Interplay between Magnetic Order and Non-Fermi Liquid Behavior in U_2Co_2In Hydride

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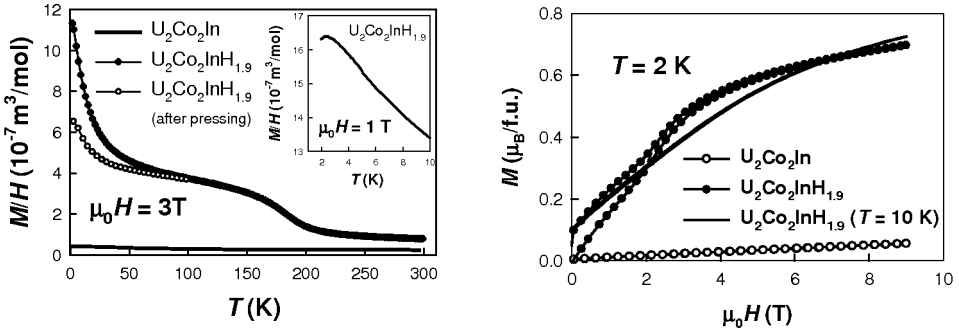
It has been shown that properties U_2T_2X (T – transition metal, X – Sn, In) compounds, crystallizing with tetragonal Mo_2FeB_2 structure type (space group *P4/mbm*), can be tuned by interstitial H doping. For example, non-magnetic U_2Co_2Sn, which is known as non-Fermi liquid system with spin-fluctuation features, orders magnetically after hydrogenation [1]. Moreover, the type of magnetic order depends on the amount of hydrogen absorbed. Whereas hydride with small content of hydrogen (<0.1 H/f.u.) is ferromagnetic, further hydrogenation leads to the onset of antiferromagnetic order, typical for other magnetically ordered non-hydrogenated U_2T_2X compounds. U_2Co_2In is another non-magnetic representative of the U_2T_2X series. Therefore we were particularly interested in the impact of hydrogenation on the magnetic properties of this compound.

We already reported the formation of the $U_2Co_2InH_{1.9}$ hydride [2,3]. The hydrogenation results in the lattice expansion by 8.4% without changing the metallic atoms arrangement. Such hydrogenation leads to a pronounced enhancement of magnetism. Weakly paramagnetic U_2Co_2In turns to the Curie-Weiss behaviour ($\mu_{eff} = 1.6\ \mu_B$/U) after hydrogenation. A maximum of magnetic susceptibility found at $T = 2.4$ K (Fig. 1*A* - inset) could be attributed either to antiferromagnetic ordering or to spin-fluctuations. Magnetization curve at $T = 2$ K showed the shape typical for antiferromagnet with a metamagnetic transition at 2 T (Fig. 1*b*). The metamagnetic transition is shifted to the higher fields with the temperature increase, what may indicate, besides a band metamagnetism, a complicated character of its magnetic phase diagram, possibly with several magnetically ordered phases.



(*a*) (*b*)

Fig. 1 (*a*) Temperature dependences of the magnetic susceptibility of U_2Co_2In and $U_2Co_2InH_{1.9}$ measured in the magnetic field $\mu_0H = 3$ T. The magnetic susceptibility of the hydride sample after pressing is shown by open circles. The anomaly at $T = 180$ K can be attributed to a small amount of UH_3. The inset shows the low-temperature measurements in $\mu_0H = 1$ T. (*b*) Magnetization curves of U_2Co_2In and $U_2Co_2InH_{1.9}$ measured at $T = 2$ K. The solid line shows magnetization curve of $U_2Co_2InH_{1.9}$ measured at $T = 10$ K.

However, the specific heat, studied (after a delay of several weeks) on a pellet obtained by pressing in a hydraulic press, did not exhibit any anomaly related to the susceptibility maximum at $T = 2.4$ K. Instead, a pronounced upturn in the specific heat in the C_p/T representation appears at low temperatures indicating on a heavy fermion behavior of the studied hydride (Fig. 2). This feature strongly resembles the one already observed for U_2Co_2Sn [4] and, similar to U_2Co_2Sn, it is also suppressed by external magnetic field. The curve can be well described assuming the $1-T^{1/2}$ scaling, predicted for weakly interacting spin fluctuations. The extrapolated γ-value reaches 244 mJ/mol K^2.

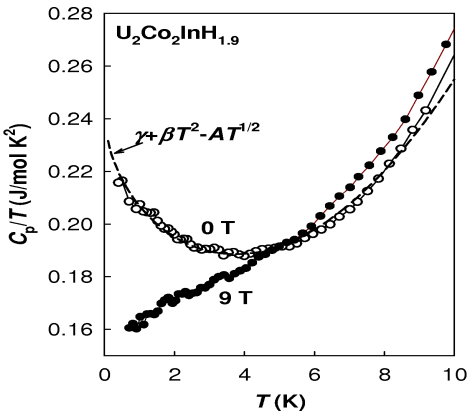


Fig. 2. Low-temperature part of the specific heat in the C_p/T representation of $U_2Co_2InH_{1.9}$ measured in $\mu_0 H = 0$ T (empty dots) and 9 T (full dots).

The situation became more puzzling after the measurement of magnetic susceptibility of the pressed hydride sample, used before for the specific-heat measurement. We registered a suppression of the susceptibility values, and no anomaly at $T = 2.4$ K showed up (Fig. 1*a*). Moreover, the XRD pattern indicated a reduction ($\Delta V/V = 0.9\%$) of the lattice parameters proving, that the stoichiometry of the hydride changed. The reason can be a partial hydrogen release due to aging (experiments over several months) or due to the pressing procedure.

To clarify the ambiguous behaviour of the U_2Co_2In hydride, another synthesis was performed under the same conditions ($P_{H2} = 100$ bar, $T = 650^{\circ}$C). We succeeded to obtain reproducibly the $U_2Co_2InH_{1.9}$ hydride ($\Delta V/V = 8.5\%$). In order to perform specific heat measurements, the powder was compacted into a thin pellet, 3 mm in diameter, using a hydraulic press and an anvil cell with WC faces, reaching 700 MPa. The X-ray diffraction analyses of the pressed sample revealed the co-existence of at least two hydride phases with relative volume expansion 7.9% and 5.1%. The specific heat studies are currently in progress.

Although the U_2Co_2In–H study has not been yet concluded, the diversity of behaviour reflects the fact that small variations of the hydrogen content result in dramatic impact on magnetism in the critical region at the onset of magnetism.

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