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Cu-Fe-Mn (Copper-Iron-Manganese)

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The review of this ternary system by [1988Ray] presented a liquidus surface and four isothermal sections at 1050, 950, 900, and 850 °C. The updates by [1994Rag] and [2002Rag] added two computed isothermal sections at 1300 and 1150 °C from the work of [1981Nis] and an experimental section at 1200 °C based on the studies of [1997Oht]. The compilation of [1995Vil] included a liquidus projection and four isothermal sections assessed by [1988Ray], eight computed isothermal sections between 1300 and 600 °C from [1978Has], four vertical sections from [1913Par] and computed isothermal sections near the Fe corner by [1989Har]. Miscibility gaps in the liquid and solid states were calculated by [2004Wan]. A thermodynamic description of the system near the Fe-Cu side was given by [2003Mie]. Recently, [2007Wan] carried out a thermodynamic assessment of this ternary system and computed nine isothermal sections, six vertical sections and a liquidus projection. The work of [2007Wan] was reviewed by [2008Rag]. Very recently, [2008Zha] carried out another detailed thermodynamic description and presented a number of computed isothermal sections, vertical sections and a liquidus projection, which were compared with the available experimental results. This update will be limited to a discussion of the similarities and differences between these two recent thermodynamic assessments.

Binary Systems

There are no intermediate phases in any of the three binary subsystems. A metastable liquid miscibility gap is known in the Cu-Fe and Cu-Mn systems. Computed phase diagrams of Cu-Fe, Cu-Mn and Fe-Mn were given by [2008Zha]. Continuous face-centered cubic (fcc) solid solutions exist between γFe and γMn (denoted fcc_1) and between Cu and γMn (denoted fcc_2).

Ternary Phase Equilibria

With starting metals of 99.999% Cu, 99.99% Fe and 99.9% Mn, [2008Zha] arc-melted under Ar atm four Fe-rich alloys containing up to 20 mass% Cu and 30 mass% Mn. The alloys were annealed at 800 °C for 30 d and quenched in water. Differential thermal analysis was carried out on the annealed samples at a heating/cooling rate of 5 °C per min. The phase equilibria were studied with optical metallography, x-ray powder diffraction and electron probe microanalysis. The tie-lies determined between fcc_2 (Cu, γMn) and fcc_1 (γFe, γMn) or between fcc_2 and (αFe) were listed. Microstructural examination by [2008Zha] showed that the fcc_1 phase (γFe, γMn) undergoes a massive transformation to (αFe) during quenching in alloys with Mn equal to 5 or 10 mass%. These alloys were classified as having (Cu, γMn) + (γFe, γMn) equilibrium at 800 °C. This result is at variance with that of [2007Wan], who did not consider the possible intervention of the massive transformation.

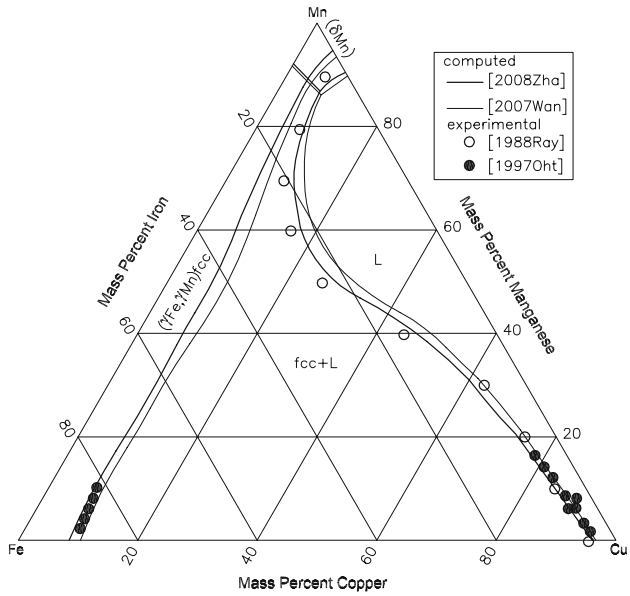

Fig. 1 Cu-Fe-Mn computed isothermal section at 1200 °C

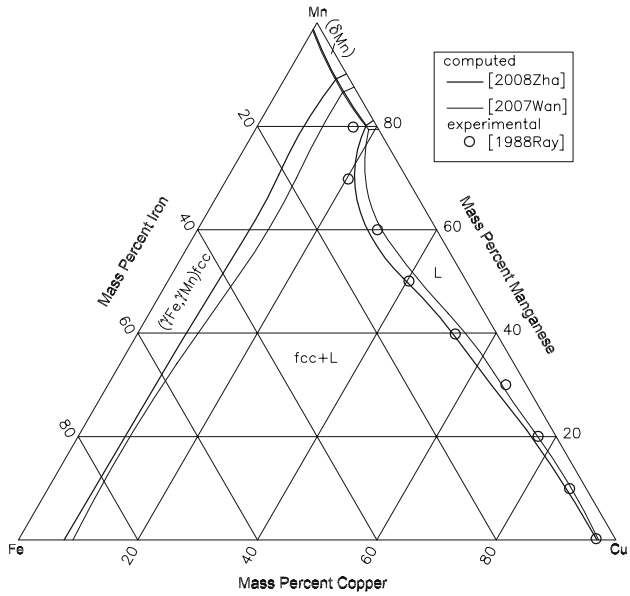

Fig. 2 Cu-Fe-Mn computed isothermal section at 1150 °C

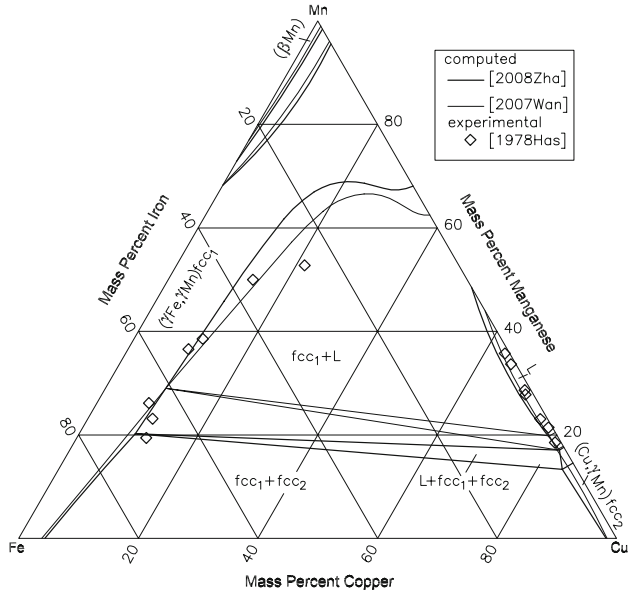

Fig. 3 Cu-Fe-Mn computed isothermal section at 950 °C

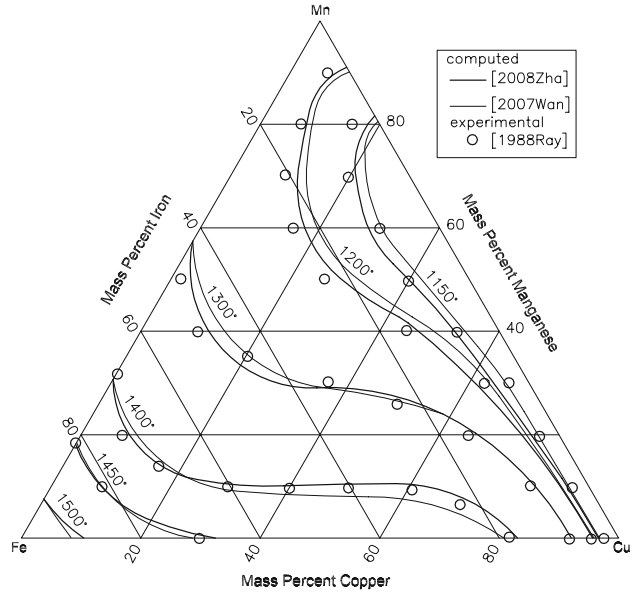

Fig. 5 Cu-Fe-Mn computed isotherms on the liquidus surface

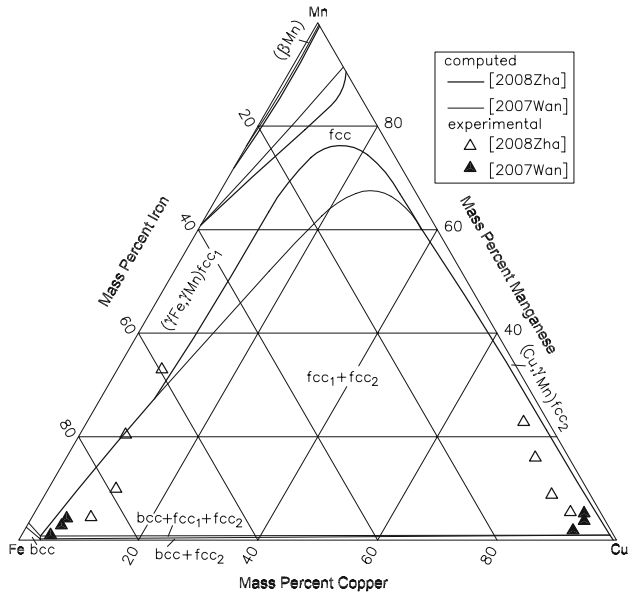

Fig. 4 Cu-Fe-Mn computed isothermal section at 800 °C

In their thermodynamic analysis, [2008Zha] used a more recent description of the Cu-Mn system by [2008He]. The liquid phase and the fcc phase (fcc_1 and fcc_2) and the bcc phase (δFe, δMn, and αFe) were described as single-lattice substitutional solutions. In modeling (βMn) and (αMn) phases, the solubility of Cu and Fe was considered. The magnetic contribution to the Gibbs energy was taken into account in the case of fcc, bcc and (αMn) phases. The experimental data of [1913Par], [1978Has], [1997Oht], [2001Wan] and [2008Zha] were used in the optimization. Fewer ternary interaction parameters were determined for the liquid, fcc and bcc phases (a total of 9 instead of 14 evaluated by [2007Wan]).

Eleven isothermal sections at 50° intervals between 1300 and 800 °C, nine vertical sections at 10, 20 and 30 mass% each of Cu, Fe and Mn and a liquidus projection were computed and compared with experimental data. The agreement with experiments is about the same between the two assessments [2007Wan] and [2008Zha]. However, there are some improved fitting seen in the description of [2008Zha]. The isothermal sections at 1200, 1150 and 950 °C, where such improvement is discernible, are shown in Fig. 1-3. The slightly-better fit is seen in the L/(fcc_1 + L) phase boundary in Fig. 1 and 2. The location of the tie-triangle (L + fcc_1 + fcc_2) of [2008Zha] shows better agreement with experimental data in Fig. 3. The isothermal section at 800 °C (Fig. 4), where new data obtained by [2008Zha] were used in the optimization, shows no better agreement than [2007Wan]. This poor fit is also seen at 900 and 850 °C (not shown here). [2008Zha] attributed this discrepancy to the experimental difficulties in determining the equilibrium between (Fe) and (Cu) near the Fe-Cu side. As with the results of [2007Wan], the fit of the computed vertical sections of [2008Zha] with the experimental data of [1913Par] (not shown here) is good. Figure 5 shows the isotherms (constant-temperature contour lines) on the liquidus surface. Some improvement is discernible in the fit between the computations of [2008Zha] and the experimental data assessed by [1988Ray].

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