Aluminium – Boron – Magnesium

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Literature Data

Grain refining of boron additions to Al-Mg alloys was the basis for early studies of the Al-B-Mg system [1949Ebo]. No complete phase diagram exists, although several groups investigated the interactions in the ternary system [1959Hof, 1970Mat, 1971Vek, 1981Por, 1983Sho]. Considerable interest was further devoted to the rather hard compound "$MgAlB_{14}$" [1970Mat, 1971Vek, 1983Hig, 1990Hig, 1993Hig]. Single crystals were obtained from aluminum high temperature flux starting from the nominal composition $MgAl_{31}B_6$ which was heated under argon in an alumina crucible to 1500°C, kept at this temperature for 1h and slowly cooled to RT ($10K·min^{-1}$). The excess Al was then dissolved in hot HCl [1983Hig, 1993Hig]. From a batch with ~100 g, crystals were formed up to 5 mm in size and predominantly as plates with the habit {001} [1993Hig]. When starting mixtures with smaller amounts of Mg were used, γAlB_{12} type crystals $Mg_{0.45}Al_{0.77}B_{12}$ were obtained, mostly as thin hexagonal plates [1993Hig].
[1959Hof] mixed magnesium, aluminum and boron in order to study the formation of $(Al,Mg)B_2$ solid solutions. After sintering in argon at temperatures between 725 and 790°C the formation of such a solid solution was identified despite the kinetic difficulty of formation. From 99.9 % pure metals and 99.2 % pure amorphous boron [1971Vek] synthesized 22 ternary alloys. The mixtures were briquetted and heated to temperatures of 850 to 1000°C under an argon atmosphere in sintered alumina crucibles. The reaction products were investigated by X-ray phase analysis. [1970Mat] prepared "$MgAlB_{14}$" by heating a mixture of magnesium, aluminum and boron in atomic proportions of 1:2:14 to 900°C for 6 h. The sample was then cooled and treated with concentrated hydrochloric acid. The crystal structure of this phase was determined by X-ray (probably on single crystal) diffraction.
The present evaluation was published in the MSIT Evaluation Program earlier and reflects today's state of knowledge.

Binary Systems

The systems Al-B [1994Dus] and B-Mg [1978Spe] are accepted.

Solid Phases

According to [1971Vek] the phase "$MgAlB_{12}$" is identical to "$MgAlB_{14}$". The structure of which was determined in detail from several attempts to obtain single crystal material from high temperature aluminum solutions [1983Hig, 1990Hig, 1993Hig]. In agreement with the chemical analysis (atom emission spectroscopy, $Mg_{0.79}Al_{0.80}B_{14}$), X-ray single crystal studies revealed significant defects on the metal sites: $Mg_{0.78}Al_{0.75}B_{14}$ [1983Hig, 1990Hig, 1993Hig]. For smaller Mg-concentrations in the Al-melt crystals "$Mg_{0.5}Al_{1.4}B_{22}$" of the γAlB_{12} type were obtained [1990Hig, 1993Hig], suggesting a high temperature solid solution of Mg in γAlB_{12} (about 3.5 at.% Mg at ~1500°C).

Isothermal Sections

A tentative isothermal section at approximately 900°C (Fig. 1) is constructed from the results of [1971Vek]. [1971Vek] reported a region of (Al) solid solution containing more than 65 at.% B, which is quite improbable and might be the result of the difficult formation of the $(Al,Mg)B_2$ phase as stated by [1959Hof]. For the phase relations at 900°C a small solid solution of Mg in αAlB_{12} was assumed as well as for Al in (βB). The ternary compound was taken at the composition $Mg_{0.78}Al_{0.75}B_{14}$ [1983Hig, 1990Hig, 1993Hig].

Notes on Materials Properties and Applications

Microhardness (Vickers hardness under a load of 100g) for $Mg_{0.78}Al_{0.75}B_{14}$ crystals was found to range from 27.70 to 28.90 GPa [1993Hig].

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Table 1: Crystallographic Data of Solid Phases

Phase/ Temperature Range [°C]	Pearson Symbol/ Space Group/ Prototype	Lattice Parameters [pm]	Comments/ References
(Al) < 660.452	*cF*4 $Fm\overline{3}m$ Cu	*a* = 404.96	[Mas2]
(βB) < 2092	*hR*333 $R\overline{3}m$ βB	*a* = 1093.30 *c* = 2382.52 *a* = 1096.5 *c* = 2386.8	[1993Wer] at AlB_{31} [V-C2]
Al_2B_3 ≤ 525	*hR** Al_2B_3 (?)	*a* = 1840 *c* = 896	at 60 at.% B [1992Var]
αAlB_{12} ≤ 2050	*tP*216 $P4_12_12$ αAlB_{12}	*a* = 1015.8 *c* = 1427.0 *a* = 1018 *c* = 1434.3	[1994Dus] $\rho_{exp.}$ = 2.65 Mgm^{-3} [1991Pri]
γAlB_{12}	*oP*384 $P2_12_12_1$ γAlB_{12}	*a* = 1014.4 *b* = 1657.3 *c* = 1751.0 *a* = 1019.5 *b* = 1666 *c* = 1769	[1994Dus] metastable phase or ternary product stabilized by small amounts of impurity metals present in Al-flux grown material $\rho_{exp.}$ = 2.56 Mgm^{-3} [1991Pri]
$Mg_{0.25}Al_{0.77}B_{12}$		*a* = 1018.7 *b* = 1663.3 *c* = 1754.7	solid solution of Mg in γAlB_{12} [1990Hig, 1993Hig]
$(Al_{1-x}Mg_x)B_2$ AlB_2 ≤ 975	*hP*3 *P6*/*mmm* AlB_2	 *a* = 300.6 *b* = 325.2 *a* = 304.7 *c* = 336.6	0 < *x* < 1 [1959Hof, 1971Vek] at *x* = 0 [1994Dus] at *x* = 0.5 [1971Vek]
MgB_2 ≤1550(BP)		*a* = 308.5 *b* = 352.3	at *x* = 1 [V-C2]
MgB_4 ≤ 1775 (BP)	*oP*20 *Pnma* MgB_4	*a* = 546.4 *b* = 442.8 *c* = 747.2	[V-C2]
MgB_7 ≤ 2150 (BP)	*oI*64 *Imma* MgB_7	*a* = 597.0 *b* = 1048.0 *c* = 812.5	[V-C2]
*τ_1, $Mg_{0.78}Al_{0.75}B_{14}$	*oI*68 *Imma* $MgAlB_{14}$	*a* = 584.8 *b* = 1031.2 *c* = 811.2	[1970Mat, 1983Hig, 1993Hig]

Fig. 1: Al-B-Mg. Tentative partial isothermal section at about 900°C