MAGNETORESISTANCE OF $PrOs_4Sb_{12}$: SEARCH FOR AN EVIDENCE OF HEAVY FERMION BEHAVIOR

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Introduction

A recent claim[1] of heavy fermion behavior in $PrOs_4Sb_{12}$ is an important milestone in heavy fermion research. The crystalline electric field (CEF) configuration[2] of Pr in $PrOs_4Sb_{12}$ excludes a conventional magnetic Kondo effect as the origin of heavy fermions and provides an opportunity for novel mechanisms of this state and superconductivity. However, the only direct indication of heavy electrons comes from a large discontinuity in C/T at T_c while other measurements are not conclusive. We have suppressed the superconductivity of $PrOs_4Sb_{12}$ by magnetic fields and searched for signatures of the heavy fermion state in the magnetoresistance.

Experimental

Measurements were performed in a top loading dilution refrigerator in the 18 T superconducting magnet (SCM1). The (100) axis of a single crystal was parallel to both magnetic field and applied current.

Results and Discussion

Both residual resistivity and the temperature variation are strong functions of the external field. The residual resistivity (ρ_o) seems to be dominated by crystalline electric field (CEF) effects. In particular, ρ_o shows a pronounced maximum near 10 T, i.e., in a field corresponding to the crossing of the zero-field ground state singlet and the lowest energy level of the Zeeman split triplet. This quasi-doublet formed in magnetic fields possesses a quadrupolar electric moment. The antiferro-quadrupolar (AFQ) transition temperature has also maximum value near 10 T.

On the other hand, the temperature dependence of the resistivity (ρ) in a fixed field is complex. Below 0.3 K, ρ has very week temperature dependence. In some cases, we have observed a slight increase of ρ upon lowering the temperature and time variation of ρ after switching the field from zero to a final value. The time scale was consistent with one of the spin-lattice relaxation times detected in calorimetric measurements. Thus, we believe that at the lowest temperatures the resistivity has a component due to scattering of electrons on hyperfine enhanced nuclear moments. Above 0.4 K, and over a limited range of temperatures, ρ can be approximated by the Fermi-liquid formulae

$$\rho = \rho_o + AT^2 \qquad [1]$$

The quadratic temperature coefficient A is 0.52, 1.8, and 0.27 $\mu\Omega$ cm K^{-2}, for H=3, 10, and 18 T, respectively. Using the empirical Kadowaki-Woods relationship, they correspond to the electronic specific heat coefficient of approximately 200 mJ/K^2mol for H=3 and 18 T, and to about 400 mJ/K^2mol for H=10 T.

Conclusions

The resistivity of $PrOs_4Sb_{12}$ reflects a complicated low temperature state of this system. We find strong correlations between the resistivity and CEF parameters deduced from the specific heat investigation and AFQ transition temperature. The analysis of the resistivity in magnetic fields provides support for the presence of heavy electrons in this system at low temperatures. Furthermore, these results suggest importance of CEF effects and proximity to AFQ order on the heavy fermion state.

Acknowledgements

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References

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