LTC SQUID DEVICES FOR BIOMAGNETIC INSTRUMENTATION

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One of the most relevant dc-SQUID application concerns with MEG and MCG measurements. They require a low frequency high magnetic field sensitivity.
In this framework, improved design and reliable procedures to fabricate LTc superconducting SQUID devices, based on niobium technology, have been developed.
Presently such devices are working in a 28-channel system, in two 80-channel planar systems and a 160-channel helmet system. Moreover a 500-channel vectorial system is under construction.

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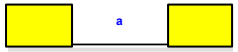
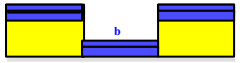
Aims of this project are:

- **Development of dc-SQUID sensor for measurements in Biomagnetism, Geophysics, Susceptometry in the framework of specific projects.**
- **Development of multichannel SQUID system for measurements in biomedicine.**
- **Foundry activity for: •research purposes •industrial applications**

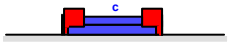
Fabrication procedure



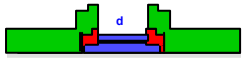
Photoresist patterning for multilayer lift-off process



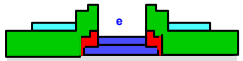
Deposition of multilayer sandwich by dc-magnetron sputtering



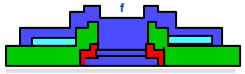
Junction geometry definition and insulation by Selective Anoditation Process (SNAP)



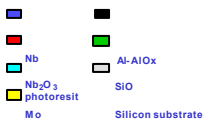
Junction insulation by SiO layer patterned by lift-off



Shunt resistor by molibdenum layer patterned by lift-off



Niobium wiring

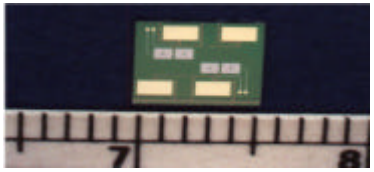


SQUID sensors: dc-SQUIDs in magnetometer and gradiometer configurations

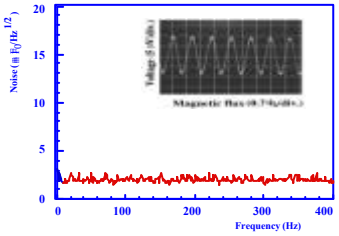
dc-SQUID magnetometers and dc-SQUID in a double-washer parallel configuration have been fabricated.
For dc-SQUID magnetometers field-noise improvements have been achieved by increasing the effective area by higher SQUID inductance in order to increase the mutual inductance between the input coil and SQUID. A design of dc-SQUID magnetometer is shown at right. The feed-back coil, the APF coil, and a set of thin film Mo resistors for APF are integrated on the chip. The devices measured in FFL configuration with APF scheme exhibit a magnetic field noise sensitivity better than 3fT/Hz$^{1/2}$ in the white noise region.
For double-washer dc-SQUID the two niobium washers are connected in such a way to form a first order planar gradiometer with respect to background fields. The high input coil inductance, more than 500nH, allows a good matching with external load inductance.

DOUBLE-WASHER dc-SQUID PERFORMANCES

Modulation depth	15-20 mΦ
Responsivity	50-100 mΦ/FΦ
Input current sensitivity	0.5 mΦ/ FΦ
SQUID flux noise	2 m FΦ /Hz$^{1/2}$
1/f corner	less than 1 Hz
Intrinsic SQUID current noise	1 pA/ Hz$^{1/2}$



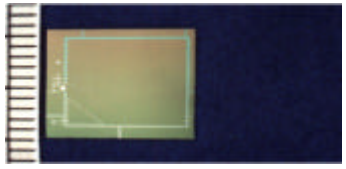
dc-SQUID in a double-washer configuration. The two washers accommodate an input coil consisting of 80 turns of 4 μm wide niobium strip.



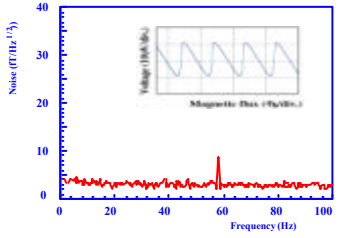
Flux-noise spectrum for Flux-Locked-Loop operation of dc-SQUID in a double-washer configuration measured using conventional modulated electronics. The voltage-flux characteristic is also shown in the inset.

dc-SQUID MAGNETOMETER PERFORMANCES

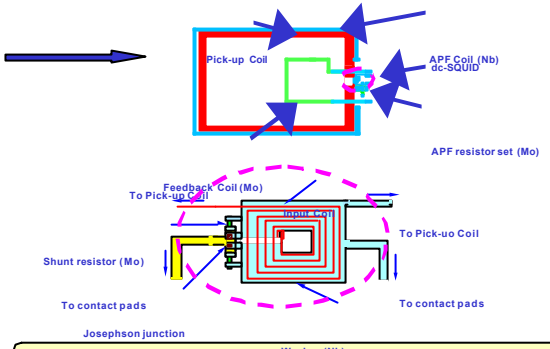
Modulation depth	15-20 mΦ
Responsivity	50-100 mΦ/FΦ
Field-flux sensitivity	0.7 nT/ FΦ
Effective area	3 mm^2
Magnetometer flux noise	4.3 m FΦ/Hz$^{1/2}$
Magnetometer field noise	3 fT/ Hz$^{1/2}$
1/f corner	less than 3 Hz



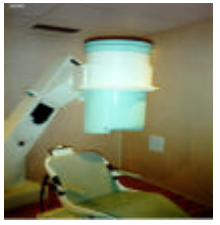
Integrated magnetometer and particular of the dc-SQUID. Washer, input coil, Josephson junctions and shunt resistors are shown.

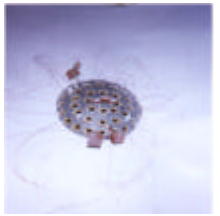


Field-noise spectrum for Flux-Locked-Loop operation of an integrated dc-SQUID magnetometer measured using Additional Positive Feedback (APF). The inset shows the voltage-flux characteristic with APF.



Real Systems





80-channels planar system for biomagnetic measurements. It is operating at ZIMBT University of Ulm (Germany). The system is developed by AtB-Advanced Technologies Biomagnetics.
The sensor electronic read-out, shown in the lower picture, is positioned at the top of the dewar.

160-channels helmet system for biomagnetic measurements. It is operating at ITAB University of Chieti (Italy). The system is developed by AtB-Advanced Technologies Biomagnetics.
In the lower picture part of the dc-SQUID magnetometers arranged in a helmet shape is shown.

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