Electrons in mesoscopic structures at very low temperatures

PICO-GROUP

LOW TEMPERATURE LABORATORY

Electron beam lithography in combination with state of the art cryogenic techniques allows the study of electronic systems under extreme conditions: For structures in the mesoscopic range and at ultra low temperatures in the region of 0.05 K above absolute zero, the temperature of the electrons starts to be independent of the lattice (phonon) temperature: one has to define individual temperatures for both subsystems. Once the electronic system can be considered in good approximation as a free subsystem, many fundamental and interesting questions show up: How can the energy exchange between electrons and phonons be described? How efficiently can the electron subsystem be cooled, when one allows only the hot electrons to tunnel into the surrounding superconductor (SINIS cooler)? Is there a noticeable energy exchange between the electrons and the environment via electromagnetic radiation? These questions concern the understanding of very basic physical phenomena and lead also to new applications like SINIS coolers.

RECENT RESULTS

The principle of solid state SINIS coolers is already well established and is has been considered as an alternative cooling technique for bolometric radiation detections. SINIS structures allow the cooling of an electronic system starting from 300 mK down to below 100 mK, a temperature range which normally requires complicated and heavy techniques like dilution refrigerators. Nevertheless, the performance of SINIS coolers is still quite limited. Substantial progress both in practical performance as well as in understanding the limiting factors was achieved in our group during the last years [J. P. Pekola, et al. Phys. Rev. Lett. **92**, 056804 (2004)]. Figure 1 shows another application of the SINIS technique: One SINIS structure connected to the central island is used to probe the temperature of the electronic subsystem in a metallic island and another one to heat or cool the electrons. The coupling via electromagnetic radiation to the environment can then be investigated as a function of temperature using the SQUIDs as tunable transmission lines.

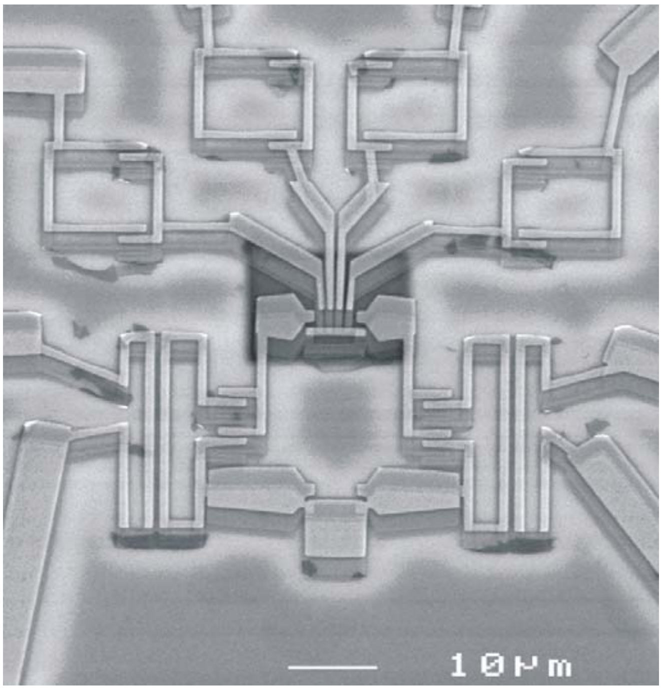

Figure 1: A SEM image of a sample for investigation of electron coupling to the environment via electromagnetic radiation. It is created by three angle shadow evaporation of copper as a normal metal (strong contrast in SEM picture) and aluminium as superconductor (weak contrast, shifted by 2.5 µm to the bottom). The substrate is a standard silicon wafer with an isolating oxide layer. Oxidizing the aluminium and evaporating a 2nd layer of aluminium (SQUID) or copper (SINIS) forms the tunnel barriers.

In the centre, one finds a normal metal island. It is connected via tunnel junctions to four superconducting probe lines, forming two SINIS structures. The coupling of the island to its electrical environment is made tunable by fabricating an SQUID within each line.

A second island (lower part of the image) is connected via SQUIDS with on chip coils, allowing individual tuning of theses transmission lines.

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