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Magnetic properties of $R_2(Fe_{1-x}Ga_x)_{17}$ compounds with $R = Y, Sm, Dy, Ho$

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Abstract

The magnetic properties of the $R_2(Fe_{1-x}Ga_x)_{17}$ ($R = Y, Sm, Dy, Ho$) compounds have been studied. The effects of the Ga substitution on the crystal structure, the magnetic moment of Fe, the easy-magnetization direction and the R–T exchange interaction in the various compounds are reported.

1. Introduction

Substitution of other elements for the rare earth (R) and transition metal (T) atoms in R–T compounds is often a very helpful tool in the study of the magnetic properties of these compounds. Jacobs et al. have derived the intersub-lattice-coupling strength for $R_2Fe_{17-x}Al_x$ ($R = Tb, Dy, Er$ and Tm) compounds from a mean-field analysis of the magnetic isotherms measured in magnetic fields up to 35 T [1]. Recently, it has become clear that Ga-substituted $Sm_2Fe_{17-x}Ga_x$ compounds are very interesting since in these compounds the easy magnetization direction changes to along c -axis when $x > 0.1$ [2]. In the present paper, the structure, magnetization, Curie temperature and anisotropy of Ga-substituted R_2Fe_{17} compounds with $R = Y, Sm, Dy$ and Ho are presented.

2. Experimental results and discussion

The samples were prepared by arc melting the constituent elements with a purity of 99.9% or better and followed by annealing in argon atmosphere at 1473 K for 4 h. The temperature dependence of the magnetization was measured between 300 and 800 K in a field of 0.05 T by means of a vibrating sample magnetometer. The magnetization in fields up to 35 T was carried out in the Amsterdam high-field installation [3].

From X-ray diffraction patterns, a structural transition from Th_2Ni_{17} to Th_2Zn_{17} -type of structure can be seen to occur at $x \approx 0.2$ in the systems $Y_2(Fe_{1-x}Ga_x)_{17}$, $Dy_2(Fe_{1-x}Ga_x)_{17}$ and $Ho_2(Fe_{1-x}Ga_x)_{17}$. The $Sm_2(Fe_{1-x}Ga_x)_{17}$ compounds all crystallize in a Th_2Zn_{17} -type of structure. The maximum number of Ga atoms that can be

Fig. 1. Curie temperature as a function of Ga content in $R_2(Fe_{1-x}Ga_x)_{17}$ compounds.

substituted in one formula unit is about eight, just like it is the case with Al substitution in R_2Fe_{17} compounds [1]. The large size of the Ga atom leads to increasing lattice

Table 1

Magnetic-coupling constants for $Dy_2(Fe_{1-x}Ga_x)_{17}$ and $Ho_2(Fe_{1-x}Ga_x)_{17}$ derived from high-field measurements (n_{RT} : molecular-field coefficient, J_{RT} : exchange parameter)

Compound	n_{RT} [10^{23} T f.u./A m ²]	J_{RT}/k [K]
$Dy_2(Fe_{0.7}Ga_{0.3})_{17}$	3.6	7.9
$Dy_2(Fe_{0.6}Ga_{0.4})_{17}$	4.0	8.9
$Ho_2(Fe_{0.853}Ga_{0.147})_{17}$	2.7	7.5
$Ho_2(Fe_{0.765}Ga_{0.235})_{17}$	2.8	7.8
$Ho_2(Fe_{0.65}Ga_{0.35})_{17}$	2.8	7.8
$Ho_2(Fe_{0.53}Ga_{0.47})_{17}$	3.0	8.4

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Fig. 2. Average iron moment μ_{Fe} as a function of the Ga content in $\text{R}_2(\text{Fe}_{1-x}\text{Ga}_x)_{17}$ compounds.

constants with increasing x in all $\text{R}_2(\text{Fe}_{1-x}\text{Ga}_x)_{17}$ series studied.

There are three types of magnetic interactions (T–T, R–T and R–R) in R–T compounds. The R–R interaction is the weakest and is usually neglected. The variation of the Fe–Fe interaction and of the Fe moments resulting from the Ga substitution is reflected in the variation of the Curie temperature, which first increase and then decrease, as shown in Fig. 1. Information about the R–T interaction, expressed in terms of a mean-field description by the intersublattice-coupling constant n_{RT} , can be obtained from

the part of the high-field magnetization that can be described by $n_{\text{RT}} = dB/dM$ [5] (Table 1). Fig. 2 shows that the Fe-sublattice moment not only decreases because it is diluted but also that the iron magnetic moment μ_{Fe} decreased by the introduction of Ga. It is likely that this is related to the transfer of valence electrons of Ga to the Fe 3d band.

The X-ray diffraction patterns of magnetically aligned powders show that in the $\text{Sm}_2(\text{Fe}_{1-x}\text{Ga}_x)_{17}$ compounds the easy magnetization direction is in the basal plane for $x < 0.1$, parallel to the c -axis for $0.1 < x < 0.3$ and complex for $x > 0.3$. The introduction of Ga not only ‘dilutes’ the easy-plane anisotropy of the Fe-sublattice but also affects the crystal field so that the easy axis anisotropy of the Sm-sublattice is increased. As a result the total uniaxial anisotropy of the compounds increases.

References

- [1] T.H. Jacobs, J.H.J. Buschow, G.F. Zhou and F.R. de Boer, *Physica B* 179 (1992) 177.
- [2] W.Z. Li, N. Tang and Yang Fu-ming, *J. Appl. Phys.*, to be published.
- [3] R. Gersdorf, F.R. de Boer, J.C. Wolfrat, F.A. Muller and L.W. Roeland, In: *High Field Magnetism*, ed. M. Date (North-Holland, Amsterdam, 1983) p. 277.