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Letter

Magnetic phase diagrams of the $TbRh_{2-x}Pd_xSi_2$ and $TbRu_{2-x}Pd_xSi_2$ systems

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Abstract

The a.c. susceptibility and high field magnetization of $TbRh_{2-x}Pd_xSi_2$ and $TbRu_{2-x}Pd_xSi_2$ compounds were investigated up to 140 kOe. The (T, x) magnetic phase diagrams were determined. For both systems, an increase in the Pd content causes a decrease in the Néel temperature and changes the magnetization curves.

Keywords: $TbRh_{2-x}Pd_xSi_2$ and $TbRu_{2-x}Pd_xSi_2$ systems; Magnetic phase diagram; Magnetic properties; Rare earth compounds

1. Introduction

Continuing our studies of the pseudo-ternary $RT_{2-x}T'_xSi_2$ compounds, we present results for $TbRh_{2-x}Pd_xSi_2$ and $TbRu_{2-x}Pd_xSi_2$. Ternary RT_2Si_2 compounds crystallize in the body-centered tetragonal $ThCr_2Si_2$-type structure [1]. The $TbRh_2Si_2$ is a colinear antiferromagnet of the AF I type [2], whereas the $TbRu_2Si_2$ and $TbPd_2Si_2$ have modulated magnetic structures. The $TbRu_2Si_2$ has a sine-modulated structure with the wave vector $k = (0, k_y, 0)$ [3]. At low temperatures a squaring of the modulation is observed [4]. The $TbPd_2Si_2$ has a sine-modulated structure with the propagation vector $k = (0.602, 0, 0.148)$ [5].

In this work, results of a.c. susceptibility and high field magnetization measurements of $TbRh_{2-x}Pd_xSi_2$ and $TbRu_{2-x}Pd_xSi_2$ for $x = 0$, 0.5, 1.0, 1.5 and 2 systems are reported.

2. Experimental details and results

The experiments were carried out on polycrystalline samples which were prepared by arc-melting stoichiometric amounts of the constituent elements in an inert atmosphere of argon. The samples were subsequently annealed in a vacuum for 1 week at 800 °C.

Powder X-ray diffraction studies were performed using a Dron-3 X-ray diffractometer equipped with CuK_α radiation. The obtained data show that all samples are single-phase and of the tetragonal $ThCr_2Si_2$ type of crystal structure. Lattice parameters of all compounds were obtained by a least-squares fit to the experimental data. The obtained values are shown in Fig. 1. For the $TbRh_{2-x}Pd_xSi_2$ system, an increase in the a and decrease in the c constant are observed when the Pd content increases. For $TbRu_{2-x}Pd_xSi_2$, both a and c constants increase with increasing x.

The a.c. susceptibility was measured using a mutual inductance bridge. The temperature dependence of the a.c. magnetic susceptibility of both series is shown in Fig. 2. In the $TbRh_{2-x}Pd_xSi_2$ compounds with $x =$ 0.5 and 2.0 one maximum is observed, whereas for $x = 1.0$ and 1.5 two anomalies appear. The $TbRu_{2-x}Pd_xSi_2$ has only one phase transition. A phase diagram as a function of x for both systems (see Fig. 3) was constructed. The magnetization of the samples was measured by means of a ballistic magnetometer in a Bitter-type magnet in magnetic fields up to 140 kOe. The magnetization curves measured at $T = 4.2$ K for the compounds with different x values are presented

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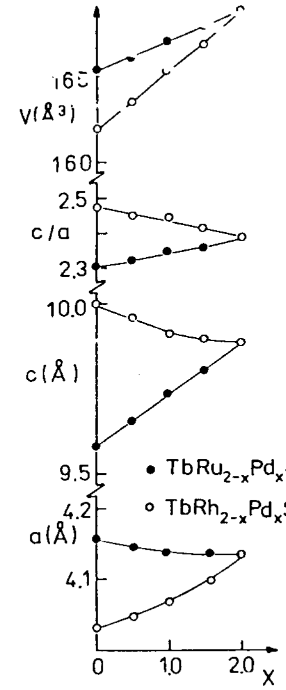

Fig. 1. Concentration dependence of the lattice a and c constants of the ratio a/c and of the unit cell volume for $TbRh_{2-x}Pd_xSi_2$ and $TbRu_{2-x}Pd_xSi_2$.

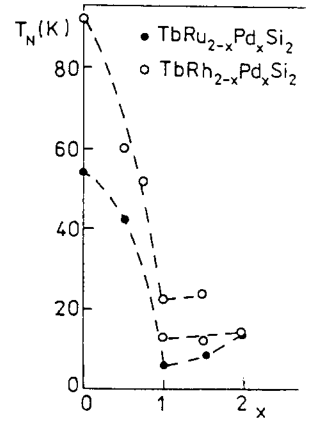

Fig. 3. Magnetic phase diagrams of $TbRh_{2-x}Pd_xSi_2$ and $TbRu_{2-x}Pd_xSi_2$.

in Fig. 4. For $TbRh_2Si_2$, a one-step metamagnetic transition with the critical field of ~90 kOe is observed. An increase in the Pd content changes the character of the magnetization curves. The magnetization is almost a linear function of an external magnetic field with a small ferromagnetic component. For $TbPd_2Si_2$, a two-step metamagnetic transition with the critical fields of 25 kOe and 56 kOe is observed. The magnetization curve of a single-crystal $TbRu_2Si_2$ measured at 4.2 K has a two-step character with the critical fields of 22 kOe and 27 kOe [6]. For the polycrystalline sample, only a one-step transition with the H_{Cr} = 16 kOe is observed [3]. A similar character of the magnetization curve is observed for the sample with $x = 0.5$. The magnetization curves for the samples with $x = 1.0$ and 1.5 are different. They are similar to the curve in the paramagnetic state. For all compounds the magnetic moments determined at T = 4.2 K and H = 140 kOe are smaller than the free Tb^{3+} ion value (9.0 μ_B).

3. Discussion

The magnetic phase diagrams of both $TbRh_{2-x}Pd_xSi_2$ and $TbRu_{2-x}Pd_xSi_2$ systems are simi-

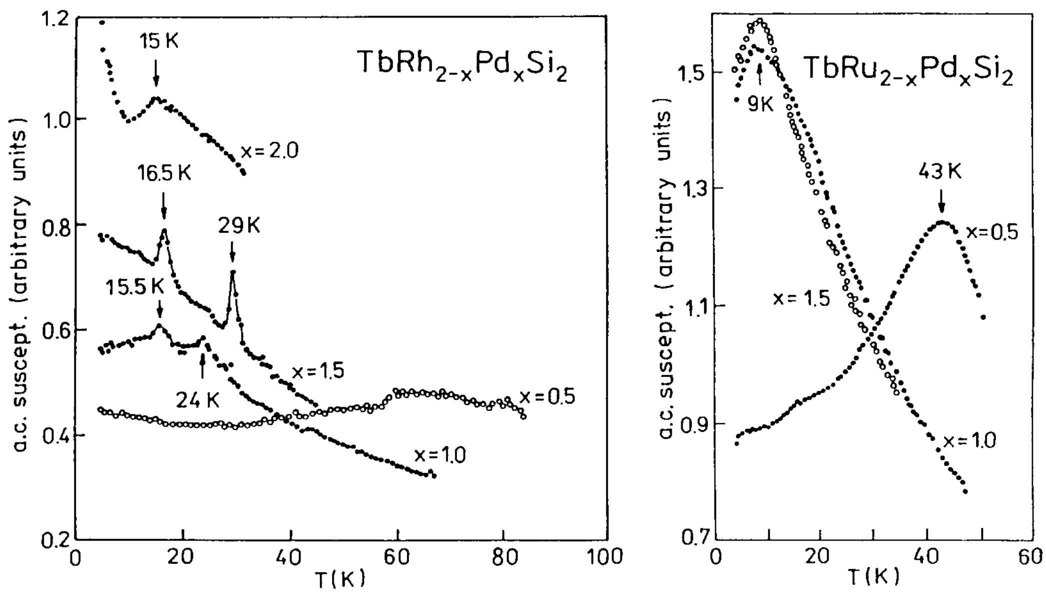

Fig. 2. Temperature dependence of the a.c. susceptibilities for $TbRh_{2-x}Pd_xSi_2$ and $TbRu_{2-x}Pd_xSi_2$.

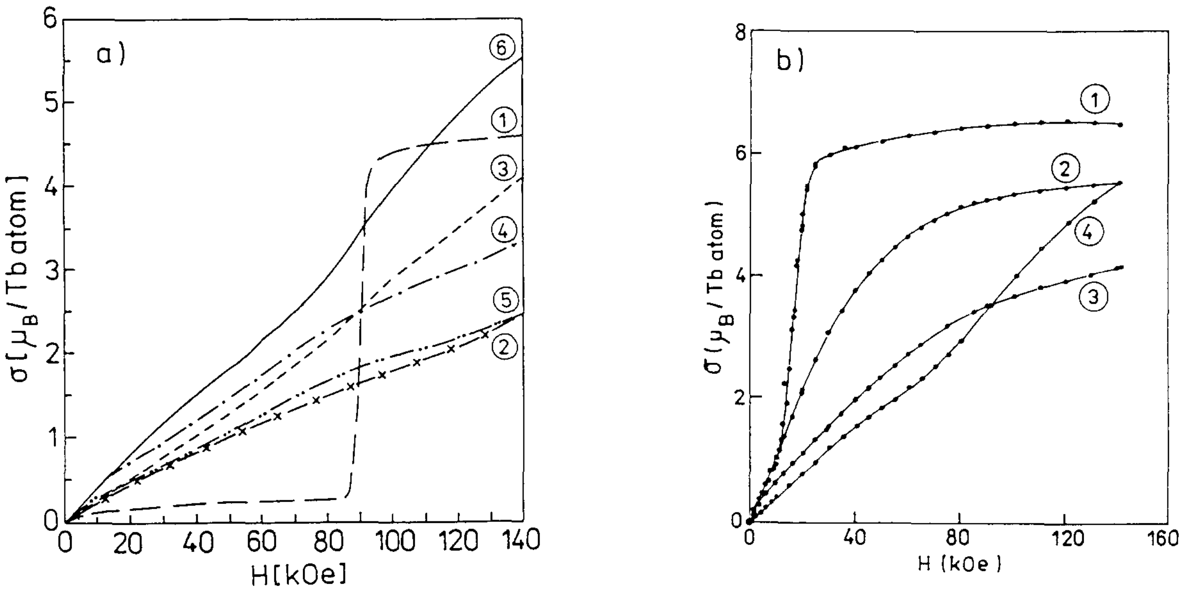

Fig. 4. High field magnetization curves at $T = 4.2$ K for (a) $TbRh_{2-x}Pd_xSi_2$ ($1 - x = 0$, $2 - x = 0.5$, $3 - x = 0.75$, $4 - x = 1$, $5 - x = 1.5$, $6 - x = 2$) and (b) $TbRu_{2-x}Pd_xSi_2$ ($1 - x = 0.5$, $2 - x = 1$, $3 - x = 1.5$, $4 - x = 2$).

lar to that for $TbRh_{2-x}Ru_xSi_2$ [7]. In the region $0 < x < 1$ the Néel temperature decreases while for $1 < x < 2$ the values of T_N are constant.

The results indicate that the magnetic properties of these systems depend on the 4d electron concentration. The substitution of rhodium and ruthenium by palladium causes a change in the magnetic interactions.

The external magnetic field changes the magnetic properties. For $TbRh_2Si_2$ and $TbRu_2Si_2$ compounds a two-step metamagnetic process occurs [6,8] which is typical for a number of RT_2X_2 compounds [9]. The observed change in the magnetization curves with an increasing Pd content indicates a complicated character of magnetic structures of these compounds.

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