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Al-Fe-Zn (Aluminum-Iron-Zinc)

V. Raghavan

The early results on this ternary system were reviewed by [1992Rag]. An update on the phase equilibria of Zn-rich alloys by [2003Rag1] presented an isothermal section at 450 °C for metastable and stable equilibria from [1992Per] and two sections at 470 and 440 °C from [1995Yam]. Recently, a full thermodynamic description of this system was reported by [2007Nak], using in the optimization the activities derived from the emf measurements of [1995Yam, 1998Yam].

Binary Systems

The Al-Fe phase diagram [Massalski2] depicts several intermediate phases. Apart from the high temperature phase Fe_4Al_5 (ε), there are three phases stable down to room temperature: $FeAl_2$ (triclinic), Fe_2Al_5 (70-73 at.% Al; orthorhombic) and $FeAl_3$ (Fe_4Al_{13}) (74.5-76.6 at.% Al; monoclinic). The Al-Zn phase diagram [Massaslski2] depicts a eutectic reaction at 381 °C between (Al) and (Zn). In the (Al) region, a miscibility gap occurs in the solid state with the monotectoid reaction at 277 °C and the critical temperature at 351.5 °C. There are no intermediate phases in this system. In the Fe-Zn system [2003Rag2], the intermediate phases are: Γ (Fe_3Zn_{10}; Cu_5Zn_8-type cubic), Γ_1 ($Fe_{11}Zn_{40}$; cubic, space group $F\bar{4}3m$, 408 atoms/cell), δ ($FeZn_{10}$; $FeZn_{10}$-type hexagonal), and ζ ($CoZn_{13}$-type monoclinic). The above nomenclature for the Fe-Zn compounds is from [1982Kub] and is adopted among others by [2007Nak]. Γ and Γ_1 are denoted as Γ_1 and Γ_2 respectively in the publications of Perrot and co-workers. Recently, [2005Nak] provided a revised thermodynamic description of the Fe-Zn system.

Computed Ternary Phase Equilibria

Nakano et al. [2007Nak] presented a full thermodynamic assessment of this system. Crystallographically-consistent sublattice models for the Fe-Zn intermetallic phases [2005Nak] were used to predict the most probable host sublattices for the Al atoms. The sublattice models of Fe-Al binary compounds $FeAl_2$, Fe_2Al_5, and Fe_4Al_{13} were suitably modified to allow the description of the Zn solubility in them. The ternary phase found by [1992Per], [1995Yam], and [2002Tan] and discussed in [2003Rag1] was denoted variously as Γ_2 by [1992Per] and [2007Nak], T by [2002Tan] and Γ_1' by [2003Rag1]. The cubic structure of this ternary phase is presumably isomorphic with the binary phase Γ_1 (denoted Γ_2 by [1992Per]). According to [2007Nak], "it is justifiable to deem that Γ_2 (ternary phase) and Γ_1 are two composition sets of the same phase having a miscibility gap". However, using a single analytical expression for this phase led to difficulties in the optimization. Due to this, [2007Nak] considered the ternary phase to be a separate phase, whose sublattice model resembled that of the binary phase. Experimental results for the optimization were carefully chosen by [2007Nak] from those which correspond to the equilibrium state. Extensive data on the activities derived from the emf measurements of [1995Yam, 1998Yam] were used in the optimization. The optimized interaction parameters for the binary phases and the ternary phase were listed.

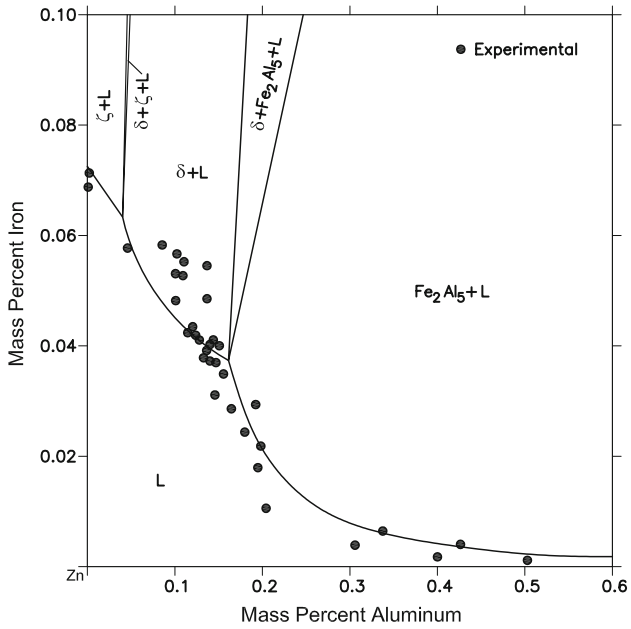

Fig. 1 Al-Fe-Zn computed metastable isothermal section at 480 °C near the Zn corner [2007Nak]

Industrial galvanizing conditions correspond to short annealing times and to metastable equilibrium. The ternary phase does not appear under such conditions. The isothermal sections near Zn corner calculated by [2007Nak] by suppressing the ternary phase at 480, 470, 460, and 450 °C are shown in Fig. 1-4, respectively. The experimental points from different sources for the liquid/solid equilibrium are marked. Figure 5 shows the isothermal section at 450 °C under equilibrium conditions. The ternary phase (marked Γ_1') is present. [2007Nak] also plotted a computed isothermal section at 450 °C for a wider area near the Zn corner and compared them with more experimental results.

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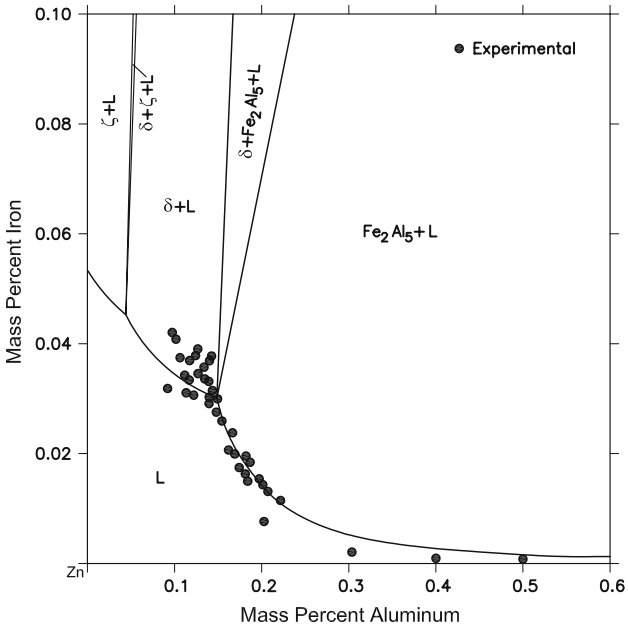

Fig. 2 Al-Fe-Zn computed metastable isothermal section at 470 °C near the Zn corner [2007Nak]

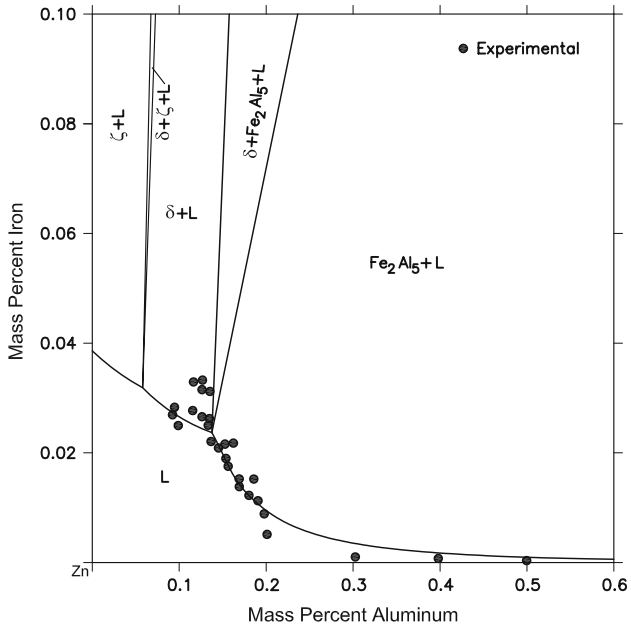

Fig. 3 Al-Fe-Zn computed metastable isothermal section at 460 °C near the Zn corner [2007Nak]

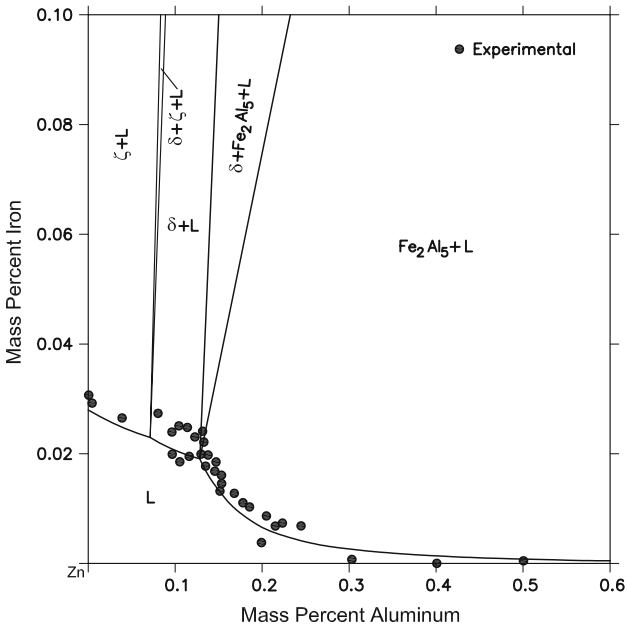

Fig. 4 Al-Fe-Zn computed metastable isothermal section at 450 °C near the Zn corner [2007Nak]

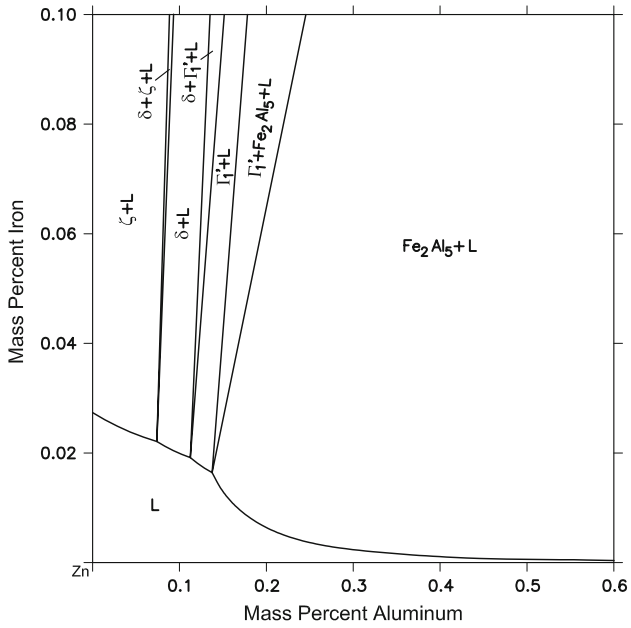

Fig. 5 Al-Fe-Zn computed stable isothermal section at 450 °C near the Zn corner [2007Nak]

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