, NiTi or NiAl ($B2$ type, denoted β by [2004Pic]) and Ni_2AlTi ($L2_1$-type cubic, denoted H by [2004Pic]), in regions where no experimental points were determined. The computed isothermal sections at 1100 °C and at constant Al contents of 76.5 and 71.5 at.% are shown in Fig. 3 and 4, respectively, along with four experimental points in each case. There is general agreement between the experimental results and the computed equilibria, with one or two small differences. The experimental homogeneity range of γ in Fig. 3 is smaller than the computed range.

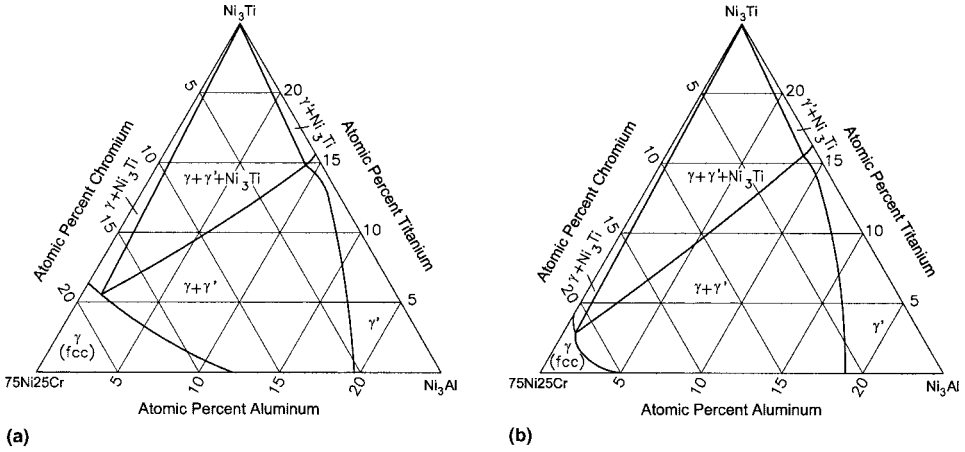

Fig. 1 Al-Cr-Ni-Ti pseudoternary sections on the Ni_3Al-'Ni_3Cr'-Ni_3Ti plane at (a) 1000 °C and (b) 750 °C [1956Tay]

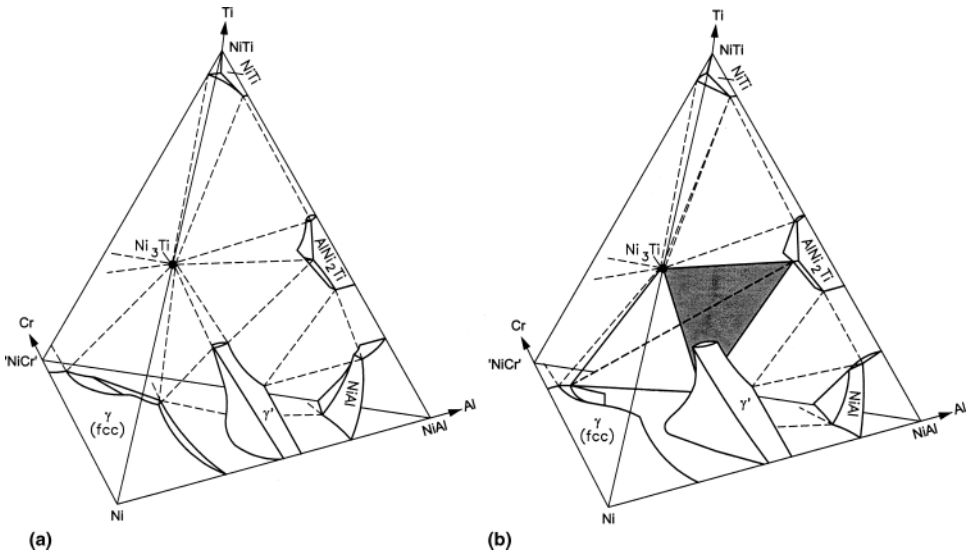

Fig. 2 Al-Cr-Ni-Ti perspective view of the phase relationships at (a) 1000 °C and (b) 750 °C [1956Tay]

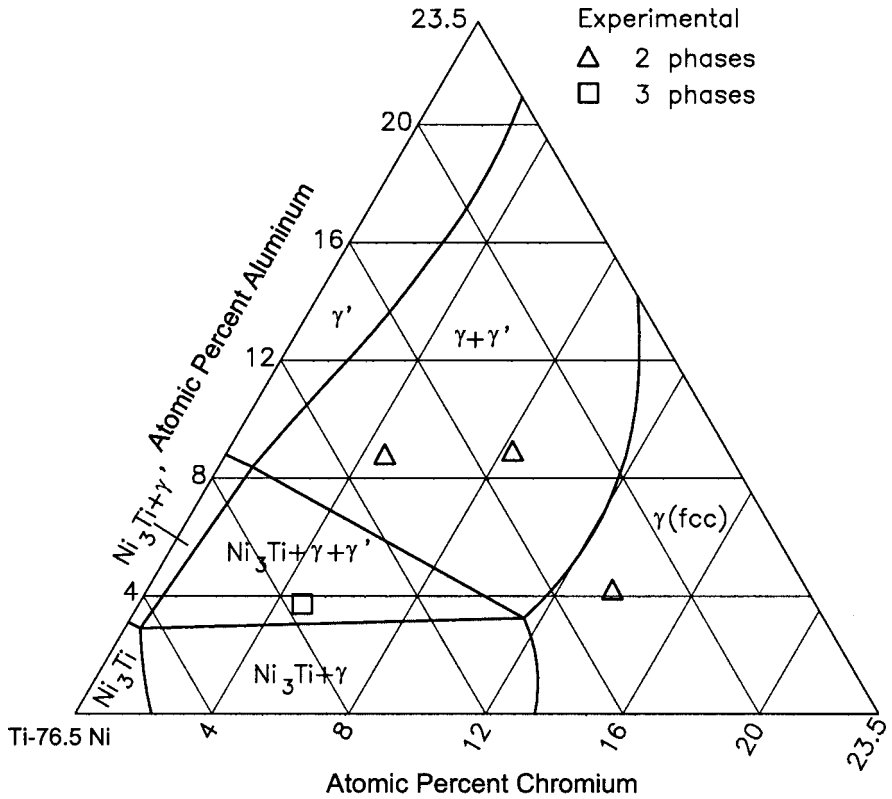

Fig. 3 Al-Cr-Ni-Ti computed isothermal section at 76.5 at.% Ni and 1100 °C [2004Pic]

In the four-phase field marked 1 in Fig. 4, the experimental point is expected to lie in the adjacent three-phase region to the left.

With starting metals of 99.99+ % Al, 99.7+ % Cr, 99.95+ % Ni, and 99.5+ % Ti, [2001Ish] arc-melted under Ar atm two quaternary alloys with a constant Ni content of 50 at.%. Diffusion couples prepared by welding were annealed at 1300 and 1200 °C. The compositions of the coexisting phases were measured by energy dispersive x-ray spectroscopy. Partial isothermal sections were constructed on the NiAl-Ni_2AlTi-'Ni_2AlCr' plane (Fig. 5). The $L2_1$-type phase exists in this system only along the NiAl-NiTi join. The $B2$-$L2_1$ two-phase field is drastically decreased by the addition of Cr. Beyond 5 at.% Cr, the bcc phase appears in the equilibrium.

[2001Dup] developed a thermodynamic data base for

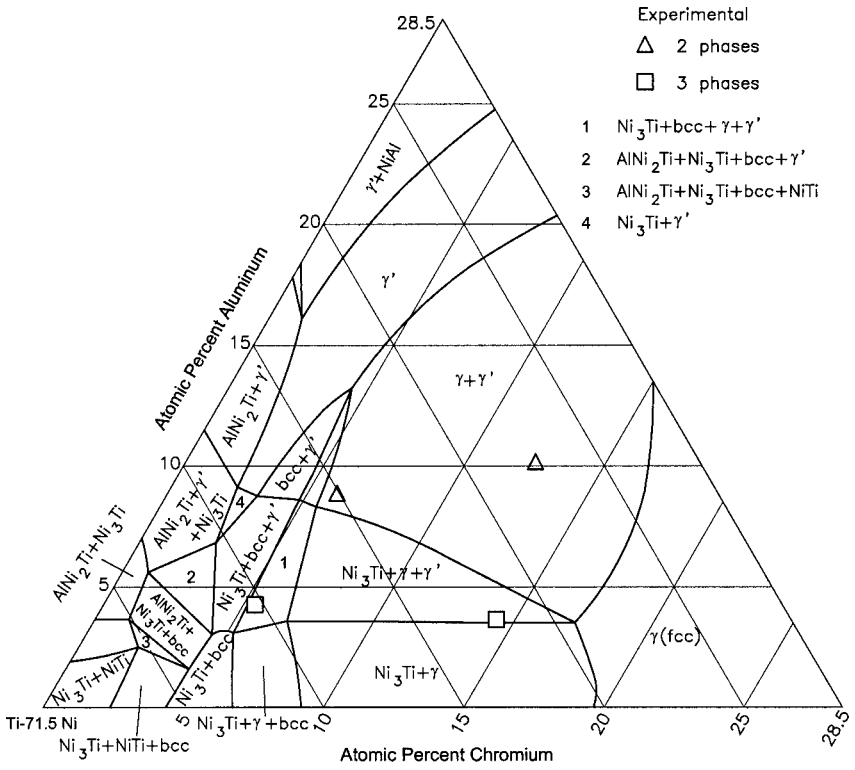

Fig. 4 Al-Cr-Ni-Ti computed isothermal section at 71.5 at.% Ni and 1100 °C [2004Pic]

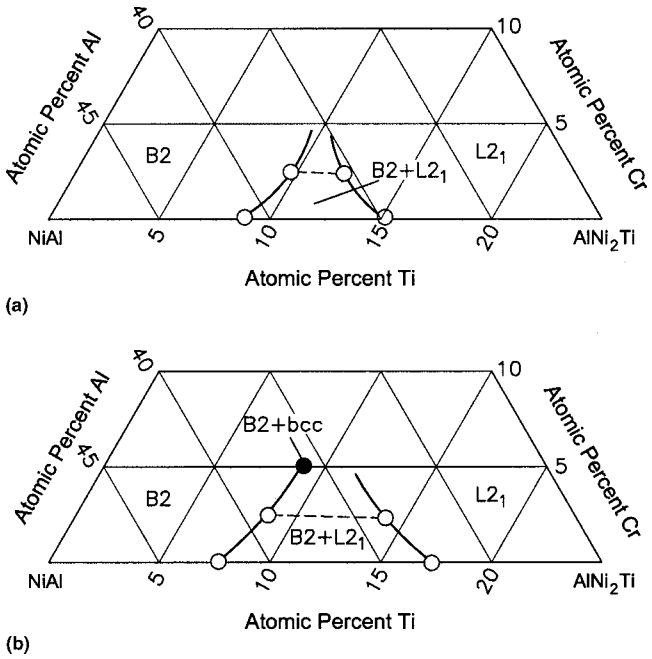

Fig. 5 Al-Cr-Ni-Ti partial isothermal sections at 50 at.% Ni and at (a) 1300 °C and (b) 1200 °C [2001Ish]

Ni-base superalloys, which includes the phases of this system.

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