Magnetostriction Investigation of the 4% Rh Doped URu_2Si_2 Heavy Fermion Compound Near the Quantum Critical Point

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Introduction

URu_2Si_2 is a heavy fermion compound the low-temperature high-magnetic field phase diagram of which is characterized by the formation of multiple field induced ordered phases in the 30 to 42 T field range around a putative quantum critical point (QCP) located at 38 T **[1]**. When 4 % of the Ru atoms are substituted with Rh, the hidden order phase is suppressed and a single field-induced robust phase II remains around a putative QCP at 35 T **[2][3]**. A proposed scenario is one in which the order parameter in phase II is of the electrical quadrupolar- *type* and the strong coupling of the order parameter with the lattice induces the transition **[3]**. Outside the ordered phase, important volume effects are expected as observed in the 4f itinerant electron metamagnet $CeRu_2Si_2$ **[4]**. In the present experiment, magnetostriction measurements were carried out in $URu_{1.92}Rh_{0.08}Si_2$ between 1.5 and 15 K in DC fields between 12 and 45 T in the 45T – Hybrid magnet at NHMFL-Tallahassee.

Experimental, Results and Discussion

The $URu_{1.92}Rh_{0.08}Si_2$ single-crystal sample of ~ 2 x 2 x 3 mm^3 parallel-plate shape was glued with GE-varnish on the sample platform screw of a 0.750 in. diameter Titanium capacitive dilatometer **[5]** with the easy axis of magnetization *c* oriented orthogonal to the plates. The capacitance recorded with a AH2700 capacitance bridge was set at 9.5 (± 0.5) pF at 300 K (RT). The cell was screwed to the bottom brass part of a capacitance probe allowing it to enclose the cell in a conical seal. The sample space was pumped down to a 10^{-5} mbar vacuum and leak detected prior inserting the probe inside the He^4 fridge. Up to 8 mbar He^3 exchange gas had to be inserted inside the sample space so as to reach 4 K. The amount of He^3 was tlater adjusted. Two thermometers calibrated in field were placed on the top of the cell and close to the sample allowing it to notice the presence of a linear thermal gradient over the height of the cell and correct for it. Heat was applied on a heater wrapped around the brass piece above the cell. We performed mainly field sweeps at fixed temperature between 1.5 and 15 K. When approaching the transition into phase II, attention was paid to sweep the field slowly at a rate of 0.5 T/mn up and down in order to avoid magnetocaloric effects and check for putative hysteretic effects.

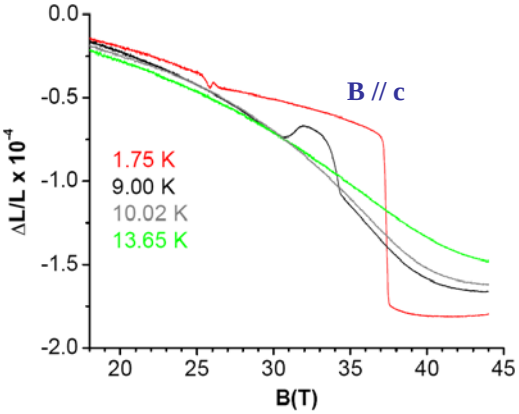

Fig.1. Field induced relative length changes along the *c* axis at several temperatures in $URu_{1.92}Rh_{0.08}Si_2$.

As shown **[Fig.1]**, important volume effects are evidenced at the entrance into and exit from phase II and in the underlying Fermi liquid. The ordering into phase II is found associated with an abrupt field-induced expansion of a 10^{-4} order of magnitude tending at maximizing *c*. Outside phase II, an important contraction follows the field-induced polarization of the 5f electrons in the underlying Fermi liquid. A further analysis allows it to calculate the coefficient of linear magnetostriction $\lambda = 1/L \times dL/dT$ that is shown to present an extremum at the metamagnetic field B_M as previously observed in the 4f analog $CeRu_2Si_2$.

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References

[1] Kim K. H. *et al.*, Phys. Rev. Lett. 91(25), (2003), **[2]** Kim K. H. *et al.*, Phys. Rev. Lett. 93**,** 206402 (2004) **[3]** Silhanek A. V. *et al.*, Phys. Rev. Lett**.** 96**,** 136403 (2006) **[4]** Lacerda, A. *et al.*, Phys. Rev. B 40 (16), 11429, (1989) **[5]** Schmiedeshoff G. *et al.*, Rev. Sci. Instrum. 77, 123907 (2006)