STATUS OF LANL ACTIVITIES

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Status of LANL Activities for Superconducting RF (SRF) Cavities

- In FY07, LANL has joined the effort to improve the performance of ILC Superconducting RF (SRF) cavities

Projects

- Analysis of failed SRF cavities will be our task
  - Development of a system to create a temperature mapping of the cavity surfaces during RF tests of a 9-cell TESLA/ILC type cavity is underway
- Study of MgB$_2$ as an alternative superconductor for SRF cavities
SRF cavities performance has been widely scattered

TESLA type cavity

Reproducibility Study
DESY: $E_{\text{acc}}$ vs. time

H. Padamsee, ILC Workshop, Bangalore, March 2006
T-mapping has been very useful to detect and localize areas of problem on SRF cavity surfaces

- A full fixed-board system for a 9-cell cavity has not been tried yet
- For 9-cell cavities, only a rotating arm system has been developed

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<th>Fixed-board system</th>
<th>Rotating arm</th>
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<tbody>
<tr>
<td><strong>Pros</strong></td>
<td>Real time acquisition</td>
<td>Small number of sensors needed</td>
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<tr>
<td><strong>Cons</strong></td>
<td>Large number of sensors</td>
<td>Slow</td>
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T-mapping: how we will reduce the number of cables that go out of cryostat

- 17 sensors/cell x 9 cell/board x 36 board/cavity = 5,508 sensors/cavity
- Multiplexing inside cryostat = 612 sensors/4 boards get out
T-mapping: Illustration of one board. We will have 36 boards to cover every 10 degrees in azimuthal direction.
MgB$_2$, an alternate superconductor

Very weak dissipation at $H < H_{c1}$ ($Q = 10^{10}$-$10^{11}$)

Q drop due to vortex dissipation at $H > H_{c1}$

Nb has the highest lower critical field $H_{c1}$

Thermodynamic critical field $H_c$ (surface barrier for vortices disappears)

\[
H_{c1} = \frac{\phi_0}{4\pi\lambda^2} \left( \ln \frac{\lambda}{\xi} + 0.5 \right)
\]

\[
H_c = \frac{\phi_0}{2\sqrt{2}\pi\lambda\xi}
\]

A. Gurevich, Thin film Workshop, Padova, Italy, October 2006

Material | $T_c$ (K) | $H_c(0)$ [T] | $H_{c1}(0)$ [T] | $H_{c2}(0)$ [T] | $\lambda(0)$ [nm]
--- | --- | --- | --- | --- | ---
Pb | 7.2 | 0.08 | na | na | 48
Nb | 9.2 | 0.2 | 0.17 | 0.4 | 40
Nb$_3$Sn | 18 | 0.54 | 0.05 | 30 | 85
NbN | 16.2 | 0.23 | 0.02 | 15 | 200
MgB$_2$ | 40 | 0.43 | 0.03 | 3.5 | 140
YBCO | 93 | 1.4 | 0.01 | 100 | 150
Thin film superconductor and its benefit

- For thin films:

Enhanced lower critical field and surface barrier in films

Use thin films with \( d < \lambda \) to enhance the lower critical field

\[
H_{c1} = \frac{2\phi_0}{\pi d^2} \left( \ln \frac{d}{\xi} - 0.07 \right)
\]

where \( \Phi_0, \xi \) are the fluxon and coherence length, respectively.

Field at which the surface barrier disappears

\[
H_s = \frac{\phi_0}{2 \pi d \xi}
\]
MgB$_2$ : enhancement of $H_{c1}$ with very thin film

Hc1 vs Thickness for MgB2 films

Hc1(T)

$H_{c1}(d \text{ nm})$

$H_{s}(d \text{ nm})$

Layer thickness (nm)
What gradient can we get theoretically?

Simple example

- Assumptions
  - $H_{c1}(Nb) = 0.17T$
  - $\lambda(MgB_2) = 140\text{nm}$
  - $\xi(MgB_2) = 5\text{nm}$

- What is the optimum $[d, H_{c1}(MgB_2)]$?
  - $H_{c1}(MgB_2) = 355\text{mT}$
  - $d = 105\text{nm}$

2x greater than Nb!
No vortex penetration
$E_{acc} \approx 100\text{MV/m}$
What we can observe during the tests of MgB$_2$

- $d < d_{opt}$
  - Quench due to Nb substrate

- $d > d_{opt}$
  - Quench due to MgB$_2$ layer

- Therefore, the key is to determine $d_{opt}$
  Given a MgB$_2$ coating method:
  - Accurate determination of $\lambda$ and $\xi$
  - Calculation of $d_{opt}$ using previous formulas
MgB$_2$ Coating methods

- What is the most suitable coating method for SRF cavities?

Ongoing research:

- RE – Reactive Evaporation
  Superconductor Technologies, Inc. (STI)

- PAD – Polymer-Assisted Deposition
  Superconductivity Technology Center at LANL

- HPCVD – Hybrid Physical-Chemical Vapor Deposition
  Pennsylvania State University
More details are found in
T. Tajima et al, Proc. PAC05.
RE at STI (B. Moeckly et al.)

R-plane sapphire

Si₃N₄ / Si

B.H. Moeckly, ONR Superconducting Electronics Program Review
Red Bank, NJ, February 8, 2005
PAD at LANL (Q. Jia et al.)

- A chemical solution technique to deposit films of nearly any metal-oxide using aqueous solution by mixing metal precursors with water-soluble polymers
- Polymer plays a critical role in metal-oxide films

Typical chemical solution deposition process flowchart
PAD at LANL (Q. Jia et al.)

- Process

1. Select metal precursor
2. Mix with polymer (adjust pH)
3. Polymer filtration and removal of all non-bound cations & anions
4. Mix different metal - polymer solutions
5. Adjust viscosity
6. Burning and/or de-polymerizing the polymer
7. Apply coating
8. Thermal treatment
Examples
HPCVD at PSU (X. Xi et al.)

- Get rid of oxygen to prevent oxidation.
- Pure source of B.
- Generate high Mg pressure: required by thermodynamics.
- High enough $T$ for epitaxy.
- Make high Mg pressure possible.
- B supply ($B_2H_6$ flow rate) controls growth rate.
- Pure source of Mg.

Schematic View:
- $H_2$ (~100 Torr)
- $B_2H_6$ (~ 5 - 250 sccm)
- Substrate
- Susceptor
- 550–760 °C

By courtesy of Xiaoxing Xi from Penn State.
HPCVD at PSU (X. Xi et al.)

- Example of epitaxial MgB2 Films by HPCVD: $RRR > 80$

![Graph showing resistivity and temperature relationship](image)
References

- Alex Gurevich, “RF breakdown in multilayer coatings: a possibility to break the Nb monopoly” Thin films applied to Superconducting RF: Pushing the limits of RF Superconductivity. Padova, ITALY, October 9-12, 2006.
