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Al-Ni-Ti (Aluminum-Nickel-Titanium)

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The review of this ternary system by [1991Lee] presented a liquidus projection, a reaction scheme and isothermal sections at 1150, 900, and 800 °C. The update by [2005Rag] reviewed the results of [1999Hun] (experimental isothermal section at 900 °C) and of [1999Zen] (computed liquidus surface and computed isothermal sections at 1200, 900 and 800 °C). In his review of this system, [2006Sch1] came to the conclusion that the isothermal section at 900 °C is the only result known with reasonable completeness and confidence. More recently, [2007Sch] reinvestigated this system and presented an isothermal section at 1000 °C (omitting the Ti-rich corner), a partial isothermal section for the Ti corner at 900 °C, a liquid projection, and a reaction scheme. The results of [2007Sch] are reviewed in this update.

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′). Recently, [2006Sch2] carried out a new assessment of the Al-Ti system and presented a revised phase diagram. The intermediate phases in the system are: Ti_3Al ($D0_{19}$, Ni_3Sn-type hexagonal, denoted as α_2), TiAl ($L1_0$, AuCu-type tetragonal, denoted γ), $TiAl_2$ ($HfGa_2$-type tetragonal), $TiAl_3$ (HT) ($D0_{22}$-type tetragonal), and $TiAl_3$ (LT) (tetragonal, space group $I4/mmm$). Some of the previously known phases such as $Ti_{1-x}Al_{1+x}$, Ti_5Al_{11}, and Ti_3Al_5 were ruled out by [2006Sch2]. The Ni-Ti phase diagram depicts the following intermediate phases [2005Rag]: Ni_3Ti ($D0_{24}$-type hexagonal, denoted η), NiTi ($B2$, CsCl-type cubic), and $NiTi_2$ (cubic).

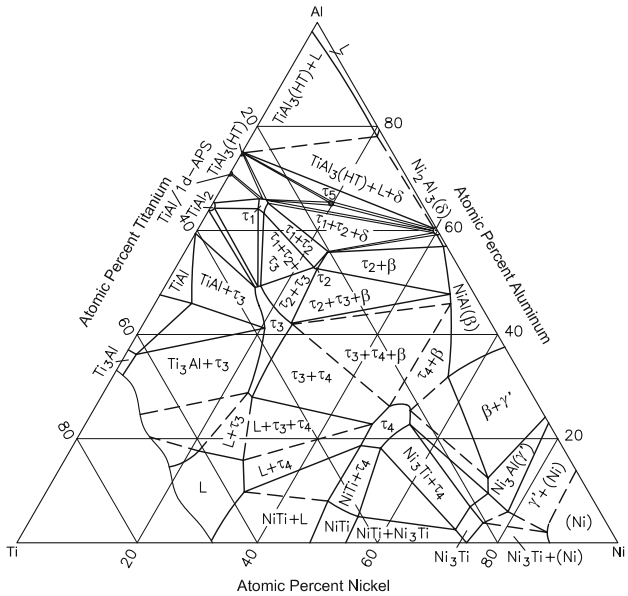

Fig. 1 Al-Ni-Ti isothermal section at 1000 °C [2007Sch]

Ternary Phases

The structural characteristics of four known ternary phases in this system were summarized by [2005Rag]. The nominal compositions of the phases are: $Al_{13}Ni_2Ti_5$ (τ_1), Al_2NiTi (τ_2), Al_3NiTi_2(τ_3), and $AlNi_2Ti$ (τ_4). In addition to the above, [2007Sch] found an Al-rich (decagonal?) phase (denoted τ_5) at the composition $Al_{65}Ni_{20}Ti_{15}$. The phases τ_3 and τ_4 melt congruently at 1289 and ∼1500 °C respectively. The other ternary phases τ_1, τ_2, and τ_5 melt incongruently at 1347, 1225, and 1107 °C respectively [2007Sch].

Ternary Phase Equilibria

With starting metals of 99.99% Al, 99.9+% Ni and 99.98% Ti, [2007Sch] arc- melted a number of alloys and annealed them between 1000 and 600 °C for at least two weeks followed by quenching. The phase equilibria were studied with x-ray powder diffraction and energy dispersive x-ray analysis on a scanning electron microscope. Differential thermal analysis (DTA) was carried out at a heating rate of 5 °C/min. The isothermal sections constructed by

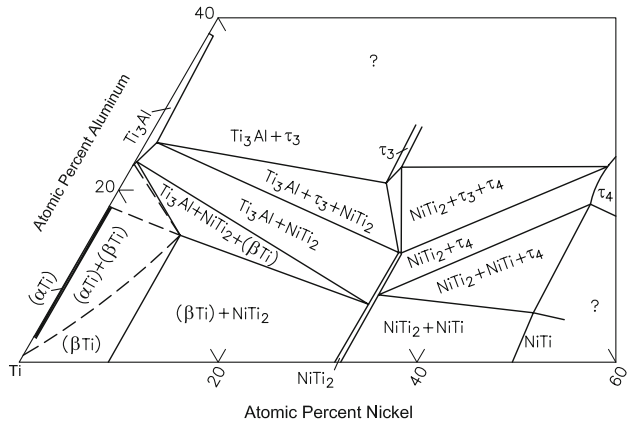

Fig. 2 Al-Ni-Ti partial isothermal section at 900 °C [2007Sch]

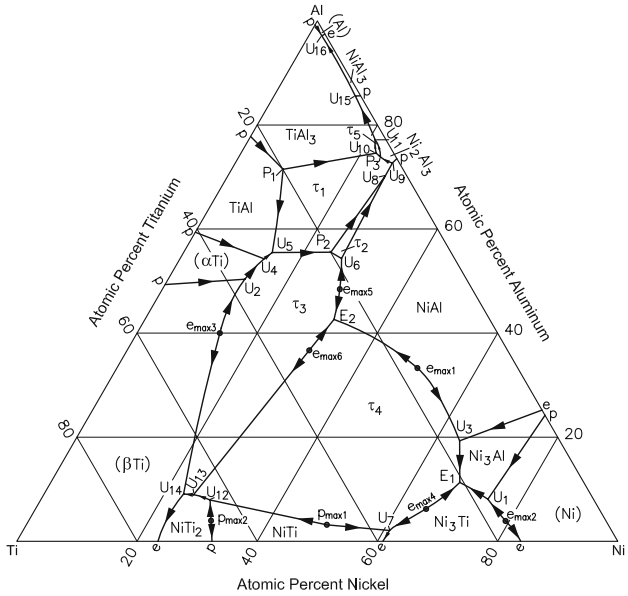

Fig. 3 Al-Ni-Ti liquidus projection [2007Sch]

[2007Sch] at 1000 and 900 °C are redrawn in Fig. 1 and 2. At 1000 °C, Fig. 1 shows the phase equilibria, omitting the Ti corner. The five ternary phases τ_1 to τ_5 are present. The homogeneity ranges of τ_1 to τ_4 measured by [2007Sch] agree well with previous data. The NiAl-τ_3 and τ_1-τ_3 tie-lines found by [2007Sch] at 1000 °C differ from the earlier findings. At 900 °C (Fig. 2), the phase equilibria are depicted near the Ti corner [2007Sch]. The tie-line between $NiTi_2$ and τ_3 at 900 °C found by [2007Sch] disagrees with the findings of [1999Hun], see Fig. 2 in [2006Rag]. The liquidus projection determined by [2007Sch] is redrawn in Fig. 3 and is in qualitative agreement with the tentative projection reviewed by [2005Rag], except for the presence of the primary crystallization region of τ_5. Fig. 3 can be taken as the updated version, as [2007Sch] plotted the data from DTA measurements. Reaction schemes covering different composition regions were also given by [2007Sch].

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