FIRST RESULTS FROM Nb_3Sn COATINGS OF 2.6 GHz Nb SRF CAVITIES USING DC CYLINDRICAL MAGNETRON SPUTTERING SYSTEM

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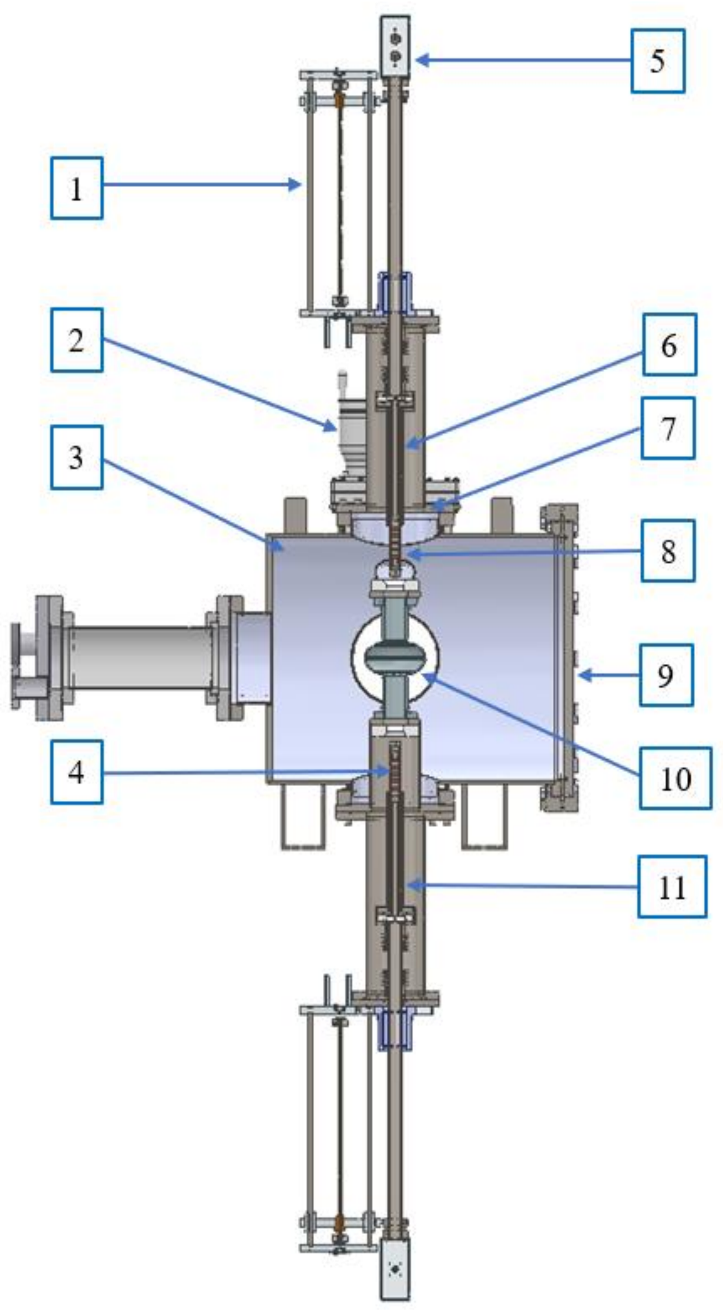
Abstract

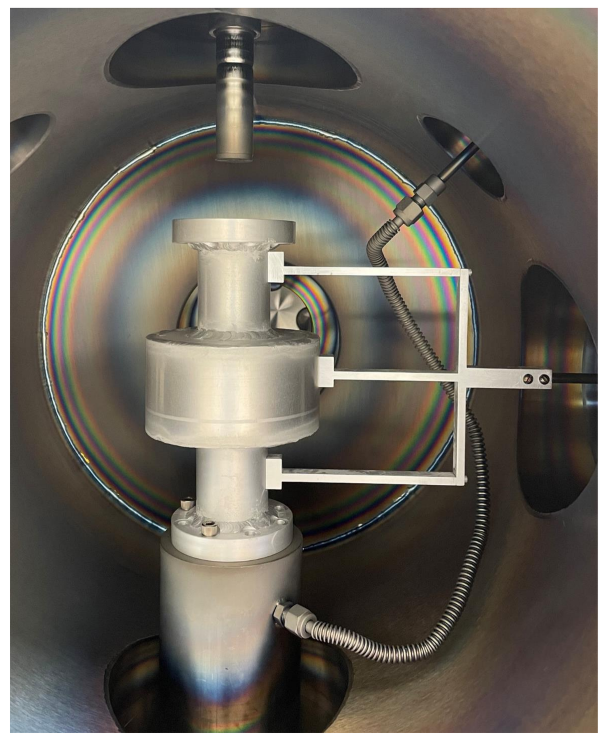
Nb_3Sn is considered as the next generation material to replace Nb for SRF cavity. A DC cylindrical magnetron sputtering system is designed and commissioned to coat Nb_3Sn into SRF cavity. After optimizing the deposition conditions in mockup cavity, using multilayer sequential sputtering of Nb and Sn followed by annealing at 950 ^{0}C for 3 hours, Nb_3Sn films are fabricated on flat substrates. Later, three 2.6 GHz Nb cavities are coated with ~1 µm Nb_3Sn film and the coated cavities showed superconducting transition between 17.9 – 18 K. One of the Nb_3Sn coated cavities demonstrated Q_0 of 3.2 × 10^8 at 4.4 K and Q_0 of 1.1 × 10^9 at 2.0 K, both at E_{acc} = 5 MV/m. The operation of the cylindrical sputtering system and results from Nb_3Sn fabrication by cylindrical magnetron sputtering system on flat samples and into Nb cavities are presented.

Operation of cylindrical magnetron sputter coater



Nb discharge at 30 W

Sn discharge at 8 W



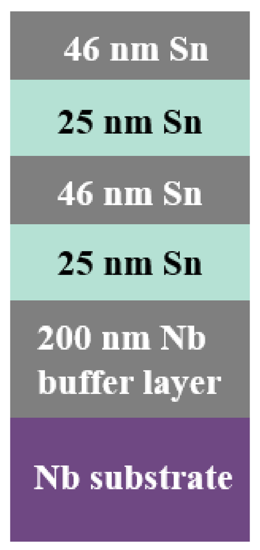
Nb and Sn discharge conditions are optimized to produce stable and symmetric plasma formation.

Deposition conditions for Nb_3Sn fabrication are optimized at 10 mTorr in a mockup cavity replicating 2.6 GHz Nb cavity.

Sketch of the cylindrical magnetron sputtering system (1) Magnetron movement controller shaft, (2) Gate valve, (3) Vacuum chamber, (4) Magnets, (5) Water flow controller, (6) Top magnetron, (7) 8'' ConFlat port of top magnetron, (8) Tube target, (9) Chamber door, (10) 2.6 GHz Nb SRF cavity, (11) Bottom magnetron. The magnetrons were made by Plasmionique to fit an ODU custom chamber.

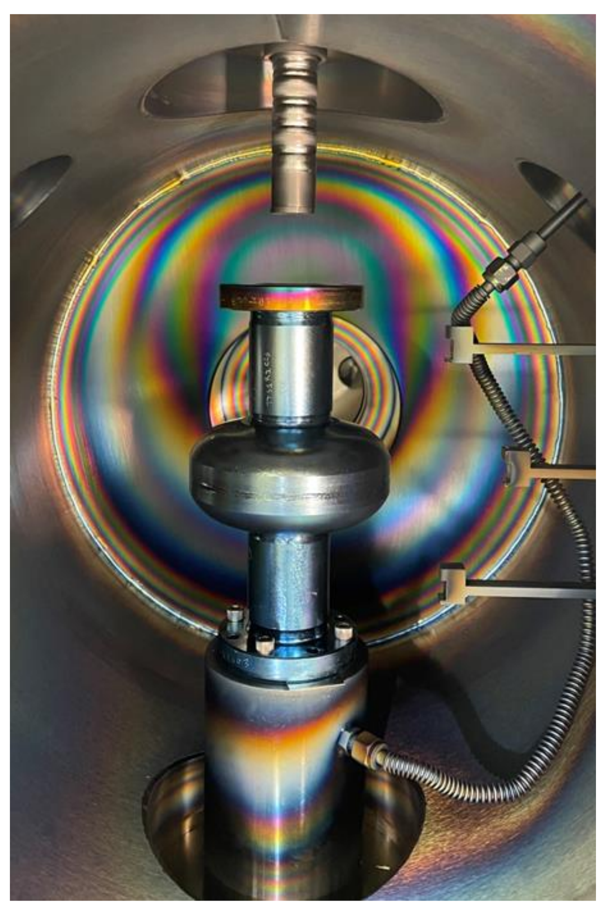
Multilayer Sequential Sputtering

Position	Total thickness of film (nm)
Top beam tube	1036
Equator	1008
Bottom beam tube	952



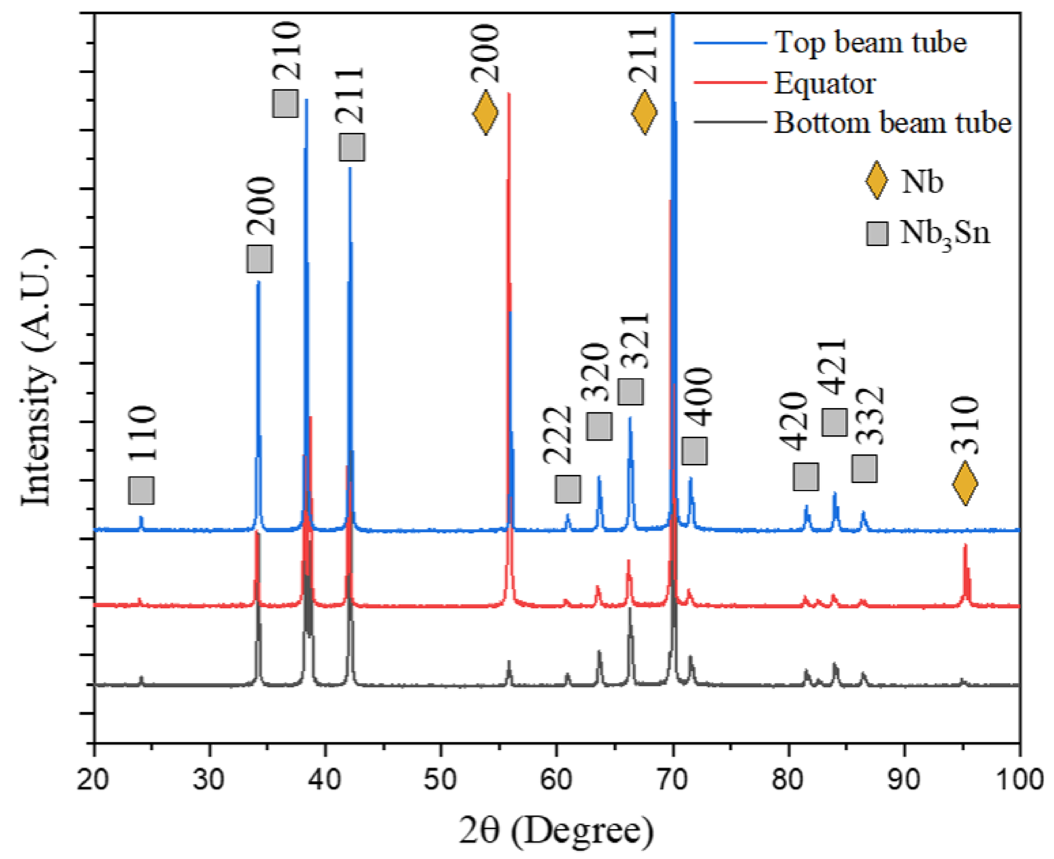
Multilayers of Nb (~46 nm) and Sn (~25 nm) are sequentially deposited for ~1 µm Nb-Sn film on Nb substrates mounted on three positions of the cavity and later annealed at 950 ^{0}C for Nb_3Sn growth.

Three 2.6 GHz cavities were coated with ~1 µm Nb_3Sn.



2.6 GHz Nb SRF cavity installed in the system for Nb_3Sn coating.

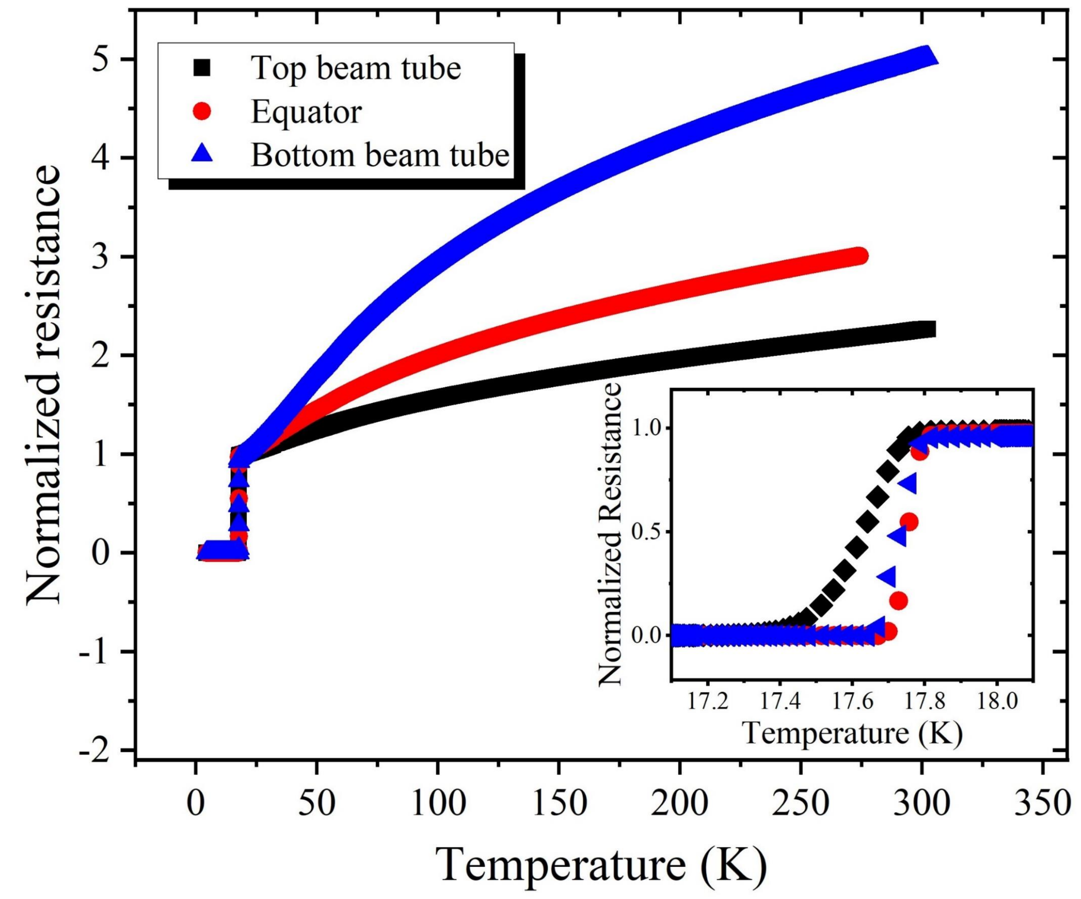
Nb_3Sn on flat Nb substrate



XRD pattern of annealed samples on Nb substrate at 950 ^{o}C for 3 h; Diffraction peaks are observed only for Nb_3Sn. Nb peaks are coming from substrate.

Positions	Sn (at.%) of As-deposited films	Sn (at.%) of Annealed films
Top beam tube	33	22
Equator	32	19
Bottom beam tube	25	19

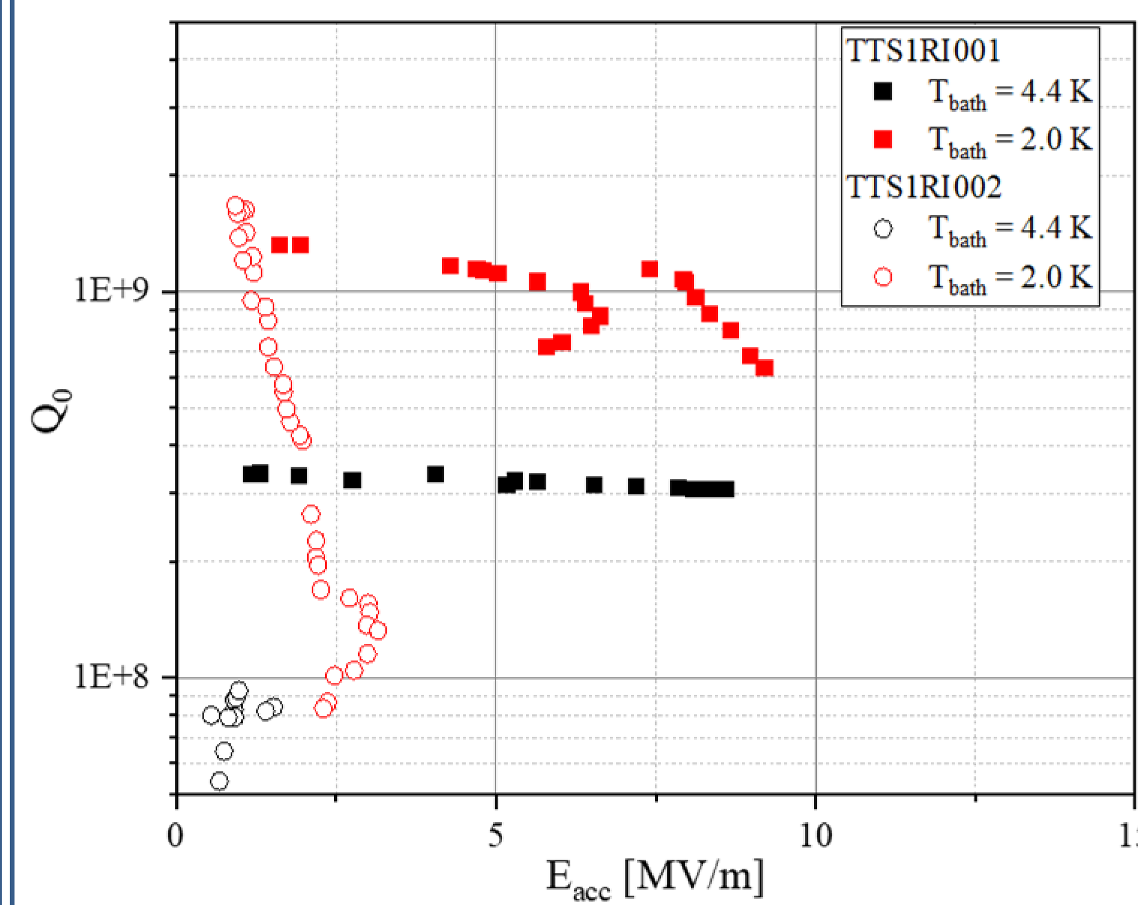
Sn atm. composition in as-deposited and annealed samples.



Sample resistance with temperature down to 4 K.

Position	T_c (K)	ΔT_c (K)	RRR
Top beam tube	17.61	0.24	2.26
Equator	17.76	0.06	3.00
Bottom beam tube	17.73	0.1	5.01

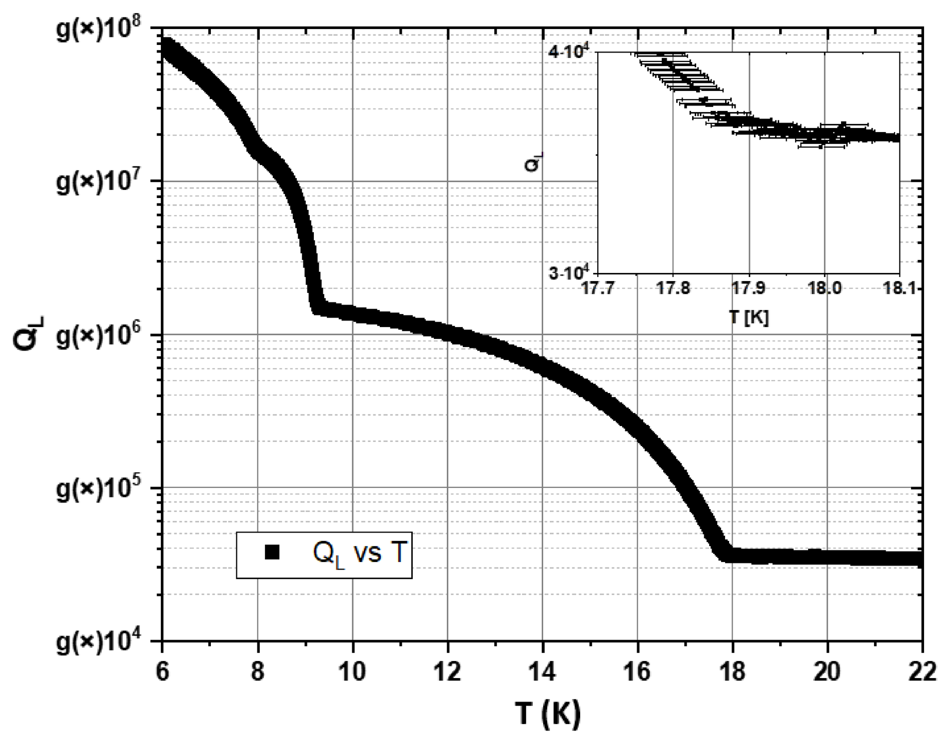
Nb_3Sn coated cavity performance



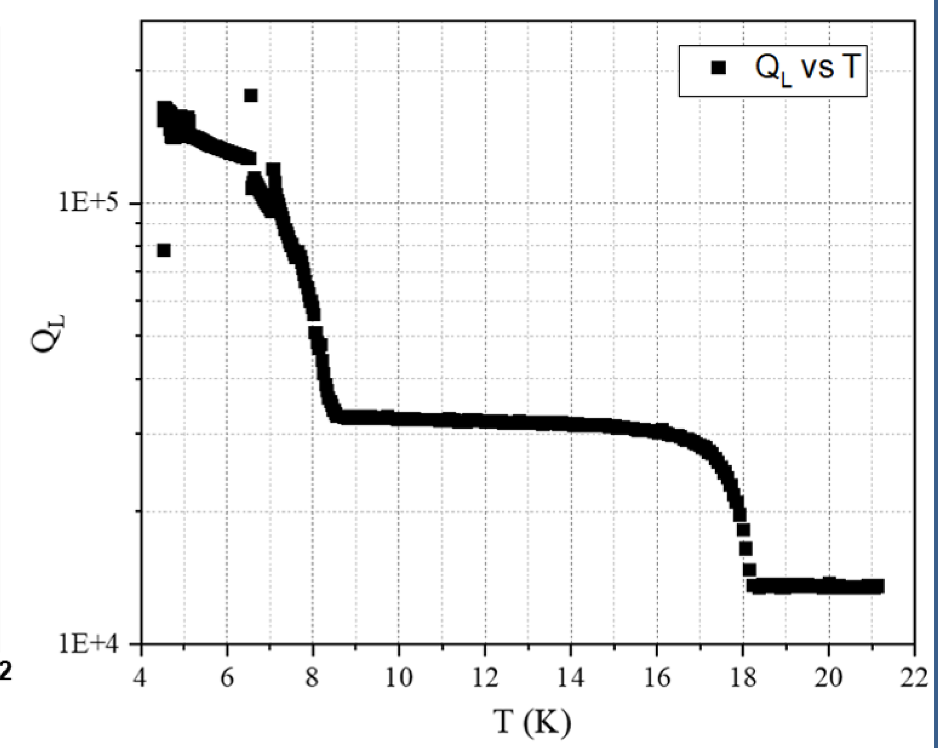
Nb_3Sn coated TTRIS1002, after annealing at 950 ^{0}C for 3 hrs.

TTS1RI001 demonstrated Q_0 of 3.2 x 10^8 at E_{acc} = 5 MV/m at T_{bath} = 4.4 K and Q_0 of 1.1 x 10^9 at E_{acc} = 5 MV/m at T_{bath} = 2 K.

TTS1RI002 demonstrated Q_0 of 9.3 x 10^7 at E_{acc} = 1 MV/m at T_{bath} = 4.4 K and Q_0 of 1 x 10^9 at E_{acc} = 1 MV/m at T_{bath} = 2 K. TTS1RI002 was limited by a strong Q-slope.



Q_L vs T (K) of Nb_3Sn coated cavity TTS1RI001. Superconducting transition T_c observed at ~17.9 K due to Nb_3Sn. Another transition is seen at ~9.2 K.



Q_L vs T (K) of Nb_3Sn coated cavity TTS1RI002. Superconducting transition T_c observed at ~18 K due to Nb_3Sn. Another transition is seen below 9 K.

Conclusion

Recently commissioned cylindrical magnetron sputtering system is used to coat Nb_3Sn into 2.6 GHz Nb SRF cavity using multilayer sequential sputtering method. The coated cavity achieved Q_0 of 1.1 × 10^9 at 2.0 K and Q_0 of 3.2 × 10^8 at 4.4 K, both at E_{acc} = 5 MV/m, and achieved superconducting transition temperature T_c in 17.9 – 18 K range.

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