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Al-Hf-Ni (Aluminum-Hafnium-Nickel)

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The previous review of this system by [1991Lee] presented an estimated liquidus projection and a reaction scheme for Ni-rich alloys, two isothermal sections at 1200 and 1000 °C from [1981Nas], and an isothermal section at 800 °C from [1969Mar]. The section at 800 °C depicts ten ternary compounds; see [1991Lee] for structural details. New data on this system include the determination of the equilibria near the Ni_3Al phase by [1997Nag] and the characterization of the (Ni) liquidus and solidus surfaces by [1999Miu].

Binary Systems

The Al-Hf system [1998Mur] depicts a number of intermediate phases: Hf_2Al (*C*16, $CuAl_2$-type tetragonal), Hf_3Al_2 (Zr_3Al_2-type tetragonal), Hf_4Al_3 (Zr_4Al_3-type hexagonal), HfAl (B_f, CrB-type orthorhombic), Hf_2Al_3 (Zr_2Al_3-type orthorhombic), $HfAl_2$ (*C*14, $MgZn_2$-type hexagonal), $\beta HfAl_3$ ($D0_{23}$, Zr_3Al-type tetragonal), and $\alpha HfAl_3$ ($D0_{22}$, Ti_3Al-type tetragonal). A thermodynamic description of the Al-Hf phase diagram was given by [2002Wan]. 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), NiAl (*B*2, CsCl-type cubic, also denoted β), Ni_5Al_3 (Ga_3Pt_5-type orthorhombic), and Ni_3Al ($L1_2$, $AuCu_3$-type cubic; also denoted γ′). The Hf-Ni phase diagram [2001Wan] depicts the intermediate phases: Hf_2Ni (*C*16, $CuAl_2$-type tetragonal), αHfNi (B_f, CrB-type orthorhombic), βHfNi, Hf_9Ni_{11}(tetragonal), Hf_7Ni_{10} (orthorhombic), Hf_3Ni_7 (triclinic), Hf_8Ni_{21} (triclinic), $\beta HfNi_3$ (hexagonal), $\alpha HfNi_3$ ($BaPb_3$-type rhombohedral), Hf_2Ni_7 (monoclinic), and $HfNi_5$ ($C15_b$, $AuBe_5$-type cubic).

Ternary Phase Equilibria

With starting metals of 99.999% Al, 99.9% Hf, and 99.9% Ni, [1997Nag] arc melted under Ar atmosphere ten alloys with Ni range of 72.5 to 80 at.%, Al of 15 to 27 at.%, and Hf of 2.5 to 7.5 at.%. The final anneal was at 1130 °C for 7 to 20 days, followed by water quenching. The phase equilibria were studied by scanning electron microscopy with energy dispersive x-ray spectroscopy attachment and x-ray powder diffraction. The partial isothermal section constructed by them in the region of Ni_3Al (γ′) is redrawn in Fig. 1. Four phases were found in the alloy with 80 at.% Ni, 15 at.% Al, and 5 at.% Hf, even after prolonged annealing. [1997Nag] suggested a four-phase invariant plane of ($\gamma + \gamma' + HfNi_5 + Hf_2Ni_7$) at this temperature.

With starting metals of 99.99% Al, 95% Hf, and 99.95% Ni, [1999Miu] arc melted about 12 alloy compositions with Hf content up to 1.5 at.%. Differential thermal analysis (DTA) was carried out at a cooling rate of 10 °C/min. The (Ni) liquidus and solidus temperatures derived from DTA curves are shown in Fig. 2 as a function of Al and Hf contents. The solidus temperatures are tentative, as they were deduced from scattered DTA data.

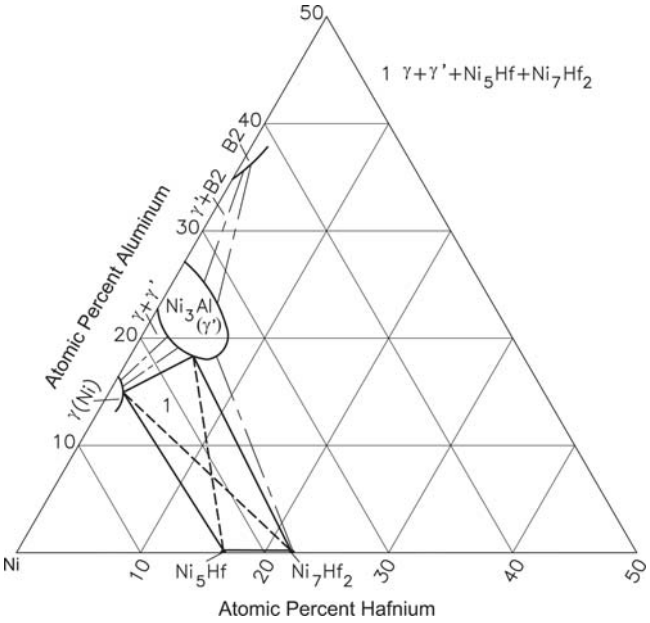

Fig. 1 Al-Hf-Ni partial isothermal section at 1130 °C [1997Nag]

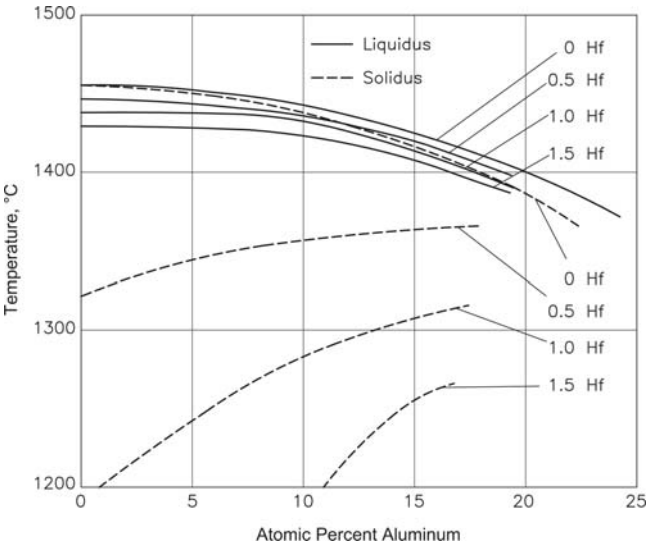

Fig. 2 Al-Hf-Ni liquidus and solidus temperatures of (Ni) [1999Miu]

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