UC Irvine
UC Irvine Previously Published Works

Title
Magnetoresistance of thoriated UBe13

Permalink
https://escholarship.org/uc/item/2871d229

Journal
Physica B Condensed Matter, 165(PART 1)

ISSN
0921-4526

Authors
Allor, BA
Graf, MJ
Smith, JL
et al.

Publication Date
1990-08-01

DOI
10.1016/s0921-4526(90)81029-n

Copyright Information
This work is made available under the terms of a Creative Commons Attribution License, availalbe at https://creativecommons.org/licenses/by/4.0/

Peer reviewed

eScholarship.org Powered by the California Digital Library
University of California

Physica B 165&166 (1990) 359–360
North-Holland

MAGNETORESISTANCE OF THORIATED UBe_{13}

B. A. ALLOR and M. J. GRAF

Dept. of Physics, Boston College, Chestnut Hill, MA 02167 USA

J. L. SMITH and Z. FISK

Center for Materials Science, Los Alamos National Laboratory, Los Alamos, NM 87545, USA

We have measured the magnetoresistance for the heavy-fermion system $U_{1-x}Th_xBe_{13}$ for x=0, 0.006, 0.015, and 0.033 at temperatures between 1.2 K and 6K. The samples with x=0.006 and 0.015 develop a positive magnetoresistance as the temperature is *increased* above approximately 2 K. We observe the large negative magnetoresistance for the pure UBe_{13} and the sample with x=0.033, in agreement with the results of previous studies.

1. INTRODUCTION

Studies of the magnetoresistance (MR) have been useful in describing the properties of heavy-fermion systems. For many of the Ce-based compounds, such as $CeCu_{2.2}Si_2$ and $CeAl_3$, the high-temperature ($T > 1K$) negative MR characteristic of incoherent Kondo scattering of the conduction electrons gives way at lower temperatures to a low-field positive MR This has been interpreted as the onset of coherent Kondo scattering from the magnetic lattice sites. This explanation agrees with measurements of the specific heat.(2) The situation is much different for UBe_{13}, however, where the strong negative MR has been observed down to the lowest temperatures.(3,4) Samples studied with 3.3 % thorium substituted for uranium show similar behavior.(4) This has been attributed to the fact that the coherent Kondo state is not fully formed at temperatures above T_c (about 1 K), an interpretation that has been supported by studies of MR above 1 K and at high pressures,(5) and possibly by high-field, low-temperature specific heat measurements(6).

In this work we present measurements of the magnetoresitance of $U_{1-x}Th_xBe_{13}$ and find a *positive* MR for samples with x = 0.006 and 0.015 at temperatures above about 2-3 K, while the results for x= 0 and 0.033 show the typical strong negative MR at all temperatures.

2. EXPERIMENT

2.1 Samples

The four samples studied are polycrystalline with thorium concentrations of 0, 0.006, 0.015, and 0.033. Magnetization measurements show that all four samples exhibit superconducting transitions at temperatures of 0.90 K, 0.71 K, 0.52 K, and 0.57 K, respectively. The superconducting transitions have also been observed in specific heat measurements on the pure UBe_{13},(6) the x=0.015 sample, and 2 transitions for the x=0.033 sample. Specific heat measurements have not yet been made on the x=0.006 sample.

2.2 Procedure

Transverse magnetoresistance measurements were made on the four samples in the temperature range of 1.2 - 6 K, and for fields up to 9 T. Four gold wires of 0.002" diameter provided electrical contact to the samples, which were mounted on a copper block. The block was thermally connected to a ^4He pumped pot by a 0.25" diameter brass rod. The temperature was determined by a calibrated carbon-glass resistor, and was varied by applying fixed current to a (field-independent) heater on the copper block. The resistance was measured using the standard 4-terminal ac technique, with frequencies between 15 and 20 Hz and rms current levels of less than 1 mA. The current dependence of the measured voltage across the samples was measured to ensure that no self-heating of the samples occured. Magnetic fields were applied perpendicular to the current flow using a 9 T superconducting magnet, and were ramped at a rate of approximately 0.3 T/min. No hysteresis effects between up and down sweeps was observed. The temperature for each field sweep was determined by measuring the calibrated thermometer just before and after the field sweep, and the observed temperature drift was always less than 1 % .

3. RESULTS

The resistivities of the samples at 4.2 K are: $\rho(x=0) = 130\ \mu\Omega$-cm, $\rho(x = 0.006) = 170\ \mu\Omega$-cm, $\rho(x = 0.015) = 110\ \mu\Omega$-cm, and $\rho(x = 0.033) = 110\ \mu\Omega$-cm. The estimated error is approximately 10 % . We have measured the resistivities versus temperature between 1.2 K and 6 K and find the characteristic shoulder for pure UBe_{13} at 2.5 K. This structure is suppressed to 2 K for the x= 0.006 thoriated sample, and is not observed at all for the samples with higher thorium concentrations.

We now discuss the MR measurements. The results for x=0 and 0.033 agree well with previous measurements.(3,4) For both samples we observe a large negative MR that becomes more pronounced at lower temperatures (a reduction of approximately 50 % at

0921-4526/90/$03.50 © 1990 – Elsevier Science Publishers B.V. (North-Holland)

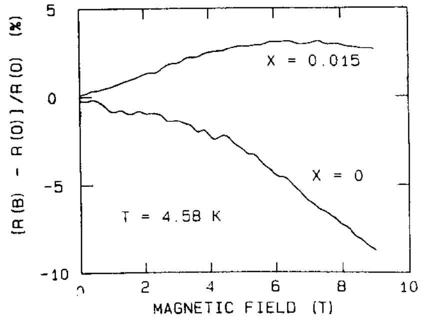

Figure 1
The fractional change in the resistance of UBe_{13} and of $U_{0.985}Th_{0.015}Be_{13}$ vs. magnetic field at T= 4.58 K.

1.2 K for UBe_{13}, and of about 20 % for x= 0.033 at 1.3 K). This MR is shown for UBe_{13} at 4.58 K in Figure 1. The behavior for the samples with *intermediate* thorium concentrations is more complicated. At low temperatures we observe the typical large (reductions of about 25-30 %), negative MR. As the temperature is raised, however, a low-field, positive MR becomes apparent, and results in a peak in the MR. This is also shown in Figure 1 for the sample with x= 0.015. In Figure 2 we show the temperature progression of the MR for the sample with x=0.015, and the development of a positive MR as the temperature increases is evident. In Figure 3 we have plotted the peak location in field, H_{max}, versus temperature for the x= 0.006 and 0.015 samples. As the temperature increases, this crossover field increases. The effect is evident at lower temperatures for the sample with higher thorium concentration, indicating that the effect is probably intrinsic; however we note that the positive MR is *not* observed at any temperature studied here for the x=0.033 sample.

4. DISCUSSION

The development of positive MR for samples with intermediate thorium impurities is difficult to understand. Clearly the nature of this effect is different than for $CeAl_3$, where the positive MR develops as the temperature is *lowered*, and is interpreted as signaling the onset of coherent Kondo scattering of electrons. One might conclude that the thorium impurities are simply

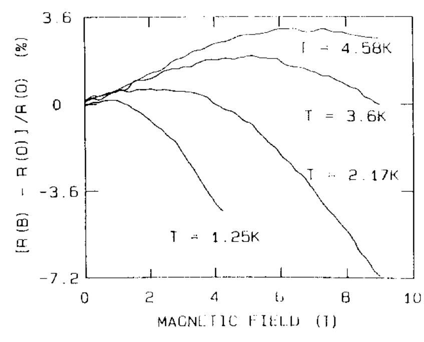

Figure 2
The fractional change in resistance of $U_{0.985}Th_{0.015}Be_{13}$ vs. magnetic field at several different temperatures.

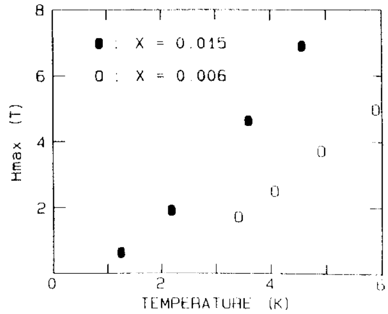

Figure 3
The variation of the field at which the maximum in magnetoresistance occurs with temperature for samples with thorium concentrations of x= 0.006 and x= 0.015.

weakening the Kondo scattering, and so at higher temperatures these samples are behaving more like normal metals. While the impurities could have an appreciable effect on coherent scattering by destroying the periodicity of magnetic scatterers, low levels of impurities should have little effect on incoherent Kondo scattering. Also, the large negative MR characteristic of incoherent Kondo scattering is observed once again for the sample with 3.3 % thorium. It is interesting to note that of the three thoriated samples studied here, the two which show positive MR have concentrations which, at low temperatures, have one superconducting transition, while the sample which shows negative MR has a concentration corresponding to two transitions at low temperatures.(7) Clearly more work is necessary to better understand this behavior.

5. CONCLUSION

We have measured the MR of $U_{1-x}Th_xBe_{13}$ for x= 0, 0.006, 0.015, and 0.033, and find that the samples with intermediate thorium concentrations have positive MR at temperatures above approximately 2 K. The pure and x=0.033 samples have the expected large negative MR at all temperatures studied. We are presently extending these studies.

REFERENCES

(1) U. Rauchschwalbe, F. Steglich, and H. Rietschel, Physica 148B (1987) 33, and references therein.
(2) C.D. Bredl, S. Horn, F. Steglich, B. Lü thi, and R.M. Martin, Phys. Rev. Lett. 52 (1984) 1982.
(3) B. Batlogg, D.J. Bishop, E. Bucher, B. Golding, Jr., A.P. Ramirez, Z. Fisk, and J.L. Smith, J. Magn. Magn. Mat. 63& 64 (1987) 441.
(4) H.M. Mayer, U. Rauchschwalbe, F. Steglich, G.R. Stewart, and A.L. Giorgi, Z. Phys. B 64 (1986) 299.
(5) M.C. Aronson, J.D. Thomson, J.L. Smith, Z. Fisk, and M.W. McElfresh, Phys. Rev. Lett. 63 (1989) 2311.
(6) M.J. Graf, N.A. Fortune, J.S. Brooks, J.L. Smith, and Z. Fisk, Phys. Rev. B40 (1989) 9358.
(7) H. R. Ott, H. Rudigier, Z. Fisk, and J.L. Smith, Phys. Rev. B31 (1985) 1651.