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PRESSURE EMERGENCE OF MAGNETIC ORDERING IN UBe$_{13}$

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The electrical resistivity and the thermopower of UBe$_{13}$ have been measured between 1.2 and 300 K at pressures up to 67 kbar and in magnetic fields up to 6 T. While the resistivity reflects the partial delocalization of the f resonance, the marked oscillation of the low temperature thermopower strongly suggests that pressure drives a magnetic order well above $T_c$.

1. Introduction

Usually the transport properties of heavy fermion compounds (HFC) are described by independent Kondo-like scattering at high temperature ($T \gg T_K$) and in terms of a coherence effect at low temperature ($T \leq T_K$). In UBe$_{13}$, unlike other heavy electron superconductors, coherence scattering is still not developed when superconductivity arises at $T_c \sim 0.9$ K.

Indeed the resistivity $\rho$ is still very large just above $T_c$, and the thermopower $Q$ has not even reached its negative peaks [1]. To observe the low $T$ excitations of the normal phase, high pressure transport experiments under magnetic field were performed. Pressure was generated by a pair of opposed Bridgman anvils made of non-magnetic tungsten carbide.

2. Resistivity

Low temperature results of resistivity $\rho$ are presented in fig. 1. The pressure delocalization of the $f$ resonance induces the strong depression of $\rho$ and the increase of the temperature $T_{\text{max}}^\rho$ of its maximum value, in good agreement with refs. [2] and [3]. A resistivity behavior rather similar to UPt$_3$, i.e. without resistivity maximum, is expected at about 200 kbar.

At low pressure, the large and negative magnetoresistance $\Delta \rho/\rho$ is characteristic for the presence of local magnetic moments. At intermediate pressure ($P = 45$ kbar) $\Delta \rho/\rho$ is still negative but weaker and at high pressure ($P = 67$ kbar) $\Delta \rho/\rho$ is slightly positive below 4 K. Such a positive magnetoresistance has been observed in moderate HFC like UPt$_3$, CeRu$_2$Si$_2$ or CeAl$_3$ under pressure [4].

At 67 kbar, preliminary data do not show any superconducting transition down to 0.1 K and above 1.2 K, the $T^2$ law of $\rho$ is still not recovered.

At $P = 0$, for a sample from the same batch, a residual resistivity $\rho_0 \sim 12$ $\mu\Omega$cm has been measured at $B = 12$ T [5]. Our results then suggest a maximum of $\rho_0$ near 45 kbar.

3. Thermopower

As often observed in HFC, the thermopower $Q$ of UBe$_{13}$ is positive at high temperature and takes large negative values at low temperature. Fig. 2 shows that the negative peak of $Q$, centered at $T_{\text{min}}^Q$, emerges above $T_c$ under pressure. The clear correlation of $T_{\text{min}}^Q$ with $T_{\text{max}}^Q$ asserts the same physical origin. The pressure independence of the magnitude of $Q(T_{\text{min}}^Q)$ agrees with a $P$ increase of the width of the $f$ resonance.

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The most interesting feature in fig. 2 is the low $T$ positive contribution of $Q$ which is clearly resolved at 67 kbar. We claim that such a peak is the signature of an antiferromagnetic order. If a magnetic gap opens only in parts of the Fermi surface, it may be possible that no corresponding anomaly occurs in the resistivity. Large positive peaks of $Q$ have been observed for well characterized antiferromagnets like UCu$_5$ [6], TmSe or TmS [7]. In these cases the change of sign of $Q$ corresponds to the ordering temperature $T_N$. The recently discovered antiferromagnet UPt$_3$ ($T_N \sim 5$ K) with a very low ordered moment also shows a positive peak of $Q$ at $\sim 8$ K and a change of sign at $\sim 24$ K [8]. This thermoelectric behavior is expected for UBe$_{13}$ at roughly 200 kbar, i.e. the same pressure estimated from the resistivity.

From our previous study at $P = 0$ [1], a positive peak of $Q$ can be extrapolated at $T \sim 150$ mK. A specific heat anomaly was recently discovered at the same temperature [5]. So it appears that the magnetic ordering sets in above $T_c$ under pressure.

The highly magnetic field dependence of the low $T$ thermopower is another evidence of its magnetic origin (fig. 2). As $P$ increases, increasing fields are needed to destroy the positive contribution.

4. Conclusion

As pressure certainly induces the decrease of the low temperature electronic specific heat coefficient per unit volume $\gamma_e$, our results illustrate the correlation which has been found at zero pressure between $\gamma_e$ and the ground state configuration of uranium based HFC [9]. It is not so surprising that at high pressure UBe$_{13}$ behaves rather like the antiferromagnetically ordered HFC UCu$_5$ or UPt$_3$.

References