La – Mg (Lanthanum – Magnesium)

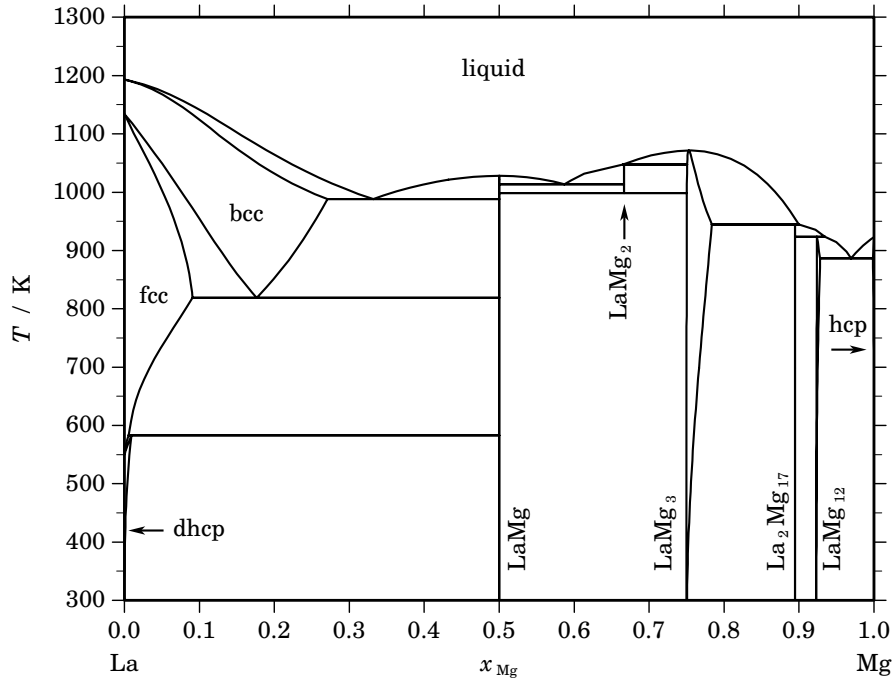

Fig. 1. Calculated phase diagram for the system La-Mg.

The addition of rare-earth metals to magnesium alloys retains their strength at elevated temperatures and improves their creep resistance over a wide range of temperature. The literature on the La-Mg system has been reviewed in [1988Nay] and a thermodynamic dataset has been optimised by [2004Guo]. For the assessment [2004Guo] have selected literature data on the phase diagram [1931Can, 1940Wei, 1947Vog, 1965Jos, 1986Man], activities of Mg in the melt at 1133 K [1973Afa], and enthapies of mixing in the melt for various temperatures and composition ranges [1995Aga]. Data for the intermetallic compounds have not been available.

Table I. Phases, structures and models.

Phase	Struktur-bericht	Prototype	Pearson symbol	Space group	SGTE name	Model
liquid					LIQUID	$(La,Mg)_1$
bcc	$A2$	W	$cI2$	$Im\overline{3}m$	BCC_A2	$(La,Mg)_1$
fcc	$A1$	Cu	$cF4$	$Fm3\overline{3}m$	FCC_A1	$(La,Mg)_1$
dhcp	$A3'$	αLa	$hP4$	$P6_3/mmc$	DHCP	$(La,Mg)_1$
LaMg	$B2$	CsCl	$cP2$	$Pm\overline{3}m$	LAMG	La_1Mg_1
$LaMg_2$	$C15$	$MgCu_2$	$cF24$	$Fd\overline{3}m$	LAMG2	La_1Mg_2
$LaMg_3$	$D0_3$	BiF_3	$cF16$	$Fm\overline{3}m$	LAMG3	$(La,Mg)_1Mg_3$
La_2Mg_{17}	···	$Ni_{17}Th_2$	$hP38$	$P6_3/mmc$	LA2MG17	La_2Mg_{17}
$LaMg_{12}$	···	$Mg_{12}Ce$	$oI338$	$Immm$	LAMG12	La_1Mg_{12}
hcp	$A3$	Mg	$hP2$	$P6_3/mmc$	HCP_A3	$(La,Mg)_1$

Table II. Invariant reactions.

Reaction	Type	T / K	Compositions / x_{Mg}			$\Delta_{\mathrm{r}}H$ / (J/mol)
liquid $\rightleftharpoons$ $LaMg_3$	congruent	1071.4	0.753	0.753		−18545
liquid + $LaMg_3$ $\rightleftharpoons$ $LaMg_2$	peritectic	1047.6	0.665	0.751	0.667	−7650
liquid $\rightleftharpoons$ LaMg	congruent	1027.9	0.500	0.500		−18136
liquid $\rightleftharpoons$ LaMg + $LaMg_2$	eutectic	1013.8	0.587	0.500	0.667	−12552
$LaMg_2$ $\rightleftharpoons$ LaMg + $LaMg_3$	eutectoid	998.2	0.667	0.500	0.750	−9747
liquid $\rightleftharpoons$ bcc + LaMg	eutectic	987.9	0.332	0.271	0.500	−10085
$LaMg_3$ + liquid $\rightleftharpoons$ La_2Mg_{17}	peritectic	944.8	0.784	0.900	0.895	−10282
La_2Mg_{17} + liquid $\rightleftharpoons$ $LaMg_{12}$	peritectic	923.3	0.895	0.935	0.924	−6900
liquid $\rightleftharpoons$ $LaMg_{12}$ + hcp	eutectic	886.5	0.970	0.928	0.999	−8589
bcc $\rightleftharpoons$ fcc + LaMg	eutectoid	818.8	0.176	0.091	0.500	−4114
fcc + LaMg $\rightleftharpoons$ dhcp	peritectoid	583.0	0.006	0.500	0.010	−357

Table IIIa. Integral quantities for the liquid phase at 1200 K.

x_{Mg}	ΔG_{m} [J/mol]	ΔH_{m} [J/mol]	ΔS_{m} [J/(mol·K)]	$G_{\mathrm{m}}^{\mathrm{E}}$ [J/mol]	$S_{\mathrm{m}}^{\mathrm{E}}$ [J/(mol·K)]	ΔC_P [J/(mol·K)]
0.000	0	0	0.000	0	0.000	0.000
0.100	−5531	−1117	3.679	−2288	0.976	0.000
0.200	−8688	−2535	5.127	−3695	0.966	0.000
0.300	−10677	−4270	5.339	−4582	0.260	0.000
0.400	−11899	−6210	4.740	−5184	−0.856	0.000
0.500	−12524	−8118	3.671	−5608	−2.092	0.000
0.600	−12551	−9629	2.435	−5836	−3.161	0.000
0.700	−11819	−10253	1.305	−5724	−3.774	0.000
0.800	−9992	−9372	0.517	−5000	−3.644	0.000
0.900	−6510	−6245	0.221	−3266	−2.482	0.000
1.000	0	0	0.000	0	0.000	0.000

Reference states: La(liquid), Mg(liquid)

Table IIIb. Partial quantities for La in the liquid phase at 1200 K.

x_{La}	ΔG_{La} [J/mol]	ΔH_{La} [J/mol]	ΔS_{La} [J/(mol·K)]	$G_{\mathrm{La}}^{\mathrm{E}}$ [J/mol]	$S_{\mathrm{La}}^{\mathrm{E}}$ [J/(mol·K)]	a_{La}	γ_{La}
1.000	0	0	0.000	0	0.000	1.000	1.000
0.900	−1562	138	1.417	−511	0.541	0.855	0.950
0.800	−3726	634	3.634	−1500	1.778	0.688	0.860
0.700	−5993	1330	6.102	−2434	3.137	0.548	0.784
0.600	−8259	1686	8.287	−3162	4.040	0.437	0.728
0.500	−10825	784	9.674	−3909	3.911	0.338	0.676
0.400	−14423	−2672	9.793	−5281	2.174	0.236	0.589
0.300	−20274	−10358	8.264	−8262	−1.747	0.131	0.437
0.200	−30273	−24330	4.953	−14215	−8.429	0.048	0.241
0.100	−47858	−47021	0.698	−24884	−18.447	0.008	0.083
0.000	$-\infty$	−81245	∞	−42390	−32.379	0.000	0.014

Reference state: La(liquid)

Table IIIc. Partial quantities for Mg in the liquid phase at 1200 K.

x_{Mg}	ΔG_{Mg} [J/mol]	ΔH_{Mg} [J/mol]	ΔS_{Mg} [J/(mol·K)]	$G^{\mathrm{E}}_{\mathrm{Mg}}$ [J/mol]	$S^{\mathrm{E}}_{\mathrm{Mg}}$ [J/(mol·K)]	a_{Mg}	γ_{Mg}
0.000	$-\infty$	−10025	∞	−28798	15.644	0.000	0.056
0.100	−41252	−12408	24.037	−18279	4.892	0.016	0.160
0.200	−28534	−15213	11.100	−12476	−2.282	0.057	0.286
0.300	−21606	−17338	3.557	−9594	−6.453	0.115	0.382
0.400	−17359	−18055	−0.580	−8217	−8.199	0.176	0.439
0.500	−14223	−17021	−2.332	−7307	−8.095	0.240	0.481
0.600	−11303	−14267	−2.470	−6206	−6.717	0.322	0.537
0.700	−8195	−10208	−1.677	−4636	−4.643	0.440	0.628
0.800	−4922	−5633	−0.592	−2696	−2.448	0.611	0.763
0.900	−1916	−1714	0.168	−864	−0.708	0.825	0.917
1.000	0	0	0.000	0	0.000	1.000	1.000

Reference state: Mg(liquid)

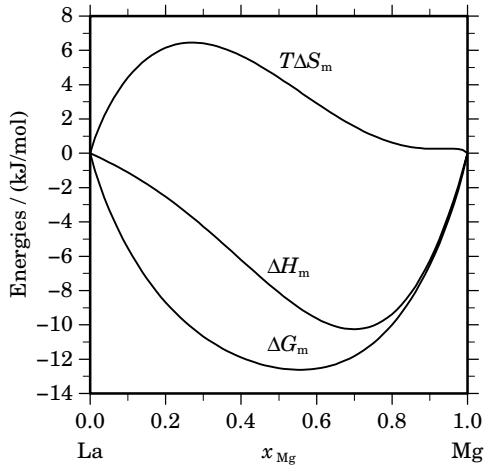

Fig. 2. Integral quantities of the liquid phase at T=1200 K.

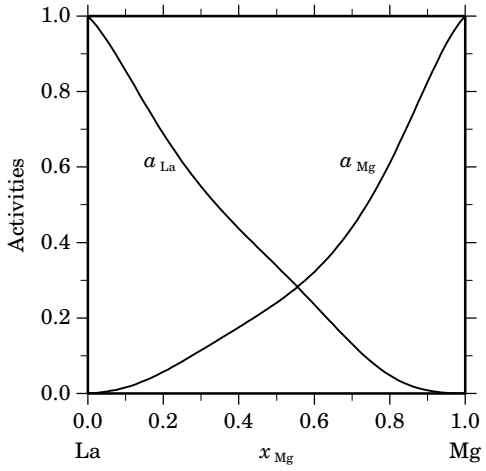

Fig. 3. Activities in the liquid phase at T=1200 K.

Table IV. Standard reaction quantities at 298.15 K for the compounds per mole of atoms.

Compound	x_{Mg}	$\Delta_{\mathrm{f}}G^{\circ}$ / (J/mol)	$\Delta_{\mathrm{f}}H^{\circ}$ / (J/mol)	$\Delta_{\mathrm{f}}S^{\circ}$ / (J/(mol·K))	$\Delta_{\mathrm{f}}C^{\circ}_{P}$ / (J/(mol·K))
La_1Mg_1	0.500	−15331	−16701	−4.594	0.000
$LaMg_3$	0.750	−17520	−19698	−7.303	0.000
La_1Mg_2	0.667	−9946	−8938	3.379	0.000
La_2Mg_{17}	0.895	−8046	−8663	−2.070	0.000
$LaMg_{12}$	0.923	−6009	−6398	−1.304	0.000

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