New University Based SRF Materials Research Efforts (in the US)

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Snowmass 2005
Materials R&D / WG5
LCRD 2005 – 6 Proposals

**Funded:**

P. Lee: Magnetic Investigation of High Purity Niobium for Superconducting RF Cavities, new proposal, DOE

D. N. Seidman: 3D Atom-Probe Microscopy on Niobium for SRF Cavities, new proposal, DOE

L. Vuskovic: Investigation of Plasma Etching for Superconducting RF Cavities, new proposal, DOE

**Not funded:**

R. Schill: Investigation of Secondary Electron Emission from Nb Surfaces with Different Surface Treatments, new proposal

V. Nesterenko: Evaluation of MgB2 for Future Accelerator Cavities, new proposal

D. N. Seidman: Experimental Study of High Field Limits of RF Cavities, new proposal
Magnetic Flux Penetration
Final / University of Wisconsin

Magneto-optical measurements show clear evidence of “pre-mature” flux penetration into samples via the grain boundary. Example below: large grain material from JLab before processing.

Top Surface Light Image

ZFC T=5.6 K H=8.4 mT

3D Model of GB

Zero field cooled (ZFC) to the superconducting state, then field applied.
Mixed Josephson/Abrikosov vortex penetration

bulk superconductor  H-field penetration  “weak” superconductor

$H(t)$  $E(t)$  $\lambda$

$H \ll H_{c1,\text{weak}}$
$J \ll J_{d,\text{weak}}$

$H < H_{c1,\text{weak}}$
$J < J_{d,\text{weak}}$

$H > H_{c1,\text{weak}}$
$J > J_{d,\text{weak}}$

“mixed” vortex

$J_{d,\text{weak}}$

$J_{d,\text{bulk}}$
Other Activities
University of Wisconsin

- Microscopy and related material characterization
  (surface roughness,  metallurgical,
  crystallo-graphical, chemical,..)

- Theoretical work by A. Gurevich:
  “hot spot model”
  Non-linear BCS resistance
  Thermal Feedback model
UW – mid-term program

Achievements:

- Evidence of pre-mature flux penetration through GBs;
  (Mixed Abrikosov-Josephson flux lines a la Gurevich)

Mid-term program:

- Disentangle topology from “chemistry”
- Measure grain boundary Hc, Jd
- Understand “defects” other than GB
- Theoretical support – surface resistance contribution from vortex penetration, ... etc!
3D atomic probe at NU / Final

First results: Smooth transition from Nb$_2$O$_5$ to Nb with 5-10% interstitial O, ~20 nm oxide
NU - mid-term program

- Oxide composition/thickness
- Interstitial elements in bulk (H is a problem)
- Nano-chemistry of grain-boundaries

- EP, BCP
- Fine grain - single crystal
- Bakes, etc
A.M. Valente / L. Vuskovic:  
**Plasma-etching:**

- Takes place under vacuum.
- Allows “control” on the final oxidation phase.
- Allows the possibility to avoid final oxidation.

1) plasma oxidation in Ar-O after plasma etching (stable surfaces with a much higher pentoxide to sub-oxide ratios?)

2) dielectric layers

3) thin superconducting layers;- i.e. NbN which is quite stable in the presence of air.

**JLab/ODU – Plasma-Etching**

Combines well w. other JLab programs:

- L. Phillips: TE011 cavity
- G. Wu: Plasma Coating
Another Gurevich Idea

Higher-$T_c$ SC: NbN, Nb$_3$Sn, etc

Multilayer coating of SC cavities: alternating SC and insulating layers with $d < \lambda$

Higher $T_c$ thin layers provide magnetic screening of the bulk SC cavity (Nb, Pb) without vortex penetration

For NbN films with $d = 20$ nm, the rf field can be as high as 4.2 T!

No open ends for the cavity geometry to prevent flux leaks in the insulating layers
LANL/UC – MgB2 Development

T. Tajima / STI / Padamsee / Geng / Romanenko:

~400 nm film was grown on 1.5 cm Nb at STI.
First attempt to coat on a Nb substrate. The Nb substrate was rough ($R_a \sim 400$ nm).

Measurement at Cornell with $TE_{011}$ Nb cavity at 4.2 K. There was only one test and the result needs to be confirmed with others.
ANL/NU – Field Emission

Atom Probe samples look like field emission (breakdown) sites.
- Atom Probe work is useful for two reasons:
  1) It provides a detailed look at high electric field on materials.
  2) It provides a way of looking at surface composition.

<table>
<thead>
<tr>
<th></th>
<th>Emitter in Cavity</th>
<th>Atom Probe Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface field</td>
<td>4 - 8 GV/m</td>
<td>4 - 40 GV/m</td>
</tr>
<tr>
<td>Size</td>
<td>~100 nm</td>
<td>~100 nm</td>
</tr>
<tr>
<td>Temperature</td>
<td>300+ K</td>
<td>20 - 300 K</td>
</tr>
<tr>
<td>Pulsing</td>
<td>200 - 12000 MHz</td>
<td>0.2 MHz</td>
</tr>
<tr>
<td>Stored energy</td>
<td>1 - 100 J</td>
<td>&lt; 10^-6 J</td>
</tr>
</tbody>
</table>

J. Norem / D. Seidman / J. Sebastian / K. Yoon:

08/18/2005
We need more university involvement!

- Chemical analysis (3DAP, XPS, SIMS, AES, ...)
- Superconducting properties (magnetization, STM, SQUID microscopy, ...)
- Low and high power RF properties (sample in host cavity tests, microwave microscopy, ??)
- Microscopy, surface roughness
- Defect detection – ECS, SQUID-ECS, ...
- More ideas??
MSU – Thermal Properties

A. Aizas, T. Grimm:
Kapitza and $\kappa$ measurements
MSU – Mechanical Properties

H. Jiang, T. Bieler:

mechanical properties,
formability, texture, creep

Next: single crystal material

Orientation Imaging Microscopy shows microstructure and texture information together

Texture in weld is similar to parent material

5 mm from center of weld (2 mm from edge of fusion zone) 10 mm from fusion zone Unaffected Sheet

[001] // ND on surface
IPF OIM Viewpoint is along ND
[111] // ND in center
2 mm

TD
Laser Annealing Experiments with Niobium

W.R. Frisken, Physics and Astronomy, York Univ., Toronto, Canada
L.N. Hand, Physics and CCMR, Cornell University, Ithaca NY, USA