High-field magnetization studies of some U2T2X compounds

Fukushima, T.; Matsuyama, S.; Kumada, T.; Kindo, K.; Prokes, K.; Nakotte, H.; de Boer, F.R.; Havela, L.; Sechovsky, V.; Winand, J.M.; Rebizant, J.; Spirlet, J.C.

DOI
10.1016/0921-4526(94)00967-Z

Publication date
1995

Published in
Physica B-Condensed Matter

ELSEVIER

Physica B 211 (1995) 142–144

PHYSICA B

High-field magnetization studies of some U_2T_2X compounds

T. Fukushima[a], S, Matsuyama[a], T. Kumada[a], K. Kindo[a], K. Prokeš[b,*], H. Nakotte[b,1], F.R. de Boer[b], L. Havela[c], V. Sechovský[c], J.M. Winand[d], J. Rebizant[d], J.C. Spirlet[d]

[a] *Research Center for Extreme Materials, Osaka University, Toyonaka, Osaka 560, Japan*
[b] *Van der Waals–Zeeman Laboratory, University of Amsterdam, 1018 XE Amsterdam, The Netherlands*
[c] *Department of Metal Physics, Charles University, 121 16 Prague 2, Czech Republic*
[d] *European Commission, Joint Research Centre, Institute for Transuranium Elements, Postfach 2340, 76125 Karlsruhe, Germany*

Abstract

High-field magnetization measurements at 4.2 K on several U_2T_2X (T = Ni, Rh, Pd, Pt; X = In, Sn) compounds have been performed on free and fixed powders up to 57 T. An antiferromagnetic ground state of U_2Ni_2Sn is corroborated by metamagnetic transitions at 30, 39 and 51 T. U_2Rh_2Sn shows one metamagnetic transition at 21 T and U_2Pd_2Sn two metamagnetic transitions at 39 and 45 T. U_2Pt_2In shows no metamagnetism up to 57 T which is in agreement with the non-magnetic ground state of this compound. The short-pulsed measurements up to 57 T are compared with previous results obtained in quasi-static fields up to 35 T.

Recently, a new large isostructural group of U compounds with stoichiometry U_2T_2X (T = transition metal, X = p-metal) was discovered [1, 2] offering thus a new possibility to follow the development of magnetic properties with respect to the constituent elements.

The U_2T_2X compounds with T = Co, Rh, Ir, Ni, Pd and Pt, X = In, Sn were synthesized by arc-melting appropriate amounts of the constituting elements. The structure and phase purity of the resulting samples were checked by X-ray powder diffraction. Several compounds were checked also by means of microprobe analysis and it was found that some of them contain small amounts of impurities. The atomic positions were determined on small single crystals extracted from bulk pieces by means of an Enraf–Nonius four-circle diffractometer. All compounds are found to adopt the ternary derivative version of the tetragonal U_3Si_2-type of structure (space group P4/mbm, $Z = 2$), only the Pt containing samples exhibit an additional superstructure (space group $P4_2/mnm$) [3]. The structure consists of two alternating plane sheets (Fig. 1), one containing only U atoms at positions 4 h (x, $x + 0.5$, 0.5) with x about 0.17 and the other containing T atoms (at positions 4 g (y, $y + 0.5$, 0)) as well as X atoms (at positions 2 a (0, 0, 0)).

The majority of the investigated samples exhibits antiferromagnetic ordering with transition temperatures ranging from 14.3 K for U_2Ni_2In to 40.6 K for U_2Pd_2Sn. Both Co containing samples, U_2Rh_2In, U_2Pt_2In and U_2Ir_2Sn are paramagnetic down to 1.3 K. An antiferromagnetic ground state of the ordered samples is corroborated by the metamagnetic transitions in rather high magnetic fields [4]. Nevetheless, the previous high-field magnetization studies at the University of Amsterdam in fields up to 35 T have shown that even these fields are not sufficient to saturate the magnetization in most of the cases and sometimes not even high enough to cause a metamagnetic transition [4]. In the present paper new results are presented obtained in short-pulsed

* Corresponding author.
[1] Present address: Los Alamos National Laboratory, Los Alamos, NM 87545, USA.

SSDI 0921-4526(94)00967-8

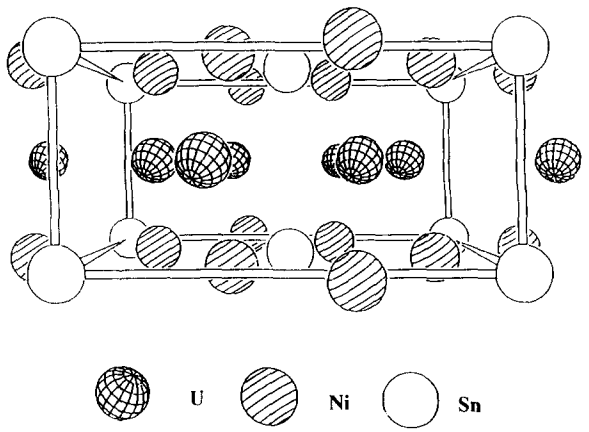

Fig. 1. Schematic representation of the structure of U_2Ni_2Sn as an example of a member of U_2T_2X compounds.

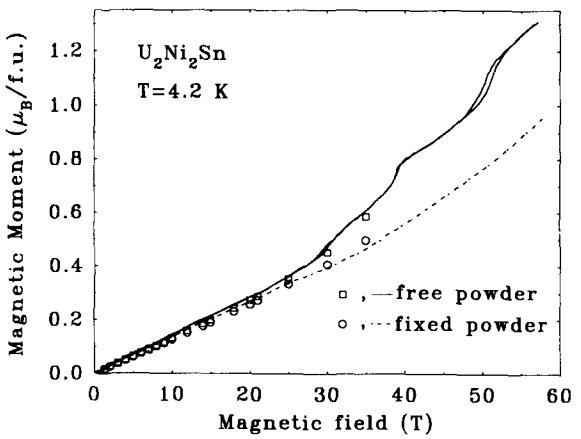

Fig. 2. Filed dependence of the magnetization in quasi-static fields of U_2Ni_2Sn for powder free to orient in the external field (□) and for powder fixed by frozen alcohol (○). The lines represent continuous-field sweeps.

fields up to 57 T at the High Field Facility at Osaka University.

In Fig. 2 measurements performed on two kinds of samples of U_2Ni_2Sn are depicted which is reported to order antiferromagnetically below $T_N = 26$ K [4–6]. The first type of sample is a fine powder consisting of (presumably) single-crystalline particles which are free to be oriented by the external magnetic field. A measurement on this type of sample represents a measurement along the easy magnetization direction. In the second type of sample the powder is fixed by frozen alcohol in a random orientation and the measurement represents an experiment on an ideal polycrystalline sample. Three metamagnetic transitions at 30, 39 and 51 T are detected at 4.2 K for the free powder which reaches a magnetization of $1.3\mu_B$/f.u. at 57 T. The powder fixed by frozen alcohol does not exhibit any metamagnetic transition. For both types of U_2Ni_2Sn samples no tendency for saturation at high fields is observed. Only in the case of magnetic saturation, where complete ferromagnetic alignment is achieved, a firm conclusion can be drawn regarding the type of magnetic anisotropy by comparing the saturated values for fixed and free powder. Nevetheless, from the observed ratio M_{fix}/M_{free} which amounts 0.74 at 57 T and from the presence of a number of metamagnetic transitions we may conclude that U_2Ni_2Sn does not exhibit uniaxial type of magnetic anisotropy. The new results are in very good agreement with the earlier studies in quasi-static fields up to 35 T [4, 5].

The magnetization measurements on U_2Rh_2Sn which orders antiferromagnetically below $T_N = 24.4$ K [4, 5] are shown in Fig. 3. For the free powder a metamagnetic transition at 21 T is observed. The magnetization curves measured with increasing and decreasing field are quite different. This peculiarity as well as the lower values with respect to the measurements in quasi-static fields may be due to imperfect alignment of the particles during the very short field pulse. The slight saturation tendency yields a value of $1.12\mu_B$/f.u. at 57 T. The magnetization curve obtained on the fixed-powder sample also exhibits a metamagnetic transition at 21 T and has a saturation magnetization of $0.86\mu_B$/f.u. From the observed ratio

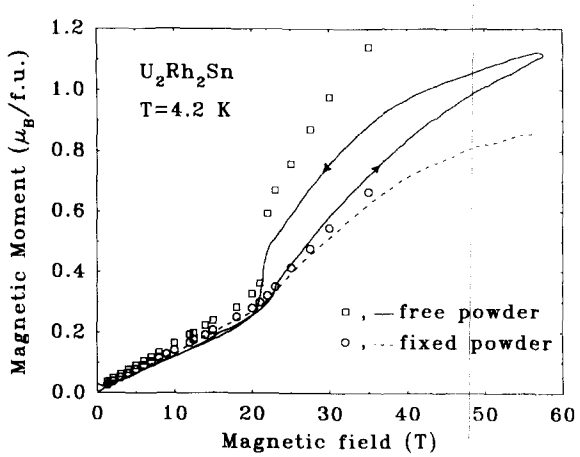

Fig. 3. Field dependence of the magnetization in quasi-static fields of U_2Rh_2Sn for powder free to orient in the external field (□) and for powder fixed by frozen alcohol (○). The lines represent continuous-field sweeps.

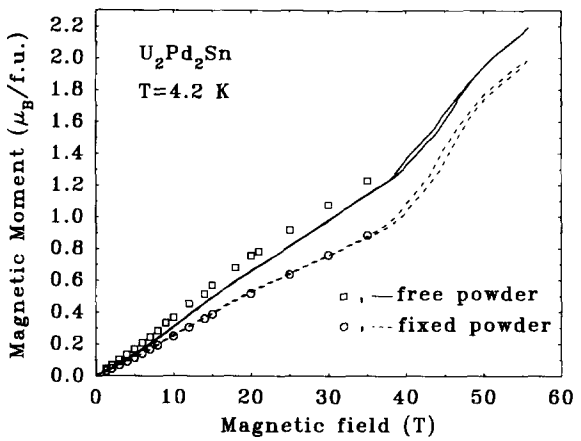

Fig. 4. Field dependence of the magnetization in quasi-static fields of U_2Pd_2Sn for powder free to orient in the external field (□) and for powder fixed by frozen alcohol (○). The lines represent continuous-field sweeps.

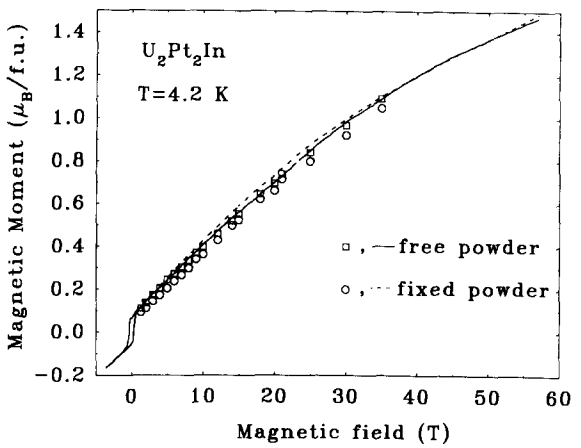

Fig. 5. Field dependence of the magnetization in quasi-static fields of U_2Pt_2In for powder free to orient in the external field (□) and for powder fixed by frozen alcohol (○). The lines represent continuous-field sweeps.

M_{fix}/M_{free} which amounts 0.76 we conclude that also U_2Rh_2Sn does not exhibit uniaxial type of magnetic anisotropy.

The magnetization curves of U_2Pd_2Sn, which orders antiferromagentically below $T_N = 40.6$ K [4, 5, 7], are depicted in Fig. 4. For both type of samples metamagnetic transitions at 39 and 45 T are found with slight hysteresis on going up and down with field. The magnetizations do not saturate even at 57 T. From the ratio M_{fix}/M_{free} at the highest fields which amounts to 0.90 and from the presence of a number of metamagnetic transitions we conclude that also U_2Pd_2Sn does not exhibit uniaxial type of magnetic anisotropy. Quite remarkable are the high magnetization values obtained at 57 T which reach 2.19 and $1.98\mu_B$/f.u. for free and fixed powder, respectively. These values are about one-half of the value of the U magnetic moment obtained from neutron-diffraction experiments at 10 K which amounts to $1.89 \pm 0.01\mu_B$/U [7].

U_2Pt_2In is reported to be paramagnetic down to 1.3 K [4, 5] with a low-temperature specific-heat coefficient γ of 850 mJ/mol$_{f.u.}$K^2. The magnetization exhibits no metamagnetic transition up to 57 T. The slightly bended magnetization curves of the free and the fixed powder are nearly identical and at the highest fields the magnetization reaches a value of $1.46\mu_B$/f.u. The small hysteresis loop around zero field may be attributed to UPt impurity of which microprobe analysis showed a small amount of about 2% to be present. These results are in good agreement with studies in quasi-static fields up to 35 T, as can be seen in Fig. 5. Surprising are the rather high values of the magnetization for paramagnetic compound.

This work is part of the research program of the "Stichting voor Fundamenteel Onderzoek der Materie (FOM)", The work of V.S. and L.H. was supported by the Grant Agency of The Czech Republic (grant. no. 202/93/0184). Support to J.M.W. given in the framework of the E.C. funded training program HC&M is acknowledged.

References

[1] F. Mirambet, P. Gravereau, B. Chevalier, L. Trut and J. Etourneau, J. Alloys Comp. 191 (1993) L1.
[2] M.N. Peron, Y. Kergadallan, J. Rebizant, D. Meyer, S. Zwiner, L. Havela, H. Nakotte, J.C. Spirlet, G.M. Kalvius, E. Colineau, J.L. Oddou, C. Jeandey, J.P. Sanchez and J.M. Winand, J. Alloys Comp. 201 (1993) 203.
[3] P. Gravereau, F. Mirambet, B. Chevalier, F. Weill, L. Fournès, D. Laffargue and J. Etourneau, 24èmes Journées des Actinides Obergurgl (1994) 114.
[4] H. Nakotte, K. Prokeš, E. Brück, N. Tang, F.R. de Boer, P. Svoboda, V. Sechovský, L. Havela, J.M. Winand, A. Seret, J. Rebizant and J.C. Spirlet, Physica B 201 (1994) 247.
[5] H. Nakotte, PhD Thesis, Amsterdam, 1994.
[6] K. Kindo, T. Fukushima, T. Kumada, F.R. de Boer, H. Nakotte, K. Prokeš, L. Havela, V. Sechovský, A. Seret, J.M. Winand, J.C. Spirlet and J. Rebizant, submitted to ICM'94, Warsaw.
[7] A. Purwanto, R.A. Robinson, L. Havela, V. Sechovský, P. Svoboda, H. Nakotte, K. Prokeš, F.R. de Boer, A. Seret, J.M. Winand, J. Rebizant and J.C. Spirlet, Phys. Rev. B 50 (1994) 6792.