Magnetic flux trapping in superconducting nanostructures fabricated with the STM

J.G. Rodrigo, V. Crespo and S. Vieira

Laboratorio de Bajas Temperaturas, Departamento de Física de la Materia Condensada
Instituto de Ciencia de Materiales Nicolás Cabrera,
Facultad de Ciencias, Universidad Autónoma de Madrid, 28049 Madrid, Spain
jose.rodrigo@uam.es

The Scanning Tunneling Microscope can be used to fabricate nanoscopic size structures by means of the indentation of the tip against the surface of the studied sample. The resulting connective neck between tip and sample can be elongated in a controlled way until the rupture of the contact, leading to atomically sharpened nanostructures.
This process allows to perform spectroscopic measurements from tunneling to contact regimes at the nanoscale, which permit the investigation of topics like conductance quantization or the presence of different quantum channels that contribute to the conductance of atomic size contacts [1].

If a superconducting material is used as tip and sample, a variety of new phenomena can be investigated in the presence of an external magnetic field. As a result of the sharpening process, the final part of the tip, the nanotip, will have typically dimensions smaller than the coherence length and the penetration depth in the bulk superconductor. This makes the nanotip to remain superconducting at fields much larger that the bulk critical field. If a Type I superconductor is used, we can produce a situation in which the magnetic field penetrates the nanotip, while it is expelled from the rest of the tip due to the Meissner effect [2].

In this work we present experiments on such type of nanostructures made of lead (type I superconductor, Tc=7.2K, Hc(0)=800 G), using a STM operating at low temperatures (from 0.3K to 10K) and under magnetic field up to 1 Tesla. We study the evolution of the electronic density of states of the superconducting nanotip under variations of an external magnetic field. A rich structure is found in the conductance vs field diagrams, which is discussed in terms of the competition between flux quantization effects and the induced field due to Meissner shielding currents in the tip [3].

After the magnetic field is cycled, we obtain conductance curves that indicate the presence of magnetic flux trapped at the tip for zero external field. This effect depends on the tip geometry and temperature and disappears after cycling the tip above the critical temperature. New experimental possibilities based in the controlled confinement of the superconducting condensate in the tip apex region by the application of magnetic fields are discussed, like its use as a magnetic probe in the nanoscale.

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References:

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