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The Mg-Ni-Pd (Magnesium-Nickel-Palladium) System

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Introduction

The Mg-Ni-Pd ternary system has been studied only at the Mg corner. A partial isothermal section, a partial liquidus projection, and two partial isopleths have been established.

Binary Systems

The Mg-Ni system [1988Nay, Massalski2 (Fig. 1)] shows the presence of two intermediate phases $Mg_2Ni(\beta)$ and $MgNi_2(\lambda)$ of which the $MgNi_2$ phase melts congruently at 1147 °C. The Mg_2Ni phase forms through a peritectic reaction L + $MgNi_2$ ↔ Mg_2Ni at 760 °C. Two eutectic reactions L ↔ (Mg) + Mg_2Ni and L ↔ (Ni) + $MgNi_2$ occur at 506 and 1097 °C, respectively.

The Mg-Pd system [1988Nay, Massalski2 (Fig. 2)] has five intermediate phases Mg_6Pd (ρ), Mg_4Pd (ξ), Mg_3Pd (ν), Mg_5Pd_2 (ψ), MgPd (ζ), and $Mg_{0.9}Pd_{1.1}$ (ϕ), of which only the latter phase melts congruently at 1350 °C. All other phases form through peritectic or peritectoid reactions: L + $Mg_{0.9}Pd_{1.1}$ ↔ Mg_3Pd at 1130 °C, L + Mg_3Pd ↔ Mg_4Pd at 790 °C, L + Mg_4Pd ↔ Mg_6Pd at 700 °C, $Mg_{0.9}Pd_{1.1}$ + Mg_3Pd ↔ MgPd at 700 °C, and Mg_3Pd + MgPd ↔ Mg_5Pd_2 at ~450 °C. Two eutectic reactions L ↔ $Mg_{0.9}Pd_{1.1}$ + (Pd) and L ↔ Mg_6Pd + (Mg) occur at 1280 and 540 °C.

The Ni-Pd system [Massalski2] (Fig. 3) is an isomorphous system with a solidus/liquidus minimum of ~1237 °C at ~45 at.% Pd.

Binary and Ternary Phases

Seven binary intermediate phases form in the three binary systems of the Mg-Ni-Pd system. No ternary phase forms in the Mg-Ni-Pd system. The binary phases and their structure data are given in Table 1.

Ternary System

The Mg corner of the Mg-Ni-Pd system has been investigated by [1981Kol] between 35 wt.% and 100% Mg and up to ~50 wt.% Pd. The alloys were melted in corundum crucibles under a flux. The alloys were annealed at 400 °C but the duration of anneal was not mentioned. The annealed alloys were characterized by x-ray diffraction (XRD), metallography, and electron probe microanalysis (EPMA).

A partial isothermal section at 400 °C was established (Fig. 4). A small extension of the β phase up to ~15 wt.% Pd occurs. The ρ phase extends up to ~3 wt.% Ni and there is practically no solubility of Ni and Pd in Mg. The β phase was found in equilibrium with the ρ phase. A three-phase

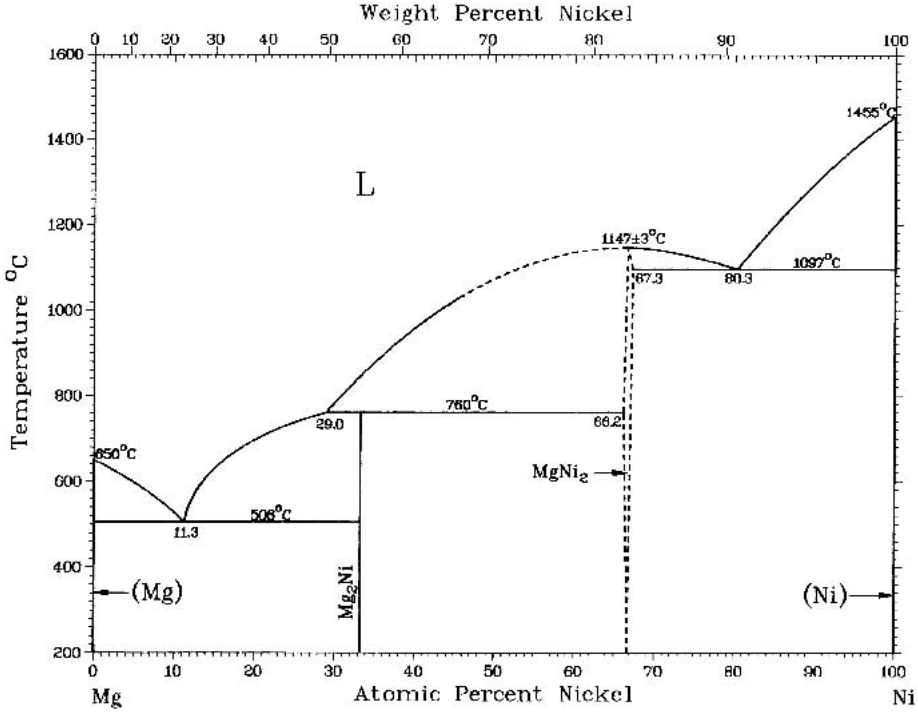

Fig. 1 Mg-Ni binary phase diagram [Massalski2]

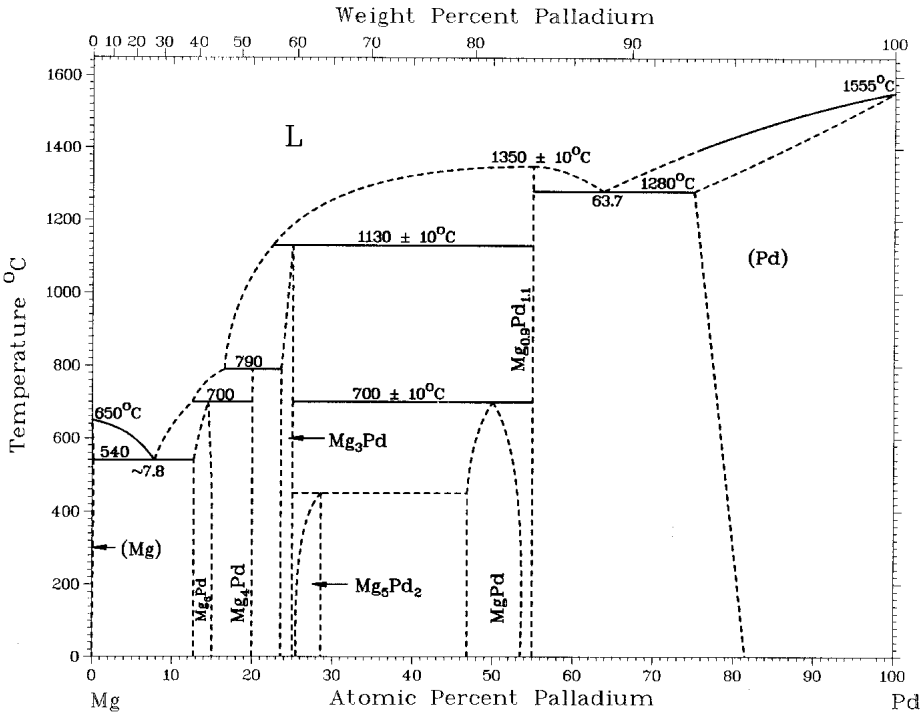

Fig. 2 Mg-Pd binary phase diagram [Massalski2]

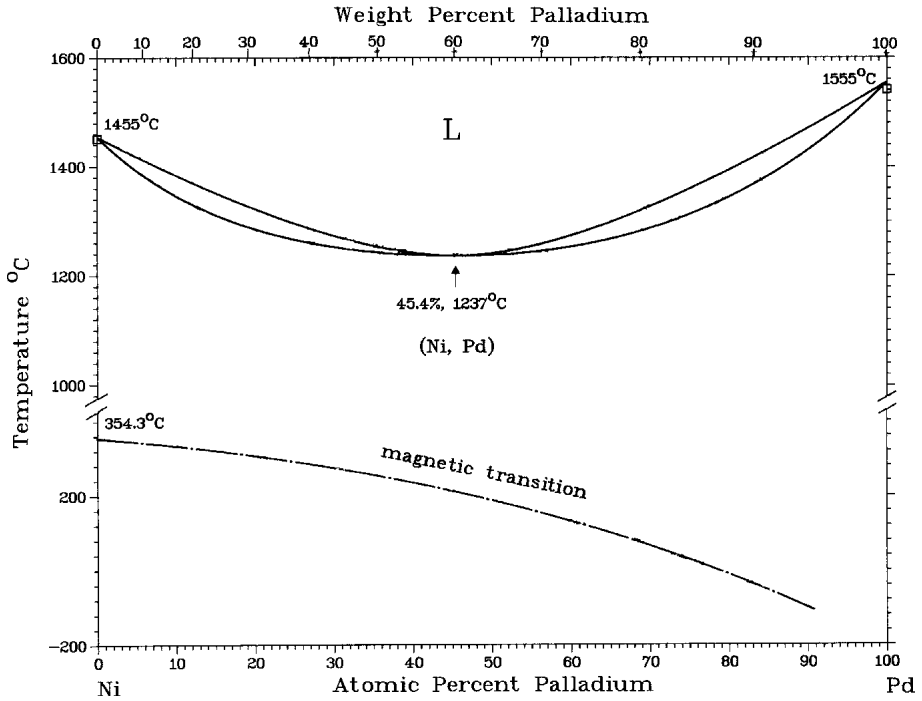

Fig. 3 Ni-Pd binary phase diagram [Massalski2]

region ϵ + β + ρ was established between Mg (ϵ), β (45 wt.% Mg, 52 wt.% Ni, and 3 wt.% Pd), and ρ (55 wt.% Mg, 3 wt.% Ni, and 42 wt.% Pd). Beyond ~55 wt.% Ni the β phase was found in equilibrium with the λ phase.

Thermal analysis was done to establish two partial isopleths at the Mg corner at 5 wt.% Pd and at 53 wt.% Mg (Fig. 5 and 6) and a partial liquidus projection (Fig. 7). Both isopleths indicated the presence of a four-phase reaction plane at 490 °C.

The β and ρ phases were reported to form a eutectic

Table 1 Phases in the Binary Mg-Ni, Mg-Pd, and Ni-Pd Systems and Their Structure Data

Phase Designation	Composition	Pearson's Symbol	Space Group	Type	Lattice Parameter, nm*	
					a	*b*
ϵ	(Mg)	*hP*2	$P6_3/mmc$	Mg	…	…
δ	(Ni, Pd)	*cF*4	$Fm\bar{3}m$	Cu	…	…
β	Mg_2Ni	*hP*18	$P6_222$	(a)	0.5198	1.322
λ	$MgNi_2$	*hP*24	$P6_3/mmc$	$MgNi_2$	0.4824	1.5826
ρ	Mg_6Pd	*cF*396	$Fm\bar{3}m$	(b)	2.0182	…
ξ	Mg_4Pd	…	…	…	…	…
ν	Mg_3Pd	*hP*8	$P6_3/mmc$	$AsNa_3$	0.4609	0.8420
ψ	Mg_5Pd_2	*hP*28	$P6_3/mmc$	Co_2Al_5	0.8660	0.8169
ζ	MgPd	*cP*2	$Pm\bar{3}m$	CsCl	0.317	…
ϕ	$Mg_{0.9}Pd_{1.1}$	*tP*2	*P*4/*mmm*	AuCu	0.303	0.342

* Lattice parameters are from [1988Nay].
(a) The structure is related to the Al_2Cu phase.
(b) The structure is similar to Na_6T1 and $Mg_{44}Th_7$, but not identical.

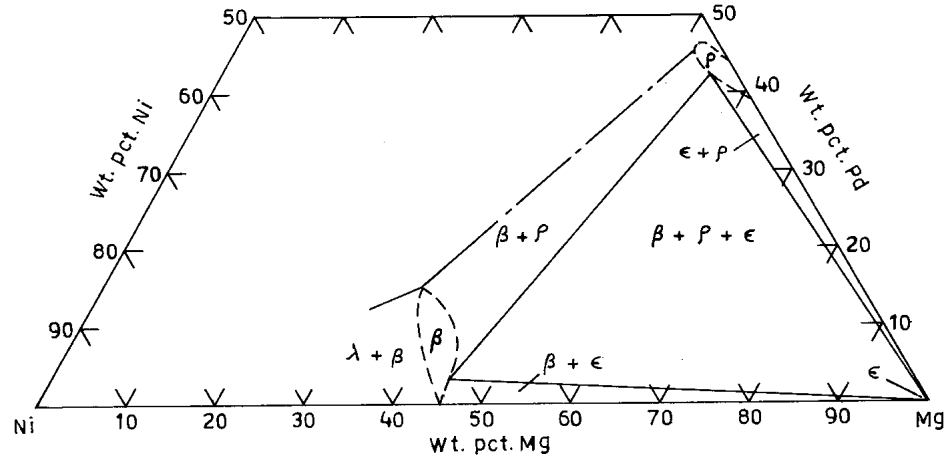

Fig. 4 A 400 °C partial isothermal section of Mg-Ni-Pd system at the Mg corner

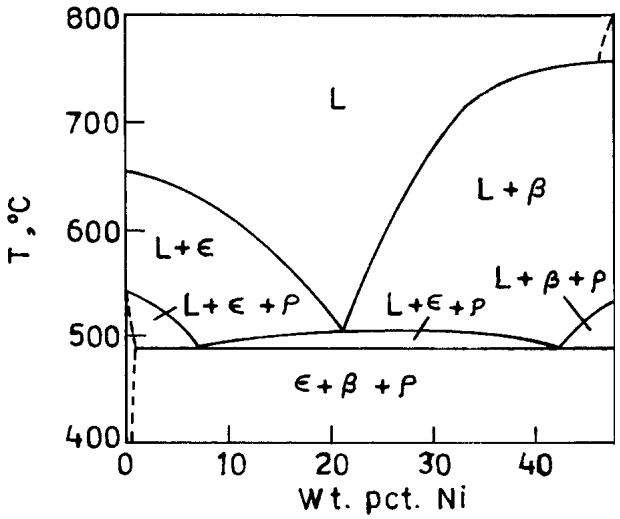

Fig. 5 A partial isopleth at 5 wt.% Pd at the Mg corner of Mg-Ni-Pd system

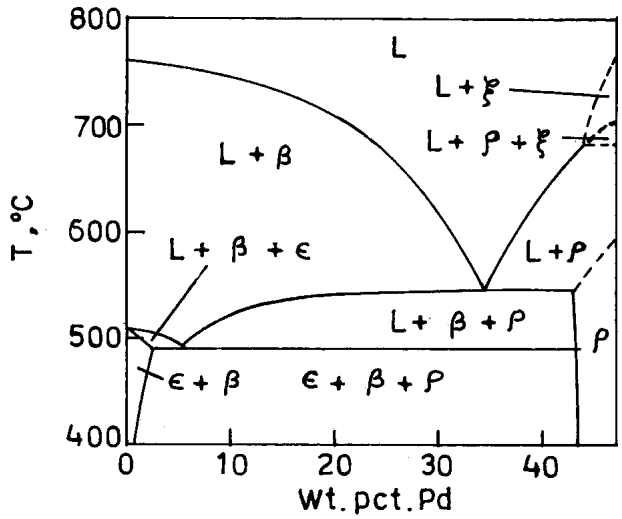

Fig. 6 A partial isopleth at 53 wt.% Mg at the Mg corner of Mg-Ni-Pd system

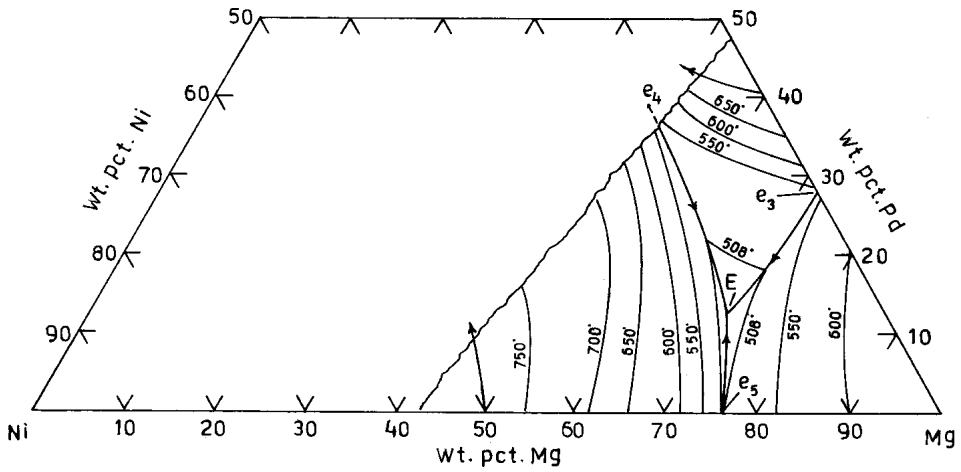

Fig. 7 A partial liquidus projection at the Mg corner of Mg-Ni-Pd system

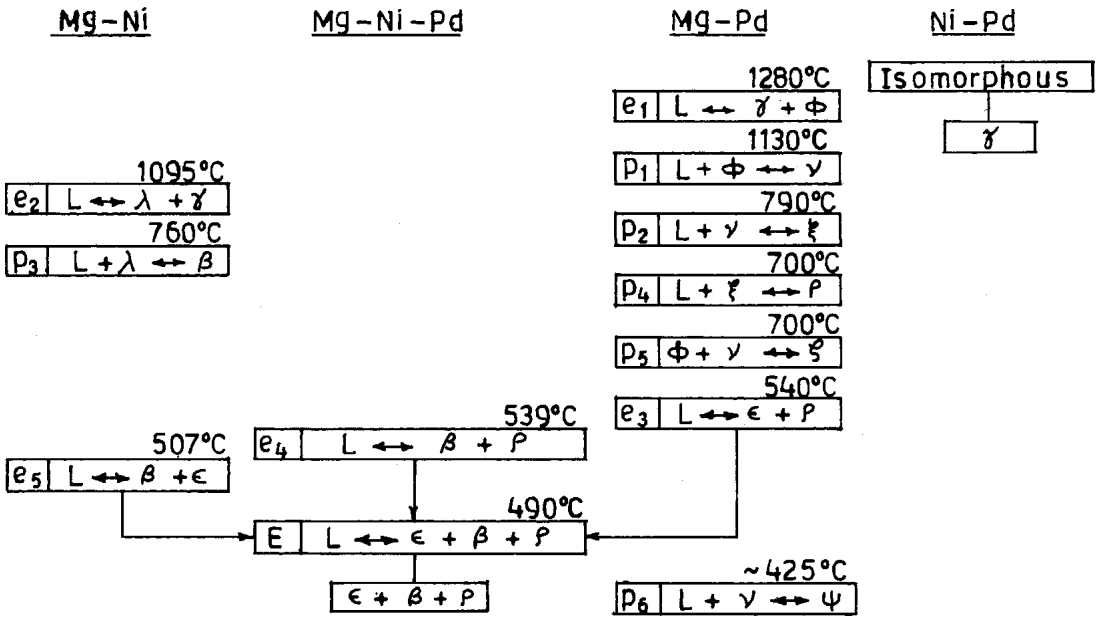

Fig. 8 A partial reaction scheme corresponding to the liquidus projection of Fig. 7

pseudobinary, and the eutectic temperature was quoted to be 535 °C. Neither the eutectic composition nor the pseudobinary phase diagrams were reported but from Fig. 4 and 7 the eutectic composition appears to be approximately 48 wt.% Mg, 13 wt.% Ni, and 39 wt.% Pd.

A four-phase eutectic type (E) reaction L ↔ ε + β + ρ arises due to the interaction of three three-phase eutectic reactions L ↔ ε + Mg_2Ni, L ↔ ε + Mg_6Pd, and the pseudobinary eutectic reaction L ↔ β + ρ at the four-phase reaction plane at 490 °C. The composition of the four-phase eutectic point E is reported to be at 71 wt.% Mg, 17 wt.% Ni, and 12 wt.% Pd. The liquidus temperatures of the various alloys were used to construct a partial liquidus projection with isotherms in the composition region of investigation; this projection is shown in Fig. 4. The corresponding partial reaction scheme is given in Fig. 8.

References

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Mg-Ni-Pd evaluation contributed by **K.P. Gupta,** The Indian Institute of Metals, Metal House, Plot 13/4, Block AQ, Sector V, Calcutta 700091, India. Literature searched through 1993. Dr. Gupta is the Alloy Phase Diagram Program Co-Category Editor for ternary nickel alloys.