

INFLUENCE OF HYDROGEN ON MAGNETOCRYSTALLINE ANISOTROPY OF $\text{TbFe}_6\text{Co}_5\text{Ti}$ SINGLE CRYSTAL

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Introduction

The magnetic properties of iron-rich rare-earth intermetallic RFe_{11}Ti compounds have attracted much attention in recent years [1-2]. This series of alloys adopts the tetragonal ThMn_{12} -type crystal structure (space group $I4/mmm$). The unit cell contains 26 atoms (two formula units per unit cell). The rare-earth atoms occupy only one kind of high-symmetry site (2a) while iron and titanium atoms occupy three different sites (8i, 8j, and 8f). The RFe_{11}Ti compounds have high Curie temperatures (T_C) around 600 K. Some of them have a large magnetic anisotropy and high saturation magnetization and may be considered as potential candidates for permanent magnet materials.

A replace of Fe by Co leads to increase the Curie temperature and a change of magnetocrystalline anisotropy of the 3d-sublattice [3-4]. The easy magnetization direction coincides with [100] axis for $\text{TbFe}_{11}\text{Ti}$ at 4.2 K [3]. As the temperature is increased a first order spin-reorientation transition (SRT) occurs at 325 K, where the easy direction changes from the [100] to the [001] axis. The introduction of hydrogen into the crystalline lattice of $\text{TbFe}_{11}\text{Ti}$ induces easy plane states at temperature below T_C [5]. At Fe replacement by Co temperature of SRT decrease [4]. The purpose of this work was to investigate the magnetic properties (magnetization and magnetic anisotropy) of the of the $\text{TbFe}_6\text{Co}_5\text{Ti}$ compound and its hydride. In contrast to previous works we investigate single crystals samples of hydride.

Results and discussion

The detailed description of the preparation method of the single crystal samples $\text{TbFe}_{11-x}\text{Co}_x\text{Ti}$ used in the works were given somewhere else [4]. The metal hydride syntheses were carried out in a high-pressure reactor chamber of a conventional Sieverts-type volumetric system. The samples were activated for 4 hours in vacuum ($4 \cdot 10^{-4}$ Pa) at 670 K. At this temperature high purity hydrogen

gas obtained from the LaNi_5H_6 hydrogen storage was admitted at a pressure of 1.2 MPa. To achieve a good homogenization, the samples were slowly cooled (about 4 K per hour) down to room temperature. The amount of absorbed hydrogen was determined from the hydrogen pressure change in the reactor chamber.

Magnetization measurements were carried out with a SQUID (Quantum Design MPMS 5-S) magnetometer from 5 to 300 K in magnetic fields up to 50 kOe.

X-ray diffraction measurements show that the ThMn_{12} -type crystalline structure of $\text{TbFe}_6\text{Co}_5\text{Ti}$ compound is retained upon hydrogenation. The

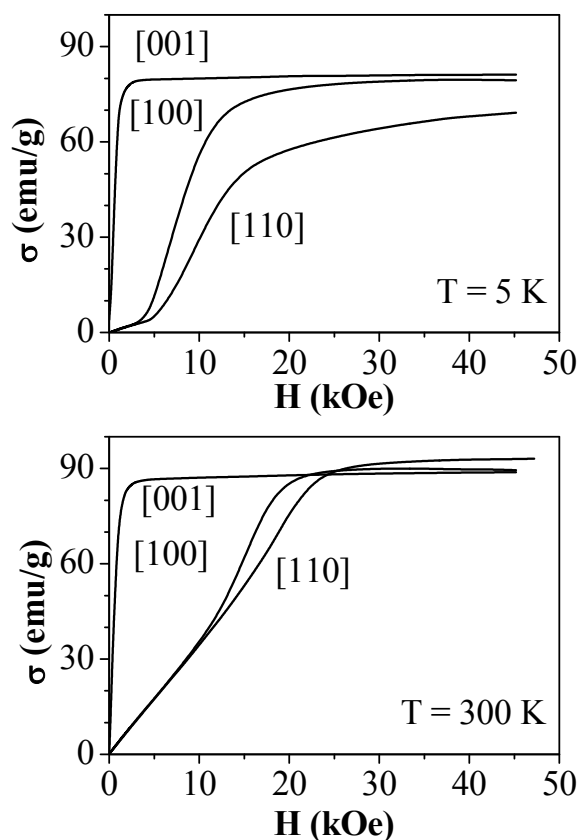


Fig. 1. Isothermal magnetization curves at 5 and 300 K on a single crystal of $\text{TbFe}_6\text{Co}_5\text{Ti}$ for magnetic field along the main symmetry directions: [100], [110] and [001].

Compounds	σ_s (emu/g)		$K_1 \cdot 10^{-7}$ (erg/cm ³)		$K_2 \cdot 10^{-7}$ (erg/cm ³)	
	5 K	300 K	5 K	300 K	5 K	300 K
TbFe ₆ Co ₅ Ti	81	88	2.95	0.74	-2.88	-0.43
TbFe ₆ Co ₅ TiH	73.7	85.1	-1.83	-0.24	0.73	0.09

introduction of hydrogen atoms is increased the lattice constants. It leads to an isotropic volume expansion with the c/a ratio being almost unchanged.

Figs. 1 and 2 show the isotherms obtained from the magnetization measurements at $T = 5$ K and 300 K for TbFe₆Co₅Ti and its hydride, respectively. Unlike TbFe₁₁Ti, the TbFe₆Co₅Ti single crystal exhibits a uniaxial magnetic anisotropy over the entire studied range of temperatures from 4.2 K to the Curie points. It is show that Fe replacement by Co suppress easy plane anisotropy at Co concentration $x = 5$.

The magnetization curves for the TbFe₆Co₅Ti single crystal along the [110] and [100] directions in the basal plane (Fig. 1) show a sharp jump of the magnetization in the temperature below 300 K at the specific threshold fields H_{cr} . The H_{cr} increases with temperature. These transitions — the first-order magnetization processes (FOMP) [6]. This can be explained by the irreversible rotation of the magnetization vector at $H = H_{cr}$. Using theory [6]

we calculate anisotropy constant which represent in Table.

As can be seen from Fig. 2, hydrogenation induced easy plane anisotropy in TbFe₆Co₅TiH. The [100] becomes easy magnetization axis and critical fields are not observed in the field dependences of the magnetization for TbFe₆Co₅TiH. As can be seen from Table, the anisotropy constants change sign under hydrogenation. These facts indicate there is a change of magnetic properties in both Tb and 3d-sublattices under hydrogenation of TbFe₆Co₅Ti [7].

The magnetocrystalline anisotropy depends strongly on the values of the electric fields at the site of the R-ions. The interstitial H atoms occupy the 2b sites adjacent to the rare earth, creating a change of crystal field. The insertion of H leads to an expansion of the temperature range in which the easy plane magnetic anisotropy of the rare-earth sublattice dominates over that of the 3d-sublattice.

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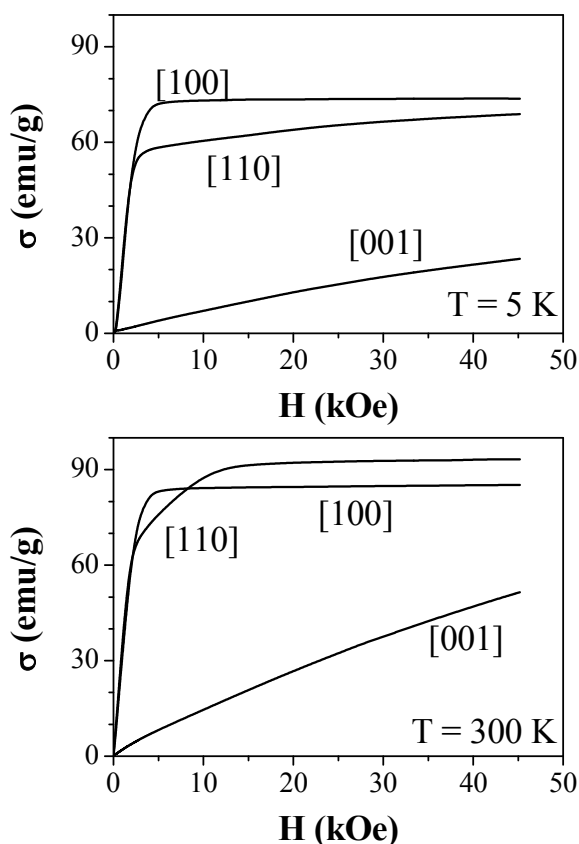


Fig. 2. Isothermal magnetization curves at 5 and 300 K on a single crystal of TbFe₆Co₅TiH for magnetic field along the main symmetry directions: [100], [110] and [001].

References

1. J.M.D. Coey, Rare-earth Iron Permanent Magnets, Clarendon Press, Oxford, 1996.
2. W. Suski, in: Handbook on the Physics and Chemistry of Rare Earths, vol. 22, ed. By K.A. Gschneidner, Jr. and L.R. Eyring, Elsevier Science, Amsterdam, 1996, pp. 143-294.
3. I.S. Tereshina, S.A. Nikitin, I.V. Telegina, V.V. Zubenko, Yu.G. Pastushenkov, K.P. Skokov, J.Alloys Comp. 1999; 283; 45-48.
4. T.I. Ivanova, Yu.G. Pastushenkov, K.P. Skokov, I.V. Telegina, I.A. Tskhadadze, J.Alloys Comp. 1998; 280; 20-25.
5. S.A. Nikitin, I.S. Tereshina, V.N. Verbetsky, A.A. Salamova, J.Alloys Comp. 2001; 316; 46-50.
6. G. Asti and F. Bolzoni, J. Magn. Magn. Mater. 1980; 20; 29.
7. E.Tereshina, S.A.Nikitin, K.P.Skokov, T.Palewski, L.Folcik, H.Drulis, International symposium on metal-hydrogen systems: fundamentals and applications, Abstracts book, Cracow, Poland, 2004; 156.