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HALL EFFECT AND MAGNETORESISTANCE IN THE HEAVY-ELECTRON COMPOUND UCu$_5$ AT AMBIENT PRESSURE AND 1 GPa

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Magnetoresistance and Hall effect measurements on a polycrystalline sample of UCu$_5$ have been made in magnetic fields up to 20 T and at temperatures as low as 0 3 K The results give evidence for a magnetic field induced high resistive state and a magnetic transition in high fields

In recent work UCu$_5$ was characterized as a magnetically ordered heavy electron compound, that undergoes a phase transition at about 1 K to a sofar unidentified state [1] Neutron diffraction measurements showed an antiferromagnetic phase transition at 15 K [2]

Here we present preliminary results of Hall effect and magnetoresistance measurements obtained with the van der Pauw technique on a square shaped polycrystalline sample of 0 5 mm thickness and 3 mm length We used fields up to 20 T and temperatures as low as 0 3 K The pressure of 1 GPa was obtained in a miniature pressure cell using a mixture of isoamyl and pentane as pressure media

Fig 1 shows the temperature dependence of the resistivity for the two different pressures In the virgin curves, i e cooling in zero magnetic field, we do not observe a resistance jump at about 1 K as reported by Ott et al [1] Instead our results seem to indicate a flat residual resistance of about 95 μΩ cm at ambient pressure and of 80 μΩ cm at 1 GPa Below 1 K at ambient pressure and below 0 75 K at 1 GPa a magnetic field induced state with a largely enhanced resistance can be maintained after a magnetic field cycle Fig 2 displays typical hysteresis curves of the magnetoresistivity at ambient pressure and for temperatures of 0 35 and 1 8 K Beginning with the virgin value of 95 μΩ cm we observe at 0 35 K with increasing field a rise in magnetoresistance by about a factor of 3 between 4 and 8 T At higher fields the resistance decreases slowly with increasing field Between 9 and 20 T the variation of the resistivity of our sample is reversible At lower fields we observe large hysteretic effects The value in zero field is about 3 times larger than the virgin value Within a new field cycle the resistance decreases slowly with increasing field for fields below 4 T Between 4

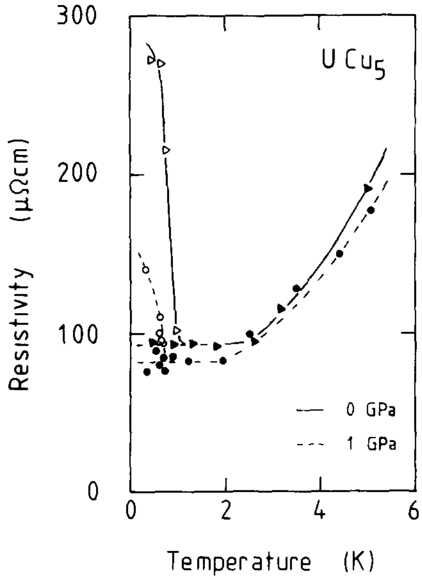

Fig 1 Resistivity versus temperature at ambient pressure and 1 GPa The very high values of the resistivity below 1 K (open symbols) are observed only after driving the sample through its metamagnetic transition The virgin data points (closed symbols) are obtained after heating the sample above 1 K in zero field

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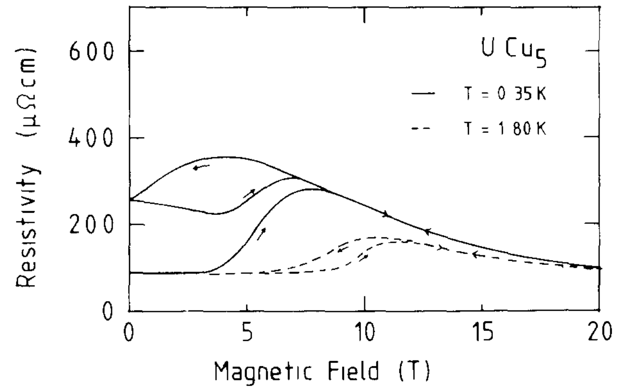

Fig. 2. Virgin and hysteretic behaviour of the magnetoresistivity at ambient pressure and for temperatures of 0.35 and 1.8 K.

and 8 T a rise in resistance similar to that in the virgin curve is observed. In order to obtain a hysteretic behaviour on a virgin sample one has to rise the field up to the onset of the magnetoresistance that is 4 T at 0.35 K.

The curve for 1.8 K shows a reversible magnetoresistance for fields below 5 T, a hysteretic transition with a resistance rise of about 50% between 5 and 12 T, and a slow reversible decrease in high fields. In comparison with the 0.35 K curve the size of the anomaly is largely reduced and the field induced persistent resistance increase has disappeared. For temperatures above 1 K our results are similar to those found by Batlogg et al. [3]. But in contrast for temperatures below 1 K their sample shows only negative magnetoresistance. This large difference found at temperatures below 1 K indicate different intrinsic sample properties and cannot be ascribed to a different demagnetization factor.

In ref. [1] it was proposed that the high resistive state is a consequence of changes of the Fermi surface due to the formation of a CDW- or SDW-gap which according to our results is magnetic field induced. Since the resistivity is nearly constant below 3 K and rather high, it is dominated by imperfections. Changes of the resistivity are then due to changes in the carrier concentration. Along a theory of Bilbro and McMillan [4] the fraction of the Fermi surface which is not gapped is given by

$$n = R_{\mathrm{virgin}}(T)/R(T)$$

This means, that at 0.5 K and at ambient pressure 63% and at 1 GPa 45% of the Fermi surface are gapped. With a hydrostatic pressure of 1 GPa the field induced state is largely suppressed and the critical temperature decreases from 1 to 0.75 K. In this sense UCu_5 behaves like a Chevrel-phase compound [5].

Fig. 3 displays the Hall resistance at ambient pressure for different temperatures as function of the magnetic field. The Hall constant, defined as the slope of the Hall voltage in the limit $B \rightarrow 0$, is positive and has for $T < 5$ K and with increasing field a value of about 10^{-3} $\mathrm{cm^3/Cb}$. With increasing temperature the Hall constant increases until at 15 K a maximum of about 1.2×10^{-2} $\mathrm{cm^3/Cb}$ is reached. This maximum is due to the antiferromagnetic ordering. The positive and even at low temperatures rather high value can be attributed to a large anomalous Hall effect due to skew scattering [6]. At temperatures below 6 K the Hall resistance shows a rather marked hysteretic jump at fields which correspond to the increase in the magnetoresistance. Below 5 K the height of the jump is roughly temperature independent and would in a single band model correspond to a reduction of the carrier concentration by a factor of about 8. The initial slope of

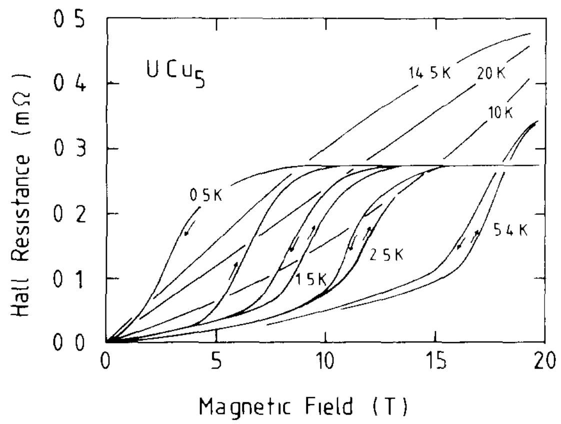

Fig. 3. Hall resistance at ambient pressure for temperatures between 0.5 and 20 K in magnetic fields up to 20 T.

the Hall resistance in increasing and decreasing field differ from each other At ambient pressure this difference disappears above 0 9 K and at 1 GPa above 0 7 K This result is consistent with the interpretation of the resistivity curves by a partial gapping of the Fermi surface below 1 K due to CDW- or SDW-formation and a corresponding reduction in carrier concentration

In general the Hall resistance depends on the scattering mechanism and the structure of the Fermi surface Accordingly the jump in the Hall resistance can be caused by a change of the scattering mechanism due to a change in the magnetic structure or (and) by a change of the Fermi surface due to partial gapping and decrease of the carrier concentration

The maximum in the magnetoresistance disappears in contrast to the behaviour of the Hall resistance rapidly with temperature Furthermore in the non-virgin curve of the magnetoresistance at 0 35 K the hysteresis is observed This suggests, that at a critical field a change in the magnetic structure and accordingly a change in the skew-scattering occurs This transition may be accompanied by a Fermi surface instability giving raise to the high resistivity, which for $T > 1$ K disappears rapidly but persists for $T < 1$ K even in zero field

Fig 4 shows the magnetic phase diagram as deduced from the jump in the Hall resistance with increasing field For fields below the indicated critical field UCu_5 is antiferromagnetic For $T \rightarrow 0$ there seems to be in contrast to Batlogg et al [2] a finite critical field of about 5 T The field induced state shows up in a strong increase of the width of the hysteresis in the Hall effect below 1 K A pressure of 1 GPa affects this phase diagram only weakly

Susceptibility and magnetization measurements are in progress to clarify the nature of the metamagnetic transition

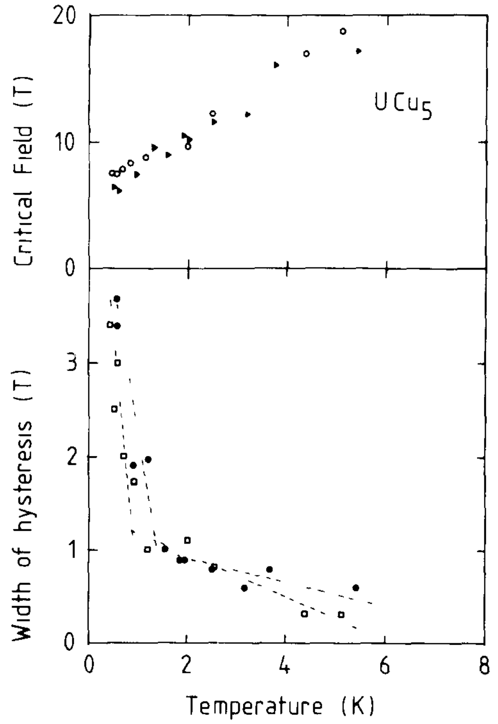

Fig 4 Width of the hysteresis in the Hall effect as a function of temperature (lower part) Upper critical field defined as the midpoint of the jump of the Hall resistance in increasing field as function of temperature (upper part) Closed symbols ambient pressure, open symbols 1 GPa

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