Vol. 97 (2000) *ACTA PHYSICA POLONICA A* No. 5

Proceedings of the European Conference "Physics of Magnetism '99", Poznań 1999

MAGNETIC PROPERTIES OF RRhGe (R = Dy AND Tm) COMPOUNDS

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The magnetic properties of the ternary intermetallic RRhGe (R = Dy and Tm) were investigated by magnetic and neutron diffraction measurements. These compounds crystallize in a TiNiSi-type orthorhombic structure and are antiferromagnets with the Néel temperature 20 K (R = Dy) and 6.2 K (R = Tm). The neutron diffraction data reveal that the magnetic order in TmRhGe is collinear with the magnetic unit doubled along the *b*-axis respective to the crystal one.

PACS numbers: 75.30.Cr, 75.30.Kz, 75.50.Ee

1. Introduction

The RRhGe compounds crystallize in the orthorhombic TiNiSi-type of structure [1]. RRhGe compounds where R is Ce, Nd [2], Tb [3], Ho and Er [4] have been found by neutron diffraction to order antiferromagnetically at low temperatures.

To continue our studies of RRhGe compounds the magnetic (for DyRhGe and TmRhGe) and neutron diffraction (for TmRhGe) measurements were performed. From these data the magnetic properties of these compounds were determined.

2. Experiment and results

The preparation of the DyRhGe and TmRhGe samples were described in [4]. The dc susceptibility and magnetization data were collected using a vibrating sample magnetometer in magnetic fields up to 50 kOe. A SQUID magnetometer was used to perform additional measurements in magnetic fields below 150 Oe. Because the absorption cross-sections for Dy and Ir are large, neutron diffractograms were obtained only for TmRhGe compound on the E6 diffractometer installed at

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*corresponding author; e-mail: szytula@if.uj.edu.pl the BER II reactor in the Hahn–Meitner Institute, Berlin. The incident neutron wavelength was 2.4 Å. The Rietveld-type program FULLPROF [5] was used to process the experimental data.

The magnetization at low magnetic field versus temperature indicates the maximum at 20 K for DyRhGe and 6.2 K for TmRhGe (Fig. 1). Above this maximum magnetic susceptibility obeys the Curie–Weiss law with the paramagnetic Curie temperature +1 K for R = Dy and −1 K for R = Tm and effective magnetic moment equal to 10.3 μ_B for R = Dy and 7.5 μ_B for R = Tm. The magnetization curves, measured at 4.2 K in applied magnetic fields ranging from 0.01 to 50 kOe, indicate the metamagnetic phase transition at the critical magnetic field H_c = 28 kOe for R = Dy and 9 kOe for R = Tm.

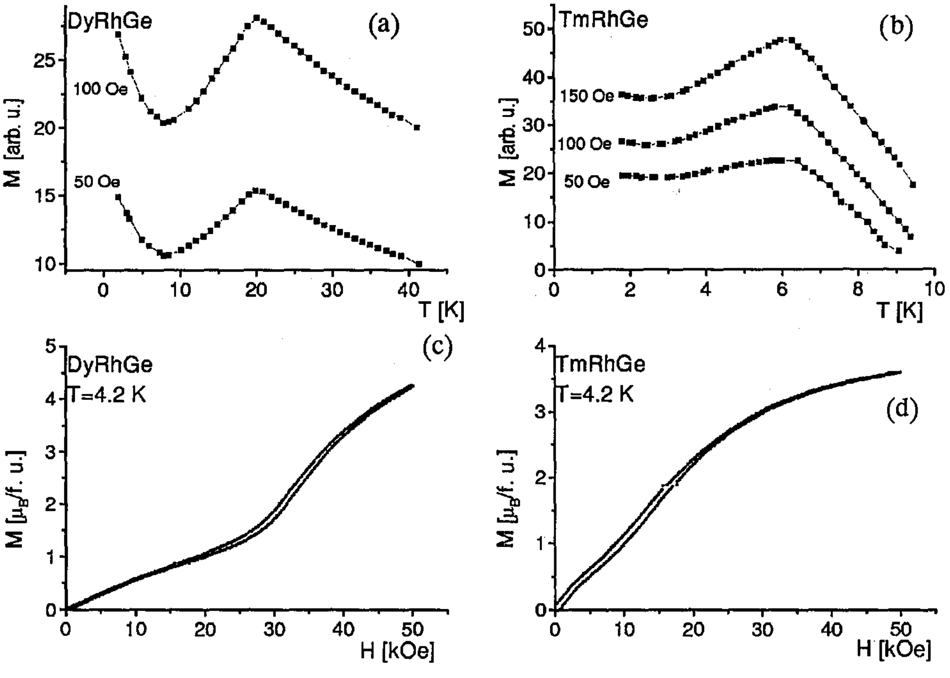

Fig. 1. The dependence of magnetization on (a,b) temperature (at low magnetic fields) and on (c,d) magnetic field (at $T = 4.2$ K) for RRhGe (R = Dy, Tm) compounds.

The neutron diffraction patterns obtained above the Néel temperature for TmRhGe show that compound has the TiNiSi-type crystal structure (*Pnma* space group). The 4 Tm, 4 Rh, and 4 Ge atoms occupy the 4(c) sites: $x, \frac{1}{4}, z$; $\overline{x}, \frac{3}{4}, \overline{z}$; $\frac{1}{2} - x, \frac{3}{4}, \frac{1}{2} + z$; $\frac{1}{2} + x, \frac{1}{4}, \frac{1}{2} - z$ with different x and z coordinates.

The neutron diffraction pattern of the TmRhGe compound recorded at T = 1.5 K shows additional peaks of magnetic ordering (see Fig. 2) which are indexed with the propagation vector $\boldsymbol{k} = (0, \frac{1}{2}, 0)$. The distribution of the peaks is similar to those observed in the isostructural ErRhGe. The magnetic unit cell is doubled along the b-axis with respect to the crystal one. The minimum of the

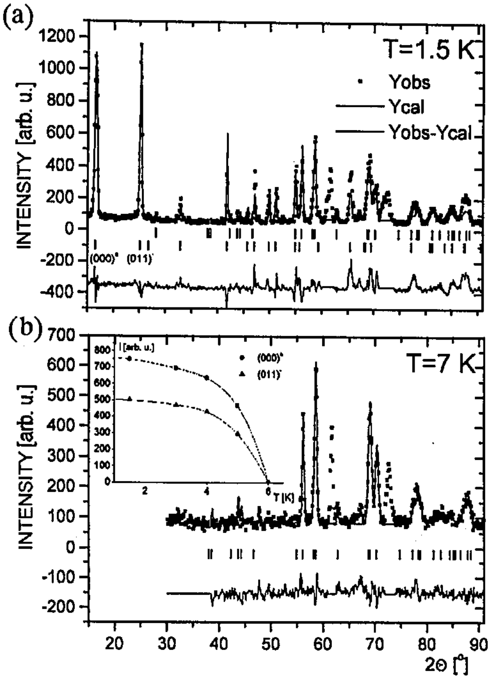

Fig. 2. Observed and calculated neutron diffraction patterns for TmRhGe at T = 1.5 K (a) and 7 K (b). The solid lines represent the profile and the difference between the observed and calculated data (below). The vertical bars indicate the nuclear and magnetic peaks. The insert shows the temperature dependence of the integrated intensities of the $(000)^{\pm}$ and $(011)^{-}$ magnetic peaks.

"agreement" R factor corresponds to the collinear magnetic structure in which magnetic moments are coupled ferromagnetically inside the chemical unit cell, but antiferromagnetically in the magnetic one. The Tm magnetic moment equal to 6.92(16) μ_B is parallel to the a-axis. This magnetic ordering is stable in the whole temperature range between 1.5 K and T_N = 6.0 K (see insert in Fig. 2).

3. Discussion

The obtained results indicate that in both investigated compounds the magnetic ordering connected with the rare-earth moments are observed at low temperatures.

In the TiNiSi-type of crystal structure the rare earth atoms lie in planes perpendicular to the b-direction ($y = \frac{1}{4}$ and $\frac{3}{4}$). In large number of the RTX compounds which crystallize in this type of crystal structure, the magnetic ordering is described by the propagation vector $k = (0, k_y, 0)$. In TmRhGe and ErRhGe (below T_t = 5 K) k_y is equal to 0.5. In ErRhGe a change to the structure with $k_y \neq 0$ is observed above T_t. These results indicate that the magnetic interactions in these compounds have the long range character, probably of RKKY-type.

In RRhGe compounds, where R = Tb, Ho, Er, and Tm, the rare-earth magnetic moments are parallel to the a-axis. This result suggests strong influence of the crystal electric field on the magnetic ordering which does not change with increase in the number of $4f$ electrons.

Acknowledgments

This work was partially supported by the Committee for Scientific Research (Poland) within the grant No. 2 P03B 024 13.

References

[1] E. Hovestreydt, N. Engel, K. Klepp, B. Chabot, E. Parthé, *J. Less-Common Met.* **85**, 247 (1982).

[2] W. Bażela, A. Zygmunt, A. Szytuła, E. Ressouche, J. Leciejewicz, W. Sikora, *J. Alloys Comp.* **243**, 106 (1996).

[3] A. Szytuła, M. Kolenda, J. Leciejewicz, N. Stüsser, *J. Magn. Magn. Mater.* **149**, 265 (1995).

[4] W. Bażela, M. Hofmann, B. Penc, A. Szytuła, *J. Phys., Condens. Matter* **10**, 2233 (1998).

[5] J. Rodriguez-Carvajal, *Physica B* **192**, 55 (1993).