# Change In High Field Q-slope By Anodizing Of The Baked Cavities

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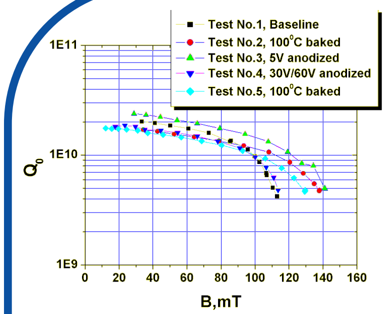
The High field Q-slope is a known effect of degradation of the Q at high fields without X-rays. The low temperature baking reduces the Q-slope by modifying the RF Nb layer. The goal of these experiments was to determine the depth of "baking modified niobium" responsible for the improvement in the high field Q-slope. We tried to approach this goal by anodizing (electrolytic "oxidizing") baked Nb cavities. Reported here are the results of these experiments supported by temperature maps.




LE1-30's story:

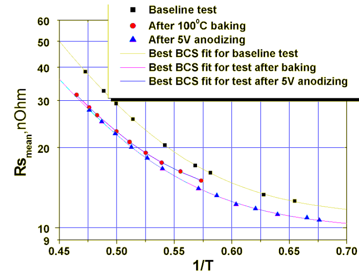
Test No.1: baseline test, the 500 RRR small grains cavity was chemical polished (BCP – 1:1:2), high pressure rinsed. All assembling and disassembling is done in the class 100 clean room. Some X-rays at B = 86 mT, processed. The highest field B = 113 mT (no more power).

Test No.2: The cavity was baked "In-situ" at 100°C, some X-rays at B = 91 mT, processed. The highest field was B = 137 mT (no more power)

Test No.3: The cavity was removed from the test stand and anodized for 5 volts. Some X-rays at B = 93 mT, processed. The highest field was B = 141 mT (no more power).

Test No.4: The top half of the cavity was anodized for 30 volts, the bottom half - for 60 volts. No X-rays. The highest field was B = 116 mT.

Test No.5: The cavity was baked at 100°C "In-situ", strong X-rays during the first test, the cavity was removed from the test stand and re-rinsed. The highest field was B = 130 mT (no more power).




An attempt to measure change in BCS properties of niobium after baking and anodizing was made, unfortunately, the data was taken only for first three tests.

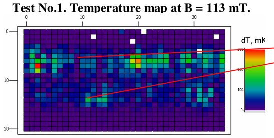
In order to measure BCS parameters of niobium, we measured quality factor of the cavity versus bath temperature at the same low field. All the data was taken for bath temperature below 2.1 K, thus we have confidence, that all niobium surface was at the same temperature. Then the mean resistance of the niobium is geometrical factor of the cavity over quality factor. For this cavity G = 255 Ω.

The data was fit with formula:

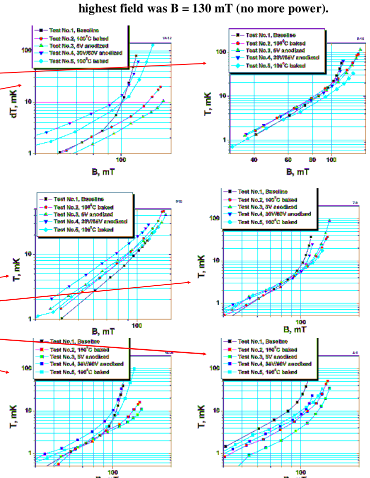
$$Rs = R_{res} + A \times \ln(4kT/hf) \times e^{-B/T}/T$$

| | Rs, nΩ | A×10⁵, Ω×K | B, K |
|---|---|---|---|
| Baseline | 10.92 ± 0.09 | 3.82 ± 0.25 | 17.03 ± 0.14 |
| 100°C bake | 11.78 ± 0.14 | 3.93 ± 0.44 | 18.07 ± 0.26 |
| 5V Anodizing | 9.79 ± 0.07 | 2.08 ± 0.19 | 16.56 ± 0.20 |

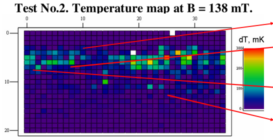
Test No.1. Temperature map at B = 113 mT.




Even so heating is pretty much uniform, one can distinguish several hot spots, which contribute to the overall heating the most.

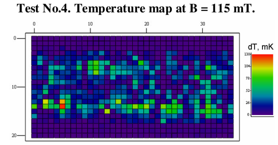



Test No.2. Temperature map at B = 138 mT.



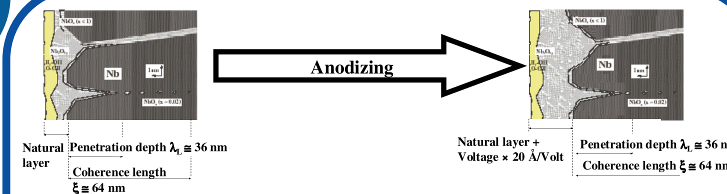

After baking two hot spots in the lower part of the cavity are removed. Some connection between hot spots in the upper part of the cavity before and after baking can be made.

Test No.4. Temperature map at B = 115 mT.




Nevertheless the upper and lower part of the cavity was anodized for different voltage, the temperature map is very uniform. Actually, we have never seen more uniform temperature map.

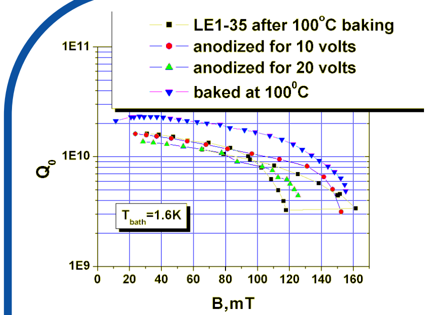
- ✓ The improvement in the high field Q-slope caused by 100⁰C baking is gone after 30 volts anodizing.
- ✓ Before baking all thermometers in the high magnetic field regions show rapid increase in losses at high field (Q-slope), thermometers in the low magnetic field region don't show anomalous slope.
- ✓ After baking some thermometers in the high magnetic field region don't show rapid increase in losses at high field, and some still show anomalous slope, but onset of the slope is shifted to higher fields.




Anodizing is a process of electrolytic oxidation of niobium. This technique was developed at Siemens laboratories by H.Martens et al. for Nb in early 70th. The idea was to create a protective oxide films on Nb surface. The thickness of grown oxide layer is proportional to applied voltage. The approximate relation is 20 angstrom per volt.

The present knowledge is that anodizing neither improves nor worsens cavity performance before bake. Thus possible conclusion to this fact can be that Nb-oxide interface created by anodizing is close by its RF properties to that of natural oxide. Thus by applying anodizing one can "eat" up Nb, create thicker Nb pentoxide and shift Nb-oxide interface deeper into niobium surface.

The present knowledge is that some kind of diffusion process involved in the mild "in-situ" baking of the niobium cavities. Successful baking modifies Nb-oxide interface and adjacent niobium. By applying anodizing on the successfully baked BCP and EP cavities, we consume some part of "baking modified niobium" and move deeper in the Nb with the hope to reach the layer of niobium, that was not modified by baking.




LE1-35's story:

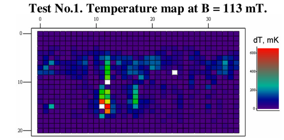
Test No.1: baseline test, the 300 RRR small grains cavity was vertically elctropolished, slightly chemically polished (BCP – 1:1:2), high pressure rinsed, and then baked "In-situ" at 100°C. All assembling and disassembling is done in the class 100 clean room. X-Rays at highest field. The highest field B = 162 mT.

Test No.2: The cavity was removed from the test stand and anodized for 10 volts. Field emission at B = 118 mT, processed. X-rays at the highest field. The highest field was B = 152 mT.

Test No.3: The cavity was removed from the test stand and anodized for 20 volts. X-rays at the highest field. The highest field was B = 125 mT.

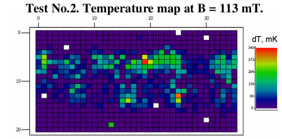
Test No.4: The cavity was baked at 100°C "In-situ". X-rays at the highest field. The highest field was B = 155 mT (no more power).

Test No.1. Temperature map at B = 113 mT.



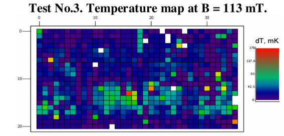

The temperature map shows hot spots characteristic for field emission. Presumably we had two emitters, which caused X-rays at highest field. But since we were looking for degradation of the Q with anodizing we continue with experiments.

Test No.2. Temperature map at B = 113 mT.



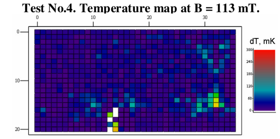

None of the hot spots here looks like field emission spot. The conclusion is – thou there were some X-rays, field emission heating was not dominating effect.

Test No.3. Temperature map at B = 113 mT.




Again we had some X-rays, but we could not identify any of the hot spot as a field emission heating.

Test No.4. Temperature map at B = 113 mT.




After baking many of the hot spots disappeared and field emission is again a limit factor for the cavity performance.

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