Nb_3Sn Coating of Complex Cavity Structures for SRF Accelerator Applications

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GOALS

- Expand the current coating system at JLAB to coat complex cavity models.
- Investigate the Nb_3Sn properties by coating twin axis and the Half wave coax cavities and identify the limitations.
- Optimize the performance of the SRF cavities with Nb_3Sn pushing towards the theoretical limits for the future.

OUTLINE…

- Introduction
    - Nb_3Sn deposition system at JLab
    - Twin axis cavity
- Recent coating of the twin axis cavity
- Future coating of the HW coaxial

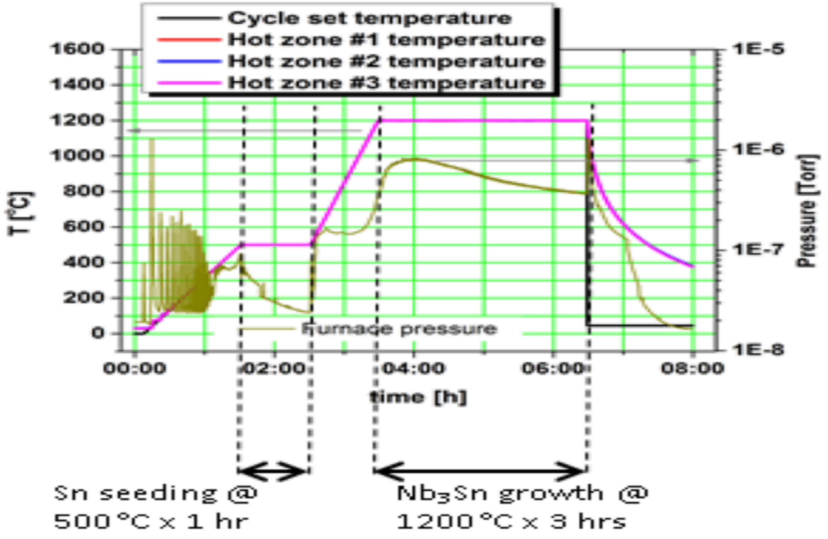
CAVITY DEPOSITION SYSTEM AT JLAB

Nb_3Sn deposition system at JLab :

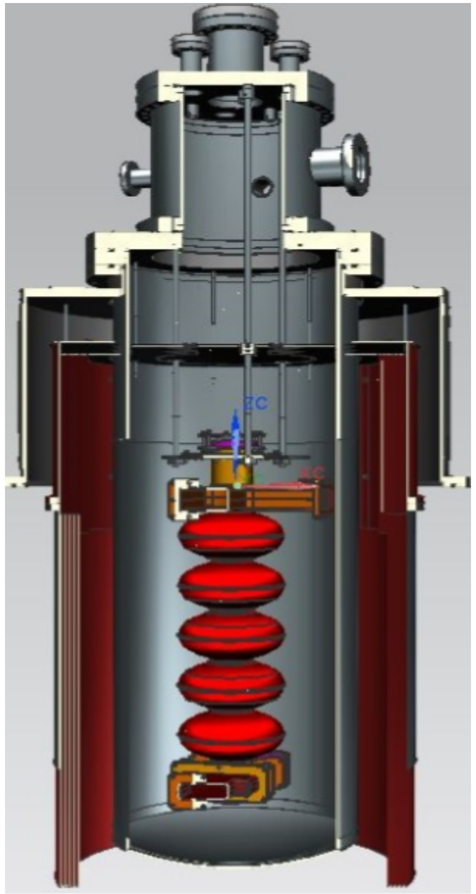
- coating chamber - hosts the cavity to be coated
- furnace - provides the desired heating to the coating chamber , commissioned to reach 1250 ^{0}C with the furnace vacuum in 10^{-7} Torr range [1]

The typical coating process at JLab :

- nucleation step - tin chloride evaporation at 500 ^{0}C for 1-hour.
- deposition step - evaporation of tin for 3-hours at 1200 ^{0}C, which is favorable to form Nb_3Sn phase on substrate niobium [2].



The temperature profile and the pressure used for coating Nb cavities.



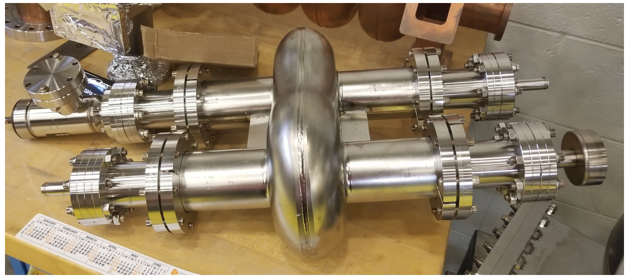
Nb_3Sn coating system

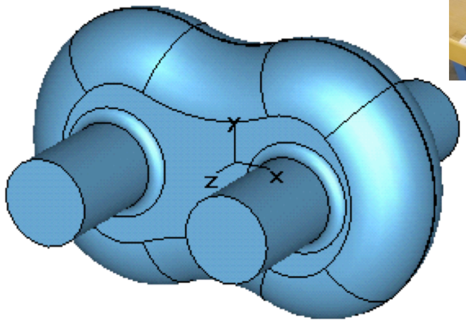
1. G. Eremeev, W. Clemens, K. Macha, H. Park and R. Williams, "Commissioning of Nb_3Sn cavity vapor diffusion deposition system at JLAB"

TWIN AXIS CAVITY

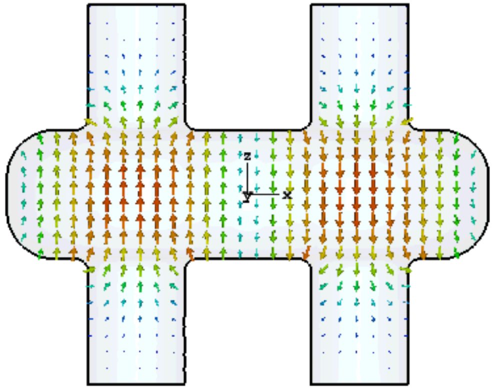
- Two beam axis structures -improve the performance of the ERL
- T M_{110} rf dipole mode with 1497 MHz frequency [1]

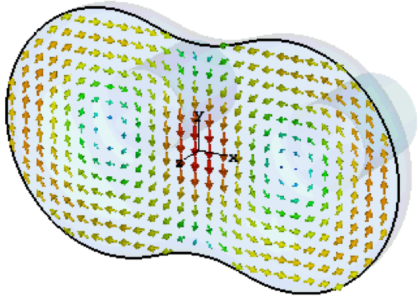
Parameter	Value as designed	Unit
Cavity height	202.5	mm
Cavity width	300.0	mm
Cavity length	100.13	mm
Cell length	81.13	mm
Iris curvature	8.0	mm
Beam aperture	60.0	mm
Beam axis separation	136.5	mm
E_p/E_{acc}^*	2.68	-
B_p/E_{acc}^*	5.5	mT/(MV/m)
$[R/Q]$	60.1	Ω
G	320.8	Ω
R_tR_s	1.93×10^4	Ω^2
LOM	1103	MHz
Nearest HOM	1806	MHz





Twin axes cavity [2]



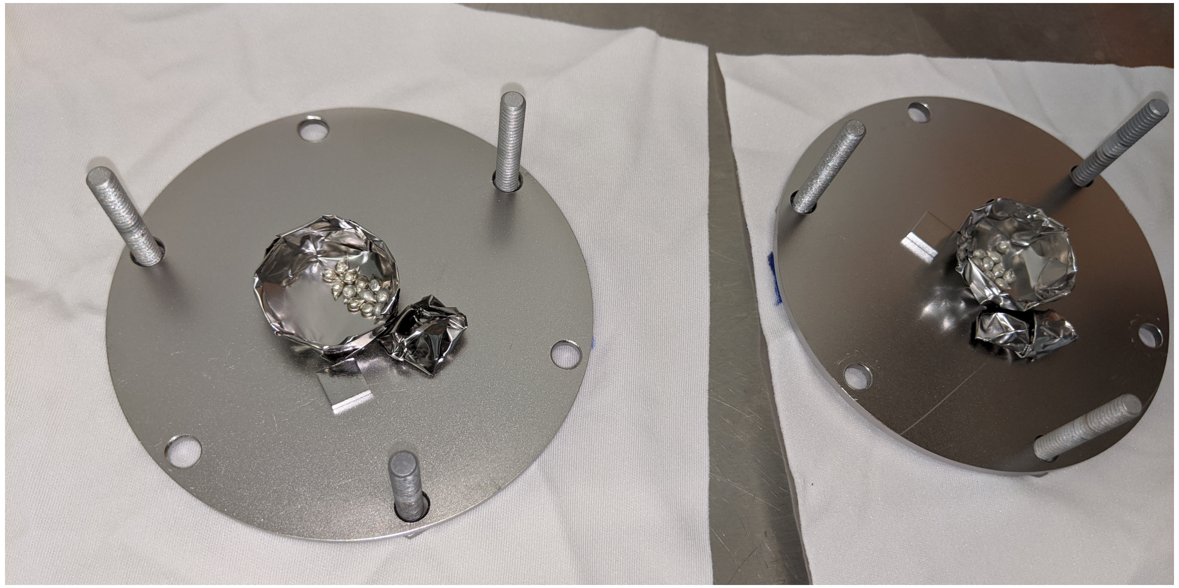


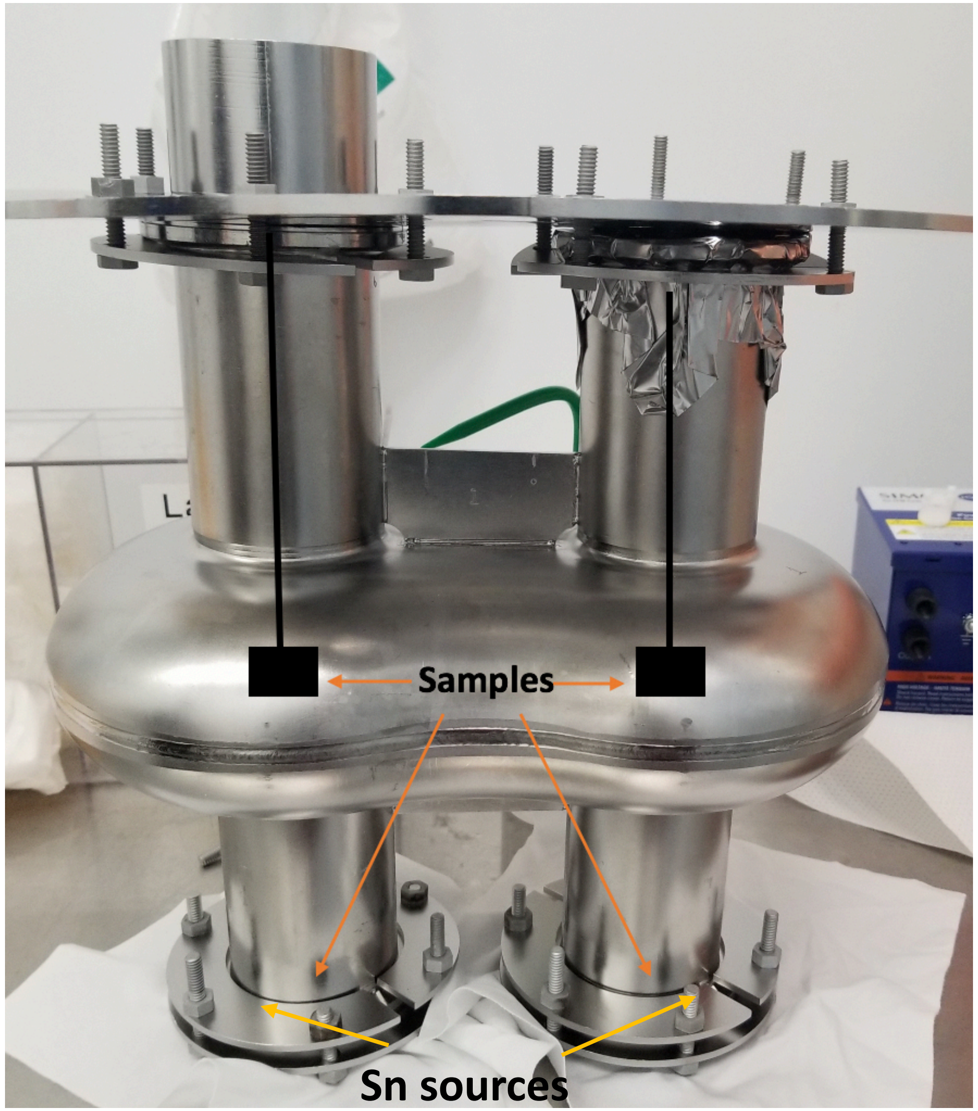
1. S. U. De Silva , H. Park, J. R. Delayen, F. Marhauser and A. Hutton, “First test results of Superconducting Twin axis cavity for ERL application”
2. S. U. De Silva , H. Park, J. R. Delayen, F. Marhauser and A. Hutton, “Electromagnetic Design of a Superconducting Twin axis cavity”

TWIN AXIS CAVITY - COATING

- Two Sn sources at the bottom
- 1.5 g × 2 Sn and 0.5 g × 2 $SnCl_2$

(Adjusted the amount of Sn/Sncl2 based on previous coatings to avoid patchy regions and Sn residues)





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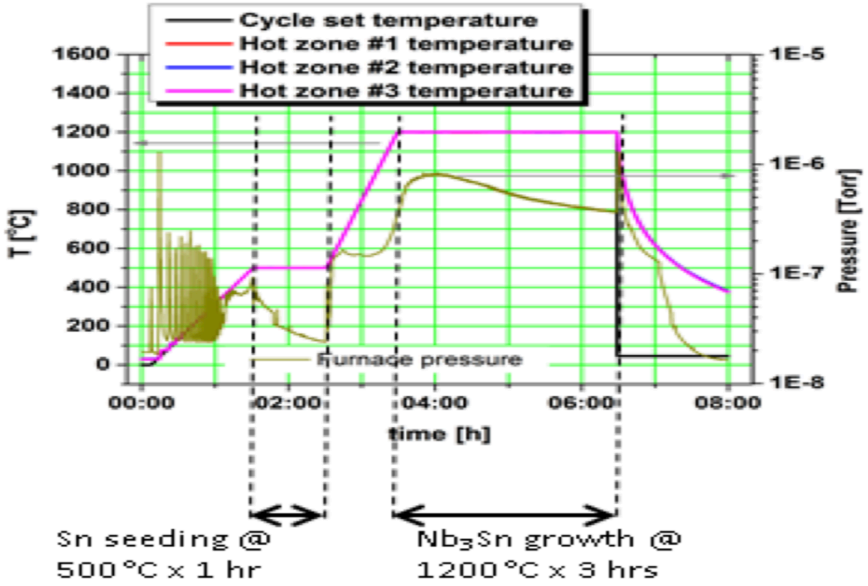
TWIN AXIS CAVITY – COATING…

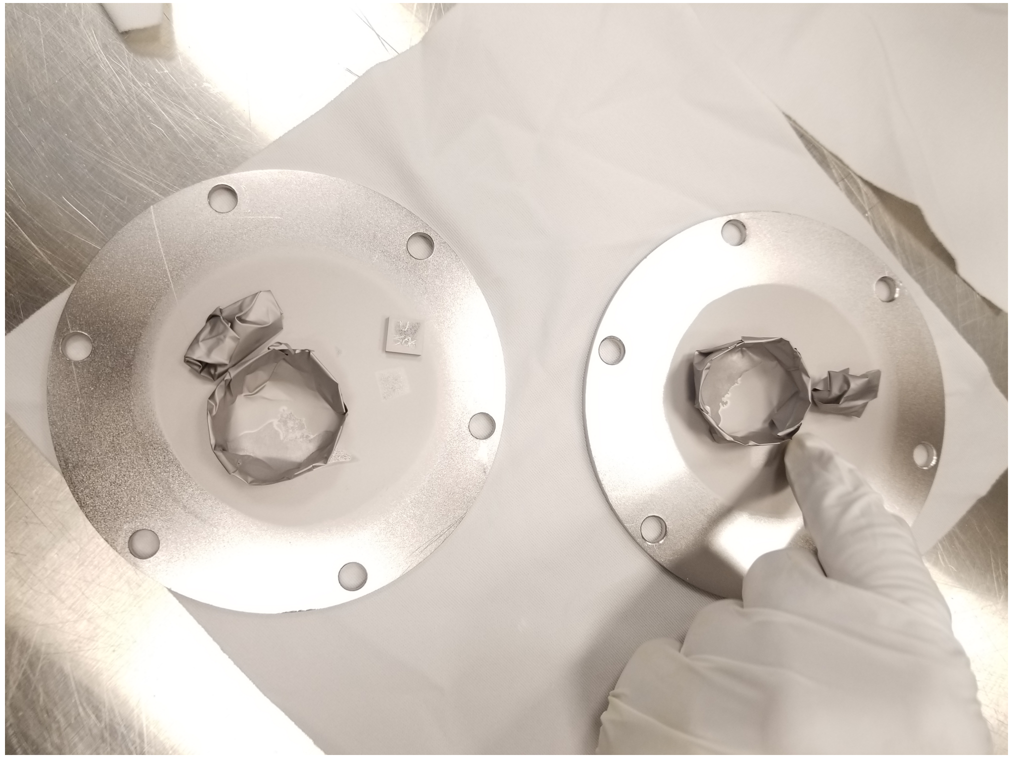
- Same temperature profile



TWIN AXIS CAVITY COATING…

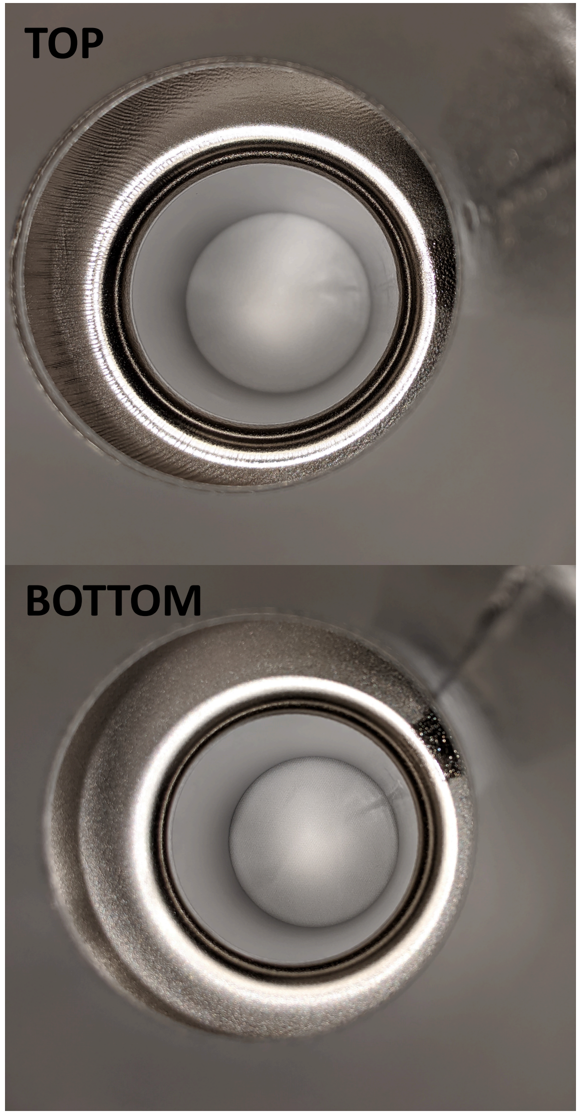
After…

- Almost all the Sn is gone
- Uniform coating

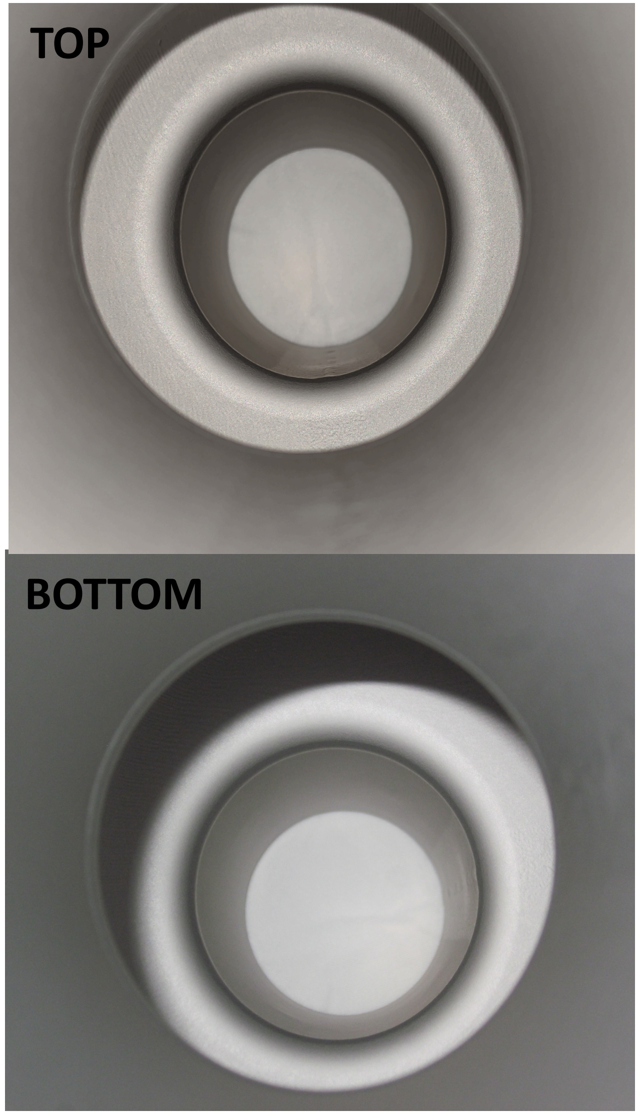


TWIN AXIS CAVITY COATING…

Before

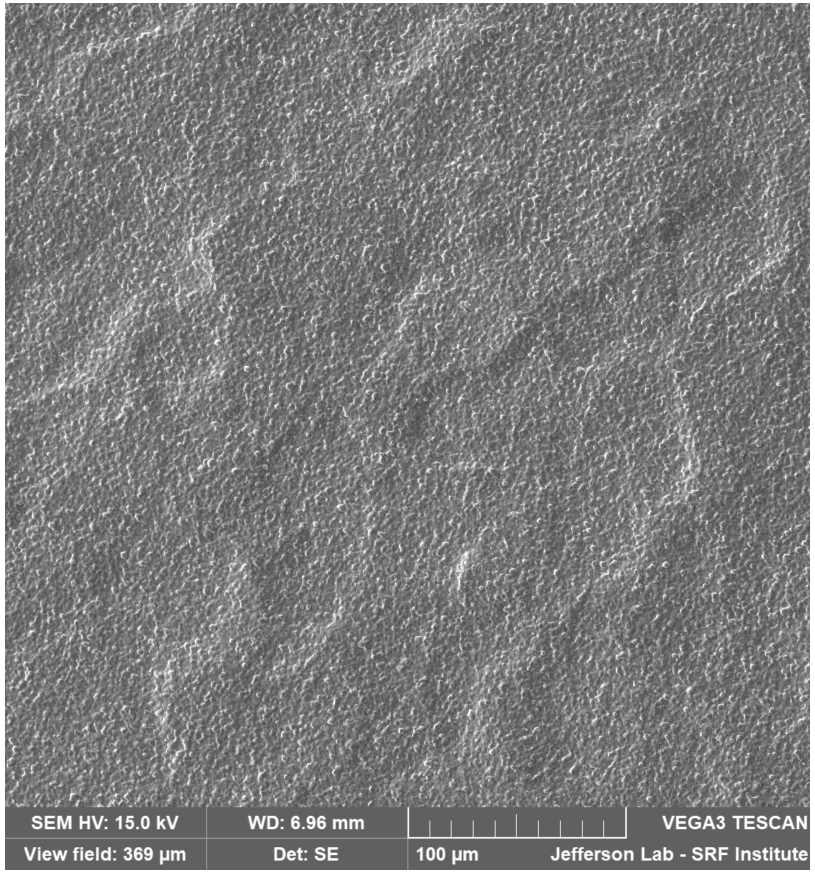


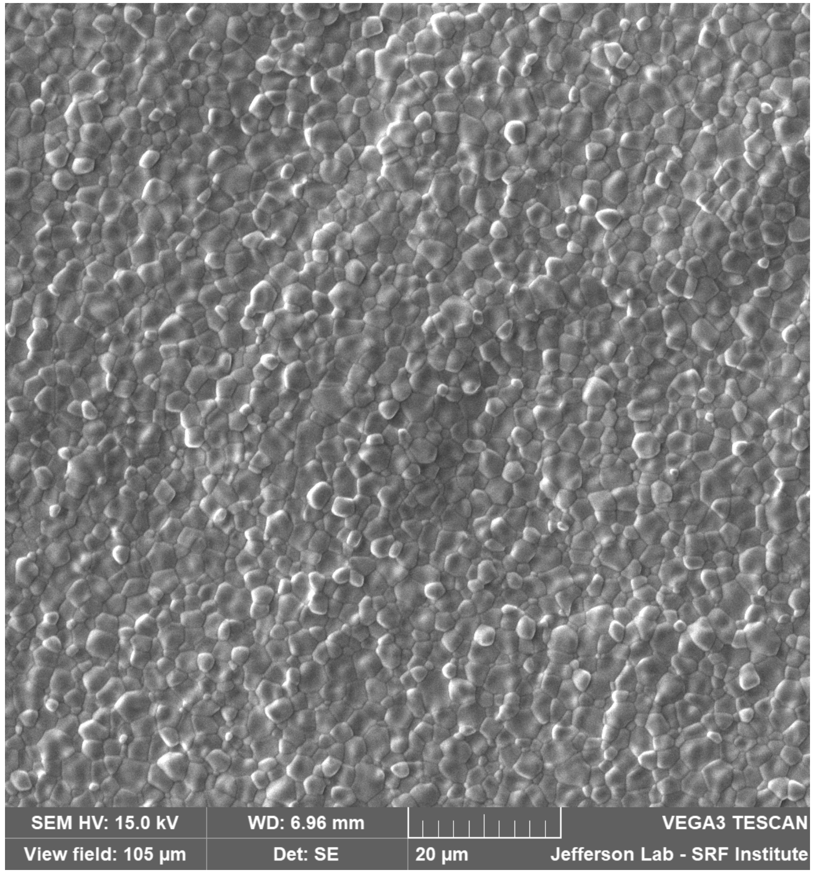
After

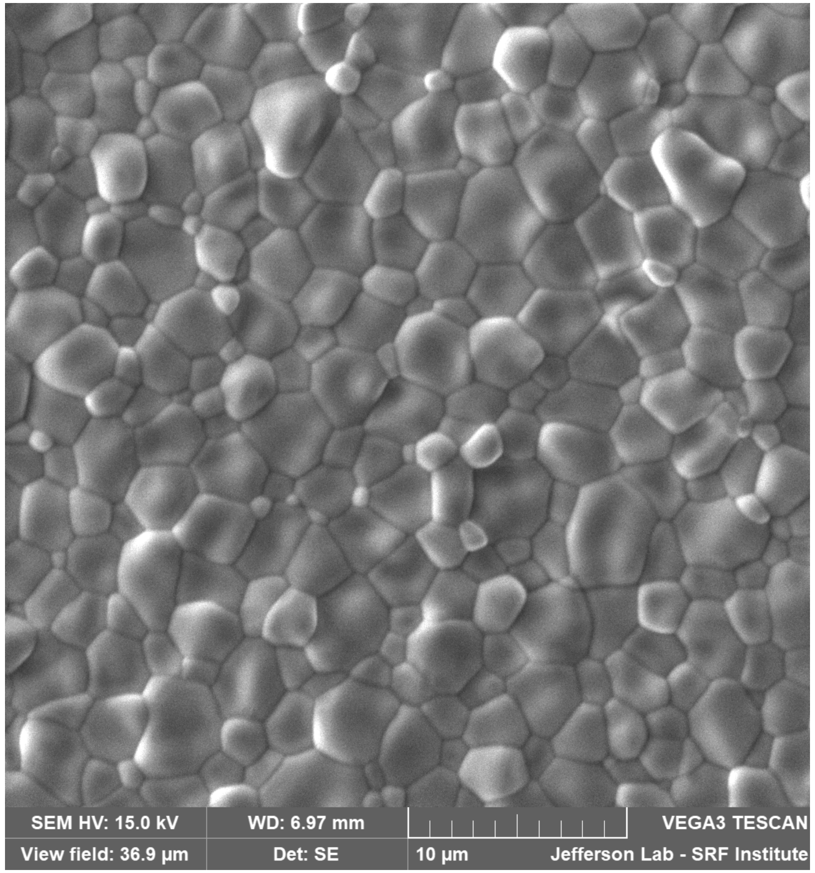


TWIN AXIS CAVITY COATING…

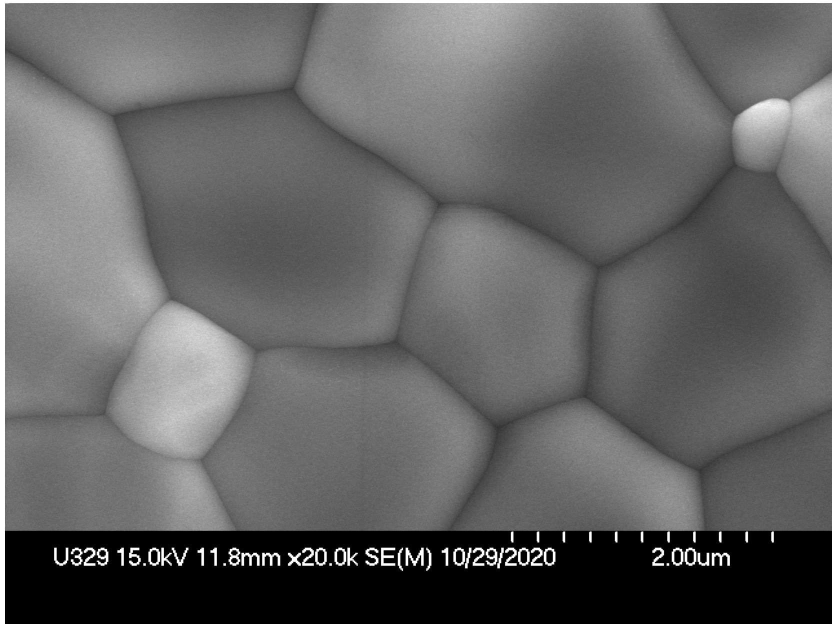
TWIN AXIS CAVITY COATING – TOP SAMPLE – SEM

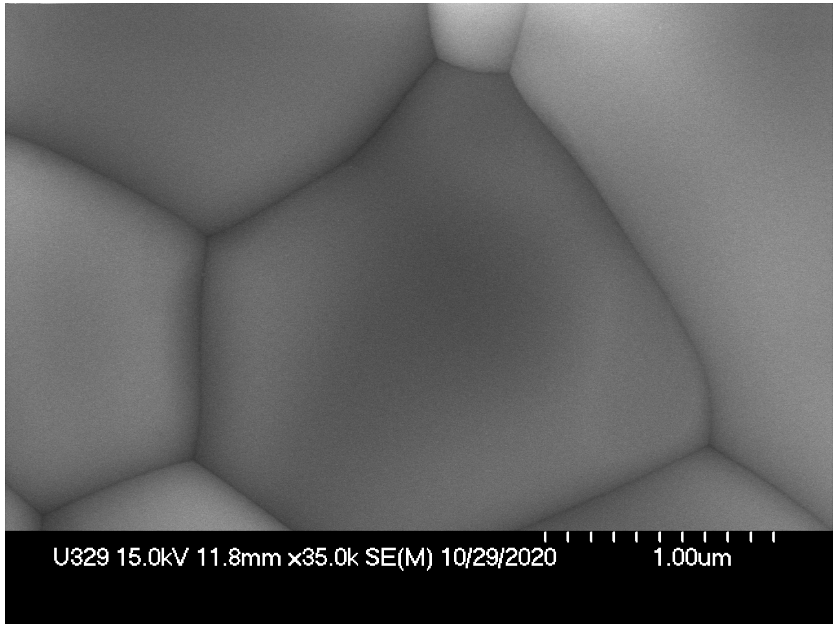


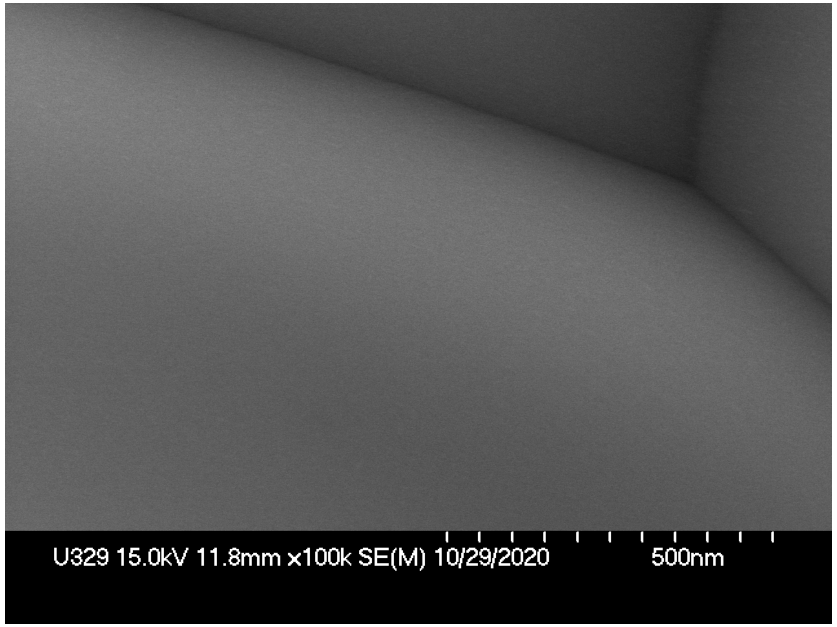




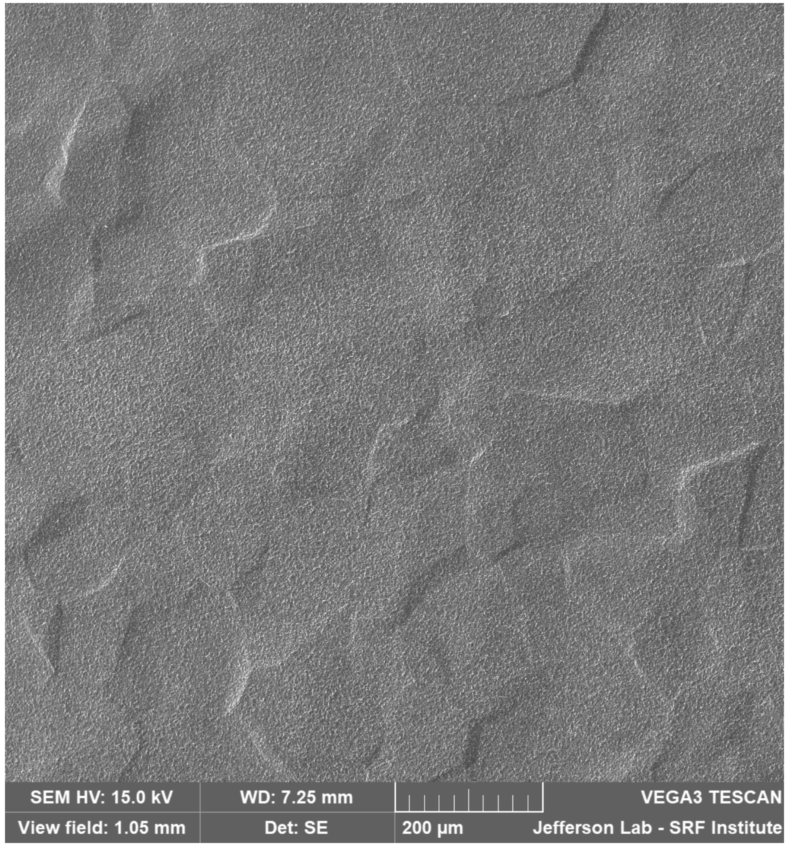
TWIN AXIS CAVITY COATING – TOP SAMPLE – SEM…

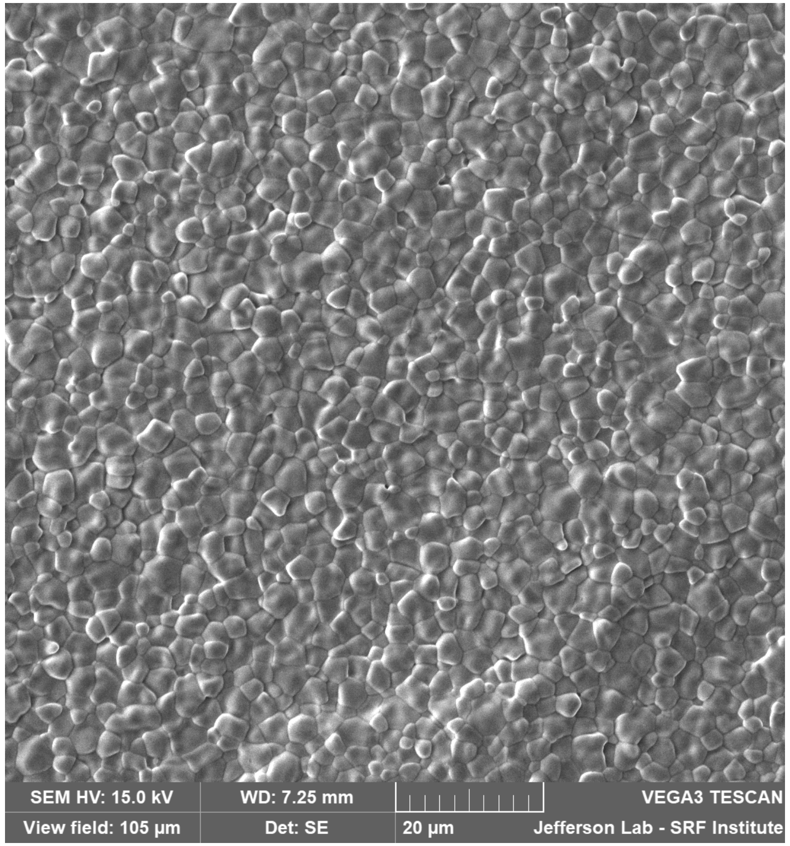


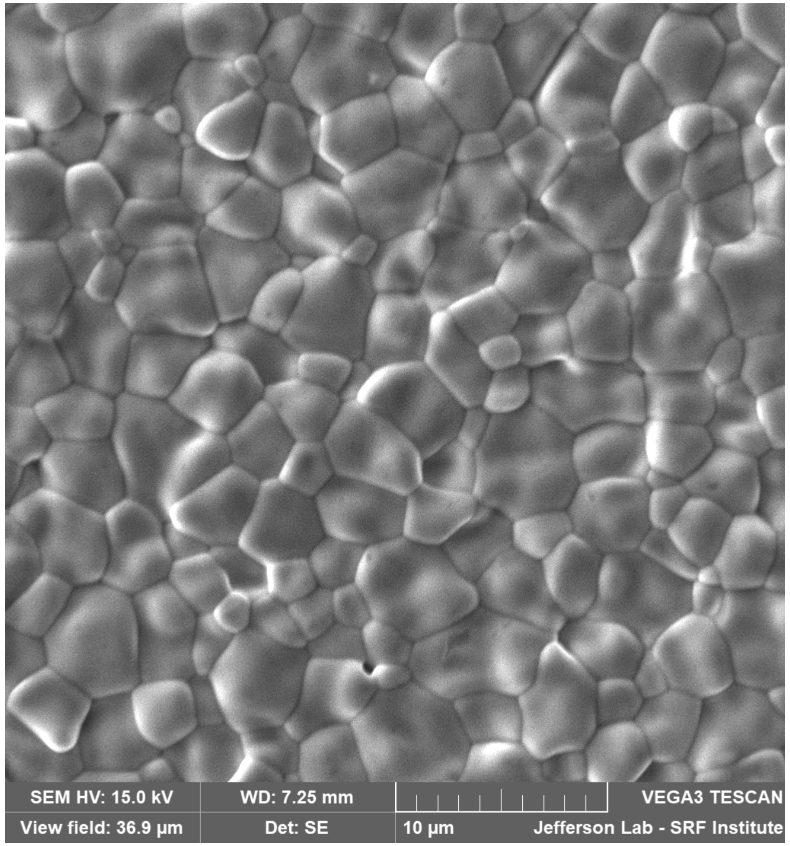




TWIN AXIS CAVITY COATING –BOTTOM SAMPLE – SEM



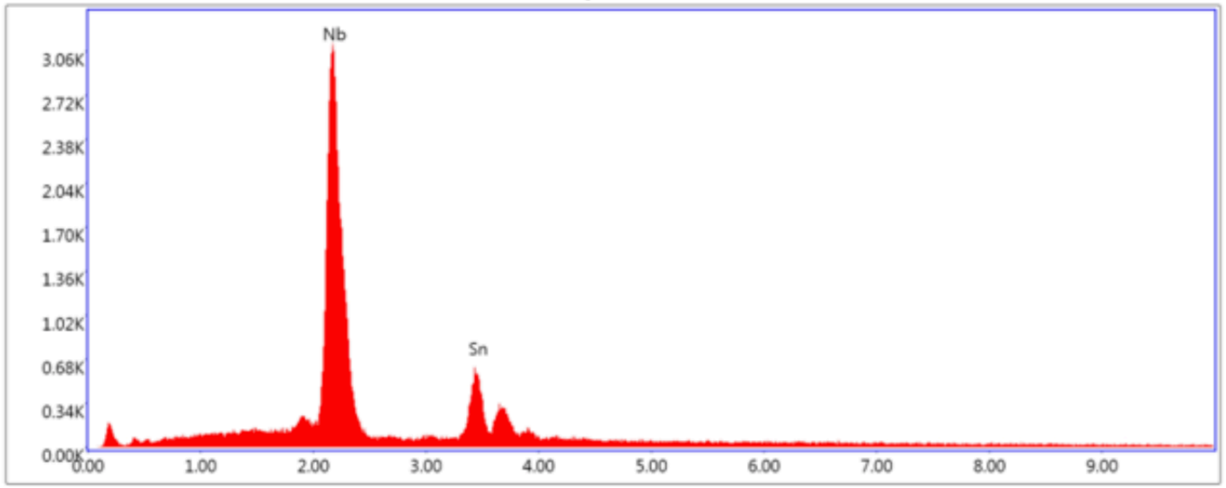


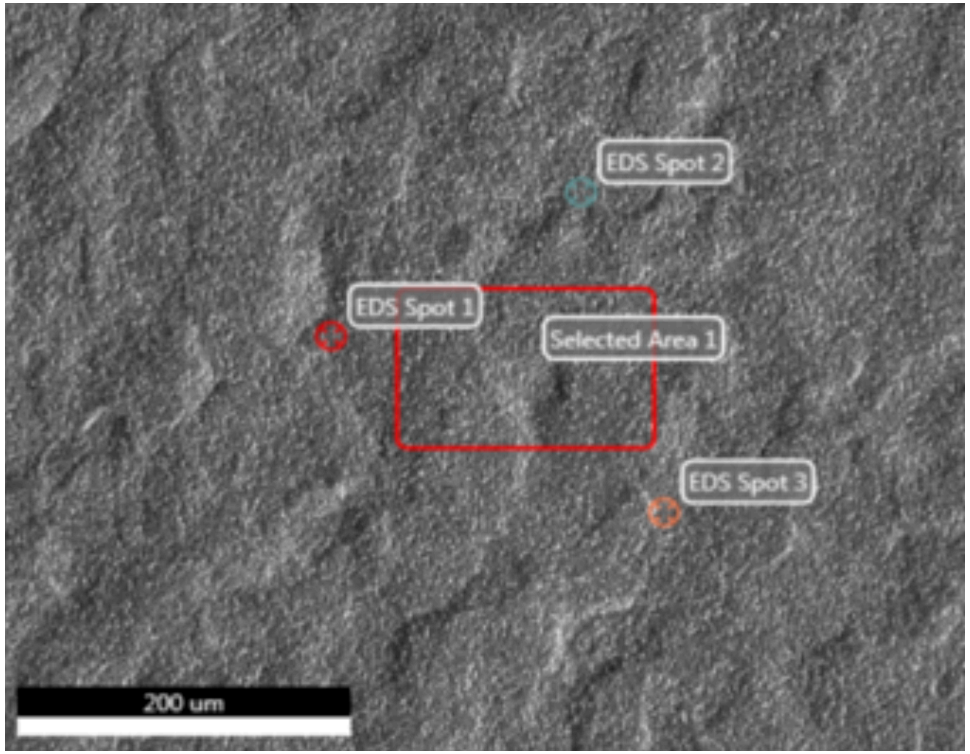


TWIN AXIS CAVITY COATING –TOP SAMPLE – SEM

EDS Spot 1

kV: 15 Mag:738 Takeoff: 30.5 Live Time(s): 20 Amp Time(µs):0.5 Resolution:(eV)133





eZAF Smart Quant Results

Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	A	F
NbL	70.29	75.14	1577.73	2.77	0.6742	1.0204	0.9389	1.0012
SnL	29.71	24.86	333.11	6.84	0.2366	0.9501	0.8392	0.9989

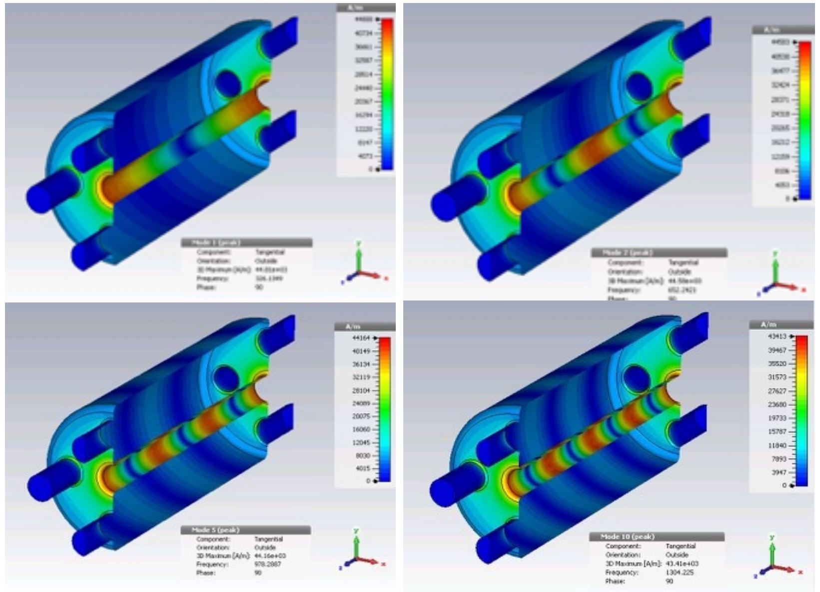
TWIN AXIS CAVITY COATING – RF TESTING

✓ Ready for the RF test

HALF WAVE COAXIAL RESONATOR

- Cylindrical-coaxial resonator -TEM modes, high surface magnetic field is concentrated on the inner cylinder.
- ODU second half-wave cavity - frequency range of 325MHz to 1.3GHz.

Complete half-wave coaxial resonator



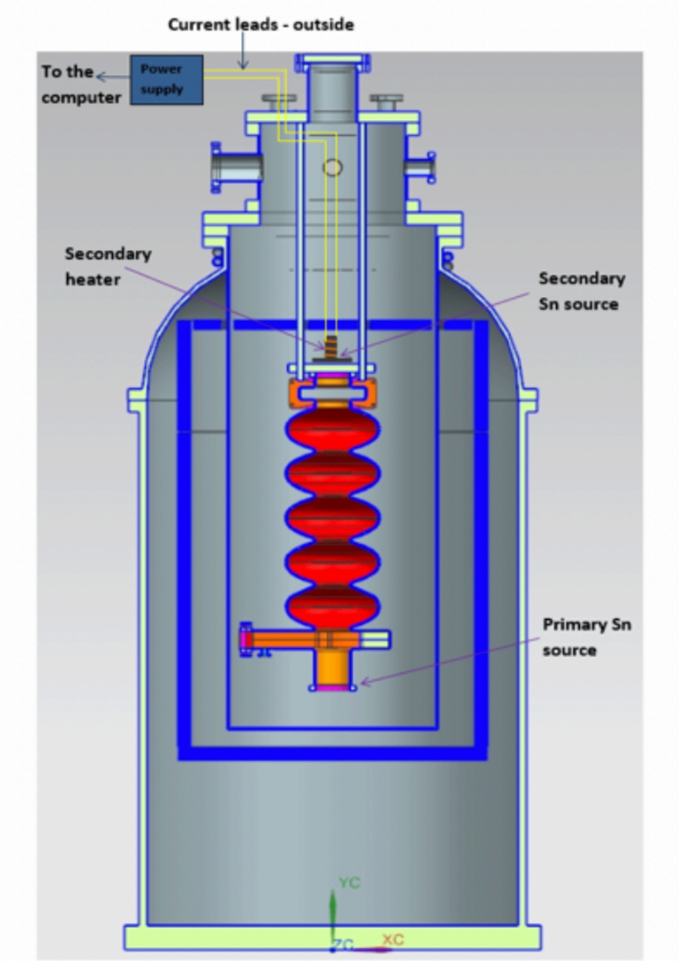
Surface magnetic field distribution of the TEM1, TEM2, TEM3, and TEM4 modes from CST Microwave studio.

Parameter	Unit	Value
Cavity length	mm	459
Outer conductor radius	mm	111
Inner conductor radius	mm	20
Peak electric field, E_p	MV/m	15.6
Peak magnetic field, B_p	mT	56
TEM1, TEM2, TEM3, TEM4 frequencies	MHz	327.1,654.3, 981.4,1308.3
Geometric factor, G	Ohm	61,123,185,247

SECONDARY TIN SOURCE

- Low tin flux.
- Increased area.
- increased number of ports.
- Temperature gradient through the cavity.

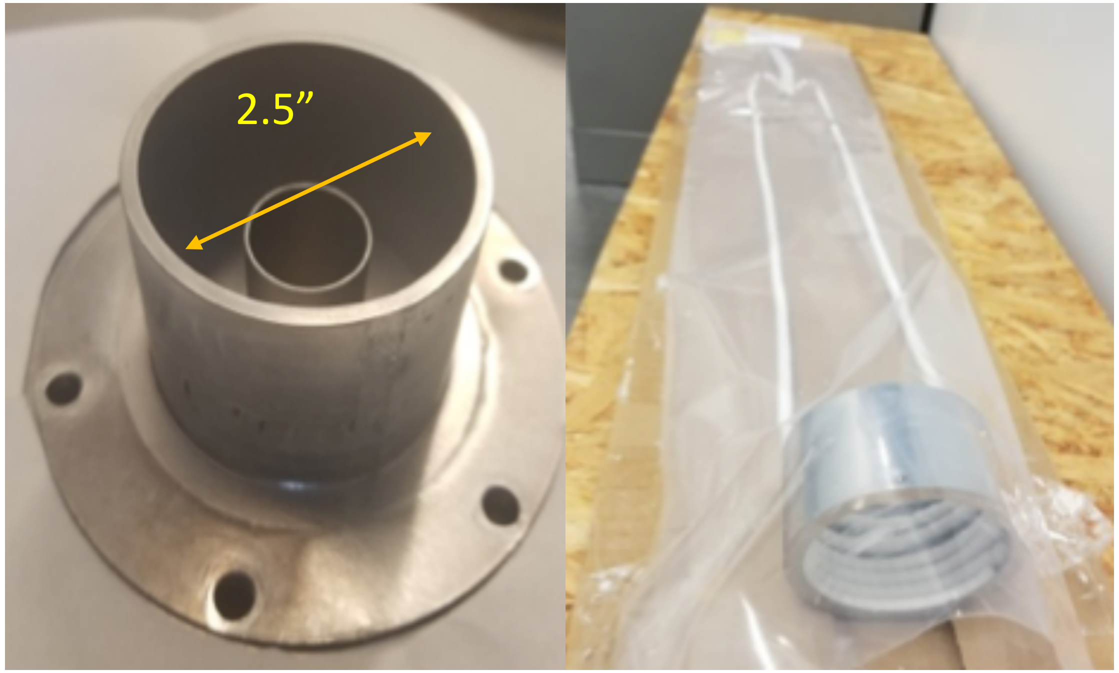
⟶ **secondary tin source and a heater**



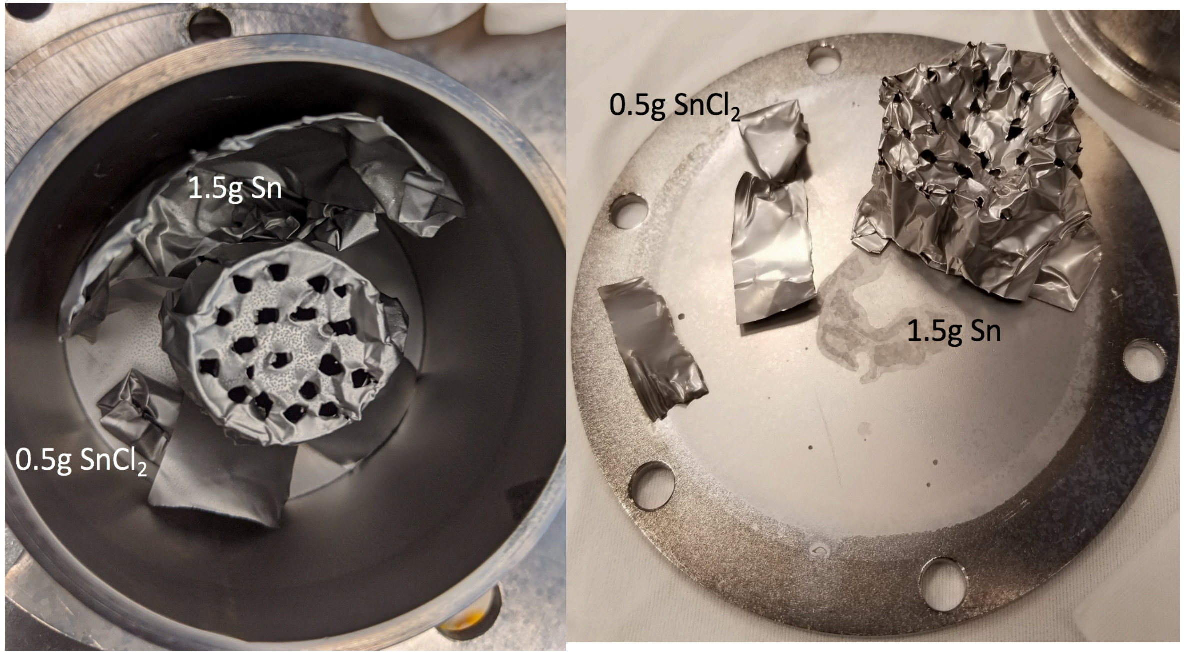
Cavity coating system model with the secondary Sn source and the heater with a 5-cell cavity

SECONDARY TIN SOURCE – DESIGN AND FABRICATION

- 2.5” outer diameter and 1” inner diameter Niobium tubes.
- Sn and $SnCl_2$ are placed in the space between.
- Heated by the secondary heater – first procured from HeatWave labs, Inc. California. It is made out of Molybdenum coil leads insulated with fish spine beads. Now using Nb wire.



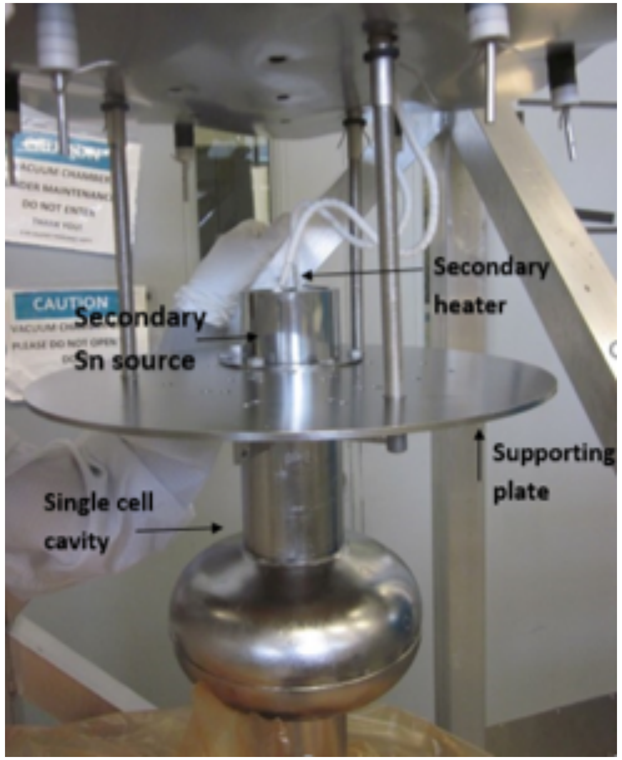
Secondary Sn source (Left) and the heater (Right)



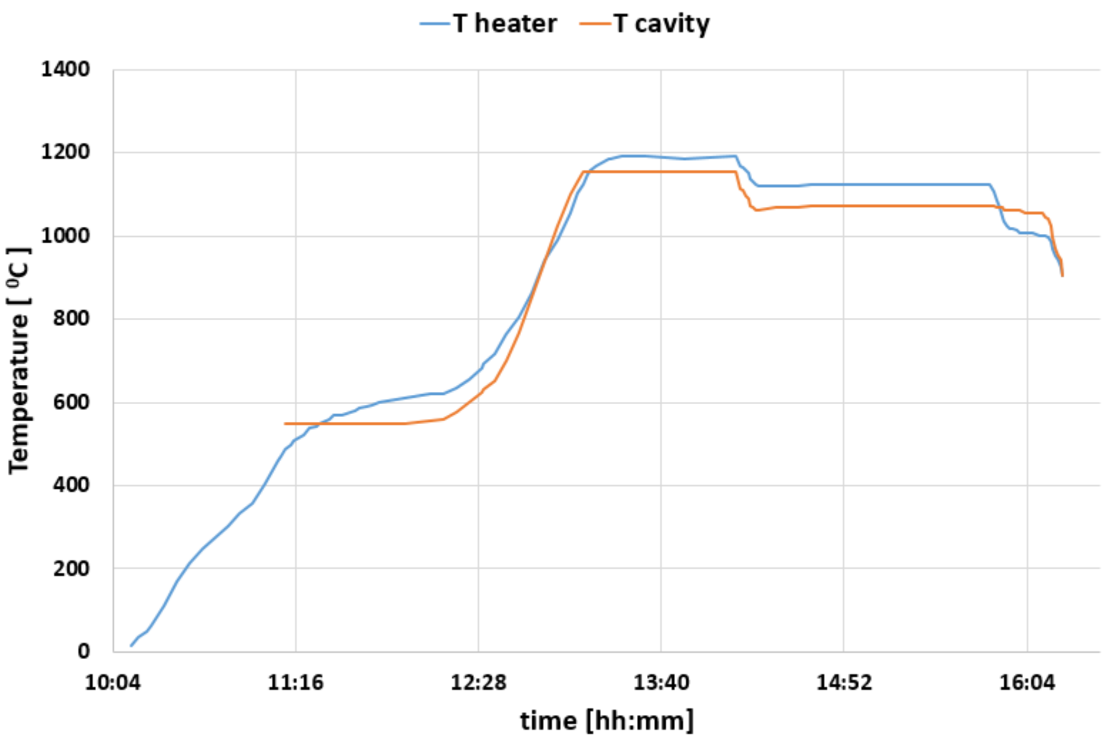
Secondary Sn source (Left) and the primary Sn source(Right)

SECONDARY TIN SOURCE – COMMISSIONING

- Secondary Sn source and the heater was tested with TE1NS001 single cell cavity.
- Heater was powered manually ,increasing the voltage in steps of 5V up to 25V.
- Same heating profile used for the furnace is followed.

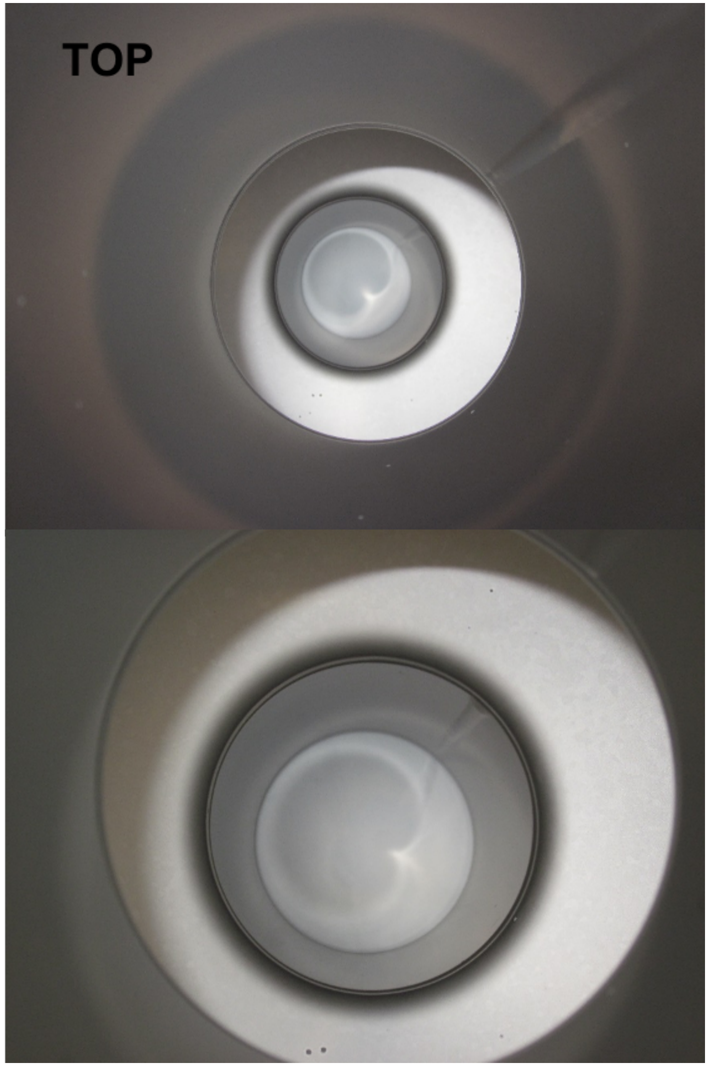


TE1NS001 single cell assembly with the secondary Sn source and the heater



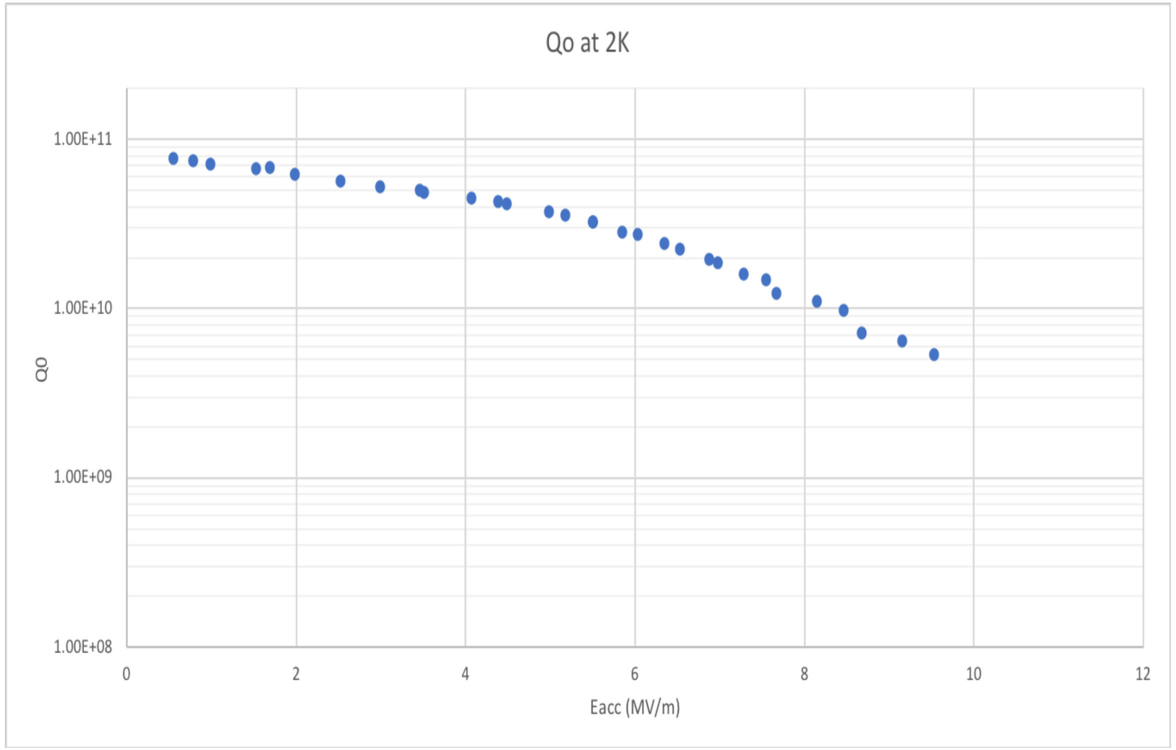
Heat profile for testing the secondary Sn source with the heater (with TE1NS001 single cell)

SECONDARY TIN SOURCE – COMMISSIONING…

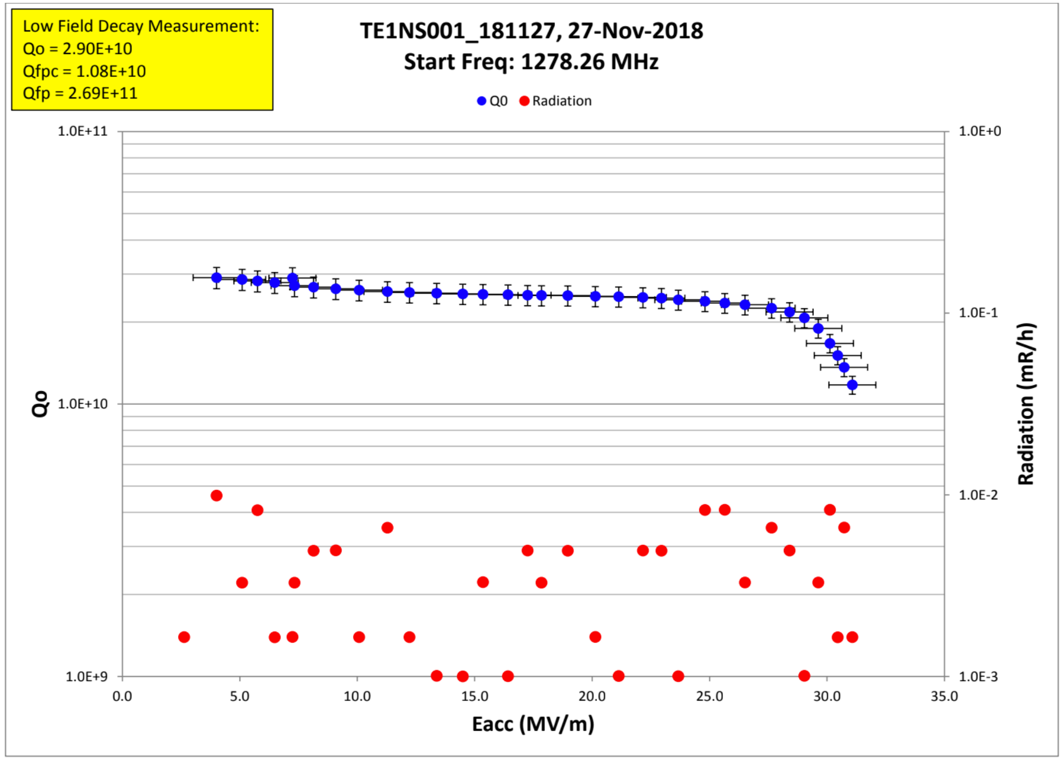


View inside the coated cavity from top and bottom

SECONDARY TIN SOURCE – COMMISSIONING – RF TESTING



TE1NS001 cavity coated with Nb_3Sn at 2K



TE1NS001 cavity at 2K

SUMMARY

- Twin cavity is coated, and ready for the RF test.
- Half wave coaxial resonator is fabricated and ready for the rf testing and then for the coating.
- New crucible to host the secondary tin source and along with a new heater to produce a uniform Nb_3Sn coating inside a cavity with complicated geometry and have been commissioned with the TE1NS001 single-cell cavity.

THANK YOU!

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