Magnetoresistance and Metamagnetic Transitions in UPdIn

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Letter to the Editor

Magnetoresistance and metamagnetic transitions in UPdIn

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The electrical resistivity of a single-crystalline whisker of UPdIn at 4.2 K was measured in magnetic fields up to 35 T applied along the *c*-axis of the hexagonal structure. The resistivity values become drastically suppressed in magnetic fields where the metamagnetic transitions appear on the magnetization curve. Taking into account these results, Fermi surface nesting due to the noncompensated antiferromagnetic structure with the propagation vector along the *c*-axis is suggested to be a source of the large values of the electrical resistivity in zero magnetic field.

UPdIn is one of the UTX compounds (T = transition metal, X = p-metal) which are characterized by the hexagonal ZrNiAl-type [1]. Magnetic and specific-heat measurements [2, 3] on UPdIn revealed magnetic phase transitions at 20.4 and 8.5 K. The C/T value reaches 280 mJ/mol K^2 at 1.3 K. Between 8.5 and 20.4 K an antiferromagnetic ordering is observed, whereas a spontaneous magnetic moment of $0.3\mu_B$/f.u. appears at temperatures below 8.5 K. Above 20.4 K, UPdIn is paramagnetic. The magnetization shows a strong uniaxial anisotropy. The magnetization curve measured at 4.2 K for the magnetic field applied along the *c*-axis exhibits two metamagnetic transitions at about 3 and 16 T, yielding an increase of the magnetization of $0.5\mu_B$/f.u. and $1.5\mu_B$/f.u., respectively. When the magnetic field is applied perpendicular to the *c*-axis, the magnetization increases linearly to a value of $0.5\mu_B$/f.u. in a field of 35 T.

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Neutron-diffraction study [4] showed a collinear magnetic structure consisting of equal uranium moments of $1.5\mu_B$ at temperatures below 8.5 K. In this structure the moments are ferromagnetically coupled within the basal-plane layers and oriented along the *c*-axis, whereas a sequence + − + + − along *c* explains the observed spontaneous magnetization of $0.3\mu_B$ ($\frac{1}{5}M_s$). Above 8.5 K, the moments are sinusoidally modulated along the *c*-axis with the propagation vector $\boldsymbol{k} = (0, 0, 0.4)$.

The anisotropy of the magnetic properties of UPdIn is accompanied by an anisotropy of the electrical resistivity. Figure 1 displays the temperature dependences of the electrical resistivity measured on a polycrystal and on a single-crystalline whisker with *i* along the *c*-axis. The latter curve corresponds well to bulk-single-crystal measurements [3]. A comparison with the *a*-axis resistance [3] shows that the $\rho(T)$ curves for the electrical current along the *a*- and *c*-axis are almost identical in the high-temperature range ($T > 50$ K). Around 50 K, they pass a minimum. Below this temperature, the resistance for *i*

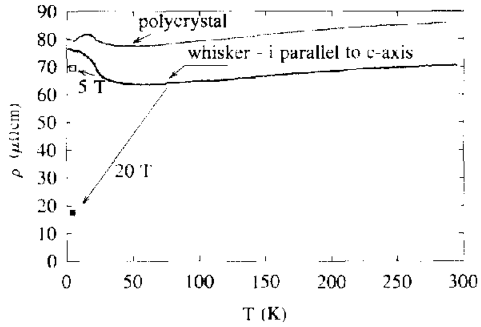

Fig. 1. Temperature dependence of the electrical resistivity of a UPdIn polycrystal and a single-crystalline whisker with i along the c-axis. The two additional points indicate the value to which the resistance of the whisker drops in applied fields above the two metamagnetic transitions.

along c increases considerably and tends to saturation at 4.2 K. The resistance for i along the a-axis is more regular. It decreases rapidly below 20 K.

The motivation for the present magnetoresistance measurements was to study the origin of the anomalous behaviour of the c-axis resistance at low temperatures. We have measured the field dependence of the resistance at 4.2 K on the whisker used in ref. [2]. The field was oriented along the long axis of the whisker, i.e. along the c-axis. We have used quasistatic fields with a typical constant-field duration of 200 ms available in the High-Field Installation of the University of Amsterdam.

The observed field dependence of the relative resistance $\rho(B)/\rho(0\,\mathrm{T})$ is shown in fig. 2. It displays two distinctive drops, one around $B = 3\,\mathrm{T}$, the other at approximately 16 T. These drops can be associated with the metamagnetic transitions found in the $M(B)$ curve. The first one corresponds to the transition from the $+\ -\ +\ +\ -$ phase to a phase with $M = \frac{1}{3}M_s$ (presumably $+\ +\ -$) and the other to a full ferromagnetic-like alignment. Besides these anomalies, there is only a very weak background decrease of the resistance with increasing field. The low-field transition has a noticeable hysteresis and $\rho(B)$ in this region is rather time dependent in a constant field (see fig. 3). This time dependence can be described as an exponential relaxation behaviour

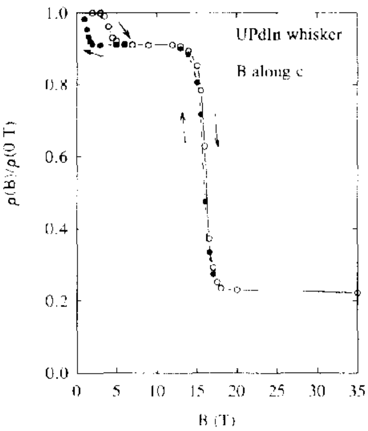

Fig. 2. Field dependence of the relative resistance of the whisker for B parallel to the c-axis. The open circles represent data obtained with increasing field, the full circles correspond to decreasing field. In reality, the latter data have been taken after a preceding 8 or 20 T pulse.

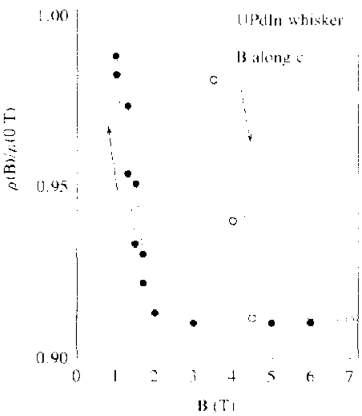

Fig. 3. Low-field detail of the fig. 2 comprising a full and dashed line, which corresponds to data taken 200 ms after the beginning of the field pulse. The dotted lines represent the asymptotic values obtained by extrapolations to $t \rightarrow \infty$ using exponential fits.

with relaxation times of the order of 100 ms. This observation is consistent with the relation between the width of the hysteresis loop and the field sweeping rate in magnetization measurements [4]. The high-field transition is practically without hysteresis. This different behaviour was ascribed to a more complicated moment rearrangement at the lower transition [4].

In fig. 1, where the resistivity values at 4.2 K in higher fields are included, we can see that the low-field transition only partly removes the upturn in $\rho(T)$, whereas the high-field transition depresses the resistivity far below its high-temperature values.

Because the ground-state uranium magnetic moments correlate well with the magnetization in fields above the transition, the magnetoresistance cannot be related to intra-ionic effects like local spin fluctuations or the Kondo effect, but it must be related to the antiferromagnetic order itself. One possible explanation is connected with the destruction of a gap across a portion of the Fermi surface existing for k_c. Such a gap can be formed due to a new periodicity of the AF state [5] and thus it can be removed by suppressing the AF correlations. The magnitude of the magnetoresistance effect (drop by 60 μΩcm, i.e. nearly 80%) at 4.2 K is similar to what was found in UNiGa, which has a comparable magnetic structure [6].

Similar to the case of UNiGa, we observe in UPdIn the negative $d\rho/dT$ already well above the ordering temperature, which was proved to be an effect related to AF correlations above T_N [7]. Thus, we can conclude that the increasing c-axis resistivity in UPdIn with decreasing temperature below 50 K can be understood as being due to antiferromagnetic correlations along the c-axis. Finally, the present results demonstrate that the low-temperature resistance limit does not need to be a good indication of the crystal quality in certain magnetic systems.

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