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Anisotropic f-electron magnetism in UNi₄B

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The hexagonal uranium compound UNi₄B 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 UCoₓNi₄₋ₓB (0 ≤ x ≤ 4).

In previous papers [1,2] we demonstrated that the hexagonal intermetallic uranium compound UNi₄B, 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 UNi₄B with Co on the Ni-sites. As both UCo₄B and UNi₄B crystallize in the same CeCo₄B-type structure, alloying is possible over the entire concentration range (0 ≤ x ≤ 4) in UCoₓNi₄₋ₓB. 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 UNi₄B. 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 ($\chi=M/H$) for polycrystalline material with $x=1$ and 2, together with low-field (3 mT) and high-field (0.5 T) data for single-crystal UNi₄B. While UNi₄B exhibits clear Curie-Weiss local-

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moment type behavior with $p_{eff}=2.81 \mu_B$ 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$_4$B to $T_N=5.0$ K for UCoNi$_3$B. The low-field magnetization of single-crystal UNi$_4$B, was measured with a SQUID magnetometer in fields of 3 mT and 0.5 T. See Fig.1. In the lowest fields, $\chi$ 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.

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$_4$B, 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 $\gamma$–values are 269 and 294 mJ/mol K$^2$ for UNi$_4$B and UCoNi$_3$B, respectively.

If we combine these new results with those obtained earlier [1,2], we can establish the magnetic phase diagram for UNi$_4$B. 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).

In conclusion, we have shown that the ordering temperature of UCo$_x$Ni$_{4-x}$B strongly depends on the 5f–3d hybridization strength. We have presented a detailed magnetic phase diagram for UNi$_4$B, which incorporates a highly unusual low temperature spin state, thought to arise from large in-plane fluctuations in the antiferromagnetically ordered state.

References