Title

Magnetic field dependence of the correlation gap in SmB6

Journal

Physica B Condensed Matter, 206(C)

ISSN
0921-4526

Authors

Cooley, JC
Aronson, MC
Lacerda, A
et al.

Publication Date

1995-02-01

DOI
10.1016/0921-4526(94)00464-7

ELSEVIER

Physica B 206 & 207 (1995) 377–379

PHYSICA B

Magnetic field dependence of the correlation gap in SmB_6

J.C. Cooley[a], M.C. Aronson[a,*], A. Lacerda[b], P.C. Canfield[c], Z. Fisk[d], R.P. Guertin[e]

[a]*University of Michigan, Ann Arbor, MI 48109-1120, USA*
[b]*National High Magnetic Field Laboratory, Los Alamos, NM 87545, USA*
[c]*Ames Laboratory, Iowa State University, Ames, IA 50011, USA*
[d]*Los Alamos National Laboratory, Los Alamos, NM 87545, USA*
[e]*Tufts University, Medford, MA 02155, USA*

Abstract

Magnetoresistance measurements were used to probe the effect of large magnetic fields on the stability of the electronic gap (Δ) in SmB_6. Although the free electron Zeeman splitting in an 18 T field is comparable to the ambient pressure Δ, and even exceeds Δ at 45 kbar, Δ is in both cases almost completely unaffected by the magnetic field.

1. Introduction

The stability of the insulating gap in Anderson lattice compounds such as SmB_6, YbB_{12}, and $Ce_3Bi_4Pt_3$ under application of high magnetic fields provides a direct test of several available theoretical scenarios. In the mean field solution to the Anderson lattice, the hybridization gap is expected to close continuously with increased magnetic field strength as the Zeeman splitting of the gap edge states increases [1]. It is believed that the magnetic field dependence of the gaps in YbB_{12} [2] and possibly in $Ce_3Bi_4Pt_3$ [1,3] can be explained by this mechanism. Alternatively, long range RKKY-like magnetic interactions are likely to destabilize the gapped state, leading to a discontinuous transition to a magnetic metallic state in sufficiently large applied field [4]. In both cases, magnetic fields providing Zeeman splitting comparable to the gap magnitude are required to test these predictions.

2. Experimental details

SmB_6 is ideal for this study, as its ambient pressure gap of 40 K can be tuned and ultimately destabilized with the application of approximately 50 kbar [5], provided here by a high pressure Bridgman anvil cell. Magnetic fields as large as 18 T were provided by a superconducting solenoid at the National High Magnetic Field Facility, Los Alamos. All experiments were carried out on high quality single crystals, grown from Aluminum flux.

3. Experimental results

In Fig. 1 the temperature dependence of the electrical resistivity of SmB_6 in zero magnetic field and in 18 T at an applied pressure of 10 kbar are compared. The magnitudes of the electronic gap determined from these activation plots for the temperature range 4 K–11 K are 30.7 ± 0.4 K ($H = 0$) and 29.5 ± 0.4 K ($H = 18$ T), a remarkably weak magnetic field dependence, considering that the Zeeman splitting associated with a

---

[*] Corresponding author.

SSDI 0921-4526(94)00464-1

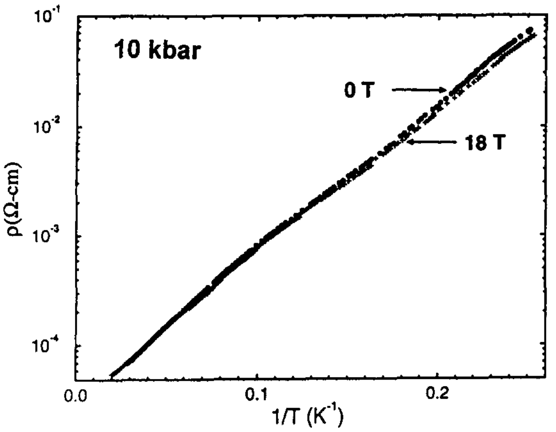

Fig. 1. The electrical resistivity of SmB_6 in zero field (●), and 18 T (+) plotted as functions of inverse temperature. The experimental pressure is 10 kbar.

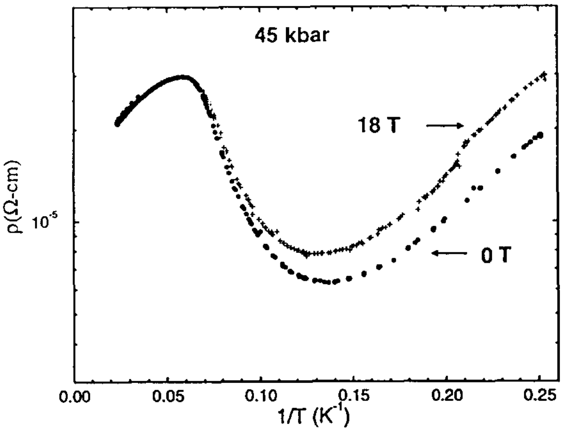

Fig. 2. The electrical resistivity of SmB_6 in zero field (●), and 18 T (+) plotted as functions of inverse temperature. The experimental pressure is 45 kbar.

field of 18 T, and assuming a g-factor of 2.0 is approximately half the electronic gap. Even so, examination of Fig. 1 reveals that the weak negative magnetoresistance observed in SmB_6 has its origins in the residual field dependence of the gap, and not in the residual resistivity, as has been previously implied [6].

This relative insensitivity to magnetic fields is even more strikingly demonstrated when high pressures are used to reduce the gap in SmB_6. We previously reported [5] that pressure monotonically reduces the electronic gap Δ, which at approximately 50 kbar drops discontinuously to zero. Activation plots of the electrical resistivity in zero field and 18 T are presented in Fig. 2 for a sample of SmB_6 carefully tuned to this critical pressure range (45 kbar). Although the gap can only be identified over a small range of temperatures, Δ is significantly more sensitive to applied magnetic field than at 10 kbar, increasing from a zero field value of 11.6 ± 0.2 K to 13.9 ± 0.2 K at 18 T. Nonetheless, this effect is still surprisingly weak, since the free electron Zeeman splitting at 18 T is now larger than the magnitude of the gap itself. Finally, since both the slope and intercept of the linear part of the activation fit are field dependent, we see from Fig. 2 that the positive magnetoresistance observed at the lowest temperatures in the vicinity of the critical pressure must include a substantial contribution from the magnetic field dependence of the residual resistivity, unlike the case at 10 kbar.

4. Discussion

To summarize, we have found that large magnetic fields have surprisingly little influence on the electronic gap in SmB_6, indicating an anomalously small coupling of the magnetic field to the gap-edge states. Accordingly, we have found no evidence for any discontinuous change in the ground state of SmB_6 on application of large magnetic fields. Both of these results are counter to theoretical predictions [1,4], as well as to previous experimental studies of Kondo insulators like $Ce_3Bi_4Pt_3$ [3] and YbB_{12} [2], in which the activation gap is rapidly suppressed by the field. Our data also demonstrate that the temperature and pressure dependences of the magnetoresistance in SmB_6 are very complex in the vicinity of the gap disappearance, and more detailed studies are currently underway to clarify this point.

Acknowledgements

Work at the University of Michigan was supported by the Office of Basic Energy Sciences, US Department of Energy. Part of the work reported here was performed at the National High Magnetic Field Laboratory, Los Alamos. Ames Laboratory is operated for the US Department of Energy by Iowa State University under contract number W-7405-Eng-82.

References

[1] C. Sanchez-Castro, Phys. Rev. B 49 (1994) 4421.
[2] K. Sugiyama, A. Ohya, M. Date, F. Iga, M. Kasaya and T. Kasuya, J. Magn. Magn. Mater. 52 (1985) 283.
[3] M.F. Hundley, A. Lacerda, P.C. Canfield, J.D. Thompson and Z. Fisk, Physica B 186–188 (1993) 425.
[4] A.J. Millis, in: Physical Phenomena at High Magnetic Fields, eds. E. Manousakis et al. (Addison-Wesley, Reading, MA, 1992) p. 146; V. Dorin and P. Schlottmann, Phys. Rev. B 46 (1992) 10800.
[5] J. Beille, M.B. Maple, J. Wittig, Z. Fisk and L.E. DeLong, Phys. Rev. B 28 (1983) 7397; I.V. Berman, N.B. Brandt, V.V. Moschalkov, S.N. Pashkevich, V.I. Sidorov, E.S. Konovalova and Yu.B. Paderno, JETP Lett. 38 (1983) 477; J.C. Cooley, M.C. Aronson, P.C. Canfield and Z. Fisk, preprint 1994.
[6] A. Lacerda, D. Rickel, M.F. Hundley, P.C. Canfield, J.D. Thompson, Z. Fisk, P. Haen and F. Lapierre, Physica B 199 & 200 (1994) 469.