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The Ni-Ti-Y (Nickel-Titanium-Yttrium) System

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Introduction

Very little work has been done in the Ni-Ti-Y system. An isothermal section at low temperature has been established and reported here.

Binary Systems

The Ni-Ti system (Fig. 1) [1991Nas] has three intermediate phases, Ni_3Ti (ρ), NiTi (β) and $NiTi_2$ (π), of which the ρ and the β phases melt congruently at 1380 and 1310 °C, respectively. The π phase forms through a peritectic reaction L + β ↔ π at 984 °C. Three eutectic and two eutectoid reactions occur: L ↔ βTi + π at 742 °C, L ↔ β + ρ at 1118 °C, L ↔ ρ + γ at 1304 °C, βTi ↔ αTi + π at 983 °C, and β ↔ π + ρ at ~630 °C.

The Ni-Y system (Fig. 2) [1991Nas] has nine intermediate phases: $Ni_{17}Y_2$ (δ), Ni_5Y (η), Ni_4Y (λ), Ni_7Y_2 (θ), Ni_3Y (ι), Ni_2Y (τ), NiY (ν), Ni_2Y_3 (ζ), and NiY_3 (ξ). All these phases are of invariant compositions at all temperatures. The η and ν phases melt congruently at 1430 and 1070 °C, respectively. All the other phases form through peritectic reactions: L + η ↔ δ at 1330 °C, L + η ↔ λ at 1340 °C, L + λ ↔ θ at 1698 °C, L + θ ↔ ι at 1237 °C, L + ι ↔ τ at 1100 °C, L + ν ↔ ζ at 820 °C, and L + αY ↔ ξ at 902 °C. Three eutectic reactions L ↔ γ + δ, L ↔ τ + ν, and L ↔ ζ + ξ occur at 1285, 950, and 902 °C, respectively.

The Y-Ti [1987Mur] (Fig. 3) has been experimentally determined at the Ti side and Y side only. In the intermediate composition range between Ni and Y, the phase diagram has been predicted through thermodynamic calculations that indicate a probable liquid phase immiscibility in the composition range of ~30 to 80 at.% Y. At the Ti side L_1 ↔ L_2 + βTi occurs at 1370 °C and at the Y side βY ↔ L + αY occurs at 1440 °C and L ↔ βTi + αY occurs at 1355 °C.

Binary and Ternary Phases

The three binary systems Ni-Ti, Ni-Y, and Y-Ti have 12 binary intermediate phases. No ternary intermediate has been reported in the Ni-Ti-Y system. The binary phases and their structure data are given in Table 1.

Ternary System

An isothermal section of the Ni-Ti-Y system has been established by [2000Zhu]. The alloys were prepared, using

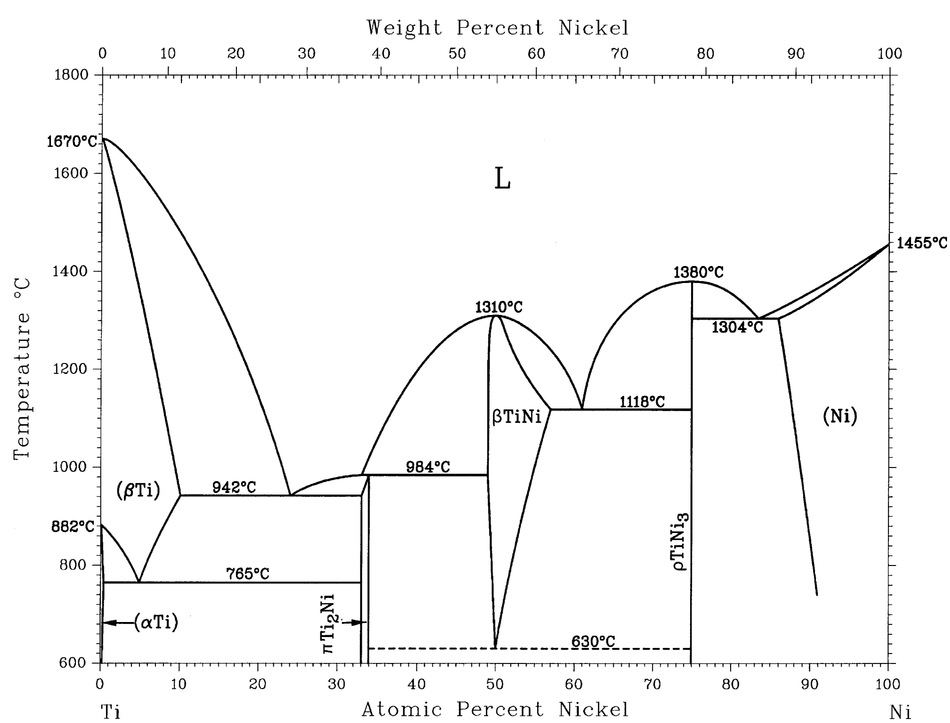

Fig. 1 Binary Ni-Ti phase diagram [1991Nas]

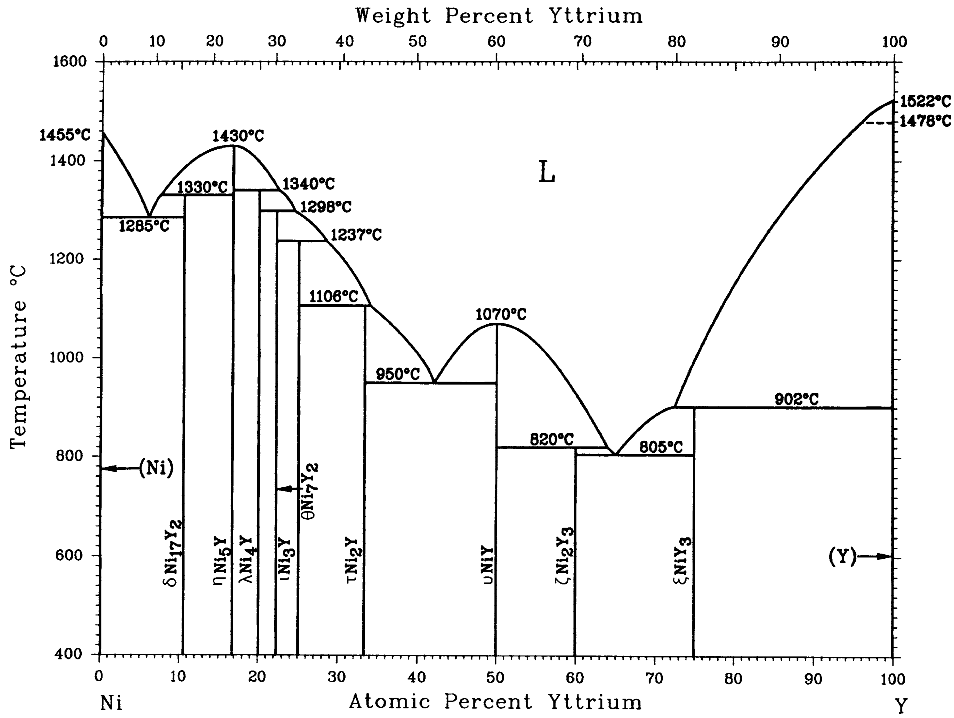

Fig. 2 Binary Ni-Y phase diagram [1991Nas]

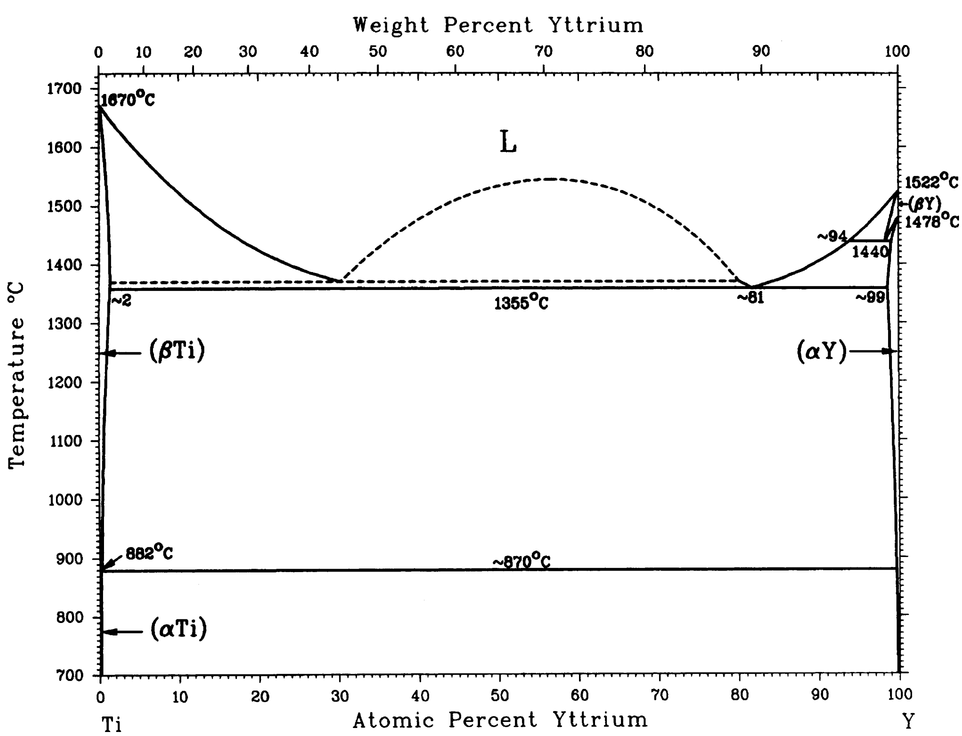

Fig. 3 Binary Ti-Y phase diagram [1987Mur]

Ni of 99.999 mass% purity and Ti and Y of 99.9 mass% purity, by arc melting. In all, 119 alloys were prepared for this investigation. The Ni-rich alloys were homogenized at 900 °C for 30 days, the Y-rich alloys were homogenized at 720 °C for 60 days, and the other alloys were homogenized at 800 °C for 45 days. After homogenization the alloys were cooled to 500 °C at the rate of 10 °C/h and annealed for 10 days and quenched in ice water mixture. All heat treatment was carried out in vacuum. Phase analysis of annealed alloys and the phase boundary determination were carried out primarily by x-ray diffraction (XRD). Binary alloy powders were annealed at 500 °C for 5 days in small

Table 1 Binary phases in the Ni-Ti-Y system and their structure data

					Lattice parameter, nm		
Phase designation	**Composition**	**Pearson's symbol**	**Space group**	**Type**	***a***	***b***	***c***
γ	(Ni)	*cF*4	$Fm\bar{3}m$	Cu	…	…	…
α_1	(βTi)	*cI*2	$Im\bar{3}m$	W	…	…	…
ε_1	(αTi)	*hP*2	$P6_3/mmc$	Mg	…	…	…
γ_1	(βY)	*cF*4	$Fm\bar{3}m$	Cu	…	…	…
ε_2	(αY)	*hP*2	$P6_3/mmc$	Mg	…	…	…
ρ	Ni_3Ti	*hP*16	$P6_3/mmc$	Ni_3Ti	0.5101	…	0.8307
β	NiTi	*cP*2	$Pm\bar{3}m$	CsCl	0.3015	…	…
π	$NiTi_2$	*cF*96	$Fd\bar{3}m$	CFe_3W_3	1.1324	…	…
δ	$Ni_{17}Y_2$	*hP*38	$P6_3/mmc$	Th_2Ni_{17}	0.8307	…	0.8040
η	Ni_5Y	*hP*6	$P6/mmm$	$CaCu_5$	0.4883	…	0.3967
λ	Ni_4Y	…	…	…	…	…	…
θ	Ni_7Y_2 (HT)	*hR*18	$R\bar{3}m$	Gd_2Co_7	0.4944	…	3.623(a)
θ_1	Ni_7Y_2 (LT)	*hR*18	$P6_3/mmc$	Ce_2Ni_7	…	…	…
ι	Ni_3Y	*hR*12	$R\bar{3}m$	$PuNi_3$	0.5	…	2.430(a)
τ	Ni_2Y	*cF*24	$Fd\bar{3}m$	Cu_2Mg	0.7181	…	…
ν	NiY	*oP*8	*Pnma*	FeB	0.712	0.41	0.551
ζ	Ni_2Y_3	*tP*80	$P4_12_12_1$	Ni_2Y_3	0.7104	…	3.6597
ξ	Ny_3	*oP*16	*Pnma*	Fe_3C	0.692	0.949	0.636

(a) Lattice parameter of hexagonal cell

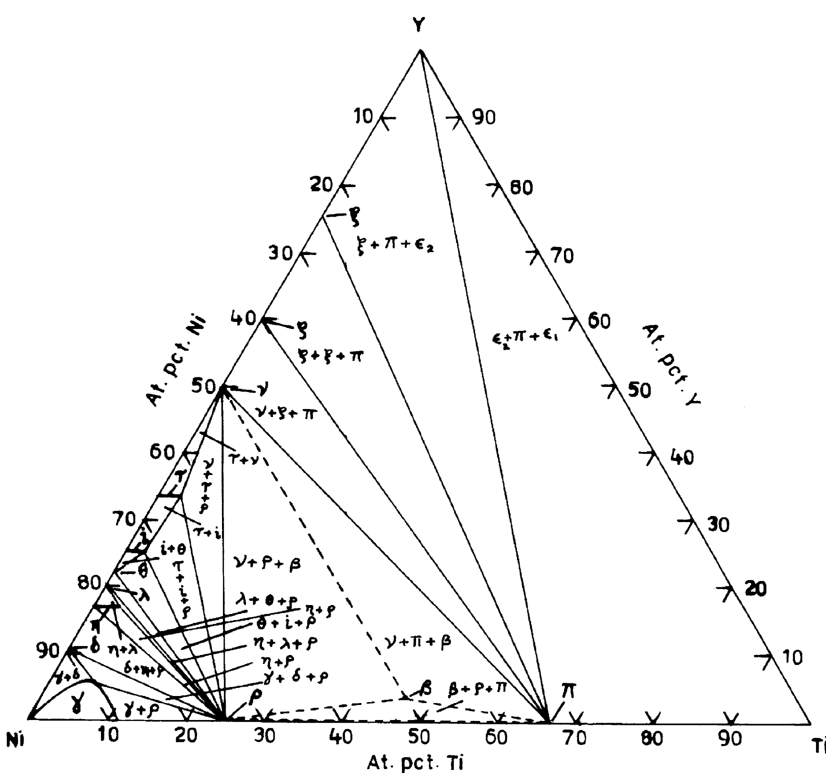

Fig. 4 The 500 °C isothermal section of Ni-Ti-Y system by [2000Zhu] with a probable phase equilibria shown schematically near the NiTi (β) phase composition

evacuated glass tubes. For a few alloys, electron probe microanalysis (EPMA) was used to determine the solubility limits of the single-phase regions.

The 500 °C isothermal section established by [2000Zhu] is given in Fig. 4. Only the Ni_5Y, Ni_3Y, and Ni_2Y phases were found to extend into the ternary parallel to the Ni-Ti base line. The extensions of these phases were, however, found to be small. The Ni_5Y phase extended up to about 5 at.% Ti, and the other two phases extended to ≤3 at.% Ti. The fcc γ phase was found to have maximum solubility of ~7 at.% Y, and the maximum solubility of Ti was found to be 11 at.% Ti. In the accepted Ni-Ti system the solubility of Ti in Ni at 500 °C is not given, but extrapolation of high-temperature data indicates it to be ~7 at.% Ti. The solubility of Ti in Ni should be redetermined to verify which data are acceptable. The experimental data of [2000Zhu] for the Ni-Ti-Y system shows (Fig. 4) 15 single-phase, 13 three-phase, and 28 two-phase regions. Most of the two-phase regions within the ternary are represented by single lines.

[2000Zhu] reported the presence of two three-phase regions $\nu + \rho + \beta$ and $\nu + \pi + \beta$ at 500 °C (Fig. 4), separated by a two-phase equilibrium line $\nu + \beta$ drawn by joining the binary ν phase and the binary β phase compositions. Since the NiTi (β)-phase exists in the Ni-Ti binary system at and above ~630 °C, [2000Zhu] suggested that the β phase system may be stable in the Ni-Ti binary down to at least 500 °C. Since no recent experimental data to support this conjecture are available at present, the suggestion made by [2000Zhu] may not be acceptable. With the accepted binary β-phase eutectoid transformation at ~630 °C, it is, however, possible to have the β phase present in the Ni-Ti-Y system due to stabilization of the β phase by Y to lower temperatures. In that case a β phase region should exist within the ternary and away from the Ni-Ti binary, as indicated schematically in Fig. 4, and a three-phase equilibrium $\beta + \rho + \pi$ should exist close to the Ni-Ti binary line. Since [2000Zhu] did not give sufficient details about the alloy compositions they investigated, it is not possible to know whether a β phase region exists in the Ni-Ti-Y system close to the Ni-Ti binary line. Further work will be necessary in the Ni-Ti binary and in the Ni-Ti-Y ternary, close to the Ni-Ti binary, to establish proper phase equilibria near the β-phase region of the Ni-Ti-Y system.

References

1987Mur: J.L. Murray, The Ti-Y System, *Phase Diagrams of Binary Titanium Alloys*, J.L. Murray, Ed., American Society for Metals, Metals Park, OH, 1987, p 333-335

2000Zhu: Y. Zhuang, Y. Cuo, and W. He, The 773 K Isothermal Section of the Phase Diagram of Ternary Ni-Ti-Y System, *J. Alloys Compd*., 2000, **298**, p 135-137 (Phase Equilibria, #)

# indicates presence of phase diagram.

Ni-Ti-Y evaluation contributed by **K.P. Gupta**, The Indian Institute of Metals, Metal House, Plot 13/4, Block AQ, Sector V, Calcutta, India. Literature searched through 2000. Dr. Gupta is the Alloy Phase Diagram Co-Category Program Editor for ternary nickel alloys.