Development of High-Efficiency, High-Gradient Superconducting RF Cavities with MgB_2 Thin Films

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Purpose of this ongoing project

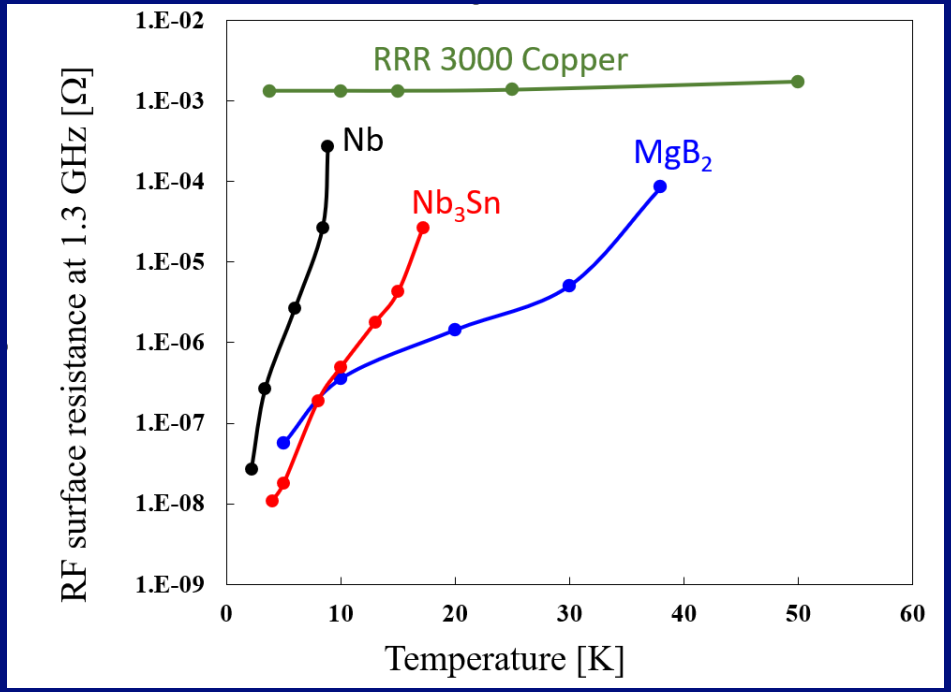
Demonstrate* a SRF cavity with a superconducting magnesium diboride (MgB_2) thin film on the interior surface

*Test to $E_{acc} \geq 10$ MV/m and reasonable Q_0

Purpose of this presentation

- Provide an update on construction and testing of the MgB_2 thin-film deposition facility for full-size cavities at Los Alamos National Lab, USA
- Provide an update on temperature sensor development and vertical test stand construction at KEK, Japan

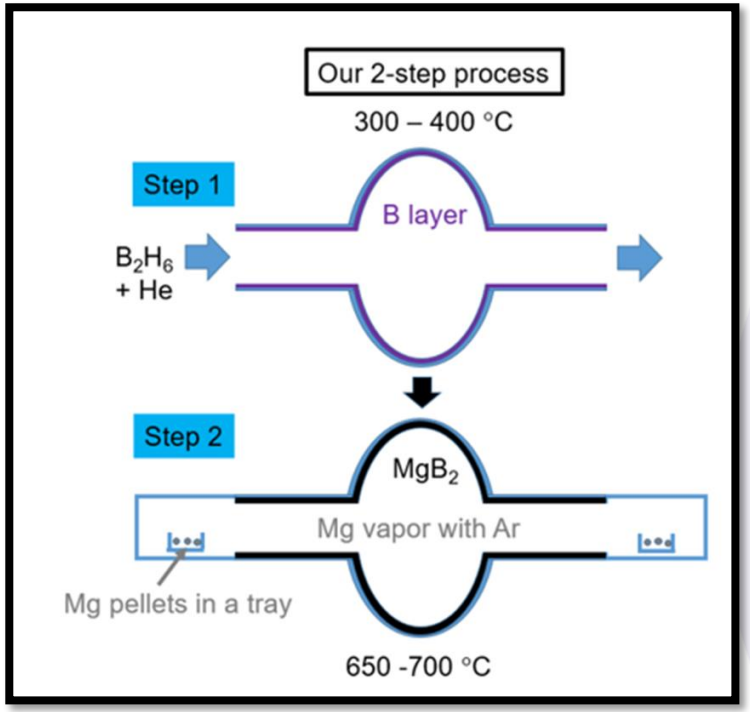
Why Magnesium Diboride?



Tajima, Tsuyoshi. "Application of MgB_2 to Superconducting Radio-Frequency Cavities." 低温工学 (J. Cryo. Super. Soc. Jpn.) 57.1 (2022): 23-30.

- Operating temperature
  - Nb: 2 K
  - Nb_3Sn: 4 K
  - MgB_2: 20 K
- Cooling method
  - Nb: LHe at 2-4 K
  - Nb_3Sn: 4 K LHe, cryocooler
  - MgB_2: Cryocoolers
- Other benefits
  - Simple film deposition process
  - Copper substrate cavities
  - RF transparent grain boundaries

Simple, two-step film deposition process



Tajima, Tsuyoshi. "Application of MgB_2 to Superconducting Radio-Frequency Cavities." 低温工学 (J. Cryo. Super. Soc. Jpn.) 57.1 (2022): 23-30.

Ongoing efforts: B_2H_6 systems design

- Diborane is toxic, flammable
- Destroys some sealing materials

- We have designed plumbing, controls, and safety systems with care

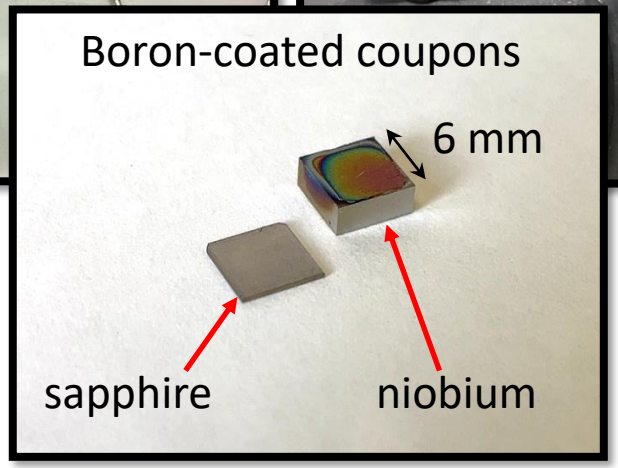
- B_2H_6 tank, plumbing contained under negative pressure hood
- Exhaust streams scrubbed of B_2H_6

- Controls: cRIO chassis with LabView, EPICS user interface
- Interlocks: key temperatures, coolant flows rates, and haz gas sensors

Ongoing efforts: MgB_2 on boron-coated coupons

1.3 GHz niobium testbed cavity

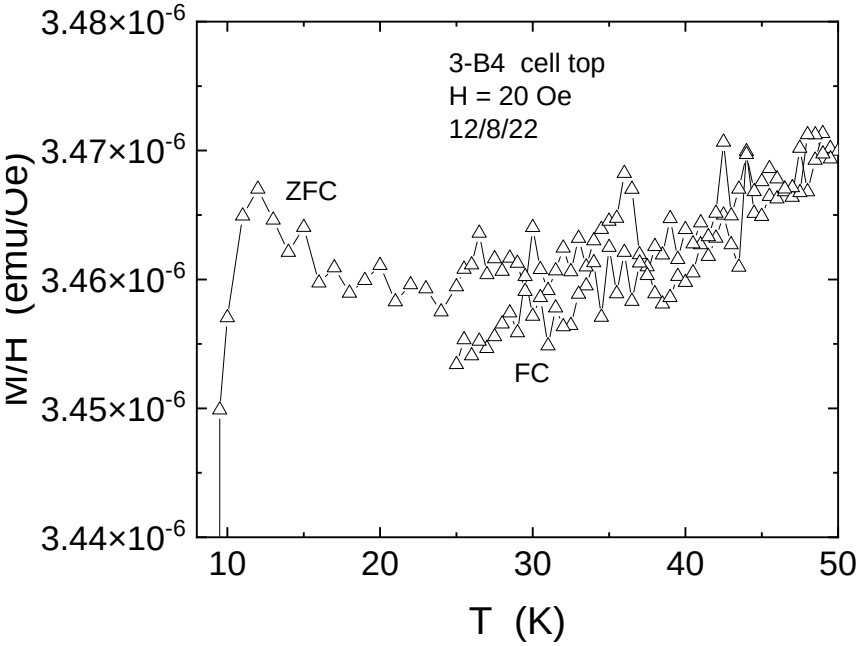
Thermocouple monitors coupon temp



Magnetometer results, discussion (1)

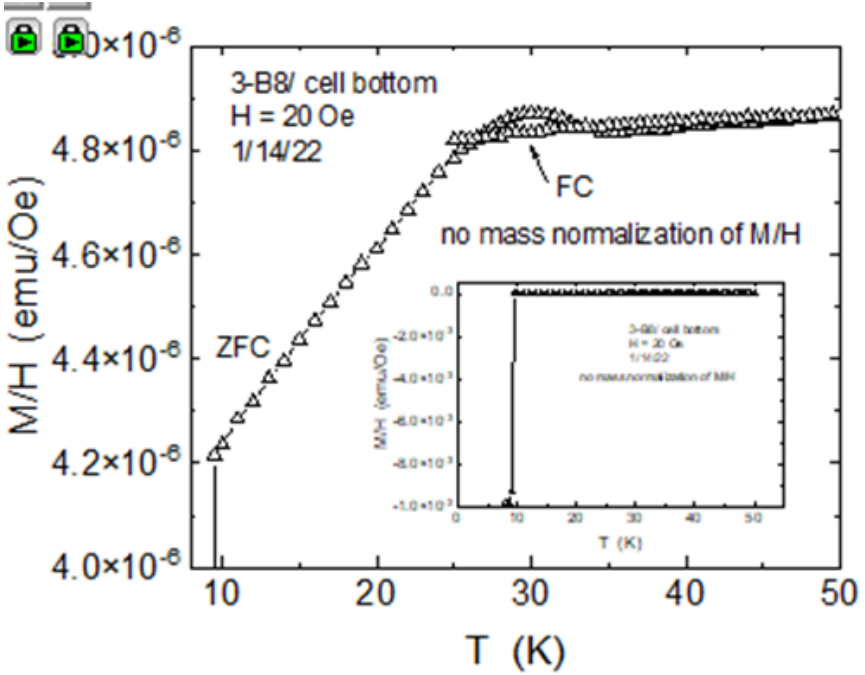
Furnace Run 3

Kept Mg tray warmer manually; flange fans



Furnace Run 4

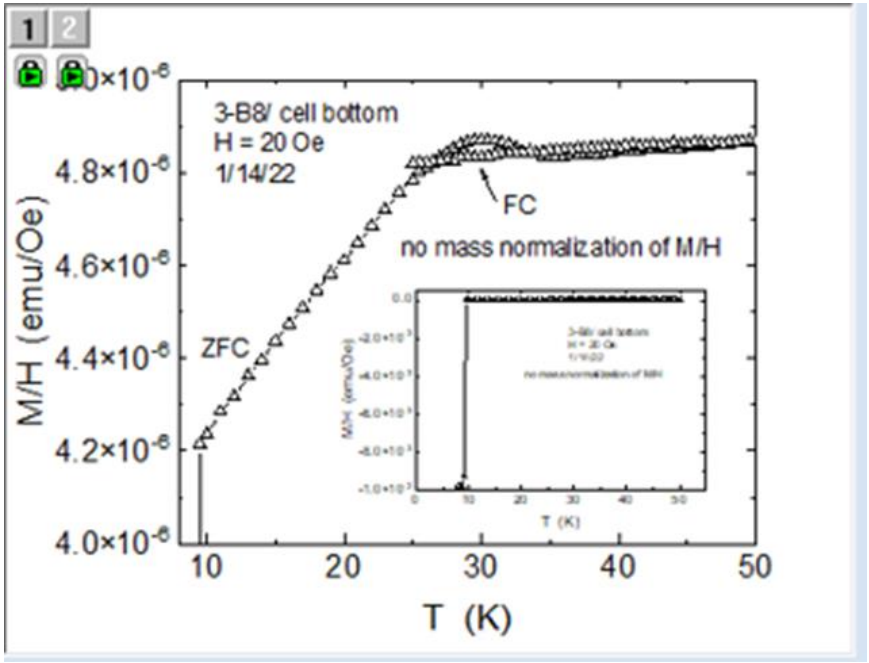
Higher temp to ensure Mg melting



Magnetometer results, discussion (2)

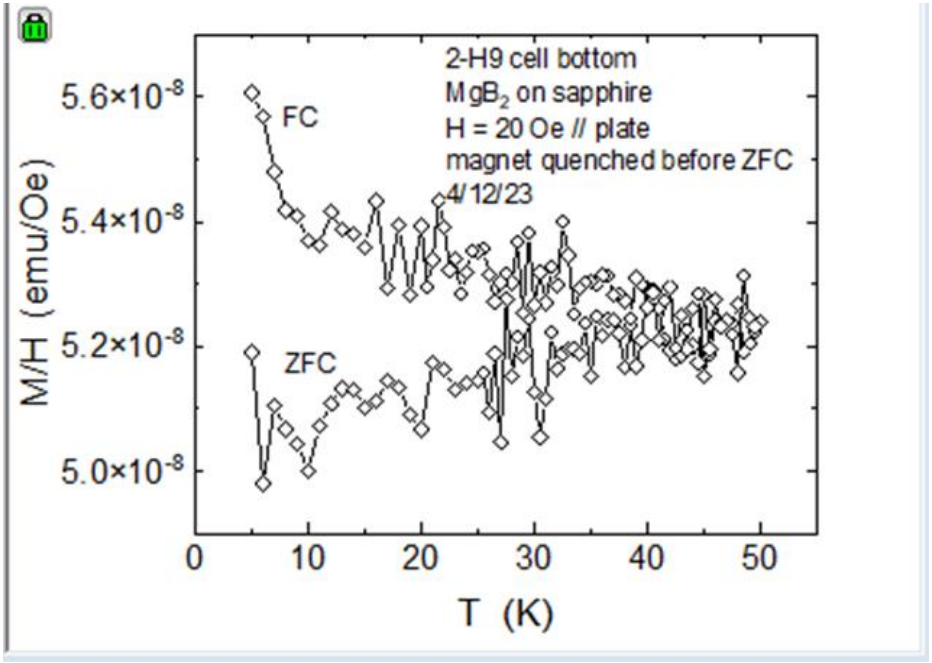
Furnace Run 5

Balance temp of north/south furnace zones



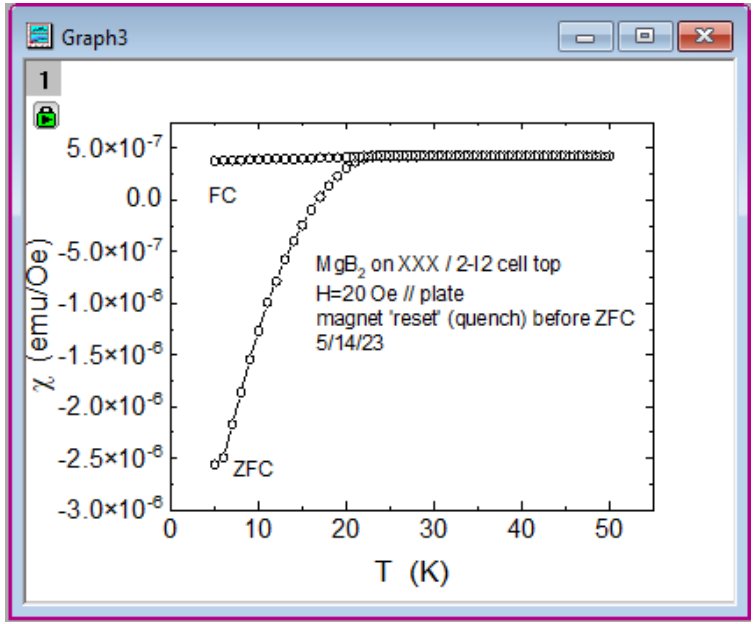
Furnace Run 6

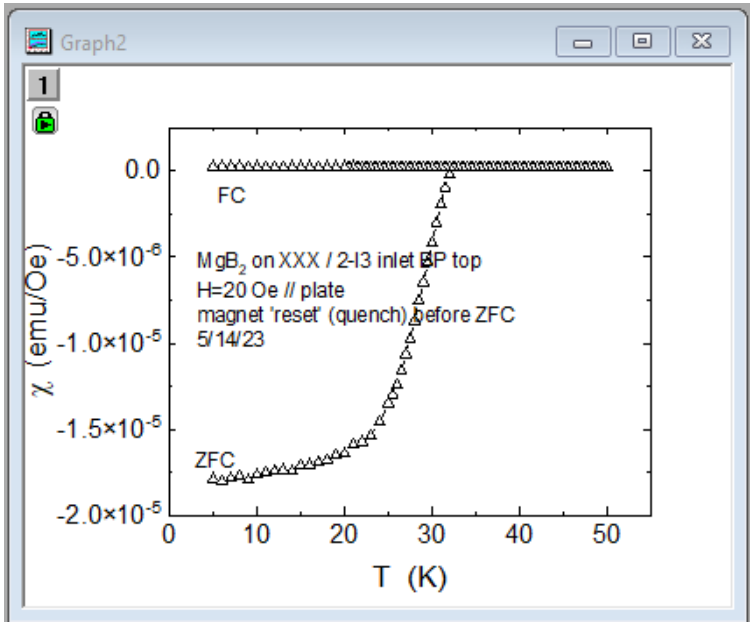
800 °C bakeout; thermal radiation shields



Magnetometer results, discussion (3)

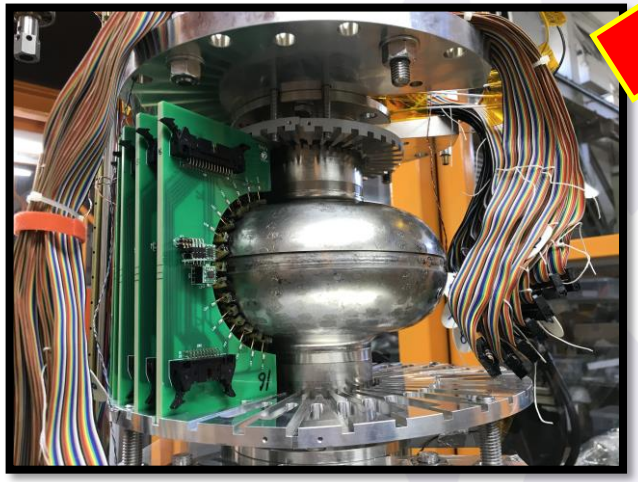
Furnace Run 7

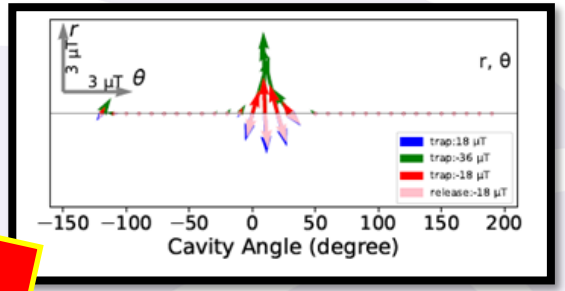




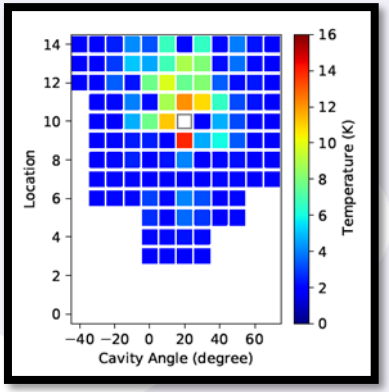
KEK: Vertical test stand for cavity testing

- To be used to test MgB_2 cavities with diagnostics
- 3D mapping of cavity temperature and magnetic field





Change in magnetic field before/after quench

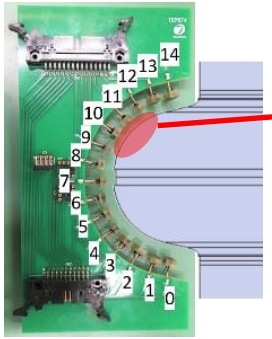


Temperature field at quench

T. Okada et al., Phys. Rev. Accel. Beams 25, 082002 (2022).

T. Okada et al., Review of Scientific Instruments 92, no. 3 (2021): 035003.

The tested Nb cavity sent to LANL (2021)

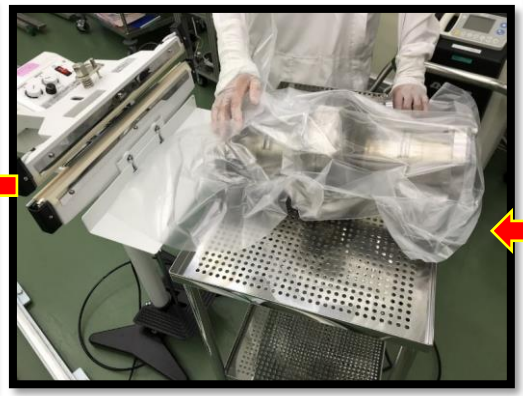


Marked at quenching point

High pressure rinsing

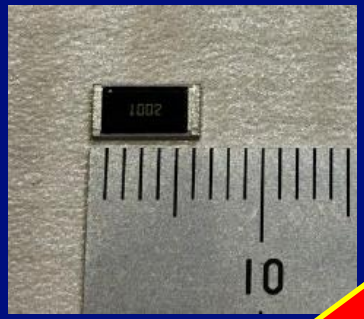
[T. Dohmae]

Assembled and packed in class 10 clean room in KEK



Shipped to LANL measured Nb cavity to be MgB_2 coated by new furnace

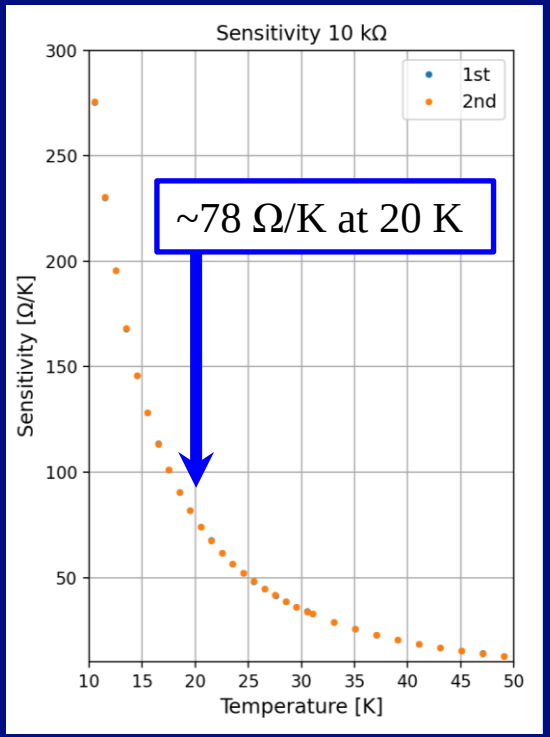
KEK: new temperature sensor for 20 K



RuO_2 temperature sensors
- Manufacturer: ROHM (Japan)
- Resistance: 10 kΩ
- ¥40 (US$0.30) per chip

Chips bonded to sapphire base and leads soldered on

[T. Yamada]



Exhibits good sensitivity at around 20 K

Conclusion

- Working toward demonstration of the very first 1.3-GHz MgB_2-coated cavity
- Goal: Minimum accelerating gradient (E_{acc}) of 10 MV/m, with sufficiently high Q_0