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SPIN REORIENTATION PHENOMENA IN SUBSTITUTED $Pr_2(Co, Fe)_{17}$ INTERMETALLICS

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Abstract. – The magnetic anisotropy phase diagrams of $Pr_2Co_{17-x}Fe_x$ and $Pr_2Co_{17-x}Fe_{x-y}T_y$ (T=Mn, Zr, Ti, Hf) compounds have been determined. Two spin reorientation temperatures, T_{sr1} and T_{sr2}, have been observed. Near the T_{sr1} or T_{sr2} boundary the anisotropy is conical; between the two spin reorientation temperatures they exhibit uniaxial anisotropy and beyond these limits they are planar.

Introduction

The $Pr_2(Co_{1-x}Fe_x)_{17}$ intermetallics exhibit interesting magnetic properties. Their anisotropies are sensitive to the composition x. For example, at room temperature, the easy direction of magnetization is uniaxial for $0.2 < x < 0.6$, but it changes from axial to basal plane for low x and high x [1-3]. The spin reorientation temperature, T_{sr}, of $Pr_2(Co_{0.8}Fe_{0.2})_{17}$ was measured by Sousa *et al.* [4] using the electrical resistivity singularity method. The partial magnetic phase diagram of this system was investigated by Mori *et al.* [5] using the magnetostriction method. But the nature of the spin reorientation in this system has not been determined unambiguously due to the limited number of compositions and/or the temperature range employed by the above investigators.

In this paper, we report the results of the variation of spin reorientation temperature in the $Pr_2Co_{17-x}Fe_x$ and $Pr_{1.8}Sm_{0.2}Co_{17-x}Fe_x$ systems. The effect of substitution of Mn, Zr, Ti and Hf on the spin reorientation temperature has also been investigated.

Experimental

The samples were prepared by induction melting in a water-cooled copper boat under a high purity argon atmosphere. As-cast ingots were annealed at 1273 K for one week in an argon atmosphere and then quenched (in water) to room temperature. Both X-ray diffraction and thermomagnetic analysis (TMA) were performed to ensure that all samples were single phase. The Curie temperature, T_c, and the spin reorientation temperature, T_{sr}, were determined by measuring temperature dependence at low external magnetic field (< 0.5 kOe) in the temperature range 4.2-1200 K. These data were then used to construct the magnetic phase diagram.

Results and discussion

The magnetic phase diagram of $Pr_2Co_{17-x}Fe_x$, where x varies from 0 to 17, is illustrated in figure 1.

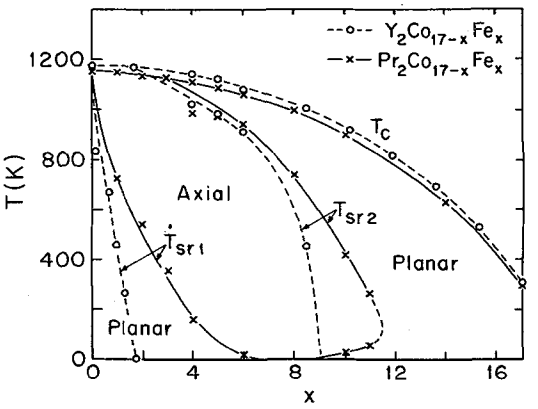

Fig. 1. – Magnetic phase diagram of $Pr_2Co_{17-x}Fe_x$ and $Y_2Co_{17-x}Fe_x$.

To determine the magnetic anisotropy arising from the transition metal sublattice, the phase diagram of $Y_2Co_{17-x}Fe_x$ (taken from Ref. [6]) is also included. Both $Pr_2Co_{17-x}Fe_x$ and $Y_2Co_{17-x}Fe_x$ systems exhibit two spin reorientation temperatures, T_{sr1} and T_{sr2}. Near the T_{sr1} or T_{sr2} boundary, the anisotropy is conical and between T_{sr1} and T_{sr2} the anisotropy is axial. The anisotropy is planar for low Fe content at lower temperatures and for high Fe content at higher temperatures. These results agree with Callen's prediction [7]. The difference between these two phase diagrams can be attributed to the negative contribution of Pr sublattice to the anisotropy. As can be seen in figure 1, the replacement of Pr for Y slightly decreases the Curie temperature, especially for Co-rich end. This may be due to the fact that the Pr atom is slightly larger than the Y atom, which results in a lattice expansion in the former and a decrease in the exchange interaction of transition metal sublattices. The replacement of Pr for Y also shifts both T_{sr1} and T_{sr2} to higher temperatures. It also reduces the composition range in which the system is easy axis at 0 K. The increase in T_{sr1} can

be explained by the fact that the Pr sublattice makes a negative contribution to the anisotropy [8]. However, the cause for the increase of T_{sr2} is unclear as yet.

Substitution of Sm for Pr was found to significantly increase the anisotropy field of $(PrSm)_2 Co_{17-x}Fe_x$ intermetallics [9, 10]. It also expands the axial zone in the anisotropy phase diagram, figure 2. As can be seen, a minor substitution of Sm for Pr shifts the T_{sr1} to lower temperatures and pushes the T_{sr2} to higher temperatures. This is because the Sm sublattice provides positive contribution to the anisotropy in the 2:17 compound. It is believed that the more the Sm substitution, the lower the T_{sr1} until T_{sr1} is not detectable. This is evidenced by the magnetic phase diagram of $Sm_2Co_{17-x}Fe_x$ [6].

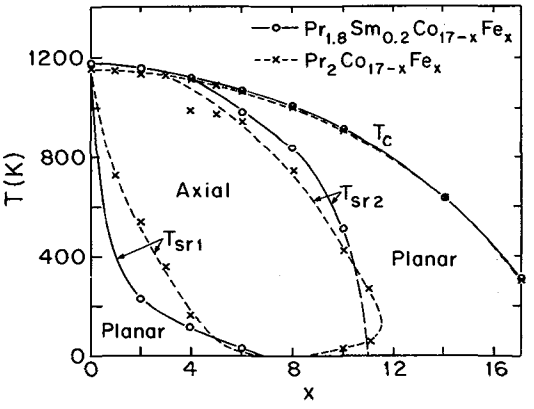

Fig. 2. – Magnetic phase diagram of $Pr_2Co_{17-x}Fe_x$ and $Pr_{1.8}Sm_{0.2}Co_{17-x}Fe_x$.

The effects of some transition metal (T) substitution for Fe on the spin reorientation of $Pr_2Co_{17-x}Fe_{x-y}T_y$, where T includes Mn, Ti, Zr, and Hf were also investigated. The effect of T on T_{sr1} in the composition $Pr_2Co_{17-x}Fe_{x-y}T_y$ (T=Mn, Ti, Zr, Hf) is sensitive to the Fe content. For example, Mn ($y < 2$) decreases the T_{sr1} when Fe content is low ($x = 2$ or 3) and increases the T_{sr1} when Fe content is raised ($x = 4$ or 6). This is presumably due to the site preference. It is known that Fe atoms prefer the 6c (dumbbell sites) and the 18h sites [11, 12]. Similar to Fe, Mn also prefers 6c sites. Thus, the negative contribution to the anisotropy from Co in these sites is diminished when Fe content is low. However, when Fe content is high, Mn or Fe may enter 18j sites and cancel out the positive contribution of Co from 18j sites to the magnetic anisotropy.

The substitution of Ti, Zr and Hf behaves similarly to that of Mn. A minor substitution ($y = 0.2$) of Ti, Zr or Hf in $Pr_2Co_{15}Fe_{2-y}T_y$ depresses the T_{sr1} from 540 K to room temperature and remains constant when y increases from 0.2 to 0.6 for Zr or Hf and to 1.0 for Ti. At higher Fe content, the substitution of Ti, Zr or Hf increases the T_{sr1}, as observed in the $Pr_2Co_9Fe_{8-y}T_y$ system [9].

Conclusions

There are two spin reorientation temperatures in the $Pr_2Co_{17-x}Fe_x$ system. Between T_{sr1} and T_{sr2} the anisotropy is axial. Substitution of Sm or Pr results in a decrease in T_{sr1} and an expansion of the axial region. T_{sr1} vanishes as Sm content is increased further; this is because the Sm sublattice provides positive (axial) contribution to the anisotropy in this system.

The effect of Mn, Ti, Zr, or Hf on the T_{sr1} is sensitive to the Fe content in the $Pr_2Co_{17-x}Fe_{x-y}T_y$ system. Owing to the preference of 6c sites of Fe, this substitution decreases the T_{sr1} at low Fe content. However, the substitution of Mn, Ti, Zr, or Hf raises T_{sr1} at high Fe content, which may be due to the cancellation of negative and positive contribution of Fe and Co, respectively, on the 18j sites.

Acknowledgement

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