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Magnetic phase diagram of Tb_3Co

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abstract

The orthorhombic Tb_3Co compound exhibits both ferromagnetic and antiferromagnetic behavior below the critical temperature $T_t = 72$ K as evidenced by metamagnetic transitions along the a- and b-axes and ferromagnetic magnetization process along the c-axis. In the temperature interval between Tt and the Neel temperature $T_N = 82$ K field-induced transitions along all three axes are observed. This behavior results from the complex noncomplanar magnetic structure of Tb_3Co. The metamagnetic transitions are accompanied by a significant magnetoresistance effect. The Tb_3Co single crystal has permanent magnet properties along the c-axis with the highest energy up to 140 MG Oe at T < 4.2 K.

Keywords: RE-compounds, phase transitions, magnetoresistance

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The Tb_3Co compound has an orthorhombic crystal structure of the Fe_3C type (space group Pnma) [1]. Below the critical temperature $T_t = 72$ K this compoundexhibits a noncomplanar magnetic structure which results from thecompetition between the influence of low symmetry crystal electric field and isotropic RKKY exchange interaction [2]. This structure has strong ferromagnetic components along the c-axis and antiferromagnetic components along a- and b-axes. Co atoms are not magnetic at T = 4.2 K.In the temperature interval from T_t up to the Neel temperature $T_N = 82$ K the Tb_3Co compound exhibits a long range antiferromagnetic modulated magnetic structure. At low temperatures the large hysteresis loops were observed [2,3].

The aim of the present study was to get some insight into the magnetic phase diagram of Tb_3Co by magnetization and magnetoresistance measurements on singlecrystals.

The magnetization measurements (Fig.1) show that the presence of antiferromagnetic components of the magnetic moments along a- and b-axes at $T < T_t$ results in metamagnetic processes in the fields applied in these directions. The field dependence of the magnetization measured along the c- axis is typical for the compounds with narrow domain walls.

The difference in magnetization processes along main crystallographic directions may be also evidenced by the measurements of the magnetoresistance. As it shown in Fig.1c the change in the resistivity under an applied magnetic field along the c-axis is small (1.5%) and is due to the changes in the number and volume of domain walls. Contrary to this the metamagnetic transition from the magnetic structure with an antiferromagnetic alignment of components of magnetic moments to the structure with ferromagnetic components is accompanied by a considerable change in the electrical resistivity. Moreover, in the field interval where the phases with the different magnetic symmetry coexist, the additional maxima of "delta rho/rho" are observed. These peaks can be connected with the s-electrons reflection from the potential barrier at the interphase boundary separating the phases with different magnetic structures [4].

Using the M(B) and $\Delta\rho(B)/\rho$ curves measured at various temperatures we have obtained the magnetic phase diagram of Tb_3Co for the main axes which details will be published elsewhere. The magnetic state of Tb3Co in different field intervals is in agreement with neutron diffraction measurements [2]. The values of T_t and T_N are close to those obtained by the specific heat measurements [2]. The magnetization processes along a- and c-axes are accompanied by large hysteresis. The coercive field along the c-axis Hc_c decreases exponentially with increasing temperature.

Owing to the very high magnetocrystalline anisotropy of Tb_3Co the propagation field of domain walls can be determined only by the exchange interactions as well as in $Tb_{0.5}Y_{0.5}Ni$ single crystal [5] in contradiction to the usual ferromagnets. For the confirmation of this suggestion we have investigated the change of the Hc_c value in Tb_3Co at the substitution of Tb atoms for the nonmagnetic yttrium. We have found that the concentration dependence of Hc_c correlates with concentration dependence of the critical field Hac of metamagnetic transitions along the c-axis of $(Gd_{1-x}Y_x)_3Co$ single crystals. Because the orbital moment L=0 for the Gd ion this correlation shows that the Hc_c value in Tb_3Co is dependent on the exchange interactions.

The large hysteresis along the c-axis causes the permanent-magnet properties of Tb_3Co with the energy up to 140 MG Oe at T = 4.2 K.

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References

[1] K.H.J. Bushow and A.S. van der Goot, J. Less-Common Met. 18 (1969) 309.
[2] D. Gignoux, R. Lemaire and J. Chassy, Int.Conf on Magnetism, ICM-73. Moscow 22-28 August,1973. Moscow Nauka,vol.5,1974,p.361.
[3] A.V. Deryagin, N.V. Baranov and V.A. Reimer, Sov.Phys. JETP, 46 (1977) 731.
[4] N.V. Baranov, P.E. Markin, A.I. Kozlov and E.V. Synitsyn, J. Alloys and Comp. 200(1993)43.
[5] D. Gignoux and R. Lemaire, Sol. State Commun. 14 (1974) 877

Figure Captions

Fig. 1: At 4.2 K, the field dependence of the magnetic moment (a) and the magnetoresistance (b) for the Tb_3Co single crystal for different field and current directions, respectively.

Tb_3Co T = 4.2 K