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Al-Fe-Mn (Aluminum-Iron-Manganese)

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The first review of this system by [1988Ray] presented liquidus and solidus projections for Fe-rich and Al-rich compositions, and partial isothermal sections between 1200 and 600 °C. An update by [1994Rag] added two computed isothermal sections at 1400 and 1100 °C from [1993Liu]. A second update [2005Rag] presented isothermal sections at 1300, 1200, 900, and 800 °C from [1996Liu1] for Al-poor alloys. Recently, [2006Umi] reported new experimental results, which include the $A2 \rightarrow B2$ order-disorder transition of the Fe-Al system extending into the ternary region.

Binary Systems

The Al-Fe phase diagram [1993Kat] shows that the face-centered cubic (fcc) solid solution based on Fe is restricted by a γ loop. The body-centered cubic (bcc) solid solution exists in the disordered $A2$ form (α), as well as the ordered $B2$ and $D0_3$ forms. The high temperature phase ε (denoted by [2006Umi] as Fe_4Al_5 to avoid confusion with the ε phase of the Al-Mn system) is stable between 1232 and 1102 °C. There are three other intermediate phases stable down to room temperature: $FeAl_2$(triclinic), Fe_2Al_5 (70-73 at.% Al, orthorhombic), and $FeAl_3$ or Fe_4Al_{13} (74.5-76.6 at.% Al, monoclinic). The Mn-rich region of the Al-Mn phase diagram was reinvestigated by [1996Liu2] by the diffusion couple technique, supplemented by metallography, x-ray diffraction, differential scanning calorimetry, and transmission electron microscopy. Figure 1 shows the Al-Mn diagram proposed by [1996Liu2] between 30 and 100 at.% Mn. The homogeneity range of the intermediate phase ε (close packed hexagonal) is 53-72 at.% Mn, which is much larger than the range of 53-60 at.% in [Massalski2]. The other intermediate phases are: γ (bcc, ~34.5-52 at.% Mn), γ_1 (~30-38.7 at.% Mn, structure not known), γ_2 (~31.4-50 at.% Mn, $D8_{10}$, Cr_5Al_8-type rhombohedral), Mn_4Al_{11} (orthorhombic and triclinic forms), μ (19-20.8 at.% Mn, hexagonal), λ (16.8-19 at.% Mn, hexagonal) and Al_6Mn ($D2_h$-type orthorhombic). The bcc phase (γ) undergoes an ordering transition to $B2$ in the lower temperature range of its stability [1999Liu]. There are no intermediate phases in the Fe-Mn system. Fcc Fe and γ Mn form a continuous solid solution labeled γ. The fcc → bcc (α) transition in Fe in lowered by the addition of Mn. βMn ($A13$-type cubic) and αMn ($A12$-type cubic) dissolve up to 35 at.% Fe.

Ternary Isothermal Sections

Using starting metals of 99.7% Al, 99.9% Fe and 99.9% Mn, [2006Umi] induction melted ternary alloys, which were given a final anneal at 1200-800 °C for 14-336 h and quenched in water. The phase equilibria were studied by electron probe microanalysis. The diffusion couple

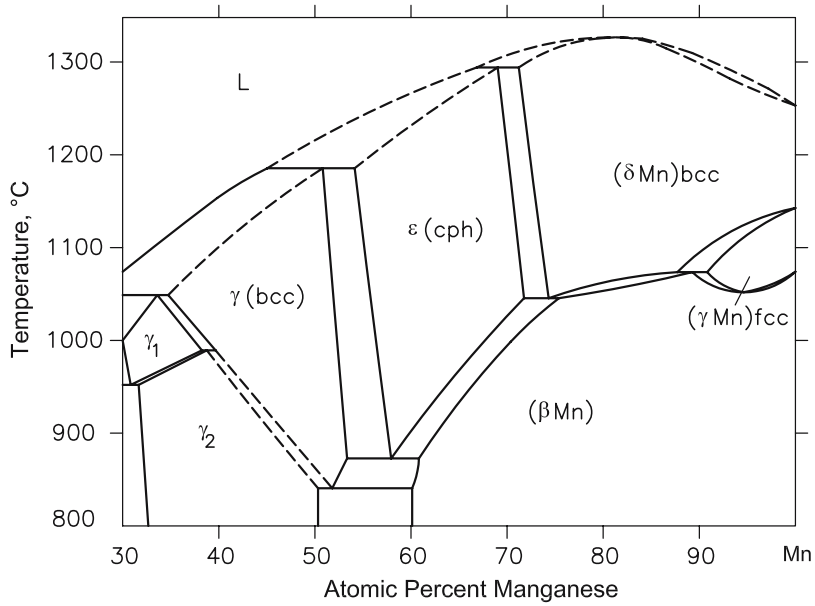

Fig. 1 Al-Mn phase diagram between 30 and 100 at.% Mn [1996Liu2]

technique and differential scanning calorimetry were used to determine the characteristics of the $A2 \rightarrow B2$ and $B2 \rightarrow D0_3$ transitions. In the composition range below than 30 at.% Al, Mn increases both $A2 \rightarrow B2$ and $B2 \rightarrow D0_3$ transition temperatures.

Based on their results and the earlier studies of [1996Liu1], [2006Umi] optimized and listed the interaction parameters for liquid, fcc, bcc, cph, $A12$, $A13$ and $B2$ phases. The binary assessments of [1989Hua] for Fe-Mn, [1999Liu] for Al-Mn, and unpublished data for Al-Fe systems were used. The computed isothermal sections of [2006Umi] at 1200, 1100, 1000, 900 and 800 °C show good agreement with the experimental results of [1996Liu1] and [2006Umi] in the Al-poor region. The computed sections at 1200, 1100, 1000, and 800 °C are redrawn in Fig. 2 and 3. At 1200 °C (Fig. 2a), the Al-Mn phase ε (cph) and the Fe-Al high temperature phase ε (Fe_4Al_5) are stable. The $A2 \rightarrow B2$ ordering extends into the ternary region and is a second-order transition. At 1100 °C (Fig. 2b), the Fe-Al ε phase is not stable. $FeAl_2$, Fe_2Al_5 and $FeAl_3$ become stable. The $A2 \rightarrow B2$ transition also covers the bcc region (γ) along the Al-Mn side. At 1000 °C (Fig. 3a), Mn_5Al_8 appears along the Al-Mn side. At 800 ° (Fig. 3b), Mn_4Al_{11} and $MnAl_4$ also appear along the Al-Mn side.

Recently, [2005Che] reported the formation of a ternary phase with the simple cubic space lattice in the bcc matrix of an Fe-24.1 wt.% Mn-7.6 wt.% Al −0.03 wt.% C alloy on air cooling from 1300 °C.

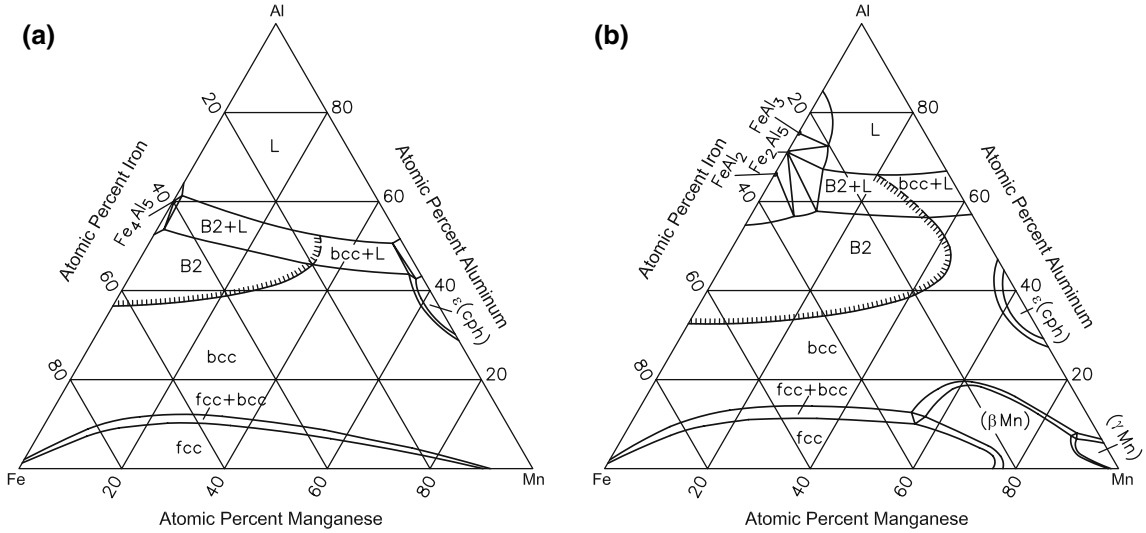

Fig. 2 Al-Fe-Mn computed isothermal sections at (a) 1200 and (b) 1100 °C [2006Umi]

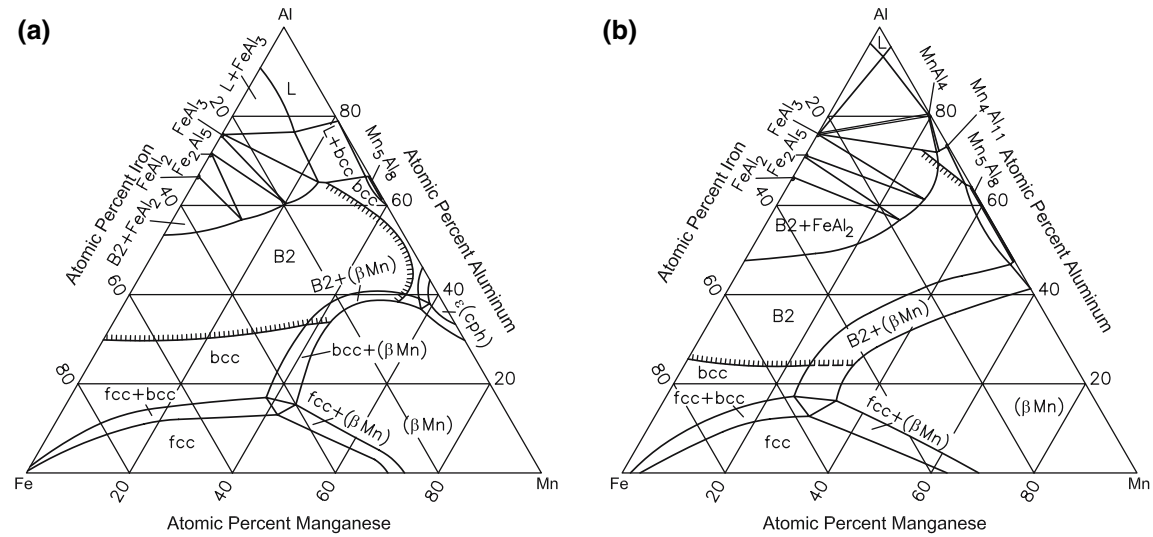

Fig. 3 Al-Fe-Mn computed isothermal sections at (a) 1000 and (b) 800 °C [2006Umi]

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