Applications of superconducting tips in STM

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Scanning tunnelling microscopy (STM) has been proven to be one the most important tools towards our knowledge and control of the nanoworld. The governing principle of the STM is the tunneling of electrons through a thin potential barrier separating two electrodes, tip and sample. By varying the bias voltage between tip and sample, one can measure I(V) spectra as well as the differential conductance dI/dV(V). This technique is known as Scanning Tunnelling Spectroscopy (STS). The differential conductance reflects the local electronic density of states (LDOS) of tip and sample. If the sample is a superconductor, one can clearly indentify and characterize the superconducting energy gap around the Fermi level.

The fabrication and characterization at low temperatures of STM tips is a very important step. We use the STM as a tool for its fabrication in situ at low temperatures [1]. We crash, in a controlled manner, a clean tip into a clean substrate, both of the same material (Pb in our experiments). As the tip is pressed against the substrate, both electrodes deform plastically, forming a connective neck (a nanobridge between the electrodes). The nanotip resulting from the rupture of the neck allows us to obtain spectroscopic information and topographic images with atomic resolution.

Our STM can be mounted in a ^{3}He refrigerator (0.3 K), and can operate under magnetic fields (up to 10 T). Using piezoelectric stacks, tip and sample can be approached from distances of several millimeters in-situ at low temperatures. The table on which the sample is located is the other important part of this instrument. At low temperatures it can be moved across the “y” direction distances in the millimetric range using piezoelectric stacks. This movement is well controlled and reproducible, and allows to access with the tip large areas in different samples (Pb, Au and $NbSe_2$).

We present the fabrication and characterization at low temperatures of superconducting STM tips of lead and its applications:

- Images with atomic resolution of an area of $NbSe_2$ scanned with a Pb tip at 0.3K. The charge density wave (CDW) is observed [Figure 1].

- Study of the presence of multiband superconductivity in $NbSe_2$ [2], it is possible due to the enhancement of the gap features resulting from convolution of the two superconducting DOS (tip and sample).

- Measurement of the Josephson current of Cooper pairs in atomic size junctions of lead [3][Figure 2]. It allows the possibility of Josephson scanning tunneling microscopy experiments [4][5][6].

- Images of vortices of $NbSe_2$ (type II- superconductor) [7] scanned with a Pb tip at 0.3 K and under magnetic fields up to 0.5 T.

References:

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Figures:

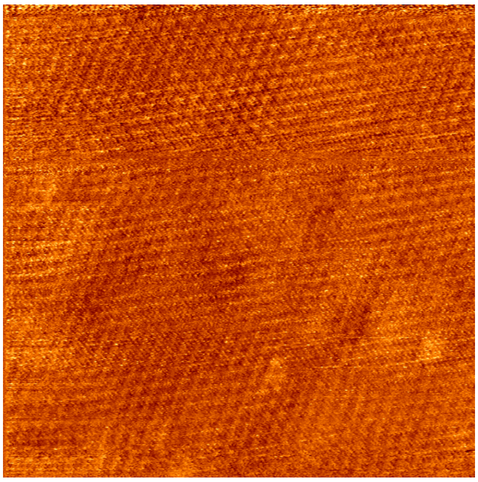

Fig.1: 33x33 nm^2 STM topographic image of a $NbSe_2$ surface using a Pb tip. Obtained at 300mK, it shows atomic resolution and the charge density wave.

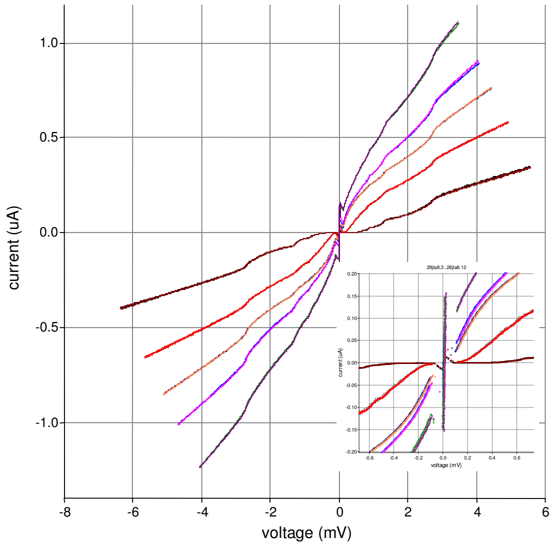

Fig.2: I-V curves showing the evolution of Andreev reflections and Josephson current from vacuum tunnel regime to atomic size junctions of lead.