Update on Resistivity Measurements Coated Collimators and Control Procedure

Adnan Kurtulus, Nicolò Biancacci, Benoit Salvant

• **Summary of DTI Mo coating measurements followup:**
  – Quick introduction on the method
  – How close measurements are to expectation?
  – Thermal process impacts
  – Follow up status
  – New cavity production for smaller samples

• **Additional contents:**
  – Measurements on HRMT-35 impacted blocks
  – Measurements on DTI coated CERN Blocks

• **Bench measurements plan on low impedance collimators**
Quick introduction on the method

• The procedure is based on the application of a pillbox cavity optimized for H011 mode operation.
• Mode of operation: H011 (most insensitive to cap contacts)
• Mitered internal part to separate adjacent E modes.

Electric and Magnetic Field distribution of H011 mode at 16.63 GHz
Quick introduction on the method

- The procedure is based on the application of a pillbox cavity optimized for H011 mode operation.
- Mode of operation: H011 (most insensitive to cap contacts)
- Mitered internal part to separate adjacent E modes.
- Copper cavity with open cap -> reference copper end cap.
- DUT replacing end cap: wall resistivity change -> Q change
Simulated Q change vs end cap resistivity

Change in Q vs change in resistivity simulated in CST and reproduced by curve

\[
\frac{Q^m}{Q^{ref}} = \frac{a + b}{a\sqrt{x} + b}
\]

with \( x = \frac{\rho^m}{\rho^{ref}} \), \( a \) and \( b \) resp. power dissipated in the end cap and rest of the cavity.

- **Measured relative Q change for thick metals** (e.g. Cu, Al, In, Ta, Mo, SS, ...) borrowed from TE-VSC-SCC (many thanks!).
- **Resistivity was accurately measured with the Sigmameter** (at 900kHz, many thanks Carlotta, Fede and Jorge for the support!)
- **Curve in excellent agreement with measured data!**
• **Summary of DTI Mo coating measurements followup:**
  – Quick introduction on the method
  – How close measurements are to expectation?
  – Thermal process impacts
  – Follow up status
  – New cavity production for smaller samples

• **Additional contents:**
  – Measurements on HRMT-35 impacted blocks
  – Measurements on DTI coated CERN Blocks

• **Bench measurements plan on low impedance collimators**
How close measurements are to expectation?

Summary of Mo Coated blocks

Resistivity nOhm.m

Decision taken in December

CERN old block: 523
Politeknik old block: 418
DTI old block: 54
How close measurements are to expectation?

Summary of Mo Coated blocks

Measurements are done on samples

Decision taken in December

Resistivity nOhm.m

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>December</th>
<th>January</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cern old block</td>
<td>523</td>
<td></td>
</tr>
<tr>
<td>Politainik old block</td>
<td>418</td>
<td></td>
</tr>
<tr>
<td>DTI old block</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>Pre batch sample-1</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Pre batch sample-2</td>
<td>72</td>
<td></td>
</tr>
</tbody>
</table>

December

January
How close measurements are to expectation?

Summary of Mo Coated blocks

Decision taken in December

Measurements are done on samples

Measurements are done on blocks

Resistivity nOhm.m

- December
- January
- February

- Corn old block
- Politiehok old block
- DTI old block
- Pre batch sample-1
- Pre batch sample-2
- Pre Batch AB1-44
- Pre Batch AB1-45
- Pre Batch AB1-50
- Pre Batch AB1-60

523
418
54
56
72
52
52.6
52.1
66.5
How close measurements are to expectation?

Resistivity nOhm.m

Close measurement follow up

$$\rho = 58 \pm 7.4 \text{ nOhm.m} \quad \text{(Theoretical 53.4 nOhm.m)}$$
• **Summary of DTI Mo coating measurements followup:**
  – Quick introduction on the method
  – How close measurements are to expectation?
  – **Thermal process impacts**
  – Follow up status
  – New cavity production for smaller samples

• **Additional contents:**
  – Measurements on HRMT-35 impacted blocks
  – Measurements on DTI coated CERN Blocks

• **Bench measurements plan on low impedance collimators**
Thermal process impacts

- Thermal treatment is applied to Pre-batch DTI samples.
- It observed that there is **no impact** on resistivities.
• Summary of DTI Mo coating measurements followup:
  – Quick introduction on the method
  – How close measurements are to expectation?
  – Thermal process impacts
  – Follow up status
  – New cavity production for smaller samples

• Additional contents:
  – Measurements on HRMT-35 impacted blocks
  – Measurements on DTI coated CERN Blocks

• Bench measurements plan on low impedance collimators
Follow up status

- Pre-serie B was shipped last Friday to DTI.
- Coated items are expected to be back at CERN in week 22 (27-31/05).
- Actions starting from week 22 will be as follows:
  1) Thermal Treatment (post Mo coating) of MoGr blocks and MoGr samples. (EN-MME)
  2) RF impedance measurement on samples.
  3) Outgassing measurements by TE-VSC-BVO.
  4) Thickness measurement and adhesion.
• **Summary of DTI Mo coating measurements followup:**
  – Quick introduction on the method
  – How close measurements are to expectation?
  – Thermal process impacts
  – Follow up status
  – New cavity production for smaller samples

• **Additional contents:**
  – Measurements on HRMT-35 impacted blocks
  – Measurements on DTI coated CERN Blocks

• **Bench measurements plan on low impedance collimators**
New cavity production for small samples

• New small cavity is on fabrication.
• New connectors are bought with spares (thanks to Elias and Francesco!)
• Dielectric material will be used to shift resonant frequency down (25GHz -> 15.6 GHz).
• It will be used to measure new/old smaller samples (20X20mm).

Courtesy of I.L.Garcia and R.Fiastre
• **Summary of DTI Mo coating measurements followup:**
  – Quick introduction on the method
  – How close measurements are to expectation?
  – Thermal process impacts
  – Follow up status
  – New cavity production for smaller samples

• **Additional contents:**
  – Measurements on HRMT-35 impacted blocks
  – Measurements on DTI coated CERN Blocks

• **Bench measurements plan on low impedance collimators**
Measurements on both clean and impacted surfaces.
• ~fact2 increase in effective resistivity (S21 curve distorted.)
Measurements on both clean and impacted surfaces.

~fact2 increase in effective resistivity (S21 curve distorted.)

Special thanks to Manfred Wendt and C. Castro for the portable VNA!
Measurements on both clean and impacted surfaces.

~fact2 increase in effective resistivity (S21 curve distorted.)
Measurements on both clean and impacted surfaces.

~fact2 increase in effective resistivity (S21 curve distorted.)
Measurements on both clean and impacted surfaces.

~fact2 increase in effective resistivity (S21 curve distorted.)
Measurements on HRMT-35 impacted blocks

Cu on Gr #2

- Measurements on both clean and impacted surfaces.
- ~fact2 increase in effective resistivity (S21 curve distorted.)
- Same relative behaviour for both Mo and Cu impacted blocks.
Measurements on both clean and impacted surfaces.

~fact2 increase in effective resistivity (S21 curve distorted.)

Same relative behaviour for both Mo and Cu impacted blocks.
• Working on simulation to observe stripe effect.
• Summary of DTI Mo coating measurements followup:
  – Quick introduction on the method
  – How close measurements are to expectation?
  – Thermal process impacts
  – Follow up status
  – New cavity production for smaller samples

• Additional contents:
  – Measurements on HRMT-35 impacted blocks
  – Measurements on DTI coated CERN Blocks

• Bench measurements plan on low impedance collimators
Performed measurements on an old CERN produced Mo coating on Gr block.
- 1 face: old CERN coating
- 3 remaining faces coated by DTI.
- Good performance confirmed but **old non-smooth bulk surface decreases conductivity.**
Measurements on DTI coated CERN Blocks

Mo coating at DTI

- Measurement done also on specific samples by C.Accettura at DC.
- Resistivity of Mo on Gr (R4450) and MoGr (Nb8304Ng)

<table>
<thead>
<tr>
<th>Material</th>
<th>#sample</th>
<th>Average [nOhm.m]</th>
<th>Dev. Standard [MS/m]</th>
<th>Dev. Standard [% of the average value]</th>
<th>Uncertainty [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphite R4550</td>
<td>8</td>
<td>476</td>
<td>2</td>
<td>~36</td>
<td>~36</td>
</tr>
<tr>
<td>Nb8304Ng (MoGr)</td>
<td>12</td>
<td>43.4</td>
<td>6</td>
<td>~30</td>
<td>~43</td>
</tr>
</tbody>
</table>

- **Roughness effect** might play a role on Gr meas.

https://indico.cern.ch/event/816840/contributions/3412132/attachments/1842475/3021740/20190510_4probesmethod.pdf
Measurements on DTI coated CERN Blocks

- Performed measurements on an old CERN produced Cu coating on Gr block.
- 3 remaining faces coated by DTI.
- Less effect of bulk surface properties.

<table>
<thead>
<tr>
<th>Cu on Gr face 2</th>
<th>Cu on Gr face 3</th>
<th>Cu on Gr face 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 nOhm.m</td>
<td>19 nOhm.m</td>
<td>24 nOhm.m</td>
</tr>
</tbody>
</table>
Measurements on DTI coated CERN Blocks

Cu coating at DTI

- Measurement done also on specific samples by C.Accettura at DC
- Resistivity of Mo on Gr (R4550) and MoGr (Nb8304Ng)

<table>
<thead>
<tr>
<th>Material</th>
<th>#sample</th>
<th>Average [nOhm.m]</th>
<th>Dev. Standard [MS/m]</th>
<th>Dev. Standard [% of the average value]</th>
<th>Uncertainty [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphite R4550</td>
<td>9</td>
<td>19.2</td>
<td>4</td>
<td>~7</td>
<td>~57</td>
</tr>
<tr>
<td>Nb8304Ng</td>
<td>8</td>
<td>26.3</td>
<td>14</td>
<td>~37</td>
<td>~64</td>
</tr>
</tbody>
</table>

- Good agreement with DC measurements.

https://indico.cern.ch/event/816840/contributions/3412132/attachments/1842475/3021740/20190510_4probesmethod.pdf
• **Summary of DTI Mo coating measurements followup:**
  – Quick introduction on the method
  – How close measurements are to expectation?
  – Thermal process impacts
  – Follow up status
  – New cavity production for smaller samples

• **Additional contents:**
  – Measurements on HRMT-35 impacted blocks
  – Measurements on DTI coated CERN Blocks

• **Bench measurements plan on low impedance collimators**
Bench measurements plan on low impedance collimators

The status of collimators measurements will be follow as below:

• Asking for **pictures of the assembled jaw** before closing the collimator cover (to check for scratches or obvious issues)

• Performing **probe measurements** to check if there is any non-conformity. Repeating measurements for **different insertion length of probes and jaw apertures**. Applying it to each collimators to compare the results one to one for easy comparison.

• In case of issue, requesting to **measure with the wire**. Measurements for **different wire positions and jaw apertures**.
Follow-up of low impedance collimator’s block:
• DTI’s Pre-Batch samples and blocks resistivity shows good agreement with expectations.
• It is observed that there is no impact on resistivity from thermal treatment.
• The design of new small cavity has finalized. It is on fabrication.
• RF impedance measurement on Pre-serie B will be week 22.

Additional development and observations:
• HRMT-35 impacted blocks:
  o The effects of damage due to beam impact is clearly observed and reproducible across coating materials (Mo, Cu).
  o Simulations are on going with CST to reproduce S21 measurement.
• Measurements are done on DTI coated old CERN blocks. The results of DTI coatings are consistent.

Bench measurements plan on low impedance collimators:
• Visual check of the assembled jaw before closing the collimator.
• Probe measurements on selected configurations (probes/jaws).
• In case of issue -> Wire Measurements.
Thanks for your attention!