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Al-Ni-Re (Aluminum-Nickel-Rhenium)

V. Raghavan

The computed phase equilibria of this ternary system by [1999Hua] were reviewed in the update by [2006Rag]. The update presented a tentative liquidus projection, an isothermal section at 1040 °C for Ni-rich alloys and a vertical section along the NiAl-Re join. Recently, [2009Gru] investigated this system between 1030 and 700 °C and found a ternary phase in the Al-rich region. Earlier, [2007Sai] had determined a number of tie-lines at 1150 °C.

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 ($B2$, 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 Al-Re phase diagram [2008Bal, 2009Gru, 2009Oka] depicts the following intermediate phases: $Al_{12}Re$ ($Al_{12}W$-type cubic), Al_6Re (Al_6Mn-type orthorhombic), Al_4Re(HT) (monoclinic), Al_4Re(LT) (triclinic), Al_3Re, $Al_{11}Re_4$ ($Al_{11}Mn_4$-type triclinic), AlRe ($B11$, CuTi-type tetragonal), and $AlRe_2$ ($C11_b$, $MoSi_2$-type tetragonal). The Ni-Re phase diagram is of the simple peritectic type [Massalski2].

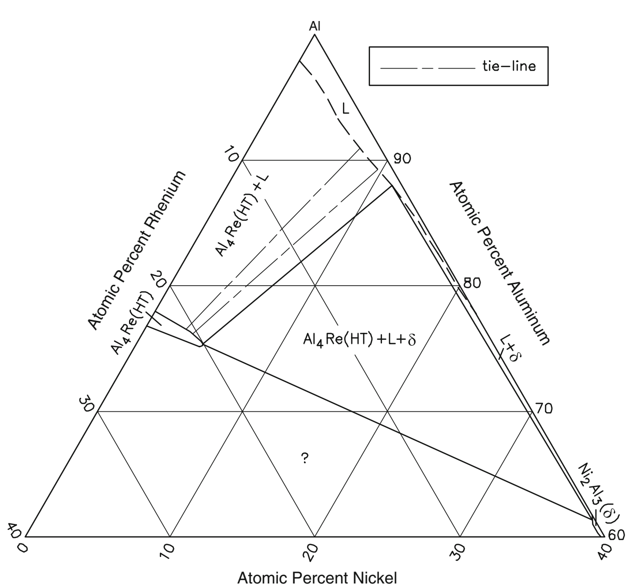

Fig. 1 Al-Ni-Re partial isothermal section for Al-rich alloys at 1030 °C [2009Gru]

Ternary Isothermal Sections

With starting metals of 99.999% Al, 99.98% Ni, and 99.95% Re, [2009Gru] levitation-melted about 10 Al-rich

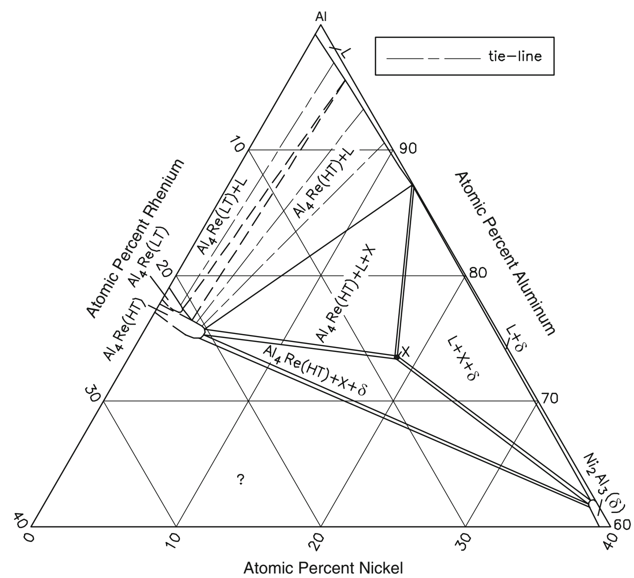

Fig. 2 Al-Ni-Re partial isothermal section for Al-rich alloys at 870 °C [2009Gru]

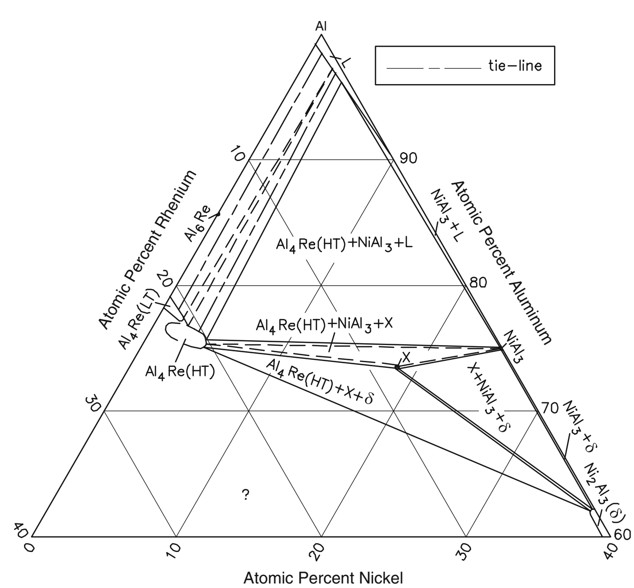

Fig. 3 Al-Ni-Re partial isothermal section for Al-rich alloys at 800 °C [2009Gru]

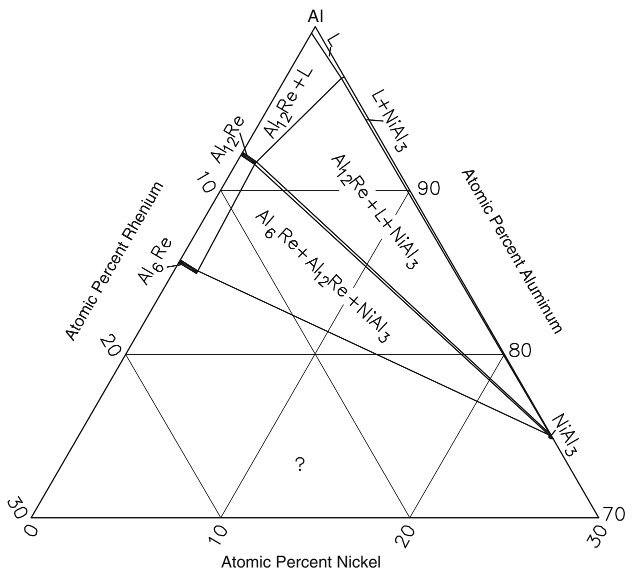

Fig. 4 Al-Ni-Re partial isothermal section for Al-rich alloys at 700 °C [2009Gru]

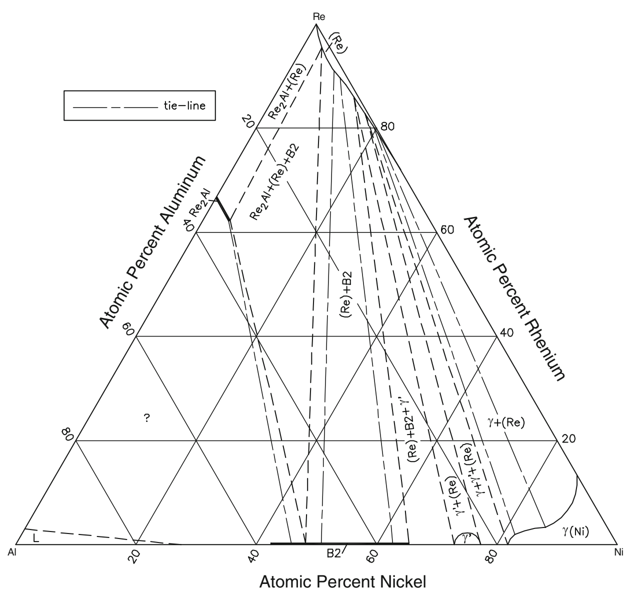

Fig. 5 Al-Ni-Re tentative partial isothermal section at 1150 °C [after 2007Sai]

ternary alloys under Ar atm. The alloys were annealed at 1030, 870, 800, and 700 °C for 140, 210, 1313, and 306 h, respectively. The phase equilibria were studied with x-ray powder diffraction, scanning and transmission electron microscopy, energy dispersive x-ray analysis, and differential thermal analysis at heating/cooling rates of 20 °C per min. The partial isothermal sections constructed by [2009Gru] at 1030, 870, 800, and 700 °C are shown in Fig. 1-4. At 1030 °C (Fig. 1), liquid, Al_4Re(HT), and Ni_2Al_3 are present. No ternary phase was found. Al_4Re(HT) dissolves up to ~4.5 at.% Ni. The solubility of Re in Ni_2Al_3 is less than 0.5 at.%. At 870 °C (Fig. 2), the ternary phase X is present around the composition $Al_{73.5}Ni_{18.5}Re_8$. It has orthorhombic symmetry (*Pbm*2 or $Pb2_1m$ or *Pbmm*), with the lattice parameters of $a = 1.0048$ nm, $b = 1.5423$ nm, and $c = 0.8367$ nm [2009Gru]. It forms peritectically at 888 °C. Al_4Re(LT) dissolves at least 1.5 at.% Ni at 870 °C. The tie-triangle between Al_4Re(HT), Al_4Re(LT) and liquid shown in Fig. 2 is provisional. At 800 °C (Fig. 3), $NiAl_3$ is present and forms tie-lines with Al_4Re(HT). A narrow tie-triangle (not shown) is expected between Al_6Re, Al_4Re(LT) and liquid. At 700 °C (Fig. 4), only two samples with 90 and 85 at.% Al were investigated by [2009Gru]. The solubility of Ni in $Al_{12}Re$ and Al_6Re is about 1 at.%.

[2007Sai] arc-melted six ternary alloys containing 36.4-81.8 Ni, 9.1-54.5 Al, and 9.1 Re (at.%). The alloys were annealed at 1150 °C for 1000 h and quenched in water. The phase compositions were measured with electron probe microanalyzer. The tie-lines of coexisting phases were listed. Using the tie-line results and the binary phase diagrams as a guide, a tentative isothermal section at 1150 °C is drawn in Fig. 5. No ternary phases were found at 1150 °C. The maximum solubility of Ni and Al in (Re) is 28 and 1.2 at.%, respectively.

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