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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/molK² at 1.3 K. Between 8.5 and 20.4 K an antiferromagnetic ordering is observed, whereas a spontaneous magnetic moment of 0.3μₜ/μ.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 0.5μₜ/μ.u. and 1.5μₜ/μ.u., respectively. When the magnetic field is applied perpendicular to the c-axis, the magnetization increases linearly to a value of 0.5μₜ/μ.u. in a field of 35 T.

Neutron-diffraction study [4] showed a collinear magnetic structure consisting of equal uranium moments of 1.5μₜ 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 0.3μₜ (½Μₛ). Above 8.5 K, the moments are sinusoidally modulated along the c-axis with the propagation vector 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 ρ(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...
The temperature dependence of the electrical resistivity of a UPdIn polycrystal and a single-crystalline whisker with $i$ along the $c$-axis is shown in fig. 1. The two additional points indicate the value to which the resistance of the whisker drops in applied fields above the two metamagnetic transitions.

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 $\rho(B)/\rho(0T)$ is shown in fig. 2. It displays two distinctive drops, one around $B = 3T$, 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 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 re-
arrangement 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 up-
turn 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 magnetoresis-
tance cannot be related to intra-ionic effects like
delayed 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 $k_{\parallel}$. Such a gap can
be formed due to a new periodicity of the AF
state [5] and thus it can be removed by suppres-
sing the AF correlations. The magnitude of the
magnetoresistance effect (drop by 60 $\mu$Ωcm, i.e.
early 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 tem-
perature 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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