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Electronic in-plane symmetry breaking at field-tuned quantum criticality in $CeRhIn_5$

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Introduction

Electronic nematicity appears in proximity to unconventional high-temperature superconductivity in the cuprates and iron-arsenides, yet whether they cooperate or compete is widely discussed. While many parallels are drawn between high-T_c and heavy fermion superconductors, electronic nematicity was not believed to be an important aspect in their superconductivity. We have found evidence for a field-induced strong electronic in-plane symmetry breaking in the tetragonal heavy fermion superconductor $CeRhIn_5$. At ambient pressure and zero field, it hosts an anti-ferromagnetic order (AFM) of nominally localized 4f electrons at TN=3.8K(1). Moderate pressure of 17kBar suppresses the AFM order and a dome of superconductivity appears around the quantum critical point. Similarly, a density-wave-like correlated phase appears centered around the field-induced AFM quantum critical point. In this phase, we have now observed electronic nematic behavior.

Experimental

We probe the electronic in-plane symmetry by detailed measurements of the resistivity anisotropy within the tetragonal basal plane. Such measurements in high magnetic fields are commonly difficult due to the high conductivity of high quality crystalline CeRhIn5. To address this experimental issue, we have fabricated microstructures from a single crystal using Focused Ion Beam machining. The structures feature resistance bars along the relevant symmetry related in-plane directions [100],[010] and [110], [1-10]. This allows simultaneous measurements of the resistance anisotropy and the electronic in-plane symmetry breaking.

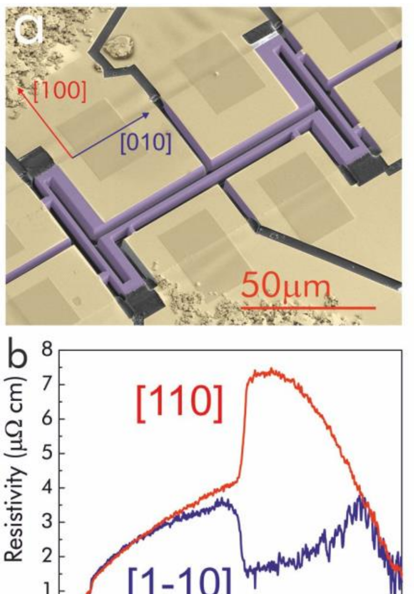

Fig.1 a) Single crystal microstructure of $CeRhIn_5$ designed to detect in-plane symmetry breaking. b) Magnetoresistance at T=0.5K for fields 20° off the c-direction. The nematic behavior is indicated by the sudden appearance of a strong difference between the tetragonal symmetry equivalent [110] and [1-10] directions.

Results and Discussion

We present evidence for a field-induced breaking of the electronic tetragonal symmetry of $CeRhIn_5$ in the vicinity of an AFM quantum phase transition at H_c~50T. This phase appears in out-of-plane fields of H*~28T and is characterized by substantial in-plane resistivity anisotropy (Fig.1). The anisotropy can be aligned by a small in-plane field component, with no apparent connection to the underlying crystal structure. Furthermore no anomalies are observed in the magnetic torque, indicating the absence of metamagnetic transitions in this field range. These observations are indicative of an electronic nematic character of the high field state in $CeRhIn_5$. The appearance of nematic behavior in a phenotypical heavy fermion superconductor highlights the interrelation of nematicity and unconventional superconductivity. An intriguing aspect of this apparent nematicity in $CeRhIn_5$ is the role of low electronic dimensionality. All prior candidate systems for electronic nematic materials such as $Sr_3Ru_2O_7$, cuprates, pnictides etc. are characterized by a strongly two-dimensional electronic structure. By contrast, $CeRhIn_5$ is a strongly three-dimensional metal as evidenced by its low resistivity anisotropy of 1.8 and quantum oscillation experiments. Yet despite this three-dimensional structure, the nematic phase transition appears to occur in a strongly two-dimensional electronic sub-system that dominates the in-plane transport but contributes negligibly to the out-of-plane conduction. Thus again a connection between nematic behavior and electronic two-dimensionality emerges.

Acknowledgements

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References

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