STATUS OF LANL ACTIVITIES

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Los Alamos National Laboratory

US High Gradient Research Collaboration Workshop

Stanford Linear Accelerator Center

May 23 – 25, 2007

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**

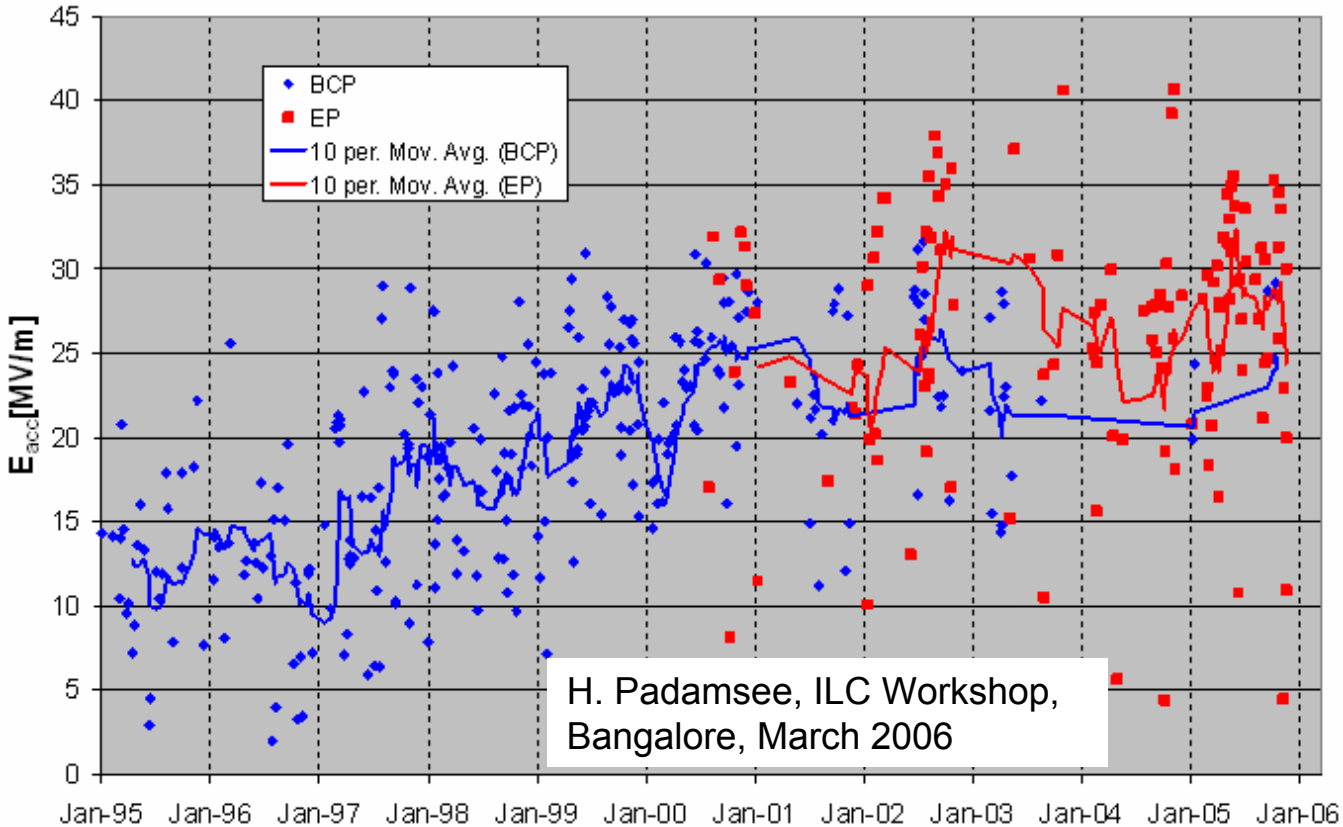
Projects

- **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_{acc} vs. time



H. Padamsee, ILC Workshop, Bangalore, March 2006

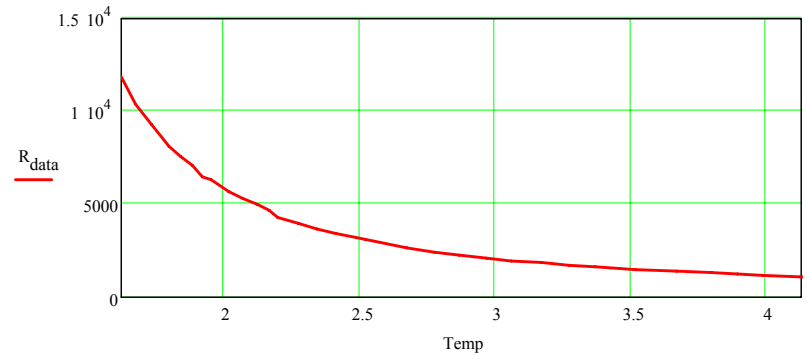
T-mapping has been very useful to detect and localize areas of problem on SRF cavity surfaces

- 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

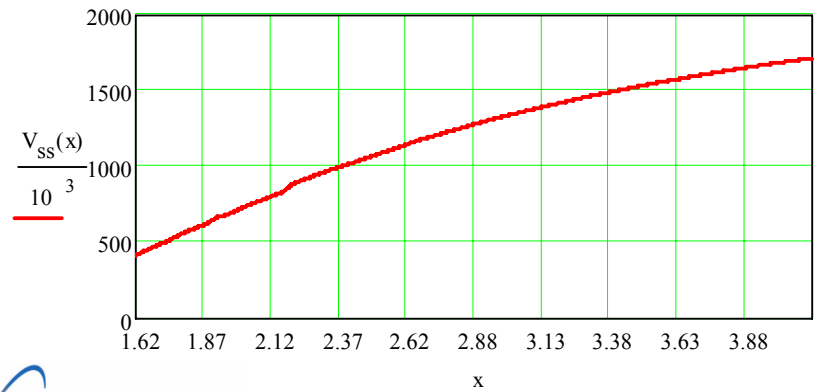
	Fixed-board system	Rotating arm
Pros	Real time acquisition	Small number of sensors needed
Cons	Large number of sensors	Slow

T-mapping: how we will reduce the number of cables that go out of cryostat

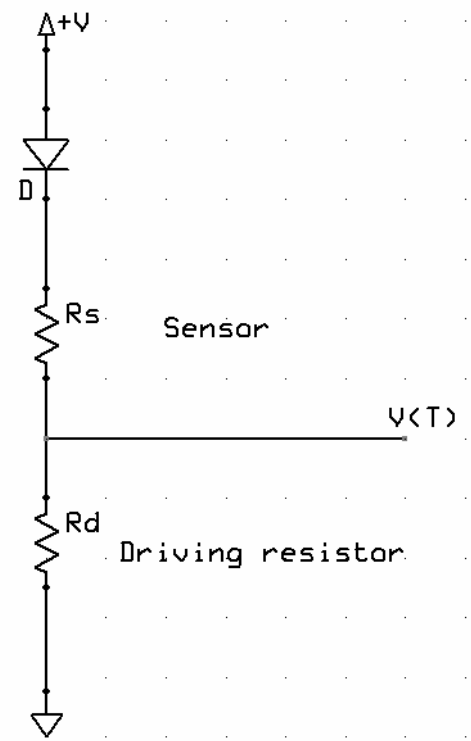
- **17 sensors/cell x 9 cell/board x 36 board/cavity = 5,508 sensors/cavity**
- **Multiplexing inside cryostat = 612 sensors/4 boards get out**



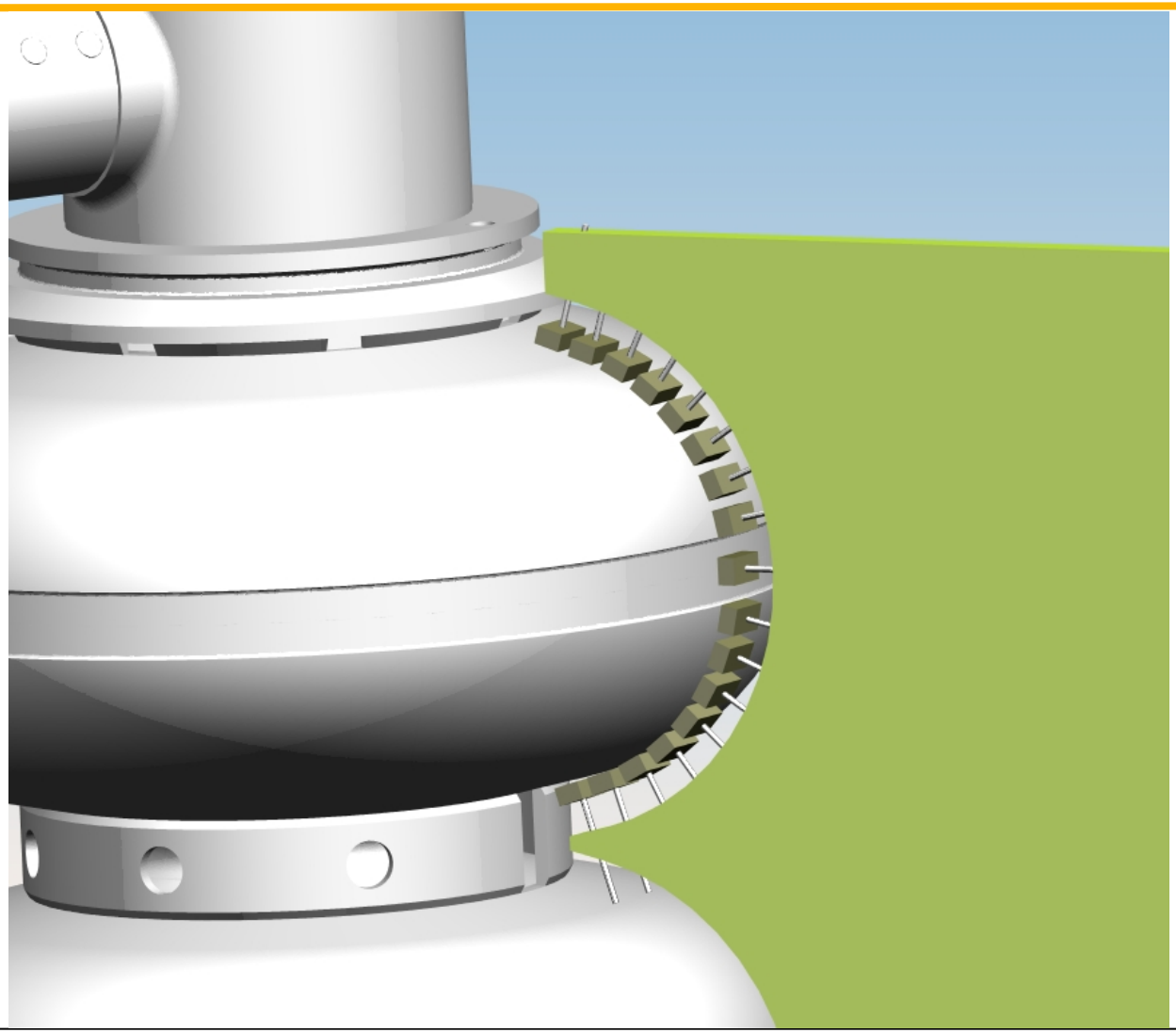
Allen Bradley resistors



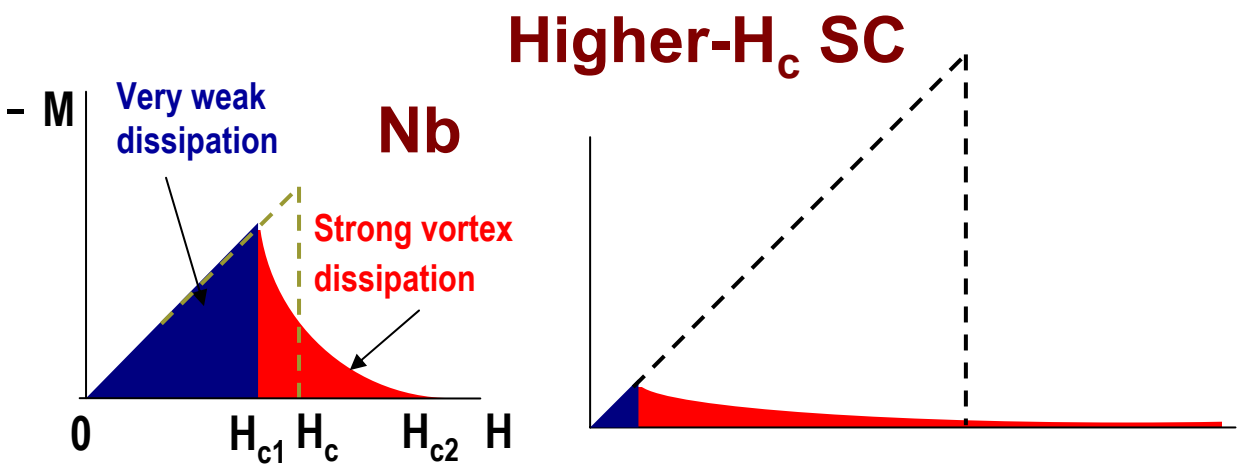
Output voltage



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}

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_3Sn	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

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

Thermodynamic critical field H_c (surface barrier for vortices disappears)

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

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

Thin film superconductor and its benefit

- **For thin films:**

Enhanced lower critical field and surface barrier in films

Use thin films with d < λ to enhance the lower critical field

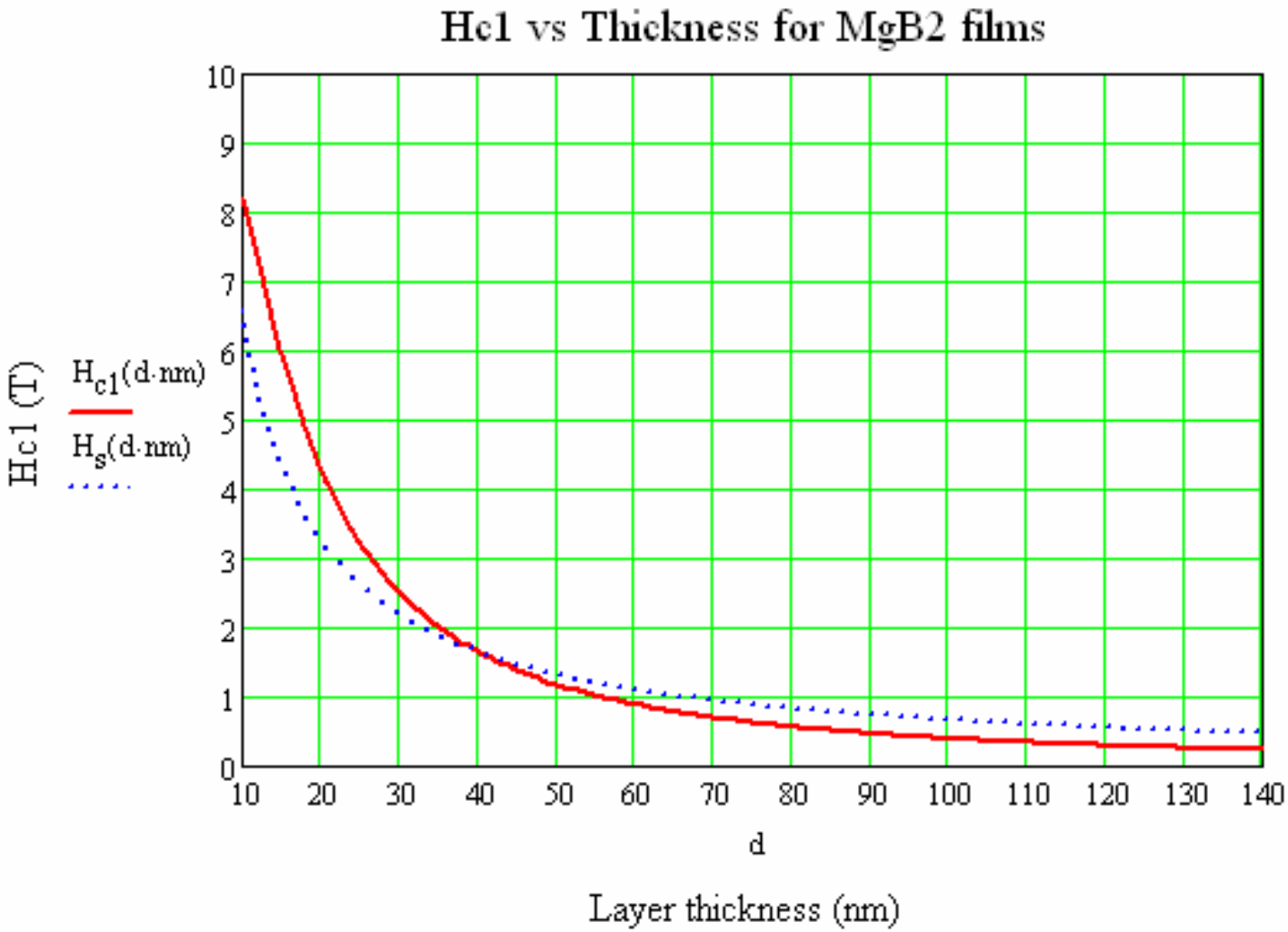
$$H_{c1} = \frac{2\phi_0}{\pi d^2}\left(\ln\frac{d}{\xi} - 0.07\right)$$

where Φ_0, ξ 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



What gradient can we get theoretically?

Simple example

- **Assumptions**

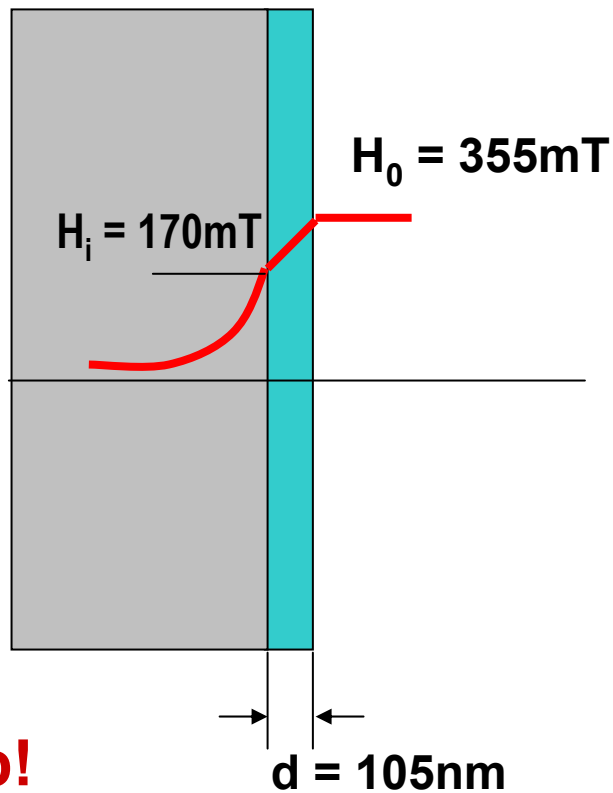
  Hc1(Nb) = 0.17T

  $\lambda(MgB_2)$ = 140nm

  $\xi(MgB_2)$ = 5nm

  What is the optimum [d,Hc1(MgB_2)] ?

- Hc1(MgB_2) = 355mT
- d=105nm



2x greater than Nb!
No vortex penetration
Eacc ≈ 100MV/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 λ and ξ
  - Calculation of d_{opt} using previous formulas

MgB_2 Coating methods

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

Ongoing research:

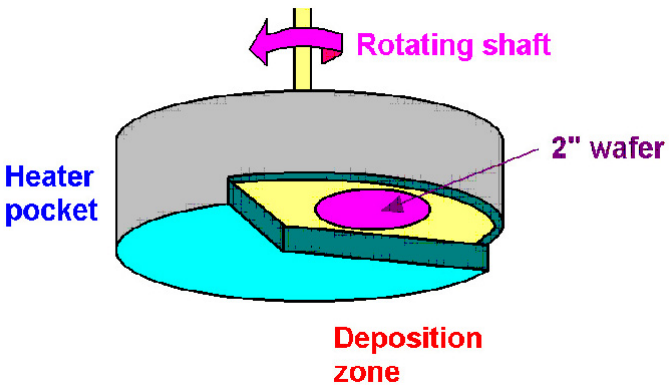
- **RE – Reactive Evaporation**

  Superconductor Technologies, Inc. (STI)
- **PAD – Polymer-Assisted Deposition**

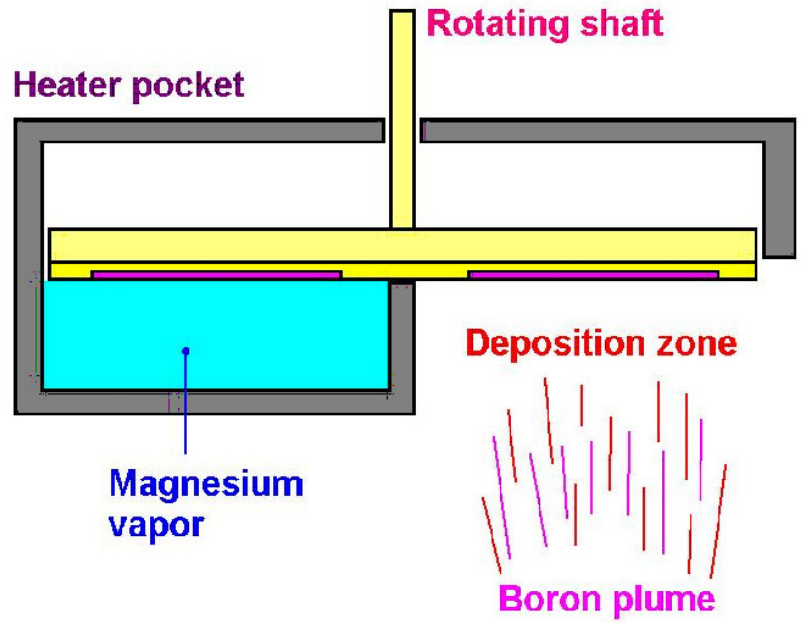
  Superconductivity Technology Center at LANL
- **HPCVD – Hybrid Physical-Chemical Vapor Deposition**

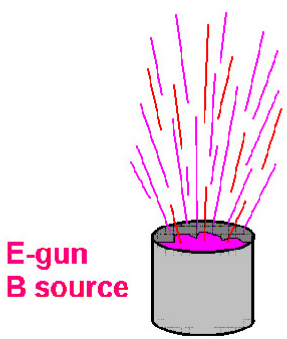
  Pennsylvania State University

RE at STI (B. Moecly et al.)



In-situ reactive evaporation

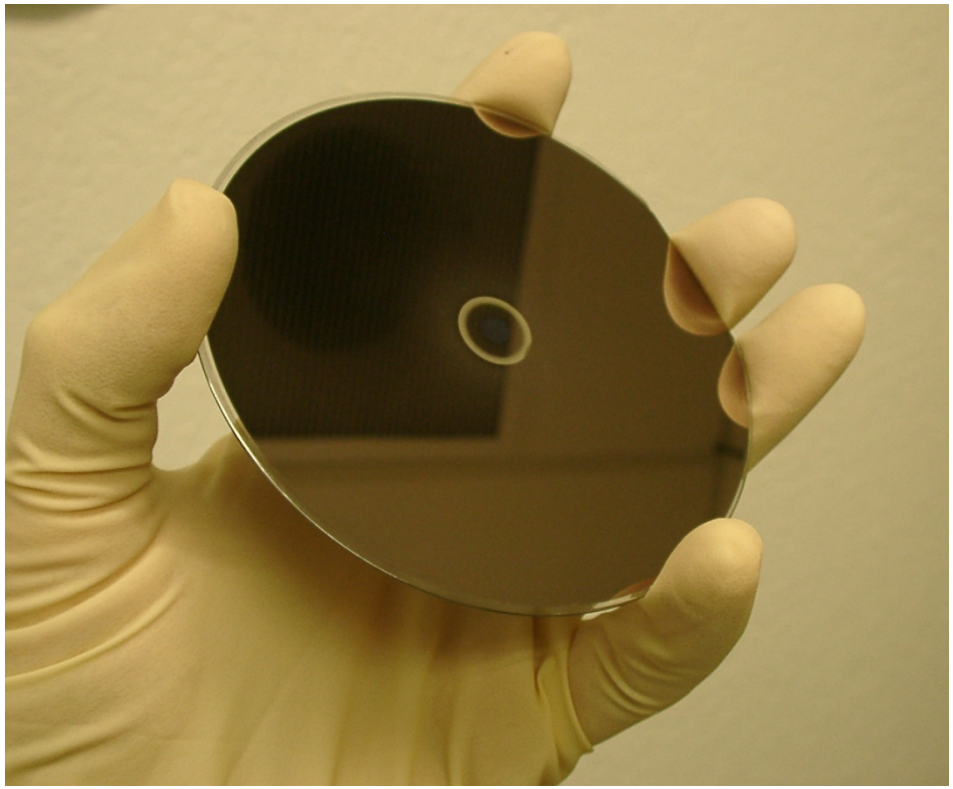




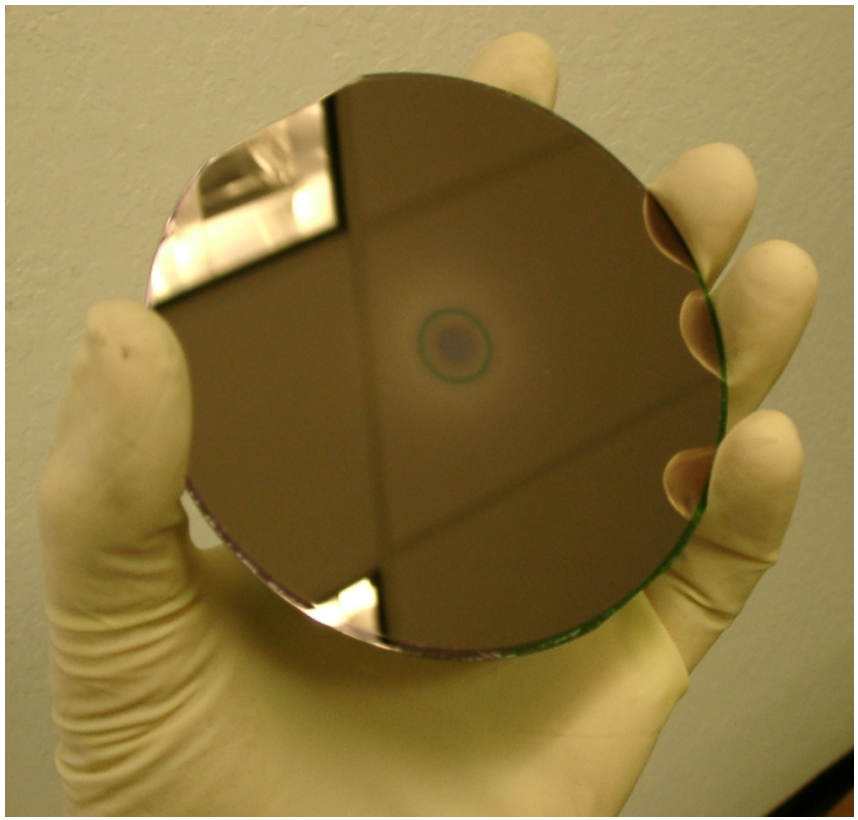
More details are found in
B.H. Moeckly et al., IEEE Trans. Appl. Supercond. 15 (2005) 3308.
T. Tajima et al, Proc. PAC05.

RE at STI (B. Moecly et al.)

R-plane sapphire



Si_3N_4 / Si

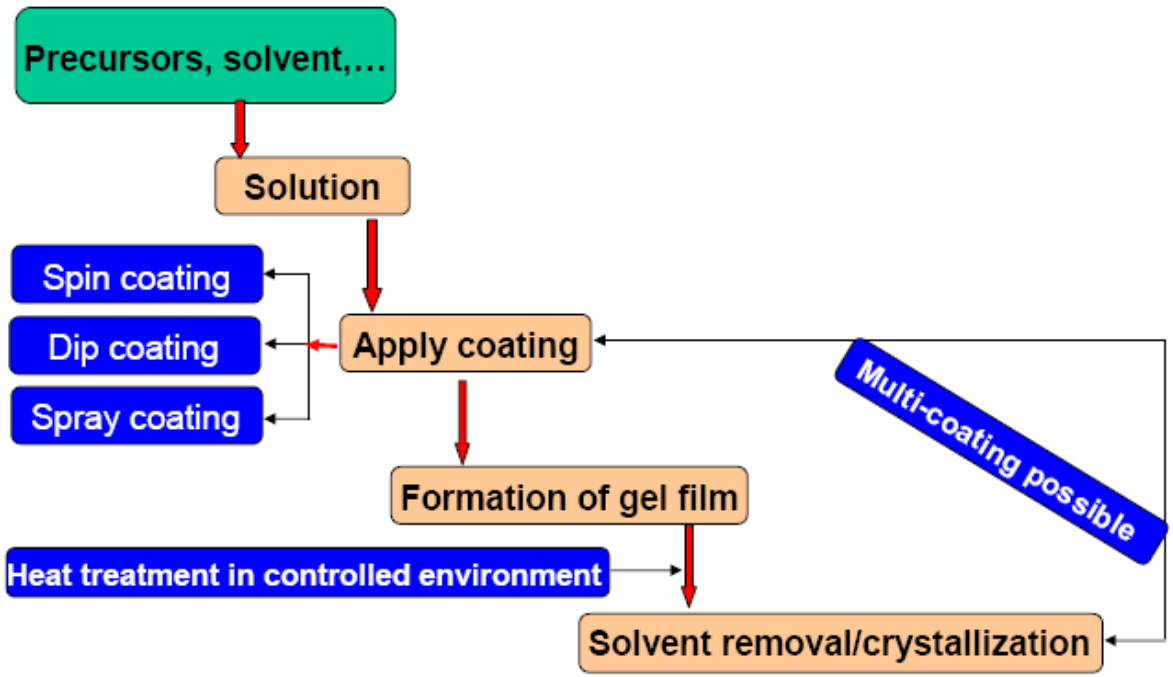


B.H. Moeckly, ONR Superconducting Electronics Program Review
Red Bank, NJ, February 8, 2005

PAD at LANL (Q. Jia et al.)

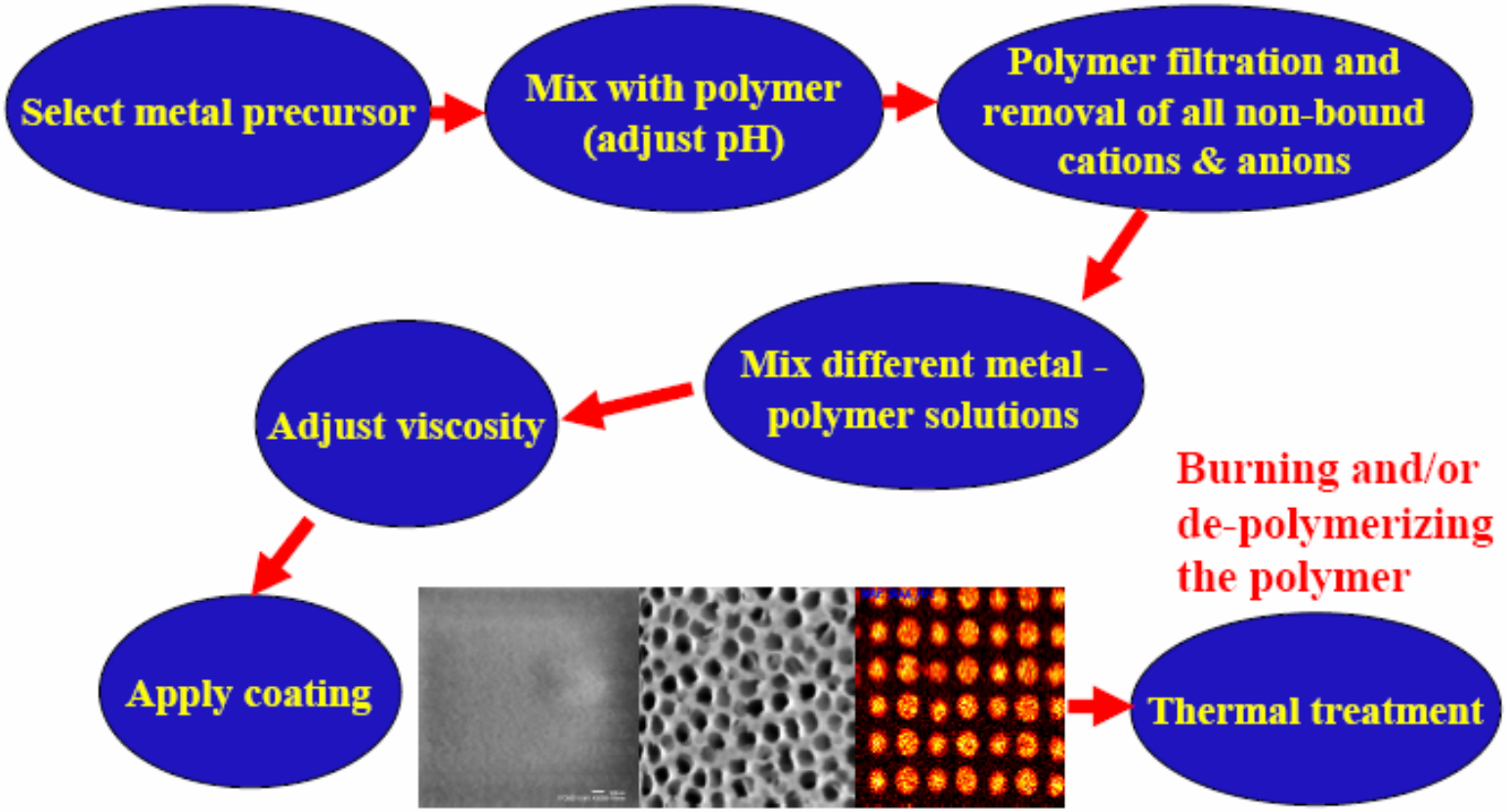
- A chemical solution technique to deposit films of nearly any metal-oxide using aqueous solution by mixing metal precursors with water-soluble polymers
- Polymer plays a critical role in metal-oxide films

Typical chemical solution deposition process flowchart



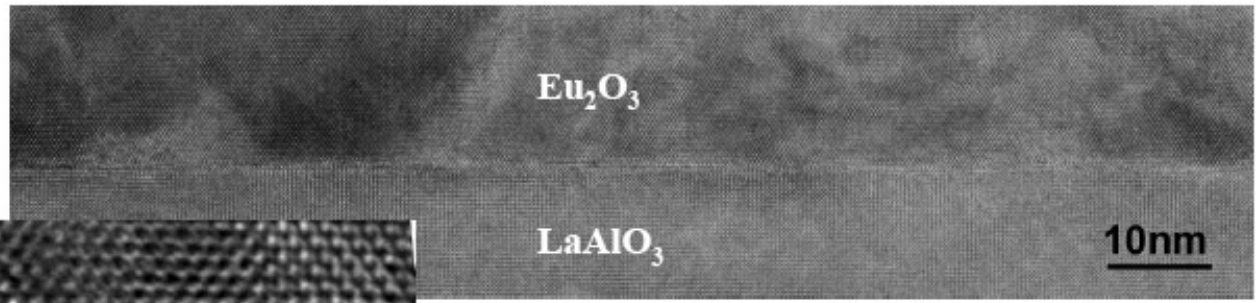
PAD at LANL (Q. Jia et al.)

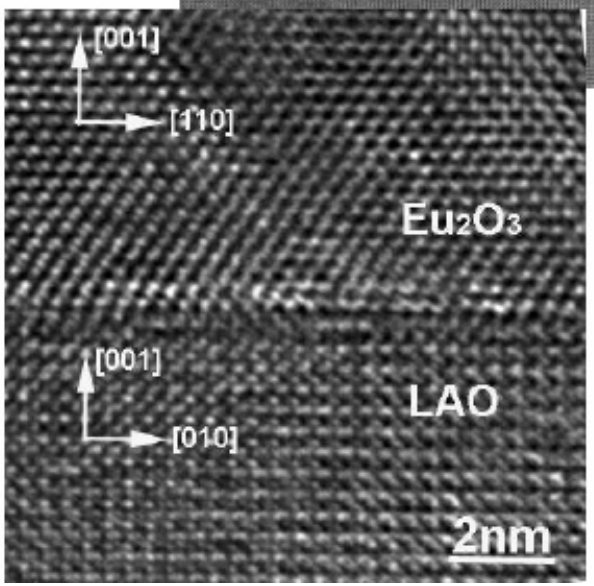
- **Process**

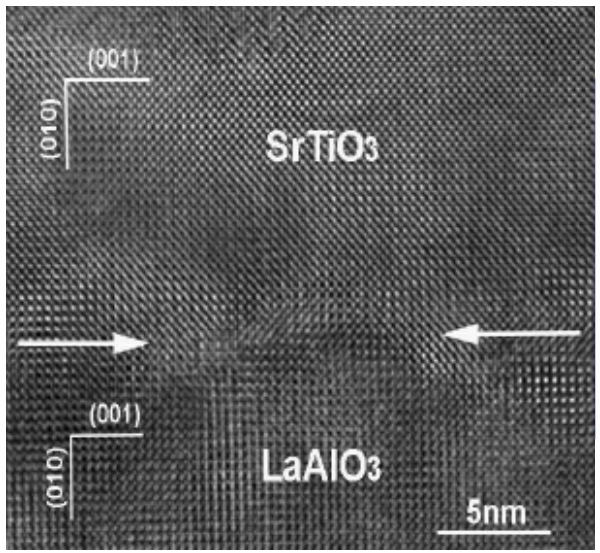


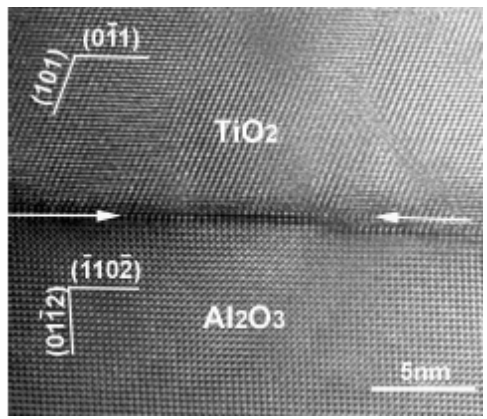
PAD at LANL (Q. Jia et al.)

- **Examples**



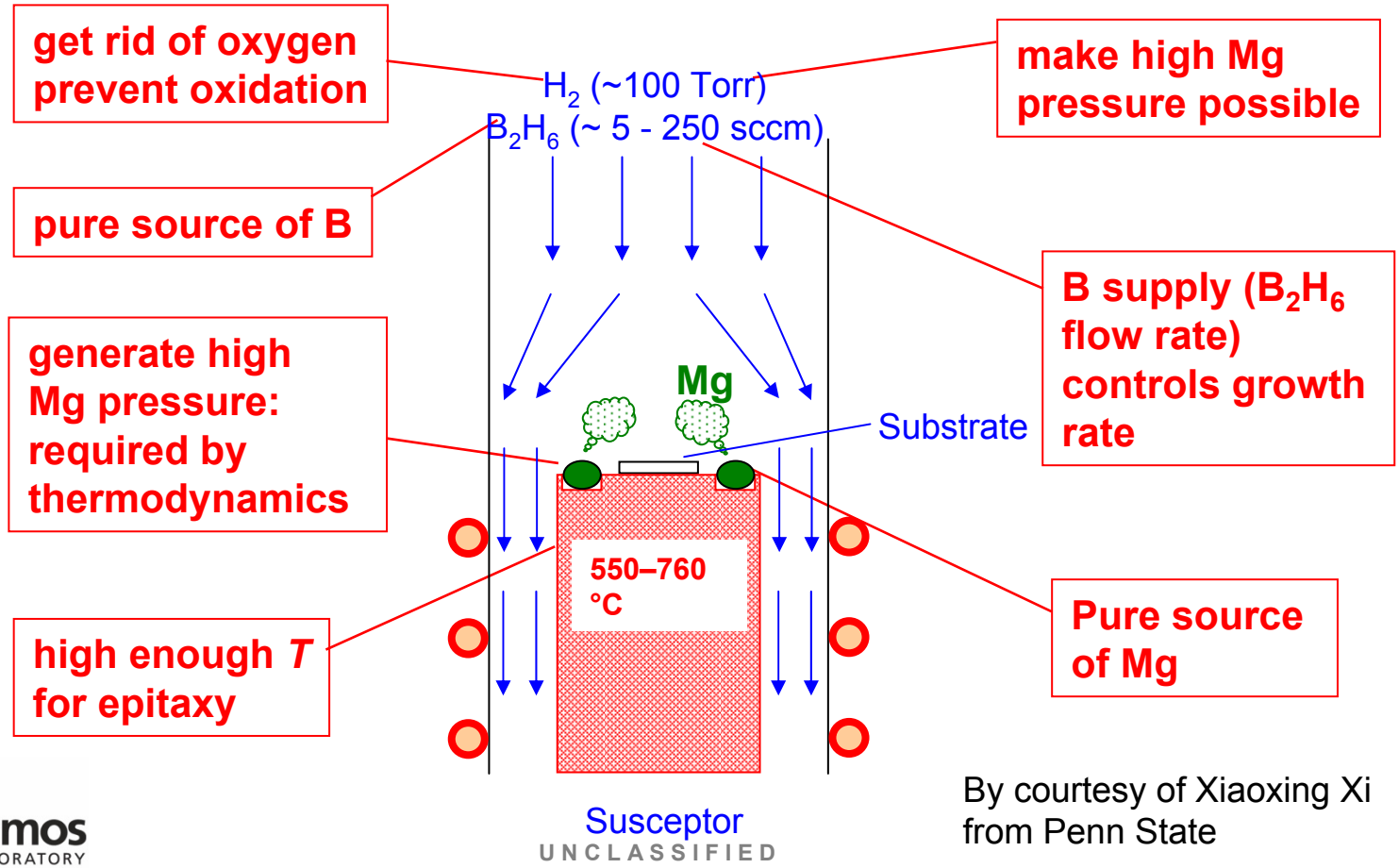






HPCVD at PSU (X. Xi et al.)

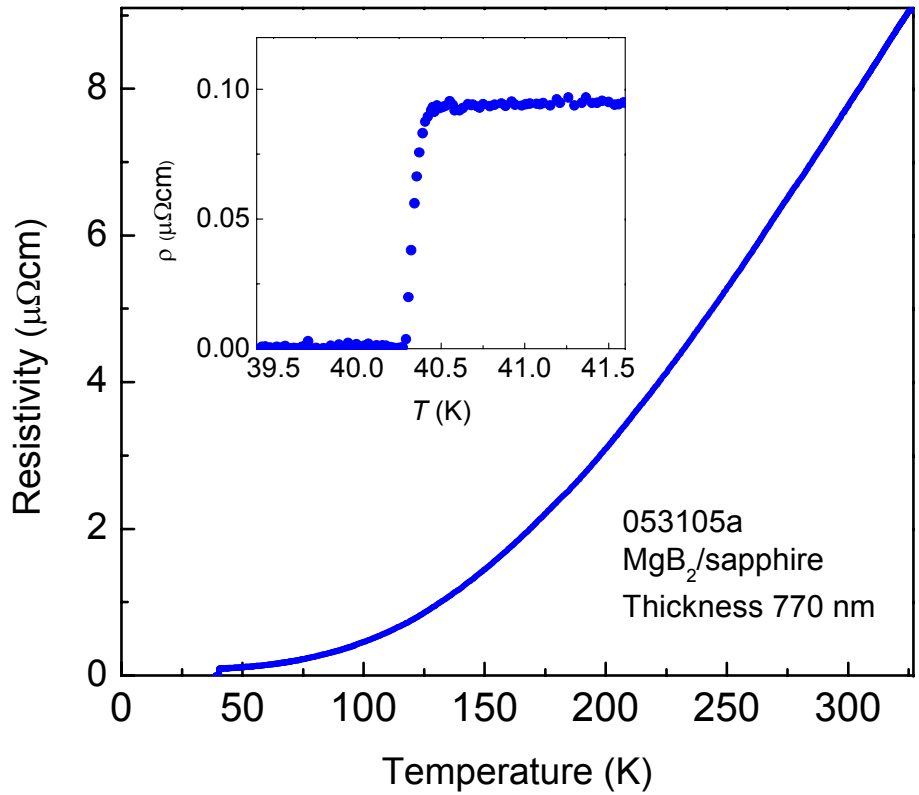
Schematic View



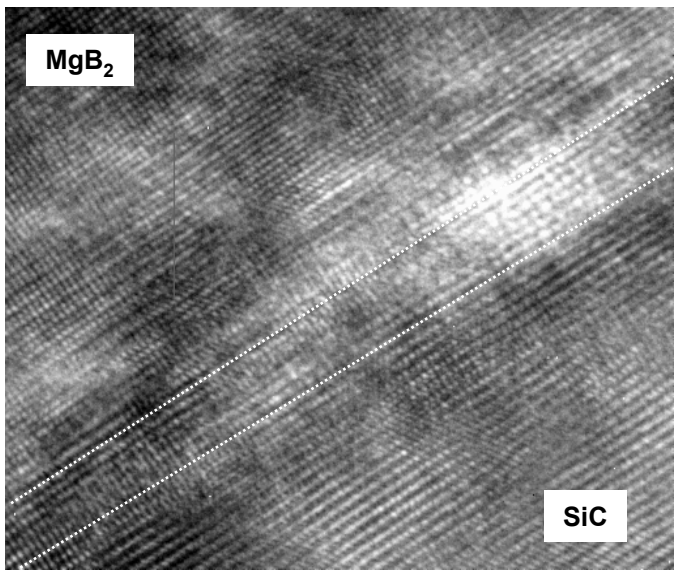
By courtesy of Xiaoxing Xi from Penn State

HPCVD at PSU (X. Xi et al.)

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



interface



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.
- X. H. Chen, et al., "Penetration depth and anisotropy in MgB_2 ", Physical Review B, 64, 172501, 2001.
- "Polymer-Assisted Deposition of Metal-Oxide Films," Nature Materials 3, 529-532 (2004).