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Al-Ni-Rh (Aluminum-Nickel-Rhodium)

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Very recently, [2007Prz] investigated the phase relationships in the Al-rich region of this ternary system and presented partial isothermal sections at 1080, 1000, 900, and 800 °C. Besides the quasicrystalline decagonal phase D, a ternary phase of hexagonal symmetry labeled χ and another phase labeled *x* of unknown structure were found.

Binary Systems

The Al-Ni phase diagram [1993Oka] shows five intermediate phases: $NiAl_3$ ($D0_{11}$, Fe_3C-type orthorhombic), Ni_2Al_3 ($D5_{13}$-type hexagonal, denoted δ), NiAl (*B*2, 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 Al-Rh phase diagram [2006Kho] depicts the following intermediate phases: Rh_2Al_9 ($D8_d$, Co_2Al_9-type monoclinic), $Rh_{1-x}Al_3$ (orthorhombic, denoted O_1 or ε_{16}), $RhAl_3$ (orthorhombic, denoted O_2 or ε_6), Rh_2Al_5(c) (space group $Pm\bar{3}$, cubic, denoted C), Rh_2Al_5(h) ($D8_{11}$, Co_2Al_5-type hexagonal, denoted H), Rh_7Al_3 (monoclinic, denoted V) and RhAl (*B*2, CsCl-type cubic). Ni and Rh form a continuous face-centered cubic solid solution.

Ternary Phase Equilibria

The decagonal D phase has a basic periodicity of ~0.4 nm. The χ phase forms between $Al_{76}Ni_4Rh_{20}$ and $Al_{76}Ni_{13}Rh_{11}$ and has the hexagonal lattice parameters of $a = 1.2229$ nm and $c = 2.7158$ nm at the composition $Al_{76}Ni_8Rh_{16}$. The phase *x* of unknown structure forms around $Al_{70}Ni_{11}Rh_{19}$ [2007Prz].

With starting metals of 99.999% Al, 99.99% Ni, and 99.95% Rh, [2007Prz] induction-melted under Ar atm a number of alloys. The alloys were annealed at 1080-800 °C for 24-3168 h and quenched in water. The phase equilibria were studied with scanning and transmission electron microscopy, x-ray powder diffraction, energy dispersive x-ray spectroscopy, and differential thermal analysis at heating/cooling rates of 10-50 °C per min. For each alloy, the phases identified and their compositions were listed. All the structurally related ε phases were clubbed together and labeled ε. The isothermal sections for Al-rich alloys constructed by [2007Prz] at 1080, 1000, 900, and 800 °C are redrawn in Fig. 1-4.

At 1080 °C (Fig. 1), the decagonal D phase is stable around the composition $Al_{71}Ni_{18}Rh_{11}$ and forms tie-lines with ε, Ni_2Al_3, and liquid. The *x* phase is present around $Al_{70}Ni_{11}Rh_{19}$. Ni_2Al_3 dissolves up to 4 at.% Rh. The ε, C, and V phases dissolve up to 12.5, 10.5, and 3 at.% Ni, respectively. The *B*2 phases NiAl and RhAl probably form a continuous solid solution (denoted *B*2), which extends up to 60 at.% Al [2007Prz].

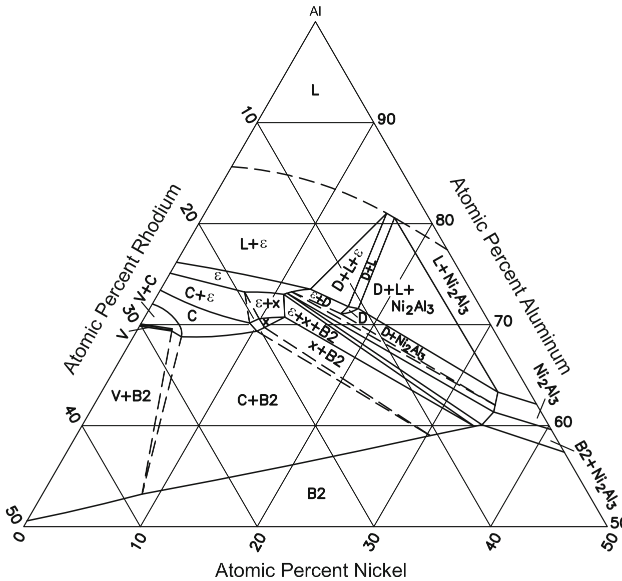

Fig. 1 Al-Ni-Rh isothermal section at 1080 °C for Al-rich alloys [2007Prz]

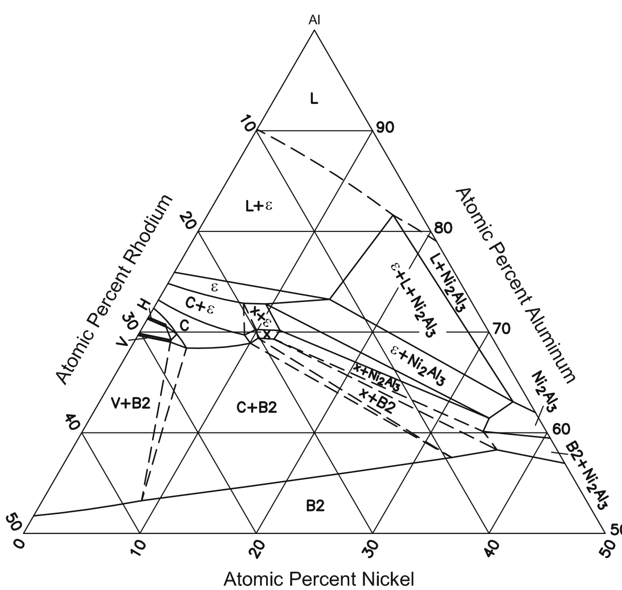

Fig. 2 Al-Ni-Rh isothermal section at 1000 °C for Al-rich alloys [2007Prz]

At 1000 °C (Fig. 2), the D phase is not stable. The third component solubility in ε and Ni_2A_3 has slightly increased, whereas it remains almost the same in C, V and *x* phases.

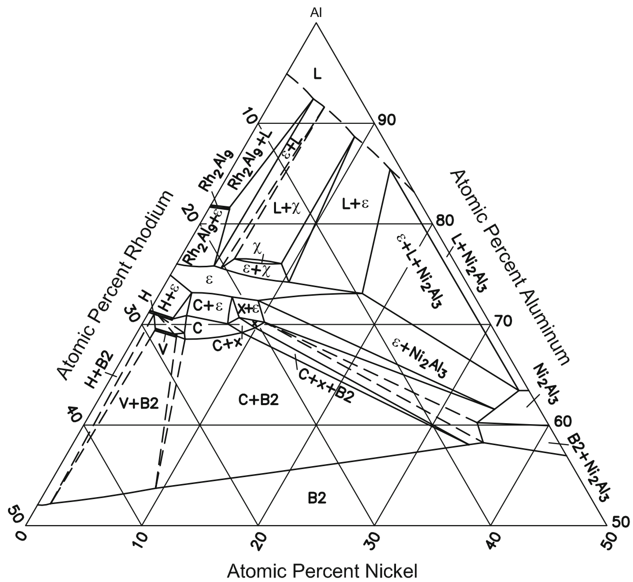

Fig. 3 Al-Ni-Rh isothermal section at 900 °C for Al-rich alloys [2007Prz]

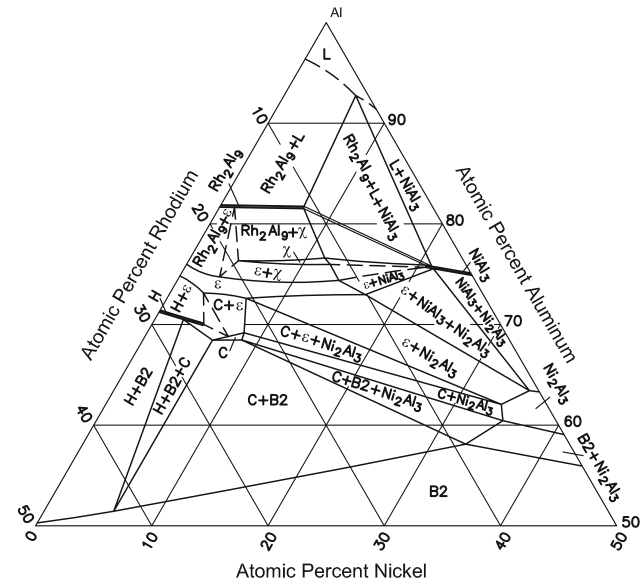

Fig. 4 Al-Ni-Rh isothermal section at 800 °C for Al-rich alloys [2007Prz]

The low-temperature phase H has appeared. At 900 °C (Fig. 3), Rh_2Al_9 is present and dissolves up to 2 at.% Ni. The C and V phases occur only in the ternary region and have ranges of ~3-9 and ~1-3 at.% Ni, respectively. The χ phase is present and has a Ni range of 5-9 at.%. At 800 °C (Fig. 4), the ε range is up to 17 at.% Ni. $NiAl_3$ is present and dissolves up to 3 at.% Rh. The homogeneity range of χ increases to 4-13 at.% Ni. The C phase region shrinks to a narrow strip between $Al_{69}Ni_6Rh_{25}$ and $Al_{69}Ni_8Rh_{23}$. The *x* phase is not stable at this temperature [2007Prz].

References

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