Using Gold Tips to Measure Superconducting Niobium

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Background

- Point-contact spectroscopy (PCS) was introduced by Yanson et al more than 40 years ago, when they studied nonlinearities in the current-voltage characteristics of micro-shorted tunnel junctions between two metals.
- PCS provides spectroscopic information via detection of quasiparticle scattering such as electron-phonon scattering across a ballistic junction (Fig. 1).
- To form such a junction, a sharp metallic tip is essential (Fig. 2). Here we use gold tips made using electrochemical etching.

Fig. 1. Experimental arrangement for PCS in the so-called needle-anvil configuration. The dash circle is a schematic of the ballistic flow of electrons with mean free path \( l \) through the point contact with characteristic size \( a \) (<< \( l \)).

Fig. 2. (Left Panel) Schematic of the electrochemical etching setup for gold tips. The solution is either stock HCl or HCl-glycerol mixture. (Right Panel) Images of a finished gold tip taken by using a scanning electron microscope (A) and an optical microscope (B).

Growth of Nb Thin Films

Preparation of the Nb samples was completed using the DC magnetron sputtering technique in a ultra-high-vacuum compatible chamber. The topography of the Nb thin film (roughness and grain structure) is carefully assessed using the Atomic Forces Microscope (AFM).

Fig. 3. Ultra-High Vacuum compatible chamber

Fig. 4. AFM image of the Nb thin film

PCS Measurement

The sample and a gold tip are attached onto a PCS probe, which is inserted into the Quantum Design Physical Property Measurement System (PPMS) for the measurement at liquid helium temperature. The junction was formed by progressively moving the tip towards the sample by means of the \( z \) nanopositioner. In this way it was possible to form ballistic contacts and observe the Andreev reflection phenomenon.

Fig. 5. Photo of the PCS rig showing the sample and the tip

Fig. 6. Quantum Design Physical Property Measurement System. The PCS probe is inserted into the cryostat on the right

Results

Fig. 7. Conductance curves calculated using MATLAB codes. The parameter \( Z \) represents the strength of electrostatic potential barrier between a normal metal (Au) and a superconductor (Nb). The charge transport mechanism transitions from Andreev reflection to single particle tunneling with increasing \( Z \).

Fig. 8. Resistance versus temperature of the same Nb thin film. The inset is a plot zoomed in around \( T_C \).

Fig. 9. Real differential conductance (dI/dV) data taken from the Nb thin film whose micro-structure is shown in the AFM image (Fig. 4). The lineshape indicates the existence of Nb oxide layer at the top surface of Nb.

References

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