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The Ni-Re-V (Nickel-Rhenium-Vanadium) System

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Introduction

Only one isothermal section for the Ni-Re-V system has been established and is reported here.

Binary Systems

The Ni-Re system [Massalski 2] (Fig. 1) is a simple peritectic system, the peritectic reaction $L + \varepsilon \leftrightarrow \gamma$ occurs at 1620 °C where ε and γ are the terminal solid solutions (Re) and (Ni), respectively.

The Ni-V system [Massalski 2] (Fig. 2) has five intermediate phases: $Ni_8V(\zeta)$, $Ni_3V(\pi)$, $Ni_2V(\rho)$, σ, and $NiV_3(\delta)$. The ζ, π, and ρ phases form from the solid solution γ through congruent transformations at 405, 1045, and 922 °C, respectively. The σ phase appears to have two polymorphic forms σ′ and σ. The σ′ phase forms through a peritectic reaction $L + \alpha \leftrightarrow \sigma'$ at 1280 °C, where α is the terminal solid solution (V). The σ phase occurs below ~790 °C, the probable reaction at the high Ni side is a peritectoid reaction $\sigma' + \rho \leftrightarrow \sigma$ at ~790 °C and a eutectoid reaction $\sigma' \leftrightarrow \sigma + \delta$ probably occurs at the high V end. The δ phase forms through a peritectoid reaction $L + \alpha \leftrightarrow \delta$ at 900 °C. A eutectoid reaction $L \leftrightarrow \gamma + \sigma'$ occurs at 1202 °C and two eutectoid reactions $\gamma \leftrightarrow \pi + \rho$ and $\gamma \leftrightarrow \rho + \sigma'$ occur at 908 and 890 °C.

The Re-V system [Massalski 2] has two intermediate phases σ and δ. The σ phase forms through a pertiectic reaction $L + \varepsilon \leftrightarrow \sigma$ at 2460 °C. The δ phase forms through a peritectoid reaction $\sigma + \alpha \leftrightarrow \delta$ at 2280 °C. The α phase extends from V to 56 at.% Re and has a congruent melting temperature of ~2400 °C at ~47 at.% V. A eutectic reaction $L \leftrightarrow \sigma + \alpha$ occurs at 2380 °C. The σ and δ phases exist only at high temperatures and undergo eutectoid transformations $\sigma \leftrightarrow \varepsilon + \delta$ at 1970 °C and $\delta \leftrightarrow \varepsilon + \alpha$ at ~1470 °C.

Binary and Ternary Phases

The Binary systems Ni-Re, Ni-V, and Re-V systems have seven intermediate phases. The Ni-Re-V ternary system has one intermediate phase σ″. The structure data for the binary and ternary phases are given in Table 1.

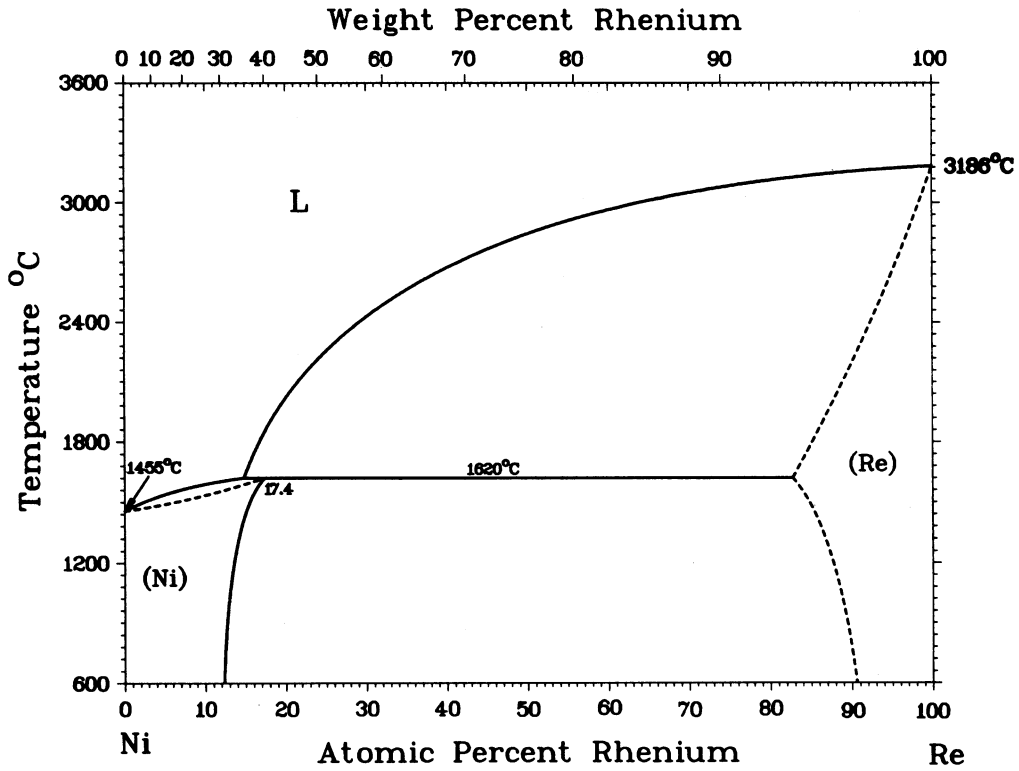

Fig. 1 Ni-Re system [Massalski 2]

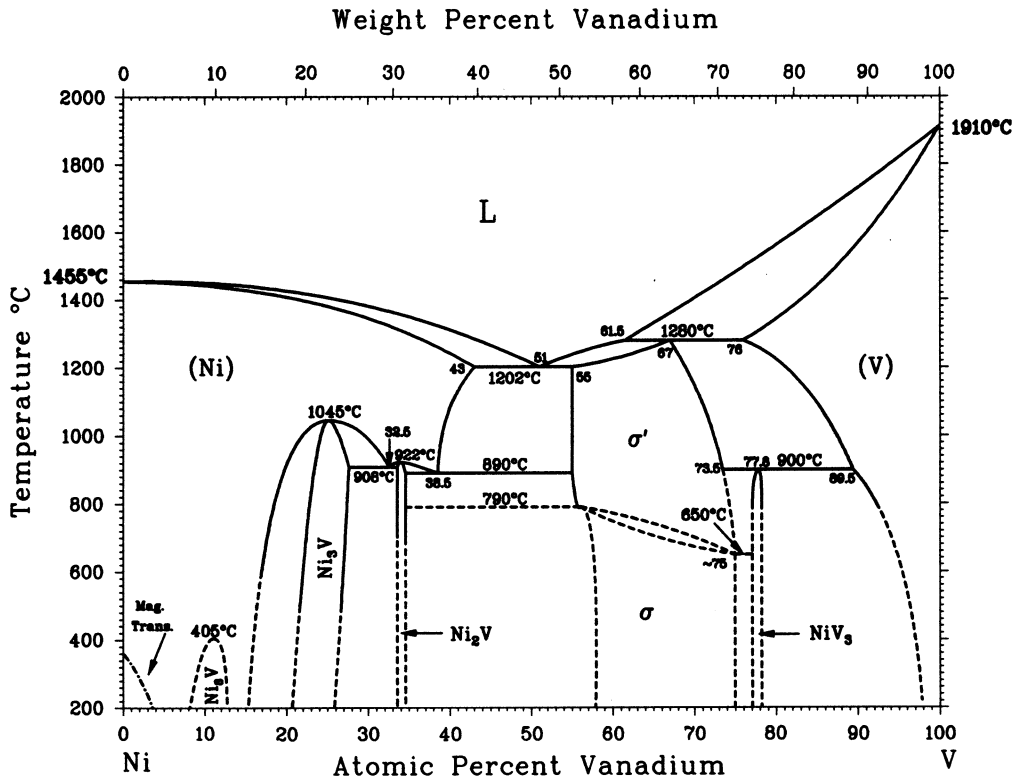

Fig. 2 Ni-V system [Massalski 2]

Table 1 Phases of the Ni-Re, Ni-V, and Re-V binary system and Ni-Re-V ternary system and their structure data

					Lattice parameters, nm		
Phase designation	**Composition**	**Pearson's symbol**	**Space group**	**Type**	***a***	***b***	***c***
γ	(Ni)	*cF*4	$Fm\bar{3}m$	Cu	···	···	···
α	(V)	*cI*2	$Im\bar{3}m$	W	···	···	···
ε	(Re)	*hP*2	$P6_3/mmc$	Mg	···	···	···
ξ	Ni_8V	*tI*18	···	$NbNi_8$	1.08	···	0.36 (a)
π	Ni_3V	*tI*8	*I*4/*mmm*	Al_3Ti	0.3524	···	0.71731
ρ	Ni_2V	*oI*6	*Immm*	$MoPt_2$	0.2559	0.7641	0.3549
σ′	$Ni_{11}V_{19}$	···	···	σ type	···	···	···
σ	$Ni_{11}V_{19}$	*tP*30	$P4_2/mnm$	σ (CrFe)	0.8980	···	0.4640
δ	NiV_3	*cP*8	$Pm\bar{3}n$	Cr_3Si	0.4710	···	···
σ	Re_3V	*tP*30	$P4_2/mnm$	σ (CrFe)	0.9475	···	0.4900
δ	$Re_{70}V_{30}$	*cP*8	$Pm\bar{3}n$	Cr_3Si	0.4869	···	···
σ″	$Ni_{15}Re_{64}V_{21}$	···	···	σ type	···	···	···

(a) Lattice parameter of fct cell within 36 atoms/cell

Ternary System

The Ni-Re-V system has been investigated by [1998Sly] using diffusion couples and eight arc melted alloys. The materials used for this study were electrolytic Ni, vacuum melted Re and induction melted V. The purity of the materials, however, was not mentioned. Sandwiched diffusion couples were prepared by embedding 50-μm thick Ni layer between Re and V, welded at 902 °C for 10 min under 15 MPa pressure. The diffusion couples were annealed at 1152 °C for 4-49 h. Eight solid alloys were prepared by arc melting, sealed in argon filled silica capsules and annealed at 1152 °C for 500 h. The phase analysis of the diffusion zones of the diffusion couples and the arc melted alloys was done using scanning electron microscopy (SEM), x-ray diffraction (XRD), and electron probe microanalysis (EPMA) methods.

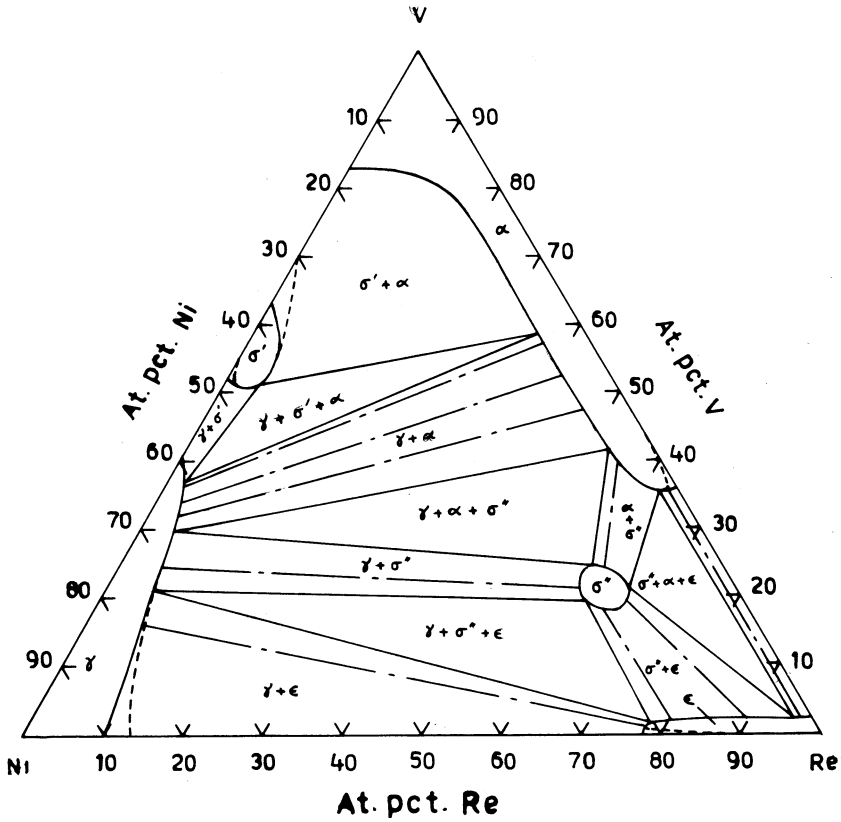

Fig. 3 An isothermal section of the Ni-Re-V system at 1152 °C [1998Sly]

The analysis of the diffusion zones of the sandwiched diffusion couples showed the existence of a new ternary intermediate phase σ″ of composition $Ni_{15}Re_{63}V_{22}$. The sequence of phases found in a diffusion couple after 9 h annealing was Re-σ″-Ni-σ′-V and after 36 h the sequence of phase found in a diffusion couple was Re-(V,Ni)-σ′-V. Phase analysis of the annealed arc melted alloys showed that the σ′ phase dissolves up to ~6 at.% Re. The solubility of Re in V was found to be ~64 at.% Re whereas the solubility of V in Re was found ≤2 at.% V. The alloy of composition $Ni_{15}Re_{64}V_{21}$ was found to be single phase σ″. XRD study of the σ″ phase suggested it to be of a σ-type phase. The σ″ phase was found in the composition region $Ni_{13\text{-}20}Re_{57\text{-}66}V_{19\text{-}26}$. The alloys of compositions $Ni_{17}Re_{50}V_{33}$, $Ni_{32}Re_{33}V_{35}$, $Ni_{35}Re_{15}V_{50}$, and $Ni_{50}Re_{10}V_{40}$ were found to have three phases. The first two alloys were in a three-phase region γ + α + σ″ and the latter two alloys were found to have three phases α + σ′ + γ. The rest of the arc melted alloys possessed two phases; the $Ni_{39}Re_{40}V_{21}$ alloy showed γ + σ″, the $Ni_{75}Re_{10}V_{15}$ alloy showed γ + ε and the $Ni_{60}R_{10}V_{30}$ alloy showed γ + α two-phase equilibrium. The isothermal section at 1152 °C by [1998Sly] is given in Fig. 3. Figure 3 also shows some tie lines determined by [1998Sly] which are shown by dash-dot lines. The isothermal section of Ni-Re-V systems shows four three-phase equilibrium triangles: σ″ + α + γ, σ′ + α + γ, σ″ + ε + α, and σ″ + ε + γ. Of these only the first two three-phase equilibrium triangles have been established on the basis of EPMA analysis of alloys containing three phases. The σ″ + ε + γ three-phase equilibrium triangle has been drawn on the basis of two-phase alloys. The σ″ + ε + α region at the high Re side is shown in Fig. 3 to indicate that this region is to be expected in the 1152 °C isothermal diagrams. The location of both σ″ + ε + γ and σ″ + ε + α three-phase regions have to be redetermined on the basis of EPMA analysis of three phase alloys.

The phase boundaries determined by [1998Sly], solid lines in Fig. 3, however, do not agree with the accepted binary data. The probable phase boundaries are shown in Fig. 3 by dashed lines. The phase boundaries of the terminal solid solution phases and the σ′ phase should be reestablished.

References

1998Sly: E.M. Slyusarenko, A.V. Peristyi, E. Yu. Kerimov, M.V. Sofin, and D. Yu Skorbov, Ternary Systems of Nickel and Rhenium with Transition Metals, *J. Alloys Compd.*, 1998, **264**, 180-189. (Phase Equilibrium, #)

# indicates presence of phase diagram.

Ni-Re-V 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 1996. Dr. Gupta is the Alloy Phase Diagram Co-Category Program Editor for ternary nickel alloys.