MgB_2 for SRF Cavities

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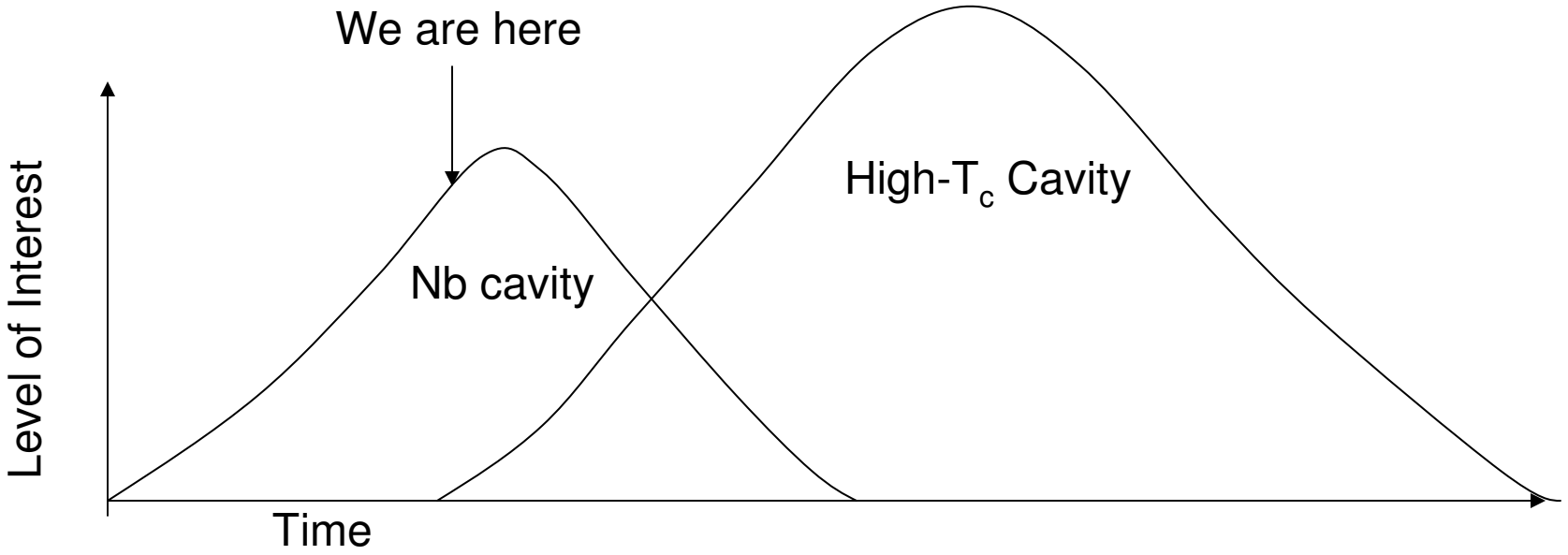
Why do we need to look for new SC materials for RF cavities?

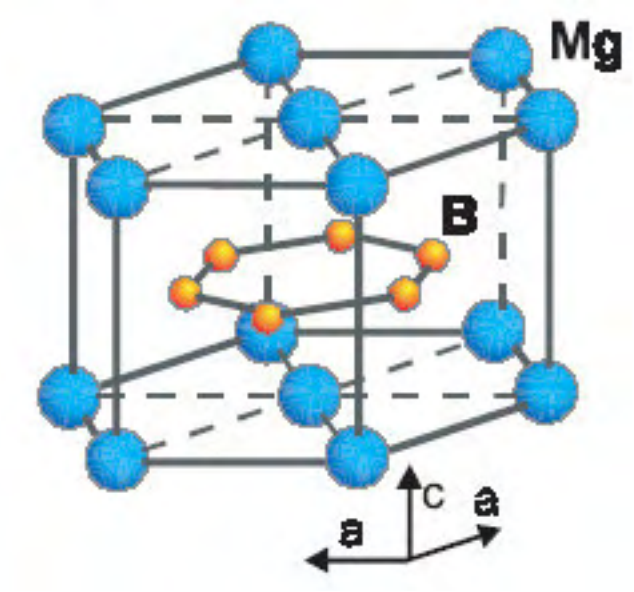
- High-purity Nb and cavities are still expensive.
- Refrigeration to get to 4 K or lower is expensive
- Nb cavities have reached close to its theoretical limit and the recipe to get good results such as E_{acc} >35 MV/m repeatedly will be established within ~5 years.



Magnesium Diboride (MgB_2)

- MgB_2 was discovered to be superconductive at ~**40 K** in early 2001. It was a surprise since it is a simple binary intermetallic compound.

Magnesium Diboride (MgB_2)



Graphite-type boron layers separated by hexagonal close-packed layers of magnesium

Superconductivity comes from the phonon-mediated Cooper pair production similar to the low-temperature superconductors except for the two-gap nature.

Compared to cuprates:

- Cheaper
- Lower anisotropy
- Larger coherence length
- Transparency of grain boundaries to current flows

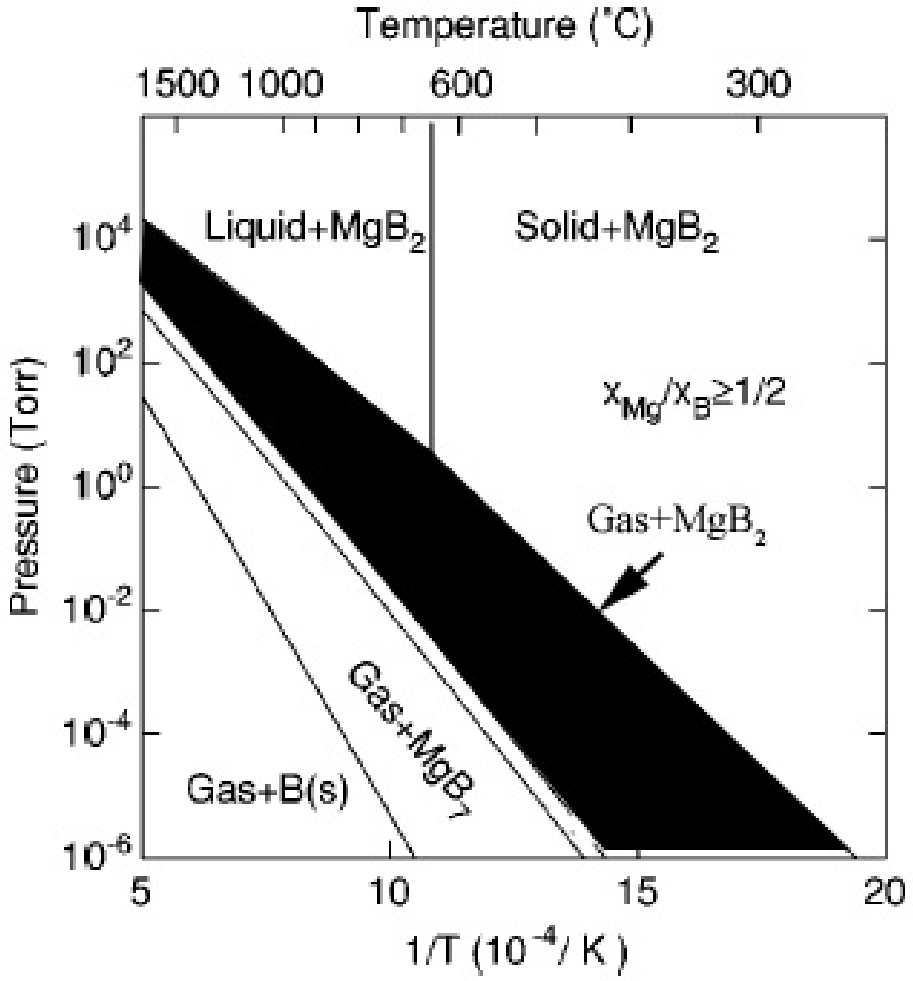
These makes MgB_2 attractive for applications.

C. Buzea and T. Yamashita, Superconductor Sci. Technol. 14 (2001) R115.

Developments in the past 2 years

- In 2003, R_s lower than Nb at 4 K was demonstrated with a ~400 nm film. An order of magnitude lower BCS R_s is predicted.
- A preliminary test showed little increase of R_s up to H_{RF}~120 Oe (limited by available power), i.e., equivalent of E_{acc}~3 MV/m. Encouraging.

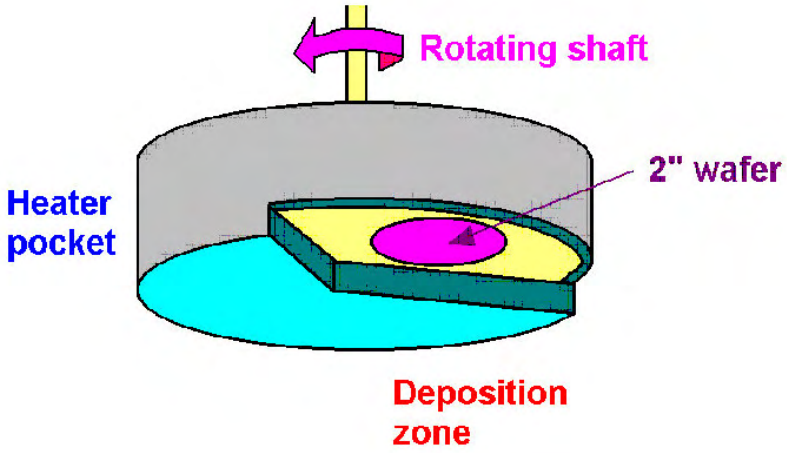
Simple binary compound, but needs high Mg pressure to form MgB_2 phase

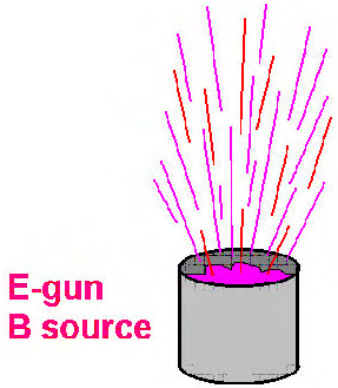


Pressure-temperature phase diagram for the Mg:B

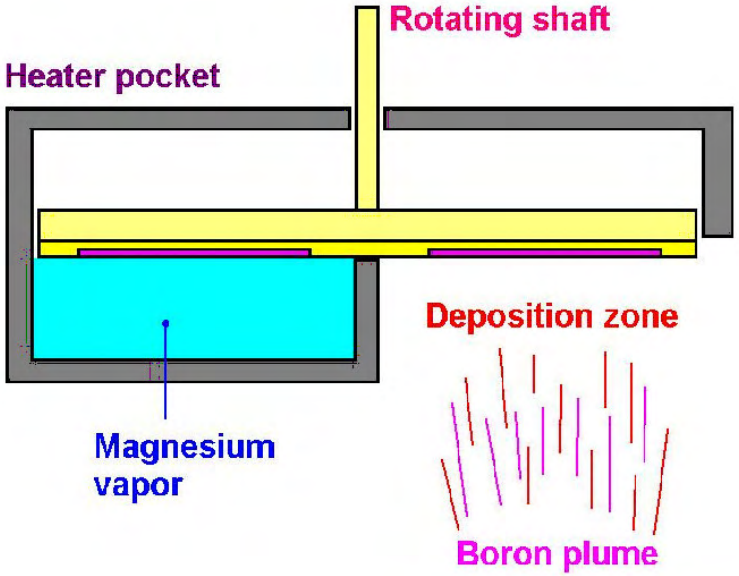
Zi-Kui Liu et al., Appl. Phys. Lett. 78 3678 (2001).

MgB_2 Film Growth, an example at the Superconductor Technologies, Inc. (STI)





In-situ reactive evaporation

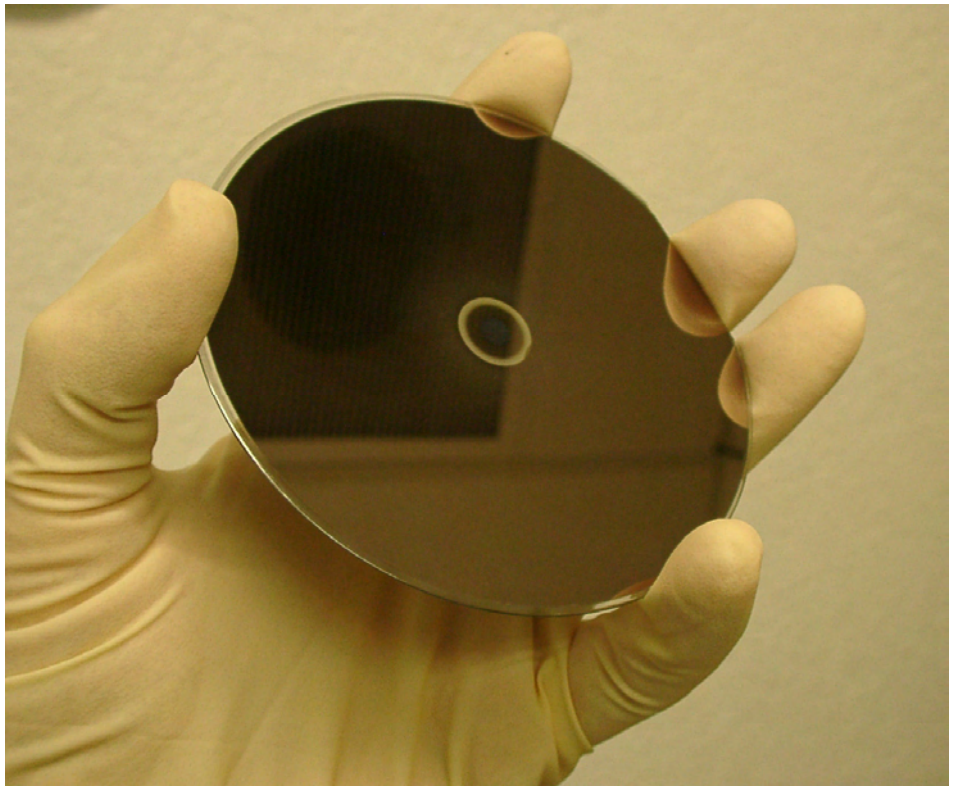


More details are found in
B.H. Moeckly et al., IEEE Trans. Appl. Supercond. 15 (2005) 3308.
T. Tajima et al, Proc. PAC05.

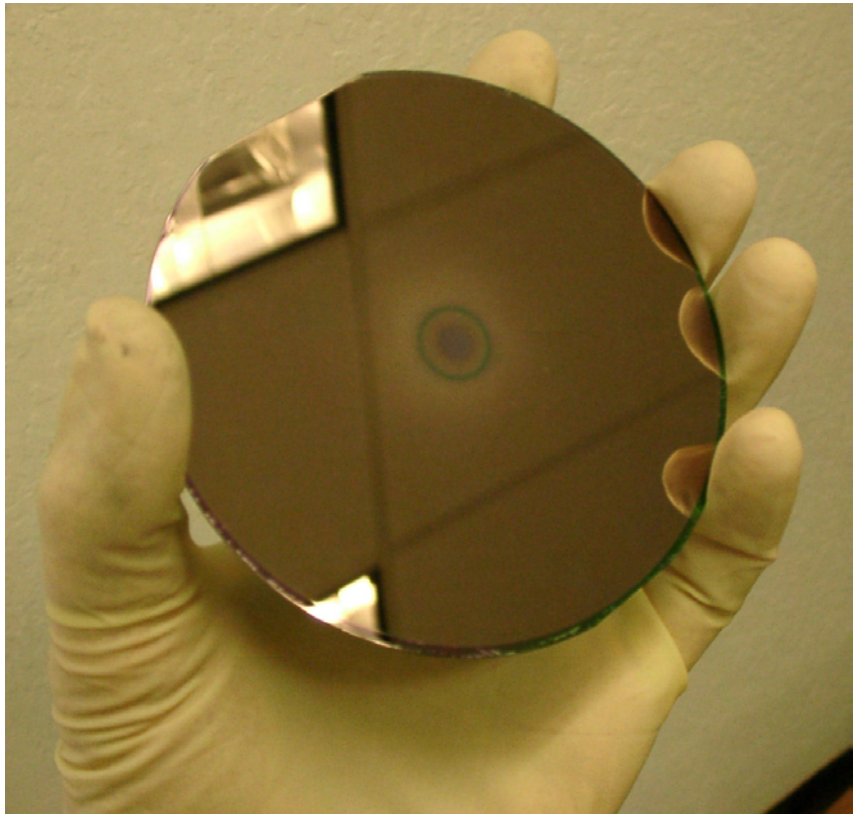
B.H. Moeckly, ONR Superconducting Electronics Program Review
Red Bank, NJ, February 8, 2005

MgB_2 on 4" substrates

R-plane sapphire



Si_3N_4 / Si



B.H. Moeckly, ONR Superconducting Electronics Program Review
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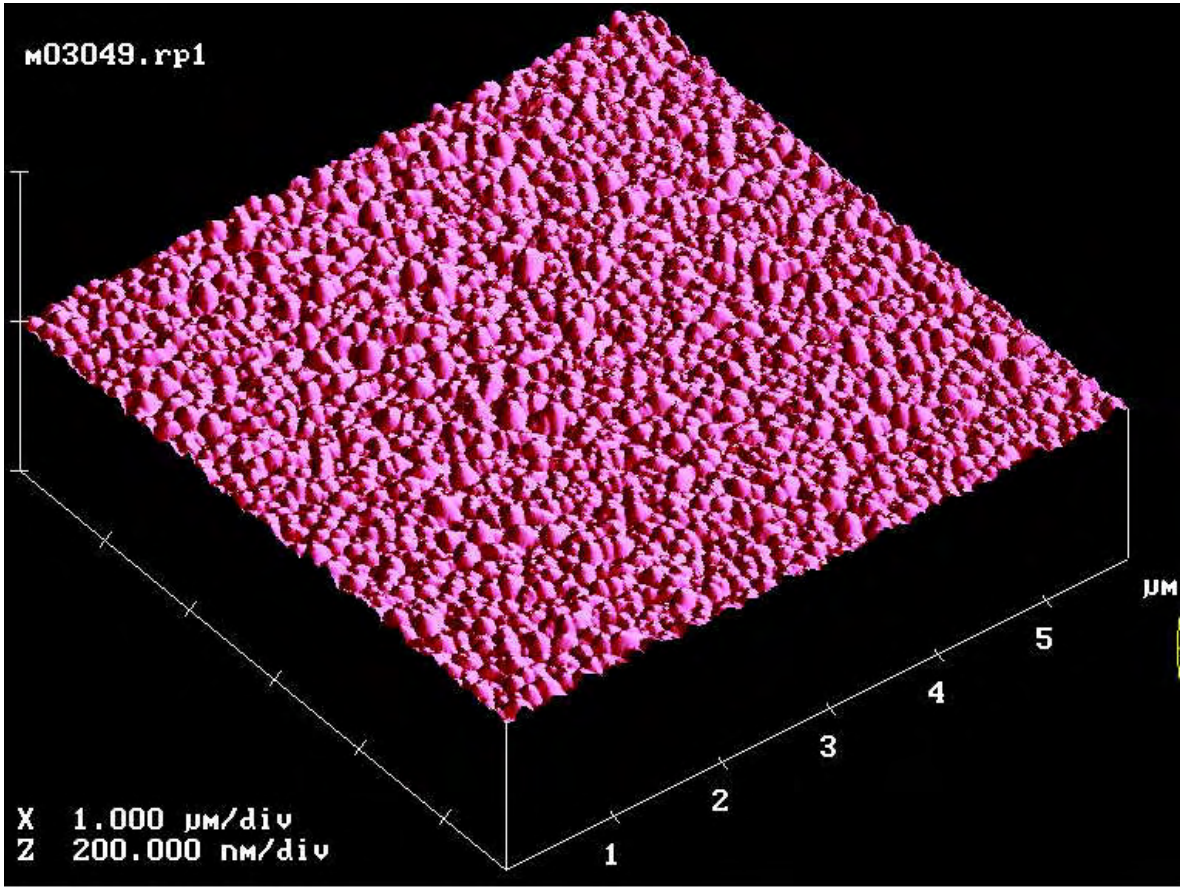
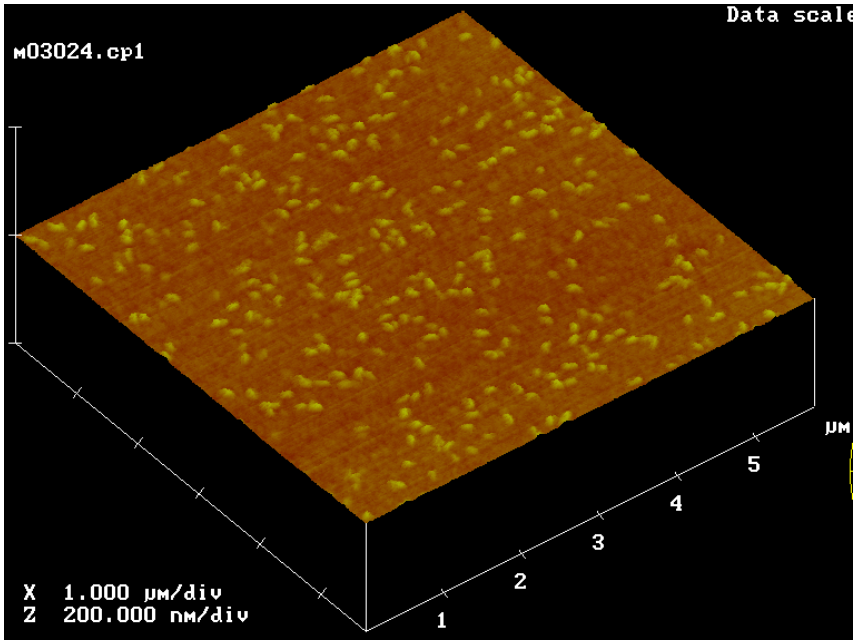
Surface morphology – MgB_2 on *r*-plane sapphire



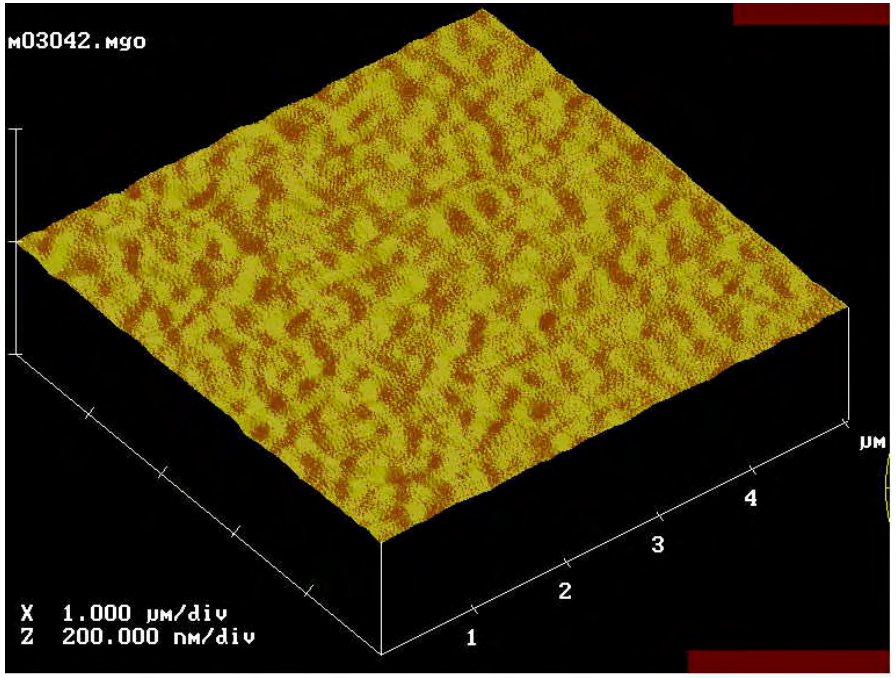
- Typical surface on *r*-plane sapphire
- Growth T = 550 °C
- t = 5500 Å
- Small, conical grains
- ~1000 – 2000 Å diameter
- RMS roughness = 44 Å

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

Surface morphology – smoother films



- MgB2 on sapphire
- Low *T* growth: 450 °C
- *t* = 1500 Å
- RMS roughness = 12 Å

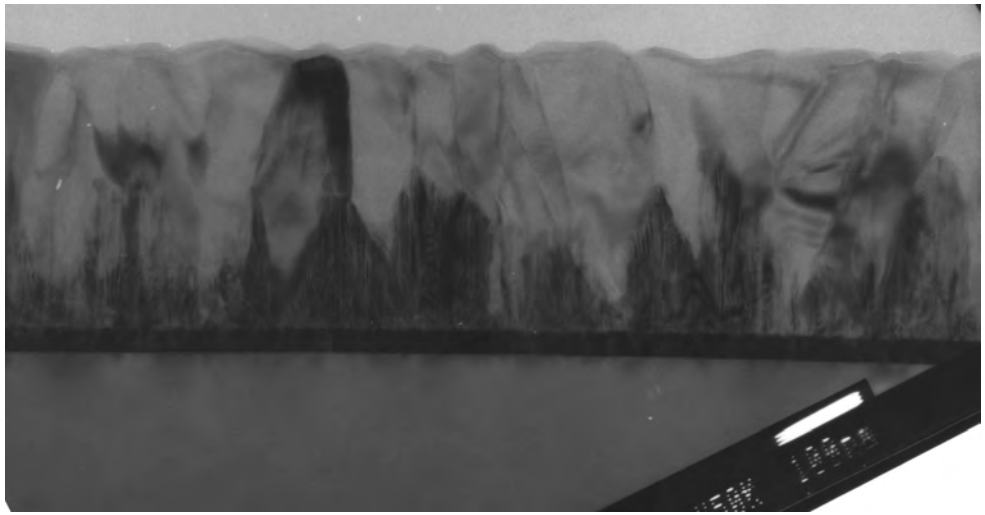


- MgB_2 on MgO
- Growth *T* = 550 °C
- *t* = 3000 Å
- RMS roughness = 22 Å

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

Microstructure – MgB_2 on *c*-plane sapphire

- Columnar growth
- Clear layer at interface
- Layer looks grown, not reacted
- Grain size ~100 nm
- Numerous threading defects in lower half
- Defects decrease with thickness

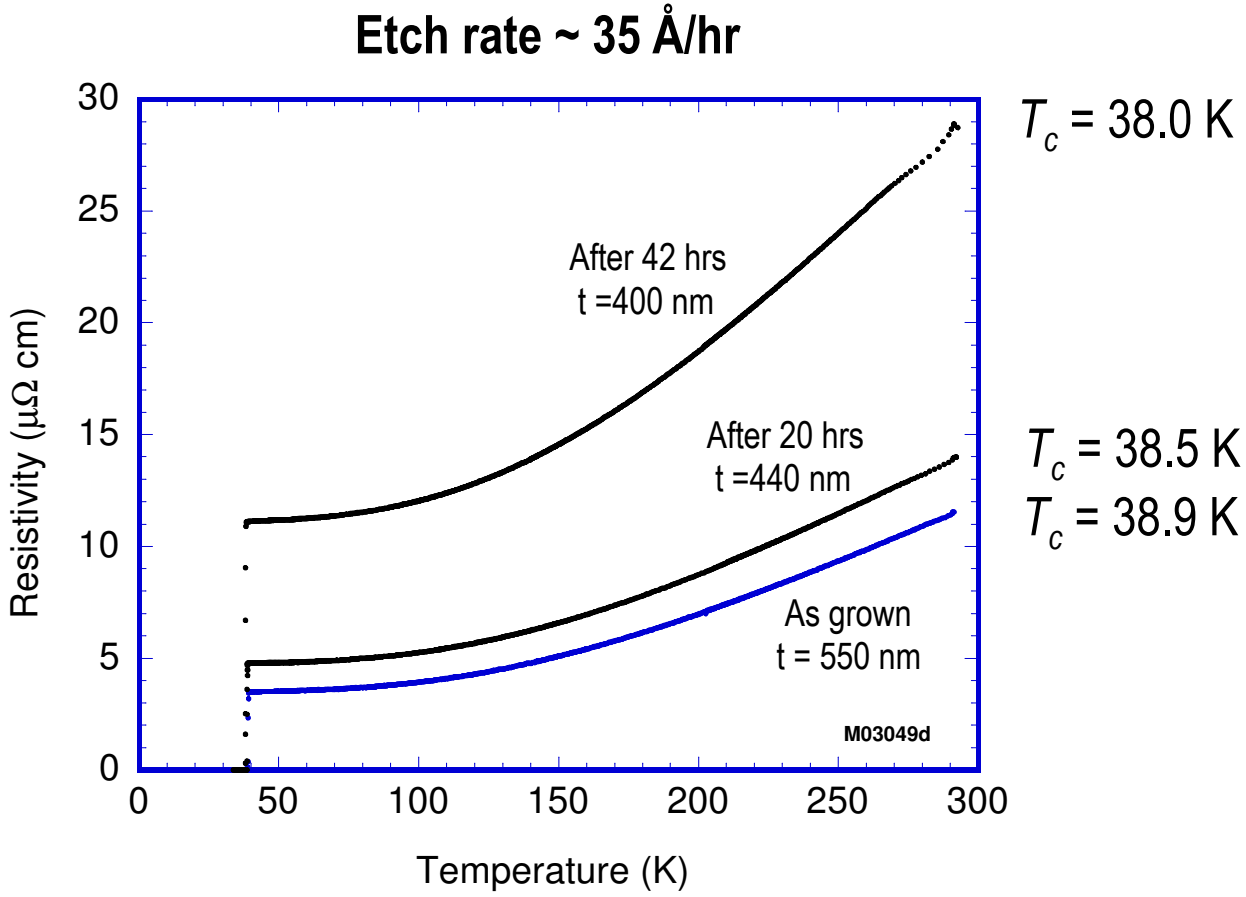


B.H. Moeckly, ONR Superconducting Electronics Program Review Red Bank, NJ, February 8, 2005

Dave Smith

Stability – DI water soak

- Films etch very slowly in water
- Films also seem stable with time

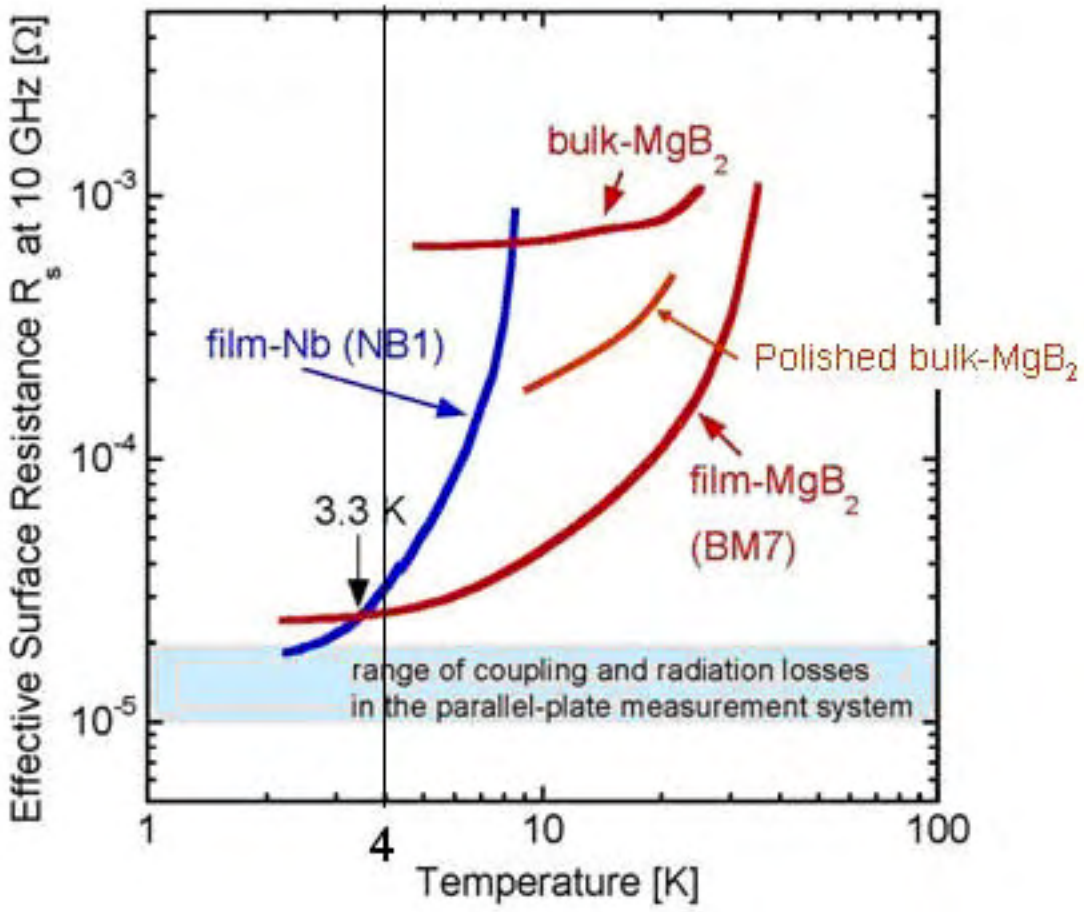


B.H. Moeckly, ONR Superconducting Electronics Program Review Red Bank, NJ, February 8, 2005

Latest films have shown R_s lower then Nb at 4 K.

Residual resistance still dominates at lower temperatures.

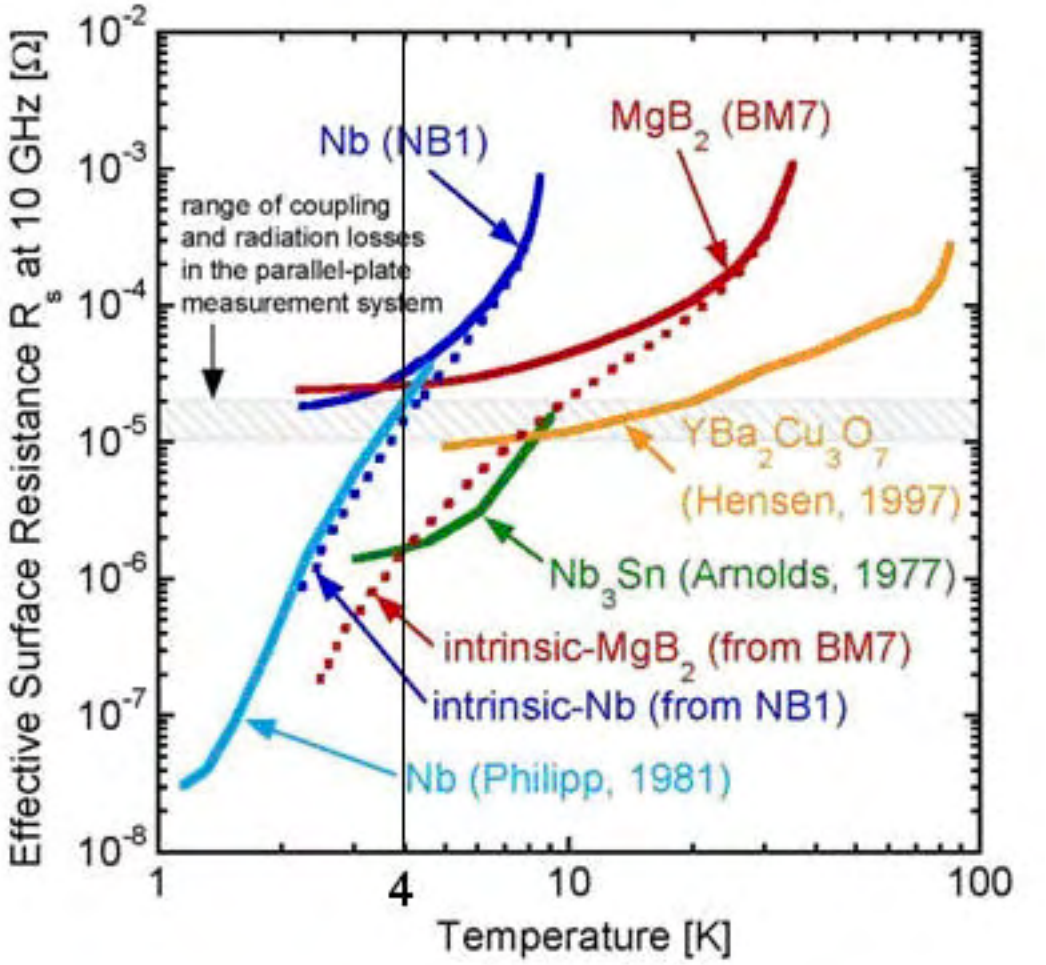
1 cm^2 sample on r-cut sapphire



A.T. Findikoglu et al., NSF/DOE Workshop on RF Superconductivity, Bethesda, MD, Aug. 29, 2003.
B.H. Moeckly et al., IEEE Trans. Appl. Supercond. 15 (2005) 3308.
T. Tajima et al., Proc. PAC05.

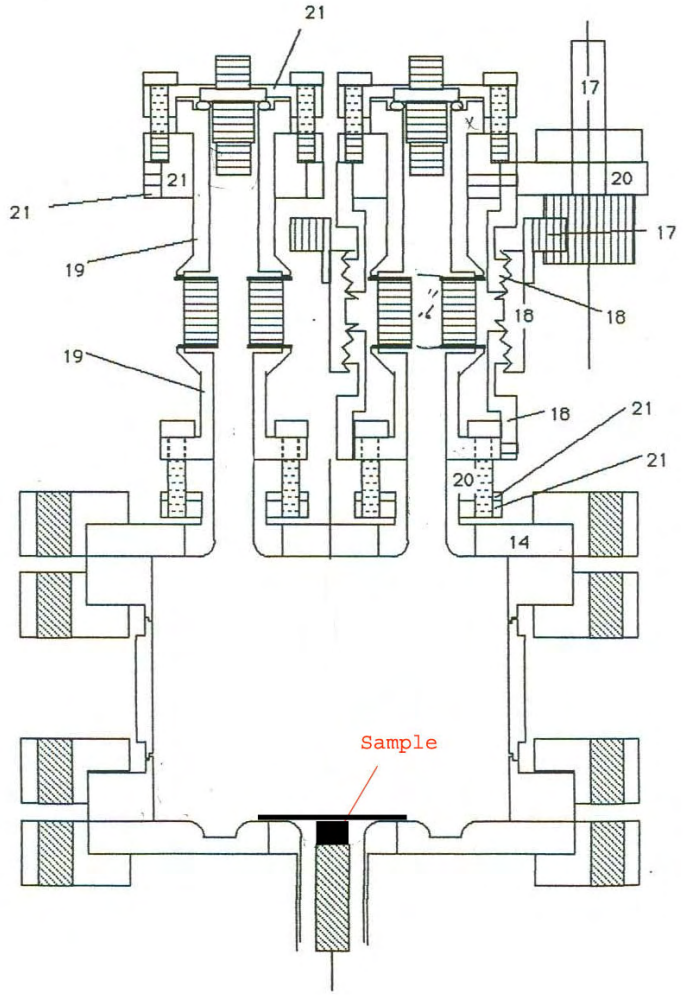
Predicted BCS R_s is ~1/10 of Nb

Dotted lines are predicted BCS resistance.

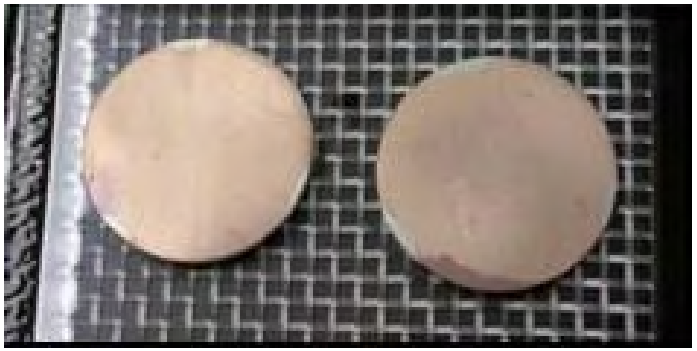


A.T. Findikoglu et al., NSF/DOE Workshop on RF Superconductivity, Bethesda, MD, Aug. 29, 2003.
B.H. Moeckly et al., IEEE Trans. Appl. Supercond. 15 (2005) 3308.

Power Dependence Tests at Cornell with 6-GHz Nb TE_{011} Cavity

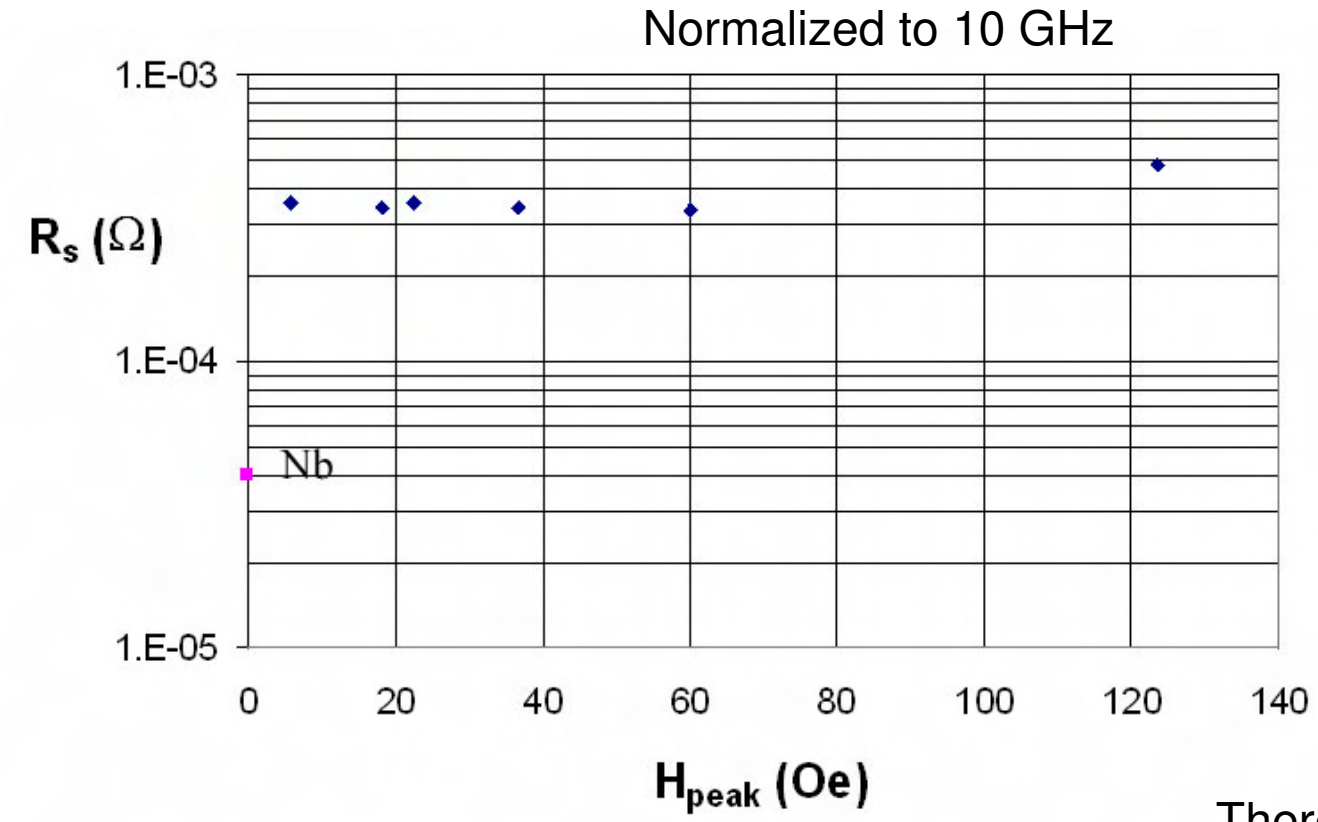


~400 nm film was grown on 1.5 cm Nb at STI.
First attempt to coat on a Nb substrate. The Nb substrate was rough (R_a ~ 400 nm).



Measurement by Alexander Romanenko, Hasan Padamsee

R_s does not change much with H_{RF}.



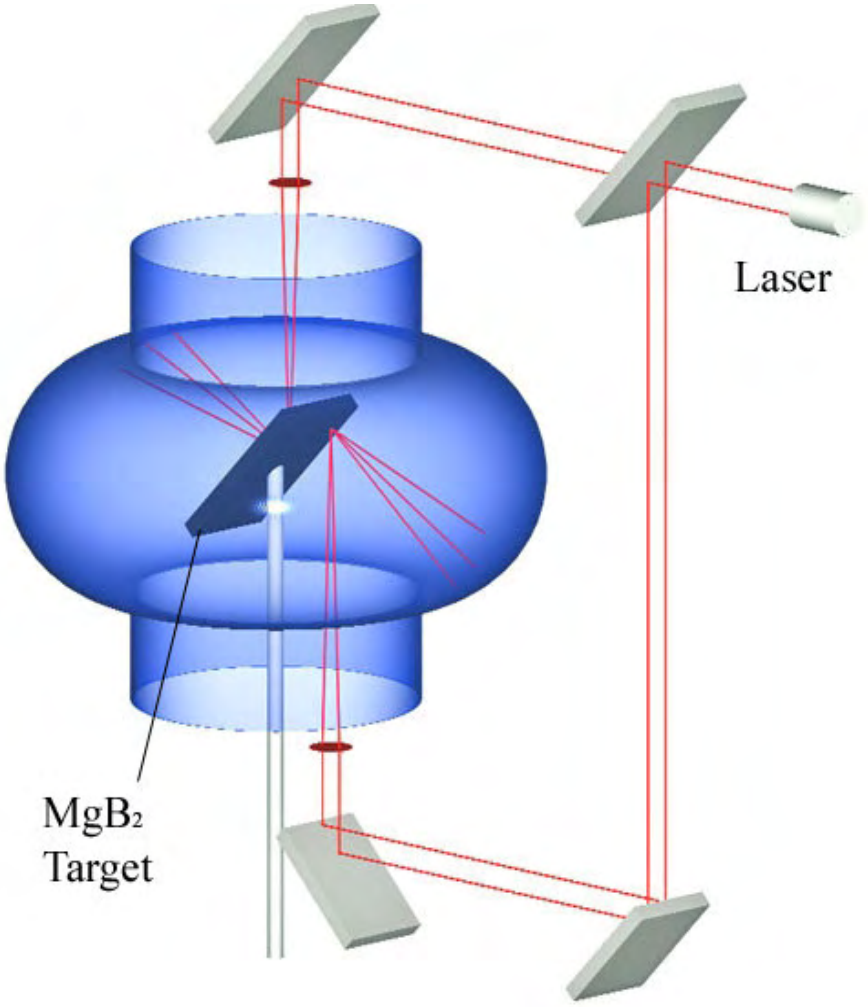
R_s was higher than Nb possibly due to the rough (R_a~400nm) substrate.

The highest H was limited by available power.

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.

An idea of coating a cavity with PLD



T. Tajima et al., PAC05, Knoxville, TN, May 16-20, 2005.

KrF Excimer laser or FEL??

Participants in this R&D (informal)

- Present

A. Findikoglu, A. Jason, F. Krawczyk, F. Mueller, A. Shapiro (LANL)

H. Padamsee, A. Romanenko, R. Geng (Cornell) – TE cavity measurements

B. Moeckly (STI)

H. Abe (NIMS, Japan) – Electroplating

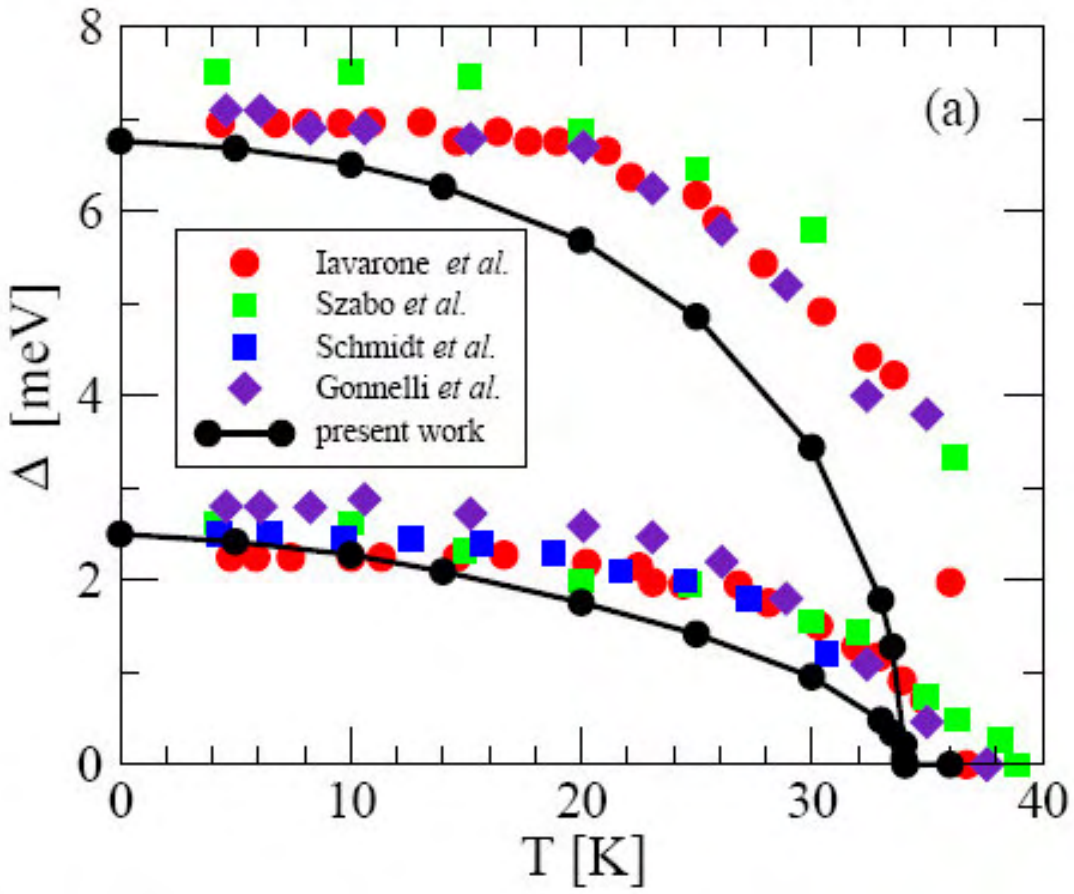
Y. Zhao (Univ. Wollongong, Australia) – PLD

- Future

L. Phillips, A-M, Valente, G. Wu (JLab) – TE cavity measurements, coating with FEL??

I. Campisi/S. Tantawi (SNS/SLAC) – Crititcal H measurements

rgy gaps



RF response has shown lower energy gap behavior.

← Nb

A. Floris et al., cond-mat/0408688v1 31 Aug 2004