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Magnetic phase diagrams of the $HoRh_{2-x}T'_xSi_2$ (T' = Ru, Pd) systems

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Abstract

The a.c. susceptibility and high field magnetization of $HoRh_{2-x}T'_xSi_2$ compounds were investigated up to 140 kOe. The (T, x) magnetic phase diagrams were determined. The Néel temperatures are an oscillatory function of the number of 4d-electrons of the T atoms.

Keywords: Ternary holmium compounds; High field magnetization; Magnetic phase diagram

1. Introduction

In continuation of our studies of the pseudo-ternary $RT_{2-x}T'_xSi_2$ compounds [1–4] we present results for $HoRh_{2-x}T'_xSi_2$ (T' = Ru, Pd). Ternary RT_2Si_2 compounds crystallize in the body-centred tetragonal $ThCr_2Si_2$ ($CeAl_2Ge_2$)-type structure [5]. $HoRh_2Si_2$ is a collinear antiferromagnet of the AF I type [6], whereas $HoRu_2Si_2$ [7] and $HoPd_2Si_2$ [8] have modulated magnetic structures.

In this work, the results of X-ray diffraction, a.c. susceptibility and high field magnetization measurements of $HoRh_{2-x}T'_xSi_2$, where T' are Ru and Pd for $x = 0$, 0.5, 1.0, 1.5 and 2.0 systems are reported.

2. Experiment 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. Afterwards the samples were annealed at 800°C for 1 week.

Powder X-ray diffraction studies were performed using DRON-3 diffractometer equipped with a Co Kα radiation source. The obtained data show that all samples are single phase and have the tetragonal $ThCr_2Si_2$-type 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 both systems the a-constants increase with increasing concentration of the T' elements. The c-constants decrease with increasing Ru content, whereas the admixture of Pd does not change the values of this parameter.

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 $HoRh_{2-x}Ru_xSi_2$ compounds, with $x = 0$ and 1.5, two anomalies are observed, whereas in the other compounds only one anomaly is detected. The $HoRh_{2-x}Pd_xSi_2$ samples, excluding $HoRh_2Si_2$, have only one anomaly. A phase diagram as a function of x for both systems was constructed (see Fig. 3).

The magnetization curves at low fields were measured by means of a vibrating sample magnetometer. The results obtained for the $HoRh_{2-x}Ru_xSi_2$ compounds are presented in Fig. 4. For pure $HoRh_2Si_2$ the magnetization is a linear function of the magnetic field up to 300 Oe. With increasing Ru content the magnetization curves have a metamagnetic character with critical fields smaller than 100 Oe. The addition of Pd changes the character of the magnetization curves, which have ferromagnetic character. For $HoPd_2Si_2$ the magnetization curve is a linear function of the magnetic field.

The magnetization in high magnetic fields was

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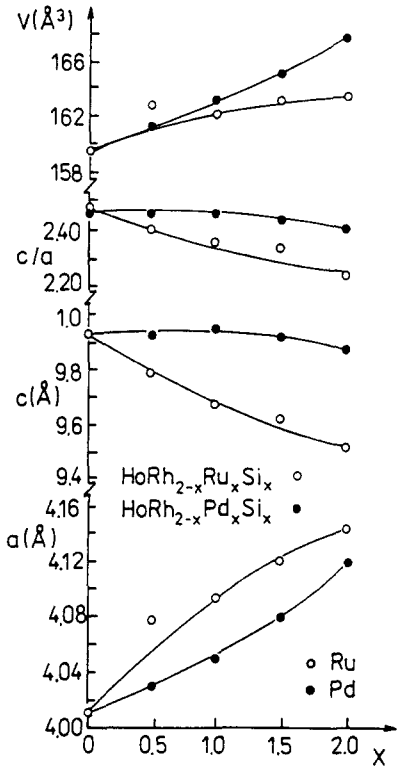

Fig. 1. Concentration dependence of the lattice constants a and c, of the ratio a/c and of the unit cell volume V for $HoRh_{2-x}T'_xSi_2$ (T' = Ru and Pd).

measured by means of a ballistic magnetometer in a Bitter-type magnet in magnetic fields up to 140 kOe. The magnetization curves measured for several x values are presented in Figs. 5 and 6. For $HoRh_2Si_2$, a two-step metamagnetic transition with critical fields of

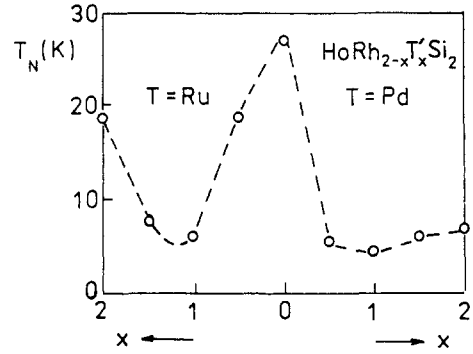

Fig. 3. Magnetic phase diagrams of $HoRh_{2-x}T'_xSi_2$ (T' = Ru and Pd).

about 17 and 46 kOe is observed. The addition of Ru and Pd changes the character of magnetization curves. High magnetic fields induce the ferromagnetic state, as in $HoRu_2Si_2$ [7].

For all compounds, the magnetic moments determined at $T = 4.2$ K and $H = 140$ kOe are smaller than the value for the free Ho^{3+} ion (10 μ_B).

3. Discussion

The results presented here and published previously [1–4] indicate that the magnetic properties of the RT_2X_2 systems depend on the 4d electron concentration and that the magnetic moment is localized on the rare earth R^{3+} ions only. The T atoms in these compounds have the following number of 4d electrons: Ru–6, Rh–7 and Pd–8. With increasing number of 4d-electrons an oscillatory character of the Néel tem-

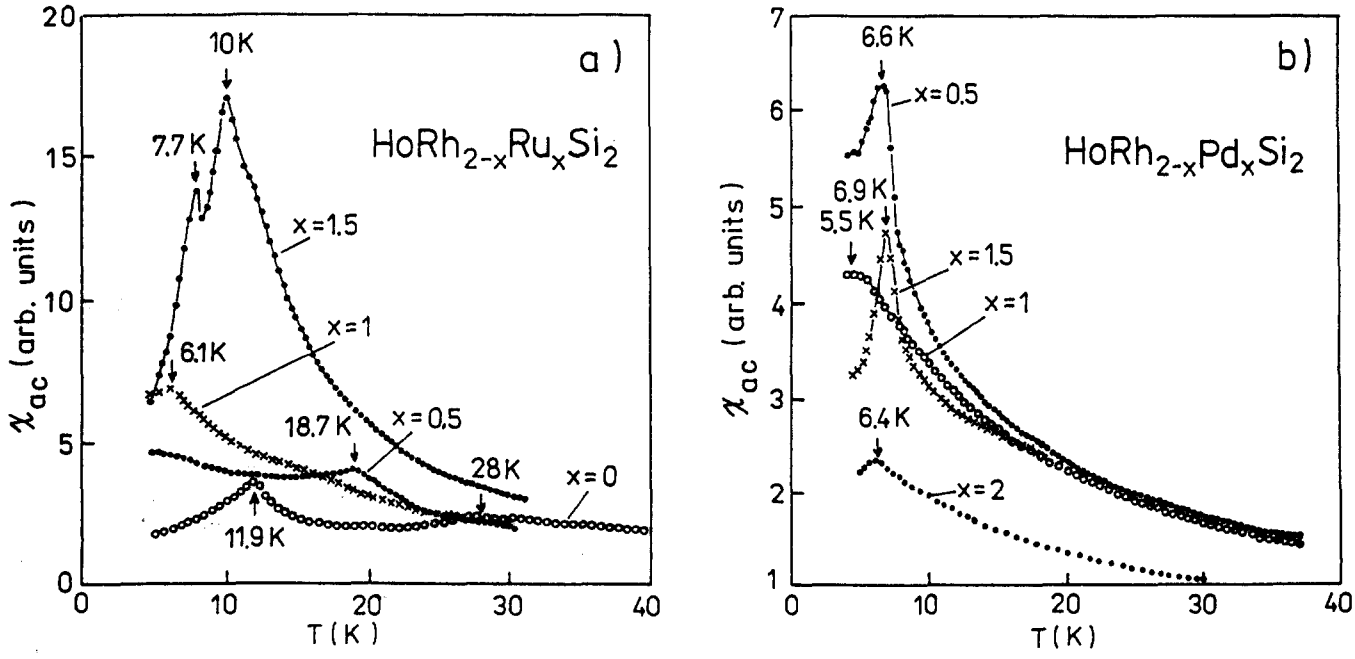

Fig. 2. Temperature dependence of the a.c. susceptibilities for $HoRh_{2-x}T'_xSi_2$ (T' = Ru and Pd).

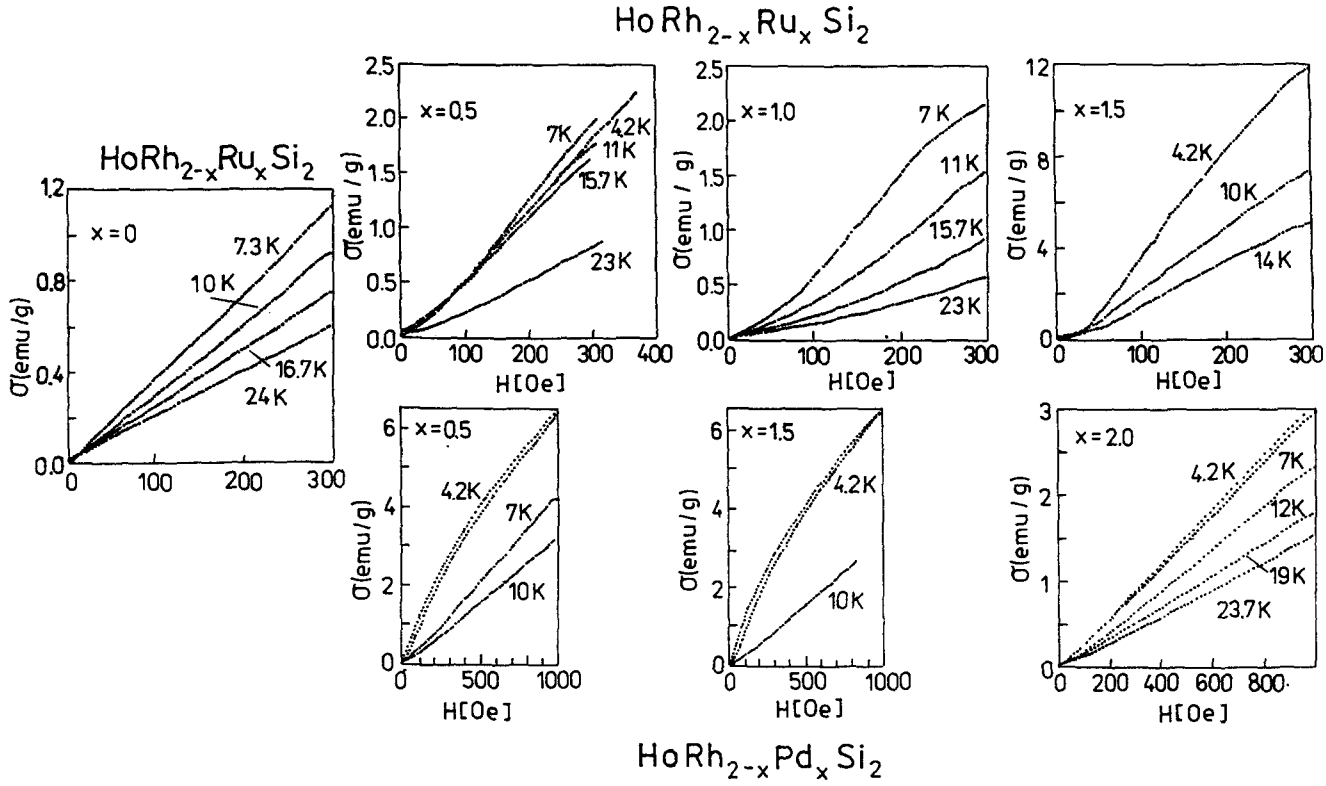

Fig. 4. Magnetization curves of $HoRh_{2-x}T'_xSi_2$ (T' = Ru and Pd) in magnetic fields up to 1000 Oe.

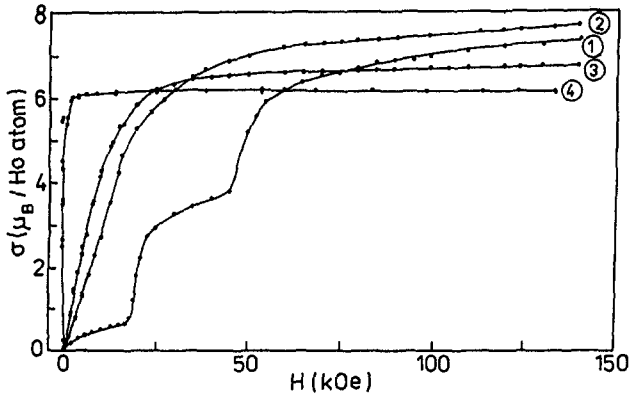

Fig. 5. High field magnetization curves at $T = 4.2$ K for $HoRh_{2-x}Ru_xSi_2$: (1) $x = 0$, (2) $x = 0.5$, (3) $x = 1$, (4) $x = 1.5$.

perature T_N is observed (see Fig. 3). Similar results are observed in other investigated isostructural systems [1,2,4] and also in $CeRh_{2-x}Ru_xSi_2$ [9], $CeCu_{2-x}Ni_xGe_2$ [10] and $URh_{2-x}Ru_xSi_2$ [11]. These results confirm that the magnetic interactions in these compounds are of the RKKY type.

For an exact interpretation of the obtained phase diagram it is necessary to determine the type of magnetic ordering. The results of the neutron diffraction indicate a collinear antiferromagnetic AF I type for $HoRh_2Si_2$, a sine modulated LSW III type for $HoRu_2Si_2$ and LSW IV type for $HoPd_2Si_2$ (see Fig. 23 in Ref. [5]). Also, preliminary results of the neutron diffraction for some $HoRh_{2-x}T'_xSi_2$ compounds indicate a modulated character of the magnetic ordering.

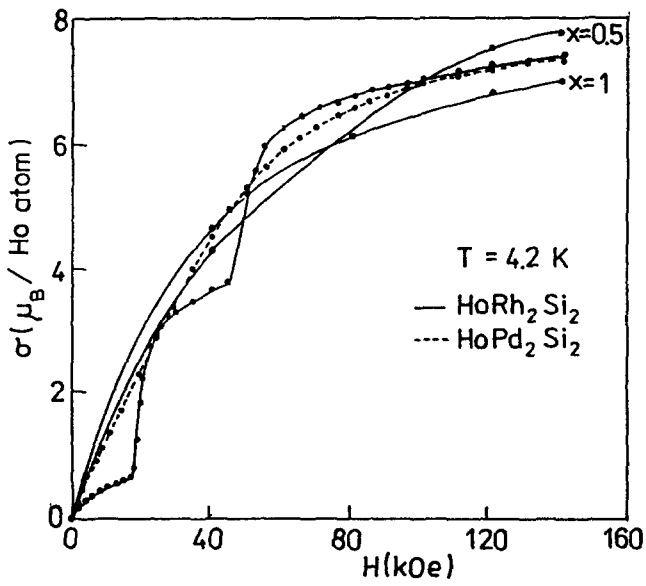

Fig. 6. High field magnetization curves at $T = 4.2$ K for $HoRh_{2-x}Pd_xSi_2$.

Acknowledgements

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References

[1] V. Ivanov, L. Vinokurova and A. Szytuła, *J. Alloys Comp., 201* (1993) 109.

[2] V. Ivanov, L. Vinokurova, A. Szytuła and A. Zygmunt, *J. Alloys Comp., 191* (1993) 159.

[3] V. Ivanov, L. Vinokurova and A. Szytuła, *J. Alloys Comp. 218* (1995) L19.

[4] V. Ivanov, L. Vinokurova, T. Mydlarz and A. Szytuła, *J. Alloys Comp.*, in press.

[5] A. Szytuła and J. Leciejewicz, in K.A. Gschneidner, Jr. and L. Eyring (eds.), *Chemistry of Rare Earths*, Vol. 12, North-Holland, Amsterdam, 1989, p. 133.

[6] M. Ślaski, A. Szytuła and J. Leciejewicz, *J. Magn. Magn. Mater., 39* (1983) 268.

[7] M. Ślaski, A. Szytuła, J. Leciejewicz and A. Zygmunt, *J. Magn. Magn. Mater., 46* (1984) 114.

[8] J. Leciejewicz and A. Szytuła, *J. Magn. Magn. Mater., 49* (1985) 177.

[9] B. Lloret, B. Chevalier, B. Buffat, J. Etourneau, S. Quezel, A. Lamharrar, J. Rossat-Mignod, R. Celemczuk and E. Bonjour, *J. Magn. Magn. Mater., 63–64* (1987) 85.

[10] F. Steglich, G. Sparn, R. Moog, S. Horn, A. Grand, M. Lang, M. Nowak, A. Loidl, A. Krimmel, K. Knorr, A.P. Murani and M. Tachki, *Physica B, 163* (1990) 19.

[11] Y. Miyako, T. Kuwai, T. Tamiguchi, S. Kawarazaki, H. Amitsuka, C.C. Paulsen and T. Sakakibara, *J. Magn. Magn. Mater., 108* (1992) 190.