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Al-Mg-Y (Aluminum-Magnesium-Yttrium)

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The early work on this system by [1979Dri] presented partial isothermal sections between 500 and 300 °C for Y-lean alloys and a vertical section at 80 mass% Mg. [1980Zar] determined an isothermal section at 400 °C and reported the existence of a ternary compound Al_4MgY (denoted τ here). [1987Ran] calculated the phase equilibria of this system and presented a liquidus projection, nine isothermal sections, and ten vertical sections, but this assessment did not include the ternary compound τ. [1989Odi] constructed an isothermal section for the entire composition range at 400 °C, which confirmed the ternary compound Al_4MgY (τ) and extensive solubility of the third component in YAl_2, MgY, and Mg_2Y binary compounds. More recently, [2004Rok] determined two vertical sections at 0.6 mass% Y and at Mg/Y mass ratio of 0.27, respectively. [2006Als] developed a thermodynamic model based on the extrapolation from the binary subsystems.

Binary Systems

The Al-Mg phase diagram [1998Lia] has the following intermediate phases: Mg_2Al_3 (cubic, labeled β), R or ε (rhombohedral), and $Mg_{17}Al_{12}$ (*A*12, αMn-type cubic, denoted γ). The Al-Y phase diagram [Massalski2, 2006Als] depicts the following intermediate compounds: YAl_3 ($D0_{19}$, Ni_3Sn-type hexagonal), YAl_2 (*C*15, $MgCu_2$-type cubic), YAl (B_f, CrB-type orthorhombic), Y_3Al_2 (Zr_3Al_2-type tetragonal), and Y_2Al (*C*23, Co_2Si-type orthorhombic). The Mg-Y phase diagram [Massalski2, 2006Als] shows the following intermediate phases: $Mg_{24}Y_5$ (*A*12, αMn-type cubic) Mg_2Y (*C*14, $MgZn_2$-type hexagonal), and MgY (*B*2, CsCl-type cubic). $Mg_{24}Y_5$ and MgY have a significant range of homogeneity.

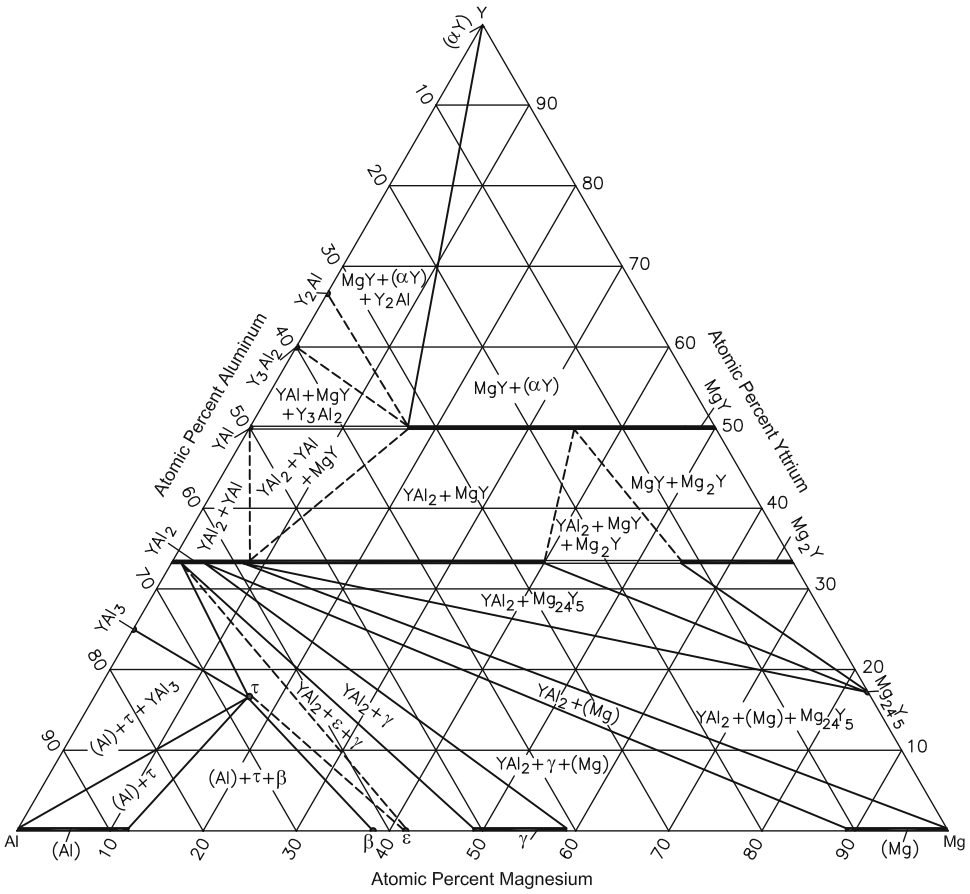

Fig. 1 Al-Mg-Y isothermal section at 400 °C [1989Odi]. Narrow two-phase regions are omitted

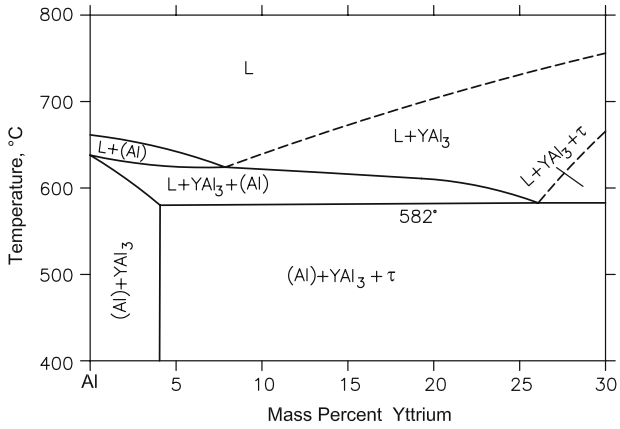

Fig. 2 Al-Mg-Y vertical section at constant Mg/Y mass ratio of 0.27 [2004Rok]

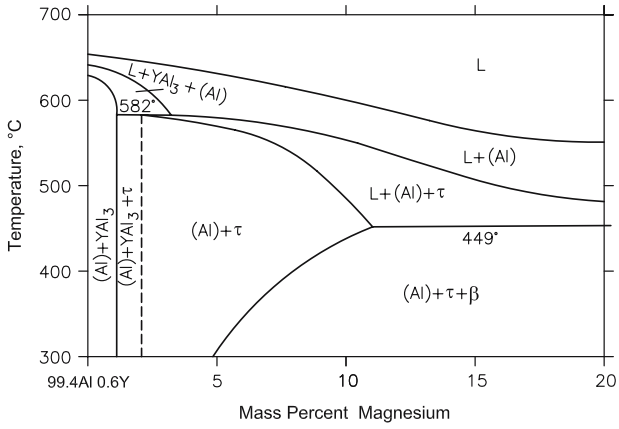

Fig. 3 Al-Mg-Y vertical section at 0.6 mass% Y [2004Rok]

Ternary Phase Equilibria

Figure 1 shows the isothermal section at 400 °C determined by [1989Odi]. The ternary compound Al_4MgY (τ) is present. It has the $MgZn_2$-type hexagonal structure and lattice parameters of $a = 0.5511$ nm and $c = 0.8880$ nm [1989Odi]. YAl_2 dissolves 40 at.% Mg, with the lattice parameter a increasing linearly from ~0.782 nm at 0% Mg to ~0.799 nm at 40 at.% Mg. MgY dissolves about 32 at.% Al, with a~0.376 nm at 0% Al decreasing linearly to ~0.365 nm at 32 at.% Al. Mg_2Y dissolves 12 at.% Al. [2006Als] has questioned the large solubilities reported by [1989Odi].

With starting metals of 99.99% Al, 99.96% Mg, and 99.83% Y, [2003Rok] and [2004Rok] melted Al-rich ternary alloys in an electric furnace under the protective cover of a salt mixture. The alloys were annealed for 100-50 h at different temperatures between 275 and 430 °C. The phase equilibria were studied with optical microscopy, x-ray powder diffraction, and electron probe microanalysis. Differential thermal analysis (DTA) was performed at a heating/cooling rate of 3 °C/min. Two vertical sections determined by [2004Rok] at Mg/Y mass ratio of 0.27 and at 0.6 mass% Y are shown in Fig. 2 and 3. Two invariant horizontals are seen in the figures. At 582 °C, the transition reaction $L + YAl_3 \leftrightarrow (Al) + \tau$ occurs. The reaction at 449 °C is probably the ternary eutectic: $L \leftrightarrow (Al) + \tau + \beta$.

[2006Als] carried out a detailed thermodynamic assessment of this ternary system and the binary subsystems. The thermodynamic descriptions of the Al-Y and Mg-Y systems were developed by [2006Als], who considered all relevant phase diagram data, the experimental thermodynamic properties, and the crystallographic information. The description of the Al-Mg system was taken from the COST 507 database. The ternary equilibria were calculated by combining the descriptions of the three constituent binaries and the parameters for the ternary compound τ. In the liquidus projection computed by [2006Als], 16 four-phase invariant reactions and 8 temperature maxima are seen. The region of primary crystallization of τ computed by [2006Als] is in accord with the DTA arrests observed by [1990Odi]. However, the two invariant reactions experimentally observed by [2004Rok] are not among the 16 computed reactions. [2006Als] did not refer to the work of [2004Rok]. In Fig. 4, a vertical section at 80 mass% Mg computed by [2006Als] is compared with the DTA points of [1979Dri]. The agreement is satisfactory. The main drawback of the thermodynamic treatment of [2006Als] appears to be the complete neglect of the third component solubility in the binary compounds. Such solubilities have been reported recently in other Al-Mg-RE systems. More reliable experimental data and a revision of the thermodynamic description are needed.

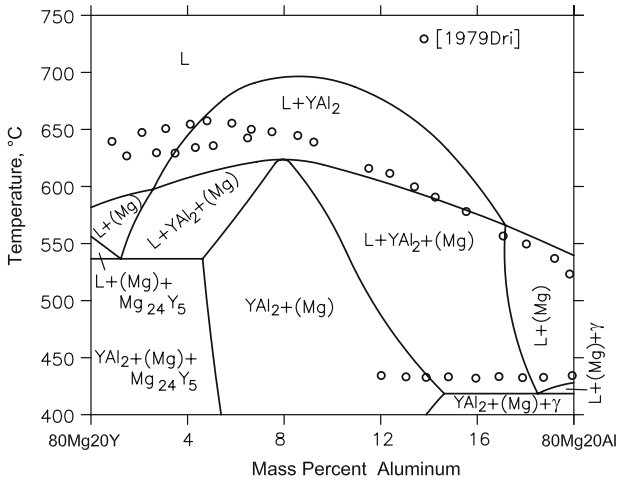

Fig. 4 Al-Mg-Y computed vertical section at 80 mass% Mg [2006Als]

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