Phase Diagram Updates

This section is intended to provide the most current phase diagram data. Guidelines for the inclusion of new information in this section are: (1) systems for which no phase diagrams are given in *Binary Alloy Phase Diagrams*, second edition; (2) complete diagrams that are substantially different from earlier versions published in *Binary Alloy Phase Diagrams*, second edition, the *Bulletin of Alloy Phase Diagrams*, or single-topic monographs; (3) partial diagrams that alter or clarify earlier versions in the above-mentioned publications; and (4) relevant new literature of interest.

Thermodynamic consistency of the new phase diagrams was checked based on phase rules, and the diagrams were modified if necessary. However, the diagrams and texts have not gone through the ordinary reviewing process, and the final evaluations may be carried out by relevant category editors of the Alloy Phase Diagram Program. For convenience, reaction tables and crystal structure data are added when new information is available.

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Al-Ni (Aluminum-Nickel)

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Figure 1 updates the Al-Ni phase diagram in [Massalski2], which was redrawn from [91Nas]. An enlarged region of Fig. 1 is shown in Fig. 2.

[87Hil], [90Jia], [91Udo1], and [91Udo3] reexamined the AlNi + $AlNi_3$ two-phase field by means of microprobe analysis of alloys equilibrated at various temperatures. Their results agreed well with [91Nas] (Fig. 1).

The melting reaction of $AlNi_3$ was controversial. [91Nas] recommended 1395 °C for the L + $AlNi_2$ → $AlNi_3$ reaction based on [37Ale], whereas [Hansen] recommended 1362 °C for the L + (Ni) → $AlNi_3$ reaction based on [41Sch]. The topology of [41Sch] was supported by [87Hil], [88Bre], [91Udo2], and [91Udo3] based on results of TEM, DTA, metallography, Knudsen effusion mass spectrometry, etc. Because the L → AlNi + $AlNi_3$ and L + (Ni) → $AlNi_3$ reactions occur at very similar (<3 °C) temperatures near 1360 °C, the resolution of DTA measurements was not high enough to distinguish these reactions [88Bre]. The reaction temperatures (2 °C difference) reported by [41Sch] are shown in Fig. 1. [87Hil] also observed a similar result, but the invariant temperatures were ~10 °C higher. [91Udo3] observed the liquidus and invariant temperatures of an alloy of 73.9 at.% Ni at, respectively, 1388 ± 4 and 1350 ± 10 °C by DTA and 1394 ± 7 and 1360 ± 5 °C by heat capacity measurements. This result is consistent with the present diagram.

The boundaries of $AlNi_3$ + (Ni) two-phase field in [91Nas] were rather uncertain due to fluctuations in variously reported experimental data. The boundaries shown in Fig. 1 are based on experimental data and thermodynamic modeling of [90Jia].

The composition of Al_3Ni_2 at 1133 °C in Fig. 1 is modified from 40 at.% Ni in [91Nas] to <40 at.% Ni, because the composition at the metastable congruent melting point, rather than at the peritectic formation temperature, of Al_3Ni_2 should be closer to the stoichiometry [91Oka].

Al-Ni crystal structure data in Table 1 is from [91Nas] with slight modifications.

[91Udo1] proposed a thermodynamic model for the Al-Ni phase diagram. However, the calculated phase diagram agreed only qualitatively with the experimental diagram.

Cited References

37Ale: W.O. Alexander and N.B. Vaughan, *J. Inst. Met.*, *61*, 247-260 (1937).

41Sch: J. Schramm, *Z. Metallkd.*, *33*, 347-355 (1941) in German.

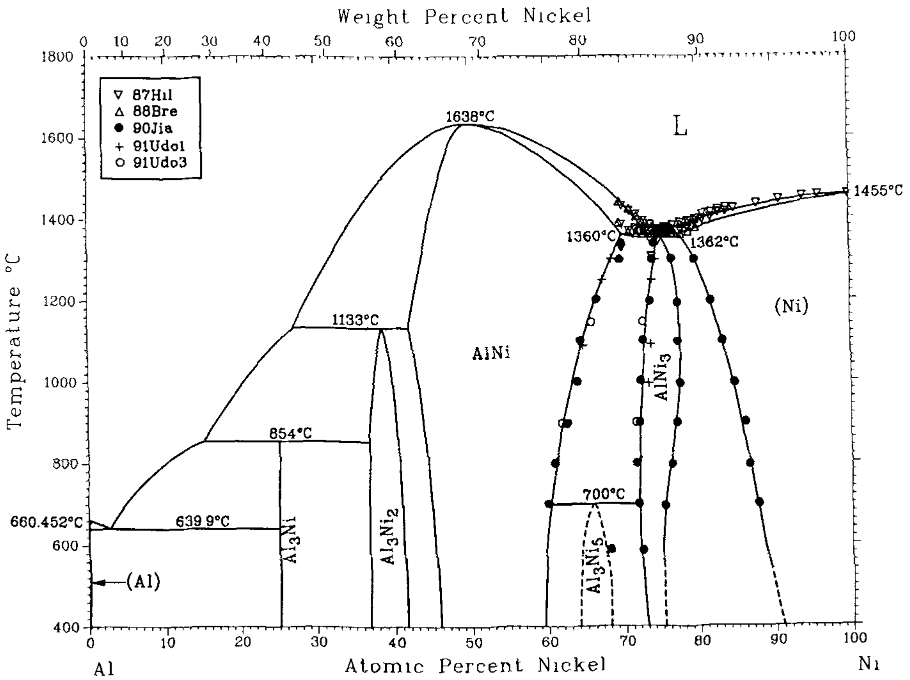

Fig. 1 Al-Ni phase diagram.

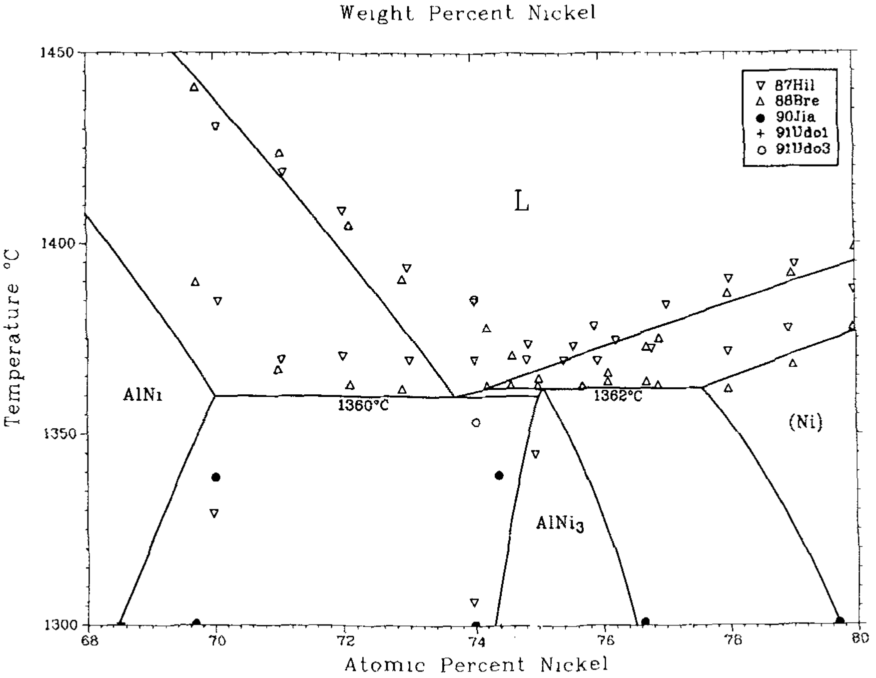

Fig. 2 68-80 at.% Ni region of the Al-Ni phase diagram between 1300 and 1450 °C.

87Hil: K. Hilpert, D. Kobertz, V. Venugopal, M. Miller, H. Gerads, F.J. Bremer, and H. Nickel, *Z. Naturforsch., A*, *42*, 1327-1331 (1987).

88Bre: F.J. Bremer, M. Beyss, E. Karthaus, A. Hellwig, T. Schober, J.M. Welter, and H. Wenzel, *J. Cryst. Growth*, *87*(2/3), 185-192 (1988).

Table 1 Al-Ni Crystal Structure Data

Phase	Composition, at.% Ni	Pearson symbol	Space group	Strukturbericht designation	Prototype
(Al)	0 to 0.11	*cF*4	$Fm\bar{3}m$	$A1$	Cu
Al_3Ni	25	*oP*16	*Pnma*	$D0_{11}$	Fe_3C
Al_3Ni_2	78 to 42	*hP*5	$P\bar{3}m1$	$D5_{13}$	Al_3Ni_2
AlNi	42 to 69	*cP*2	$Pm\bar{3}m$	$B2$	CsCl
Al_3Ni_5	64 to 68	*oC*16	*Cmmm*	...	Ga_3Pt_5
$AlNi_3$	72 to 77	*cP*4	$Pm\bar{3}m$	$L1_2$	$AuCu_3$
(Ni)	80 to 100	*cI*2	$Im\bar{3}m$	$A2$	W

90Jia: C.C. Jia, doctoral thesis, Tohoku Univ. (1990); see also C.C. Jia, H. Ohtani, K. Ishida, and T. Nishizawa, to be published in *Metall. Trans.* (1992).

91Nas: P. Nash, M.F. Singleton, and J.L. Murray, *Phase Diagrams of Binary Nickel Alloys*, P. Nash, Ed., ASM International, Materials Park, OH, 3-11 (1991).

91Oka: H. Okamoto and T.B. Massalski, *J. Phase Equilibria*, *12*(2), 148-168 (1991).

91Udo1: A.L. Udovskii, V.N. Karpushkin, and E.A. Nikishina, *Izv. Akad. Nauk SSSR Met.*, (4), 87-103 (1991) in Russian; TR: *Russ. Metall.*, (4), 85-102 (1991).

91Udo2: A.L. Udovskii, I.V. Oldakovskii, and V.G. Moldavskii, *Izv. Akad. Nauk SSSR Met.*, (4), 112-123 (1991) in Russian; TR: *Russ. Metall.*, (4), 111-122 (1991).

91Udo3: A.L. Udovskii, I.V. Oldakovskii, V.G. Moldavskii, and V.Z. Turkevich, *Dokl. Akad. Nauk SSSR*, *317*, 161-165 (1991) in Russian; TR: *Dokl. Phys. Chem.*, *317*, 234-237 (1991).

Al-Zr (Aluminum-Zirconium)

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[Massalski2] adopted the Zr-Al phase diagram evaluated by [92Mur]. [92Per] (who is one of the authors of [92Mur]) redetermined the Zr-rich part (<31.1 at.% Al) of the diagram in the range 500 to 1300 °C by means of metallography, XRD,

Table 1 Special Points of the Assessed Zr-Al Phase Diagram

Reaction		Composition of the respective phases, at.% Al		Temperature, °C	Reaction type
$L \leftrightarrow \beta Zr$		0		1855	Melting
$(\beta Zr) \leftrightarrow (\alpha Zr)$		0		863	Allotropic
$L \leftrightarrow (\beta Zr) + Zr_5Al_3$	31	25.9	37.5	1350	Eutectic
$(\beta Zr) + Zr_5Al_3 \leftrightarrow Zr_2Al$	19.9	37.5	33.3	1215	Peritectoid
$(\beta Zr) + Zr_2Al \leftrightarrow Zr_3Al$	12.0	33.3	25	1019	Peritectoid
$(\beta Zr) + Zr_3Al \leftrightarrow (\alpha Zr)$	6.8	25	8.3	910	Peritectoid
$L + Zr_3Al_2 \leftrightarrow Zr_5Al_3$	~35	40	37.5	1400	Peritectic
$Zr_5Al_3 \leftrightarrow Zr_2Al + Zr_3Al_2$	37.5	33.3	40	~1000	Eutectoid
$L + Zr_5Al_4 \leftrightarrow Zr_3Al_2$	~39	44.4	40	1480	Peritectic
$Zr_3Al_2 + Zr_5Al_4 \leftrightarrow Zr_4Al_3$	40	44.4	42.9	~1030	Peritectoid
$Zr_5Al_4 \leftrightarrow Zr_4Al_3 + ZrAl$	44.4	42.9	50	~1000	Eutectoid
$L \leftrightarrow Zr_5Al_4$		44.4		1550	Congruent
$L \leftrightarrow Zr_5Al_4 + Zr_2Al_3$	~51	44.4	60	1485	Eutectic
$Zr_5Al_4 + Zr_2Al_3 \leftrightarrow ZrAl$	44.4	60	50	1275	Peritectoid
$L + ZrAl_2 \leftrightarrow Zr_2Al_3$	~59	66.7	60	1590	Peritectic
$L \leftrightarrow ZrAl_2$		66.7		1660	Congruent
$L \leftrightarrow ZrAl_2 + ZrAl_3$	73.5	66.7	75	1500	Eutectic
$L \leftrightarrow ZrAl_3$		75		1580	Congruent
$ZrAl_3 + L \leftrightarrow (Al)$	75	99.97	99.92	660.8	Peritectic
$L \leftrightarrow Al$		100		660.452	Melting