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MAGNETIC PROPERTIES OF THE RT_2X_2, RTX_2 AND RTX COMPOUNDS IN HIGH MAGNETIC FIELDS

A. Szytuła

Institute of Physics, Jagiellonian University, Reymonta 4, 30-059 Kraków, Poland

V. Ivanov and L. Vinokurova

General Physics Institute, Academy of Sciences
Vavilov Street 38, 117942 Moscow, Russia

Magnetization curves up to 140 kOe have been measured in the temperature range 4.2–100 K on polycrystalline oriented samples for some RT_2X_2, RTX_2 RTX compounds. The magnetic phase diagrams for all samples are determined.

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1. Introduction

Ternary R–T–X compounds (R = rare earth; $T = nd$ transition element; X = Si or Ge) exhibit many interesting physical, particularly, magnetic properties [1, 2]. Special interest is concentrated on the compounds in which magnetic properties change with temperature or magnetic field [3].

In the paper results of high field magnetization measurements on some RT_2X_2, RTX_2 and RTX compounds are reported.

2. Experiment and results

The experiments were performed on polycrystalline samples oriented in a magnetic field. The magnetization of the samples was measured by means of a vibrating sample magnetometer in high magnetic fields up to 140 kOe produced in a "solenoid" installation. The obtained results of the measurements of the magnetization at different temperatures and in magnetic fields are presented below. On the basis of the magnetic data at different temperatures, magnetic (H, T) phase diagrams were constructed.

For RT_2X_2 compounds different field dependence of the magnetization curves is observed. For many compounds which have at $H = 0$ a collinear antiferromagnetic structure of AFI-type [2] the magnetization curves have a two-step character. For example in Fig. 1a the magnetization curves at different temperatures

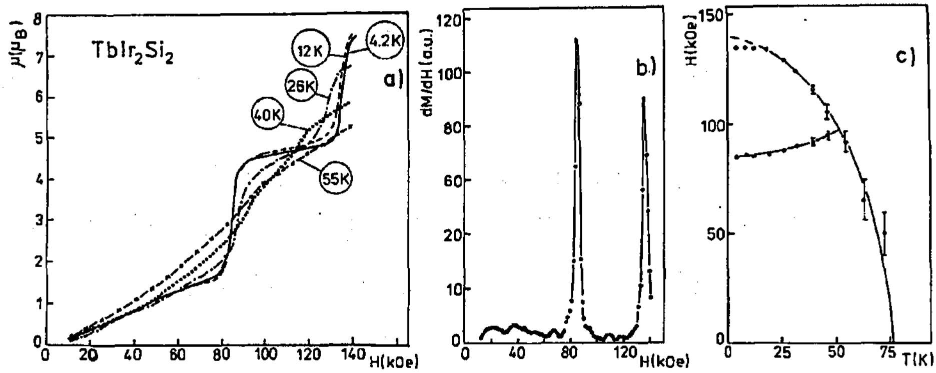

Fig. 1. (a) High field magnetization curves at different temperatures; (b) Magnetic field dependence of the differential magnetization at $T = 4.2$ K; (c) Magnetic phase diagram for $TbIr_2Si_2$.

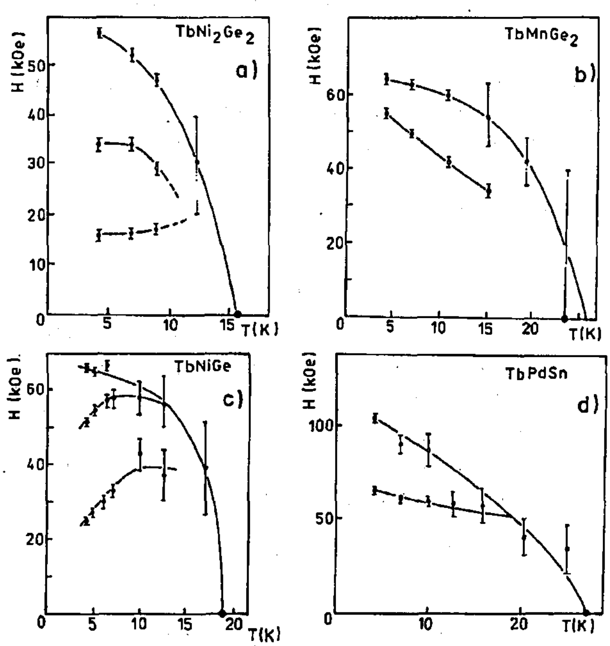

Fig. 2. Magnetic phase diagrams of (a) $TbNi_2Ge_2$, (b) $TbMnGe_2$, (c) TbNiGe and (d) TbPdSn compounds.

for $TbIr_2Si_2$ are presented. The values of the critical fields were determined from the field dependence of the differential magnetization $\mathrm{d}M/\mathrm{d}H$ (see Fig. 1b). Using the temperature dependence of the transition fields, the magnetic phase diagram was determined (see Fig. 1c). Similar dependence of the magnetization is observed in $(Tb,Dy)Co_2(Si,Ge)_2$, $(Nd,Tb)Rh_2Si_2$ and $TbCo_2B_2$. In case of $TbCu_2Si_2$,

$DyCu_2Si_2$, $PrCu_2Si_2$, $PrCu_2Ge_2$ and $TbFe_2Ge_2$ a one-step metamagnetic transition is observed.

For $TbNi_2Ge_2$ a three-step magnetization process was found at $T = 4.2$ K. Similar dependence of magnetization was observed in the isostructural $TbNi_2Si_2$ [4]. With the data obtained at different temperatures the magnetic (H, T) phase diagram of $TbNi_2Ge_2$ was determined (see Fig. 2a). Four magnetic phases can be seen. The diagram is similar to that observed in isostructural $TbNi_2Si_2$ [4].

In $TbCoSi_2$, $DyCoSi_2$ and $TbMnGe_2$ at $T = 4.2$ K the magnetization runs in two steps. The magnetic (H, T) phase diagram for $TbMnGe_2$ is shown in Fig. 2b.

The magnetization process in a high magnetic field in case of TbNiGe has a three-step form. The magnetic phase diagram is shown in Fig. 2c. A different (H, T) phase diagram is observed for TbPdSn where only three magnetic phases were observed (see Fig. 2d). The values of the Néel temperature and the critical fields for all compounds are listed in Table.

TABLE

Values of the Néel temperatures and the critical fields at $T = 4.2$ K in RT_2X_2, RTX_2 and RTX compounds.

Compound	T_N [K]	H_{C1} [kOe]	H_{C2} [kOe]	H_{C3} [kOe]
$TbCo_2Si_2$	45	65	116	
$TbCo_2Ge_2$	30	50	90	
$DyCo_2Si_2$	21	25	49	
$DyCo_2Ge_2$	16	24	40	
$NdRh_2Si_2$	53	134	143	
$TbRh_2Si_2$	94	80	190	
$TbIr_2Si_2$	75	85	135	
$TbCo_2B_2$	19	11	13	
$PrCu_2Si_2$	21	35		
$PrCu_2Ge_2$	16	15		
$TbFe_2Ge_2$	9	13		
$TbCu_2Si_2$	12	25		
$DyCu_2Si_2$	10	15		
$TbNi_2Ge_2$	17	16	34	57
$TbCoSi_2$	15.7	30	90	
$DyCoSi_2$	10.4	15	30	
$TbMnGe_2$	26	55	63	
TbNiGe	18	24	52	66
TbPdSn	23.5	65	105	

3. Discussion

The results presented in this work indicate different field dependence of the magnetization in the measured compounds. Most of these compounds have the magnetization curves of the two-step character. This type of magnetic phase transition is observed in RT_2X_2 compounds which are antiferromagnets with the simple magnetic structure of AFI-type [2]. In the temperature range 4.2–T_N and magnetic fields up to H_{C1} the magnetic ordering can be displayed as a piling up of the ferromagnetic sheets along the c-axis. With an increase in magnetic field, in an intermediate region ($H_{C1} < H < H_{C2}$ the ferromagnetic order with a $+++-$ sequence [5] is observed. For $H > H_{C2}$ the ferromagnetic ordering is stable.

Katsura and Narita [6] showed that for theoretical calculations we should use an effective Hamiltonian which includes exchange interactions J_i up to $i = 3$ to ensure the appearance of the structure with the $+++-$ sequence in the intermediate region.

At low temperatures $TbNi_2Ge_2$ compound has a commensurate antiphase structure with the wave vector $k = (0, 0, 1/4)$. An increase in the magnetic field changes the structure into an incommensurate one ($TbNi_2Si_2$ [4], $PrCo_2Si_2$ [7]).

A complex three-step metamagnetism can be described by the field theory [8, 9]. It gives a model, in which the Ising spins are immersed in an incommensurate sinusoidal exchange field $J(k) = J_0 \sin(kr + \delta)$, where r is taken along the c-axis and δ indicates a phase. Such model gives different incommensurate magnetic structures with different values of the wave vectors as a function of magnetic field.

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