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Co-Fe-Nd-Sm (Cobalt-Iron-Neodymium-Samarium)

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An isothermal section at 800 °C at a constant Sm/Nd ratio of 1 and a vertical section along the $Sm_{0.5}Nd_{0.5}Fe_2$-$Sm_{0.5}Nd_{0.5}Co_2$ join were determined recently by [2002Wan] for this quaternary system.

Binary Systems

The Co-Fe phase diagram [1984Nis] is characterized by an extremely narrow solidification range. The face-centered-cubic (fcc) Fe forms a continuous solid solution γ with αCo over a wide range of temperature. The $\gamma \rightarrow (\alpha Fe)$ body-centered cubic (bcc) transformation temperature is initially raised by the addition of Co, reaching a maximum of 985 °C at 45 at.% Co. At 730 °C, the bcc phase of equiatomic composition orders to a CsCl type *B*2 structure. The Co-Nd phase diagram [1993Oka] depicts ten intermediate compounds: Nd_2Co_{17}, $NdCo_5$, Nd_5Co_{19}, Nd_2Co_7, $NdCo_3$, $NdCo_2$, Nd_2Co_3, $Nd_2Co_{1.7}$, Nd_7Co_3, and Nd_3Co. The Co-Sm phase diagram [2000Cam] depicts eight intermediate phases: Sm_2Co_{17}, $SmCo_5$, Sm_5Co_{19}, Sm_2Co_7, $SmCo_3$, $SmCo_2$, Sm_9Co_4, and Sm_3Co. Among these, only Sm_2Co_{17} and $SmCo_5$ show small homogeneity ranges at high temperatures. The Fe-Nd system contains two intermediate phases. Nd_2Fe_{17} has the Th_2Zn_{17} type of rhombohedral structure. Nd_5Fe_{17} has hexagonal symmetry and forms peritectically at 780 °C [1990Lan]. The Fe-Sm phase diagram [1982Kub] depicts three line compounds, Sm_2Fe_{17}, $SmFe_3$, and $SmFe_2$. They all form peritectically, with the final eutectic solidification of Sm-rich alloys at 720 °C. In the Nd-Sm system [Massalski2], there are no intermediate phases. βNd and γSm (both bcc) form a continuous solid solution. For crystal structure data on the above binary compounds, see [Pearson3].

Ternary Systems

The review of the Co-Fe-Nd system by [1992Rag1] summarized the lattice parameter variation of the Th_2Zn_{17} type rhombohedral solid solution $Nd_2(Fe,Co)_{17}$. The review of the Co-Fe-Sm system by [1992Rag2] gave a schematic liquidus surface, a reaction scheme and two isothermal sections at 1200 and 800 °C. No ternary compounds were found. There appear to be no reports on the phase equilibria in the Co-Nd-Sm and Fe-Nd-Sm systems.

The Quaternary Phase Equilibria

With starting metals of purity of 99.9% Co, 99.8% Fe, 99.9% Nd, and 99.9% Sm, [2002Wan] melted 45 alloy com-

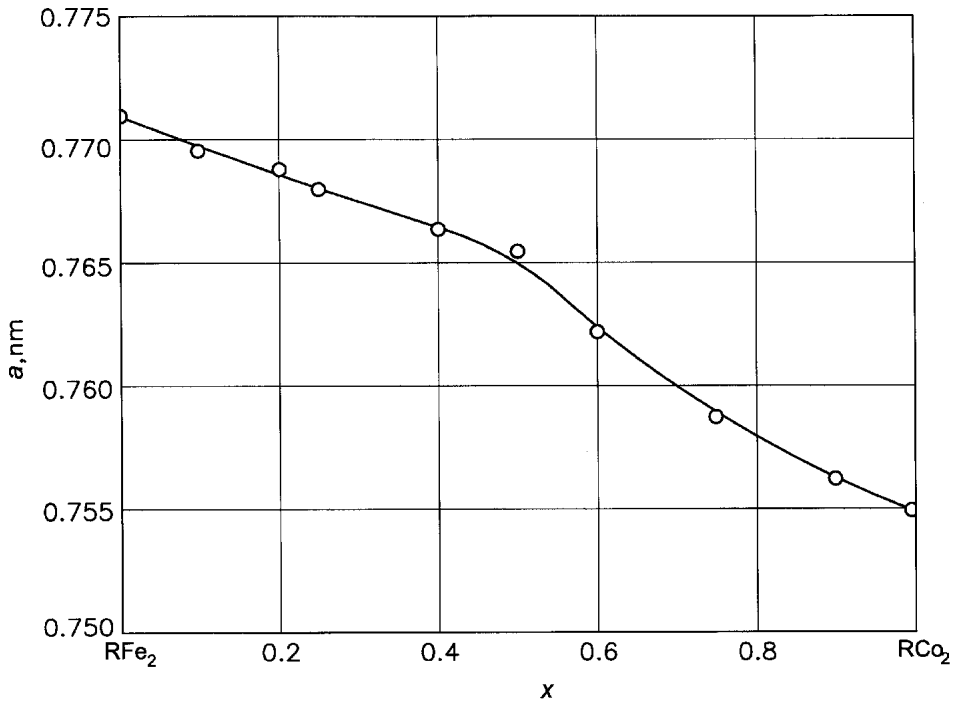

Fig. 1 Co-Fe-Nd-Sm lattice parameter variation of $R(Fe_{1-x}Co_x)_2$ alloys; R = $Sm_{0.5}Nd_{0.5}$ [2002Wan]

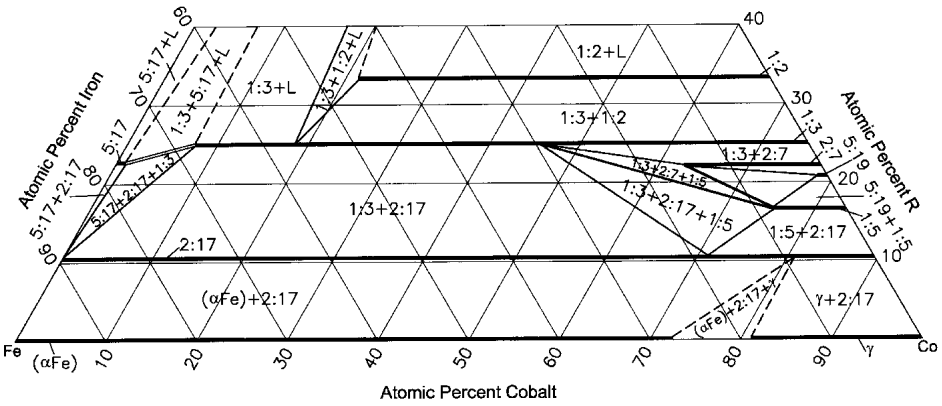

Fig. 2 Co-Fe-Nd-Sm isothermal section at 800 °C for Sm/Nd = 1 (R = $Sm_{0.5}Nd_{0.5}$) [2002Wan]

positions with Sm/Nd = 1 and (Sm + Nd) ≤33.3 at.% in an arc furnace under Ar atm. The samples were given a final anneal at 800 °C for 15-20 days and quenched in water. The phase equilibria were studied by differential thermal analysis (DTA), x-ray powder diffraction, optical microscopy, and electron probe microanalysis.

In the composition range studied, seven quaternary solid solutions based on binary compounds were found by [2002Wan]. Defining ($Sm_{0.5}Nd_{0.5}$) = R, the $MgCu_2$-type cubic structure is stable at RFe_2, even though $NdFe_2$ does not exist. X-ray analysis of the solidified alloy indicates a continuous solid solution $R(Fe,Co)_2$ (denoted 1:2) for all values of Fe or Co. The lattice parameter variation of this solid solution is shown in Fig. 1 [2002Wan]. However, the vertical section determined by [2002Wan] along the RFe_2-RCo_2 join indicates the presence of the liquid phase at the Fe rich end of the line at 800 °C. Also, metallographic observations indicated the presence of minor amounts of $R_5(Fe,Co)_{17}$ and $R(Fe,Co)_3$ phases at the Fe rich end. These observations indicate that $R(Fe,Co)_2$ becomes a continuous solid solution only below 800 °C.

The Be_3Nb (or $PuNi_3$) type rhombohedral phase $R(Fe,Co)_3$ (denoted 1:3) is stable at RCo_3 and dissolves Fe up to the composition $R(Fe_{0.9}Co_{0.1})_3$. The Nd_5Fe_{17} phase is stable at R_5Fe_{17} (denoted 5:17) and dissolves less than 4 at.% Co. The Ce_2Ni_7 type hexagonal phase (denoted 2:7) is stable at R_2Ni_7 and dissolves Fe up to the composition $R_2(Fe_{0.2}Co_{0.8})_7$. The Ce_5Co_{19} type rhombohedral phase (denoted 5:19) is stable at R_5Co_{19} and dissolves less than 4 at.% Fe. The $CaCu_5$ type hexagonal phase RCo_5 (denoted 1:5) is stable and dissolves Fe up to the composition $R(Fe_{0.1}Co_{0..9})_5$. The Th_2Zn_{17} rhombohedral phase (denoted 2:17) forms a continuous solid solution $R_2(Fe,Co)_{17}$ for all values of Fe or Co. The isothermal section of [2002Wan] at 800 °C and Sm/Nd = 1 (R = $Sm_{0.5}Nd_{0.5}$) is redrawn in Fig. 2 to agree with the accepted binary data, incorporating the seven quaternary solid solutions described above. No true ternary or quaternary compounds were found by [2002Wan].

From the DTA results, [2002Wan] constructed a vertical section along the RFe_2-RCo_2 join. Here, the liquid phase on cooling transforms to mixtures of liquid plus solid phases with less than 33.3 at.% R and finally solidifies as a continuous solid solution of $R(Fe,Co)_2$.

References

1982Kub: O. Kubaschewski: "Iron-Samarium" in *Iron – Binary Phase Diagrams,* Springer-Verlag, Berlin, 1982, pp. 104-05.

1984Nis: T. Nishizawa and K. Ishida: "The Co-Fe (Cobalt-Iron) System," *Bull. Alloy Phase Diagrams,* 1984, *5*(3), pp. 250-59.

1990Lan: F.J.G. Landgraf, G.S. Schneider, V. Villas-Boas, and F.P. Missell: "Solidification and Solid State Transformations in Fe-Nd: A Revised Phase Diagram," *J. Less-Common Met.,* 1990, *163*(1), pp. 209-18.

1992Rag1: V. Raghavan: "Co-Fe-Nd (Cobalt-Iron-Neodymium)," *Phase Diagrams of Ternary Iron Alloys. Part 6,* Ind. Inst. Metals, Calcutta, India, 1992, p. 622.

1992Rag2: V. Raghavan: "Co-Fe-Sm (Cobalt-Iron-Samarium)" in *Phase Diagrams of Ternary Iron Alloys. Part 6,* Ind. Inst. Metals, Calcutta, 1992, pp. 645-54.

1993Oka: H. Okamoto: "Co-Nd (Cobalt-Neodymium)," *J. Phase Equilibria*, 1993, *14*(1), pp. 122-24.

2000Cam: M.F. de Campos and F.J.G. Landgraf: "Remarks on the Co-Rich Region of the Co-Sm Diagram," *J. Phase Equilibria,* 2000, *21*(5), pp. 443-46.

2002Wan: B.W. Wang, W.L. Liu, G. Jin, Y.M. Hao, Y.X. Li, X.M. Jin, and Z.D. Zhang: "Phase Diagram of the Fe-Co-R System with R ≤33.3 at. % $Sm_{0.5}Nd_{0.5}$," *Z. Metallkd.,* 2002, *93*(2), pp. 143-46.