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Performance of a 2-hole Y–Ba–Cu–O rf SQUID

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Abstract. A two-hole rf SQUID has been fabricated out of bulk YBCO by drilling two holes and careful erosion of the wall between the holes. Commercial SQUID electronics is inductively coupled to the SQUID through a copper coil glued in one of the holes. Periodic oscillations in V–B characteristic of the SQUID are observed at 77 K. The spectral density of the flux noise in the white noise region is $5\cdot5 \times 10^{-4}\Phi_0/\sqrt{\text{Hz}}$. The flux noise is frequency-dependent below 200 Hz.

Keywords. Bulk rf Y–Ba–Cu–O SQUID; rf SQUID; granular weak link SQUID.

1. Introduction

A conventional rf superconducting quantum interference device (rf SQUID) has a preset point contact linking two or more holes for increasing device inductance, all made out of a bulk niobium block (Clarke 1989). This device has considerably large sensitivity capable of detecting the brain or heart signals but it can be operated only at 4·2 K, in liquid helium and this imposes experimental constraints. After the discovery of high T_c superconductor, Koch *et al* (1987) first demonstrated the SQUID behaviour in it. There are several reports on the realization of high T_c SQUID using the grain boundary weak links (Harrop *et al* 1988; Poulshkin and Vasiliev 1989). In this paper we report the fabrication of a 2-hole rf SQUID device made of bulk YBCO superconductor. After coupling to suitable electronics reasonably good V–B and flux noise characteristics are observed at 77 K.

2. Experimental

Two-hole SQUID sensor of YBCO was prepared from the polycrystalline pellet. These pellets were prepared by the standard method of calcination and sintering using 99·9% pure Y_2O_3, $BaCO_3$ and CuO. Two holes of diameter 1 mm separated by a wall of thickness 0·5 mm were drilled in the pellet. The microbridge between the two holes was realized by careful erosion of the wall between the two holes using fine needle files. The final dimension of the microbridge was 50 μm × 70 μm. Figure 1 shows the schematic diagram of the two-hole YBCO SQUID sensor. The view of the constriction illustrates the arrangement of grain boundary junctions for rf SQUID operation. Realization of the good microbridge was a very delicate process and it was done with great care so that the erosion did not lead to any crack. In order to see the V–B behaviour of the two-hole SQUID a modified commercial rf SQUID electronics was used. The schematic diagram of this electronics along with the connected SQUID sensor is shown in figure 2. The electronics consists of a 19 MHz

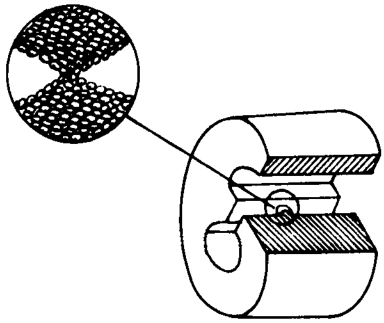

Figure 1. Schematic diagram of a 2-hole Y–Ba–Cu–O SQUID rf.

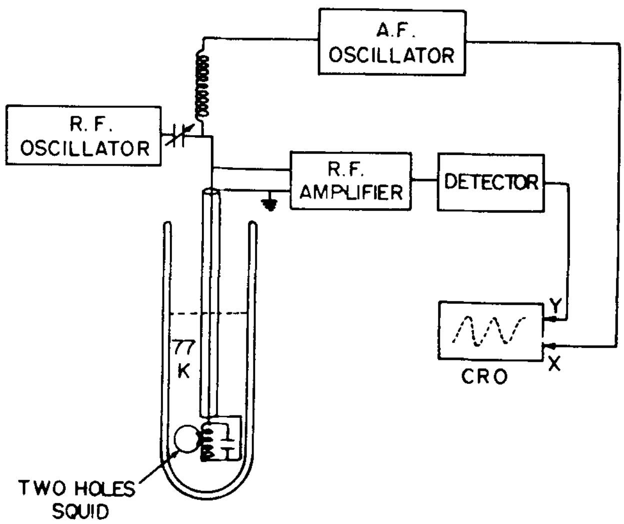

Figure 2. Schematic diagram of experimental set-up for rf SQUID characterization.

rf oscillator and a 200 Hz oscillator. A 50 turn copper wire (36 SWG) coil of diameter 0·95 mm was glued in one of the holes for rf biasing. Values of inductance and capacitance of the tank circuit were so chosen that its resonance frequency was 19 MHz. To observe the V–B SQUID behaviour of the two-hole sample, detector output of the commercial electronics was connected to Y-channel of CRO and the output from 200 Hz oscillator was given to X-terminal for providing sweep. Three layers of μ-metal were used for shielding. In addition, a high T_c superconducting YBCO tube was also used as a shield. Flux noise spectrum of the SQUID was also studied using the lock-in technique.

3. Results and discussion

Figure 3 shows V–B curves of the two-hole SQUID at 77 K. The observed triangular pattern was a typical characteristic of rf SQUID. The amplitude of the pattern was

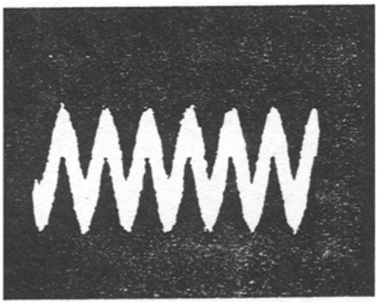

Figure 3. V-Φ curve of rf SQUID at 77 K.

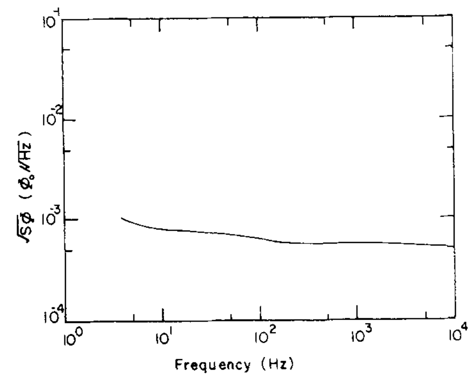

Figure 4. Flux noise spectrum of the rf SQUID at 77 K.

found to vary on changing the I_{rf} through the coil. For a suitable rf biasing current, peak-to-peak value of the detector output was 5 mV. Separation between two peaks corresponds to one flux quantum. The transfer function was calculated as $10\,mV/\Phi_0$. Figure 4 shows the flux noise density spectrum of the two-hole YBCO sensor. The flux noise density was calculated using the formula $S_\Phi(f) = S_V(f)/(\partial V/\partial\Phi)^2$, $\partial V/\partial\Phi$ being the transfer function of the SQUID. The noise spectrum shows that for frequency > 200 Hz, S_Φ was $5{\cdot}5 \times 10^{-4}\Phi_0/\sqrt{Hz}$ and it remained constant. For these range of frequencies two-hole SQUID is five times noisier than the commercial rf niobium SQUID operating at liquid helium. However at lower frequencies S_Φ was found to increase due to the intrinsic $1/f$ noise. The source of this $1/f$ noise is not yet fully understood. This perhaps arises due to the thermal activation of trapped flux (Tesche 1981). The noise observed in our experiment is also due to the quality of the micro-bridge. Our aim was to achieve a single grain boundary junction at the narrowest part of the constriction to achieve the ideal behaviour; however in practice it was extremely difficult to achieve such a good quality microbridge. The presence of three or more grains can also introduce noise. Recently Ferrari *et al* (1988) reported the measurement of noise in thin film ring of high T_c superconductors which showed that the $1/f$ noise was due to the intrinsic polycrystalline property rather than due to bulk current. The two-hole rf SQUID uses the grain boundary junction; thus it has its own intrinsic limitation for achieving ultimate sensitivity. It has been recently shown that $1/f$ noise in high quality epitaxial film is about two orders of magnitude lower than the best polycrystalline films (Ferrari *et al* 1989). Since these films do not contain grain boundary weak links, one has to use S-I-S type Josephson tunnel junctions to fabricate SQUIDs (Clarke 1989) with flux sensitivity comparable to the commercial d.c. SQUIDs based on tunnel junctions.

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