Susceptibility Measurements on Niobium for TESLA Cavities

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Mutual Induction ac-Susceptibility Measurements

- The in-phase $U'$ and out-of-phase part $U''$ of the induced signal is measured with a lock-in amplifier.
- $\chi'$ and $\chi''$ are calculated from these values:
  
  \[
  \chi' \propto \frac{U''}{\omega} \\
  \chi'' \propto \frac{U'}{\omega}
  \]
Mutual Induction ac-Susceptibility Measurements

- $B_{c2}$: Lower critical field of the bulk
- $B_{c3}^S$: Surface field of the surface layer
Mutual Induction ac-Susceptibility Measurements

- $B_{c1} = \frac{B_{c1,\text{meas.}}}{1-N}$
- $N = 0.34$
  (Demagnetisation-factor)
Sample preparation

• Cylinders, $\varnothing=2.7$ mm, $h=2.7$ mm electro-eroded from Nb sheets for cavity production
• $\sim 20 \mu m$ BCP
• 800°C annealing in vacuum for 2 hours
• $\sim 20 \mu m$ BCP
• Baked samples:
  48 hours at $\sim 120^\circ C$ in vacuum
  ($< 5 \times 10^{-7}$ mbar)
Unbaked / ~120°C baked

- Unbaked
  \( B_{c2} = 267 \text{ mT} \)
- After 120°C bake
  Calculated:
  \( B_{c2}^S = 316 \text{ mT} \)

\[ H_{c3} = 1.7 \times H_{c2} \]

\( H_{c3}^S \)

\( B_{c2} \)

\( B_{c2}^b \)

\( \text{Nb, unbaked} \)

\( \text{Nb, baked} \)
Variation of baking parameters

- Baking time:
  24, 48, 96 hours

- Temperature:
  100°C, 123°C, 144°C
Variation of baking parameters

- Saturation after 48 to 96 hours
- or even a reduction of $B_{c3}$?
Electropolished samples

Preliminary results of first measurements!

- No significant difference after a light EP (40 µm)
- Large rise of $B_{c2}^S$ to 306 mT after 150 µm EP
Baked, electropolished samples

- Large rise of $B_{c2}^S$ after baking
- from 306 mT to 365 mT (150 µm EP)
- and from 282 mT to 388 mT (40 µm EP)
Oxygen content of the surface layer

To the oxygen content of Nb+O alloys (with < 1 at% O) applies the empirical formula (from the data of Koch et al. 1974):

$$X \text{ (in at}\% \text{ O}) = (B_{c2} - 276\text{mT})10^{-3}/\text{mT}$$

<table>
<thead>
<tr>
<th></th>
<th>Bc3S/mT</th>
<th>Bc2S/mT</th>
<th>at%O</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCP unbaked</td>
<td>464</td>
<td>273</td>
<td>0.00</td>
</tr>
<tr>
<td>baked 123C, 48h</td>
<td>560</td>
<td>329</td>
<td>0.05</td>
</tr>
<tr>
<td>baked 144C, 48h</td>
<td>625</td>
<td>368</td>
<td>0.09</td>
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<tr>
<td>150µm EP unbaked</td>
<td>520</td>
<td>306</td>
<td>0.03</td>
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<tr>
<td>baked 123C, 48h</td>
<td>620</td>
<td>365</td>
<td>0.09</td>
</tr>
<tr>
<td>40µm EP unbaked</td>
<td>480</td>
<td>282</td>
<td>0.01</td>
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<tr>
<td>baked 123C, 48h</td>
<td>660</td>
<td>388</td>
<td>0.11</td>
</tr>
</tbody>
</table>
Acknowledgments

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