NON-EQUILIBRIUM EFFECTS IN METAL/SEMICONDUCTOR-SUPERCONDUCTOR STRUCTURES

PICO-GROUP

LOW TEMPERATURE LABORATORY

Significant progress in the microelectronics fabrication technologies has made it possible to realize complex devices and structures with sub-micron dimensions. Energy distribution of electrons is often non-thermal in mesoscopic structures at low temperature due to their small size and long relaxation times. Often this leads to negative effects, but it may also be useful in applications, e.g., in detectors, controllable Josephson junctions and other devices where non-equlibrium distribution may significantly enhance device parformance.

RECENT RESULTS

In our investigation of SINIS structures we observed deviation from the equilibrium energy distribution in the normal electrode, but the effect was still relatively [J.P. Pekola, T.T. Heikkila, A.M. Savin, J.T. Flyktman, F. Giazotto, F.W.J. Hekking, Limitation of electron cooling]. We are going to investigate the non-equilibrium effects in structures specially optimised for enhanced nonequilibrium. One obvious limitation of creating non-equilibrium by energy dependent injection of electrons between a superconductor and a normal electrode is the heating of superconductor and/or deviation of energy distribution in superconductor from equlibrium. Understanding deviation from equilibrium in a superconductor is one of our objectives.

A new method to control critical current by electronic cooling has been suggested recently and practical realization of supercurrent control by electronic cooling has been demonstrated in our laboratory [A. M. Savin, J. P. Pekola, J. T. Flyktman, A. Anthore, F. Giazotto, Cold electron Josepson transistor, Appl. Phys. Lett. 84 (2004) 4179]. This “cold electron transistor” is a combination of a SINIS thermoelectric cooler with an SNS weak link (Fig. 1). The transistor allows control of supercurrent, which is a few orders of magnitude higher than cooling current through SINIS junctions. High current gain and very low energy dissipation make this device a candidate as a current amplifier in low temperature microelectronic circuits. One of an aims of our research is to realize and utilize non-equilibrium in this transistor. When sufficiently high non-equilibrium can be created, the current-phase relation reverses sign and the current gain is large. The structure can be called a -transistor. The ability to control the supercurrent in the superconducting junction is very important for applied superconductivity, it can be utilised as an amplifier in different superconductor based devices.

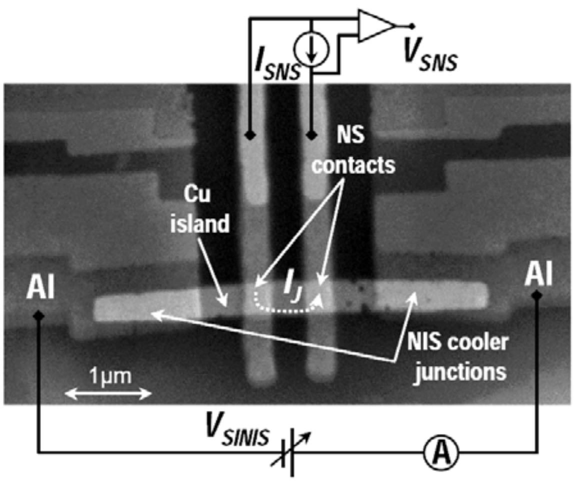

Figure 1. Scanning electron micrograph of a typical structure (“cold electron transistor”) including a sketch of the measurement circuit. Two superconducting Al electrodes are connected through insulating barriers to a Cu island to realize a symmetric SINIS electron cooler. The supercurrent I_J in the Al/Cu/Al junction is tuned upon voltage biasing the SINIS control line.

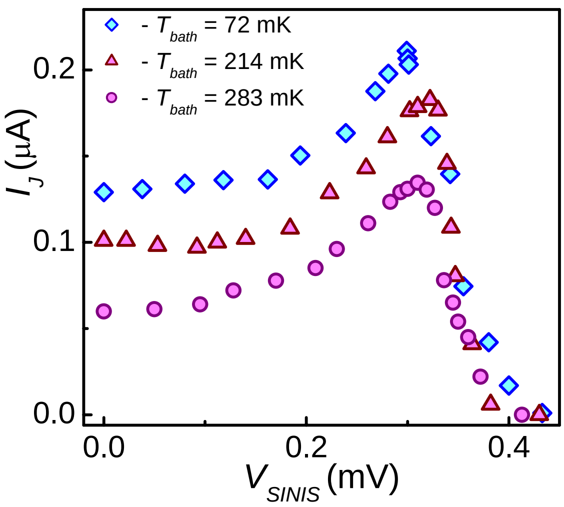

Figure 2. Critical current I_J vs control voltage V_{SINIS} at different bath temperatures. At T_{bath} = 283 mK an I_J enhancement of about 2.2 with respect to the equilibrium value is obtained under maximized hot quasiparticle extraction.

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