JPEDAV (2007) 28:395–396
DOI: 10.1007/s11669-007-9108-8
1547-7037 ©ASM International

Fe-Si-Zn (Iron-Silicon-Zinc)

V. Raghavan

The first review of this ternary system by [1992Rag] presented a schematic liquidus projection, an isothermal section at 25 °C, and a reaction scheme, based mainly on the work of [1969Kos]. An update by [2003Rag] reviewed the results of [2001Su] and presented an isothermal section at 450 °C. Recently, [2005Wan] determined two more isothermal sections at 480 and 405 °C. Also, a thermodynamic calculation of this system was carried out by [2005Su].

Binary Systems

The Fe-Si phase diagram [Massalski2] depicts a γ loop restricting the Fe-based face-centered cubic (fcc) solid solution to 3.2 at.% Si. The body-centered cubic (bcc) solid solution α exists in the disordered *A*2 form, as well as in the ordered forms of *B*2 and $D0_3$. The intermediate phases are: Fe_2Si (hexagonal), Fe_5Si_3 ($D8_8$, Mn_5Si_3-type hexagonal), FeSi (*B*20-type cubic), α$FeSi_2$ (orthorhombic), and β$FeSi_2$ (tetragonal). The Fe-Zn phase diagram exhibits a γ loop, extensive solubility of Zn in the body-centered cubic (bcc) Fe (α), and four intermediate phases: Fe_3Zn_{10} (denoted Γ; 68.5-82.5 at.% Zn, Cu_5Zn_8-type cubic), $Fe_{11}Zn_{40}$ (denoted Γ_1; 75-81 at.% Zn, cubic), $FeZn_{10}$ (denoted δ; 86.5-91.8 at.% Zn, hexagonal), and $FeZn_{13}$ (denoted ζ; 92.8-94 at.% Zn, $CoZn_{13}$-type monoclinic). The Si-Zn phase diagram is a simple eutectic system with the eutectic point very close to the Zn end.

Ternary Phase Equilibria

With starting metals of 99.99% Fe, 99.9% Si, and 99.99% Zn, [2005Wan] melted nine ternary alloys in evacuated quartz tubes. The final anneal was at 480 or 405 °C for 15 days, followed by water quenching. The phase equilibria were studied by optical microscopy and x-ray powder diffraction. The compositions of the co-existing phases were determined by energy dispersive spectroscopy and were listed. The isothermal sections at 480 and 405 °C constructed by [2005Wan] are redrawn in Fig. 1. For clarity and for easy comparison with the isothermal section at 450 °C (Fig. 1 of [2003Rag]), the Si-Zn side is drawn 4 times larger than the Fe-Zn side. The phase distribution is the same at all three temperatures. The three-phase equilibrium of $\zeta + FeSi + L$ or (Zn) is seen to be stable. The δ phase does not form tie-lines with the L or (Zn). The solubility of Si in δ is 1.2 at.% at 480 °C and 0.5 at.% at 405 °C. Very little Si dissolves in the ζ phase.

In the thermodynamic analysis of [2005Su], the liquid, fcc and bcc phases were treated as random substitutional solutions. The Fe-Si compounds and the ζ phase were treated as stoichiometric compounds. A two-sublattice model was used for δ, Γ and Γ_1 and phases, taking into account the Fe (or Zn) variations and the Si solubility. The optimized interaction parameters were listed. Isothermal sections were computed at 980, 750, 700, 600, 502, 500,

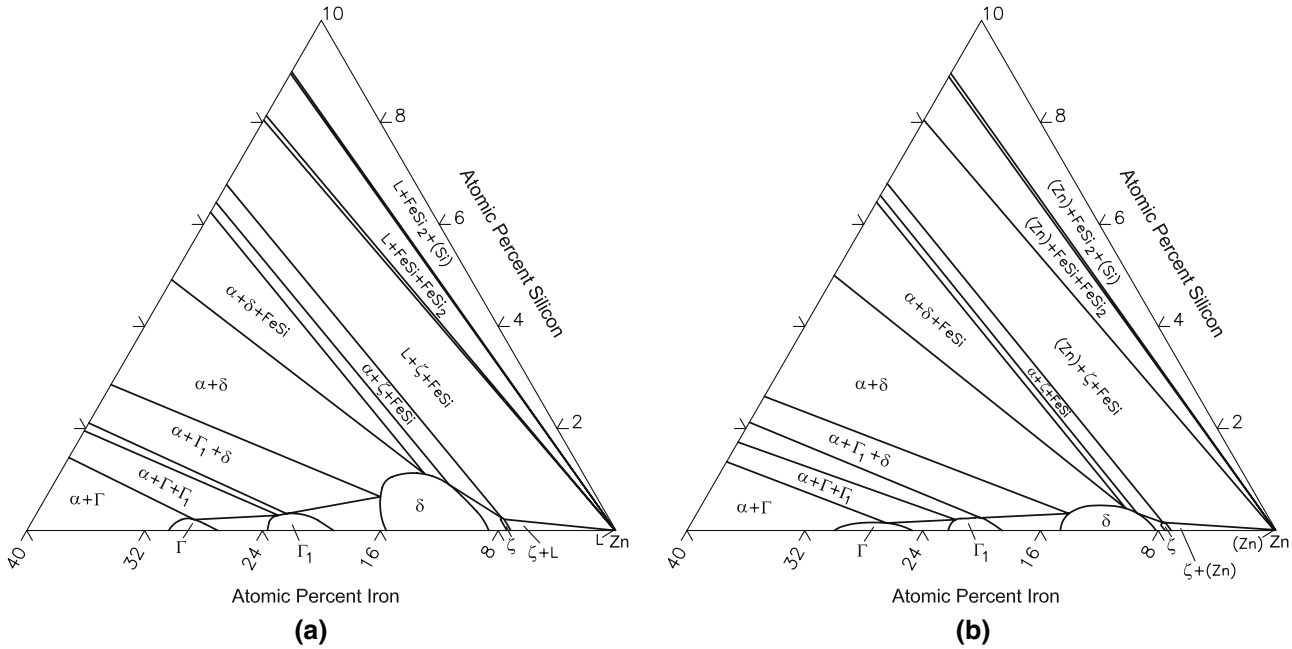

Fig. 1 Fe-Si-Zn isothermal sections at (a) 480, and (b) 405 °C [2005Wan]

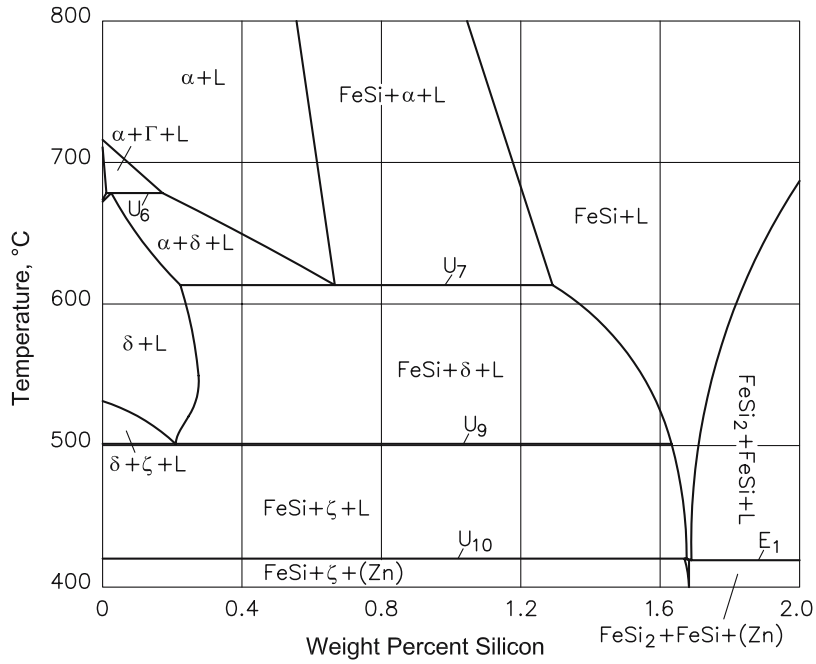

Fig. 2 Fe-Si-Zn computed vertical section at 95 wt.% Zn [2005Su]

450, and 25 °C and compared with the available experimental data. Vertical sections were calculated 64 and 95 wt.% Zn and were found to be in reasonable agreement with the experimental data of [1969Kos]. The vertical section at 95 wt.% Zn is redrawn in Fig. 2. Invariant horizontals are marked in the figure, corresponding to the four-phase reactions U_6, U_7, U_9, U_{10} and E_1 in the reaction scheme given by [1992Rag].

References

1969Kos: W. Koster, The Iron-Silicon-Zinc Ternary System, *Metallurgia*, 1969, **80**, p 219-229

1992Rag: V. Raghavan, The Fe-Si-Zn (Iron-Silicon-Zinc) System, *Phase Diagrams of Ternary Iron Alloys*, Ind. Inst. Metals, Calcutta, 1992, p 1183-1188

2001Su: X. Su, N.Y. Tang, and J.M. Toguri, 450 °C Isothermal Section of the Fe-Zn-Si Ternary Phase Diagram, *Can. Metall. Q.*, 2001, **40**(3), p 377-384

2003Rag: V. Raghavan, Fe-Si-Zn (Iron-Silicon-Zinc), *J. Phase Equilib.*, 2003, **24**(6), p 562-563

2005Su: X. Su, F. Yin, Z. Li, N.Y. Tang, and M. Zhao, Thermodynamic Calculation of the Fe-Zn-Si System, *J. Alloys Compd.*, 2005, **396**, p 156-163

2005Wan: J. Wang, X. Su, F. Yin, Z. Li, and M. Zhao, The 480 °C and 405 °C Isothermal Sections of the Phase Diagram of the Fe-Zn-Si Ternary System, *J. Alloys Compd.*, 2005, **399**, p 214-218