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Magnetic properties of $\text{ErY}_2\text{Co}_{11}\text{B}_4$

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Abstract

The free-powder (monocrystal) magnetization of $\text{ErY}_2\text{Co}_{11}\text{B}_4$ has been studied at 4.2 K in the Amsterdam High-Field Facility in fields up to 35 T. A metamagnetic transition is found. The magnetization process in this compound can be explained in terms of a two-sublattice model taking into account the Er- and Co-sublattice anisotropy, and the Er–Co exchange interaction. The anisotropy constants and the molecular-field coefficient n_{ErCo} are determined by fitting the magnetization curve. The results are in good agreement with the results of analyzing the easy- and hard-magnetization curves measured on magnetically aligned samples.

The influence of the magnetic anisotropy of both the R-sublattice (R = rare earth) and the T-sublattice (T = transition metal) on the magnetization process of free-powder samples of ferrimagnetic R–T compounds has been studied extensively in the last two years [1–3]. The magnetic anisotropy and the magnetic coupling constants between the R- and T-sublattices can be derived by analyzing the free-powder magnetization curves in terms of a two-sublattice mean-field model [1–3]. In this paper, we apply this model to one particular compound, $\text{ErY}_2\text{Co}_{11}\text{B}_4$. The sample preparation and the experimental procedures are described in Ref. [4].

The free-powder magnetization of $\text{ErY}_2\text{Co}_{11}\text{B}_4$ is shown in Fig. 1(a). A magnetic phase transition occurs at about 20 T. Assuming that the Er moment does not change during the magnetization process, the Co-sublattice moment can be determined as $M_{\text{Co}} = |M^{\text{L}} - M^{\text{H}}|/2$, where M^{L} and M^{H} are the values of M in low and high fields, corresponding to antiparallel and parallel alignment of M_{Er} and M_{Co} , respectively. The result is $0.54\mu_{\text{B}}/\text{Co}$ ($5.9\mu_{\text{B}}/\text{f.u.}$).

In order to analyze the magnetization process of $\text{ErY}_2\text{Co}_{11}\text{B}_4$ presented in Fig. 1(a), we consider the behaviour of a single crystal that is free to rotate in the applied field with a model described in Ref. [2]. The free energy can be written as

$$E = K_1^{\text{Er}} \sin^2\theta_{\text{Er}} + K_2^{\text{Er}} \sin^4\theta_{\text{Er}} + K_3^{\text{Er}} \sin^6\theta_{\text{Er}} \\ + K_1^{\text{Co}} \sin^2\theta_{\text{Co}} + K_2^{\text{Co}} \sin^4\theta_{\text{Co}} + K_3^{\text{Co}} \sin^6\theta_{\text{Co}} \\ + n_{\text{ErCo}} M_{\text{Er}} M_{\text{Co}} \cos \alpha - \mathbf{B} \cdot \mathbf{M}, \quad (1)$$

where

$$\cos \alpha = \sin \theta_{\text{Er}} \sin \theta_{\text{Co}} \cos(\varphi_{\text{Er}} - \varphi_{\text{Co}}) \\ + \cos \theta_{\text{Er}} \cos \theta_{\text{Co}},$$

$$M = (M_{\text{Er}}^2 + M_{\text{Co}}^2 + 2M_{\text{Er}}M_{\text{Co}} \cos \alpha)^{1/2},$$

and n_{ErCo} is the intersublattice molecular-field coefficient. M_{Er} and M_{Co} are the magnetic moments of the Er and Co sublattices, and α is the angle between M_{Er} and M_{Co} . The last term is the Zeeman energy, M is the total magnetization. The angles θ_{Er} , φ_{Er} and θ_{Co} , φ_{Co} are the polar and azimuthal angles of the Er- and Co-sublattice moments, respectively.

By fitting the magnetization curves of Fig. 1(a), one can obtain the anisotropy constants of the Er and Co sublattices, as well as the molecular-field coefficient n_{ErCo} . The derived parameters are listed in Table 1 and the calculated curve is also presented in Fig. 1(a) as a solid line. The field dependence of the angles θ_{Er} and θ_{Co} is shown in Fig. 1(b). It can be seen from Fig. 1(b) that the magnetic transition in Fig. 1(a) corresponds to discontinuous rotations of the two sublattice moments. The angle $\varphi_{\text{Er}} - \varphi_{\text{Co}}$ is always zero or π during the whole magnetization process. This is because the anisotropy within the basal plane of both the Er and the Co sublattice is ne-

Table 1

Magnetic parameters used for the calculation of magnetic isotherms showing the same characteristic features as the experimental curves of $\text{ErY}_2\text{Co}_{11}\text{B}_4$

$K_1^{\text{Er}}/K_1^{\text{Co}}$	$(0.029 \pm 0.002)/(0.049 \pm 0.004) \times 10^{-20} \text{ J/f.u.}$
$K_2^{\text{Er}}/K_2^{\text{Co}}$	$(0.156 \pm 0.048)/(-0.009 \pm 0.004) \times 10^{-20} \text{ J/f.u.}$
$K_3^{\text{Er}}/K_3^{\text{Co}}$	$(-0.085 \pm 0.040)/(0.007 \pm 0.005) \times 10^{-20} \text{ J/f.u.}$
n_{ErCo}	$(2.98 \pm 0.05) \times 10^{23} \text{ T f.u./A m}^2$
M_{Er}	$(9.00 \pm 0.02) \mu_{\text{B}}/\text{f.u.}$
M_{Co}	$(5.27 \pm 0.05) \mu_{\text{B}}/\text{f.u.}$

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Fig. 1. (a) Free-powder magnetization of $\text{ErY}_2\text{Co}_{11}\text{B}_4$ measured at 4.2 K. The dotted lines correspond to data taken in magnetic fields increasing and decreasing linearly with time. The circles stand for measurements done in fields that vary in a step-wise way. The solid lines represent the calculated results. (b) Field dependence of the angles θ_{Er} and θ_{Co} in the free-powder magnetization of $\text{ErY}_2\text{Co}_{11}\text{B}_4$.

Fig. 2. (a) Easy-, and (b) hard-magnetization curves of $\text{ErY}_2\text{Co}_{11}\text{B}_4$ measured at 4.2 K. The dotted lines correspond to data taken in magnetic fields increasing and decreasing linearly with time. The circles stand for measurements done in fields that vary in a step-wise way. The solid lines represent the calculated results.

glected in the calculation [2]. In this case, the moments of Er and Co sublattices and also the external field are confined to one plane.

From the magnetic anisotropy constants given in Table 1, one can see that both the Er and the Co sublattice contribute to the easy-axis anisotropy. This can further be proved by comparing the measured easy- and hard-magnetization curves of $\text{ErY}_2\text{Co}_{11}\text{B}_4$ with curves calculated on the basis of Eq. (1). The magnetization in the external field is, for the easy direction,

$$M_{\parallel} = |M_{\text{Er}} \cos \theta_{\text{Er}} + M_{\text{Co}} \cos \theta_{\text{Co}}|, \quad (2a)$$

and for the hard direction,

$$M_{\perp} = |M_{\text{Er}} \sin \theta_{\text{Er}} + M_{\text{Co}} \sin \theta_{\text{Co}}|. \quad (2b)$$

Fig. 2 shows the experimental and calculated easy- and hard-magnetization curves of $\text{ErY}_2\text{Co}_{11}\text{B}_4$. The parameters given in Table 1 were used in the calculations. The easy-magnetization curve shows a magnetic transition, and

the transition field is also about 20 T. The calculation result is in good agreement with the experimental results.

Concluding, we have derived that the discontinuous magnetization processes in the free-powder and the easy-magnetization curves of $\text{ErY}_2\text{Co}_{11}\text{B}_4$ are due to the combined influence of the magnetic anisotropy of the Er and the Co sublattices and the intersublattice interaction.

References

- [1] Z.G. Zhao, X. Li, J.H.V.J. Brabers, P.F. de Châtel, F.R. de Boer and K.H.J. Buschow, *J. Magn. Magn. Mater.* 123 (1993) 74.
- [2] Z.G. Zhao, P.F. de Châtel, F.R. de Boer and K.H.J. Buschow, *J. Appl. Phys.* 73 (1993) 6522.
- [3] Z.G. Zhao, N. Tang, F.R. de Boer, P.F. de Châtel and K.H.J. Buschow, *Physica B* 193 (1994) 45.
- [4] Z.G. Zhao, Ph.D. Thesis, University of Amsterdam, 1994.