

Vortex Imaging in Magnesium Diboride

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Research Group



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The main interest of the group of Prof. Ø. Fischer at University of Geneva is the study of the electronic properties of materials characterised by strong interactions between the conduction electrons.

Examples of materials are superconductors, in particular high temperature superconductors, magnetic materials and in general low dimensional materials.

The main focus of the group is to understand the basic properties of such systems. However, many of these materials are also potentially interesting for various applications and within the group we also address some of these aspects.

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The discovery of superconductivity in magnesium diboride (MgB_2) with a critical temperature of 39 K has created a lot of interest [1].

In addition to the high T_c , this material has turned out to be very interesting from a fundamental point of view, since it is the first clear example of a two-band/two-gap superconductor. Using scanning tunneling spectroscopy (STS) we have performed the first vortex lattice imaging in MgB_2 [2].

spectrum recorded in the so-called normal region at the centre of a vortex. Here the differential conductance is constant, meaning a perfect ohmic behaviour.

It is clear that the spectra at respectively the bulk of the superconductor and in the vortex cores are very different, and measuring the conductance at zero bias voltage one is able to distinguish between the two. In Fig. 2, we show a spectroscopic image, obtained by measuring the zero bias conductance as a function of position after application of a magnetic field of 0.2 T. This shows a hexagonal vortex lattice.

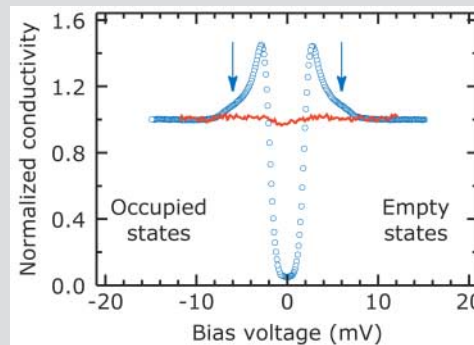


Fig. 1. Differential conductance spectra, tunneling parallel to the c -axis of MgB_2 at 2 K. The superconducting spectrum (blue) was measured in zero magnetic field, and the normal spectrum (red) was measured in the center of a vortex.

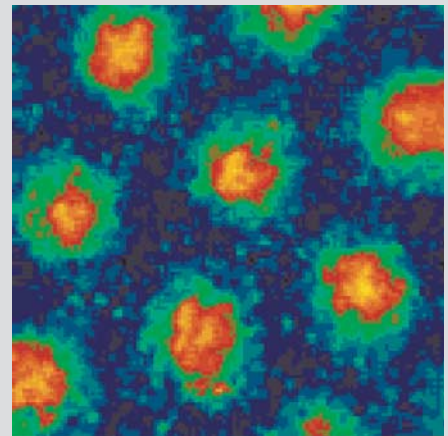


Fig. 2. Spectroscopic image 250 x 250 nm of the hexagonal vortex lattice in MgB_2 for 0.2 T.

Introduction

One of the characteristics of superconductivity is the opening of a gap in the electronic spectrum at the Fermi surface, which can e.g. be measured by tunneling spectroscopy. We have used a scanning tunneling microscope (STM), which is capable of measuring the spectrum on a local scale with atomic precision. Hence, in addition to measuring the superconducting spectrum, the STM is capable of imaging spatial modulations of the superconducting state. Such a modulation can for instance be induced by an applied magnetic field, which in a type-II superconductor such as MgB_2 will introduce vortices consisting of a normal core surrounded by circulating supercurrents, and threaded by a magnetic flux totalling one flux quantum $\phi_0 = h/2e$.

Results

Before going into details it is important to stress that a prerequisite for the results shown here, is the availability of highly homogenous samples. Such single crystals of MgB_2 has recently become available within the MaNEP network, from the group of Janusz Karpinski at ETH in Zürich. Fig. 1 shows (in blue) a superconducting spectrum with clear coherence peaks at ± 3 mV. The measurements were performed, tunneling parallel to the crystalline c -axis. In this configuration the spectrum contains essentially only contributions from one of the two band (π -band), with only a small admixture of the second band (σ -band) showing up as a shoulder at ± 6 mV indicated by the arrows. Shown by red in Fig. 1, is a

Summary and outlook

In addition to the vortex lattice imaging shown here, additional interesting results were obtained and reported in ref. [2]. We have now started measurements tunneling parallel to the basal plane, in which case both superconducting gaps are observed. Other work on MgB_2 within the MaNEP network is reported in refs. [3-6].

References

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A basic introduction on scanning probe microscopy is given at the beginning of the Newsletter.