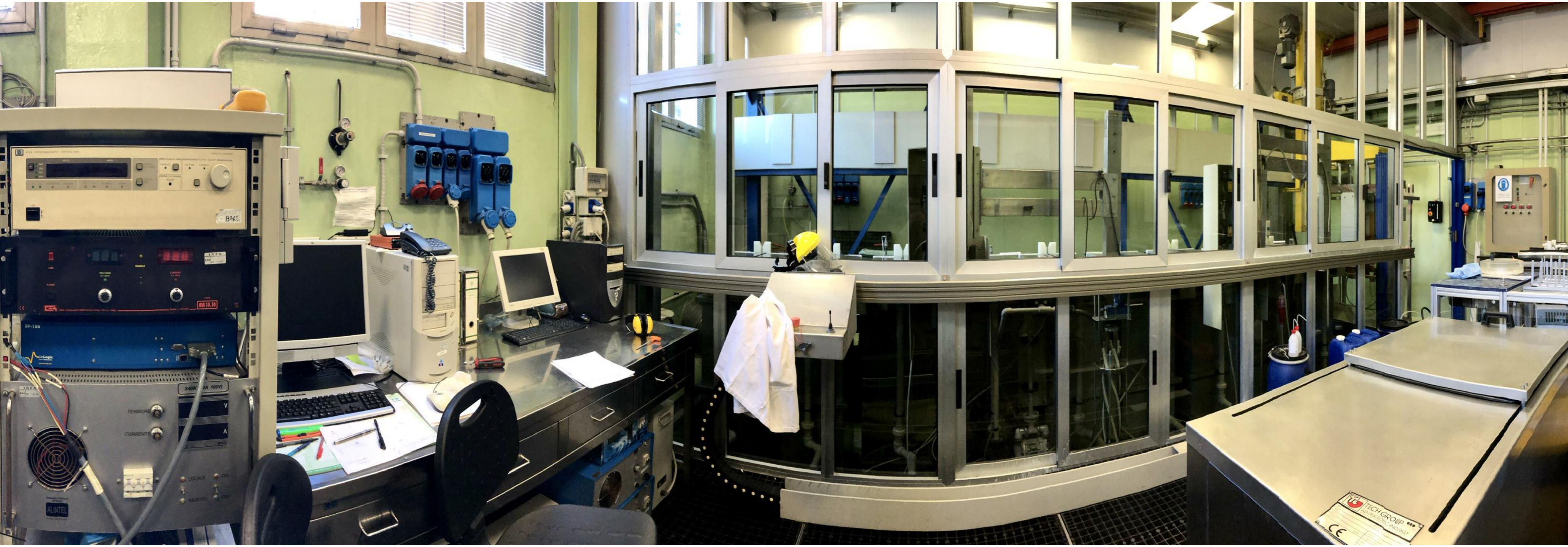
SRF activities @ LNL

The activity is partly included in the Materials Science for Nuclear Physics service that it manages:

- 2 Chemical Lab
- 2 Coating Lab
- 2 Facility for RF cold measurements (2 and 4.2 K) with 3 cryostat for measurement of QWR and 1,3 GHz elliptical cavities
- 1 characterization Lab (XRD, SEM, EDAX, profilometer, SC characterization)

Chemical Facility



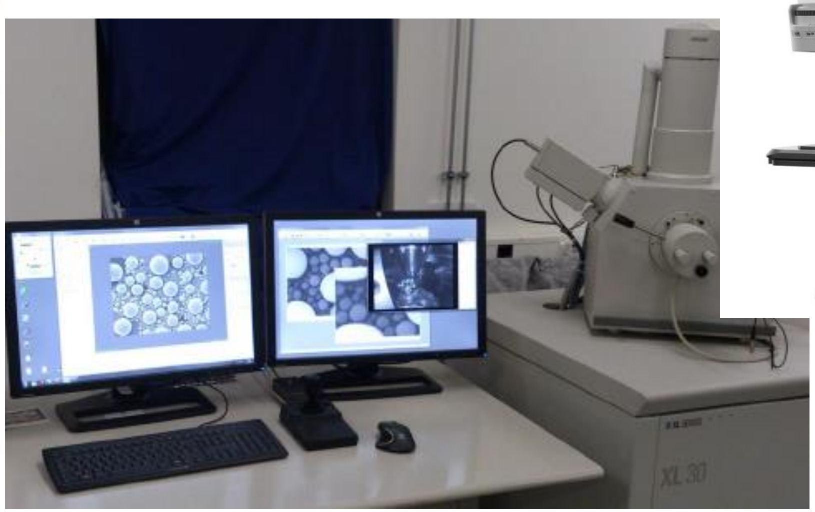
Coating Plant

Cryogenic Plant

Material characterizations

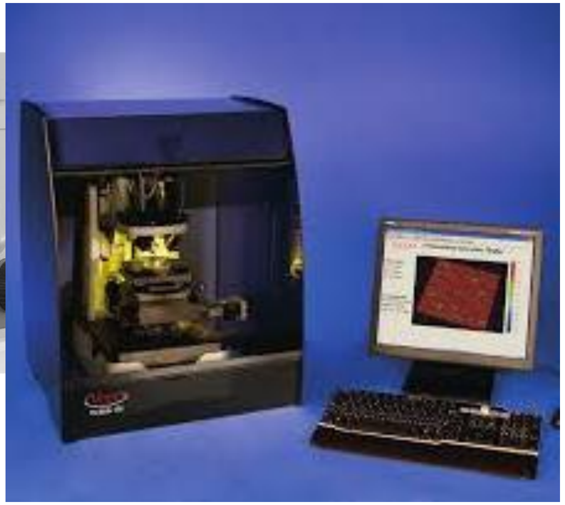
XRD

SEM-EDS



Optical Microscope

Profilometer



SRF activities @ LNL

- QWRs ALPI production
- Cavity forming by seamless techniques
- Surface preparation
- Superconductive coatings by PVD
- RF test

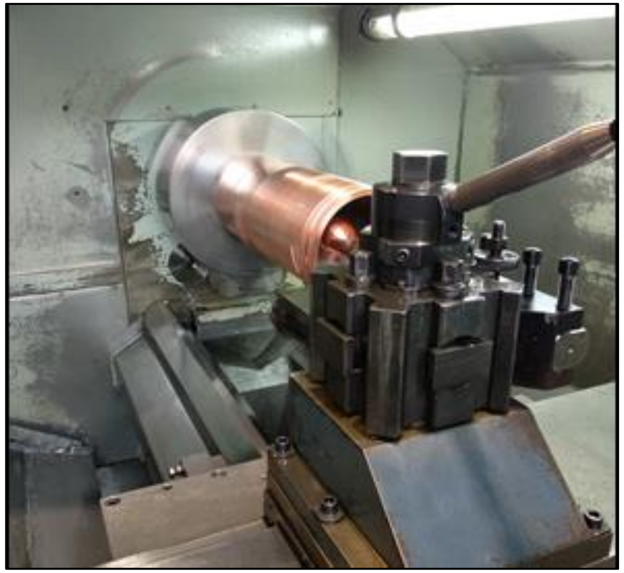
QWRs ALPI production

QWR for ALPI

Cryostat for offline measurement test

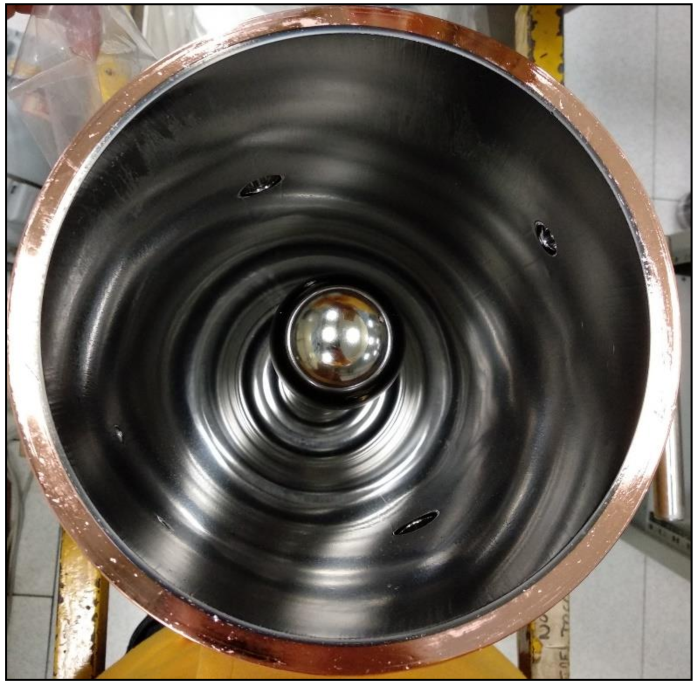
QWR sputtering system

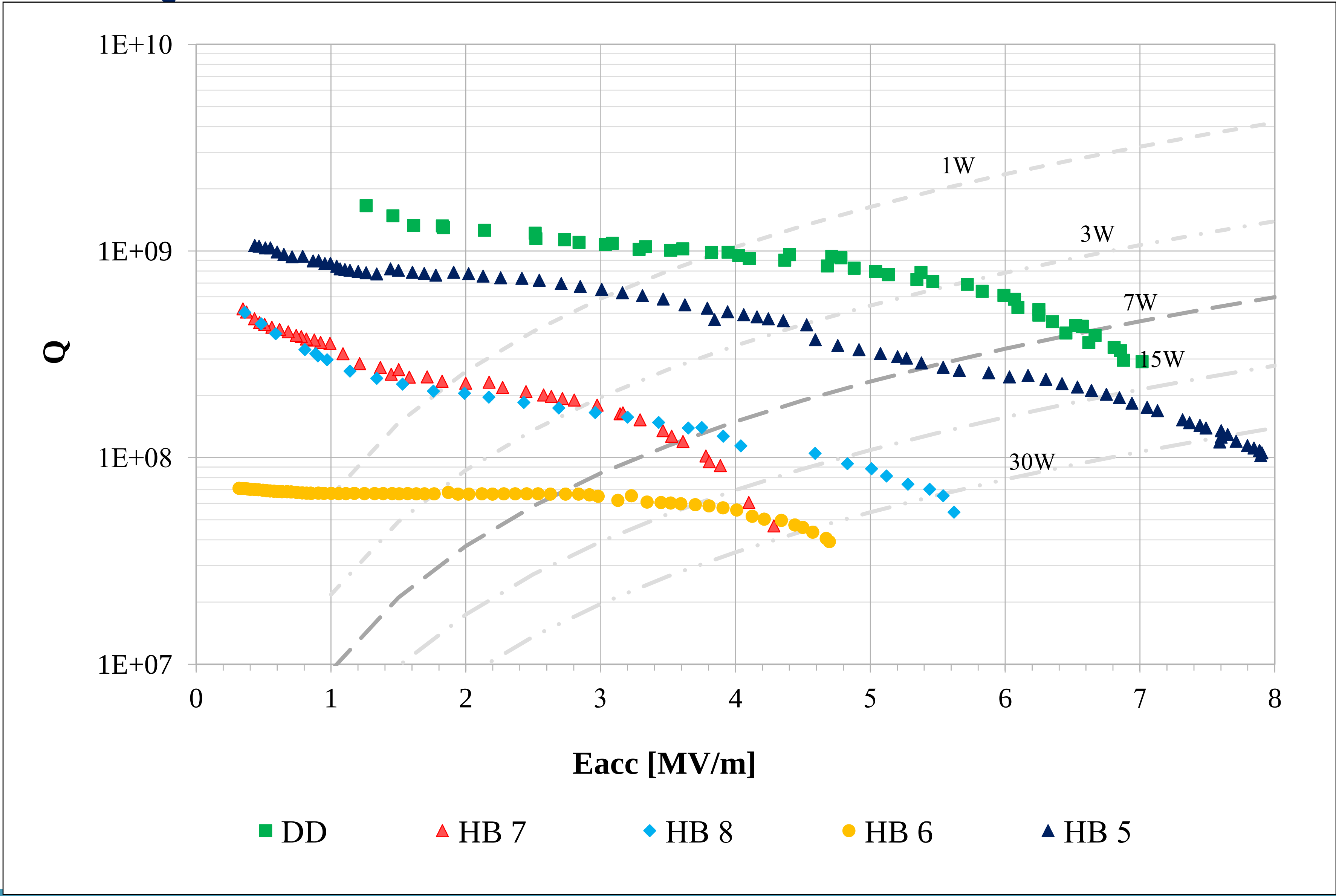
RFQ and QWR plates sputtering system



QWR cavity machining

QWR for ALPI



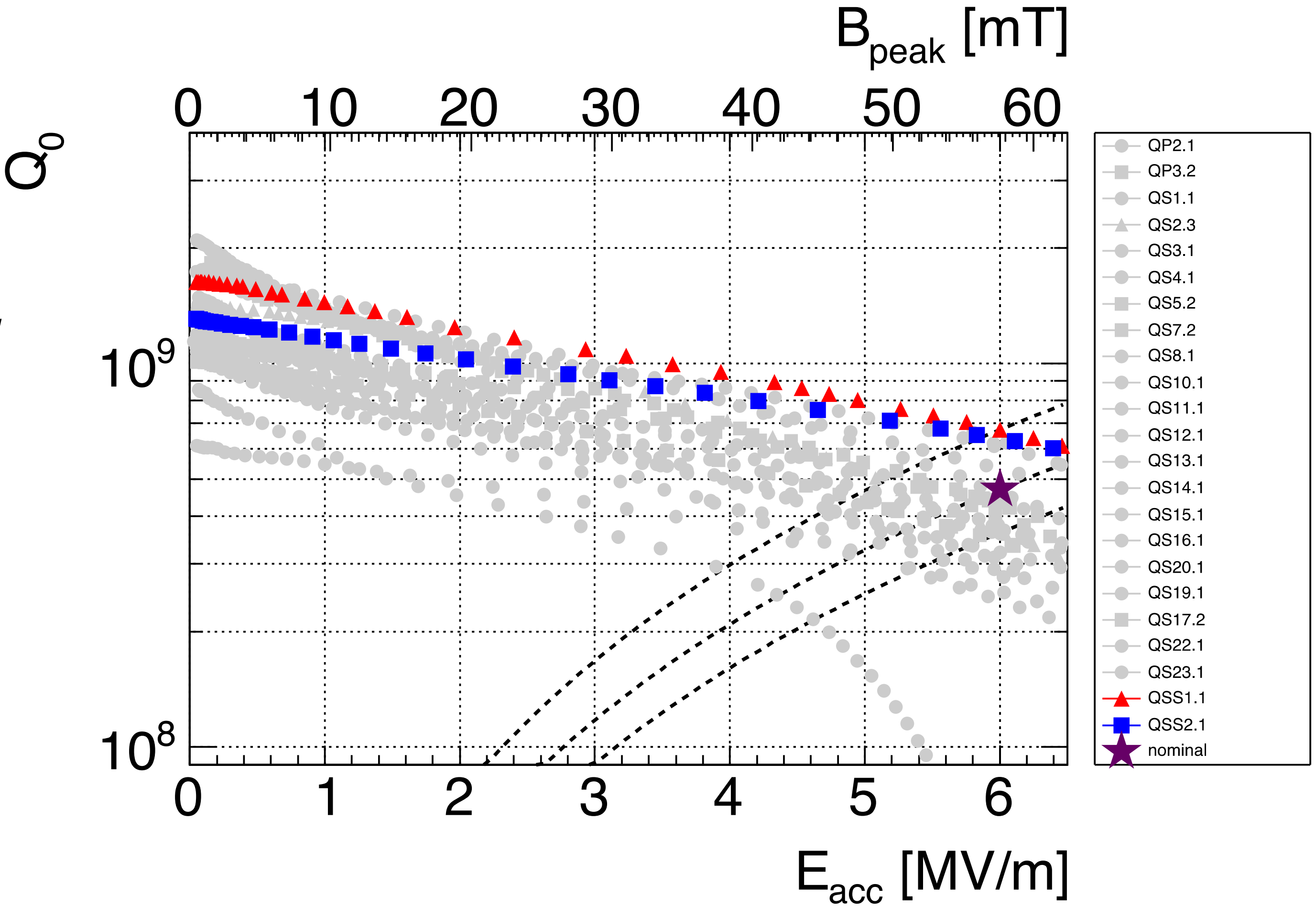


1E+10
1E+09
1E+08
1E+07
Q
0
1
2
3
4
5
6
7
8
Eacc [MV/m]
1W
3W
7W
15W
30W
DD
HB 7
HB 8
HB 6
HB 5

Cavity forming by seamless techniques

Advantages of seamless cavities

- **Cheaper**
- **Avoid defects and irregularity of welding seams**
- **Increase RF performances** *(real examples: ALPI @ INFN and HIE-ISOLDE @ CERN)*



HIE ISOLDE two seamless cavities performance at 4.5 K

Courtesy of Walter Venturini

Seamless cavities by spinning

- Hydroforming, explosive forming, **electroforming**, **electrodeposition** and **spinning** are the principal techniques explored for the production of seamless elliptical cavities

- LNL have a long experience in spinning of 1,3 and 1,5 GHz elliptical cavities

- In the framework of FCC studies spinning of 400 MHz has been explored

First seamless multicell by spinning

Spinning production steps

Step 1

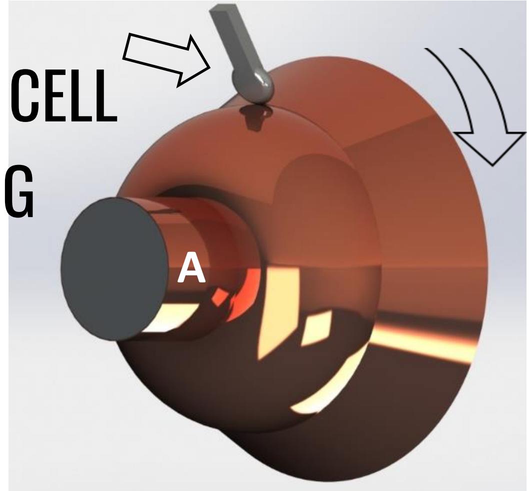
COPPER PLATE PREPARATION

Step 2

DEEP DRAWING

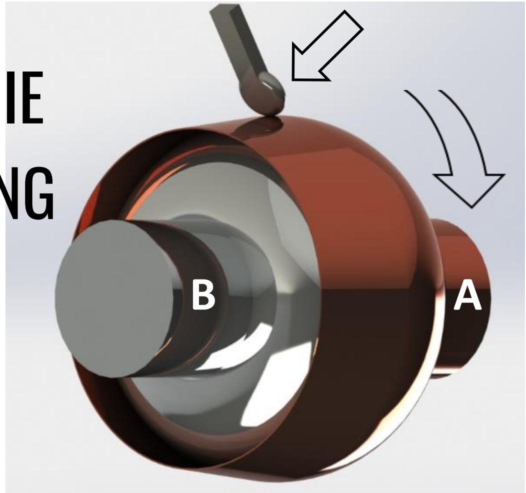
Step 3

1st HALF CELL SPINNING



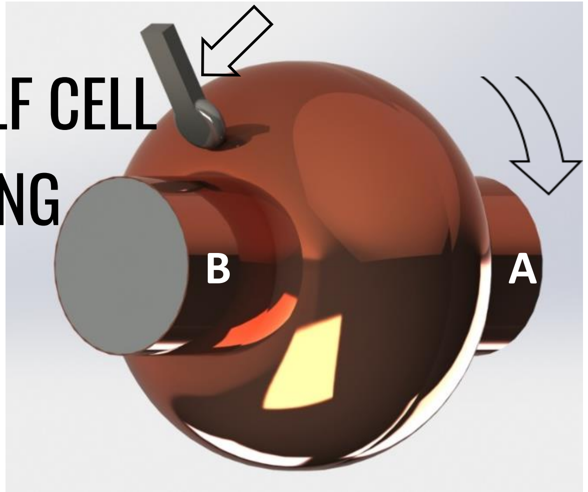
Step 4

CONE DIE SPINNING



Step 5

2nd HALF CELL SPINNING



Thermal annealings in Cavity #2

- The 2 annealings was anticipated and a third annealing was added

1st Thermal Annealing

2nd Thermal Annealing

Spinning of Cavity #2 completed

1st Thermal Annealing

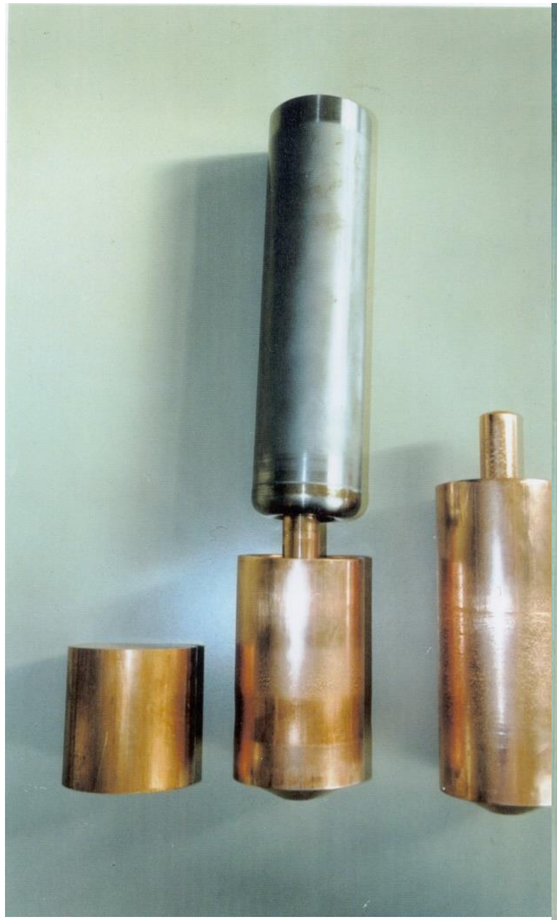
2nd Thermal Annealing

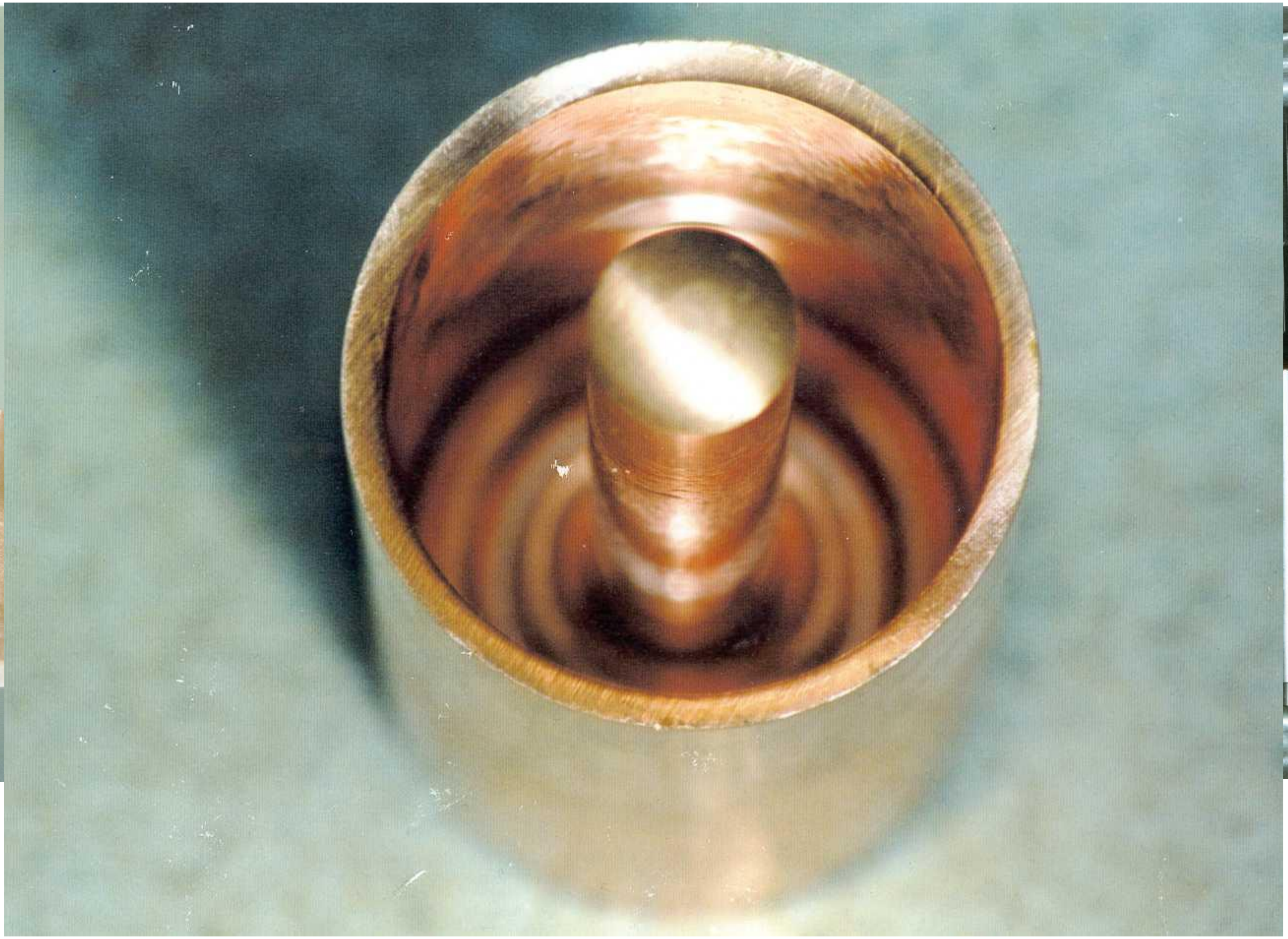
3rd Thermal Annealing

Progetto POR-FSE SEAMLESS 2020-21

- Industrializzazione del processo utilizzando macchine a controllo numerico

Cavità QWR by Cold Backward Extrusion

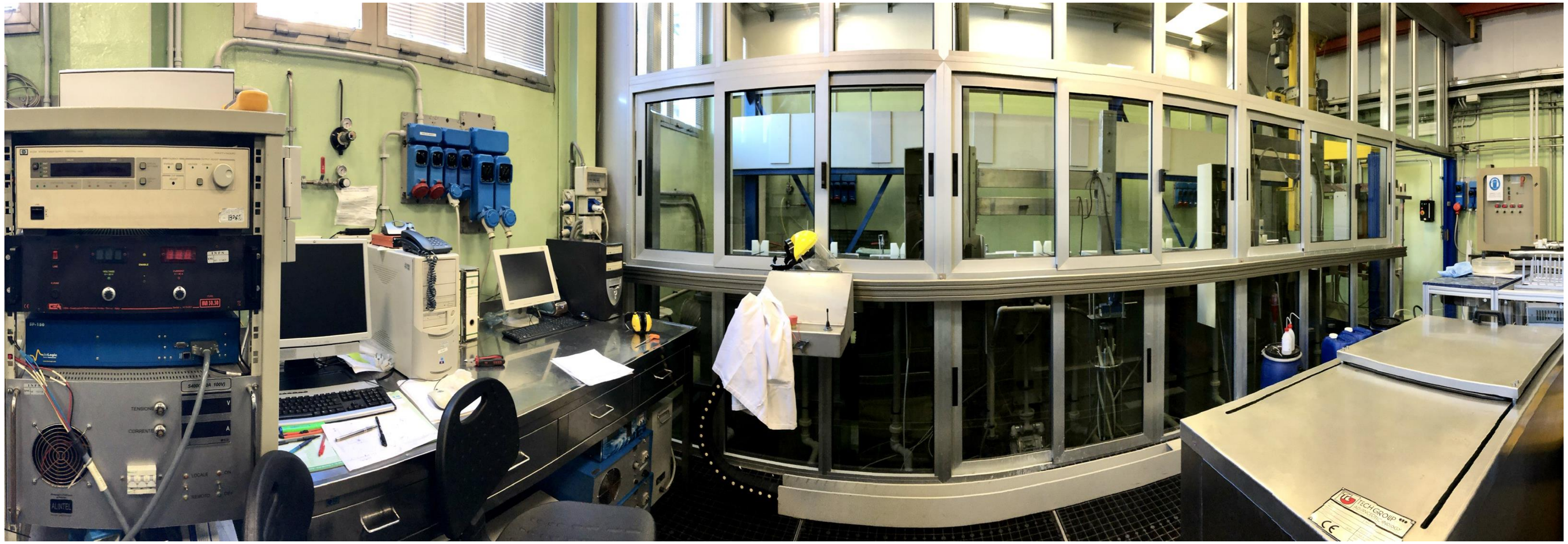




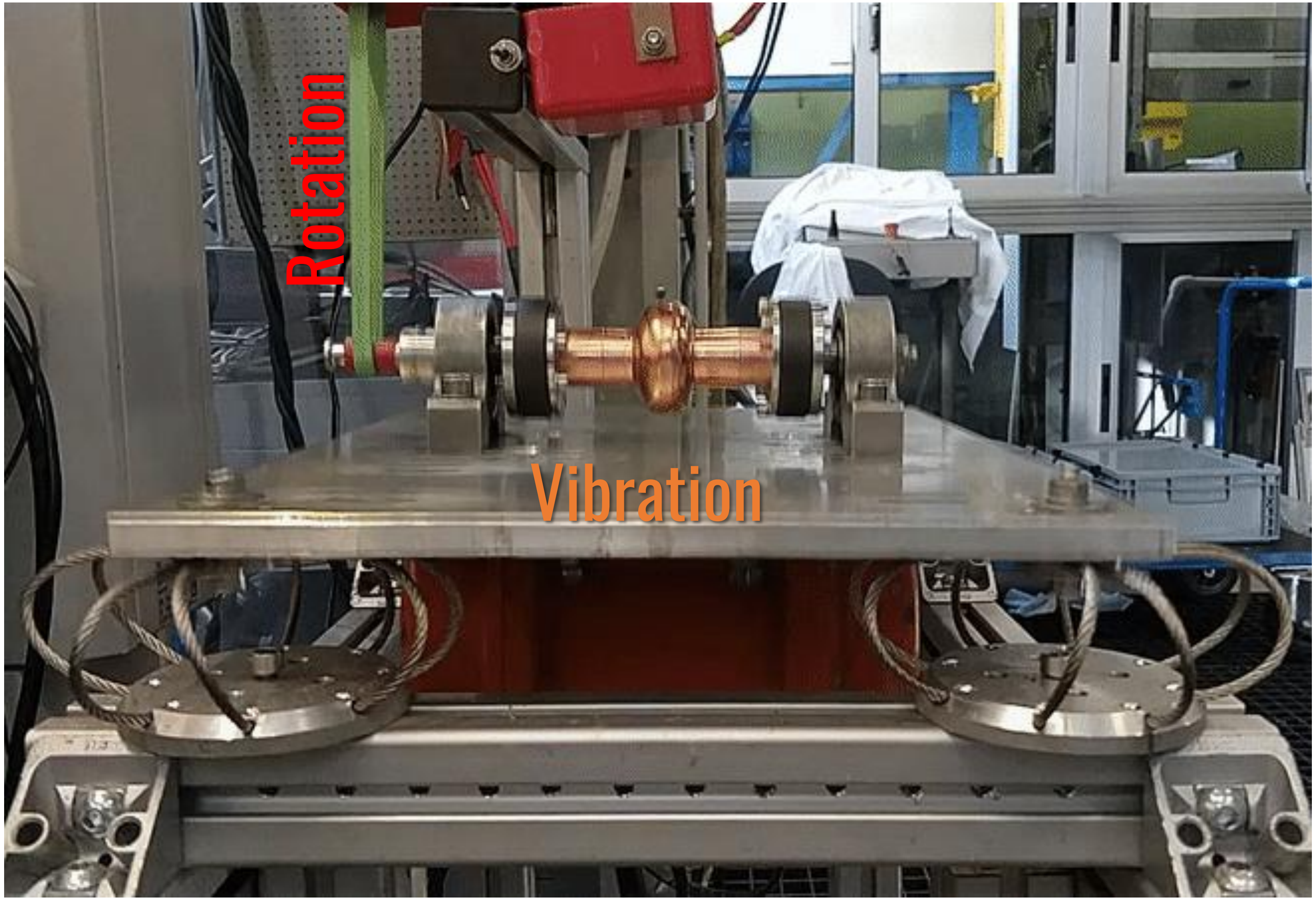
Surface preparation

Impianti chimici

- Impianti chimici per QWR e 1,3 GHz e 6 GHz per trattamenti standard

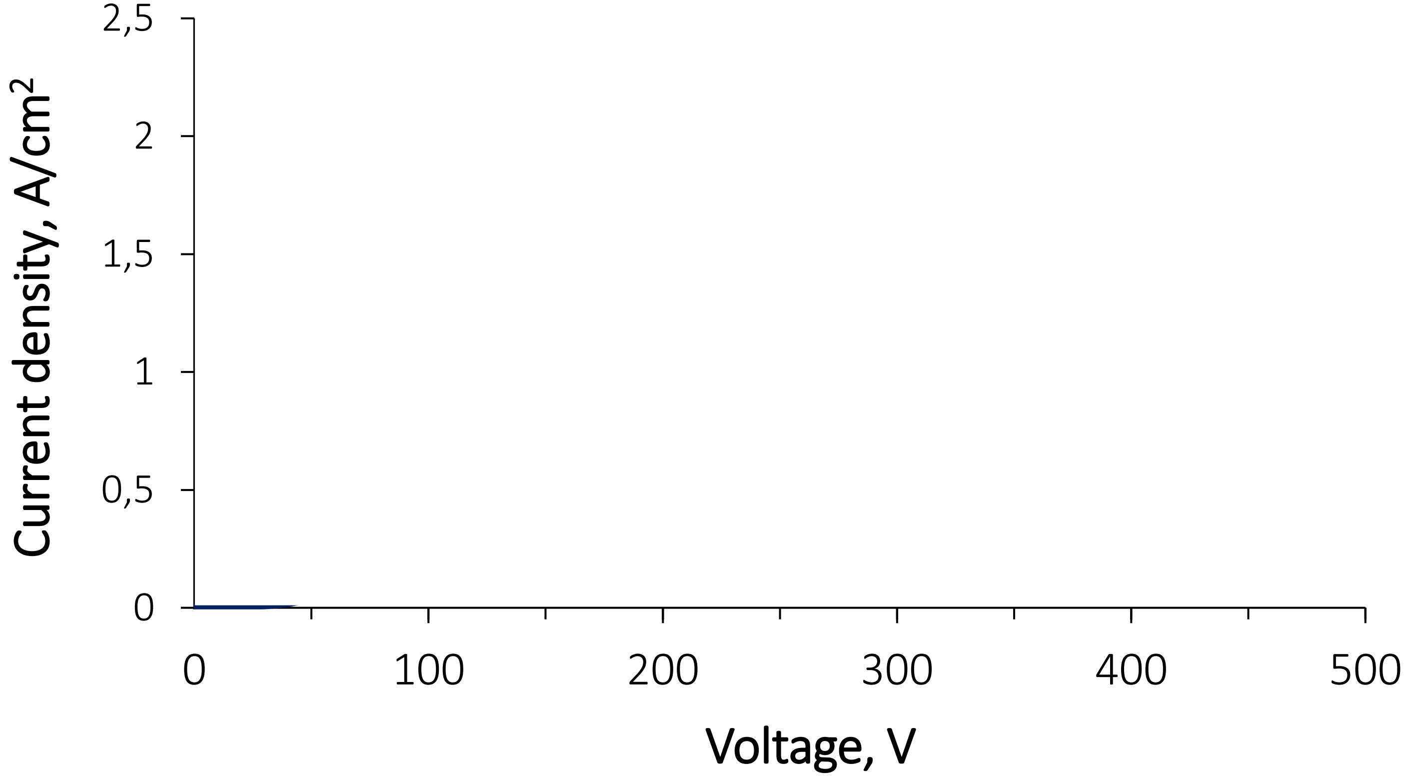


Innovative mechanical polishing: Vibro-tumbling



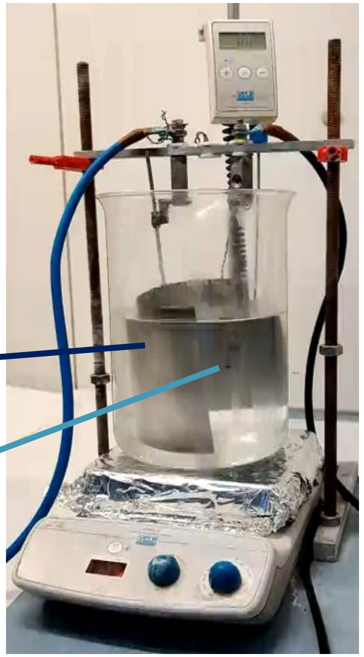
1. **Al_2O_3 Pyramids** (wet process)
2. **Cu powder 200 mesh** (dry process)
3. **Coconut powder** (dry process)

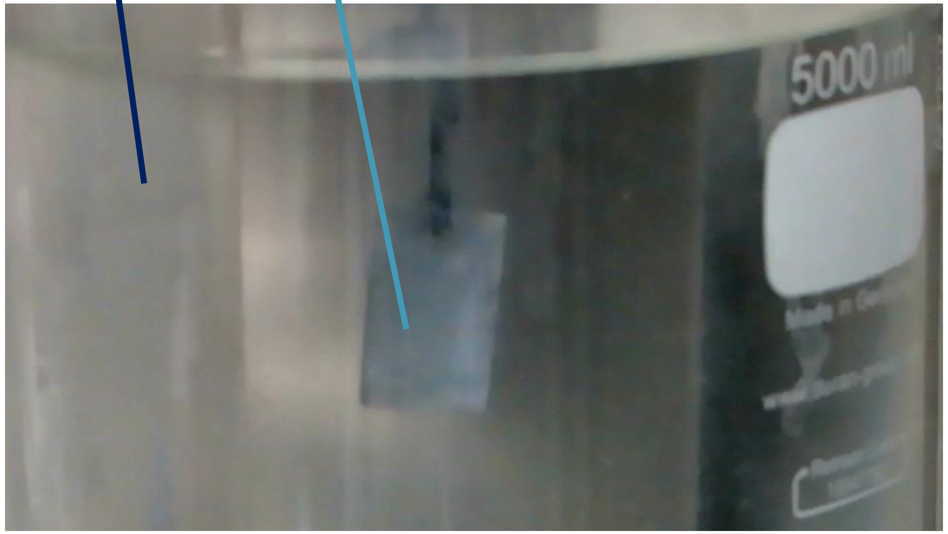
PEP introduction
Current-voltage characteristics



Cathode

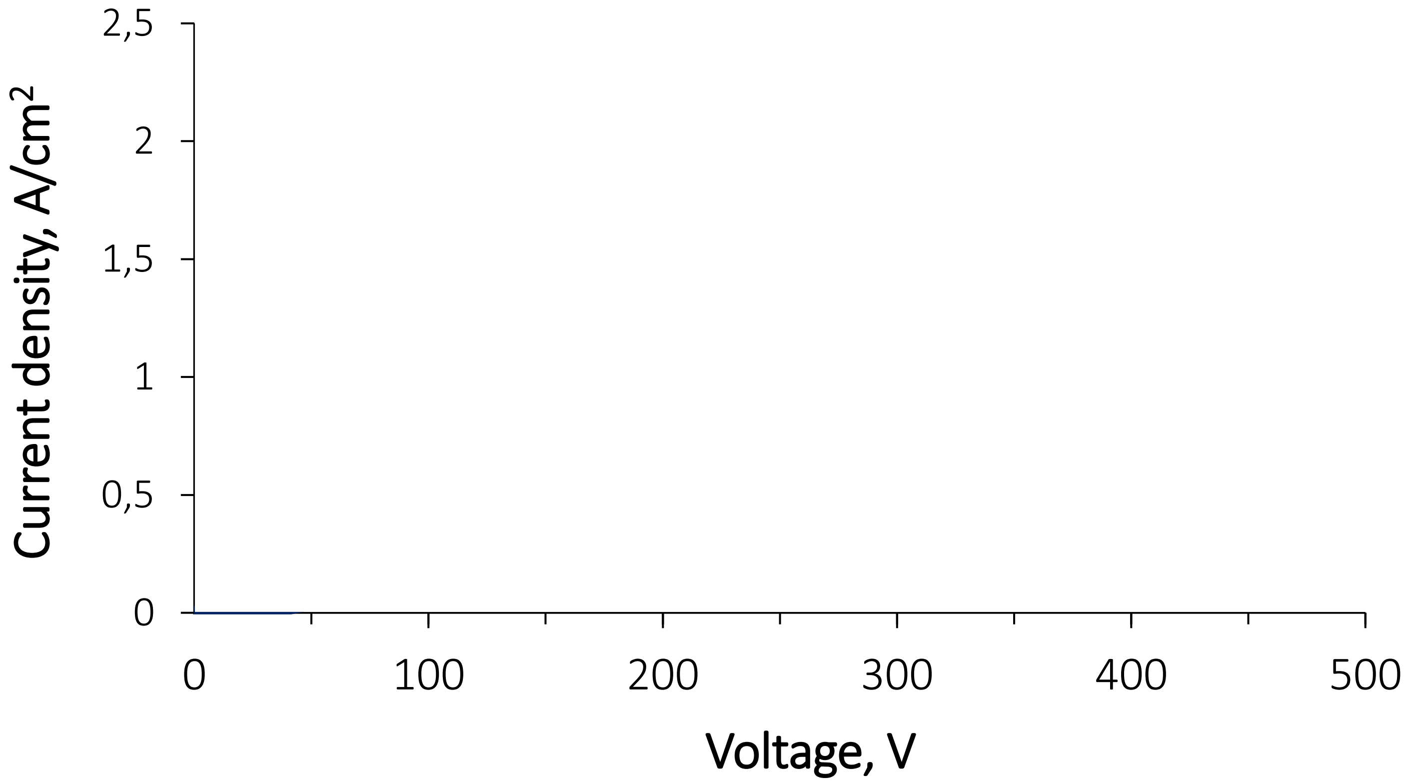
Anode/
sample





PEP introduction

Current-voltage characteristic



Results on Nb

Processes parameters comparison

Process / parameters	BCP (1:1:2)	EP (1:9)	PEP
Solution composition	$HF:HNO_3:H_3PO_4$	$HF:H_2SO_4$	**Diluted salts**
Voltage	-	18 V	**300 V**
Current density	-	0.025 A/cm^2	**0.4-0.6 A/cm^2**
Power density	-	0.45 W/cm^2	**~150 W/cm^2**
Removing rate	1 μm/min (15℃)	0.3 μm/min (30℃)	**3.5 μm/min (78℃)**

PEP

3.5 times faster than BCP

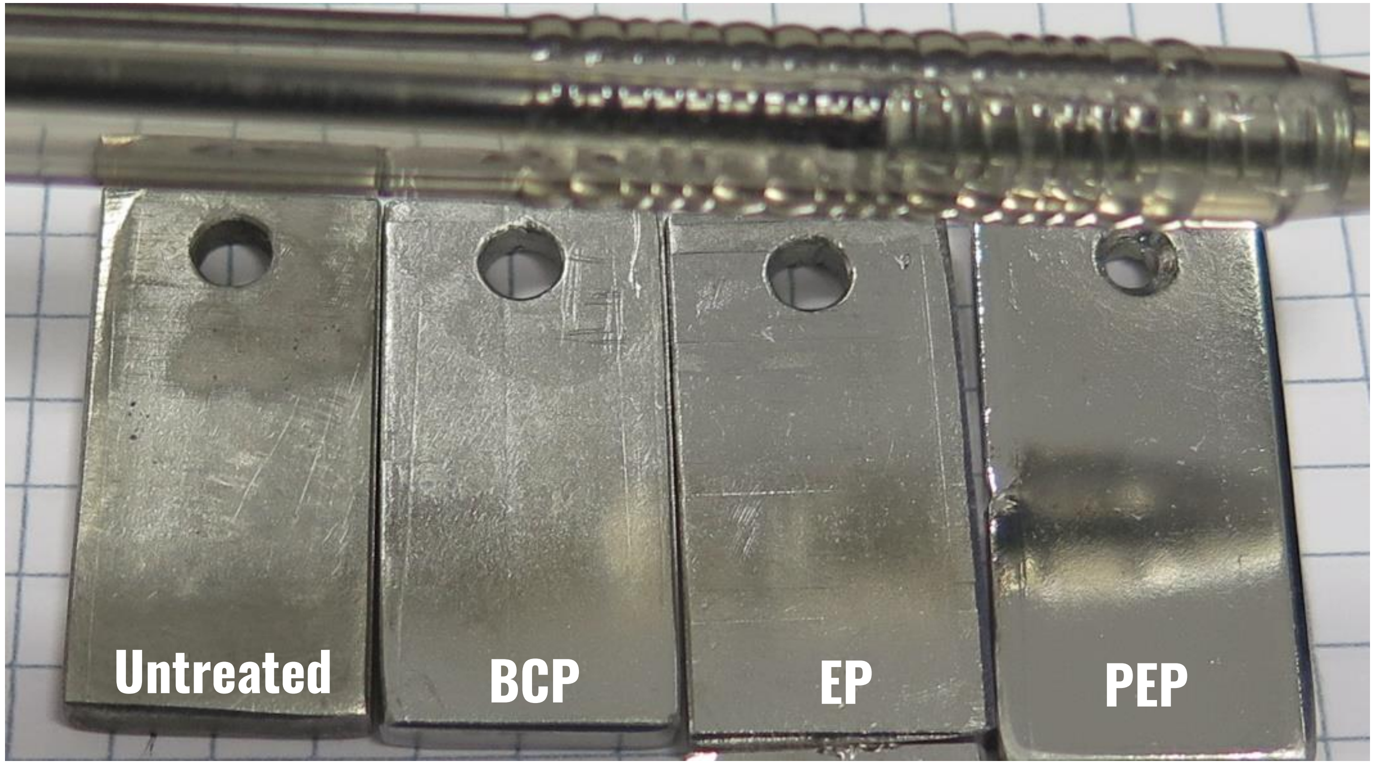
PEP

>10 times faster than EP

Results on Nb

Fast polishing test

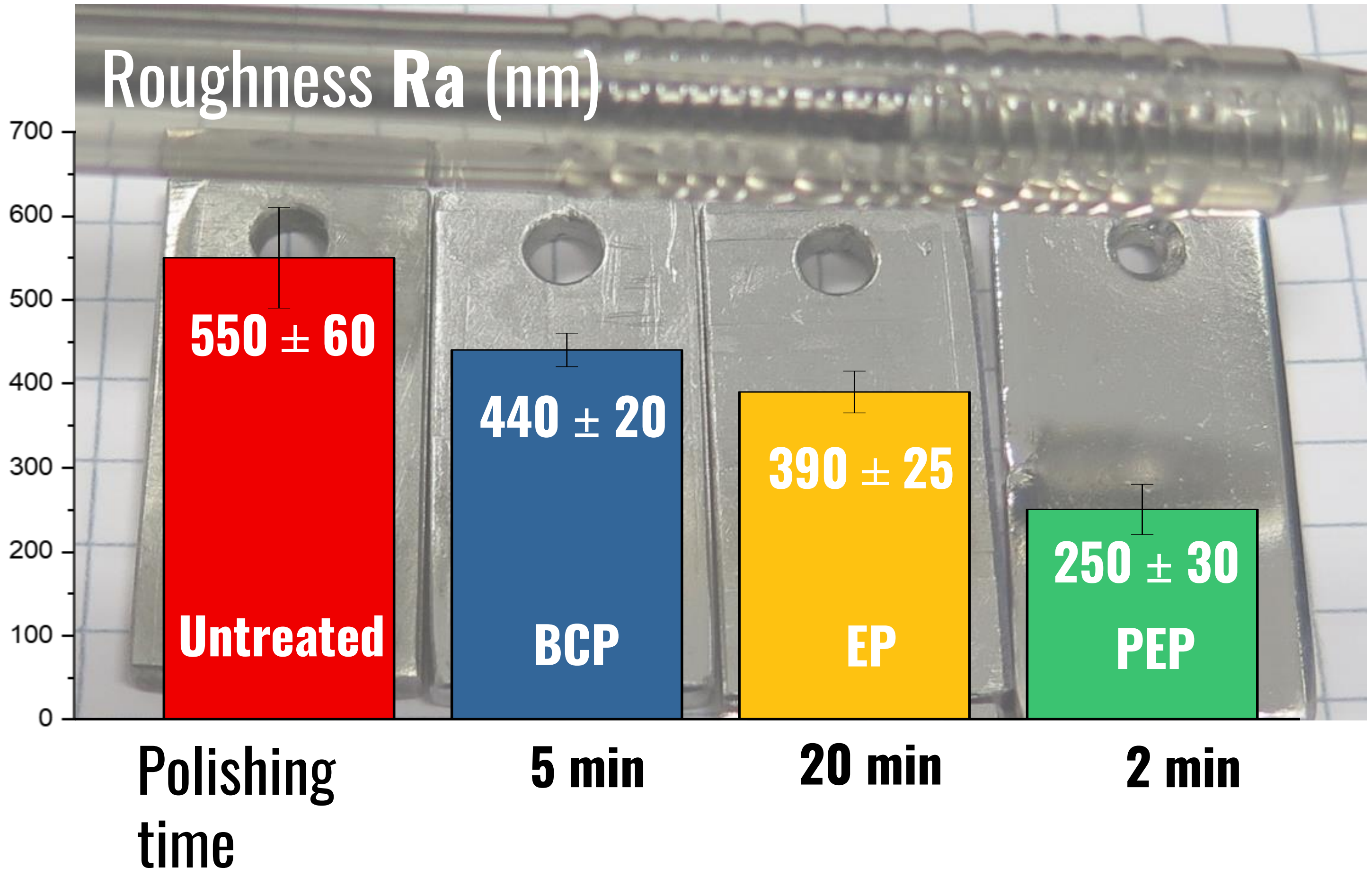
6.5 ± 0.5 μm removed



Results on Nb

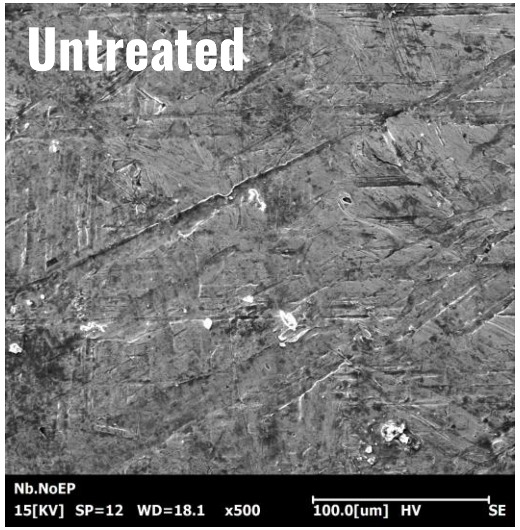
Fast polishing test

6.5 ± 0.5 μm removed

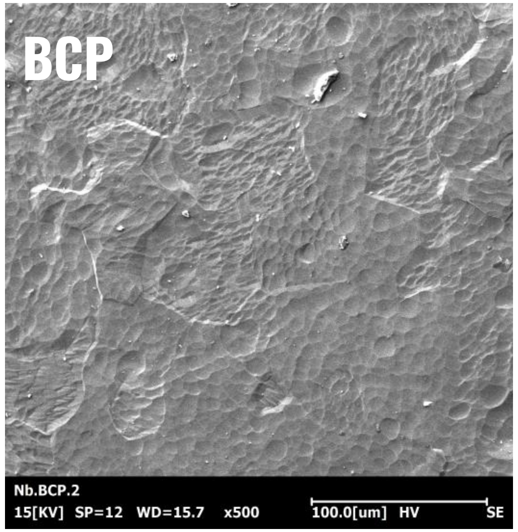


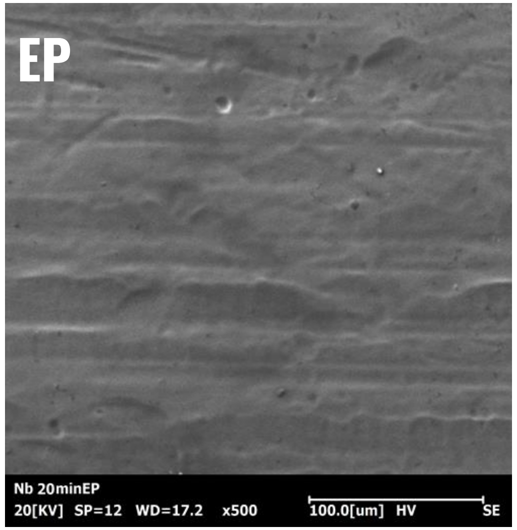
Results on Nb

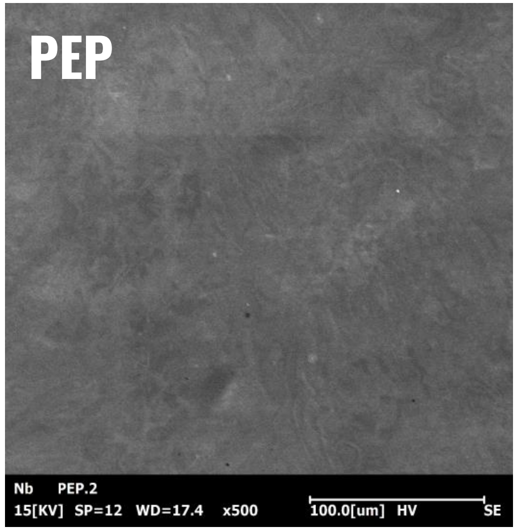
Fast polishing test



6.5 ± 0.5 μm removed





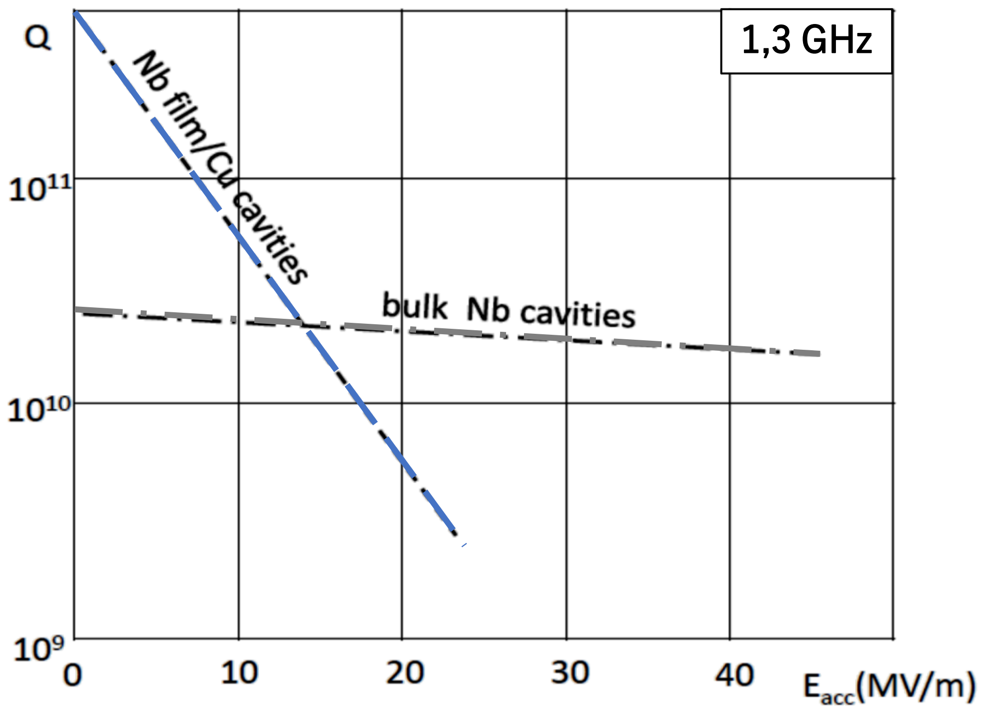


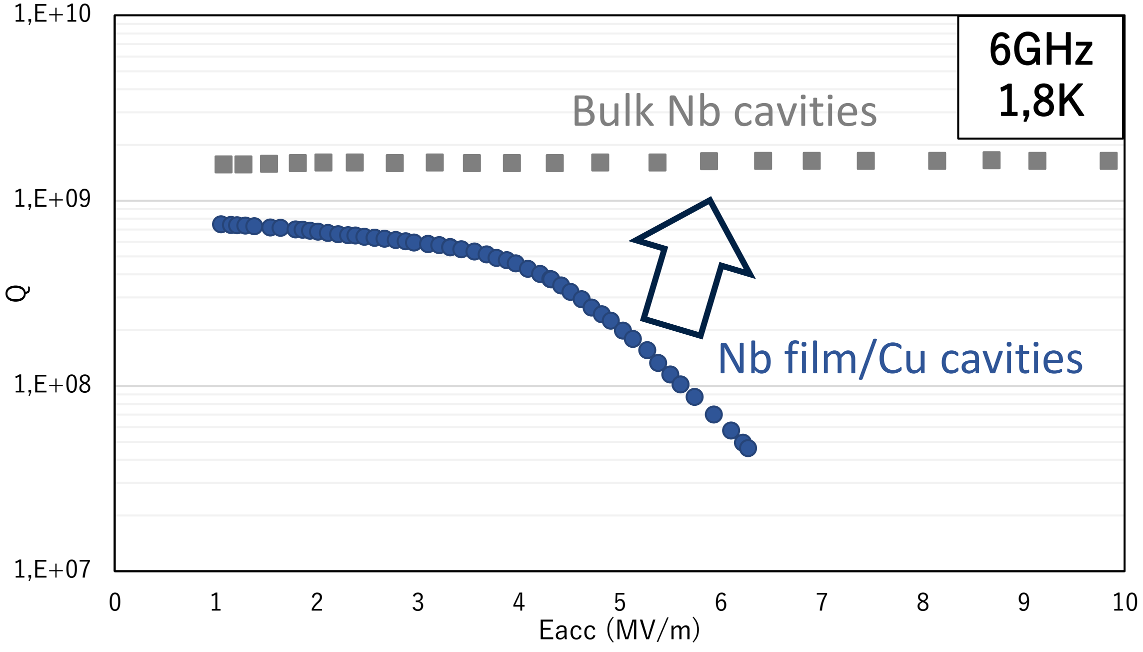
Polishing time	5 min	20 min	2 min

Superconductive coatings by PVD

Why thick films?

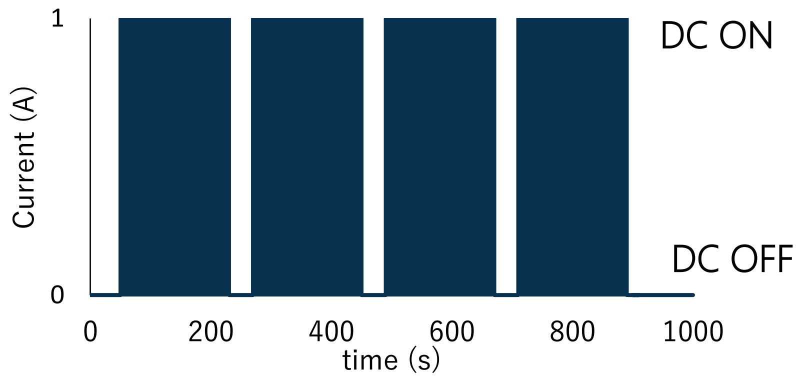
High Q_0
Thermal stability
Cost reduction



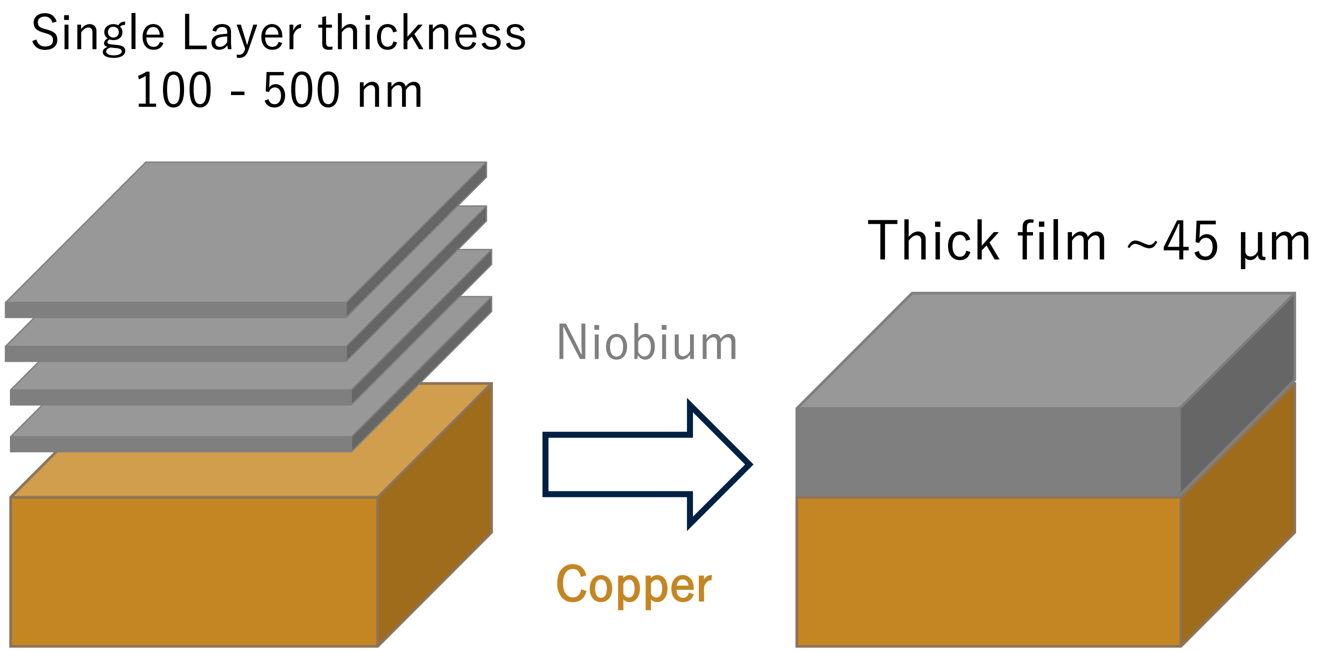


Our approach

Thick film by long pulse deposition



Total time of process ~ 5 hours



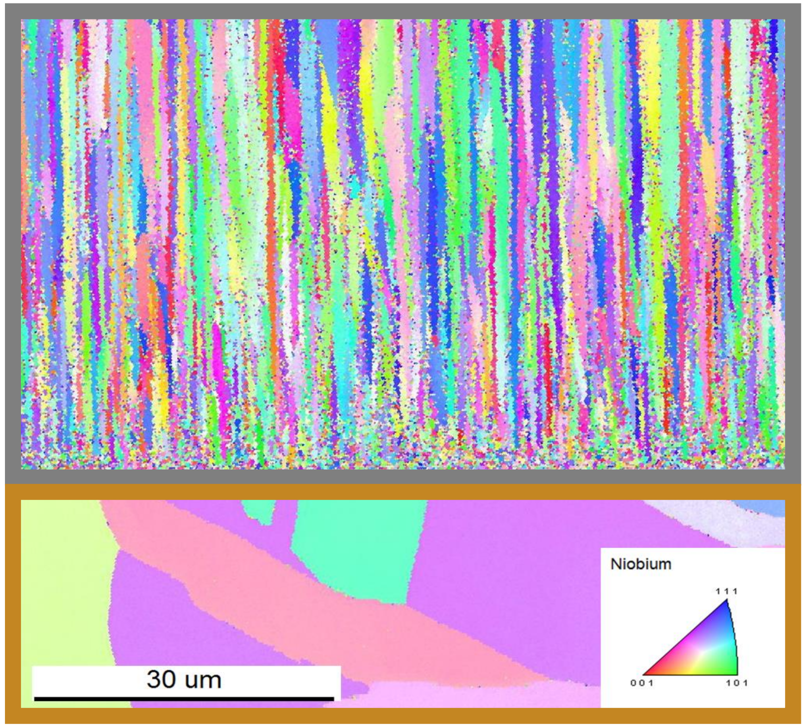
Reduce stress film!

Our approach

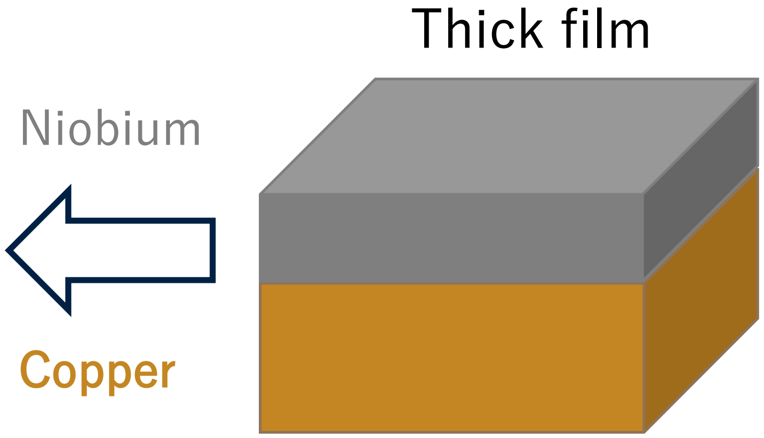
Thick film by long pulse deposition

- Columnar growth
- Larger grains

Courtesy of STFC (Reza Valizadeh)



Cav 21: 75 μm
500nm single layer thickness



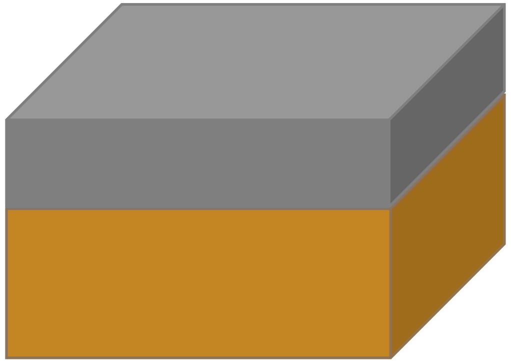
Our approach

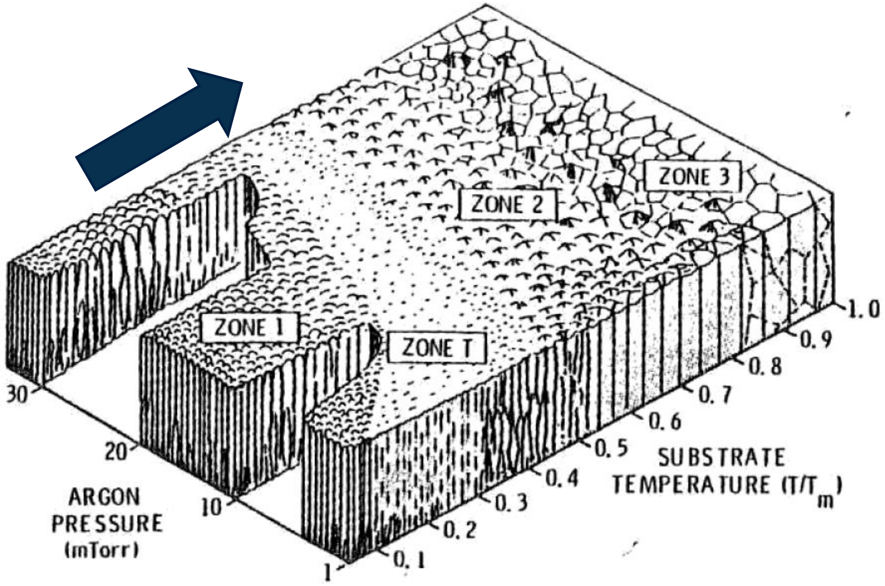
Thick film by long pulse deposition

High substrate temperature

550°C

Thick film

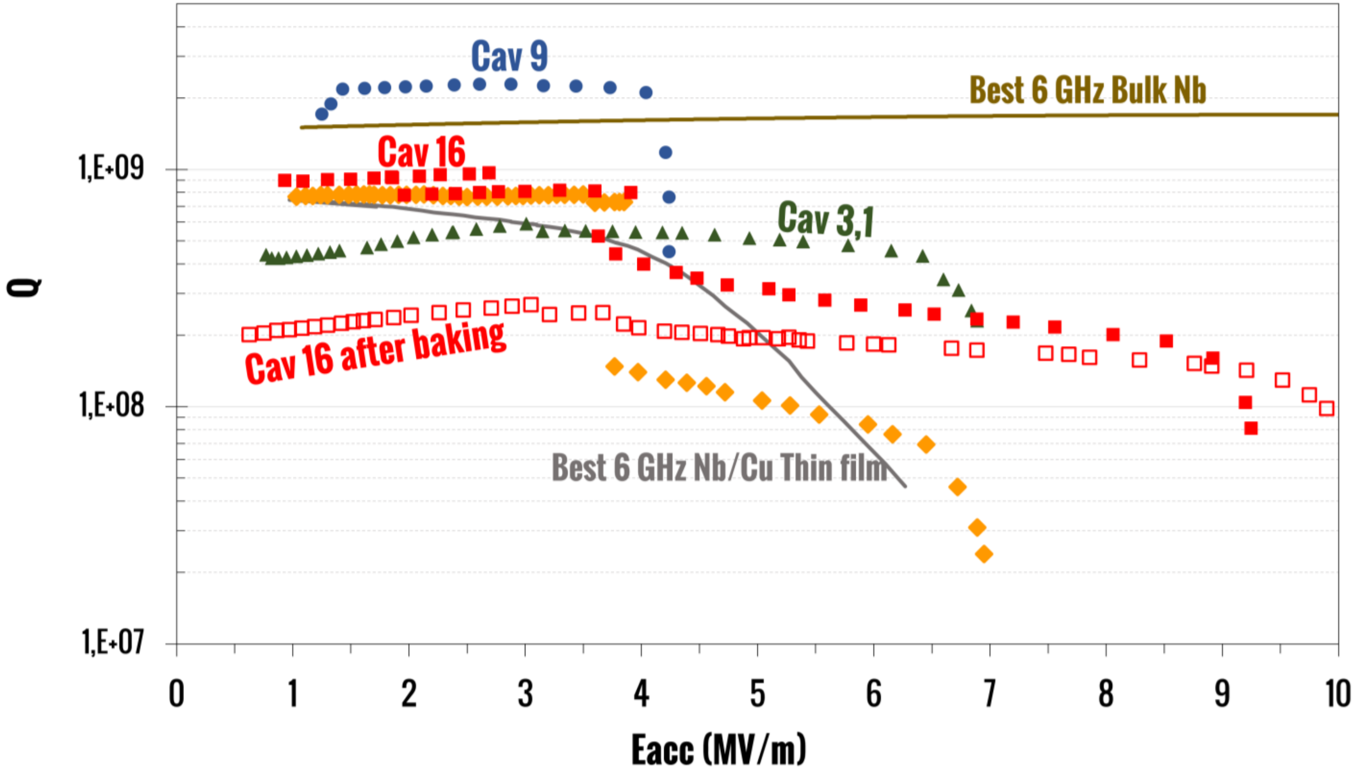




J. A. Thornton and D. W. Hoffman, "Stress-related effects in thin films," Thin Solid Films, vol. 171, no. 1, pp. 5–31, 1989.

Thick Films RF Results

- 30 cavities coated with thick films exploring different parameters
- Q-slope still remain in many cavities…
- …but not in all!

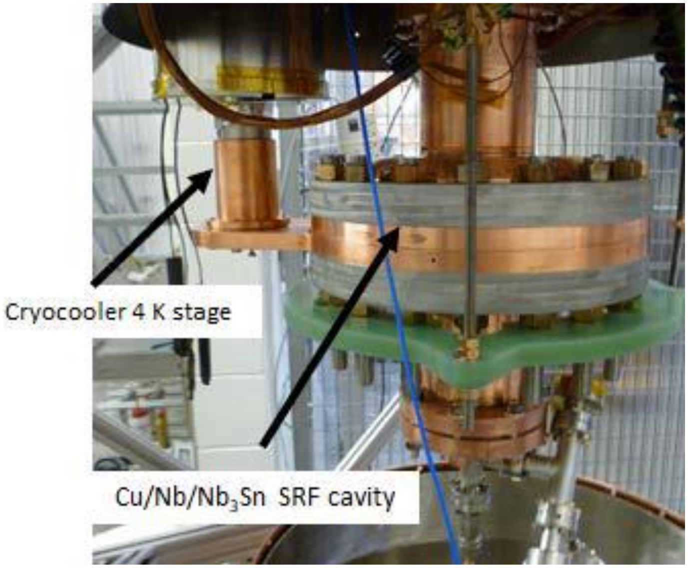


Nb_3Sn @ LNL - Motivation

High performance of Nb3Sn @ 4.2 K → cooling by cryocooler

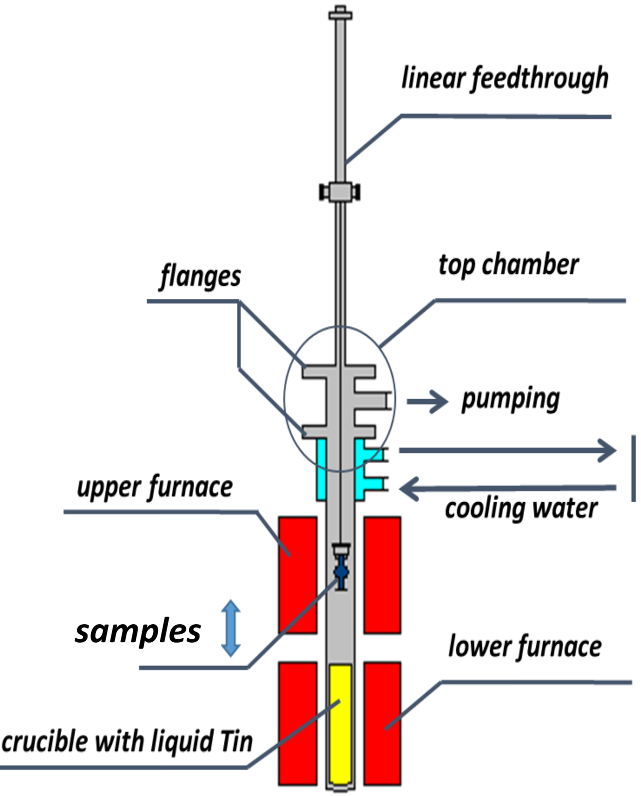
High thermal conductivity substrate is preferred

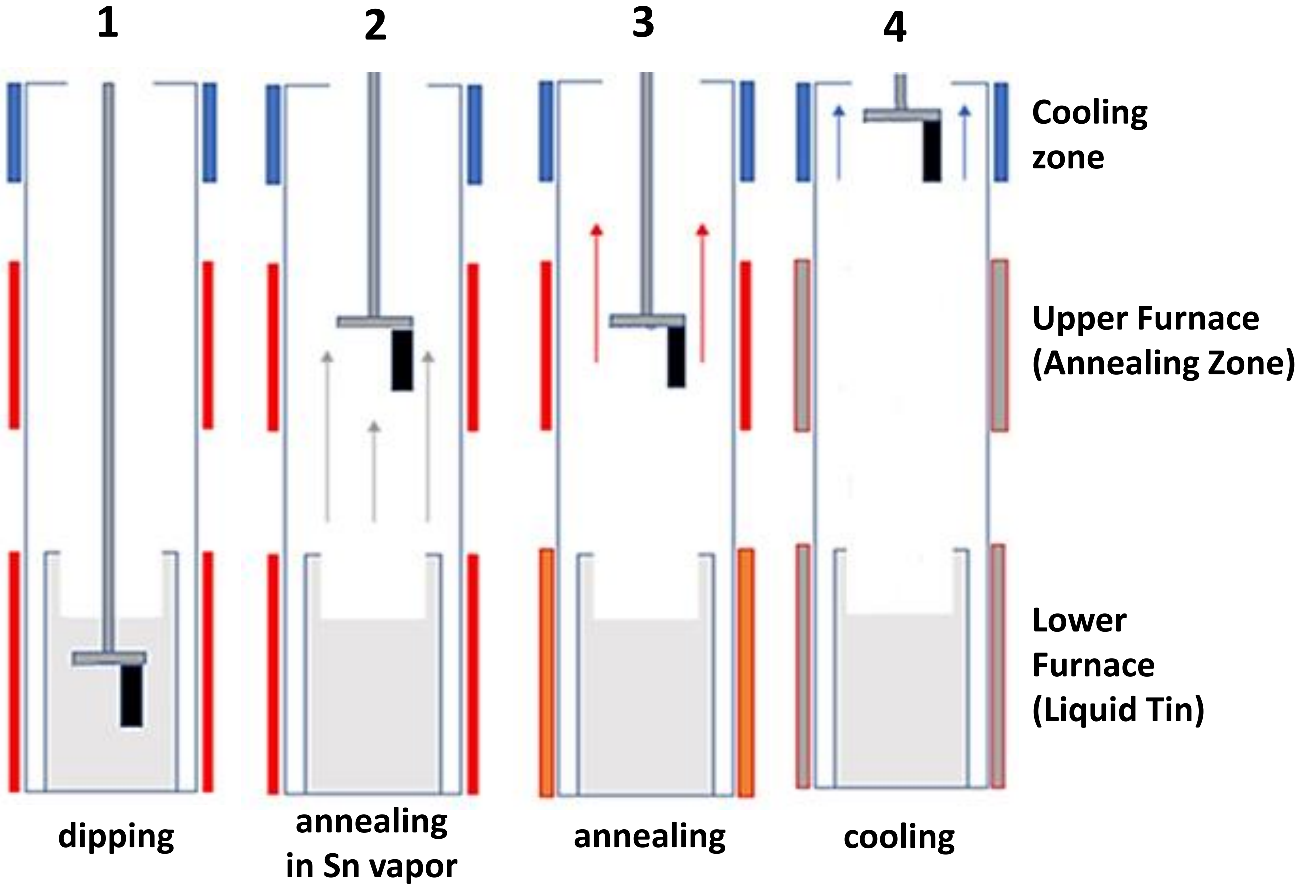
Courtesy of G. Ciovati, JLab



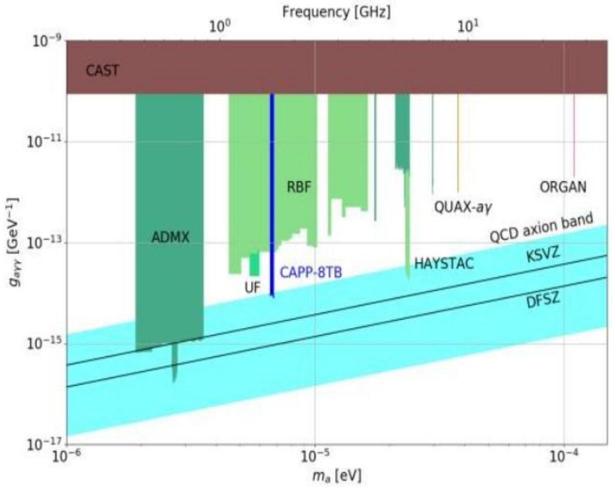
Liquid Tin Diffusion process (LNL 2006)

S. M. Deambrosis et al., "A15 superconductors: An alternative to niobium for RF cavities," Physica C, 2006





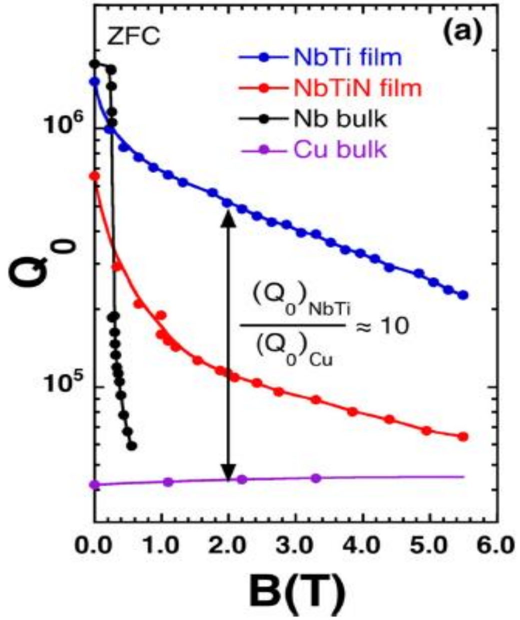
Haloscope for Axions detection



Material **request:**

Q 10^6 at high field (>5 T) is required

NbTi haloscope developed in QUAX at LNL/LNF



NbTi push Cu haloscope
Q up to 10^5 @ 5T

Nb_3Sn, H_{c2} ~ 30 T, Tc = 18 K
NbTi, H_{c2} ~ 15 T, Tc = 10 K

Nb_3Sn is a better SC than NbTi

RF Test

RF Test on accelerating cavities

- Elliptical Cavities: 1.3, 1.5, 6 GHz
- Quarter Wave Resonators: 101 – 160 MHz

Trapped Flux measurements on 6 GHz cavities

Projects and LNL role

JUST FINISHED:

CERN-INFN-STFC (KE-2722/BE/FCC):

- developing of Nb thick film technology and high temperature deposition technique in 6 GHz cavities in view of a possible application to 800 MHz and 400 MHz cavities.

- Fabrication of seamless Cu 400 MHz elliptical cavities by spinning and R&D of the spinning process

EASITRAIN (WP Leader)

- developing of Nb thick film technology and high temperature deposition technique in 6 GHz cavities in view of a possible application to 800 MHz and 400 MHz cavities.

H2020 ARIES (task leader)

- substrate surface preparation

PRESENT:

H2020 i.FAST (task leader)

- *developing of Nb3Sn on Cu PVD technology and realization of a 1.3 GHz elliptical cavities Nb3Sn on Cu*

TEFEN (CSN5, national responsable)

- *developing of Nb thick film technology and high temperature deposition technique*
- *Developing of Plasma Electroliythic Polishing*