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Al-Cr-Nb (Aluminum-Chromium-Niobium)

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The compilation of [1995Vil] from previous studies of this ternary system shows two isothermal sections at 1500 and 1000 °C. More recently, [2001Mah] and [2004Zha] redetermined the isothermal section at 1000 °C. [2006Sou] reported a partial liquidus projection in the Nb-poor region.

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]. The Al-Nb phase diagram [Massalski2] depicts three intermediate phases: Nb_3Al ($A15$, Cr_3Si-type cubic), Nb_2Al ($D8_b$, σCrFe-type tetragonal), and $NbAl_3$ ($D0_{22}$, $TiAl_3$-type tetragonal). The Cr-Nb phase diagram [Massalski2] shows two

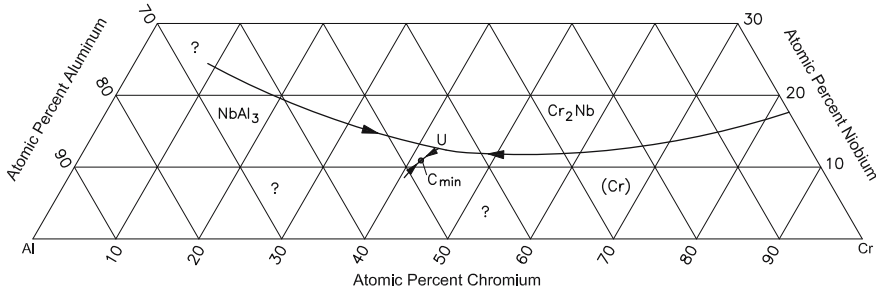

Fig. 1 Al-Cr-Nb partial liquidus projection for Nb-lean alloys [2006Sou]

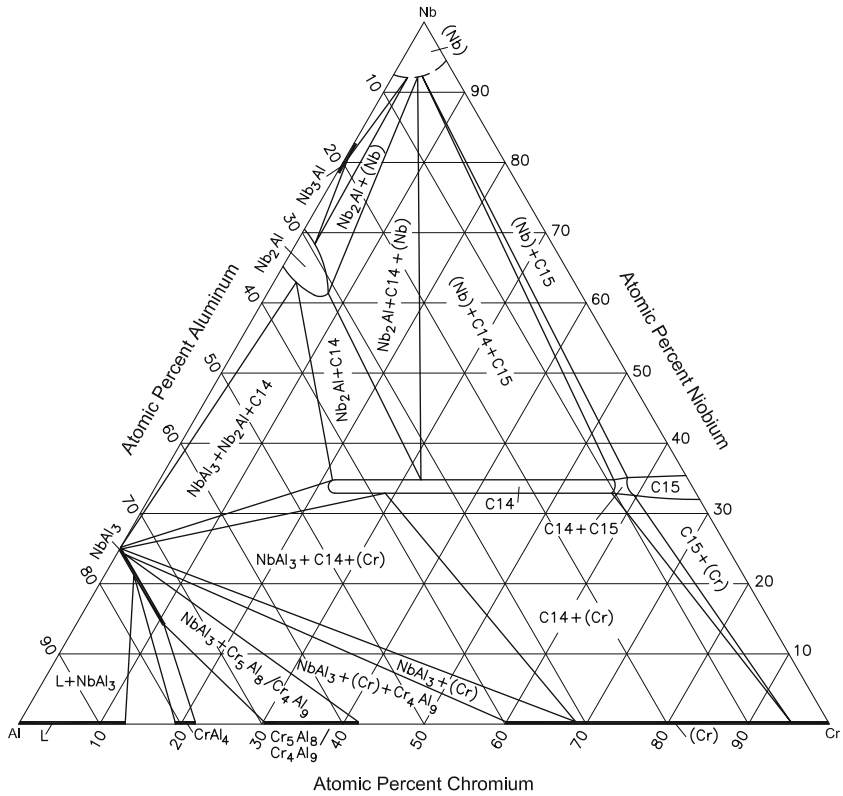

Fig. 2 Al-Cr-Nb isothermal section at 1000 °C [2001Mah, 2004Zha]

modifications of Cr_2Nb. βCr_2Nb has the *C*14, $MgZn_2$-type hexagonal structure. The low-temperature modification αCr_2Nb has the *C*15, $MgCu_2$-type cubic structure.

Ternary Phase Equilibria

With starting metals of 99.97% Al, 99.996% Cr, and 99.99% Nb, [2006Sou] arc-melted 10 ternary compositions in the Nb-lean region. The alloys were studied with scanning electron microscopy, x-ray powder diffraction, energy dispersive spectroscopy, and differential thermal analysis at a heating/cooling rate of 10 °C/min. The partial liquidus projection constructed by [2006Sou] is shown in Fig. 1. The phases of primary crystallization in this region are Cr_2Nb, $NbAl_3$, and (Cr). Subsequent to solidification, (Cr) undergoes a solid-state transformation to Cr_2Al, which appears in the microstructures examined by [2006Sou]. A U-type transition reaction L + $Cr_2Nb \leftrightarrow NbAl_3$ + (Cr) is seen. The product liquidus line L + (Cr) + $NbAl_3$ from this reaction passes through a minimum C_{min} at ~1350 °C [2006Sou]. The liquidus projection near the Al-Cr side is not defined in Fig. 1. A number of univariant liquidus lines originate along this line.

With starting metals of 99.5% Al, 99.5% Cr, and 99.8% Nb, [2001Mah] employed direct reaction calorimetry to study the phase quilibria of this system. Powders of the metals were mixed, pressed into small pellets and dropped into the calorimeter crucible to measure the heat evolved. Liquid formation was avoided by choosing the appropriate temperature range. The reacted samples were subsequently annealed at the temperature of interest for 1 week and quenched in water. They were examined by x-ray diffraction and electron probe microanalysis. An isothermal section was constructed at 1000 °C.

More recently, [2004Zha] prepared a diffusion-multiple which was comprised of four members Cr, Nb, $NbSi_2$, and $NbAl_3$. The diffusion anneal was done at 1000 °C for 2000 h, followed by water quenching. The structural and composition measurements were carried out near the tri-junction of Cr, Nb, and $NbAl_3$, using electron backscatter diffraction and electron probe microanalysis. A partial isothermal section at 1000 °C was constructed. Figure 2 shows a full isothermal section at 1000 °C, obtained by combining the results of [2001Mah], [2004Zha], and the accepted binary data. The high temperature phase βCr_2Nb (C14) is stabilized by the addition of Al and appears in the ternary region in Fig. 2. It dissolves as much as 45 at.% Al. The three-phase fields *C*14 + *C*15 + (Nb) and *C*14 + *C*15 + (Cr) were clearly identified by [2004Zha].

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