Pressure and Magnetic Field Effects in Heavy-Fermion $UCu_{3.5}Al_{1.5}$

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Introduction

Uranium compounds exhibit a wide range of interesting electronic properties, such as itinerant or localized magnetic moment, spin fluctuations, heavy-fermion behavior, non-Fermi liquid scaling, unconventional superconductivity and complex short-range or long-range magnetic correlations [1]. $UCu_{3.5}Al_{1.5}$ crystallizes in the hexagonal $CaCu_5$ structure and is described as a heavy fermion, which shows non-Fermi liquid behavior at low temperatures [2]. Considering the magnetism in these compounds, one must take into account the strong mixing of the 5*f* electrons with their own conduction-electrons as well as the hybridization of the 5*f* electrons with the electron states of the ligands. Increase of 5*f*-ligand hybridization increases the exchange coupling, but strong hybridization ultimately 'washes out' independent magnetic moments. Hydrostatic pressure will decrease the interatomic distances and hybridization effects can be expected to increase as the atoms are pushed closer together.

Experimental

Our experiments were performed on a $UCu_{3.5}Al_{1.5}$ polycrystalline sample, which was extracted from the same batch we used in the previous studies [2]. Using the 20-T superconducting magnet at the Pulse Field Facility, NHMFL, Los Alamos National Laboratory, the electrical resistance of the sample under hydrostatic pressure up to 10 kbar was measured in magnetic field up to 18 T. Magnetization measurements were performed using the VSM at the 14T superconducting magnet at the Pulse Field Facility, NHMFL, Los Alamos National Laboratory.

Results and Discussion

At ambient pressure and in zero field, the electrical resistivity shows an anomaly at about T_1 = 19 K and then it goes through a maximum around T_{max} = 12 K. These two anomalies were also observed in the susceptibility data. The anomaly in the electrical resistivity at T_1 goes to lower values with increasing fields and disappear at fields above 12 T. T_{max} on the other hand goes to higher values with increasing fields. Similar resistivity behaviors were also observed under 10 kbar (see Fig.1a). We find relatively weak pressure dependence, where both T_1 and T_{max} go down with increasing pressure at approximately constant rate of 0.37 K/kbar (some of these results are shown in Fig. 1b). In the field scan at 2 K and at ambient pressure, we find a change in the slope of the magnetoresistance at about 6.9 T. Application of pressure causes a reduction of the magnetoresistance effect. We find that $\Delta\rho / \rho_{B=0}$ is – 0.105 at ambient pressure while it decreases to –0.07 at 10 kbar.

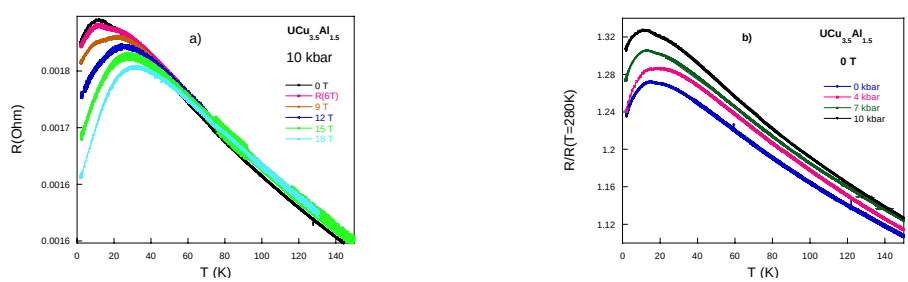

Fig. 1: a) Temperature dependence of electrical resistance of $UCu_{3.5}Al_{1.5}$ under 10 kbar pressure and at various fields. b) Temperature dependence of electrical resistance of $UCu_{3.5}Al_{1.5}$ at zero field and at various pressures.

References

[1] Sechovsky, V. and Havela, L., in Handbook of Magnetic Materials, vol. 11, ed. K.H.J. Buschow (Amsterdam) (1998).
[2] Nakotte, H., et al., Phys. Rev. B **54**, 12176 (1996).