Magnetic Properties of SmRhIn

Mar'yana Lukachuk, Rolf-Dieter Hoffmann, and
Rainer Pöttgen

Institut für Anorganische und Analytische Chemie and NRW
Graduate School of Chemistry, Westfälische Wilhelms-
Universität Münster, Corrensstraße 36, D-48149 Münster,
Germany

Reprint requests to R. Pöttgen.
E-mail: pottgen@uni-muenster.de

The indide SmRhIn (ZrNiAl type, $P\bar{6}2m$, $a = 750.93(8)$, $c = 397.52(4)$ pm) was synthesized from the elements by arc-melting. SmRhIn orders antiferromagnetically at 8.0(5) K. The non-linearity of the temperature dependence of the inverse susceptibility points to a large van Vleck term for the samarium atoms. Magnetization measurements indicate a metamagnetic transition at a flux density of 3 T.

Key words: Magnetism, Rare Earth Indides

Introduction

The equiatomic intermetallic rare earth (*RE*) compounds *RETX* (*T* = late transition element; *X* = element of the 3rd, 4th, or 5th main group) have attracted considerable interest in recent years due to their greatly varying magnetic and electrical properties. Those with cerium, europium, and ytterbium have intensively been studied with respect to their potential valence instabilities, *i.e.* Ce^{III} / Ce^{IV}, Eu^{II} / Eu^{III}, and Yb^{II} / Yb^{III}. Overviews are given in [1 – 3].

The samarium based compounds Sm*TX* mostly do not exhibit Curie-Weiss behavior. The proximity of the excited $J = 7/2$ multiplet to the ground $J = 5/2$ multiplet of the samarium ions and the effect of the anisotropic crystal field inducing an admixture of the different multiplets have a pronounced effect on the susceptibility [4]. Depending on the *T* and *X* component, the magnetic ordering of the samarium magnetic moments is different. Antiferromagnetic ordering at 9.3, 12.2, and 3.5 K has been observed for Sm*T*Sn with *T* = Ni, Pd, and Pt, respectively [5]. SmPtSi [6], SmPtIn [7], and SmPtMg [8] order ferromagnetically at the higher Curie temperatures of 15, 25, and
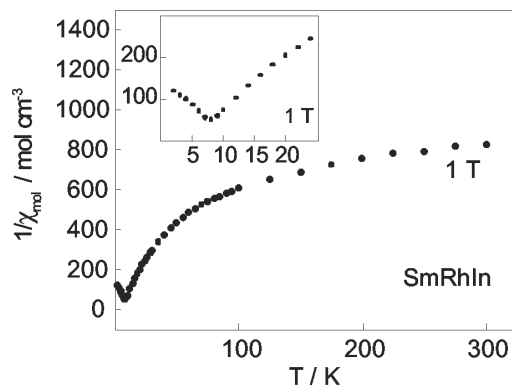

Fig. 1. Temperature dependence of the inverse magnetic susceptibility of SmRhIn measured at a magnetic flux density of 1 T. The low-temperature behavior is shown in the inset.
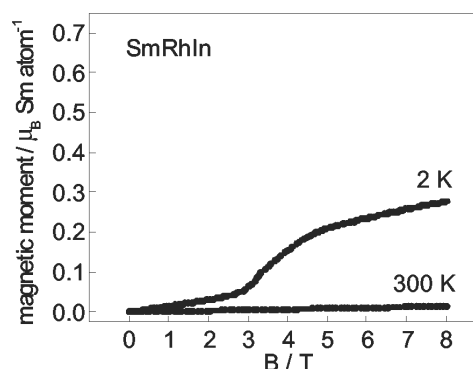

Fig. 2. Magnetic moment *vs* external magnetic flux density for SmRhIn at 2 and 300 K.

52 K, respectively. A ferrimagnetic ground state below $T_C = 54$ K was observed for SmPdIn [9]. The magnetic properties of the recently reported indide SmRhIn [10] are reported herein.

Experimental Section

Synthesis

Starting materials for the preparation of SmRhIn were sublimed dendritic pieces of samarium (Johnson Matthey), rhodium powder (Degussa-Hüls, 200 mesh), and indium tear drops (Johnson Matthey), all with stated purities better than 99.9%. In a first step the samarium ingot was cut into small pieces and melted to a button in an arc-melting furnace [11] under argon. This pre-melting procedure minimizes a shattering of samarium during the exothermic reaction with rhodium and indium. The argon was purified before over titanium sponge and molecular sieves.

SmRhIn was synthesized in an arc-furnace on a water-cooled copper chill. The samarium button was mixed with a cold-pressed pellet ($\oslash$ 6 mm) of rhodium and pieces of the indium tear drops in the ideal 1:1:1 atomic ratio and arc-melted under an argon pressure of about 600 mbar. The button was remelted three times to ensure homogeneity. The weight loss was smaller than 0.5%.

The sample was characterized through its Guinier powder pattern using Cu-K$_{\alpha1}$ radiation and α-quartz ($a = 491.30$, $c = 540.46$ pm) as internal standard. The experimental pattern compared well with a calculated one [12] taking the atomic positions obtained from the previous structure refinement [10]. No impurities were evident from the powder pattern.

The SmRhIn sample has been analyzed by an EDX measurement using a LEICA 420 I scanning electron microscope with SmF$_3$, rhodium, and InAs as standards. No impurity elements heavier than sodium (detection limit of the EDX unit) were detected. The analytical data 34 ± 2 at.-% Sm : 33 ± 2 at.-% Rh : 33 ± 2 at.-% In at various points of the bulk sample are in excellent agreement with the ideal composition SmRhIn.

Magnetic measurements

The magnetic susceptibilities of a polycrystalline, powdered sample of SmRhIn were determined with a Quantum Design Physical Property Measurement System in the temperature range 2 to 300 K with magnetic flux densities up to 8 T. The sample was enclosed in a small gelatin capsule and fixed at the sample holder rod. The sample was then cooled to 2 K in zero magnetic field and slowly heated to room temperature in the applied external field.

Results and Discussion

The inverse magnetic susceptibility of SmRhIn shows no Curie-Weiss behaviour in the whole temperature range investigated (Fig. 1). This large van Vleck contribution is typical for a samarium containing compound and results from the peculiar electronic structure of trivalent samarium. The $J = 5/2$ ground multiplet and the $J = 7/2$ excited multiplet levels are separated by only 1550 K [4]. The antiferromagnetic nature of the magnetic phase transition at $T_N = 8.0(5)$ K is evident from the 1 T measurement (inset of Fig. 1). The magnetization *vs* external magnetic field dependence is displayed in Fig. 2. At 300 K, well above the ordering temperature, we observe a linear increase. The M *vs* B dependence at 2 K also shows a linear increase at slightly higher magnetizations up to 3 T. At this critical field strength we observe a metamagnetic transition. At the highest obtainable field of 8 T the magnetization is 0.278(2) μ_B/Sm, significantly smaller than the possible saturation magnetic moment of 0.714 μ_B/Sm according to $g \times J$ [2]. The reduced moment may be due to crystal field effects or a complex magnetic spin structure which may not be of a simple collinear type. Similar small saturation magnetizations have also been observed for other Sm*TX* intermetallics [5 – 9].

[1] K. A. Gschneidner (Jr.), L. Eyring (eds.): Handbook on the Physics and Chemistry of Rare Earths, Chapters 48, 51, 88, 138, 164, 174, 207, 212, 218, Elsevier Science Ltd., Amsterdam (1984 – 2004).

[2] A. Szytuła, J. Leciejewicz, Handbook of Crystal Structures and Magnetic Properties of Rare Earth Intermetallics, CRC Press, Boca Raton, Florida, 33431 (1994).

[3] R. Pöttgen, D. Johrendt, Chem. Mater. **12**, 875 (2000).

[4] A. M. Stewart, Phys. Rev. B **47**, 11242 (1993).

[5] J. Sakurai, K. Kegai, T. Kuwai, Y. Isikawa, N. Nishimura, K. Mori, J. Magn. Magn. Mater. **140 – 144**, 875 (1995).

[6] S. Ramakrishnan, K. Ghosh, A. D. Chinchure, V. R. Marathe, G. Chandra, Phys. Rev. B **52**, 6784 (1995).

[7] V. I. Zaremba, Y. V. Galadzhun, B. D. Belan, A. Pikul, J. Stępień-Damm, D. Kaczorowski, J. Alloys Compd. **316**, 64 (2001).

[8] R. Kraft, G. Kotzyba, R.-D. Hoffmann, R. Pöttgen, Z. Naturforsch. **57b**, 488 (2002).

[9] T. Ito, K. Ohkubo, T. Hirasawa, J. Takeuchi, I. Hiromitsu, M. Kurisu, J. Magn. Magn. Mater. **140 – 144**, 873 (1995).

[10] M. Lukachuk, V. I. Zaremba, R. Pöttgen, Intermetallics **11**, 581 (2003).

[11] R. Pöttgen, Th. Gulden, A. Simon, GIT Labor Fachzeitschrift **43**, 133 (1999).

[12] K. Yvon, W. Jeitschko, E. Parthé, J. Appl. Crystallogr. **10**, 73 (1977).