JPEDAV (2004) 25:180-182
DOI: 10.1361/15477030418749
1547-7037/$19.00 ©ASM International

Co-Fe-Pr-Sm (Cobalt-Iron-Praseodymium-Samarium)

V. Raghavan

An isothermal section at 800 °C at a constant Sm/Pr ratio of 1 was determined recently by [2001Wan] for this quaternary system for compositions up to 33.3 at.% of rare earth metal content.

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 $\gamma \rightarrow$ (αFe) 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 updated Co-Pr phase diagram [2001Oka] depicts nine intermediate phases: Pr_2Co_{17}, $PrCo_5$, Pr_5Co_{19}, Pr_2Co_7, $PrCo_3$, $PrCo_2$, Pr_4Co_3, Pr_5Co_2, and Pr_3Co. See [2001Oka] for a summary of the crystal structure data. 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 crystal structure data on the Co-Sm phases are summarized by [1992Rag2]. The Fe-Pr phase diagram [1999Zha] depicts the Th_2Zn_{17} type rhombohedral phase Pr_2Fe_{17}. Both crystalline forms of $PrFe_2$ (*C*14 and *C*15) are metastable. 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. The Pr-Sm phase diagram [Massalski2] shows no intermediate phases. βPr and γSm (both bcc) form a continuous solid solution.

Ternary Systems

No phase diagram information is available for the Co-Fe-Pr system. The lattice parameter variation of the solid solutions $Pr(Co,Fe)_2$ and $Pr_2(Co,Fe)_{17}$ was summarized by [1992Rag1]. 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 of the Co-Pr-Sm and Fe-Pr-Sm systems.

The Quaternary Phase Equilibria

With starting metals of purity of 99.9% Co, 99.8% Fe, 99.9% Pr, and 99.9% Sm, [2001Wan] melted 45 alloy compositions at Sm/Pr = 1 and (Sm + Pr) $\leq$33.3 at.% in an arc furnace under Ar atm. The alloy samples were

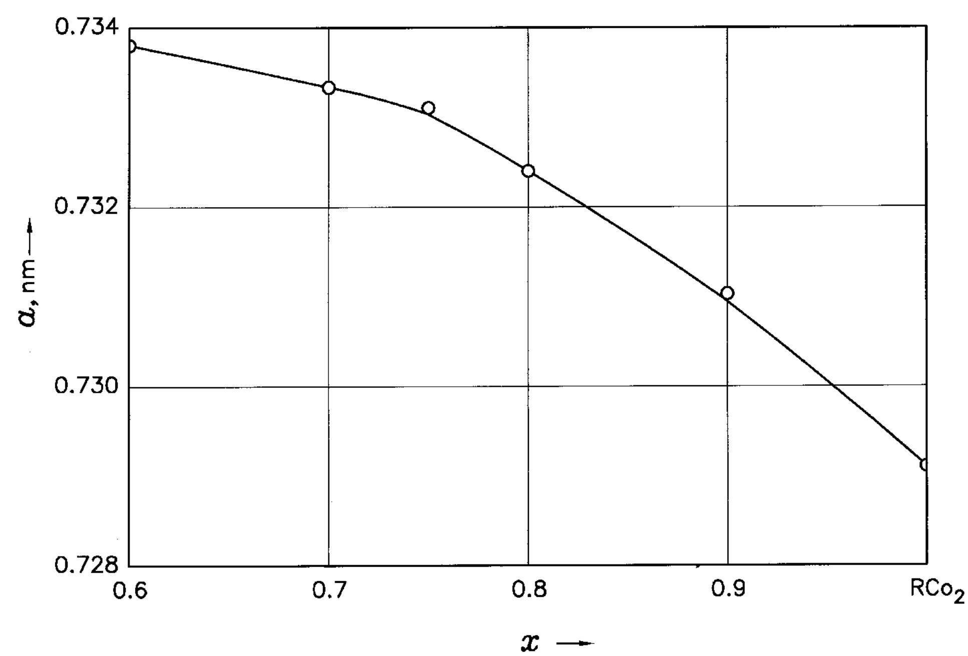

Fig. 1 Co-Fe-Pr-Sm lattice parameter variation of $R(Fe_{1-x}Co_x)_2$ alloys. R = $Sm_{0.5}Pr_{0.5}$ [2001Wan].

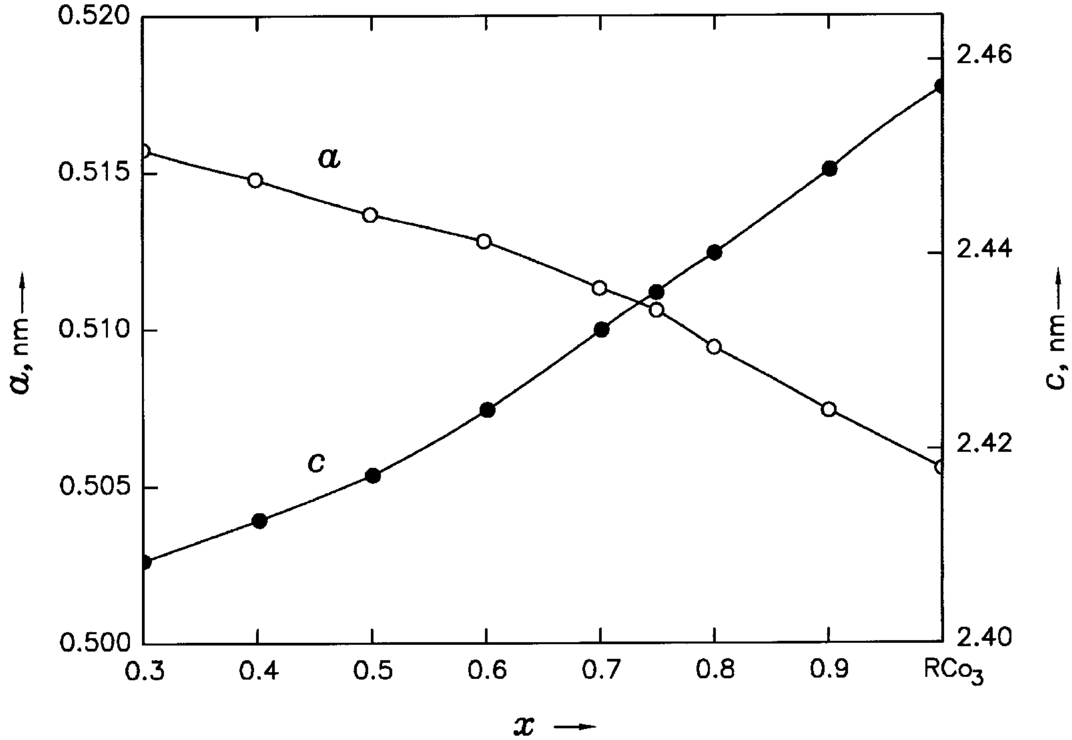

Fig. 2 Co-Fe-Pr-Sm lattice parameter variation of $R(Fe_{1-x}Co_x)_3$ alloys. R = $Sm_{0.5}Pr_{0.5}$ [2001Wan]

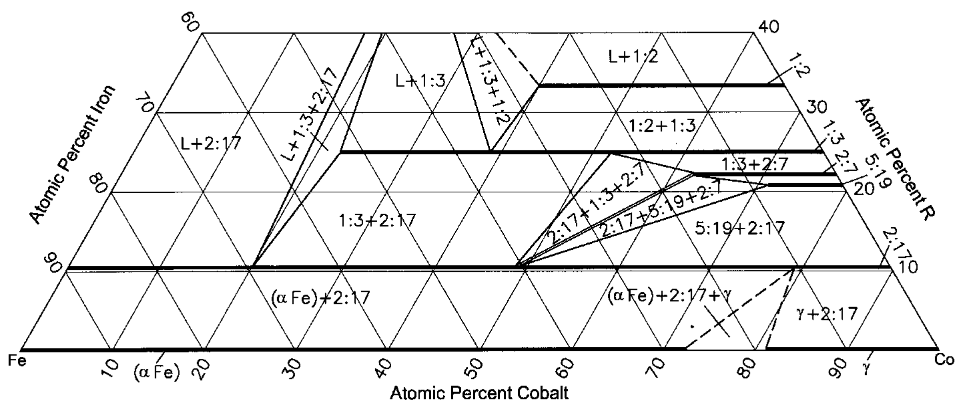

Fig. 3 Co-Fe-Pr-Sm isothermal section at 800 °C for Sm/Pr = 1 (R = $Sm_{0.5}Pr_{0.5}$) [2001Wan]

given a final anneal at 800 °C for 15-20 days and quenched in water. The phase equilibria were studied by optical microscopy, x-ray powder diffraction, and electron probe microanalysis.

In the composition range studied, five quaternary solid solutions based on binary compounds were identified by [2001Wan]: $(Sm,Pr)(Fe,Co)_2$, $(Sm,Pr)(Fe,Co)_3$, $(Sm,Pr)_2(Fe,Co)_7$, $(Sm,Pr)_5(Fe,Co)_{19}$, and $(Sm,Pr)_2(Fe,Co)_{17}$. Defining $(Sm_{0.5}Pr_{0.5})$ = R, the *C*15 type cubic phase $R(Fe_{1-x}Co_x)_2$ (denoted 1:2) is stable for $0.6 \le x \le 1.0$. The lattice parameter variation with *x* is shown in Fig. 1 [2001Wan]. The Be_3Nb type rhombohedral phase $R(Fe_{1-x}Co_x)_3$ (denoted 1:3) is stable for $0.3 \le x \le 1.0$. The lattice parameter variation in this range is shown in Fig. 2 [2001Wan]. The Ce_2Ni_7 type hexagonal structure $R_2(Fe_{1-x}Co_x)_7$ (denoted 2:7) is stable for $0.8 \le x \le 1.0$. The Ce_5Co_{19} type rhombohedral strcture $R_5(Fe_{1-x}Co_x)_{19}$ (denoted 5:19) dissolves 8 at.% Fe at constant R content. The Th_2Zn_{17} type rhombohedral structure $R_2(Fe_{1-x}Co_x)_{17}$ (denoted 2:17) forms a continuous solid solution, i.e., for all values of *x* from 0 to 1. There is no stable phase corresponding to the formula RCo_5 at 800 °C. No true ternary or quaternary compound was found by [2001Wan]. The isothermal section constructed by [2001Wan] at 800 °C for Sm/Pr ratio of 1 is redrawn in Fig. 3 to agree with the accepted binary data.

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.

1992Rag1: V. Raghavan: "Co-Fe-Pr (Cobalt-Iron-Praseodymium)," *Phase Diagrams of Ternary Iron Alloys. Part 6,* Ind. Inst. Metals, Calcutta, India, 1992, pp. 628-29.

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

1999Zha: W. Zhang, C. Li, and X. Su: "The Fe-Pr (Iron-Praseodymium) System," *J. Phase Equilibria,* 1999, *20*(2), pp. 158-62.

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.

2001Oka: H. Okamoto: "Co-Pr (Cobalt-Praseodymium)," *J. Phase Equilibria*, 2001, *22*(4), pp. 511-12.

2001Wan: B.W. Wang, Y.X. Li, Y.M. Hao, W.L. Lin, and G. Jin: "Isoplethic Section in the Quaternary System Fe-Co-Sm-Pr at 800 °C with Sm/Pr = 1 and R ≤ 33.3 at.% (R = $Sm_{0.5}Pr_{0.5}$)," *J. Alloys Compd.,* 2001, *319*, pp. 214-17.