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Investigations on Improvements of Oscillating Superleak Transducers

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Abstract

Three years ago, Oscillating Superleak Transducers (OSTs) were introduced by Cornell University for quench localisation on superconducting cavities, and are now used in several labs all over the world. There are several efforts ongoing to improve the design and accuracy of these devices. Additionally there are studies on improving the sensitivity of the OSTs themselves. This report presents the idea of changing the roughness of the electrode's surface below the membrane.

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1 Introduction

Superconducting cavities are commonly used for particle accelerators. For electron accelerators 1.3 GHz niobium cavities have been established as a quasi-standard. The performance of these cavities at high-gradients is still a challenge and often limited by local thermal breakdowns ("quench"). Gradients exceeding 30 MV/m are required for future accelerator projects like the International Linear Collider (ILC) [1]. To locate the quench positions during a cold rf test and understand its cause, one can use temperature mapping or the second sound induced by the quench. To detect the second sound in helium, Oscillating Superleak Transducers (OSTs) [2] are used. These devices are built analogously to condenser microphones and use a thin porous membrane sputtered with a conductive layer on one side. This membrane is placed on a brass electrode as second "plate" of a capacitor. The very small distance between membrane and brass electrode changes when the second sound interacts with the membrane, leading to a change in the capacity which can be measured. Current OSTs [3] show good results, however, in a "production environment" there is still a demand for improving the sensitivity of the detectors. A first attempt to modify the surface of the brass electrode as described in this report.

2 Capacity change in an OST

The distance between the porous membrane and the brass electrode is very small, typically a few 10 µm. At constant voltage the current is caused by a change of capacity $\mathrm{d}C \sim d^{-2}\,\mathrm{d}d$ so that a smaller d seems attractive. Since the brass electrode has a residual roughness from machining the capacity change can be approximated by a parallel circuit of infinitesimal plate capacitors. This leads to smaller capacity changes in the areas of grooves and larger changes in the protruding areas. To test this idea a smoothed brass surface below the membrane with defined pits (see appendix A and section 3) and a very smooth surface has been measured and the second sound signal has been recorded.

3 Test setup

The cryolab at CERN provides a vertical cryostat with an inner diameter of 19.5 cm which is sufficient for testing three different OSTs at the same time. Two SMD resistors ("heaters", see appendix B) are mounted within a distance of 122.0 mm as heat sources below each OST. The three sensors are installed with the following configuration:

– a "standard" OST as used in the vertical cavity test stands at DESY as a reference
– an OST, the Kapton-OST, with a thin (12 µm) porous Kapton[3] foil in-between membrane and electrode (for the structure of the foil see appendix A) in order to give a defined surface structure under the membrane
– an OST with a well-polished shiny brass electrode

The results of a first measurement on June 16th were verified in a second run on July 7th. For the second run the electrode of the standard OST was polished and the Kapton foil of the first OST was transferred to the original "polished" OST turning this one into the new "Kapton OST" while the old "Kapton OST" turns into a polished OST as shown in Figure 1.

[3]Kapton is a registered trademark of E. I. du Pont de Nemours and Company

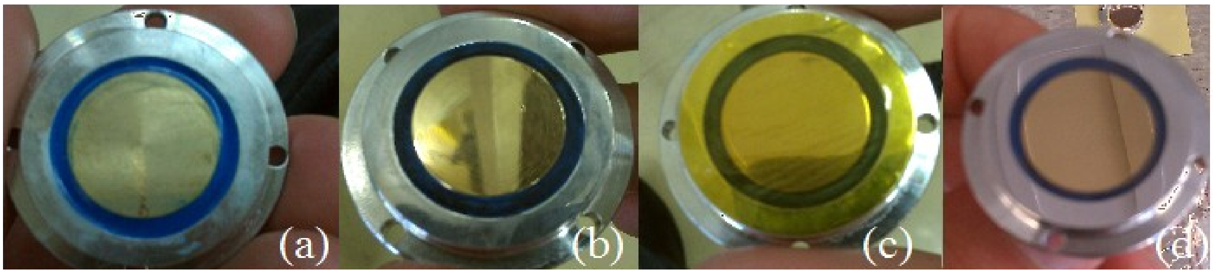

Fig. 1 – Photographs of (a) the normal electrode, (b) the polished electrode, (c) the electrode with the Kapton foil – with the polished electrode underneath – and (d) the normal electrode after treatment.

4 Test results

To compare the results for the different electrodes, the peak-to-peak values for the signals gained from the heat pulses (0.2 ms long, U=10V, R=(65±3) Ω – E≈0.3 mJ total energy deposited) of the six heaters have been registered. For each of the three OSTs two signals of the two different corresponding SMD resistors have been recorded for different temperatures (six signals per temperature level). The ratios of the maximum peak-to-peak values of the modified OSTs to the reference (normal) OST are given in the following table. “Normal polished” stands for the results of the normal electrode after polishing, i.e. picture (d) in figure 1, whereas “Kapton” and “Polished” represent the combined results of the first and second measurement.

Tab. 1 – Detected signal amplitudes normalised to the “normal” unprepared OST

	Normalised amplitudes		
Heater	**Normal polished**	**Kapton**	**Polished**
R1	3.5±0.2	0.84±0.05	2.1±0.2
R2	2.7±0.1	1.2±0.1	3.1±0.3

The results show a strong increase of at least a factor of two in the signal’s amplitude for both polished electrodes, the initial one and furthermore the normal one after its treatment. The OST with the Kapton foil does not show any significant variation in amplitude.

One possible explanation for the observed enhancement of the signal by polishing the electrode in addition to the one mentioned above is the decrease in friction during the membrane’s oscillations. The surface of the electrode becomes less adhesive towards the movement of the porous membrane after polishing. The observation that the oscillations seen in the signal of a polished OST last longer than in the other signals gives support to that assumption; cf. Figure 2.

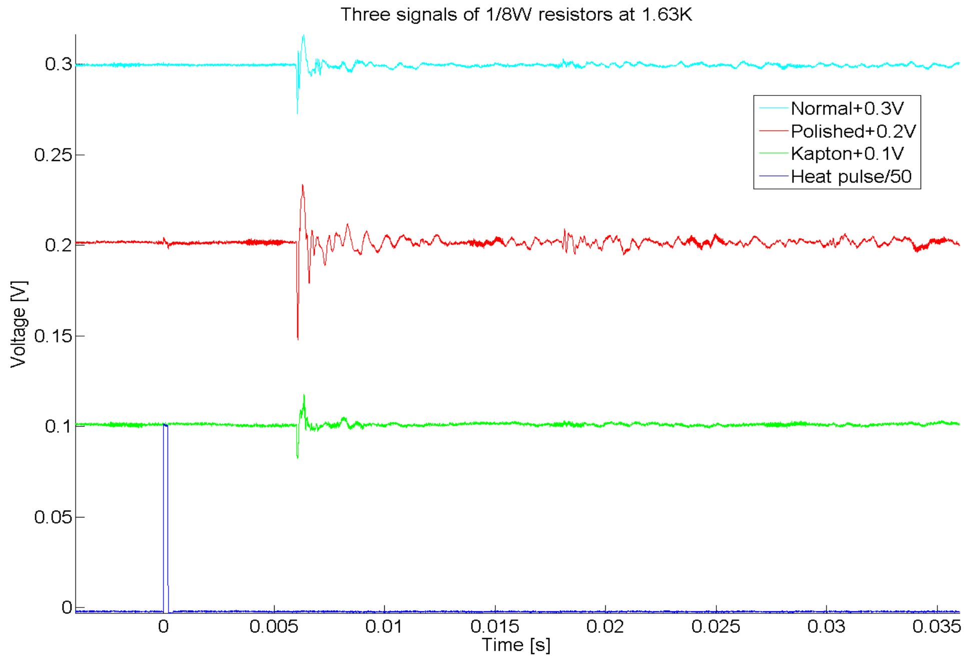

Fig. 2 – Three example signals of the different OSTs: The signals were taken individually with the corresponding 1/8 W SMD for each OST while the temperature was kept constant within the precision of the measurement.

To verify the reproducibility of the test the normal OST has been polished (as explained earlier) and a second test has been carried out. This leads to a large increase of the detected second sound signals as shown in figure 3.

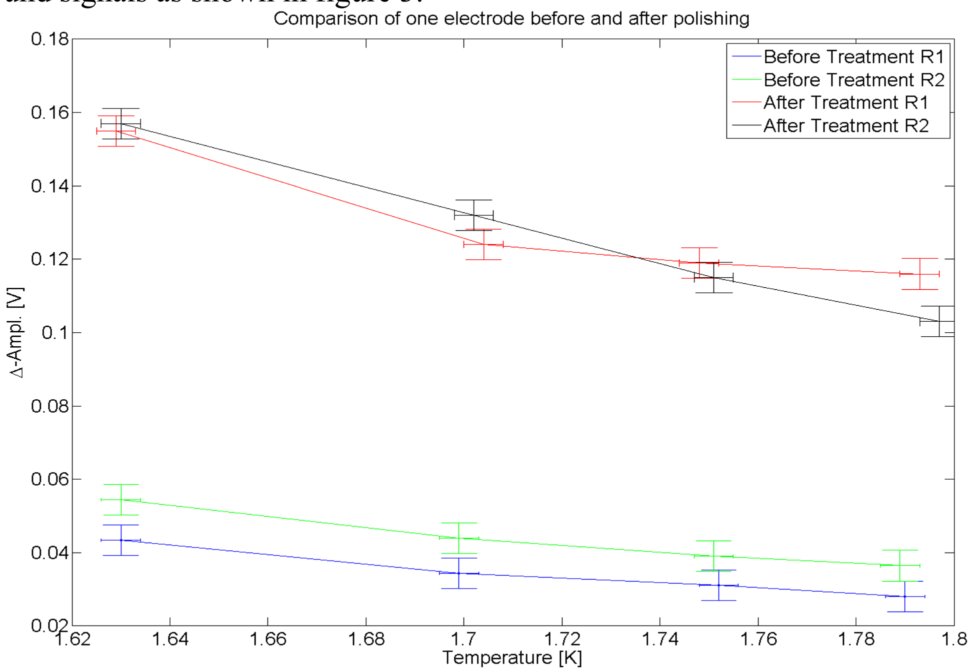

Fig. 3 – A direct comparison of the peak-to-peak measurements of the OST with the normal electrode before (June 17th) and after polishing (July 7th) for two resistors.

5 Conclusion

The signal and hence sensitivity of OST can be improved by at least a factor two by polishing the brass electrode.

Acknowledgement

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References

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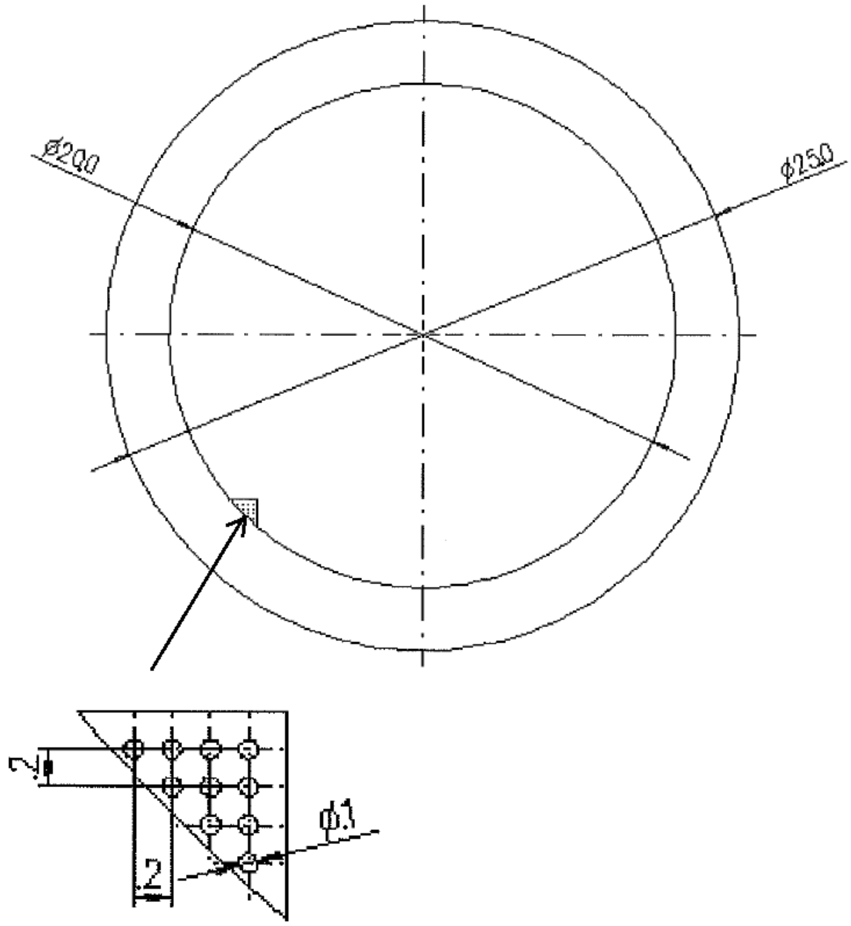
[2] R.A. Sherlock and D.O. Edwards, "Oscillating Superleak Second Sound Transducers," Rev. Sci. Instrum. 41, Pg. 1603 (1970).
[3] Z.A. Conway et al., "Oscillating Superleak Transducers for Quench Detection in Superconducting ILC Cavities cooled with He-II", LINAC '08, Vancouver, September 2008, THP036 http://www.JACoW.org.

Appendix A



This figure shows the engineering drawing of the Kapton foil

Appendix B

The two different used types of SMD resistors are thick film chip resistors of the NRC series from the NIC components corporation. Their face value is 51 Ω and their power rate 1/8 W (R1) respectively 1/10 W (R2). Their resistance was measured to be about 62 to 64 Ω fro the 1/8 W resistors and about 65 to 67 Ω for the 1/10 W resistors in the working temperature range of 1.63 to 1.8 K.