RF Characterization of an S-I-S’ Sample

S. Keckert, O. Kugeler, D. Tikhonov, J. Knobloch (HZB)
A.-M. Valente-Feliciano (JLab)
Motivation

On the way towards high gradient

- S-I-S' structure shields bulk superconductor (Nb)
  - $\lambda > \lambda_{\text{Nb}}$
  - $B_{vp}$ can be increased
  - $T_c > T_{c,\text{Nb}}$ reduces surface resistance

[A. Gurevich, Appl. Phys. Lett. 88, 012511, 2006]
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[S. Keckert, SRF’19, Dresden]

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The Quadrupole Resonator (QPR)

- Quadrupole modes at \( \approx 415, 845, 1286 \) MHz
- Operated in vertical cryostat \( \rightarrow \) LHe bath at 1.8 K
- Coaxial structure \( \rightarrow \) thermal decoupling
- Calorimetric measurement of surface resistance
- \( B_{\text{Sample, max}} \sim 120 \) mT (415 MHz) \( \sim 30 \) MV/m (TESLA)
S-I-S´ Sample

75 nm NbTiN – 15 nm AlN – bulk Nb

[Courtesy of Anne-Marie Valente-Feliciano]

THFUA3 talk by A-M. Valente-Feliciano

S. Keckert, SRF’19, Dresden
Baseline measurement – surface resistance

- Bulk niobium, RRR 300
- Sample manufactured at JLab
- nano-polish and EP
- Residual resistance
  23 nΩ (414 MHz)
  73 nΩ (846 MHz)
Baseline measurement – RF quench field

- Low stored energy in QPR: $U \approx 0.1 \text{ J @ 100 mT}$
- Pulsed measurement with few 100 W and fast power meter
- High RF quench field
  - 254 mT (414 MHz)
  - 220 mT (846 MHz)

$$B_q(T) = B_0 \left( 1 - \left( \frac{T}{T_c} \right)^2 \right)$$
S-I-S’ penetration depth

\[ \lambda_{\text{eff}}(T) = \frac{1}{B_0} \int_0^\infty B(x, T) \, dx \]

\[ \Delta f = -\frac{\pi \mu_0 f^2}{G_{\text{Sample}}} \Delta \lambda_{\text{eff}} \]

Dashed lines: Fits using S-I-S’ multilayer theory

\[ \Delta f \propto f \]

Sample Temperature [K]
S-I-S´ penetration depth

\[ \lambda_0(l) = \lambda_L \sqrt{1 + \frac{\pi \xi_0}{2l}} \]

<table>
<thead>
<tr>
<th></th>
<th>Nb</th>
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<td>( T_c ) [K]</td>
<td>9.25</td>
<td>14.3  (Lit: 17.3)</td>
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<tr>
<td>( \lambda_0 ) [nm]</td>
<td>44 ... 46</td>
<td>240 ... 250</td>
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<td>RRR (sc)</td>
<td>15 ... 25</td>
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<tr>
<td>RRR (nc)</td>
<td>320 ... 350</td>
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<tr>
<td>( \xi_0 ) [nm]</td>
<td>39</td>
<td>(5)</td>
</tr>
<tr>
<td>( \lambda_L ) [nm]</td>
<td>32</td>
<td>(150 ... 200)</td>
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<tr>
<td>( \sigma ) [S/m]</td>
<td>(2.1 ... 2.3) \cdot 10^9</td>
<td>2.86 \cdot 10^6</td>
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<td>( \sigma_{RT} ) [S/m]</td>
<td>6.58 \cdot 10^6</td>
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Dashed lines: Fits using S-I-S´ multilayer theory
R(T) at constant B

Q1, Q2: 10 mT
Q3: 8.8 mT
R(T) at constant B
Q1, Q2: 10 mT
Q3: 8.8 mT

$T_{pk} = 8.2 \text{ K}$
$T_{pk} = 4.5 \text{ K}$

$\Rightarrow T_{pk}$ changes with frequency
S-I-S’ vs. Baseline – R(T)

2

➔ non-monotonic R(T) due to increased surface resistance near $T_{pk}$
$\text{S-I-S' - R(T,B) - 845 MHz}$

$T_{pk}$ is independent of RF field
414 MHz
$T_{pk} = 8.2 \text{ K}$

845 MHz
$T_{pk} = 4.5 \text{ K}$

1286 MHz
$T_{pk} < 3 \text{ K}$?

=> Q-slope behavior changes at $T_{pk}$
S-I-S´ RF Quench field

- Hard magnetic quench limit at 20-25 mT
- **Fit** according to S-I-S´ **multilayer theory**

⇒ S-I-S´ allows increase of bulk limit

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- **S. Keckert, SRF’19, Dresden**
Conclusion

SRF characterization of NbTiN – AlN – Nb sample at HZB

➔ Penetration depth measurement consistent with S-I-S´ multilayer theory

➔ First RF critical field measurement of an S-I-S´ structure

➔ Demonstrated increase of quench field

➔ Non-monotonic surface resistance vs. temperature
  ➔ Coupling?
  ➔ ... ?

➔ To be continued: Study of $R_s$ vs. thickness

TUP073, poster by D. Tikhonov (HZB)

Thank you for your attention!