Electrical transport properties of single crystalline $U_2Cu_4As_5$

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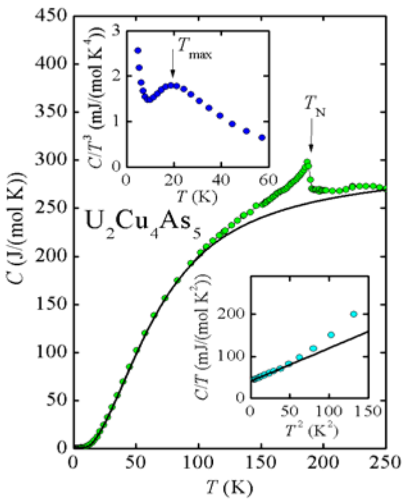

Fig. 1. Specific heat of single-crystalline $U_2Cu_4As_5$. The solid line is the phonon contribution. Upper inset: C/T^3 vs. T. Lower inset: C/T vs T^2.

The ternary uranium arsenide $U_2Cu_4As_5$ crystallizes with a body-centred tetragonal structure of its own type (space group I4/mmm, lattice parameters: $a = 3.990$ Å, $b = 24.299$ Å) [1]. Magnetic susceptibility measurements revealed that the compound orders antiferromagnetically at $T_N = 189$ K [1]. The onset of the ordered state is accompanied by a rapid drop in the electrical resistivity [1]. Here, we report on the results of our recent specific heat, electrical resistivity, magnetoresistivity and Hall coefficient measurements, performed in wide ranges of temperature and magnetic field on high-quality single crystals of $U_2Cu_4As_5$ grown by chemical vapour transport method.

The antiferromagnetic phase transition at $T_N = 189$ K manifests itself as a distinct λ-shaped anomaly in the temperature dependence of the specific heat (Fig. 1). As can be inferred from the lower inset to Fig. 1, below about 7 K, $C(T)$ follows the Debye formula $C/T = \gamma + 1944r\times\Theta_D^{-3}T^2$ (r is the number of atoms in the formula unit) with the Debye temperature $\Theta_D \approx 300$ K and the Sommerfeld coefficient $\gamma = 41.4$ mJ/(molK^2). The value of γ yields an estimate of the effective electron mass in $U_2Cu_4As_5$ to be about $7m_0$, where m_0 is the free electron mass (here the carrier concentration $n = 4 \times 10^{27}$ e$^-$/m^3 was assumed, as derived from the Hall effect data; see below). The C/T^3 curve (see the upper inset to Fig. 1) exhibits a maximum at about 20 K, which might be due to some change in the effective dimensionality of the system.

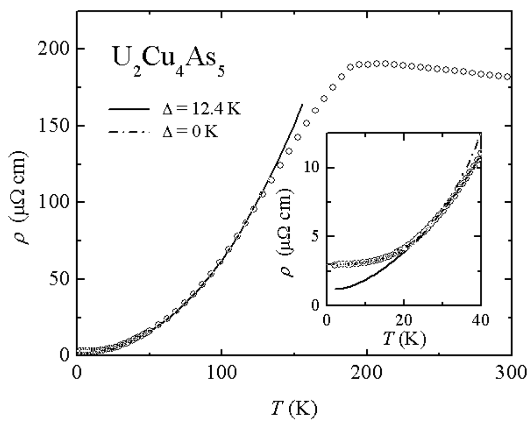

Fig. 2. Electrical resistivity of single-crystalline $U_2Cu_4As_5$ measured with $j \perp c$-axis. Inset: low-temperature data. The solid and dashed lines are the fits discussed in the text.

The electrical resistivity of $U_2Cu_4As_5$ increases upon decreasing temperature down to the Nèel temperature, in a manner characteristic of Kondo systems (Fig. 2). Below T_N, $\rho(T)$ is dominated by scattering the conduction electrons on antiferromagnetic spin-wave excitations. In the temperature range 20–120 K, it can be well described by the appropriate formula [2]: $\rho = \rho_0 + b\Delta^2(T/\Delta)^{1/2}e^{\Delta/T}[1+2/3(T/\Delta)+ 2/15(T/\Delta)^2]$

, with the residual resistivity ρ_0 = 1.2 μΩcm, the energy gap in the magnon spectrum Δ = 12.4 K and the proportionality coefficient b = 0.01 μΩ cm/K^2. Surprisingly, below about 20 K, the electrical resistivity evolves as T^3 (see the inset to Fig. 2), i.e. without any spin-wave gap in the magnon spectrum. This remarkable change in the behaviour of ρ(T) appears at the same temperature as the maximum in C/T^3 (T).

The temperature variation of the Hall coefficient in $U_2Cu_4As_5$ is characteristic of magnetically ordered materials (Fig. 3). Above about 200 K, $R_H(T)$ can be described by the formula $R_H = R_{H0} + R_{Hs}(\mu M/B)$, where $(\mu M/B)$ is the magnetic susceptibility, R_{H0} represents the normal Hall coefficient resulting from Lorenz motion of charge carriers, and R_{Hs} is the anomalous contribution due to scattering the conduction electrons on localized magnetic moments. Least-squares fitting procedure yielded $R_{H0} = -1.6 \times 10^{-9}$ m^3/C [corresponding to the carrier concentration $n = 4 \times 10^{27}$ e$^-$/m^3 (1.56 e$^-$/f.u.)] and $R_{Hs} = 6 \times 10^{-6}$ m^3/C. The antiferromagnetic phase transition manifests itself as a pronounced peak in R_H that moves towards lower temperatures with increasing B. In a field of 9 T this peak evolves into a broad hump and the magnitude of R_H is considerably reduced.

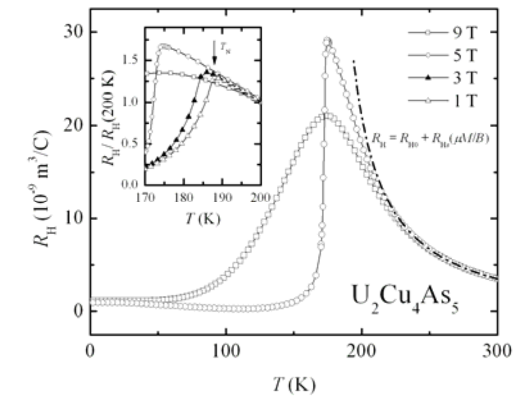

Fig. 3. Hall coefficient of single-crystalline $U_2Cu_4As_5$ measured with $j \perp c$-axis and B = 5 and 9 T applied along the c-axis. The dashed line is the fit discussed in the text. Inset: magnetic field variation of the peak at T_N.

In the ordered region, the Hall resistivity $\rho_H = R_H B$ of $U_2Cu_4As_5$ exhibits distinct jumps at a critical field B_c that decreases with increasing the temperature (Fig. 4a). This behaviour is accompanied by clear anomalies at B_c in the transverse magnetoresistance of the compound (Fig. 4b), and coincides with metamagnetic-like transitions observed in the field dependencies of the magnetization (see the inset to Fig. 4a). The $\rho_H(B)$ and MR(B) data yield the magnetic phase diagram of $U_2Cu_4As_5$ displayed in the inset to Fig. 4b. Below 20 K, some anomalous behaviour is observed that might be related to the low-temperature features in $C(T)$ and $\rho(T)$.

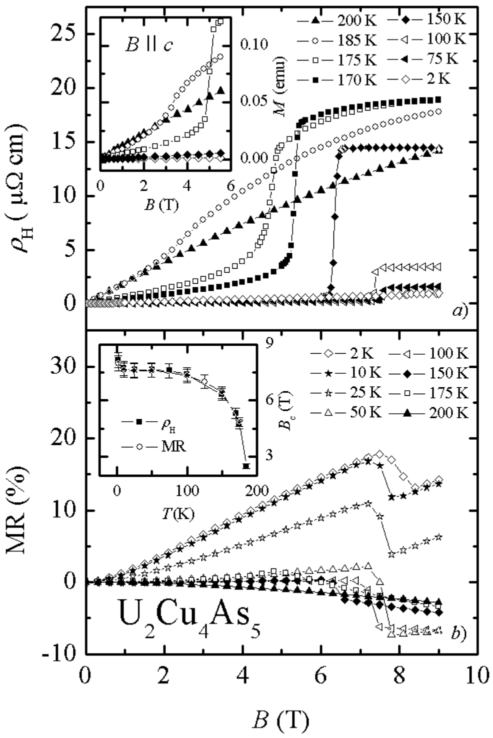

Fig. 4. Hall resistivity and magnetoresistance isotherms of single-crystalline $U_2Cu_4As_5$ measured with $j \perp c$-axis and $B \parallel c$-axis. Upper inset: corresponding magnetization isotherms. Lower inset: B-T phase diagram.

References

[1] D. Kaczorowski et al., *J. Less-Common Metals,* **170**, 255 (1991).
[2] M.B. Fontes et al., *Phys. Rev. B* **60**, 6781 (1999).