The Al-Gd (Aluminum-Gadolinium) System

26.98154 amu 157.25 amu

By R. P. Elliott and F. A. Shunk

The form of the diagram shown in Fig. 1 was established by thermal, metallographic and X-ray diffraction analyses of 16 compositions [1]. The alloys were prepared by arc melting, and alumina crucibles were used in subsequent thermal treatments. The previously reported compounds – Al_3Gd [2-4], Al_2Gd [2,3,5], AlGd [2,3], Al_2Gd_3 [2,3,6] and $AlGd_2$ (reported as $AlGd_3$ by [2,7] – were confirmed, but Al_4Gd [2] was not. An investigation of Al-rich (<15 at.% Gd) alloys that were melted in graphite crucibles [8] confirmed the eutectic reaction $L \rightleftharpoons (Al) + Al_3Gd$, which, according to [8], occurs at 643 °C, ~10 wt.% (1.87 at.%) Gd. In addition, some evidence was obtained [8] that indicated the existence of (*i*) a transformation at 641 °C (2 °C below the eutectic temperature), (*ii*) Al_4Gd, and (*iii*) peritectoidal formation of Al_4Gd from the reaction of Al_3Gd with (Al) at 400 ± 10 °C. The Gd-rich (>75 at.% Gd) side of the diagram as determined in an early survey investigation [7] is in essential agreement with [1]; the eutectic was placed at 850 °C, ~96 wt.% (80.5 at.%) Gd. A thermal arrest at 645 °C was attributed to a polymorphic transformation in "$AlGd_3$" [7]; however, systematic consideration of the constitution of Al-rare earth systems [9] suggested that neither $AlGd_3$ nor dimorphism in $AlGd_2$ occurs. The solid solubility of Al in α-Gd was <0.2 wt.% (1.2 at.%) [7]; X-ray diffraction data [1] indicated that some solubility exists.

Additional work is needed to identify the character of the transformation that occurs, according to [8], at 641 °C in Al-rich alloys. Although Al_4Gd was identified [8] on the basis of powder and single-crystal X-ray diffraction data, its identification as an equilibrium phase has not been accomplished. Specifically, [8] described the microstructure of an as-cast (water-cooled mold) 10 wt.% (1.87 at.%) Gd alloy as "showing Al dendrites in an Al-Al_4Gd matrix"; transformation of Al_4Gd to Al_3Gd was detected after heating at 410 °C but not at 390 °C. Confirmation of the thermal effect at 645 °C [7] also is needed.

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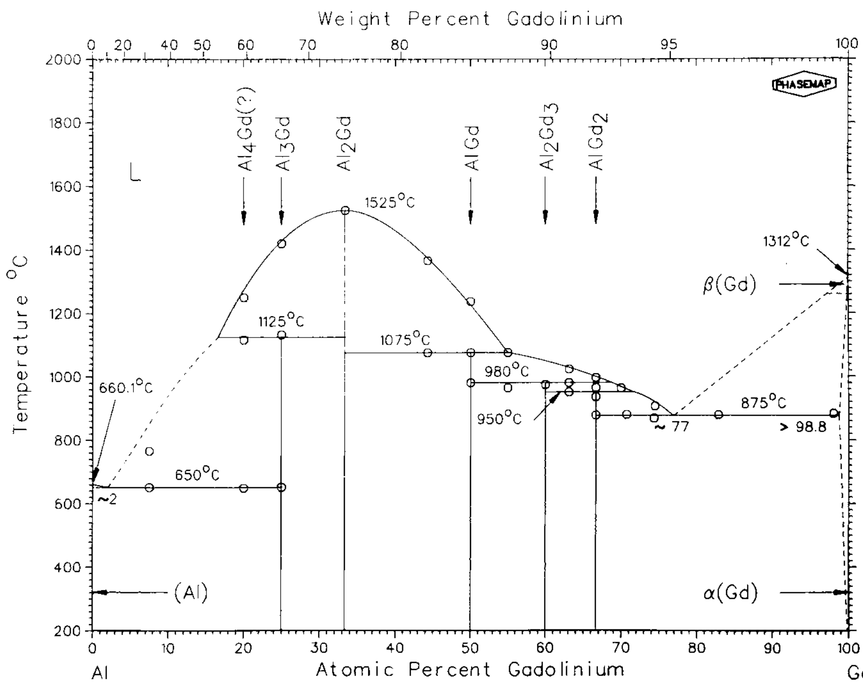
Fig. 1 Al-Gd Phase Diagram



○, [1]. From [Elliott; IITRI], 1966.

Crystal Structures

Phase	Approximate composition(a), at.% Gd	Pearson lattice designation	Space group	Prototype	Lattice parameters, nm a	b	c	Comments	References
(Al)	0	*cF*4	*Fm*3*m*	Cu	0.40497	...	...	...	(b)
Al_4Gd	20	*oI*20	*Imma*	Al_4U	0.4442	0.6316	1.3739	...	8
Al_3Gd	25	*hP*8	$P6_3/mmc$	Ni_3Sn	0.6308	...	0.4589	(c)	3
					0.6539	...	0.4619	...	10
Al_2Gd	33	*cF*24	*Fd*3*m*	Cu_2Mg	0.79020	...	...	(d)	3
					0.79028	...	...	(e)	12
AlGd	50	*oP*16	(f)	AlEr	0.5656	0.5888	1.1527	...	1,10,13
		*oC*16	*Cmcm* or $Cmc2_1$	AlCe	0.9274	0.7679	0.5584	...	14
		*cP*2	*Pm*3*m*	CsCl	0.37208	...	...	(g)	3
					0.8344	...	0.7656	...	6
Al_2Gd_3	60	*tP*20	$P4_2nm$	Al_2Zr_3	0.8329	...	0.7578	...	13
					0.8343	...	0.7625	...	10
$AlGd_2$	67	Orthorhombic (h)	...	$AlEr_2$	0.769	0.924	1.121	...	1
β(Gd)	100	*cI*2	*Im*3*m*	W	0.405	...	...	At 1312 K	(b)
α(Gd)	100	*hP*3	$P6_3/mmc$	Mg	0.36360	...	0.57826	...	(b)

(a) From the phase diagram. (b) From [Landolt-Börnstein]. (c) Intermediate values reported by [1, 4, 8, 11]. (d) Parameters by [1, 5, 10] are somewhat smaller and may indicate the existence of a homogeneity range. (e) Parameter was converted from kX units using the factor 1.00206. (f) Alternate space groups *Pmma*, $Pmc2_1$ and *Pma*2 are given. (g) At variance with [3], [16] found that the equi-atomic alloys do not exhibit the ClCs-type structure either in slowly-cooled specimens or in specimens prepared by rapidly quenching the liquid alloy. (h) 10 formula units per cell.

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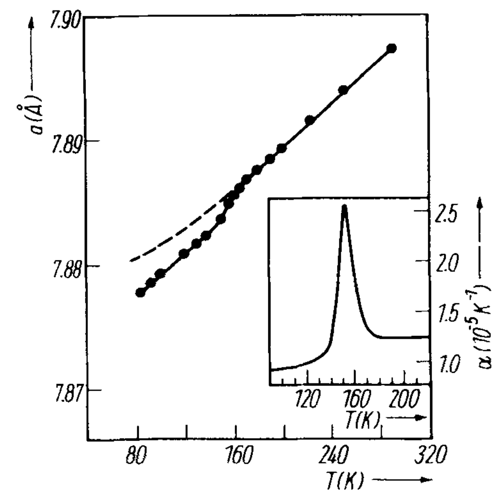
Fig. 2 Lattice Constant of Al_2Gd versus Temperature



Insert: linear thermal expansion α of Al_2Gd. From [20].

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Phase	Curie point, T_C in K	Neèl temperature, T_N in K
Al_3Gd	...	17
Al_2Gd	170	...
AlGd	...	42
Al_2Gd_3	282	...

19. W. E. Wallace, *Rare Earth Intermetallics*, Academic Press, NY (1973). (A monograph that includes extensive tables and references to magnetic properties and low-temperature specific heats of metallic rare-earth systems)

Phase	Curie point, T_C in K	Neèl temperature, T_N in K
Al_3Gd	···	17
Al_2Gd	182	···
AlGd	···	42
Al_2Gd_3	282	···

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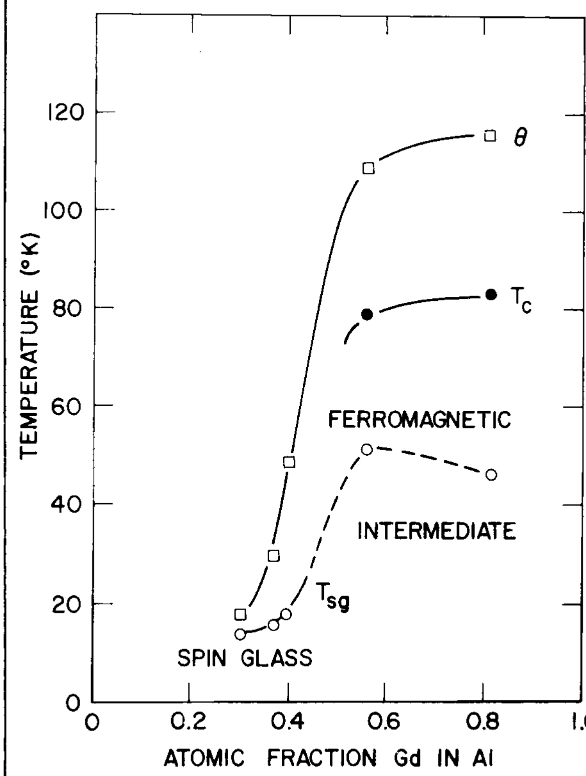
Fig. 3 Magnetic Phase Diagram for Amorphous Films of Al-Gd



○, temperatures for susceptibility peaks; ●, ferromagnetic Curie points, T_C; and □, paramagnetic θ values. From [22].

The Al-Ho (Aluminum-Holmium) System

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The diagram shown in Fig. 1, for the system Al-Ho, is based on differential thermal analysis, microscopic and X-ray investigation for 0 to 85 at.% Ho alloys prepared from 99% Ho and 99.9999% Al [1]. Five compounds were observed, two of which, Al_2Ho and $AlHo_2$, melt congruently; the others melt peritectically. Eutectic compositions were positioned at 1.8 at.% Ho, ~65 at.% Ho and 76 at.% Ho by metallographic determinations. The solubility of Ho in solid Al is certainly <0.008 at.% because an alloy of this composition annealed at 650 °C evidenced Al_3Ho at the grain boundary. The insolubility of Ho in solid Al also was indicated by [2]. [3] had recorded AlHo to be formed peritectically. [4] stated that Al_3Ho existed at the fixed stoichiometric composition. [1] did not critically evaluate possible homogeneity ranges of the five intermetallic compounds; the general agreement of lattice parameter determinations of multiple investigations of the compounds suggests none of the compounds has any appreciable homogeneity range.

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