

Superconducting gap in Nb seen by point contact spectroscopy

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Abstract. The nonlinear current voltage characteristics of a point contact convey information about various excitations in the metal. We have made a point contact study on a superconductor to see the band gap and on a normal metal to see the transport characteristics.

Keywords. Point contact spectroscopy; N–S interface; Andreev reflection.

1. Introduction

Point contact spectroscopy is a simple and sensitive technique to study the interaction of electrons with various elementary excitations in metals (Duif *et al* 1989). The I – V characteristics of two metallic “banks” connected by a narrow “neck” show deviations from Ohm’s law. This nonlinearity is a measure of the inelastic scattering of the conduction electrons and the applied voltage defines the energy scale for the interaction process. This technique also turns out to be an elegant probe to study the transport of electrons across normal-superconductor (NS) interfaces (Blonder and Tinkham 1983) and observation of bandgap of the superconductor. In this paper we report the study on NS interface between niobium (Nb) in its superconducting state and platinum (Pt) using this technique. For reference we report on a Pt–Pt (NN) point contact study also.

2. Experiment

We make the point contacts in liquid helium by gently pressing a sharply etched wire against the surface of a flat metallic foil. The tip is prepared from wires of diameter ≈ 0.25 mm by anodic electropolishing. A cryostat equipped with a differential screw is employed to make the point contact in helium. The contact resistance is adjusted by differential screw pressing on a flexible phosphor bronze strip and a piezoelectric rod to which the sample holder is fixed. The contact can be adjusted from top of the cryostat.

An ac modulation technique is used to measure the differential resistance (dV/dI) as the dc bias is swept across the point contact (Edgar and Zyskowski 1985). Any nonlinearity in the I – V characteristics of a device is accentuated in the (dV/dI) – V plot. A block diagram of the measuring system is shown in figure 1. The integrator ramps up/down the dc bias voltage V at a switch selectable rate. The summer mixes the dc bias V and the small amplitude ($\delta v = 45 \mu\text{V} \ll V$) constant modulating ac δv at frequency 511 Hz. Current boosters maintain $(V + \delta v \cos \omega t)$ constant across the point contact irrespective of resistance change as the dc voltage V is swept. Current

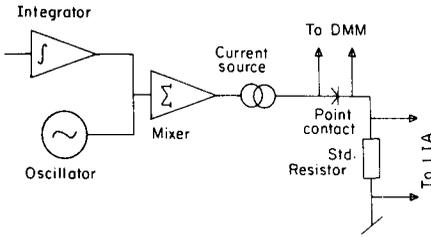


Figure 1. Experimental arrangement schematic of the measuring system.

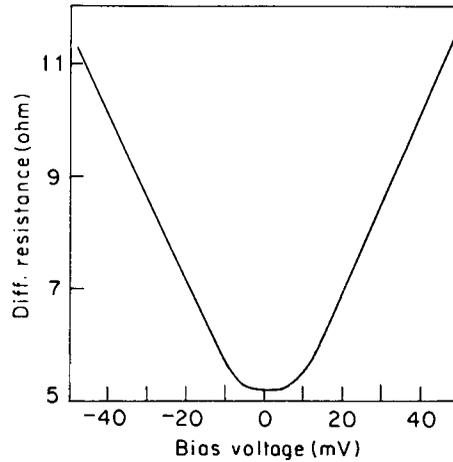


Figure 2. Pt (tip)-Pt (flat) at 4.2 K.

is detected by measuring the potential difference across a standard resistance in series with the point contact. The current through the point contact can be expanded as follows:

$$I = I_0 + (dI/dV)\delta v \cos \omega t + (1/2)(d^2I/dV^2)\delta v^2 \cos^2 \omega t + \dots \quad (1)$$

For $\delta v \ll V$, the second and higher order terms are negligible. The amplitude of the ω component gives a measure of the differential conductance. The lock-in-amplifier connected across the standard resistance detects this signal. A digital multimeter measures the dc bias voltage. The data are stored by a computer during each scan. Multiple scans are done for each contact resistance and a digital filtering software routine is used to smoothen the noisy data.

3. Results and discussion

Figure 2 shows a plot for differential resistance vs bias voltage for a Pt-Pt (*NN*) point contact. The band picture agrees quite well with published data (Eberhard 1985).

Figure 3 shows the differential resistance vs bias voltage of the Nb-Pt point contact and can be compared with figure 2. Figure 4 shows the data in an expanded scale near zero bias. The low resistance at low bias voltage arises from Andreev reflection (Andreev 1964). For energies $eV < \Delta$ (band gap) all the electrons Andreev reflect carrying twice the normal current. At voltages greater than the gap only a fraction of the incident electrons proportional to Δ/eV Andreev reflect. As the electronic energy approaches the bandgap energy, the quasiparticle propagation across the microcontact starts to dominate and ΔR increases.

Blonder *et al* (1982) proposed a model in which they introduced a dimensionless parameter Z to characterize the effective barrier strength across the NS interface. A detailed quantitative analysis of our data, based on this model shows that Z is zero in our case. This implies that our contact is purely metallic and the electron propagation is diffusive across the contact.

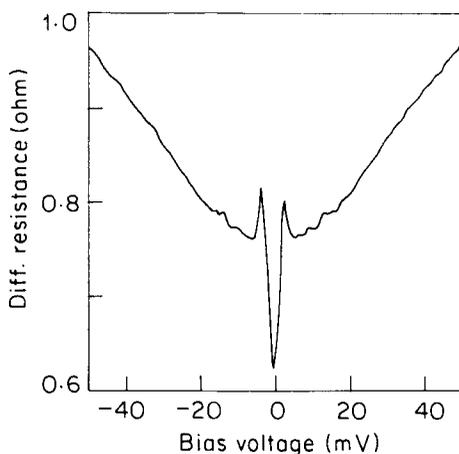


Figure 3. Nb (tip)-Pt (flat) at 4.2 K.

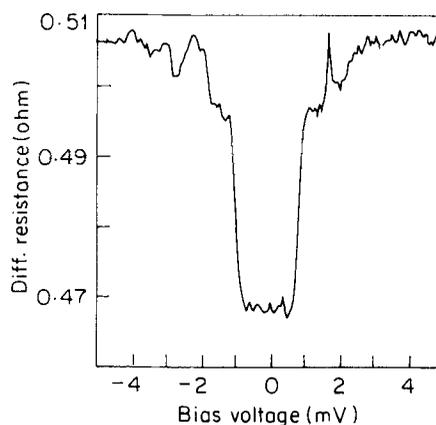


Figure 4. Nb (tip)-Pt (flat) at 4.2 K.

4. Conclusion

We have looked at the bandgap of Nb in its superconducting state using point contact spectroscopy. A conventional modulation technique is used to measure the dV/dI as a function of bias voltage across the point contact. Our experimental results indicate that the gap structure at a NS microconstriction is primarily determined by Andreev reflection below Δ and quasiparticle transmission above it.

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