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Cu-Fe-Ni (Copper-Iron-Nickel)

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The previous review of this system by [1990Gup] presented a liquidus projection, isothermal sections at 1250, 1150, 850, 750, 400, and 20 °C, the miscibility gap in the face-centered-cubic (fcc) (γ) phase between 1050 and 600 °C, and two vertical sections. Several new reports have since appeared in the literature. [2001Ser1] found a new ternary phase, which is a superlattice based on $FeNi_3$.

Binary Systems

The Cu-Fe phase diagram [Massalski2] has no intermediate phases. A metastable liquid miscibility gap is known in this system. The Cu-Ni phase diagram [Massalski2] depicts complete solid solubility between Cu and Ni (both fcc) over a wide range of temperature. This solid solution breaks up into Cu-rich and Ni-rich phases below the critical temperature of 354.5 °C at the composition of 67.3 at.% Ni. The Fe-Ni phase diagram [1991Swa] is characterized by a very narrow solidification range, with a peritectic reaction at 1514 °C between body-centered-cubic (bcc) δ and liquid that yields the Fe-based fcc solid solution. A continuous solution denoted γ between fcc Fe and Ni is stable over a wide range of temperature. At 517 °C, an ordered phase $FeNi_3$ ($L1_2$, $AuCu_3$-type cubic) forms congruently from γ.

Ternary Isothermal Sections

With starting metals of purity ≥99.9%, [1997Oht] prepared solid-liquid diffusion couples by drilling holes in a columnar sample of pure Fe and by filling the holes with Cu-Ni alloys of different composition. Annealing was done at 1300 and 1200 °C for 24-48 h, followed by quenching in iced brine. The composition of the coexisting phases was measured by the energy-dispersive x-ray spectroscopy and listed. Using the new experimental data and the available literature data in thermodynamic optimization, [1997Oht] computed an isothermal section at 1200 °C, which is redrawn in Fig. 1. This section is consistent with the sections computed by [1985Chu] at 1250 and 1150 °C.

Below the melting point of Cu in the solid state, a miscibility gap exists in the Fe-Cu binary system between fcc Fe and fcc Cu. With the addition of Ni, this gap closes. [1990Gup] reviewed the shape of this miscibility gap in the ternary alloys between 1050 and 600 °C, omitting the Fe-rich region, where bcc Fe becomes stable below 910 °C. [1985Chu] computed ternary isothermal sections at 1050, 950, and 850 °C, depicting the miscibility gap. [1989Har] computed the bcc-fcc equilibrium near the Fe corner at 850, 750, 650, and 550 °C, as well as the miscibility gaps at these

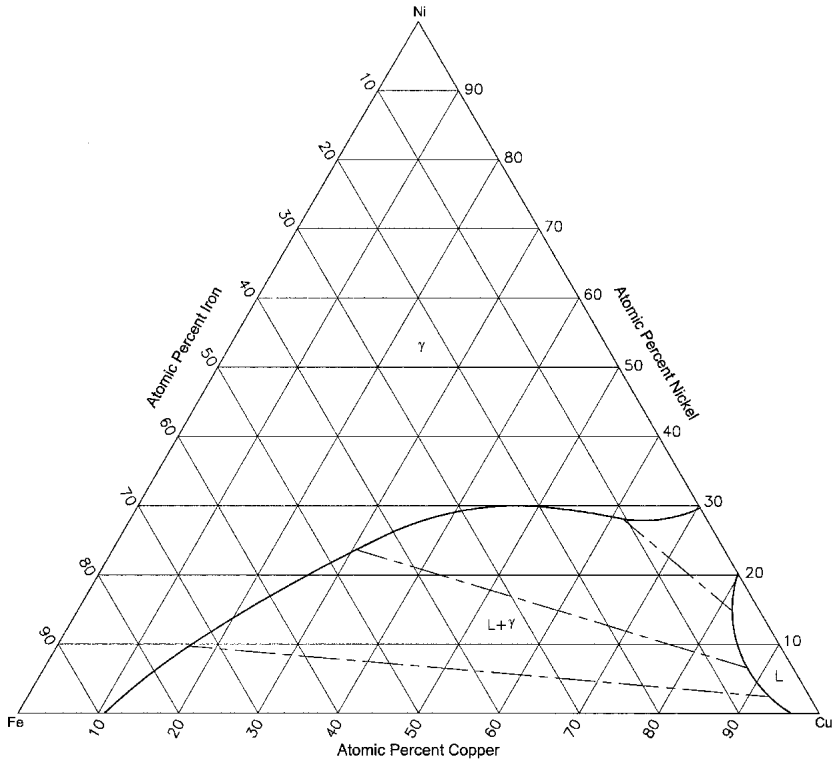

Fig. 1 Cu-Fe-Ni computed isothermal section at 1200 °C [1997Oht]

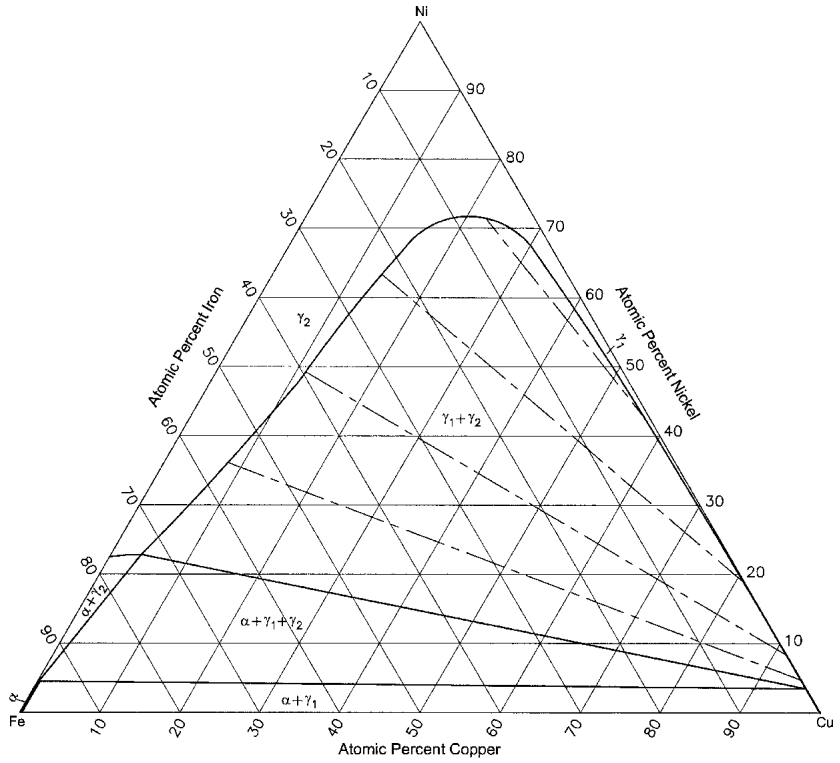

Fig. 2 Cu-Fe-Ni computed isothermal section at 550 °C [2001Ser2]

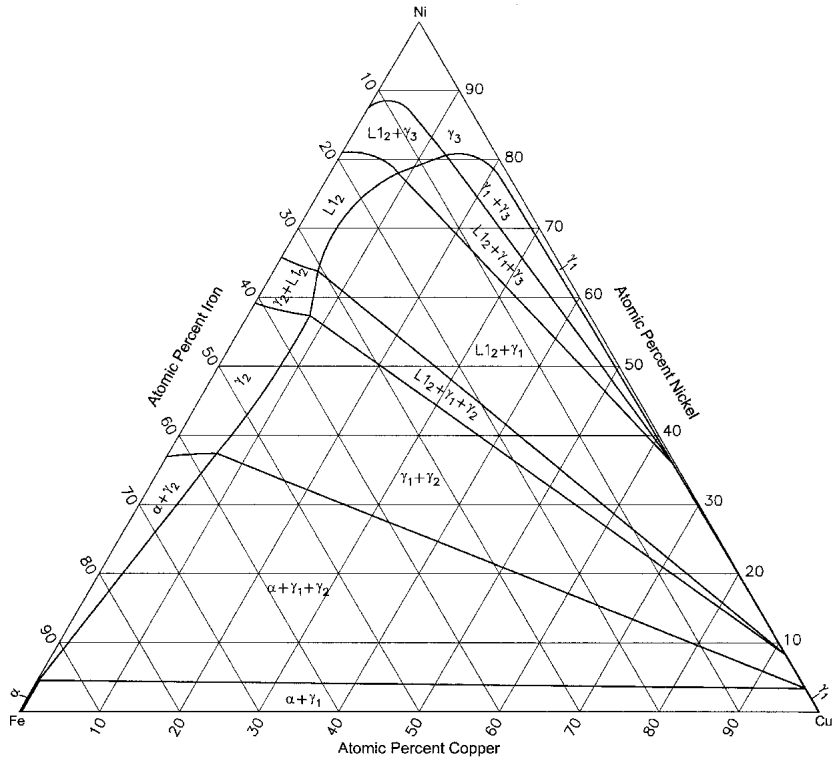

Fig. 3 Cu-Fe-Ni computed isothermal section at 450 °C [2001Ser2]

temperatures. [1992Gan] determined an isothermal section at 900 °C, using the diffusion triple technique and the electron probe microanalysis (EPMA). [1996Ron] constructed an isothermal section at 1000 °C, using the diffusion couple method and EPMA. Recently, [2000Qin] reported four isothermal sections at 1050, 1000, 800, and 600 °C. The mis-

cibility gaps in the above results are in reasonable agreement with previous results.

At temperatures lower than 550 °C, the $L1_2$ compound $FeNi_3$ becomes stable and is present in ternary alloys near the Fe-Ni side. [2001Ser1] examined this region and found that a new phase with a composition of 5.6Cu-22.2Fe-72.2Ni (at.%) is present. The new phase is a superlattice based on the $FeNi_3$ stoichiometry and has a cubic lattice parameter (a = 1.08 nm), which is three times that of the fcc phase. [2001Ser2] made a thermodynamic assessment of this system with special reference to this temperature and composition range. The liquid phase, the bcc (α) phase and the fcc phase [γ or (Cu)] were modeled as substitutional solutions. A four-sublattice model was used for the $L1_2$ structure. The disordered state is described when the site fractions of the different species are the same in the four sublattices. If three sublattices have the same site fractions, different from the fourth, the $L1_2$ ordering can be described.

Three isothermal sections were computed at 550, 500, and 450 °C by [2001Ser2]. The sections at 550 and 450 °C are redrawn in Fig. 2 and 3. In these figures, γ_1, γ_2, and γ_3 refer to the fcc phase in different composition ranges. At 550 °C, which is above the congruent formation temperature of $FeNi_3$, only the disordered fcc solid solution is present and it extends from the Cu corner via the Ni corner up to the (α + γ) field near the Fe corner, with a large miscibility gap. At 450 °C, the $L1_2$ phase is stable and dissolves about 5 at.% Cu. It comes into equilibrium with the disordered fcc phase in two different composition ranges. No distinction is seen between the $FeNi_3$ phase and the superlattice in the ternary region in Fig. 3 [2001Ser2]. More experimental results are needed in this region.

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