Field Induced Density Wave in the Heavy Fermion Compound $CeRhIn_5$

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Introduction

$CeRhIn_5$ has attracted significant interest [1] due to its rich phase diagram involving 4f local moment anti-ferromagnetism and d-wave superconductivity under pressure. We found evidence for another ground state in the system, a magnetic field induced state akin to a density-wave (DW). The DW state is signaled by a hysteretic anomaly in the in-plane resistivity accompanied by the appearance of non-linear electrical transport at high magnetic fields (>27T), which are the distinctive characteristics of density-wave states.

Experimental

The experiment relies on transport experiments in microstructures carved from a $CeRhIn_5$ single crystal by the Focused Ion Beam technique[2]. We have thereby prepared single crystal bars with μm^2 cross-section, which enables us to apply significant current densities (>500kA/cm^2) by applying only small currents in the mA range. This was the key to identify the density wave through the observation of non-linear transport due to its sliding motion. This collective excitation appears above a threshold electric field on the order of 10mV/cm. Sustaining such large electric fields in very good metals such as $CeRhIn_5$ is impractical in macroscopic single crystals.

Results and Discussion

A key signature of the transition in high fields is a large and strongly hysteretic jump of the in-plane resistivity. This large hysteresis enables us to directly investigate the Fermi surface of a supercooled electronic system and the appearance of additional quantum oscillation frequencies to clearly associate a Fermi surface reconstruction with the transition. Intriguingly, both the magnetization as well as the out-of-plane resistivity remain featureless across the transition field.

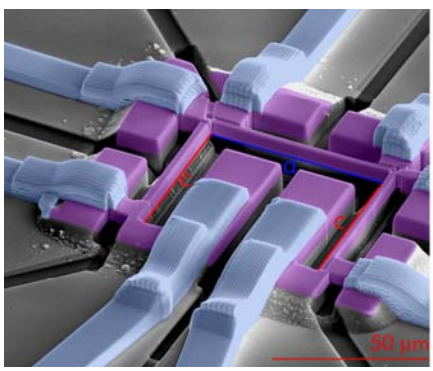

Fig.1 – FIB-cut single crystal micro-structure of $CeRhIn_5$(purple) and FIB-deposited Pt contacts (blue).

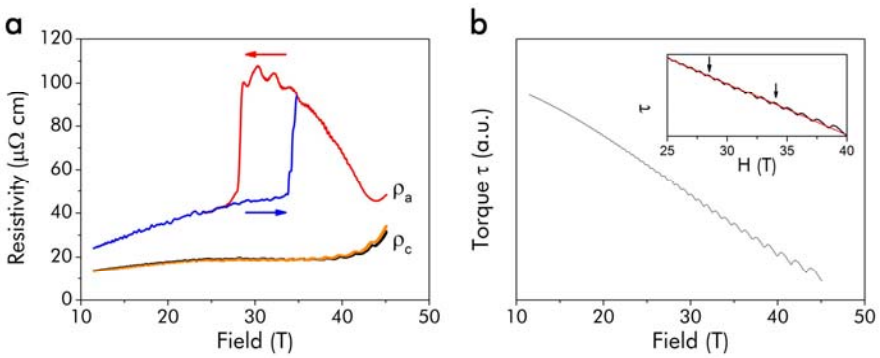

Fig.2 – (a) Resistivity across the transition for fields along *c* at 380mK. A hysteretic transition is observed in the in-plane resistivity, while the *c*-axis resistivity and (b) magnetization under same conditions remain featureless.

Conclusions

The absence of strong features in the magnetization points towards a negligible change in the density of states. Clearly just a small number of charge carriers are affected by the emergent high-field order, yet at the same time the in-plane resistivity is doubled. This implies that strong electronic correlations may lead to subtle orders, which nonetheless may significantly alter the systems properties. Such subtle orders might be a common feature among correlated electron systems, and its clear observation in the d-wave superconductor $CeRhIn_5$ adds a new perspective on the similarly subtle CDW state in the cuprates[3].

Acknowledgements

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References

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[2] P.J.W. Moll et al., Nature Materials 9, 628-633 (2010)
[3] P.J.W. Moll et al., to be published