Andreev Reflection at Point Contacts with Heavy-Fermion UBe_{13}?

In a recent Letter, Wälti *et al.* [1] have presented evidence for unconventional superconductivity in heavy-fermion UBe_{13}, using point-contact spectroscopy. They proposed that the huge zero-bias conductance peaks found for their contacts between UBe_{13} and a Au tip are due to the existence of low-energy Andreev surface bound states indicating a nontrivial energy-gap function. This interpretation implicitly assumes that the junctions are in the ballistic limit, which means the electronic mean free path l is considerably larger than the contact radius a. As will be shown below, such a condition is unlikely to be fulfilled for contacts with UBe_{13}. In the normal state just above T_c, its electrical resistivity amounts to $\rho \approx 130\ \mu\Omega$ cm; see, for example, Ref. [2]. This very large resistivity results in an extremely short electronic mean free path $l \approx 1$ nm, estimated using $\rho l = 3\pi R_K/2k_F^2$ with $R_K = h/e^2 = 25.8$ kΩ and assuming a typical metallic Fermi wave number $k_F \approx 10$ nm^{-1}.

The basic properties of a metallic junction in the normal state are described by Wexler's formula [3]. Its approximate form splits up the contact resistance R into a ballistic (also called Sharvin resistance) and a resistive part (Maxwell resistance)

$$R(T) \approx \frac{2R_K}{(ak_F)^2} + \frac{\rho(T)}{4a}. \qquad (1)$$

For simplicity, equal Fermi wave numbers with spherical Fermi surfaces on both sides of the junction are assumed, and the contribution of one of the electrodes (here the Au tip) to the resistive part has already been neglected. At large contacts with radii $a \gg l$, Maxwell's resistance $\rho(T)/4a$ dominates. In the ballistic limit ($a \ll l$) the resistive part represents a small correction to the ballistic contact resistance, describing backscattering processes. At a resistance of $R_{eq} \approx \rho^2 k_F^2/16R_K$ both parts of the contact resistance have equal size. It requires $R \gg R_{eq} \approx 410\ \Omega$ for a UBe_{13}-Au junction to be in the ballistic limit. This is indeed a very strong criterium for spectroscopy on these point contacts.

According to Wexler's formula Eq. (1), the resistive part vanishes when the UBe_{13} sample becomes superconducting, leaving the ballistic part for possible Andreev reflection processes. Therefore, any analysis in terms of Andreev reflection requires either the junction to be in the ballistic limit or to separate the different contributions to the superconducting signal.

Wexler's formula offers a straightforward strategy to solve this problem by comparing the temperature dependence of the specific resistivity in the normal state with that of the contact resistance to derive the contact radius a. Akimenko *et al.* [4] first proposed and verified the principles of such an analysis on junctions between simple normal metals. This method applied to junctions between UBe_{13} and a normal metal (tungsten) showed the size of the superconducting anomalies to coincide with the resistive (Maxwell) part of the contact resistance over a wide range of contact radii a, indicating a negligible contribution of Andreev reflection [5].

The (typical) contact discussed in Ref. [1] has a normal state $R \approx 2\Omega$. Consequently, it is not in the ballistic limit: This resistance is mainly due to Maxwell's $\rho/4a$, with a contact radius $a \approx 160$ nm, while the ballistic part $2R_K/(ak_F)^2$ is quite small. When the contact is cooled to below T_c, the electrical resistivity $\rho = 0$ and, thus, Maxwell's resistance vanishes. This leads to the observed large rise of the zero-bias conductance. Approximating the ballistic resistance by the residual contact resistance $\sim 0.2\Omega$, the Fermi wave number $k_F \approx 3$ nm^{-1}, a quite reasonable value.

Local heating is probably the most important mechanism for shaping the spectra of those junctions because of the extremely short electronic mean free path of UBe_{13} [5]. This explains the conductance being reduced at some finite bias voltage. The bias voltage itself cannot be attributed directly to an additional kinetic energy of the conduction electrons because the junctions are not in the ballistic limit but in the thermal regime. A more detailed investigation would also take into account the pressure gradient caused by the Au electrode, inducing a spatial variation of T_c. Even part of the contact region could stay normal due to this deformation of the UBe_{13} crystal lattice, enhancing the residual contact resistance. However, contributions from Andreev reflection are difficult to identify because of the large resistive (Maxwell) component of the superconducting signal.

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