A Coupon Tester for Normal Conducting High-Gradient Materials

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Outline

• What is a coupon tester?
• Why not use a $\text{TM}_{010}$-mode cavity?
• Design Considerations
• Candidate Geometries
• Conceptual Assembly
• Conclusions and Timeline

A few notes up front…
This work is supported by the Los Alamos LDRD program.

It is part of an effort to develop theoretical models of the breakdown process, to \textit{ab initio} design new materials for high-gradient operation, and to test those materials in a C-band test stand at Los Alamos.
What is a coupon tester?

• Higher fields (E, H, modified Poynting vector) are associated with higher breakdown rates, all else equal.

• A coupon tester is a specially designed RF structure to:
  – Allow high RF field gradients (electric and magnetic, in our case) to be applied to a removable part of the structure;
  – Have the highest fields in the structure, be on that removable part.

• So, a coupon tester lets us explore the behavior of candidate materials for high-gradient structures, at high fields, without having to build a complete structure
  – Faster to prepare to test a new material
  – Less expensive
  – Allows easy “post-mortem” examination of the surface post-testing
Why not use a TM$_{010}$-mode cavity with a removable back wall, like the SLAC/BNL/UCLA RF guns?

The TM$_{010}$-mode “pillbox” cavity has:
- High current at the edge of the back wall, relative to the peak cavity fields ~1.4 A/mm / (MV/m)
- High ratios of E and H fields on the cavity surface, to the coupon surface

A purpose-designed coupon tester cavity has:
- Low current at the coupon/cavity boundary, relative to the peak cavity fields, ~0.07 A/mm / (MV/m)
- Definitively higher E and H fields on the coupon, than on the cavity surface
Design considerations

RF
• Defining $E_{c(s)}$ as the peak E-field on the surface of the coupon (cavity excluding the coupon), and $H_{c(s)}$ as the corresponding H-field, maximize $E_c / E_s$, and $H_c / H_s$.
• Keep the surface current across the cavity / coupon joint as low as possible
• Good separation from neighboring modes
• Low fields on the coupler, esp. coax tip

Mechanical
• Keep the coupon as simple as possible – easy to machine, etc.
• Provide a means of temperature stabilizing the coupon
• Separate the RF and vacuum seal functions at the coupon / cavity boundary

Desirable Diagnostics (beyond reflected power)
• An on-axis port to measure field emission and breakdown current
• Cavity field probe
• Optical ports to view coupon
Candidate geometries

<table>
<thead>
<tr>
<th>Parameter</th>
<th>TM\textsubscript{020}-like</th>
<th>TM\textsubscript{041}-like</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Q_0)</td>
<td>16,800</td>
<td>23,500</td>
</tr>
<tr>
<td>(E_c/E_s)</td>
<td>2.89</td>
<td>2.33</td>
</tr>
<tr>
<td>(H_c/H_s)</td>
<td>1.42</td>
<td>2.33</td>
</tr>
<tr>
<td>(R_c (M\Omega/m^2))</td>
<td>(5.7 \cdot 10^3)</td>
<td>(3.10 \cdot 10^3)</td>
</tr>
</tbody>
</table>

- ✔ Smaller, simpler construction
- ✔ Lower RF power needed
- ✗ Low \(H_c/H_s\) ratio
- ✗ Probe ports (optical, field) problematic
- ✔ More uniform field ratios
- ✔ Good options for probe port placement
- ✗ More complex fabrication
- ✗ Physically larger
Conclusions and Timeline

• We have developed two coupon tester variants for normal-conducting high-gradient materials.

• Both use a rectangular-to-coaxial power coupler

• We will downselect, finalize and fabricate the preferred design, with the goal of having a coupon tester operational in early 2022.
Also at IPAC:

MOPAB146
Status of the C-Band Engineering Research Facility (CERF-NM) Test Stand Development at LANL, Dmitry Gorelov

MOPAB341
First C-band high gradient cavity testing results at LANL, Evgenya Simakov

MOPAB342
Design, fabrication, and commissioning of the mode launchers for high gradient C-band cavity testing at LANL, Evgenya Simakov

MOPAB362
Atomistic Modeling of the Coupling Between Electric Fields and Bulk Plastic Deformation in RF Structures, Soumendu Bagchi

THPAB138
FEbreak: A Comprehensive Diagnostic and Automated Conditioning Interface for Breakdown Analysis and Dark Current, Mitchell Schneider