Change in High Field Q-slope by Anodizing of the Baked Cavities
G. Eremeev, H. Padamsee

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.

The improvements in the high field Q-slope caused by 100°C 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.

**LEL-35’s story:**
Test No.1: baseline test, the 500 RRR small grain cavity was chemical polished (BCP) – L-T, high pressure rinsed. All anodizing and disassembling is done in the class 10 clean room.

Some X-rays at B = 46 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 = 39 mT, processed. The highest field 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 = 90 mT, processed. The highest field 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 retested. The highest field was B = 136 mT (no more power).

An 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 70’s. The idea was to create a protective oxide film on Nb surface. The thickness of grown oxide layer is proportional to applied voltage. The approximate relation is 20 Å/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 “wash” Ni, create thicker Nb protection and shift Nb-slopes into a 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-side interface and adjacent niobium. By applying anodizing on the successfully baked BC and EP cavities, we consume some part of “baked modified niobium” in a deeper in the Nb with the hope to form a layer of niobium, that is not modified by baking.

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 value of the niobium is the mean value of the cavity over quality factor. For this cavity G = 255 kHz.

The data was fit with formula:

\[ B = \frac{v_0}{2} \left( R_s + R_0 \right) \left( U + \frac{A}{R_0} \right) \times \frac{\ln(4kT/hf)}{B_s} \]

where:
- \( R_s \) = resistance of the cavity
- \( R_0 \) = resistance of the cavity
- \( A \) = area of the cavity
- \( k \) = Boltzmann constant
- \( T \) = temperature of the cavity
- \( hf \) = frequency of the cavity
- \( U \) = field at the cavity

The temperature map shows hot spots [checkbld] in the lower part of the cavity before and after baking can be made.

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.