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The superconducting energy gap of bulk UBe_{13}*

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The superconducting energy gap, Δ, of bulk UBe_{13} was measured as a function of temperature. Junctions were made by breaking a narrow region of a specimen in a vacuum and then repositioning the broken ends to form a mechanically adjustable break junction point contact. We concluded that the $2\Delta(0)/k_BT_c = 4.2$ by fitting the data to the BCS form assuming a T_c of 0.80 K.

1. INTRODUCTION

We present the first break junction study of a heavy-fermion superconductor. Previous experiments have been limited to spectroscopy of point contacts in various configurations [1]. In these experiments, relatively weak structure in the current-voltage (I-V) characteristics have been correlated to heavy-fermion superconductivity. In contrast, when break junctions in bulk UBe_{13} samples are operated in a point contact mode, distinct features are evident in the I-V curves below the critical temperature, T_c. The data are compared to those for break junctions in bulk Zn samples which have a similar T_c.

2. EXPERIMENTAL

Master samples of polycrystalline UBe_{13} were made by melting powders of U and Be in the appropriate proportions in an arc furnace. Subsequent annealing at a temperature of 1000°C for two weeks in an inert atmosphere was carried out in order to promote homogenization. Samples suitable for use in the break junction apparatus (parallelepipeds roughly 1 mm wide, 1 mm thick, and 10 mm long) were spark cut from the masters. A notch was cut in the middle of the samples thereby weakening them mechanically. The samples were placed in the break junction apparatus [2] which was mounted in turn onto the mixing chamber of a ^{3}He-^{4}He dilution refrigerator. Before the samples were broken, their electrical resistance, R, was measured as a function of temperature, T, in order to determine the T_cs. Typically we found that R began to decrease rapidly just below 850 mK, but that R was not zero until the sample was cooled to approximately 700 mK. The center of the transition was approximately 820 mK. The broad transition indicates that the samples were not phase pure.

The samples were subsequently broken at low temperatures by moving the magnetic plunger of the break junction apparatus against the substrate just beneath the mechanically-weakened section of the samples. The solenoid which drove the plunger was enclosed in a magnetic shield so that the junctions were not exposed to stray fields larger than 0.1 mT. To form the tunnel junction, the plunger was then retracted until the broken ends of the UBe_{13} touched.

3. RESULTS

Figure 1 shows the I-V curves for Zn and UBe_{13} break junctions well below T_c. The Zn curve shows typical RSJ-like behavior. In addition, Shapiro steps were observed when the Zn

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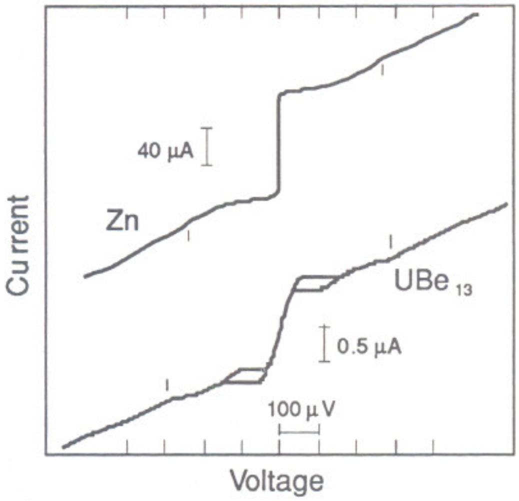

Fig. 1 Current-voltage characteristics for point contact break junctions of Zn and UBe_{13}.

junctions were exposed to rf. In contrast, the UBe_{13} curve shows a finite conductance at zero bias along with some hysteresis and Shapiro steps were not observed. The zero-bias finite conductance was present independent of the normal state resistance indicating that the surface of the UBe_{13} electrodes has a pair-breaking effect. It is interesting to note that when the UBe_{13} break junctions were adjusted to form high resistance (R>100Mohm) "vacuum barrier" tunnel junctions, the I-V curves were linear below T_c without the usual tunneling energy gap characteristic. In contrast, under similar conditions the Zn junctions showed the expected tunneling energy gap.

Point-contact energy gaps, $\Delta(T)$, were determined from the voltage at which the I-V curve deviates from the normal state characteristic [3] indicated by the tic marks in Fig. 1. To check the method, we measured $\Delta(T)$ of Zn. We found good agreement with the BCS theory, with fitted values of T_c=880 mK and $2\Delta(0)$=260 μeV. The ratio of $2\Delta(0)/kT_c$ for the Zn was 3.43.

The $\Delta(T)$ for one UBe_{13} sample is shown in Fig. 2. The best fit is obtained for values of T_c=800 mK and $2\Delta(0)$=290 μeV. The ratio of $2\Delta(0)/kT_c$ was 4.21, which is considerably larger than the BCS weak coupling limit.

4. DISCUSSION

Energy gap measurements in the heavy-fermion materials are open to a variety of interpretations.

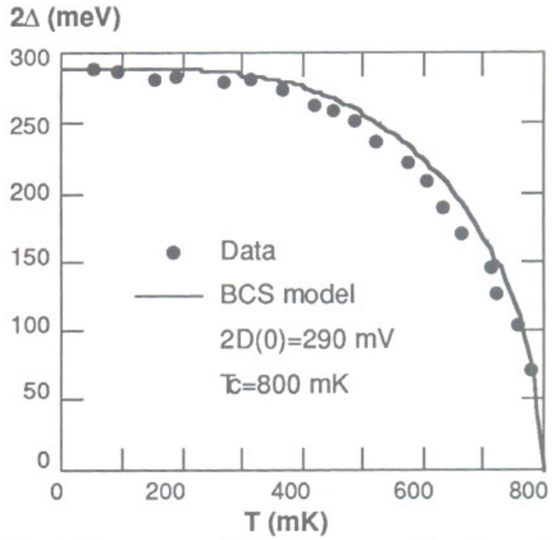

Fig. 2 Energy gap for UBe_{13} as a function of temperature.

The largest uncertainty in these analyses is, of course, the structure characteristics in the I-V curve that are used to identify gap-like behavior. The close fit to a BCS curve for the data presented here gives added assurance that superconducting energy gap behavior is being observed. Because reproducibility was good, the technique was proven with a known superconductor, Zn, and the contact surfaces are presumed to be clean, we feel the measurement should be a true reflection of the superconducting properties at the surface of this heavy-fermion material. Further studies of phase pure single crystals and the ac Josephson effect are continuing.

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