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Anisotropic f-electron magnetism in UNi_4B

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The hexagonal uranium compound UNi_4B has been shown to exhibit strongly anisotropic hybridization of f– and d–electron states. We performed low-field (3 mT) and high-field (40 T) magnetization measurements from 1.4 K to 30 K on a single crystal of this antiferromagnetically ordering compound, T_N=20 K, to further investigate the magnetic anisotropy. A phase diagram, including a spin-flop transition around 9 T, is presented. The observed large values of the electronic specific heat at low temperatures are attributed to in-plane magnetic fluctuations, which persist far below T_N. No superconductivity was found down to 40 mK. The relevance of strong $5f$–$3d$ hybridization is confirmed by extensive experiments on a series of diluted compounds $UCo_xNi_{4-x}B$ ($0 \leq x \leq 4$).

In previous papers [1,2] we demonstrated that the hexagonal intermetallic uranium compound UNi_4B, a member of the growing class of "1-5"–intermetallic compounds, exhibits highly anisotropic magnetic properties. AF ordering of U–spins lying in the basal plane occurs below T_N=20 K. However, both susceptibility and specific heat increase below T_N, which can be explained by the presence of strong in-plane magnetic fluctuations, persisting down to below 1 K [2]. In this contribution we show the importance of hybridization of the f and d–electron bands by alloying UNi_4B with Co on the Ni–sites. As both UCo_4B and UNi_4B crystallize in the same $CeCo_4B$–type structure, alloying is possible over the entire concentration range ($0 \leq x \leq 4$) in $UCo_xNi_{4-x}B$. In Table 1 we list the lattice parameters of this pseudo–ternary system, together with the observed AF ordering temperature. From these data, the different interatomic uranium distances can be derived: In the basal plane, $d_{U-U}=a$, while along the c-axis $d_{U-U} = \frac{1}{2}c$, yielding 4.952 Å and 3.477 Å for UNi_4B. In general, the magnetic moment will orient perpendicular to the direction of strongest f–f hybridization, i.e. in the basal plane.

In Fig.1 we present the magnetic susceptibility ($\chi \equiv M/H$) for polycrystalline material with x=1 and 2, together with low–field (3 mT) and high–field (0.5 T) data for single-crystal UNi_4B. While UNi_4B exhibits clear Curie-Weiss local–

Table 1: Lattice parameters and ordering temperatures of $UCo_xNi_{4-x}B$–compounds.

	a (Å)	c (Å)	V(Å^3)	T_N (K)
UCo_4B	4.895	6.933	143.88	–
UCo_3NiB	4.910	6.928	144.62	–
UCo_2Ni_2B	4.924	6.954	146.01	–
$UCoNi_3B$	4.931	6.964	146.64	5.0
UNi_4B	4.952	6.954	147.68	20.0

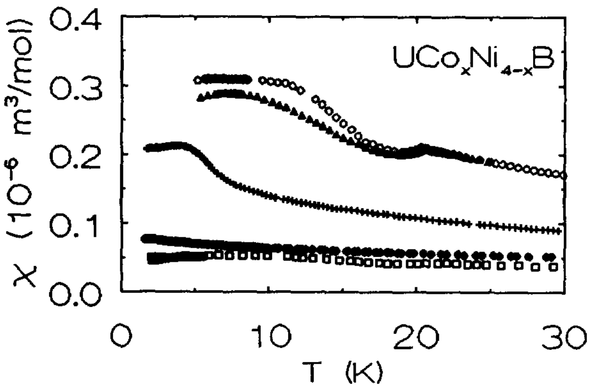

Figure 1: Susceptibility of $UCoNi_3B$ (+) and UCo_2Ni_2B (•) and single-crystal UNi_4B (Δ) with field parallel to the ab-plane and along the c-axis (□), all measured in $\mu_0 H$=0.5 T. Note the large anisotropy for UNi_4B and the saturation of $\chi \parallel ab$ in 3 mT (o) below 10 K.

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moment type behavior with p_{eff}=2.81 μ_B above 100 K (not shown), its uranium $5f$–derived moment is progressively lost upon increasing Co–concentration. This strongly suggests that the $5f$–electrons are filling the $3d$–band when Co is introduced in the system. As a result, the AF ordering temperature is strongly reduced, from T_N=20.0 K for UNi_4B to T_N=5.0 K for $UCoNi_3B$. The low–field magnetization of single-crystal UNi_4B, was measured with a SQUID magnetometer in fields of 3 mT and 0.5 T. See Fig.1. In the lowest fields, χ first increases below T_N, before it saturates below 10 K. A larger field suppresses these apparent basal–plane fluctuations, yielding a maximum around 7 K.

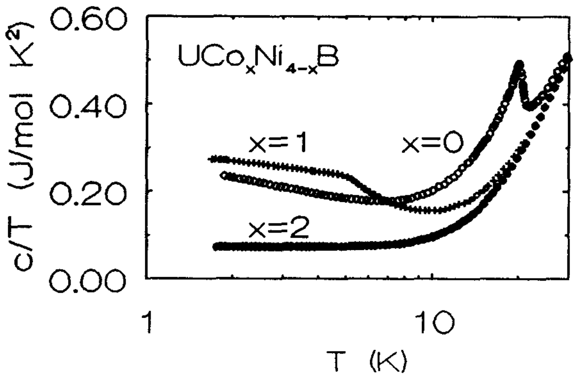

Figure 2: Specific heat of UNi_4B (o), $UCoNi_3B$ (+) and UCo_2Ni_2B (•) plotted as c/T on a logarithmic temperature scale.

The specific heat of these samples, plotted in Fig.2 on a logarithmic temperature scale, clearly shows the reduction of T_N with increasing Co–concentration. For pure UNi_4B, an increase of c/T is observed below 7 K, in accord with the susceptibility maximum. The increase in c/T, which is almost field–independent [2], follows a weak ln$T$–dependence, reminiscent of the formation of an unusual Fermi–liquid state [3,4]. An extension towards lower T is necessary to confirm this ln$T$–dependence. The extrapolated γ–values are 269 and 294 mJ/mol K^2 for UNi_4B and $UCoNi_3B$, respectively.

If we combine these new results with those obtained earlier [1,2], we can establish the magnetic phase diagram for UNi_4B. This diagram, shown in Fig.3, is a combination of high–field magnetization, specific heat and resistivity, both in magnetic fields, for two field directions in the basal plane. The AF phase boundary lies at 20 T. A spin–flop transitions is found for $\mu_0 H$=8 and 11 T for the two directions, respectively. The low-T regime for in-plane fluctuations is also indicated (shaded area in Fig.3).

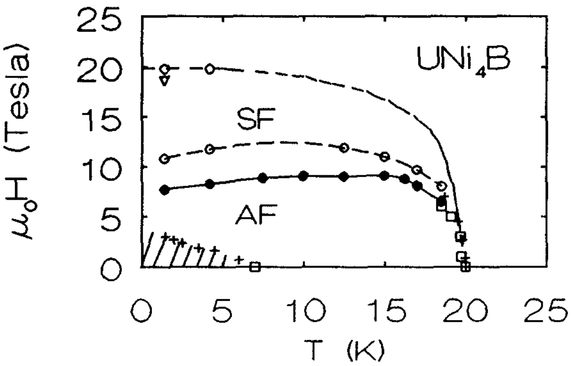

Figure 3: Magnetic phase diagram for UNi_4B with the magnetic field parallel to the basal plane. Lines are guides to the eye.

In conclusion, we have shown that the ordering temperature of $UCo_xNi_{4-x}B$ strongly depends on the $5f$–$3d$ hybridization strength. We have presented a detailed magnetic phase diagram for UNi_4B, which incorporates a highly unusual low temperature spin state, thought to arise from large in–plane fluctuations in the antiferromagnetically ordered state.

References

[1] J.A. Mydosh, G.J. Nieuwenhuys, S.A.M. Mentink, and A.A. Menovsky, Phil. Mag. B 65 (1992) 1343.

[2] S.A.M. Mentink, H. Nakotte, A. de Visser, A.A. Menovsky, G.J. Nieuwenhuys, and J.A. Mydosh, Physica B (1993), in press.

[3] H.R. Ott, E. Felder and A. Bernasconi, Physica B (1993), in press.

[4] P.D. Sacramento and P. Schlottmann, Phys. Lett. A 142 (1989) 245.