JPEDAV (2004) 25:176-177
DOI: 10.1361/15477030418721
1547-7037/$19.00 ©ASM International

Co-Dy-Fe-Sm (Cobalt-Dysprosium-Iron-Samarium)

V. Raghavan

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

Binary Systems

The Dy-Co phase diagram was redetermined by [1994Wu]. There are seven intermediate phases of fixed stoichiometry in this system: Dy_2Co_{17}, $DyCo_5$, Dy_2Co_7, $DyCo_3$, $DyCo_2$, $Dy_{12}Co_7$, and Dy_3Co. The Co-Fe phase diagram [1984Nis] is characterized by an extremely narrow solidification range. The face-centered-cubic 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-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 Dy-Fe phase diagram was updated by [1996Oka]. It depicts four intermediate compounds: Dy_2Fe_{17}, Dy_6Fe_{23}, $DyFe_3$, and $DyFe_2$. There are no intermediate phases in the Dy-Sm system. βDy and γSm (both bcc) form a continuous solid solution Also, αDy and βSm [both close-packed hexagonal (cph)] form a continuous solution [Massalski2]. 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. For crystal structure data on the above binary compounds, see [Pearson3].

Ternary Systems

The limited review of the Co-Dy-Fe system by [1992Rag1] summarizes data on the lattice parameter variation of the continuous solid solutions $Dy_2(Co,Fe)_{17}$ and $Dy(Co,Fe)_3$. The Co-Dy-Sm and the Dy-Fe-Sm phase diagrams do not appear to have been investigated. 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.

The Quaternary Phase Equilibria

With starting metals of purity of 99.9% Co, 99.9% Dy, 99.8% Fe, and 99.9% Sm, [2002Wan] melted 45 alloy compositions with Sm/Dy = 1 and (Sm + Dy) ≤ 33.3 at.% in an arc furnace under Ar atm. The final anneal of the samples was at 800 °C for 15-20 days, followed by water quenching. 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 $(Sm_{0.5}Dy_{0.5})$ = R, the $MgCu_2$-type cubic Laves phase $R(Co,Fe)_2$ (denoted 1:2) forms a continuous solid solution for all values of Fe or Co, but at the Fe rich end, a small amount of RFe_3 was found with the

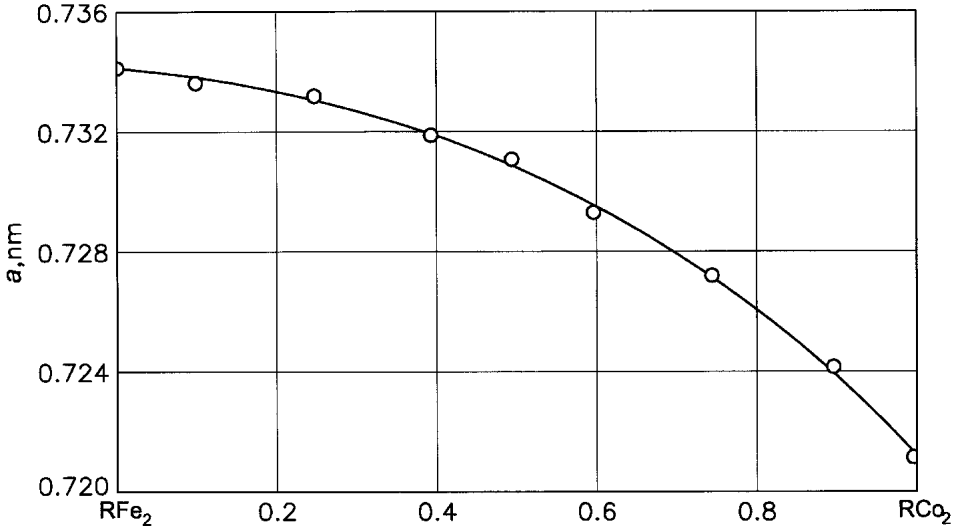

Fig. 1 Co-Dy-Fe-Sm lattice parameter variation of $R(Fe_{1-x}Co_x)_2$ alloys. R = $Sm_{0.5}Dy_{0.5}$ [2002Wan]

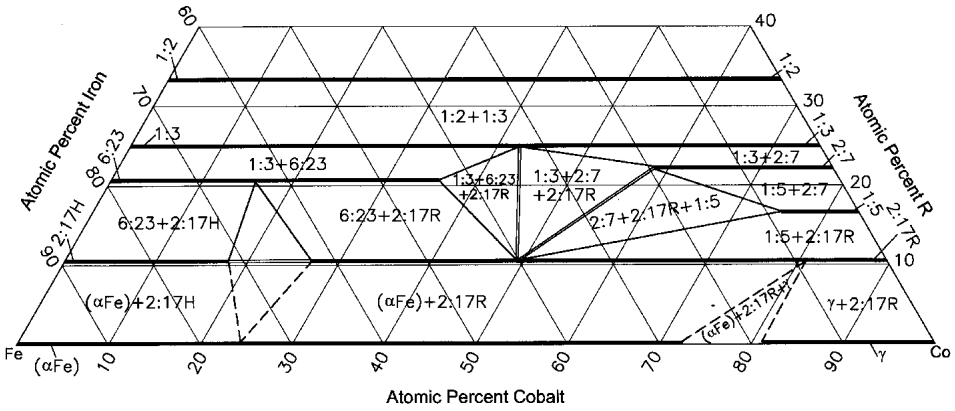

Fig. 2 Co-Dy-Fe-Sm isothermal section at 800 °C for Sm/Dy = 1 (R = $Sm_{0.5}Dy_{0.5}$) [2002Wan]

Laves phase, indicating a possible deviation from the ideal stoichiometry of the Laves phase. The lattice parameter variation of the Laves phase is shown in Fig. 1 [2002Wan]. The Be_3Nb (or $PuNi_3$) type rhombohedral phase $R(Fe,Co)_3$ (denoted 1:3) forms a continuous solid solution for all values of Fe or Co. The $Mn_{23}Th_6$ type cubic phase exists only in the Fe-Dy system. It is stable at R_6Fe_{23} (denoted 6:23) and dissolves Co up to the composition $R_6(Fe_{0.55}Co_{0.45})_{23}$. The Ce_2Ni_7 (Co_2Er_7?) type phase $R_2(Fe_{1-x}Co_x)_7$ (denoted 2:7) is stable in the range $0.75 \leq x \leq 1.0$. The $CaCu_5$ type hexagonal phase (denoted 1:5) is stable at RCo_5 and dissolves 8 at.% Fe at constant R content. The Th_2Ni_{17} type hexagonal phase (denoted 2:17H) is stable at R_2Fe_{17} and dissolves Co up to $R_2(Fe_{0.8}Co_{0.2})_{17}$. The Th_2Zn_{17} type rhombohedral structure (denoted 2:17R) is stable at R_2Co_{17} and dissolves Fe up to $R_2(Fe_{0.7}Co_{0.3})_{17}$. The isothermal section of [2002Wan] at 800 °C and Sm/Dy = 1 (R = $Sm_{0.5}Dy_{0.5}$) 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]. Based on the DTA results, [2002Fen, 2002Wan] also 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.

1992Rag1: V. Raghavan: "Co-Dy-Fe (Cobalt-Dysprosium-Iron)," *Phase Diagrams of Ternary Iron Alloys. Part 6,* Ind. Inst. Metals, Calcutta, 1992, pp. 600-01.

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

1994Wu: C.H. Wu, L.G. Yao, and Y.C. Chuang: "Reinvestigation of the Dy-Co Binary System," *Z. Metallkd.,* 1994, *85*(2), pp. 104-08.

1996Oka: H. Okamoto: "Dy-Fe (Dysprosium-Iron)," *J. Phase Equilibria,* 1996, *17*(1), pp. 80-81.

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.

2002Fen: W.J. Feng, B.W. Wang, W.L. Liu, and G. Jin: "Research of Isoplethic Section in R-Fe-Co Pseudoternary System," *J. Shenyang Univ. Technol.,* 2002, *24*(1), pp. 17-19 (in Chinese).

2002Wan: B.W. Wang, W.L. Liu, W.J. Feng, G. Jin, Y.M. Hao, and Y.X. Li: "Phase Diagram of R-Fe-Co Pseudoternary System with R ≤ 33.3 Mole % (R = $Sm_{0.5}Dy_{0.5}$)," *Trans. Nonferrous Met. Soc. China,* 2002, *12*(5), pp. 850-53.