UvA-DARE (Digital Academic Repository)

Magnetism and hybridization in UTIn compounds (T = Rh, Pt, Pd)

Sechovsky, V.; Havela, L.; Nakotte, H.; Prokeš, K.; Brück, E.; de Boer, F.R.; Buschow, K.H.J.; Andreev, A.V.

DOI

[10.1016/0304-8853\(94\)00936-8](https://doi.org/10.1016/0304-8853(94)00936-8)

Publication date

1995

Document Version

Final published version

Published in

Journal of Magnetism and Magnetic Materials

[Link to publication](#)

Citation for published version (APA):

Sechovsky, V., Havela, L., Nakotte, H., Prokeš, K., Brück, E., de Boer, F. R., Buschow, K. H. J., & Andreev, A. V. (1995). Magnetism and hybridization in UTIn compounds (T = Rh, Pt, Pd). *Journal of Magnetism and Magnetic Materials*, 140-144(2), 1391-1392.
[https://doi.org/10.1016/0304-8853\(94\)00936-8](https://doi.org/10.1016/0304-8853(94)00936-8)

General rights

It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations

If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: <https://uba.uva.nl/en/contact>, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.

UvA-DARE is a service provided by the library of the University of Amsterdam (<https://dare.uva.nl>)

Magnetism and hybridization in UTIn compounds (T = Rh, Pt, Pd)

V. Sechovsky ^{a,*}, L. Havela ^a, H. Nakotte ^b, K. Prokeš ^{a,b}, E. Brück ^b,
F.R. de Boer ^b, K.H.J. Buschow ^b, A.V. Andreev ^c

^a Department of Metal Physics, Charles University, 121 16 Prague, The Czech Republic

^b Van der Waals–Zeeman Laboratory, University of Amsterdam, 1018 XE Amsterdam, The Netherlands

^c Ural State University, 620083 Ekaterinburg, Russian Federation

Abstract

The isostructural compounds URhIn, UPtIn and UPdIn become antiferromagnetic (AF) below 7, 14 and 20.4 K, respectively. Their saturation magnetization and the uranium magnetic moments increase gradually in the sequence Rh, Pt, Pd and correlate with the expected reduction of the 5f–d hybridization. This trend is reflected also in the susceptibility behaviour (θ_p values).

The hexagonal Fe₂P (ZrNiAl)-type structure is adopted by more than 20 UTX compounds (T = transition metal, X = p-metal). Their magnetic properties range from temperature-independent paramagnetism (UFeAl) through the spin-fluctuation behaviour and/or band metamagnetism (UCoAl, URuAl, URuGa) to magnetic ordering of U moments. The U moments (and magnetic order) are gradually suppressed with enhancing the 5f-ligand hybridization (delocalizing the U 5f states). This follows from magnetic measurements [1–3] and from results of energy-band calculations [4]. The anisotropic hybridization is responsible for the huge magnetic anisotropy [5].

Three UTIn compounds (T = Rh, Pt and Pd) are formed in this structure [6,7]. UPdIn orders antiferromagnetically below 20.4 K [6–8]. Below 8.5 K a collinear magnetic structure (moments along the *c*-axis) is built up of ferromagnetic basal-plane sheets of U moments of $1.5\mu_B$ with a $+ - + - -$ coupling along the *c*-axis, yielding a net ferromagnetic component [8]. Similar to other isostructural UTX compounds, UPdIn bears a large uniaxial magnetic anisotropy (easy-magnetization direction along *c*). The nearly filled Pd 4d band and the largest size of the In atoms among the involved p-metals lead to a most reduced 5f-ligand hybridization.

In order to follow the development of magnetism in UTIn series we also prepared polycrystalline samples of

URhIn and UPtIn [9] and studied their magnetization, susceptibility and specific heat.

In Fig. 1 we show specific-heat results obtained on URhIn. The specific-heat data for UPdIn and UPtIn have been published elsewhere [6,10]. The maximum in the C_p/T vs. *T* plots for URhIn, UPtIn and UPdIn observed at 6.5, 14 and 20.4 K, respectively, marks the onset of AF ordering. For URhIn, the maximum is rather sharp and becomes more pronounced and slightly shifted towards lower temperatures in 1 T (the field around which a metamagnetic transition is seen on the magnetization curve in Fig. 2). The anomaly is gradually suppressed in higher fields. The low-temperature upturn in C_p/T vs. *T* removed in fields above 1 T, may be connected either with an additional magnetic phase transition below 1.4 K and/or a slight amount of impurities.

Fig. 1. Temperature dependence of the specific heat of URhIn in various applied fields between 0 and 5 T.

* Corresponding author. Fax: +42-2-24915050; email: sech@mag.mff.cuni.cz.

Fig. 2. Field dependence of the 'free-powder' (Δ) and 'fixed-powder' ($\circ$) magnetization of URhIn and UPtIn taken at 4.2 K. The insets show the low-field parts obtained on oriented powder of URhIn and UPtIn.

Magnetic measurements were performed on two kinds of fine-powder samples: (a) 'free powder' with grains free to rotate in the applied magnetic field, (b) 'fixed powder' with randomly oriented grains fixed by frozen alcohol or by diluted acetone glue. The 'free powder' in sufficiently high fields yields the easy-axis magnetization (M_{or}), provided the powder grains are single-crystalline and well oriented in magnetic field. The magnetization (M_{polycr}) of the 'fixed powder' represents an ideal polycrystal.

The high-temperature susceptibility of URhIn, UPtIn and UPdIn follows the Curie–Weiss law with parameters $\mu_{\text{eff}} \approx 3\mu_{\text{B}}/\text{f.u.}$ and $\theta_{\text{p}} = -123$, -48 and -37 K, respectively. The sequence of the θ_{p} values (compared to the respective T_{N} values) reflects a gradually reduced 5f–d hybridization between URhIn and UPdIn. The negative curvature of the $1/\chi$ vs. T plot observed below 150 K for URhIn and UPtIn is probably due to anisotropy in the paramagnetic range. The maximum in $\chi(T)$ is observed at 7 and 18 K for URhIn and UPtIn, respectively. In UPtIn, this temperature is 4 K lower than reported in Ref. [7], but still higher than the T_{N} value determined from the specific heat.

The 'free-powder' magnetization in both URhIn and UPtIn at 4.2 K (Fig. 2) is considerably higher than M_{polycr} , which points to a strong magnetocrystalline anisotropy with anisotropy fields exceeding 35 T. In contrast to the other ZrNiAl-type UTX compounds, however, UPtIn and URhIn exhibit poor saturation of M_{or} even in high magnetic fields. This might be due to a different type of anisotropy and single-crystal studies are desirable to prove this suggestion. The values of M_{or} in 35 T are 0.9, 1.2 and $1.5\mu_{\text{B}}/\text{f.u.}$ in URhIn, UPtIn and UPdIn (the latter value represents the saturated magnetization measured on a single crystal along c [8]), respectively. The saturated magne-

tization of 1.2 and $1.3\mu_{\text{B}}/\text{f.u.}$ can be roughly estimated for URhIn and UPtIn, respectively, from a linear extrapolation of the M_{or} vs. $1/B$ to $1/B = 0$. Assuming a negligible magnetization transition metal sites, we conclude that the U moments gradually increase in the sequence URhIn, UPtIn, UPdIn, which is reflecting expected reduction of the 5f–d hybridization (a detailed discussion of the correlation between U moments and hybridization in UTX compounds is given in Ref. [3]).

Powder neutron-diffraction studies of URhIn [11] failed to detect magnetic reflections down to 1.5 K., which might be due to small U magnetic moments $< 0.5\mu_{\text{B}}$ and/or a complex (probably incommensurate) antiferromagnetic ordering. A more fine work on single-crystals is desirable.

Concluding, both the susceptibility behaviour (θ_{p} values), and the high-field magnetization data reflect a development of the 5f-electron local-moment magnetism in UTX compounds ($T = \text{Rh, Pt, Pd}$) as a consequence of the gradually reduced 5f–d hybridization. This is consistent with overall trends in the family of UTX compounds [3] but in contradiction with suggestions presented in Ref. [7].

Acknowledgements: This work has been financially supported by the 'Stichting voor Fundamenteel Onderzoek der Materie' (FOM) and by the Grant Agency of The Czech Republic (project no. 93/202/0184).

References

- [1] V. Sechovský and L. Havela, in: *Ferromagnetic Materials*, Vol. 4, eds. E.P. Wohlfarth and K.H.J. Buschow (North-Holland, Amsterdam, 1988) pp. 309–491 and references therein.
- [2] V. Sechovský, L. Havela, F.R. de Boer, J.J.M. Franse, P.A. Veenhuizen, J. Šebek, J. Stehno and A.V. Andreev, *Physica B* 142 (1986) 283.
- [3] V. Sechovský, L. Havela, E. Brück, F.R. de Boer and A.V. Andreev, *Physica B* 163 (1990) 103.
- [4] T. Gasche, S. Auluck, M.S.S. Brooks and B. Johansson, *J. Appl. Phys.* 70 (1991) 6580; *J. Magn. Magn. Mater.* 104–107 (1992) 37.
- [5] V. Sechovský and L. Havela, *J. Magn. Magn. Mater.* 104–107 (1992) 7; *Physica Scripta T* 45 (1992) 99 and references therein.
- [6] E. Brück, F.R. de Boer, V. Sechovský and L. Havela, *Europhys. Lett.* 7 (1988) 177.
- [7] V.H. Tran and R. Troc, *J. Magn. Magn. Mater.* 88 (1990) 287.
- [8] E. Sugiura, K. Sugiyama, H. Kawanaka, T. Takabatake, H. Fujii and M. Date, *J. Magn. Magn. Mater.* 90&91 (1990) 65.
- [9] H. Nakotte, PhD Thesis, University of Amsterdam (1994) pp. 86–87.
- [10] L. Havela, V. Sechovský, H. Nakotte, E. Brück, P. Svoboda and F.R. de Boer, *Physics of Transition Metals*, Darmstadt, eds. P.M. Oppeneer and J. Kübler (World Scientific, 1992) p. 842.
- [11] A. Purwanto et al, to be published.