Update on MgB_2 Thin Film Research for SRF Cavities

T. Tajima, G. Eremeev*, M. Hawley, R. Schulze, LANL

J. Guo, S. Tantawi, V. Dolgashev, D. Martin, C. Yoneda, SLAC

B. Moeckly, Superconductor Technologies, Inc. (STI)

I. Campisi, ORNL

TTC Meeting, FNAL, Batavia, IL, USA, 19-22 April 2010

LA-UR-10-02476

*Presently at JLab

We are trying to demonstrate Gurevich's multi-layer superconductor proposal

Simple single layer example

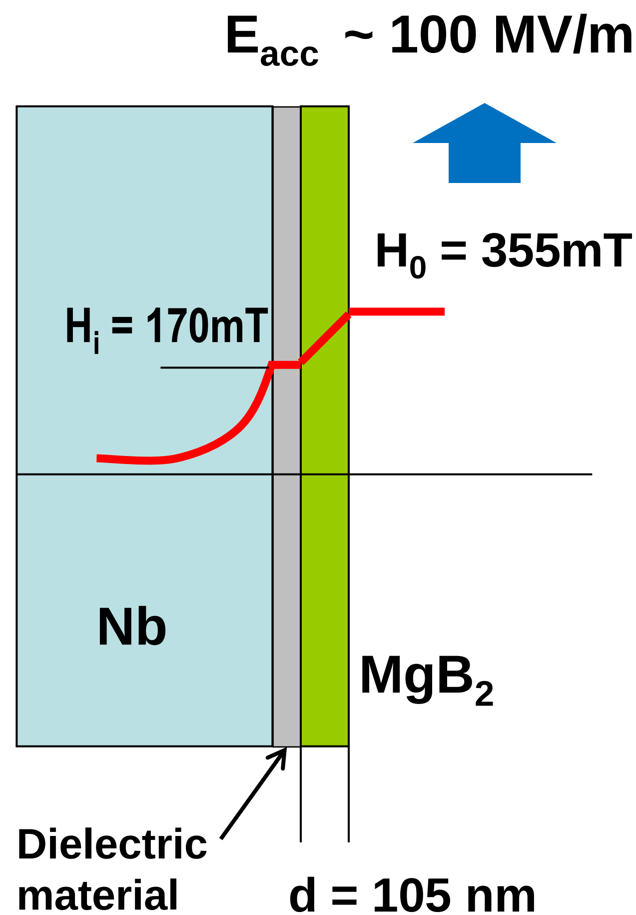
- **Assumptions**

H_{c1}(Nb) = 170 mT

λ_L(MgB_2) = 140 nm

ξ(MgB_2) = 5 nm

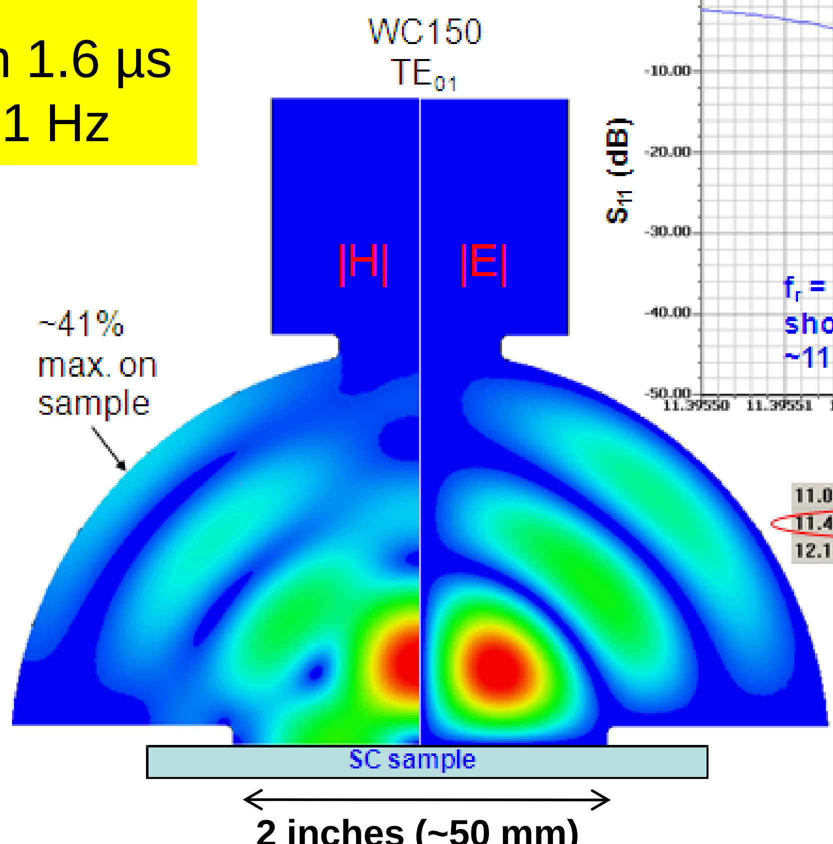
- H_{c1}(MgB_2) = 355 mT
- d = 105 nm
- **The film thickness needs to be determined so that the decayed field at the Nb surface is below the RF critical field of Nb (~200 mT).**

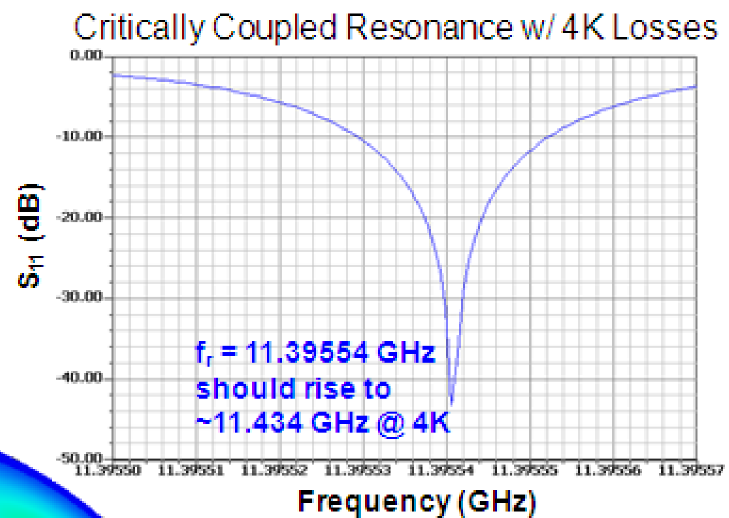


2-inch disk experiments have been carried out at SLAC using a 11.4 GHz 50 MW Klystron to generate short pulses (≤ 2 μs) and a TE_{013}-mode copper hemispheircal host cavity

New Superconducting Sample Test Cavity

Currently:
Pulse width 1.6 μs
Rep rate ≤1 Hz





11.03679067 +j ...	229721.7608
11.40143487 +j ...	336329.2824
12.18300991 +j ...	219994.4311

Q_0 = 336,330

Q_e = 337,740

→ Q_L = 168,520

τ_c = ~4.69 μs

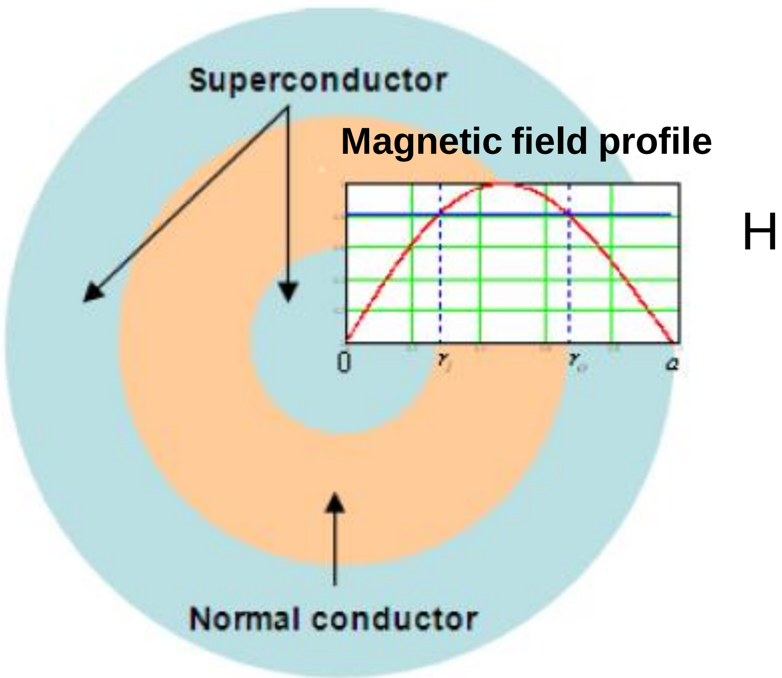
6/08

UNCLASSIFIED

Los Alamos NATIONAL LABORATORY EST.1943

The RF breakdown (quench) normally starts on the ring at half radius where the surface magnetic field peaks

Typical distribution of superconducting and normal-conducting regions after quench



G: Geometrical factor

$$\text{Sample } Q_0 \propto G_{sample}/R_{surface}$$

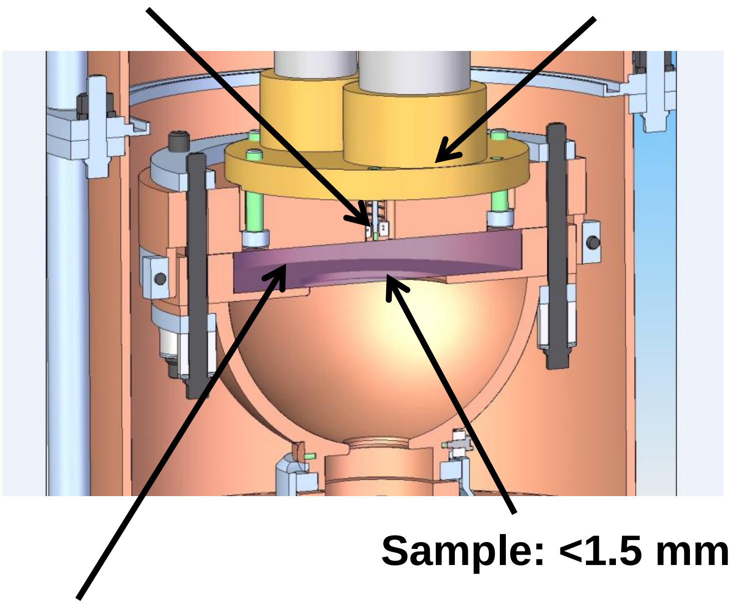
- **The cavity Q starts to decrease when part of sample quenches**
- **One can calculate approx. surface resistance from sample Q_0**

Sample setup detail and current MgB_2 coating method

Sample setup at SLAC

Temperature sensor

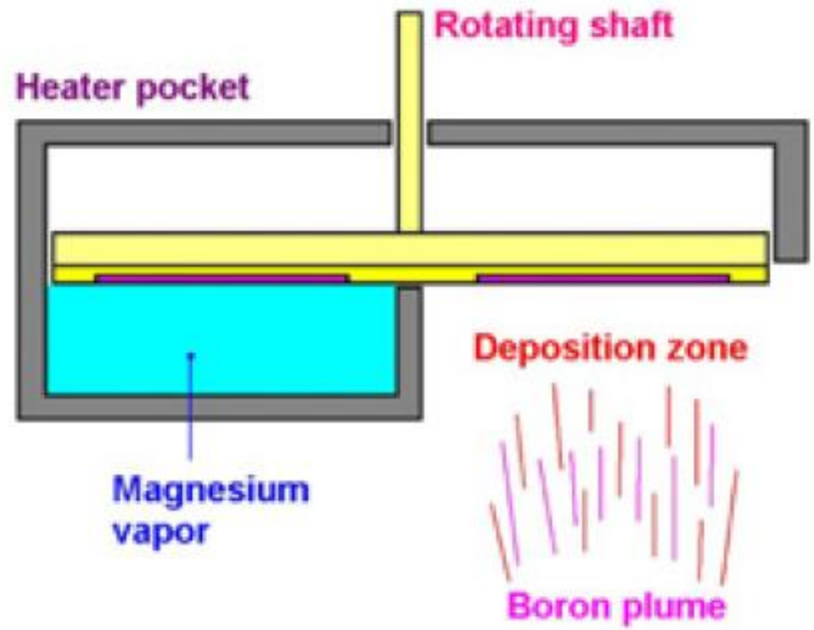
Cold head



Sample: <1.5 mm thick

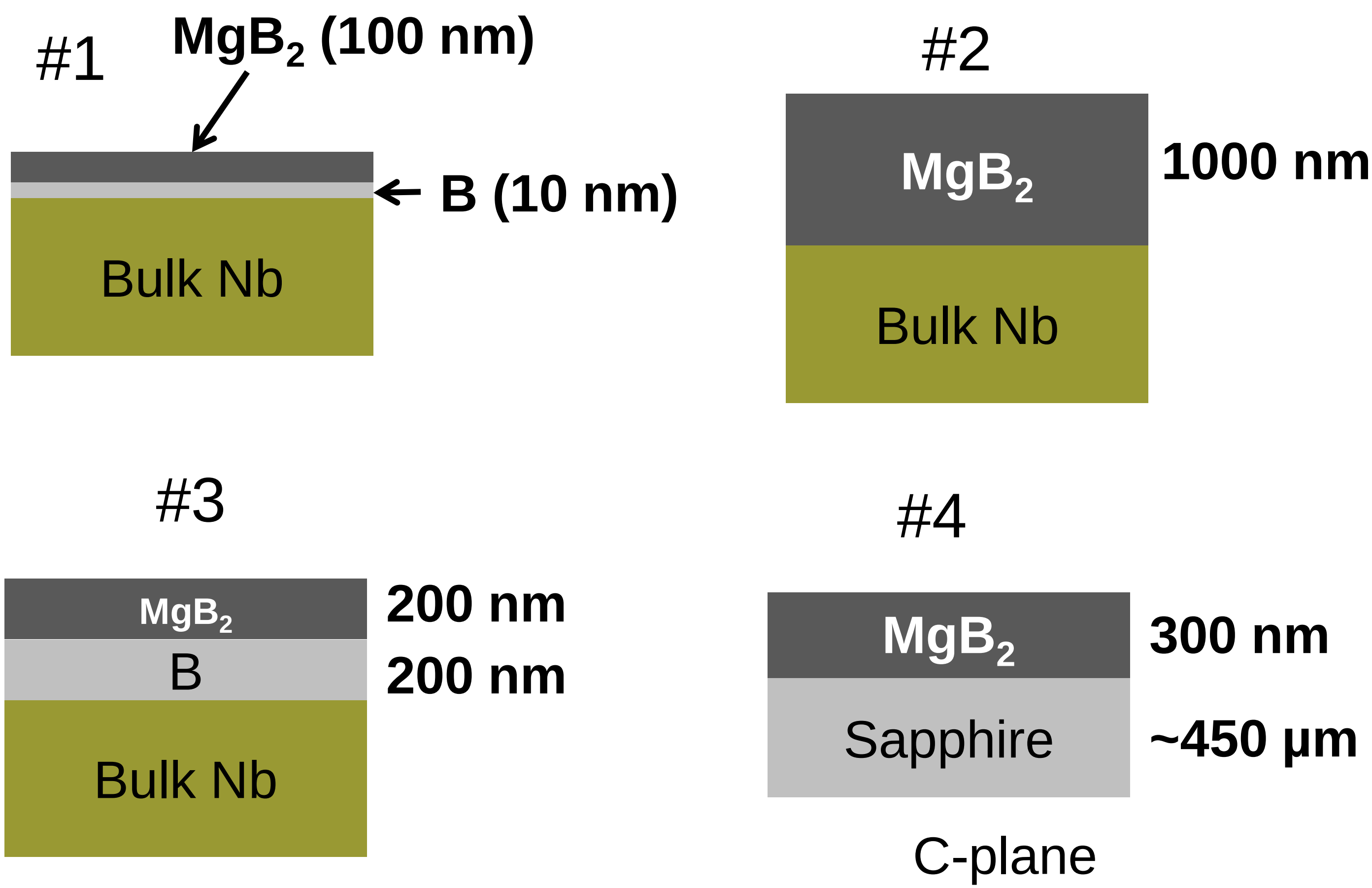
Copper sample holder: 6.35 mm thick

Reactive co-evaporation of MgB_2 at Superconductor Technologies, Inc. (STI), Santa Barbra, CA.



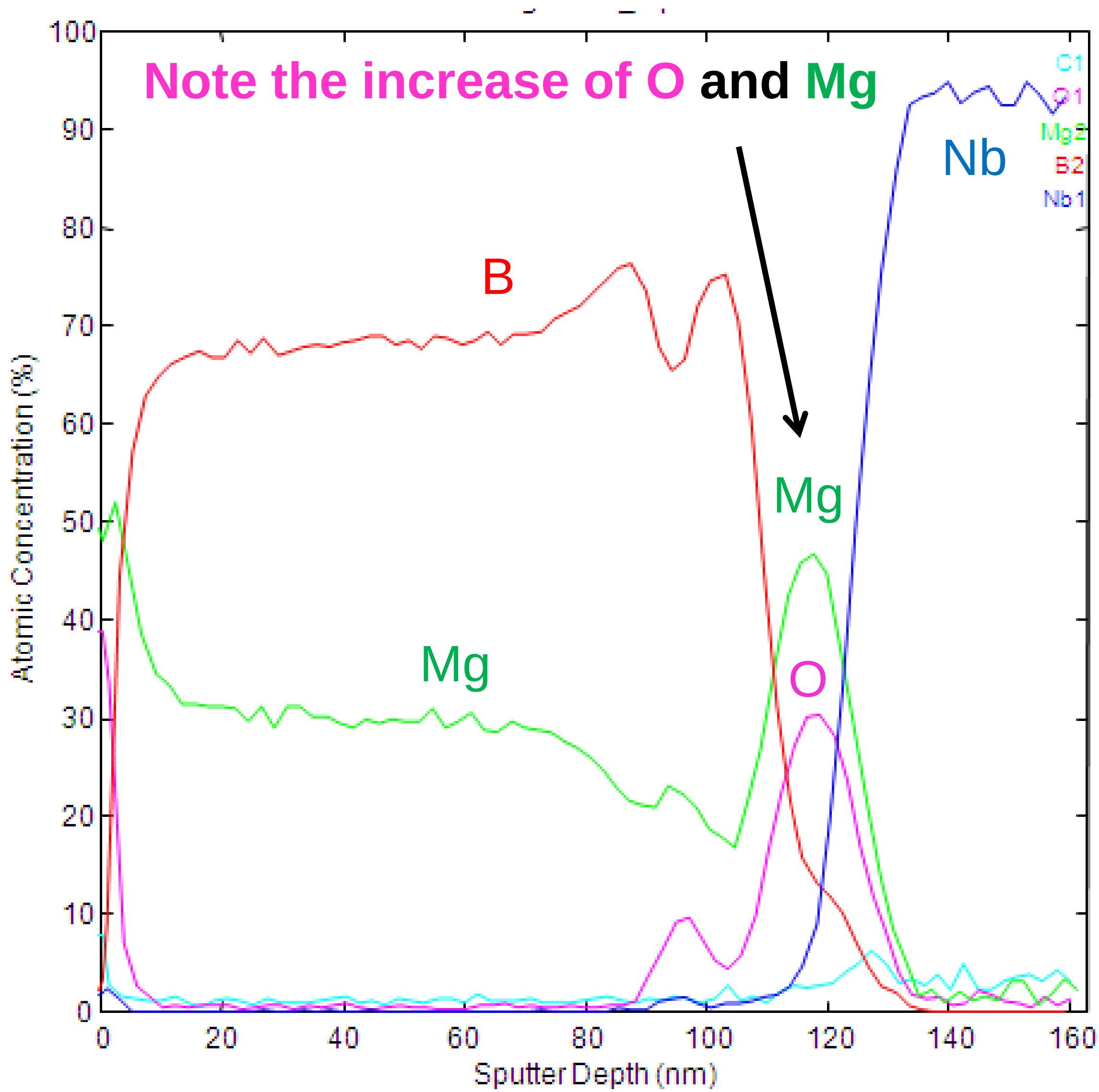
B.H. Moeckly and W.S. Ruby, Supercond. Sci. Technol. 19 (2006) L21–L24

So far, 4 types of coatings have been tried in addition to bare Nb reference samples

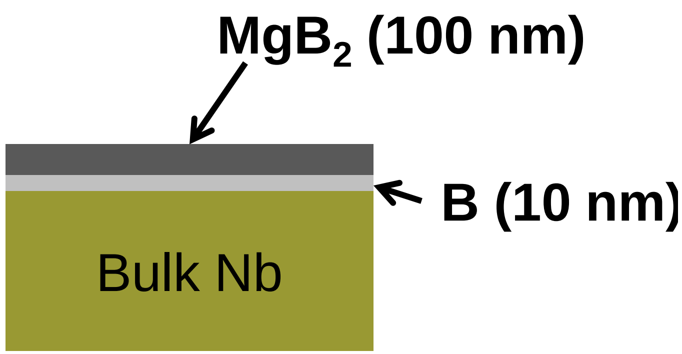


Coating #1
Element depth profile

Actual



Planned



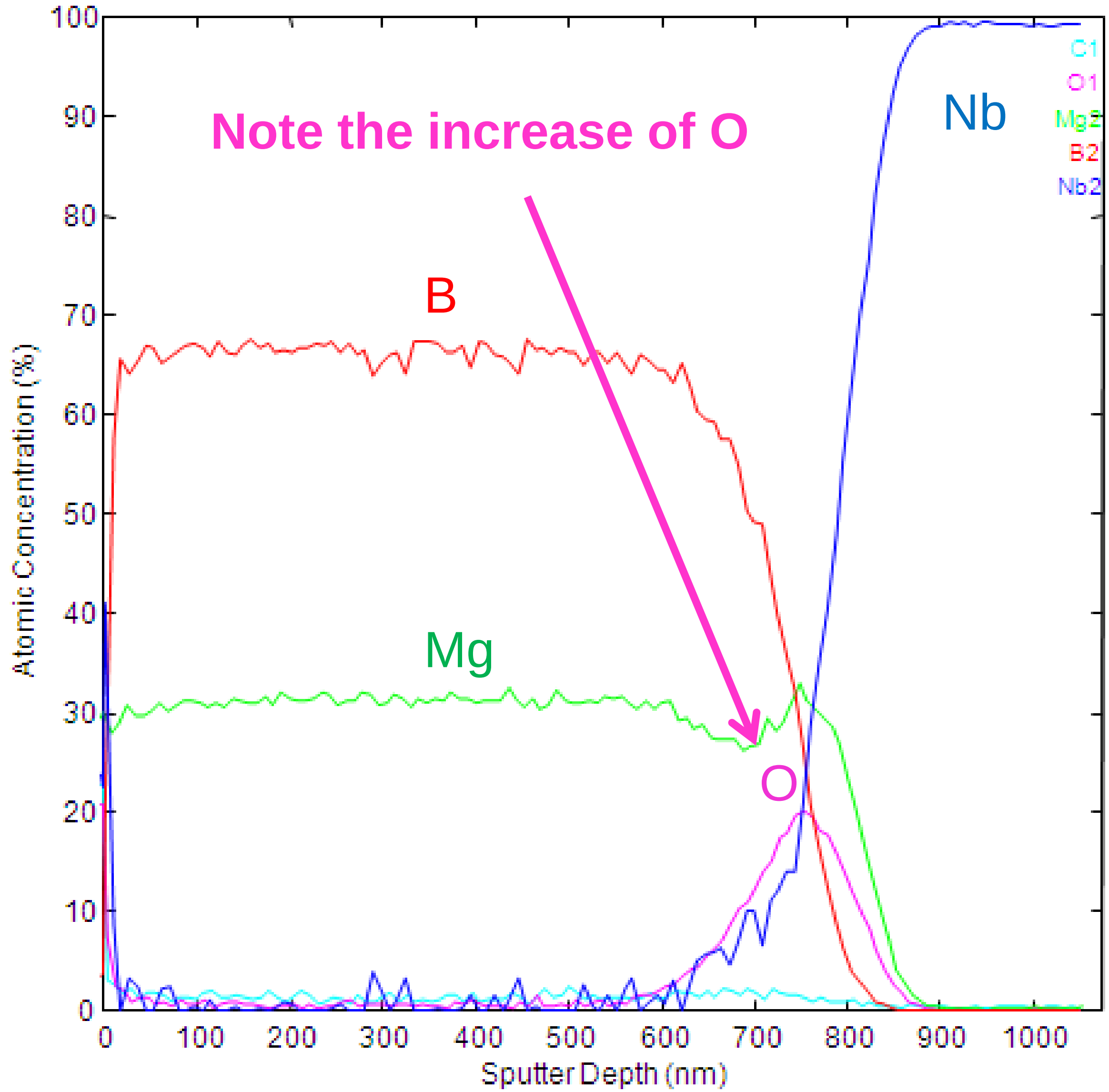
A number of cracks on MgB_2 were observed after tests.

Coating #2
Elements depth profile

Actual

Planned

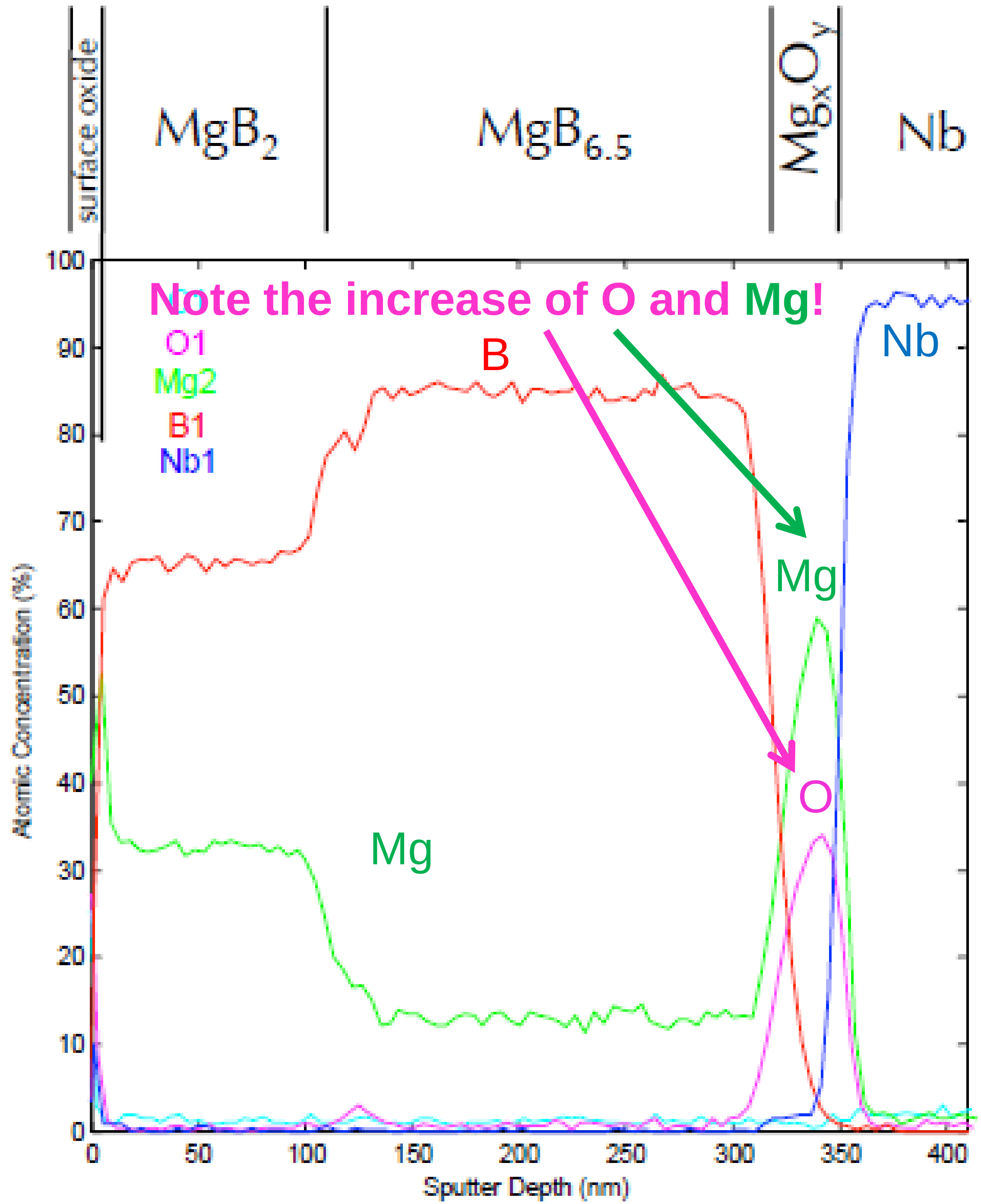
1000 nm



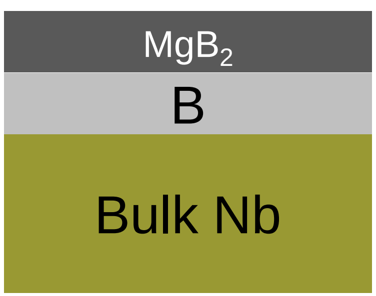
A number of cracks on MgB_2 were observed after tests.

Coating #3
Elements depth profile

Actual



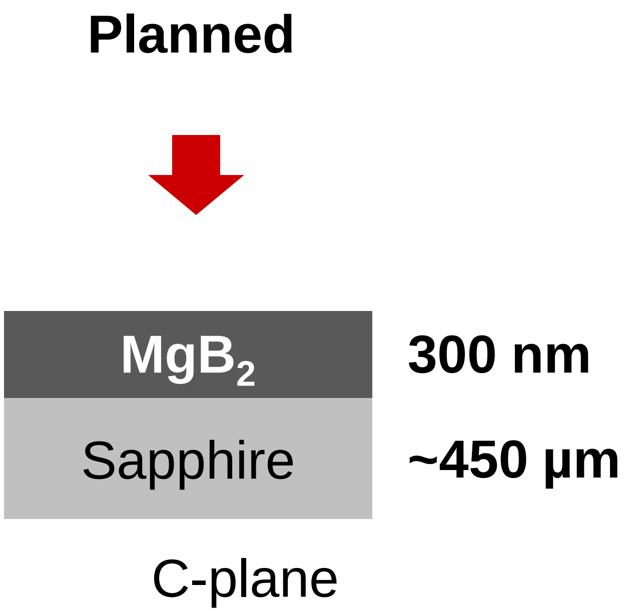
Planned



200 nm

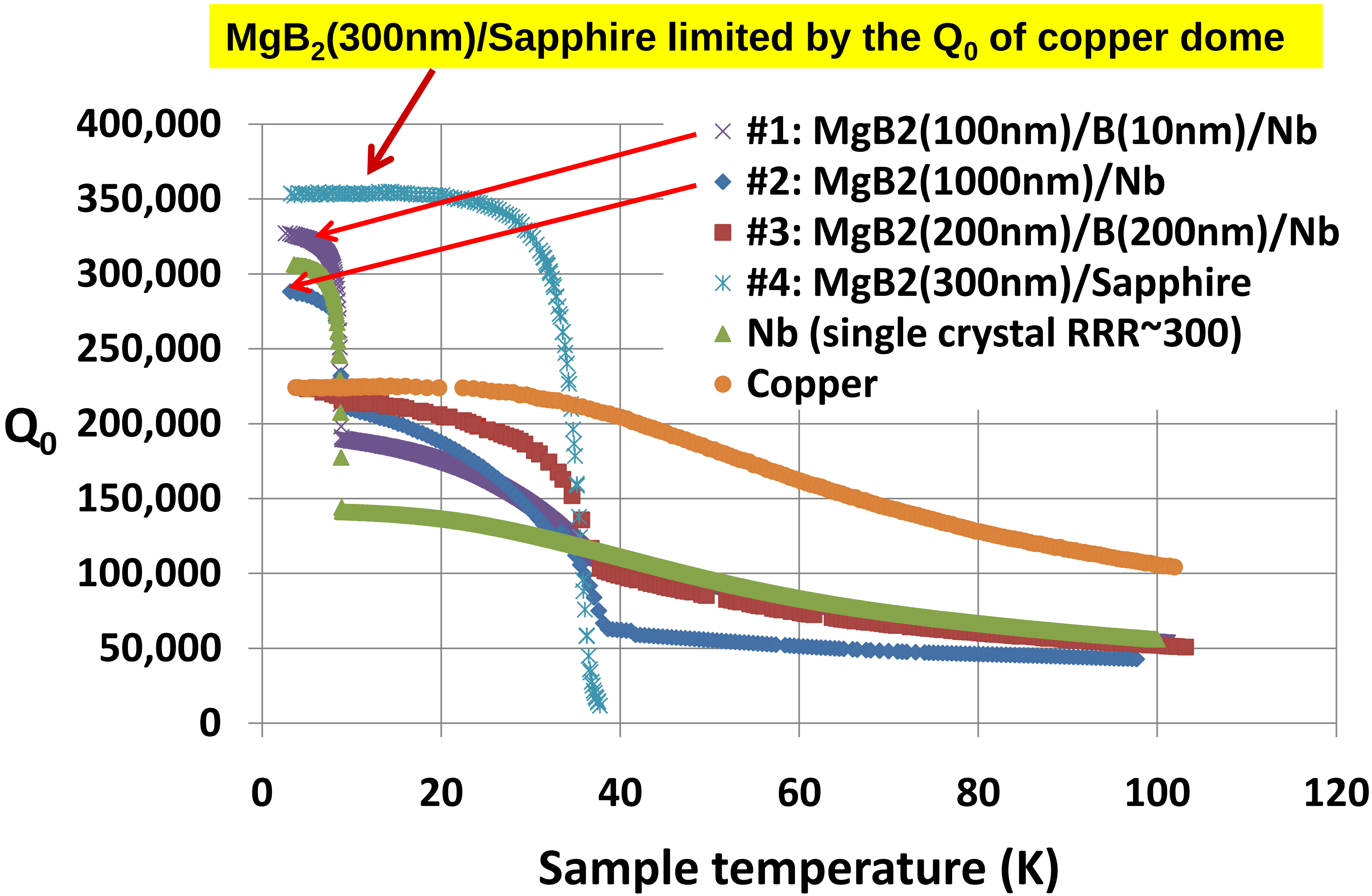
200 nm

Coating #4
Elements depth profile



- **The actual depth profile showed very small amount of oxygen and very close to the planned coating.**
- **This indicates that the increased amount of oxygen shown in the previous MgB_2/(B)/Nb systems was from bulk Nb**

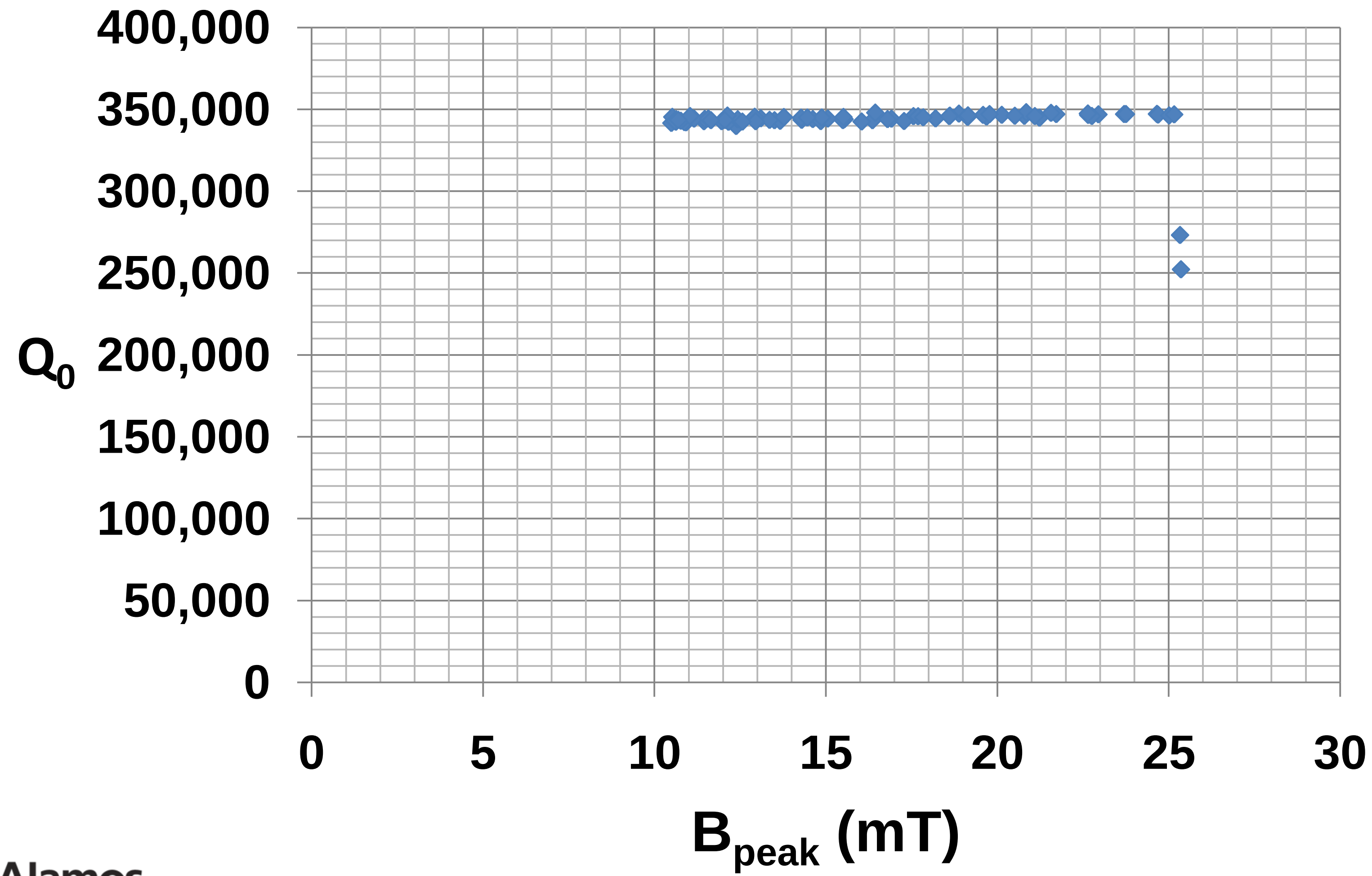
Comparison of low-power Q_0 –T data: MgB_2(300nm)/Sapphire showed significantly higher Q_0



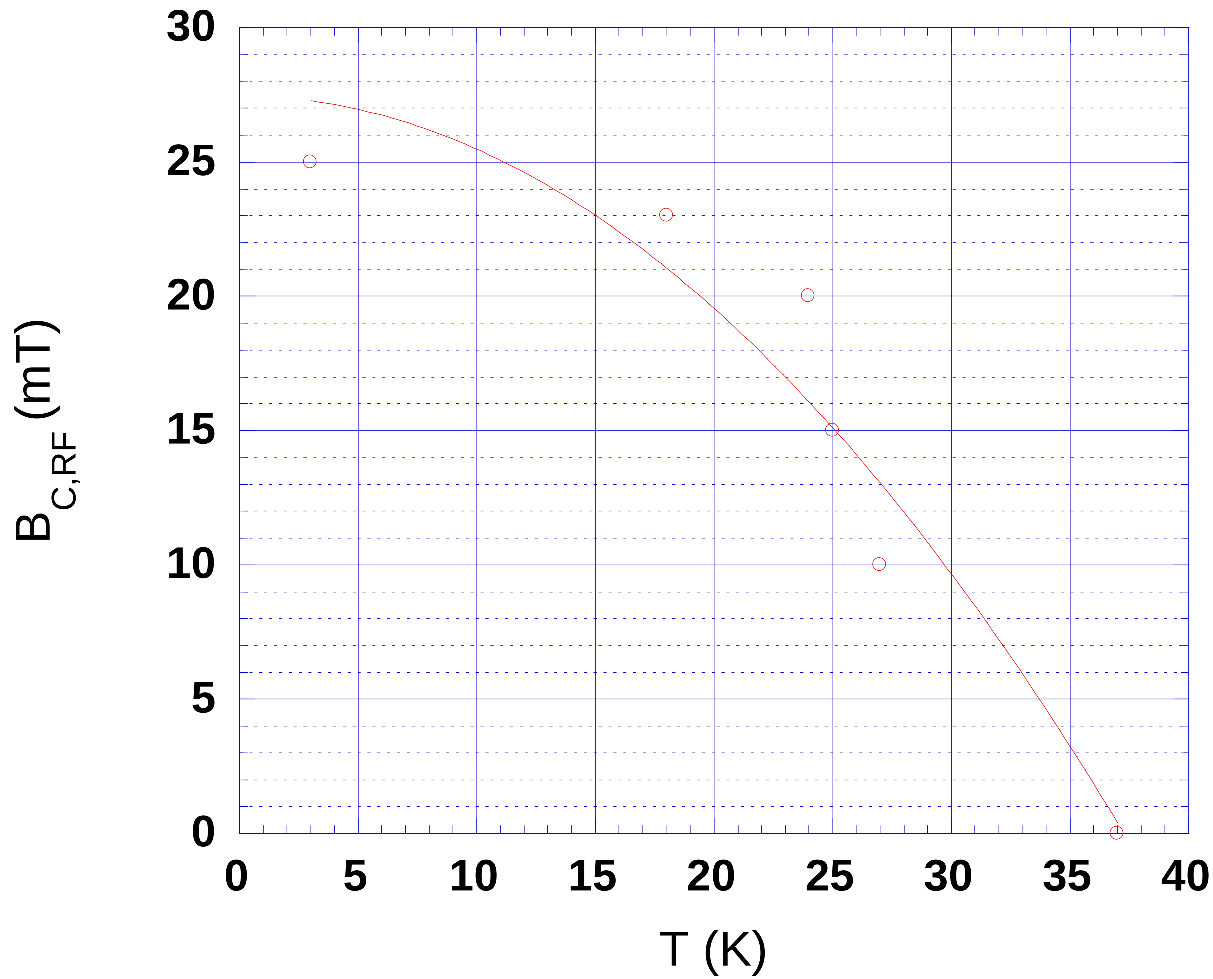
SUPERCONDUCTOR TECHNOLOGIES INC.

Defense Threat Reduction Agency

Coating #4, MgB_2(300nm)/Sapphire: Q_0 vs. B_{peak} at 3 K MgB_2 quenches at 25 mT (Only one sample has been tested so far.)



Coating #4, MgB_2(300nm)/Sapphire: $B_{C,RF}$ vs. T



Measured quench fields at 3 K have been low. For #1-#3, thermal effect due to high surface resistance and effect of cracks are involved and confusing.

Coating Series No.	Planned coating	Quench field (mT)
#1	MgB_2 (100nm)/B(10nm)/Nb	~30
#2	MgB_2 (1000nm)/Nb	~30
#3	MgB_2(200nm)/B(200nm)/Nb	≤10 (~50 on Nb)
#4	MgB_2 (300nm)/Sapphire	25

Actual T was probably higher! (#1–#3)

Nb alone has shown a quench field of 60-70 mT and it is likely to be a thermal quench not magnetic, which is caused by high residual resistance.

Issues and plans to address them

- **Unexpectedly high residual resistance of Nb (~2 mΩ) compared to the expected BCS resistance of ~15 μΩ at 11.4 GHz at 3 K**
  - Measure the external magnetic field and try to shield it and see the effect
- **The effect of reducing the film thickness has not been seen**
  - A series of $MgB_2/Al_2O_3/Nb$ is under test to reduce the reaction between MgB_2 and Nb
  - Try MgB_2 (<100nm)/Al_2O_3/MgB_2 (<100nm)/Al_2O_3/MgB_2 (<100nm)/Sapphire
- **Non-uniform coating due to relatively rough surface (R_a >10 nm)**
  - We started to use mechanical-chemical polishing by Cabot Microelectronics Polishing Company that produces R_a <1 nm
- **Cracks**
  - Changing substrate thickness from ~0.6 to ~1.2 mm has helped.

Summary

- **We are trying to demonstrate the principle of multi-layer superconductor coating to increase the achievable magnetic field**
- **We have not been successful yet, but there has been increased understanding on what is happening**
- **Our goal in 2010 is to demonstrate the first milestone of >200 mT (0 K) or equivalent fields at respective temperatures with flat 2-inch diameter samples after addressing some issues that have emerged.**

Acknowledgements

- **Many thanks to:**
  - Sponsor (DTRA)
  - P. Kneisel (JLab)
  - A. Canabal (U. Maine)
  - S. Lesiak (CMPC)
  - Other LANL workers:
    - R. Depaula, I. Apodaca (MPA-STC)
    - B. Day (MST-7)
    - R. Montoya (PF-FS)
    - J. Harrison, (AOT-MDE)

Operated by Los Alamos National Security, LLC for NNSA