MgB_2 Coating for SRF Cavities

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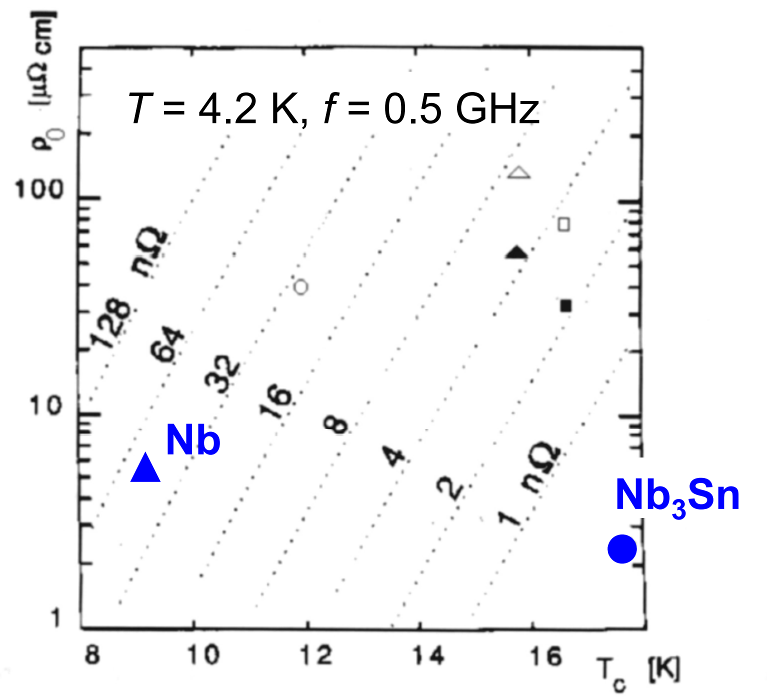
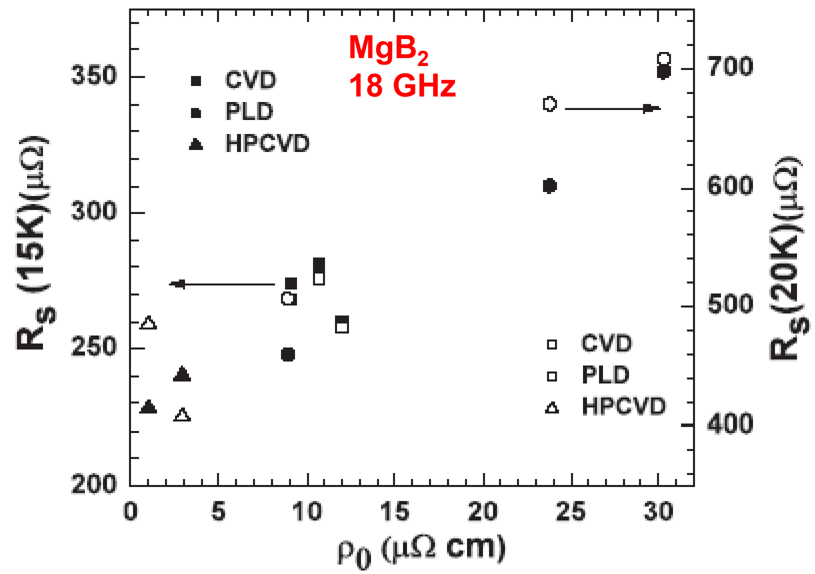
Potential Low BCS R_s in MgB_2 for RF Cavity

R_s (BCS) versus (ρ_0, T_c)





- 230 μΩ at 15 K and 18 GHz
- Scale to 0.5 GHz: 177 nΩ at 15 K.
- >20 time reduction in R_s for 15 K to 4 K has been shown for MgB_2

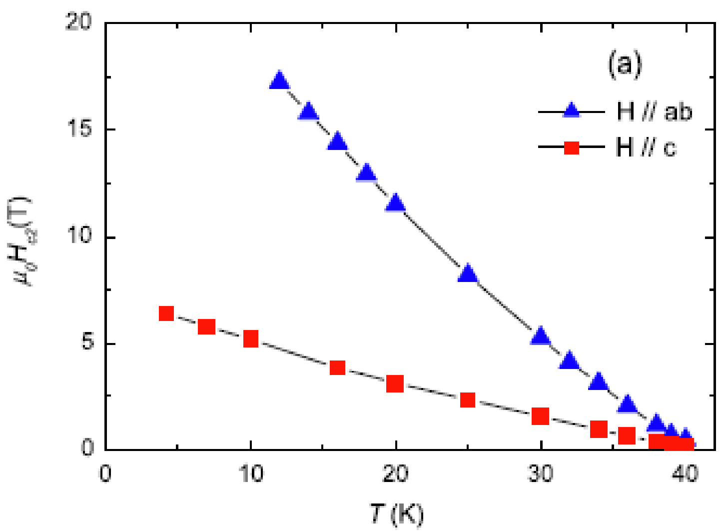
Vaglio, *Particle Accelerators* 61, 391 (1998)

R_s from π Gap

R_s from σ Gap

Potential High Maximum E_{acc} in MgB_2 for RF Cavity

Upper Critical Field

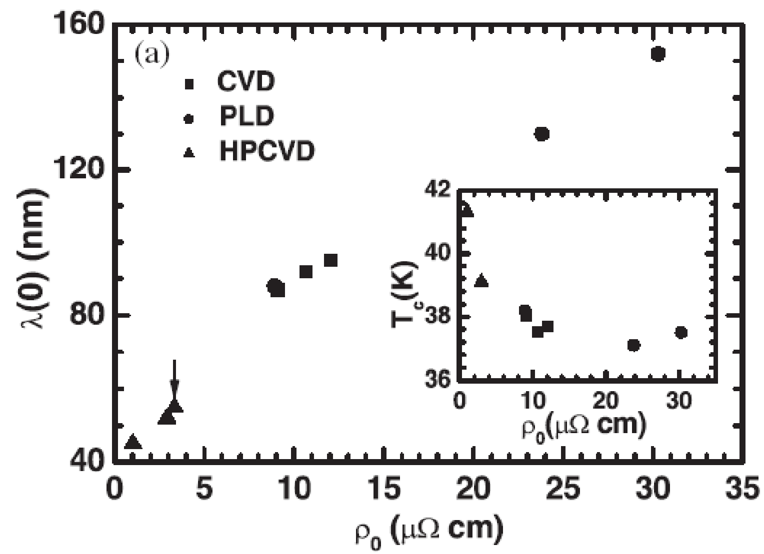


Xi, SC Sci. Tech. 22, 043001 (2009)

$$H_{c2}(0) = \Phi_0/2\pi\xi_{ab}(0)^2$$

$$\xi_{ab}(0) \approx 7\ \text{nm}$$

Penetration Depth



Jin *et al*, SC Sci. Tech. 18, L1 (2005)

$$\kappa = \lambda/\xi \approx 6$$

$$H_c = H_{c2}/\sqrt{2}\kappa \approx 820\ \text{mT}$$

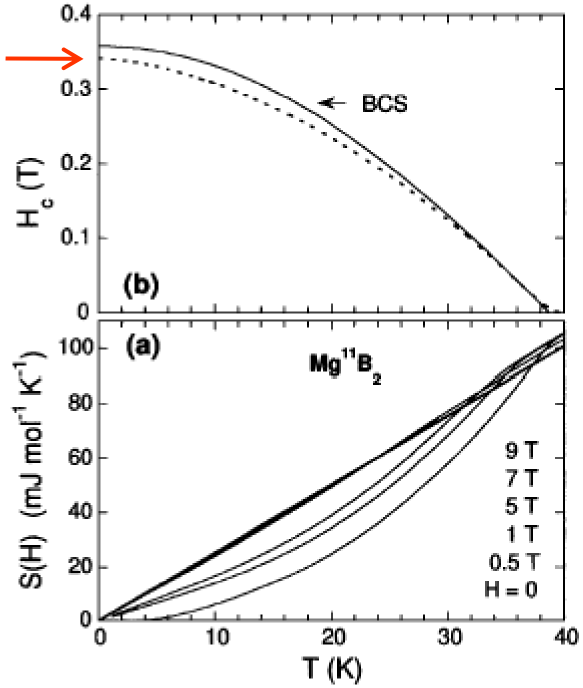
$$H_{sh} \approx 0.75\ H_c \approx 620\ \text{mT}$$

Issues to be studied:

- Effects of existence of two gaps.
- ξ is larger for π band than for σ band (Koshelev and Golubov, PRL 90, 177002 (2003)).
- λ is larger for π band than for σ band (Eisterer et al, PRB 72, 134525 (2005)).

Experimental Measurement of H_c of MgB_2

Powder, Specific Heat

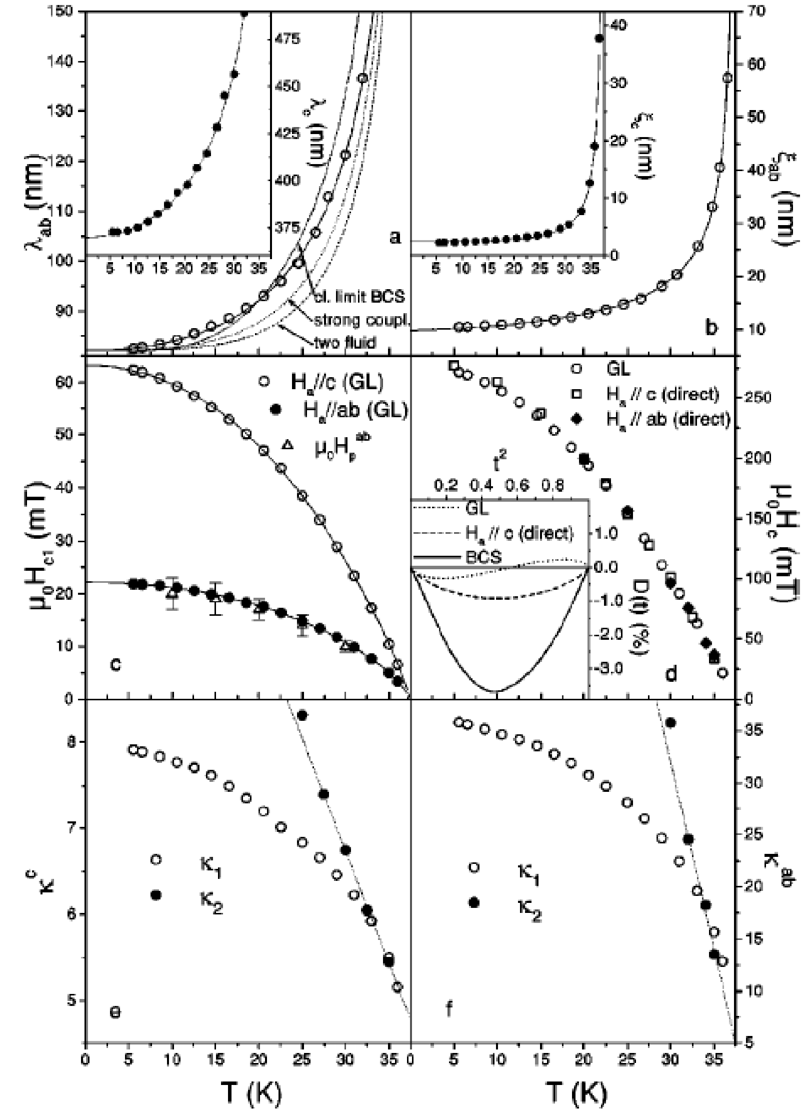


Bouquet *et al*, PRL 87, 047001 (2001)

TABLE I. Summary of mixed-state parameters for MgB_2.

$\mu_0 H_{c2}^c(0)$	3.18 T	$\mu_0 H_{c2}^{ab}(0)$	14.5 T	T_c	38 K
$\mu_0 H_{c1}^c(0)$	63 mT	$\mu_0 H_{c1}^{ab}(0)$	22 mT	$\mu_0 H_c(0)$	0.28 T
$\lambda_c(0)$	370 nm	$\lambda_{ab}(0)$	82 nm	$\gamma(0)$	4.6
$\xi_c(0)$	2.3 nm	$\xi_{ab}(0)$	10.2 nm	$\gamma(T_c)$	1
$\kappa_1^c(0)$	8.1	$\kappa_1^{ab}(0)$	37.1	$\kappa(T_c)$	4.7

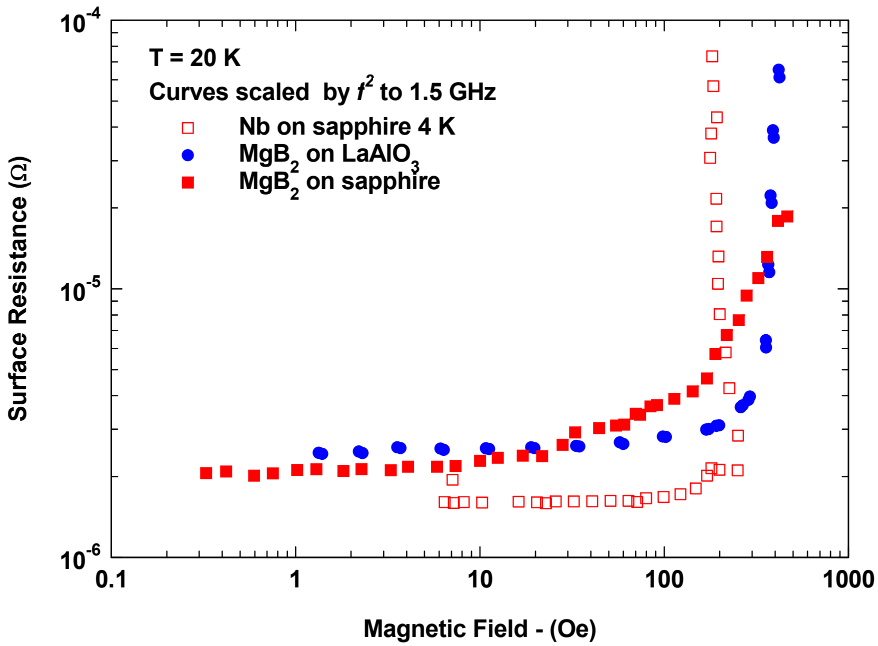
Single Crystal, Magnetization



Zehetmayer *et al*, PRB 66, 052505 (2002)

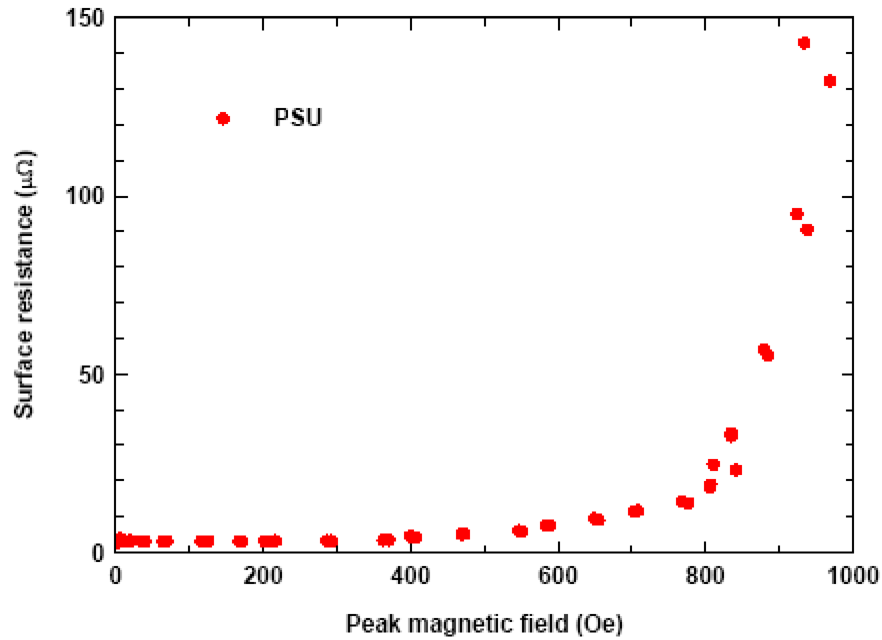
Stripline Resonator Measurement at 1.5 GHz

Films by Co-Evaporation



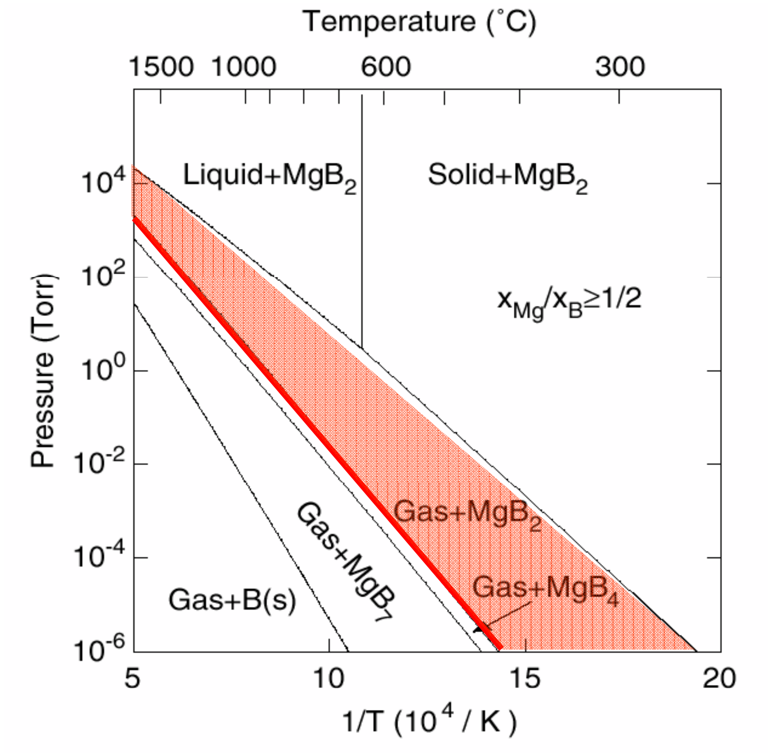
Oates, Agassi, and Moeckly, IEEE Trans. Appl. Supercond. 17, 2871 (2007)

Films by HPCVD

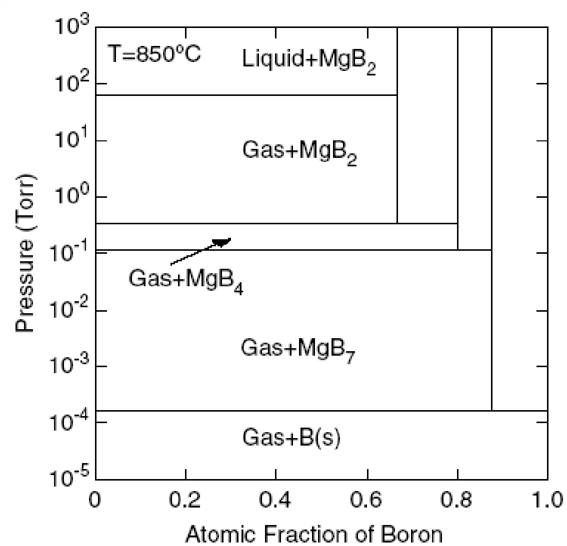


By Dan Oates, MITLL

Keys to Growth of MgB_2 Films



Liu *et al.*, APL 78, 3678 (2001)



— **Keep a high Mg pressure for phase stability**

For example, at 600°C Mg vapor pressure of 0.9 mTorr or Mg flux of 500 Å/s is needed

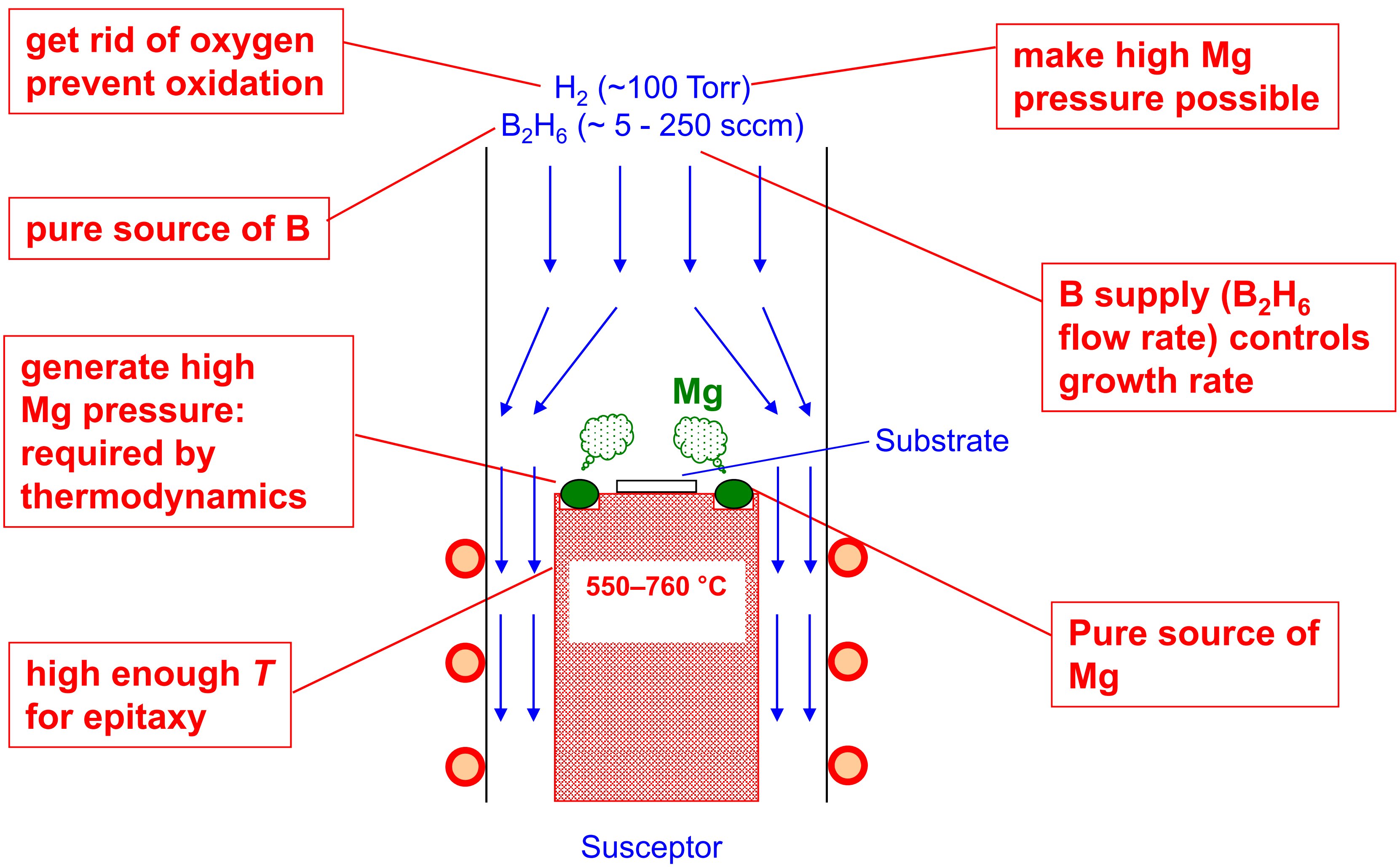
— **No need for composition control** , as long as the Mg:B ratio is above 1:2.

— **Keep oxygen away**: Mg reacts strongly with **oxygen** - forms MgO, reduces Mg vapor pressure.

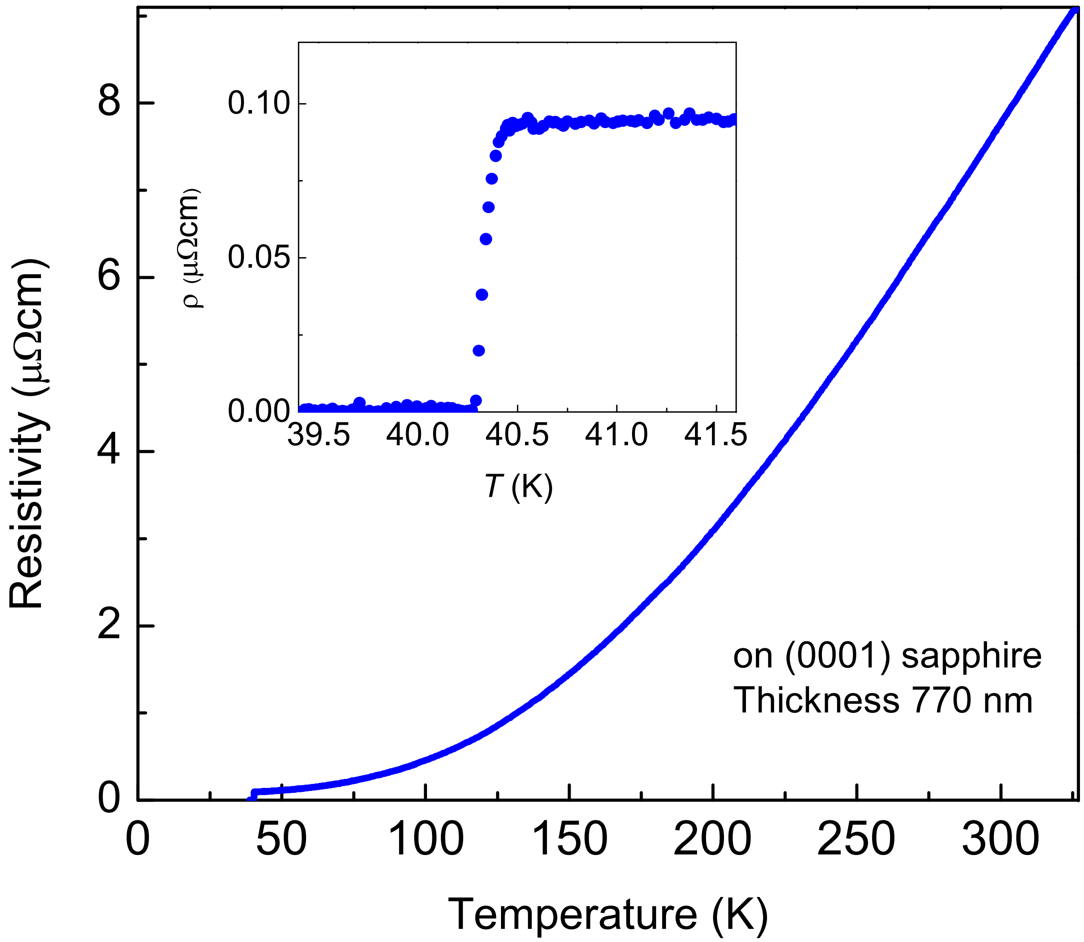
— **Avoid carbon**: **Carbon** doping reduces T_c and increases resistivity

Hybrid Physical-Chemical Vapor Deposition

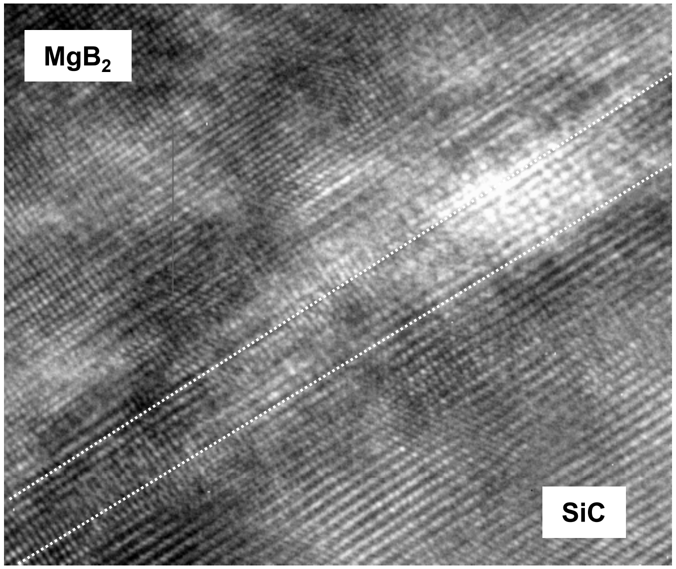
Schematic View



Clean, Epitaxial HPCVD MgB_2 Films



Xi *et al*, Physica C 456, 22 (2007)

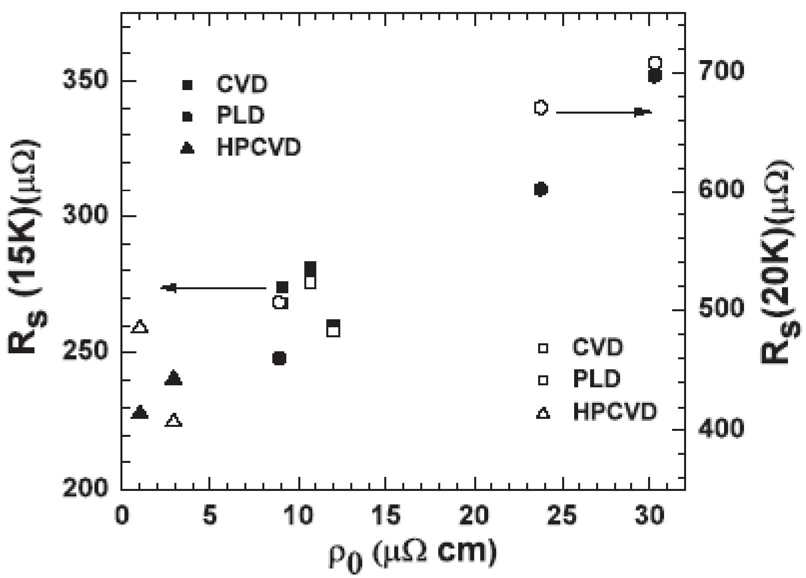


interface

Wu *et al.*, APL 85, 16 (2004)

Microwave Properties vs Cleanness of MgB_2 Films

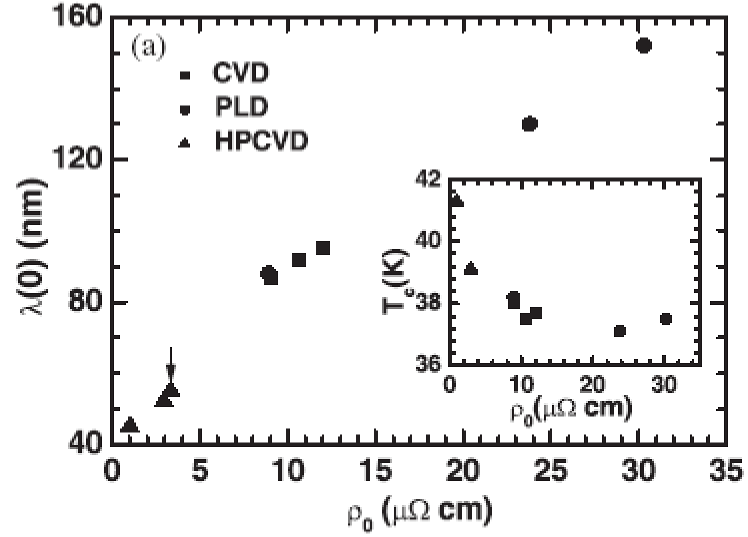
Surface Resistance @ 18 GHz



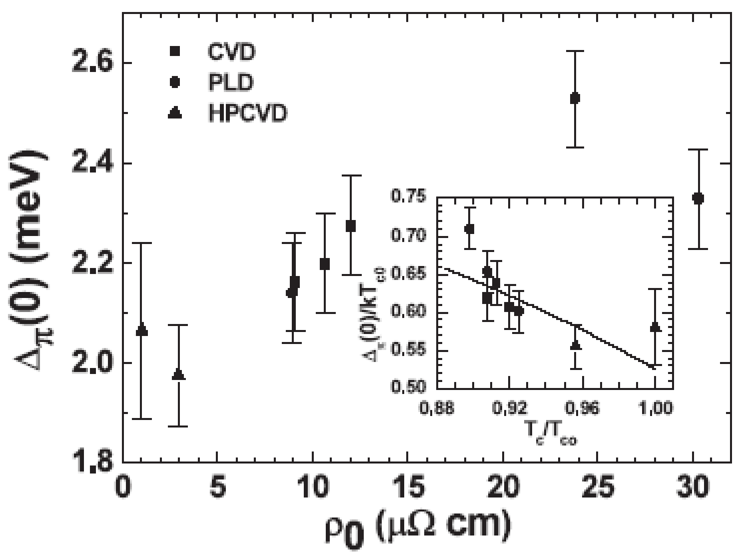
— Dielectric single-crystal sapphire puck resonator at 18 GHz.

— Cleaner films (low resistivity) leads to lower surface resistance, shorter penetration depth, and smaller πband gap (less interband scattering).

Penetration Depth

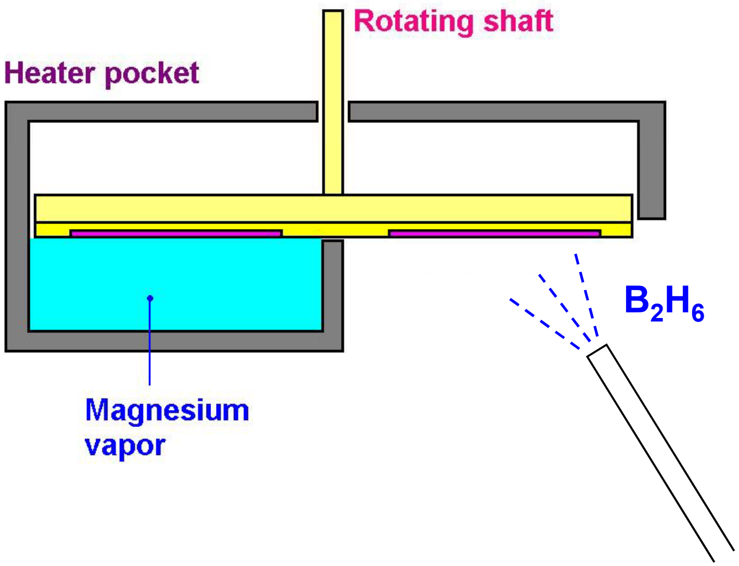


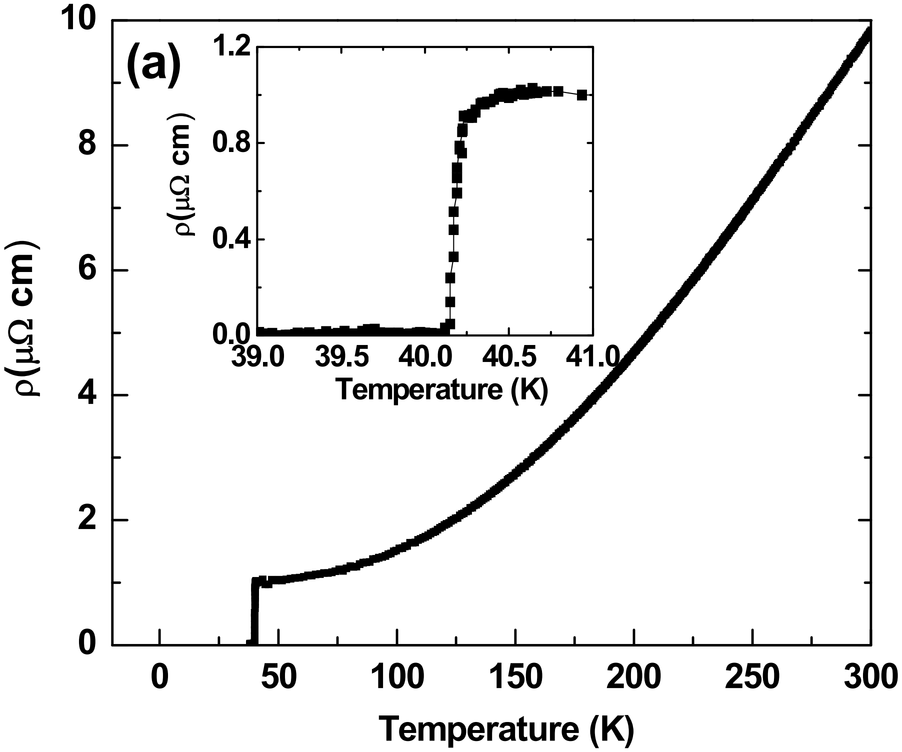
***π*-Band Gap**



Jin *et al*, SC Sci. Tech. 18, L1 (2005)

Large Area HPCVD Films Using STI Pocket Heater





Differences from reactive co-evaporation:

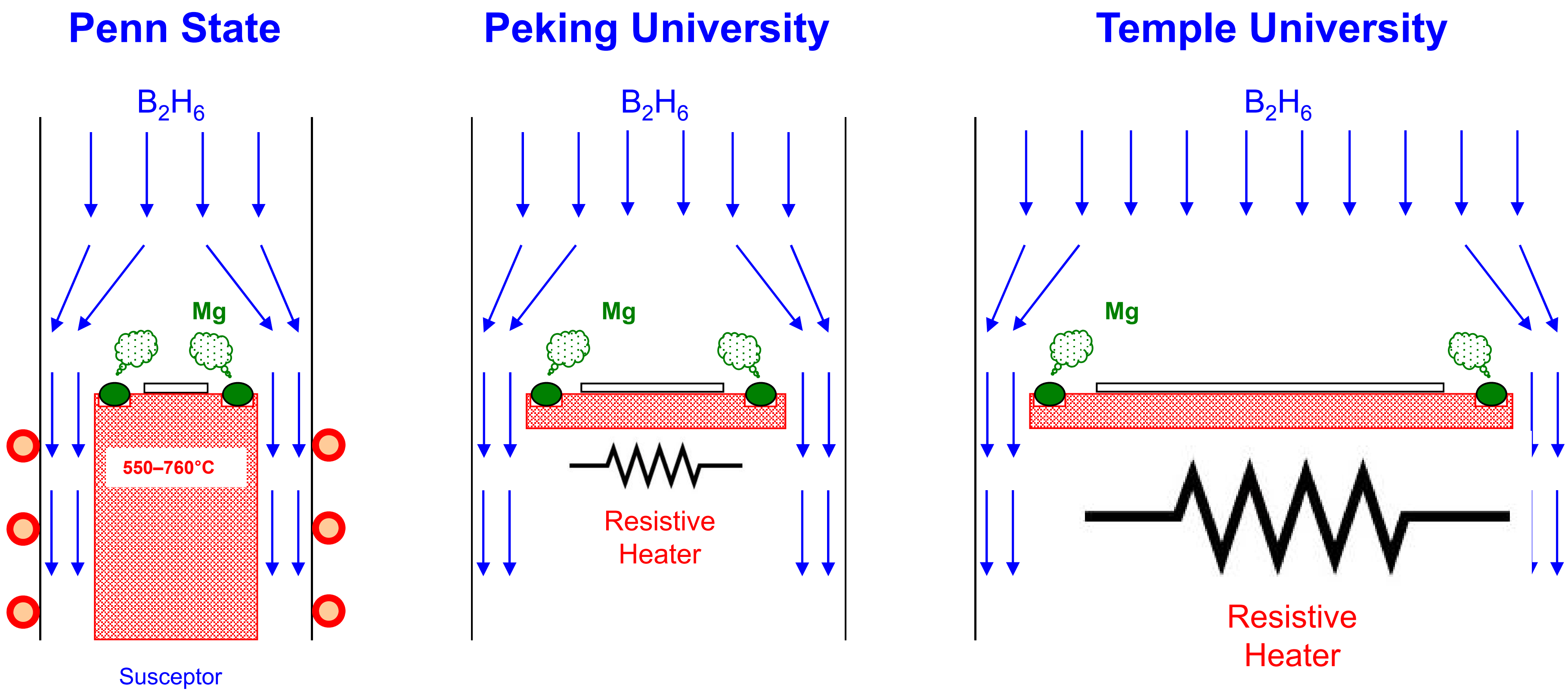
— B_2H_6 used as boron source instead of e-beam evaporation
— Hydrogen used as the carrier gas instead of HV
— Deposition temperature in broader range

Advantages:

— Large area and double sided films
— Potential for scale up for wires

Wang *et al*. Supercond. Sci. Tech. 21, 085019 (2008)

Scaling up HPCVD for Large Area Films



Penn State

- Inductive heater
- **Successful**
- 5mm x 5mm

Peking University

- Resistive heater
- **Successful**
- 15mm x 15mm

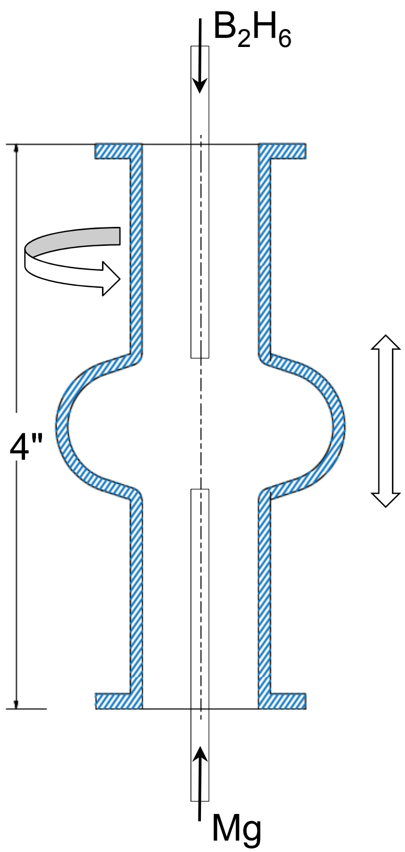
Temple University

- Resistive heater
- Designed for 2" dia.

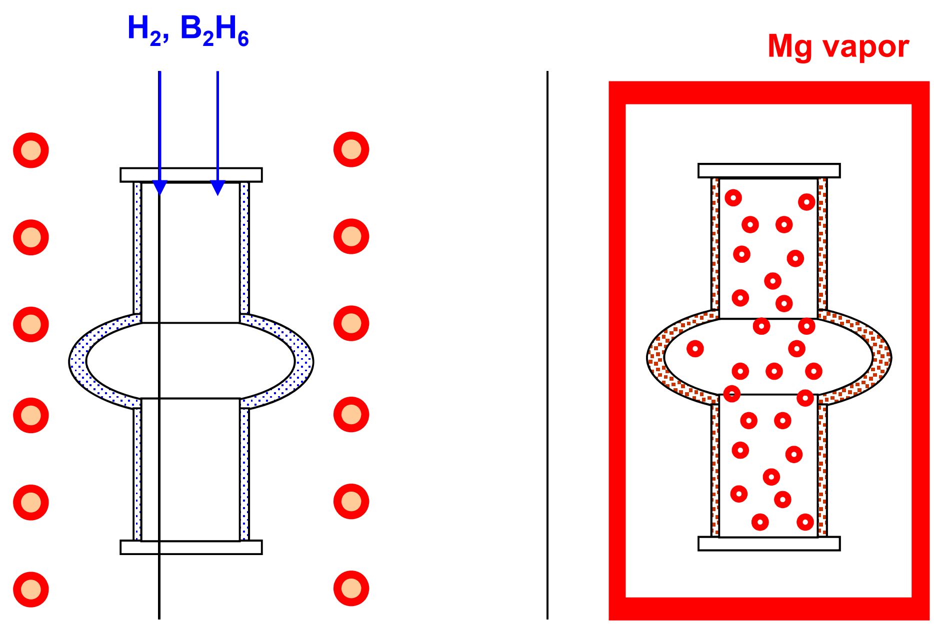
Coating of 6 GHz Nb Cavity

- 6 GHz Nb cavity provided by Enzo Palmieri, INFN. Characterization capability exists at INFN.
- Small size: Can be coated using existing equipment in the lab; Low cost for optimization; First step towards coating of larger cavities.

In Situ Process

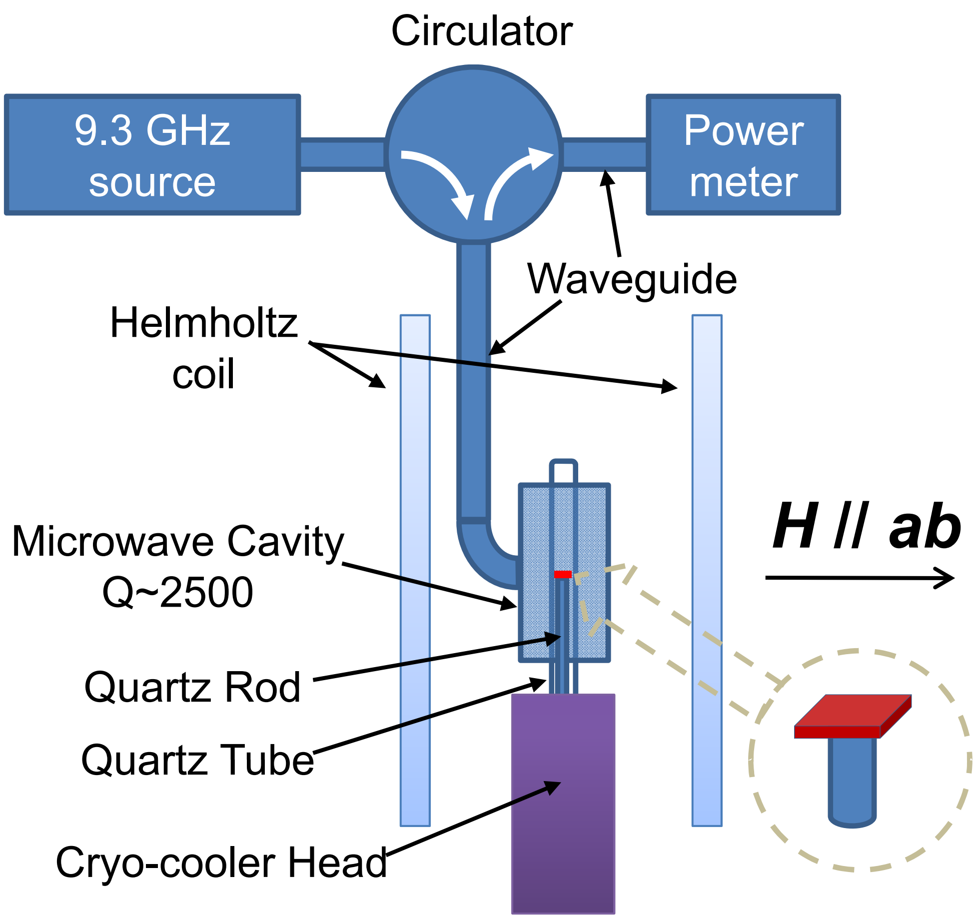


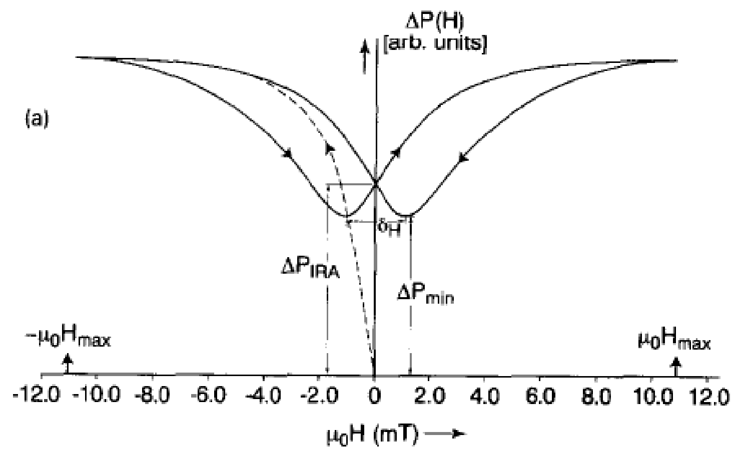
Ex Situ Process



Low-Field Microwave Magnetoabsorption

Prof. Som Tyagi, Drexel University

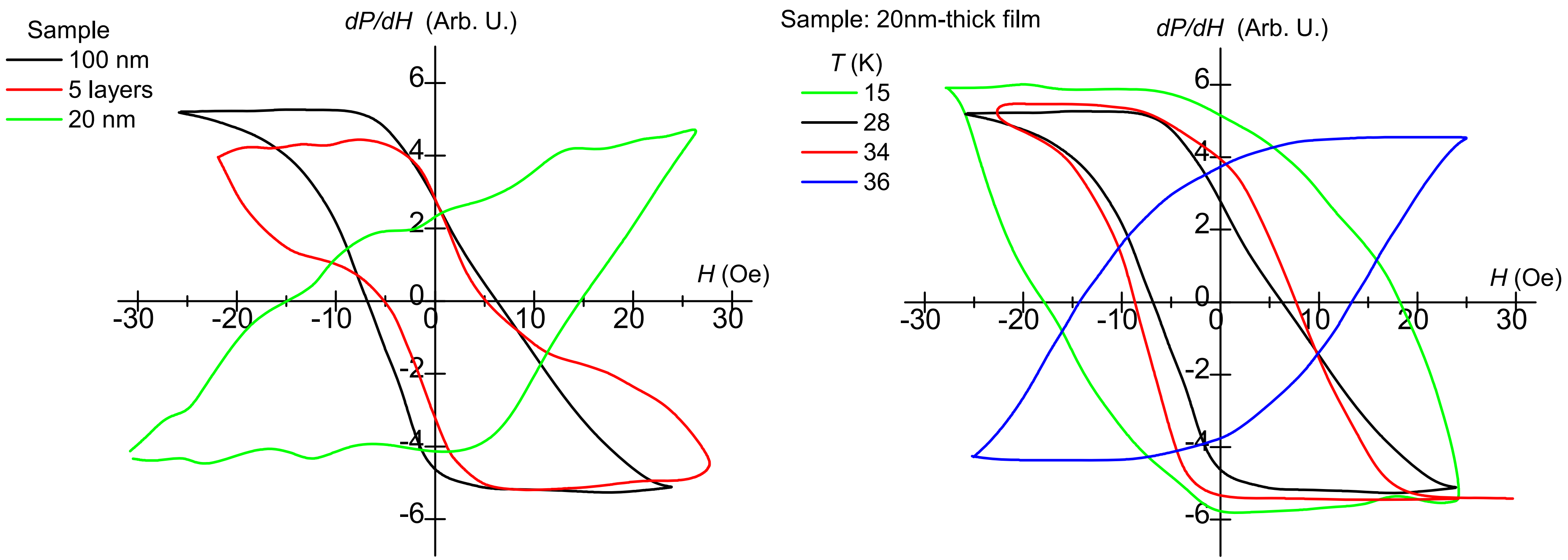




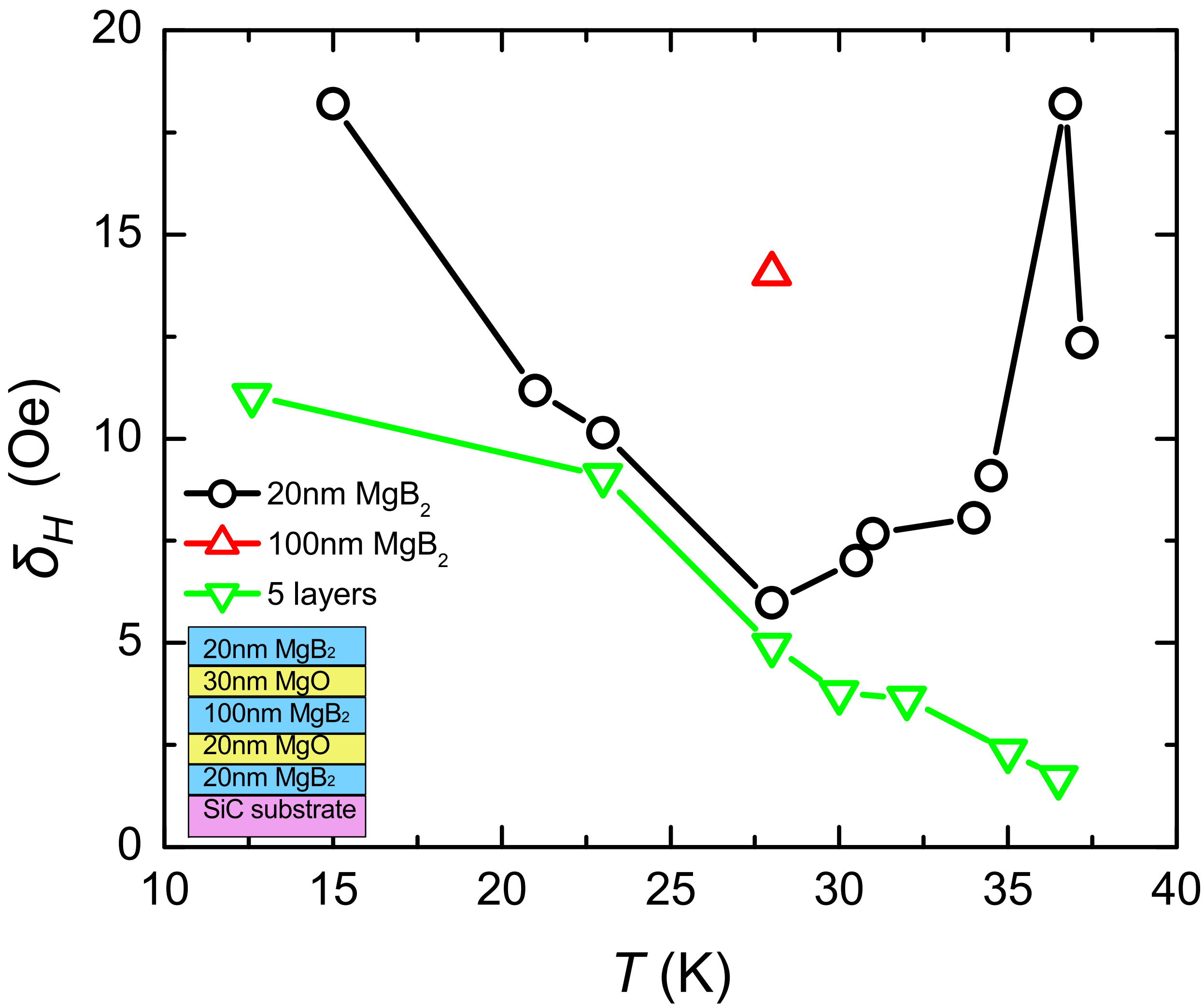
- Energy loss caused by the vortex movement leads to increase in microwave reflected power *P* from a resonated cavity
- Hysteretic loop related to trapped vortices in grain boundaries.

Bai, Patanjali, Bhagat, and Tyagi, J. Supercond. 8, 299 (1995).

dP/dH – *H* Loops for MgB_2 Films



$\delta_H - T$ for MgB_2 Films



Conclusion

— Clean MgB_2 thin films have excellent properties:

- low resistivity (<0.1 $\mu\Omega$cm) and high T_c promise low BCS surface resistance
- long coherence length and short penetration depth promise high H_c: possibly as high as ~ 820 mT
- Two gap effects need to be investigated.

— Current status of MgB_2 coating for SRF:

- Scaling up for *in situ* deposition of 2" films
- Coating of 6 GHz cavity planned by both *in situ* and *ex situ* processes

— Low-Field Microwave Magnetoabsorption may provide useful information for SRF.