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Letter

Magnetic properties of $RNiX_2$ (X≡Si, Ge) and RMn_xGe_2 compounds

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Abstract

The a.c. susceptibility and high field magnetization of $RNiX_2$ (X≡Si, Ge) and RMn_xGe_2 compounds were investigated up to 140 kOe. In all compounds one-step magnetization process is observed. The (*H, T*) magnetic phase diagrams were determined.

Keywords: Rare earth intermetallics; Magnetic properties; A.C. susceptibility; Magnetic phase diagrams

1. Introduction

RTX_2 compounds where R is rare earth element, T is transition *d*-metal and X is Si or Ge are a new class of intermetallic compounds which have interesting magnetic properties [1]. The majority of these compounds crystallize in the orthorhombic $CeNiSi_2$-type crystal structure [2]. Magnetic susceptibility and neutron diffraction data shows that RMn_xGe_2 and $RNiX_2$ compounds, with R≡Gd–Ho are antiferromagnets of a simple collinear structure at low temperatures [3–6].

In this work the results of a.c. susceptibility and high field magnetization measurements for RMn_xGe_2 (R≡Gd–Ho) and $RNiX_2$ (R≡Gd–Ho, X≡Si or Ge) are presented.

2. Experimental details and results

Experiments were carried out on polycrystalline samples, as reported in previous papers [3,4]. The a.c. susceptibility was measured using a mutual inductance bridge. 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.

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2.1. Magnetic properties at weak magnetic fields

The temperature dependence of the a.c. magnetic susceptibility is shown in Fig. 1. A typical maximum for the antiferromagnetic-to-paramagnetic phase transition is observed for all compounds. The determined values of the Néel temperatures are listed in Table 1. The results obtained agree with the data presented in Refs. [3,4].

2.2. Magnetic properties in high magnetic fields

The results of the magnetization measurements made on samples aligned in a magnetic field and recorded at different temperatures in magnetic fields up to 140 kOe are presented.

For the $GdNiX_2$ compounds the magnetization curves show an anomaly at a critical field H_c at $T=4.2$ K which are equal to 28 kOe for both compounds (see Fig. 2(a)). Above H_c the magnetization is a linear function of an applied magnetic field up to 140 kOe and the magnetic moment is smaller than the free ion value of Gd^{3+} and equals 6 μ_B (see Table 1). The magnetic phase diagrams determined for both $GdNiX_2$ compounds are shown in Fig. 3(a). For $RNiX_2$ compounds the magnetization process has a different character. Magnetization curves for $TbNiGe_2$ are presented in Fig. 2(b). These dependences are typical for all

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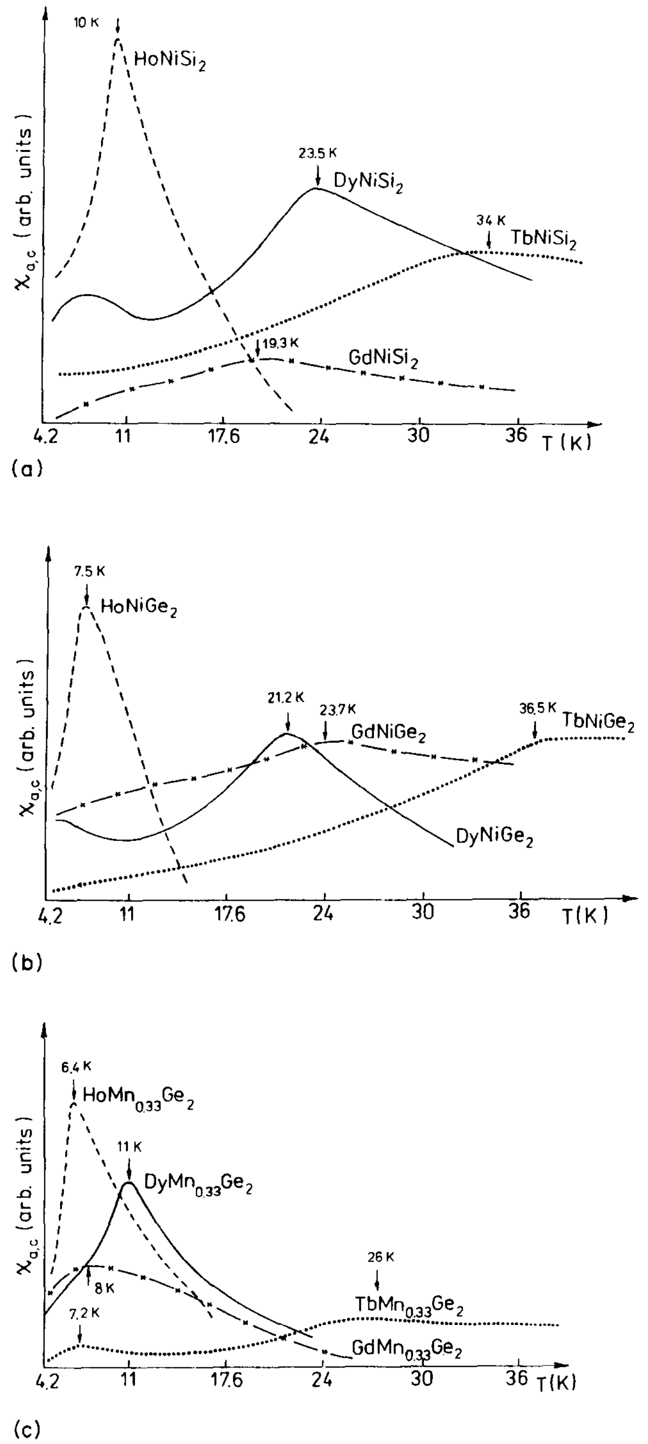

Fig. 1. Temperature dependence of the a.c. susceptibility of (a) $RNiSi_2$, (b) $RNiGe_2$ and (c) $RMn_{0.33}Ge_2$ compounds.

compounds with R ≡ Tb, Dy and Ho. The magnetization has a one-step character. The values of the critical fields were found from the field dependence of the differential magnetization d*M*/d*H*. Using the temperature dependence of the transition fields, the magnetic phase diagrams were determined (see Figs. 3(b) and 3(c)). For all compounds the value of the magnetic

Table 1
Magnetic data for $RNiX_2$ (X ≡ Si, Ge) and RMn_xGe_2

Compound	T_N (K)	H_C (kOe)	μ (μ_B)	g_J J^{-1}	H_C/T_N
$RNiSi_2$					
R ≡ Gd	19.3	27.7	5.8	7.0	1.45
Tb	34	55	8.4	9.0	1.62
Dy	23.5	30	9.4	10.0	1.28
Ho	10	4	9.3	10.0	0.4
$RNiGe_2$					
R ≡ Gd	23.7	28	5.8	7.0	1.18
Tb	36.5	66	8.2	9.0	1.81
Dy	21.2	30	7.7	10.0	1.41
Ho	7.5	4	9.5	10.0	0.53
$RMn_{0.33}Ge_2$					
R ≡ Gd	8	–	4.7	7.0	–
Tb	26	65	7.0	9.0	2.5
Dy	11	28	8.5	10.0	2.55
Ho	6.4	3	9.8	10.0	0.47

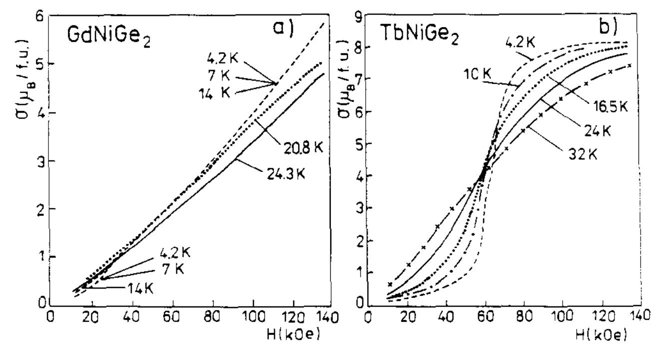

Fig. 2. High field magnetization curves for (a) $GdNiGe_2$ and (b) $TbNiGe_2$ at different temperatures.

moment at T = 4.2 K and 140 kOe is smaller than the adequate free R^{3+} ion value (see Table 1).

The magnetization curves of $GdMn_{0.38}Ge_2$ are linear functions of the magnetic field up to 140 K. For other compounds the magnetization curves have a similar character to those observed for $RNiX_2$ compounds. The determined magnetic phase diagrams for $TbMn_{0.33}Ge_2$ and $DyMn_{0.33}Ge_2$ are shown in Fig. 4.

3. Discussion

The compounds investigated in this work crystallize in the orthorhombic $CeNiSi_2$-type crystal structure. The neutron diffraction data [5,6] indicate a simple collinear antiferromagnetic structure with the magnetic moment localized only on rare earth atoms which are parallel to the c-axis. The results show that the field dependence of different magnetizations is observed for Gd compounds and Tb, Dy or Ho compounds.

The magnetization curves for $GdNiX_2$ compounds (see Fig. 2(a)) are similar to those observed for the orthorhombic $GdCu_6$ compound [7]. They are typical for spin-flop systems.

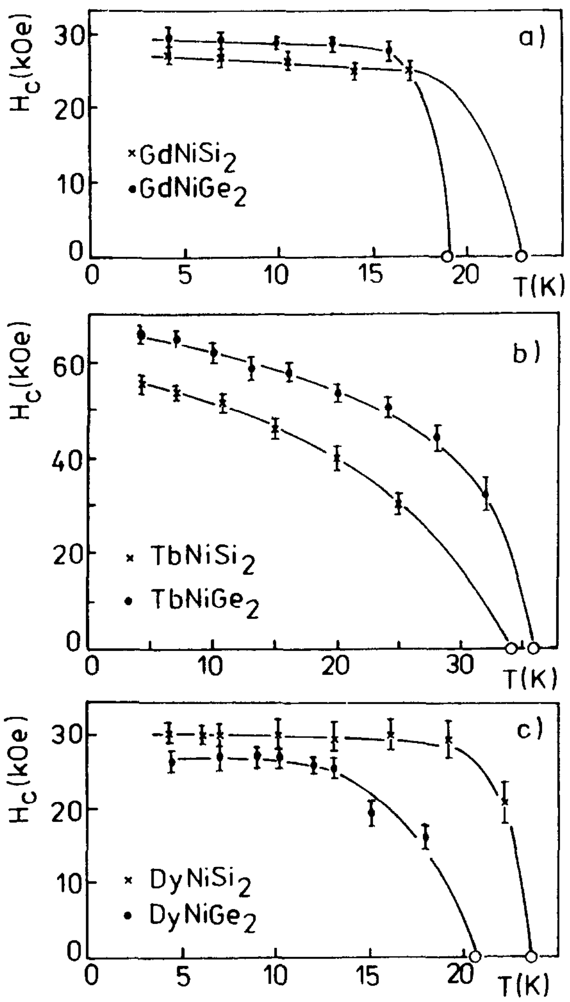

Fig. 3. Magnetic phase diagrams for (a) $GdNiSi_2$ and $GdNiGe_2$, (b) $TbNiSi_2$ and $TbNiGe_2$ and (c) $DyNiSi_2$ and $DyNiGe_2$.

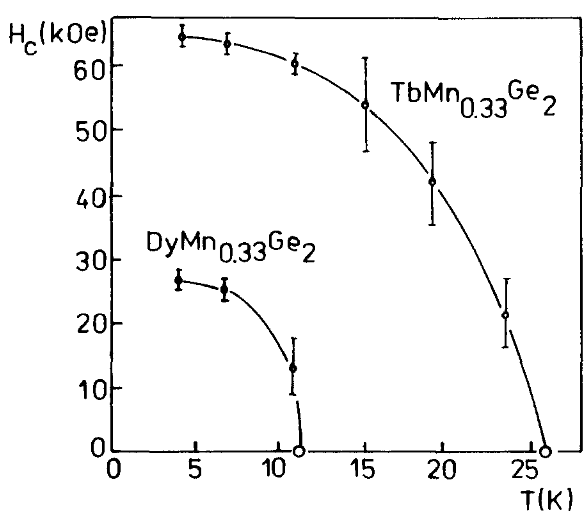

Fig. 4. Magnetic phase diagrams for (a) $TbMn_{0.33}Ge_2$ and (b) $DyMn_{0.33}Ge_2$.

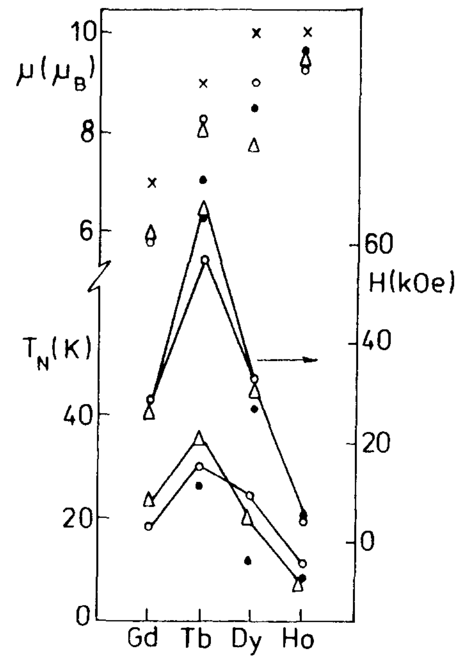

Fig. 5. (a) The Néel temperature T_N; (b) critical magnetic field H_C and (c) value of the magnetic moment μ_{ord} at $T=4.2$ K and $H=140$ kOe for (○) $RNiSi_2$, (△) $RNiGe_2$ and (●) $RMn_{0.33}Ge_2$ compounds as a function of rare earth element, (×) value for free R^{3+} ion.

The magnetization curves for the other compounds are typical for spin-flip systems. In low fields (below H_c a simple antiferromagnetic structure with the sequence $+-+-$ along the propagation vector is observed. The magnetic moments are parallel to the c-axis [5,6]. In the critical field H_c one single spin-flip transition occurs. Above this field, the magnetization reaches the saturated value, i.e. the ferromagnetic arrangement appears.

The results obtained from the Néel temperatures, critical fields and magnetic moments for three groups of compounds are summarized in Fig. 5.

The results presented indicate that:

(1) a connection between the Néel temperature and critical field values is observed;

(2) for three groups of compounds measured, the de Gennes scaling [8] is not obeyed. The shift of T_N for compounds containing Tb can result from crystal field effects [9], and

(3) values of magnetic moments are smaller than the free R^{3+} ion values.

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