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Al-Ni-Y (Aluminum-Nickel-Yttrium)

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The investigation of this ternary system by [1968Ros] presented an isothermal section at 1000 °C for Ni-rich alloys. Later studies by [1977Ryk] showed the existence of a number of ternary compounds in the Y-lean region at 800 °C. Subsequently, [1992Gla1], [1992Gla2], and [1993Gla] reported the structural characteristics of three additional Al-rich ternary compounds. A partial liquidus projection and an isothermal section at 500 °C for Al-rich alloys were determined by [2000Rag]. Recently, a thermodynamic description of this system was developed by [2009Gol], with emphasis on liquid-solid reactions.

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-Y phase diagram [Massalski2] has the following intermediate phases: αAl_3Y ($D0_{19}$, Ni_3Sn-type hexagonal), βAl_3Y (BaP_3-type rhombohedral), Al_2Y ($C15$, $MgCu_2$-type cubic), AlY (B_f, CrB-type orthorhombic), Al_2Y_3 (Al_2Zr_3-type tetragonal), and AlY_2 ($C23$, Co_2Si-type orthorhombic). The Ni-Y phase diagram [Massalski2] depicts the following stoichiometric compounds: $Ni_{17}Y_2$ ($Ni_{17}Th_2$-type hexagonal), Ni_5Y ($D2_d$, $CaCu_5$-type hexagonal), Ni_4Y, Ni_7Y_2 (Co_7Gd_2-type rhombohedral), Ni_3Y (Ni_3Pu-type rhombohedral), Ni_2Y ($C15$, $MgCu_2$-type cubic), NiY ($B27$, FeB-type orthorhombic), Ni_2Y_3 (tetragonal, $P4_12_12$), and NiY_3 ($D0_{11}$, Fe_3C-type orthorhombic).

Ternary Compounds

A number of ternary compounds in this system were first reported in a series of papers by Rykhal and coworkers, see [2000Rag] for a listing of these references. The structural characteristics of 13 ternary compounds known in this system were listed by [2000Rag] (not repeated here). In addition, [2004Vas] reported another ternary compound $Y_3Ni_5Al_{19}$ with the $Gd_3Ni_5Al_{19}$-type of structure. This compound is probably metastable. Earlier, [2000Rag] had ruled out the existence of this compound. In the Al-rich region (60-100 at.% Al) at 500 °C, four ternary compounds are present [2000Rag]: $Y_4Ni_6Al_{23}$ (monoclinic), YNi_3Al_9 ($ErNi_3Al_9$-type rhombohedral), $YNiAl_4$ (orthorhombic, space group *Cmcm*), and $YNiAl_3$ (orthorhombic, *Pnma*).

Ternary Phase Equilibria

With starting metals of 99.999% Al, 99.99% Ni and 99.9% Y, [2000Rag] induction-melted about 62 ternary alloys with Al content in the range of 60 to 98 at.%. The alloys were annealed at 500 °C for 2 weeks and slowly cooled to room temperature. The phase equilibria were

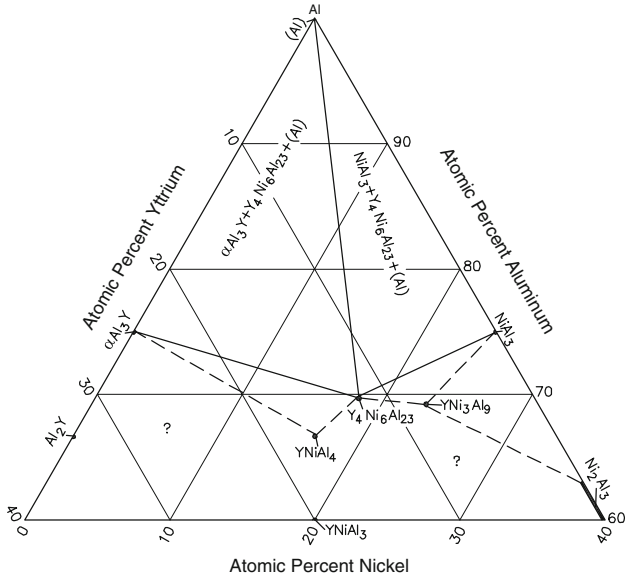

Fig. 1 Al-Ni-Y partial isothermal section at 500 °C [2000Rag]. Narrow two-phase regions are omitted

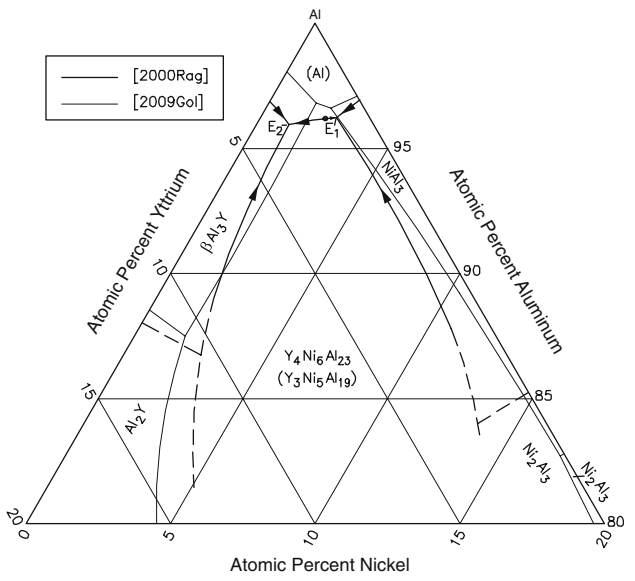

Fig. 2 Al-Ni-Y partial liquidus projection for Al-rich alloys [2000Rag, 2009Gol]

studied with x-ray powder diffraction, optical and scanning electron microscopy and electron probe microanalysis. The partial isothermal section constructed by [2000Rag] at 500 °C is shown in Fig. 1. The Al-rich region is dominated by two tie-triangles (Al) + αAl_3Y + $Y_4Ni_6Al_{23}$ and (Al) + $NiAl_3$ + $Y_4Ni_6Al_{23}$. Based on metallographic observations, a tentative liquidus projection was presented by [2000Rag], Fig. 2. The primary crystallization field of $Y_4Ni_6Al_{23}$ dominates the liquidus surface.

Recently, [2009Gol] carried out a thermodynamic analysis of the Al-rich region of this system. The liquidus projection computed by them for the Al-rich region is compared with the experimental results of [2000Rag] in Fig. 2. The agreement is satisfactory. [2009Gol], however, accepted $Y_3Ni_5Al_{19}$ as the ternary phase richest in Al, in preference to $Y_4Ni_6Al_{23}$. The ideal compositions of these two compounds are very close.

References

1968Ros: S. Rosen and J.A. Goebel, Phase Equilibria in the Nickel-Aluminum-Yttrium System at 1000 °C, *J. Less-Common Met.*, 1968, **16**, p 285-287

1977Ryk: R.M. Rykhal and O.S. Zarechnyuk, Isothermal Section at 800°C of Yttrium-Nickel-Aluminum Ternary System in the Range of 0-33.3 At.% of Yttrium, *Dopov. Akad. Nauk Ukr. RSR, Ser. A*, 1977, **39**(4), p 375-377, in Ukrainian

1992Gla1: R.E. Gladyshevskii and E. Parthe, Structure of Orthorhombic $YNiAl_3$, *Acta Crystallogr. Sect. C*, 1992, **C48**(2), p 229-232

1992Gla2: R.E. Gladyshevskii and E. Parthe, Structure of Monoclinic $Y_4Ni_6Al_{23}$, *Acta Crystallogr. Sect. C*, 1992, **C48**(2), p 232-236

1993Gla: R.E. Gladyshevskii, K. Cenzual, F.D. Flack, and E. Parthe, Structure of RNi_3Al_9 (R = Y, Gd, Dy, Er) with Either Ordered or Partially Ordered Arrangement of Aluminum-Atom Triangles and Rare-Earth-Metal Atoms, *Acta Crystallogr. Sect. B*, 1993, **B49**(3), p 468-474

1993Oka: H. Okamoto, Al-Ni (Aluminum-Nickel), *J. Phase Equilib.*, 1993, **14**(2), p 257-259

2000Rag: R. Raggio, G. Borzone, and R. Ferro, The Al-Rich Region in the Y-Ni-Al System: Microstructures and Phase Equilibria, *Intermetallics*, 2000, **8**, p 247-257

2004Vas: A.L. Vasilev, M. Aindow, M.J. Blackburn, and T.J. Watson, *Intermetallics*, 2004, **12**, p 349-362

2009Gol: W.J. Golumbfskie, S.N. Prins, T.J. Eden, and Z.K. Liu, Predictions of the Al-Rich Region of the Al-Co-Ni-Y System Based Upon First-Principles and Experimental Data, *CALPHAD*, 2009, **33**, p 124-135