Magnetic response of micro-SQUIDs containing a semifluxon

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(Dated: June 9th, 2006)

It is predicted that the current-phase relation (CPR) of weakly coupled superconductors can differ substantially from a simple sine form. This is due to higher Andreev-reflection processes in the high transparency case. The current-phase relation of Josephson-junctions is commonly investigated by embedding the junction in a superconducting ring resulting in a rf-SQUID-geometry.

We present measurements of the magnetic response of such samples. In order to measure the magnetic response of a superconducting loop with an embedded Josephson junction, we deposited the loop onto the active area of a Hall-sensor (Fig. 1a).

For the sample fabrication we are using a mask system employing shadow evaporation technique consisting of a sacrificial layer of polyethersulfone, a polymer that is highly stable under thermal stress. To match the special needs for evaporation of refractory metals like Niobium we use Si_3N_4 as mask material that is deposited by PECVD. As top layer standard PMMA for electron beam lithography is used in order to pattern the Si_3N_4. After the pattern transfer to the Si_3N_4 by reactive ion etching (RIE) an isotropic oxygen-plasma is used to create an undercut of up to 1 μm.

Upon sweeping an external magnetic field, the phase difference across the Josephson-junction can be controlled owing to the fact that the superconducting ring together with the junction needs to obey flux quantization. In order to do so, in general a circulating supercurrent that corresponds to the phase difference across the junction will flow. This circulating current can be detected via its magnetic signal by means of Hall-magnetometry. When we measure the magnetic response of the ring for one of our samples where the angle adjustment during the shadow evaporation resulted in a parallel arrangement of both, a SFS- and a SNS-junction. In these samples we see an additional substructure in the switching behavior of the loop for a certain range of the external magnetic field. A typical measurement consists of up- and down-sweep over a range of ±2mT. At the point where the critical current of the junction is reached, one quantum of magnetic flux can enter the loop which can be seen as a sharp jump in the Hall-voltage yielding a sawtooth-like pattern. Upon increasing the external magnetic field further, more flux quanta enter the loop one after another. At a certain value of the external field, depending on the temperature at which we measure, a substructure starts to evolve (Fig. 1b). An additional peak arises upon increasing the external field while the original peak gets smaller and smaller. Finally the new peak superimposes the original sawtooth giving the same switching behavior as before. We interpret this as an effect of the magnetic coupling between the superconducting loop and a semifluxon that is supposed to form at the boundary between the two different parts of the junction. A numerical simulation with realistic parameters can fully reproduce our experimental results.

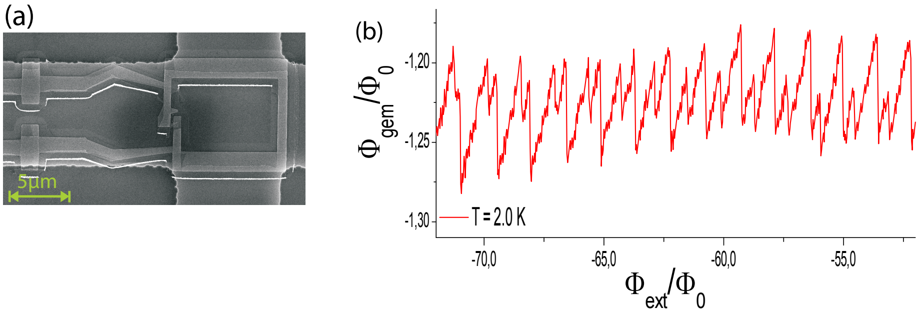

Abbildung 1: (a) Electron micrograph of the sample setup. The superconducting ring sits on top of the active area of a Hall-sensor. (b) Magnetic moment vs. external flux. The additional substructure encountered in our double junctions is clearly visible.