High-field metamagnetism in UCo_2Si_2

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UCo_2Si_2 belongs to a wide group of UT_2X_2 compounds, where T is a late *d* metal and X is Si or Ge. They exhibit a large variety of magnetic states starting from antiferromagnetic (AF) ordering for UCr_2Si_2, ferrimagnetic (UNi_2Si_2) and ferromagnetic (F) structures (UCu_2Si_2) through Pauli paramagnets (UFe_2Si_2) to compounds, which become superconducting inside an AF state (URu_2Si_2) [1-3]. UCo_2Si_2 has a tetragonal $ThCr_2Si_2$ crystal structure and orders AF below T_N = 83-85 K. The magnetic structure (from powder neutron diffraction) consists of F basal-plane layers of U moments of M_U = 1.42 μ_B oriented parallel to the *c* axis, which are coupled in a simple sequence +–+– (AF type-I structure) in the same direction [2]. Magnetic moment is carried only by U atoms.

UNi_2Si_2 exhibits in addition to the AF type I structure, a ferrimagnetic and an incommensurate AF phase. In the ground state, it exhibits ++– sequence with longitudinally modulated amplitude of the magnetic moment resulting in a spontaneous moment of 0.53 μ_B, 1/3 of M_U [4]. The ++– phase is also observed at high magnetic fields in UPd_2Si_2 (with an AF type-I structure in zero field) [5]. It was interesting to check whether UCo_2Si_2 exhibits this phase at high magnetic fields as well. In this work we indeed observed such transition.

The investigated single crystal was grown by Czochralski method in a tri-arc furnace. The x-ray powder-diffraction analysis confirmed the tetragonal body-centered $ThCr_2Si_2$-type crystal structure with lattice parameters *a* = 392.1 pm, and *c* = 963.9 pm in agreement with literature. The x-ray Laue patterns showed the high quality of the crystal. The magnetization curves were measured in pulsed fields up to 60 T applied along the *c* and *a* axes using a non-destructive pulsed magnet with pulse duration of 25 ms. The magnetization signal was detected by integrating the voltage induced in a pick-up coil surrounding the sample. The absolute values of the magnetization were calibrated from steady-field measurements up to 14 Tesla.

For the fields applied along the *c* axis, the metamagnetic transition is observed at the critical field $\mu_0 H_{cr}$ = 45 T (Fig. 1). It is very sharp but has a small hysteresis ($\mu_0 \Delta H_{cr}$ = 0.16 T). The analogous transition in UPd_2Si_2 shows huge hysteresis of more then 15 T [5]. The transition in UCo_2Si_2 is characterized by a magnetization jump of ΔM = 0.52 μ_B. ΔM roughly corresponds to 1/3 of M_U = 1.42 μ_B [2]. Therefore, we can suppose that the high-field state is ferrimagnetic with the ++– arrangement along the *c* direction. At much higher fields another transition to a fully polarized state can be expected. The magnetization curve measured along the *a* axis shows no transition and is linear up to the highest fields. The *a*-axis susceptibility of 3.7×10^{-3} μ_B/T per U atom is a typical value for the hard-axis magnetization of U intermetallic compounds independent of crystal structure and type of magnetic ground state and reflects mostly the Pauli paramagnetism of the conduction electrons [1].

The transition for H || *c* is still very sharp at 20 K. At higher temperatures, it becomes considerably wider and might loose the first-order character above 80 K (Fig. 2). The transition field $\mu_0 H_{cr}$ determined as maximum in the derivative *dM/dH* (Fig. 3) decreases with increasing temperature. At 80 K the small maximum at 21 T in *dM/dH* still indicates the metamagnetic transition.

ΔM, H_{cr}, and ΔH_{cr} decrease monotonously with increasing temperature and vanish at T_N. In the *H-T* phase diagram of UCo_2Si_2 in fields applied along the *c* axis (Fig. 4), the diamonds correspond to $T_N(H)$ taken from Ref. 3.

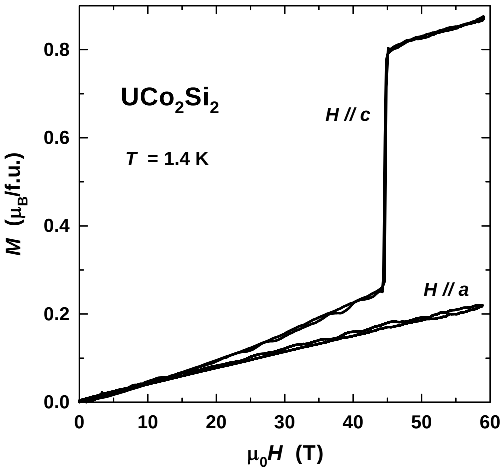

Fig. 1. Magnetization curves measured along the principal axes at 1.4 K.

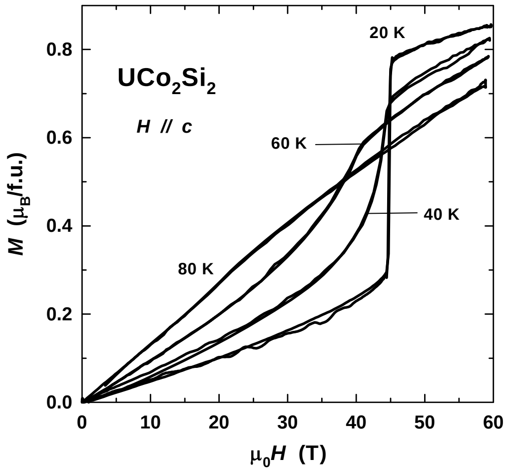

Fig. 2. Magnetization curves measured along the *c* axis at different temperatures.

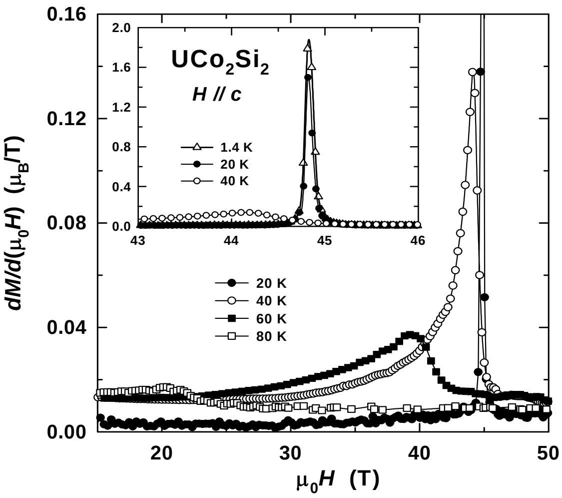

Fig. 3. Field dependence of the differential susceptibility *dM/dH* measured along the *c* axis at different temperatures.

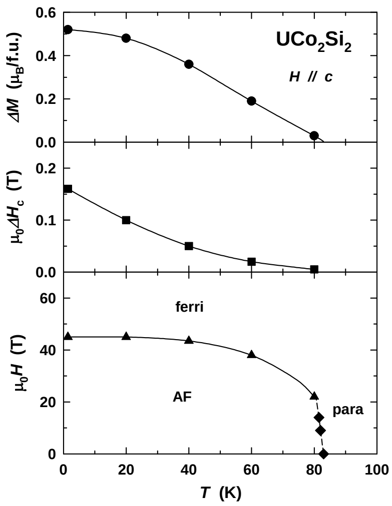

Fig. 4. Temperature dependence of the magnetization gain ΔM at the transition, the width of hysteresis $\mu_0\Delta H_{cr}$ and *H-T* phase diagram of UCo_2Si_2 in fields applied along the *c* axis.

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