DOUBLE CATHODE CONFIGURATION FOR THE Nb COATING OF HIE-ISOLDE CAVITIES

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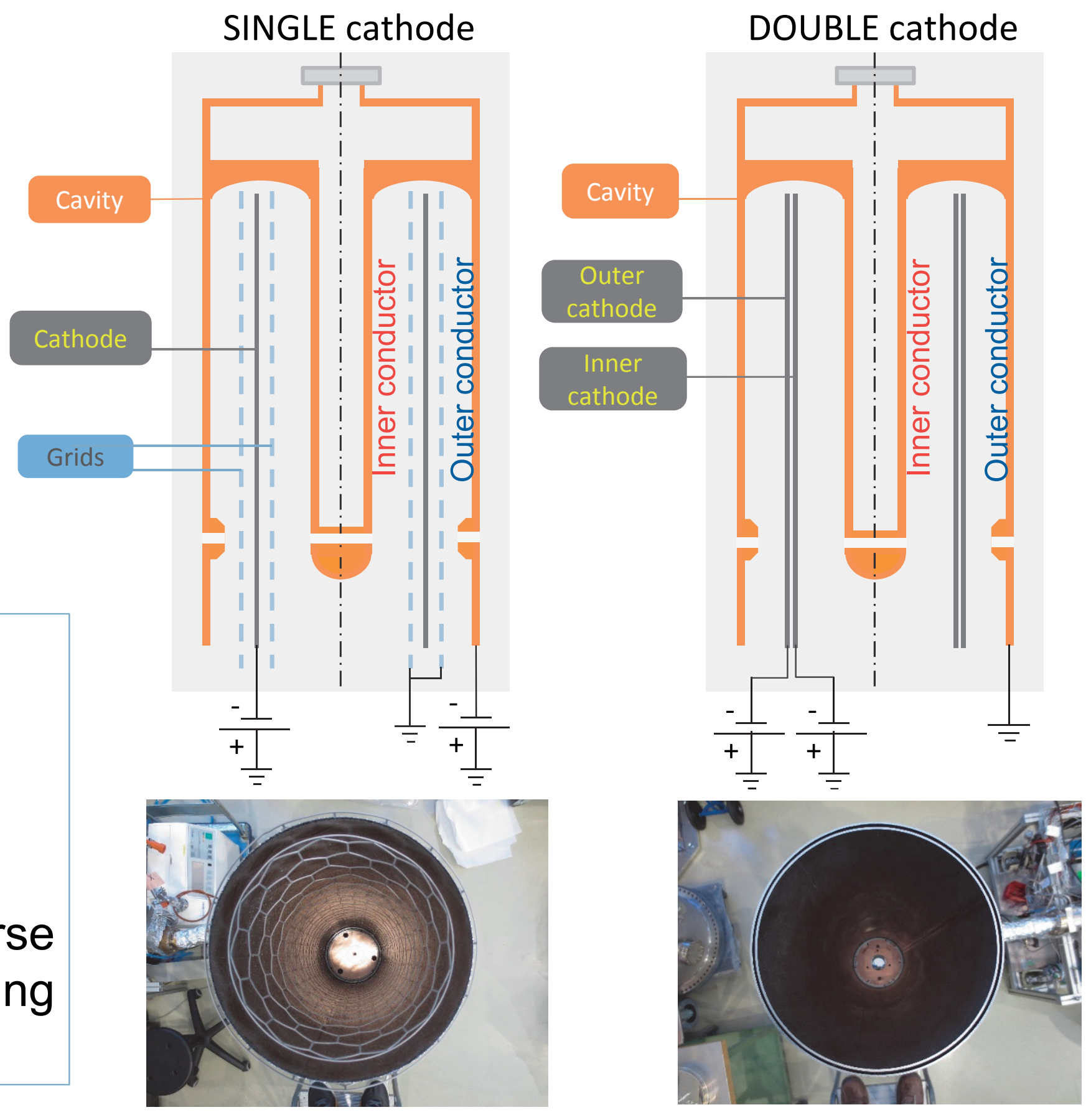
Abstract

The Quarter Wave Resonator (QWR) cavities for HIE-ISOLDE project at CERN have entered their ending phase of production. Some R&D is still required to improve the uniformity of the Nb layer thickness on the cavity surface. In order to improve this behaviour one approach which has been proposed is to replace the single cathode with a double cathode and test the suitability of different deposition techniques. With this change it is possible to control the plasma and power distribution separately for the inner and outer part of cavity and thereby potentially improve film uniformity throughout the cavity and coating duration. In this study a comparison between the deposition rates obtained using a single cathode and a double cathode using Direct Current (DC)-bias diode sputtering, DC-magnetron sputtering (DCMS) and Pulsed DC-magnetron sputtering (PDCMS) is presented. The morphology of the thin film samples were compared using Focused Ion Beam (FIB) cross section milling and Scanning Electron Microscopy (SEM) analysis.

Experimental setup

Double Cathode Scheme

- Two cathodes are used instead of a single one as used in production baseline process.
- One power supply for each cathode.
- Independent control of plasma and power distribution for inner and outer conductors.
- Can run as single cathode to extract in/out power distribution.



Coating Techniques

- DC-bias diode sputtering (diode)
- DC-Magnetron Sputtering (DCMS)
- Pulsed DC-Magnetron Sputtering (PDCMS)

In PDCMS technique a pulsed power supply with a reverse voltage pulse is used to produce a bias-like effect by repelling Ar ions towards the substrate during reverse pulse time.

Motivation

Current baseline HIE-ISOLDE cavities are known to show discrepancies between the inner and outer conductor thickness profiles. In order to achieve the desired cavity performances with the current baseline process, we target to a minimum film thickness of 1 µm. To tune the outer conductor thickness to this value the overall coating time is increased and this might increase the amount of impurities in the film → **double cathode approach to**

- **Improve thickness uniformity:** uniform coating rate profiles for inner and outer conductors.
- **Reduce coating duration/amount of impurities**: increase coating rate.

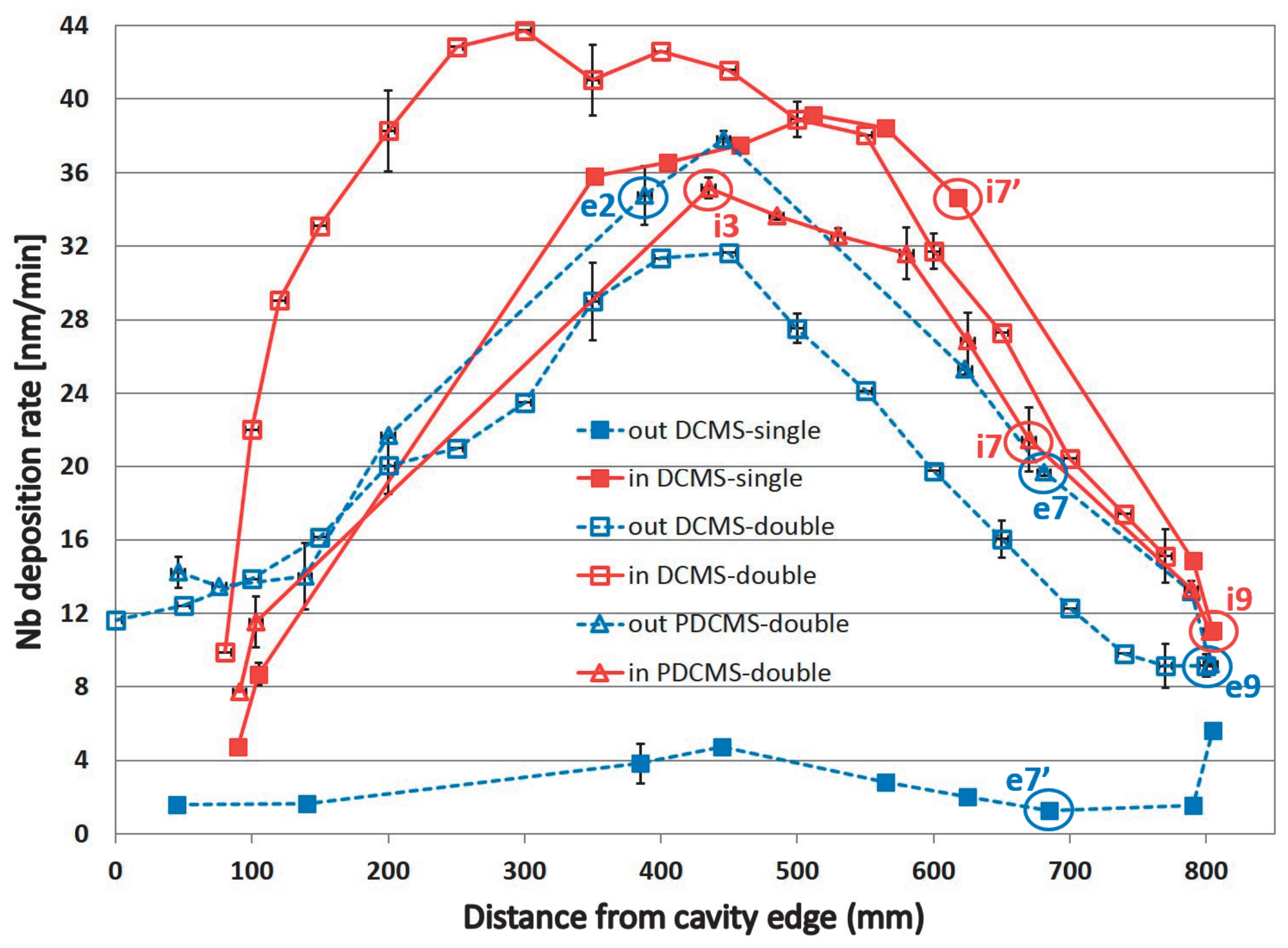
Process parameters

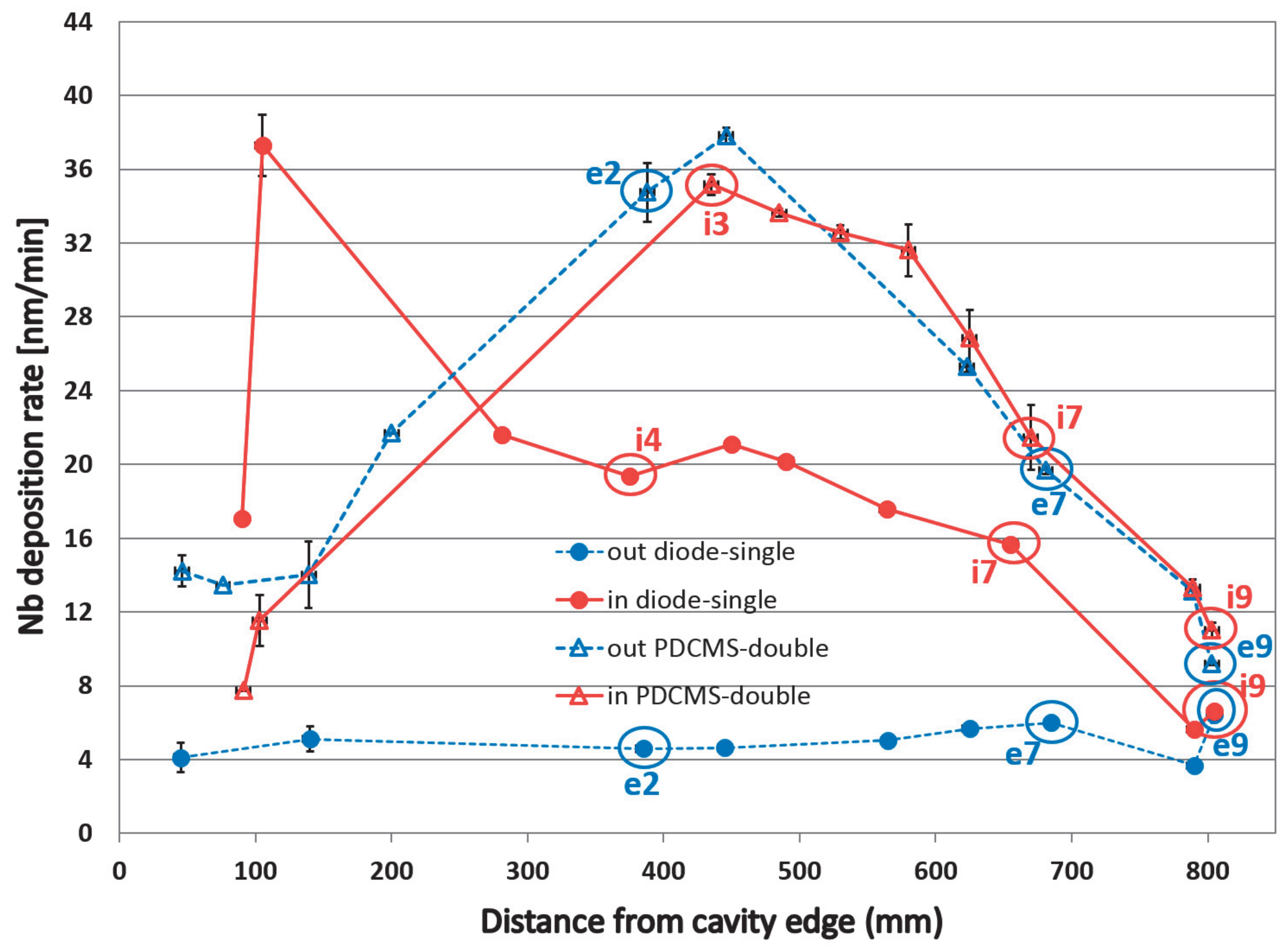
Technique	Cathode scheme	Pressure [mbar]	Magnetic field[G]	Cathode(s) power [kW]	Duration [min]	Energy [kWh]
Diode	Single	$2x10^{-1}$	none	8 (5.4 in, 2.6 out)	345	43 (29 in, 14 out)
DCMS	Single	1.3×10^{-2}	95	2 (1.6 in, 0.4 out)	421	14 (11.2 in, 2.8 out)
DCMS	Double	1.3×10^{-2}	111	2.2 in, 3.5 out	158	5.8 in, 9 out
PDCMS	Double	1.6×10^{-2}	118	2 in, 4.5 out	145	4.4 in, 9.8 out

Coating rate and layer morphology

Deposition rate profile

- **Single cathode:** difference between inner and outer conductors coating rate profile is high due to unbalanced power distribution between them and geometrical aspects.
- **Double cathode:** comparable coating rate profiles for inner and outer conductors is achieved thanks to optimized control of power for each cathode.





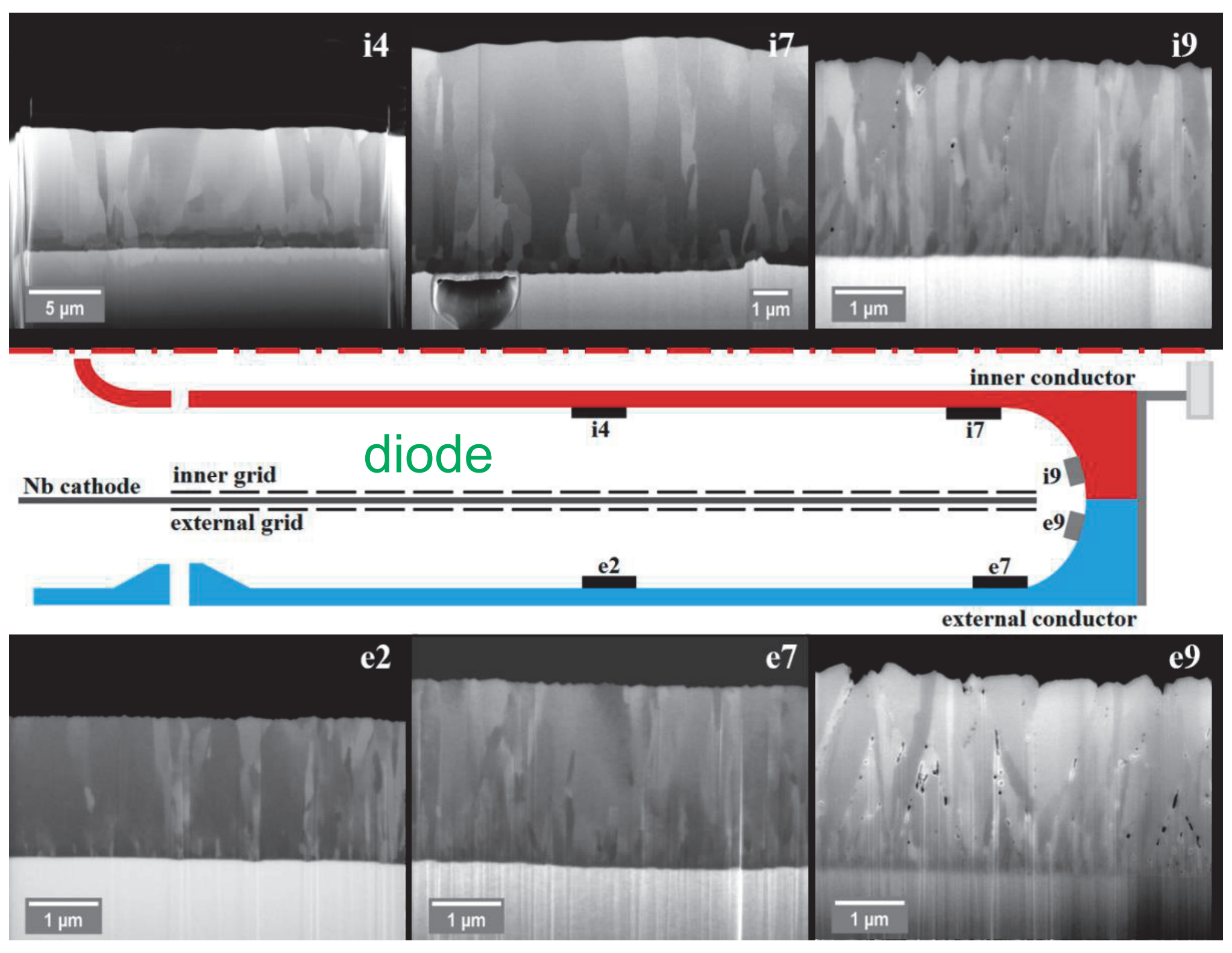
Thin film morphology (FIB/SEM cross sections)

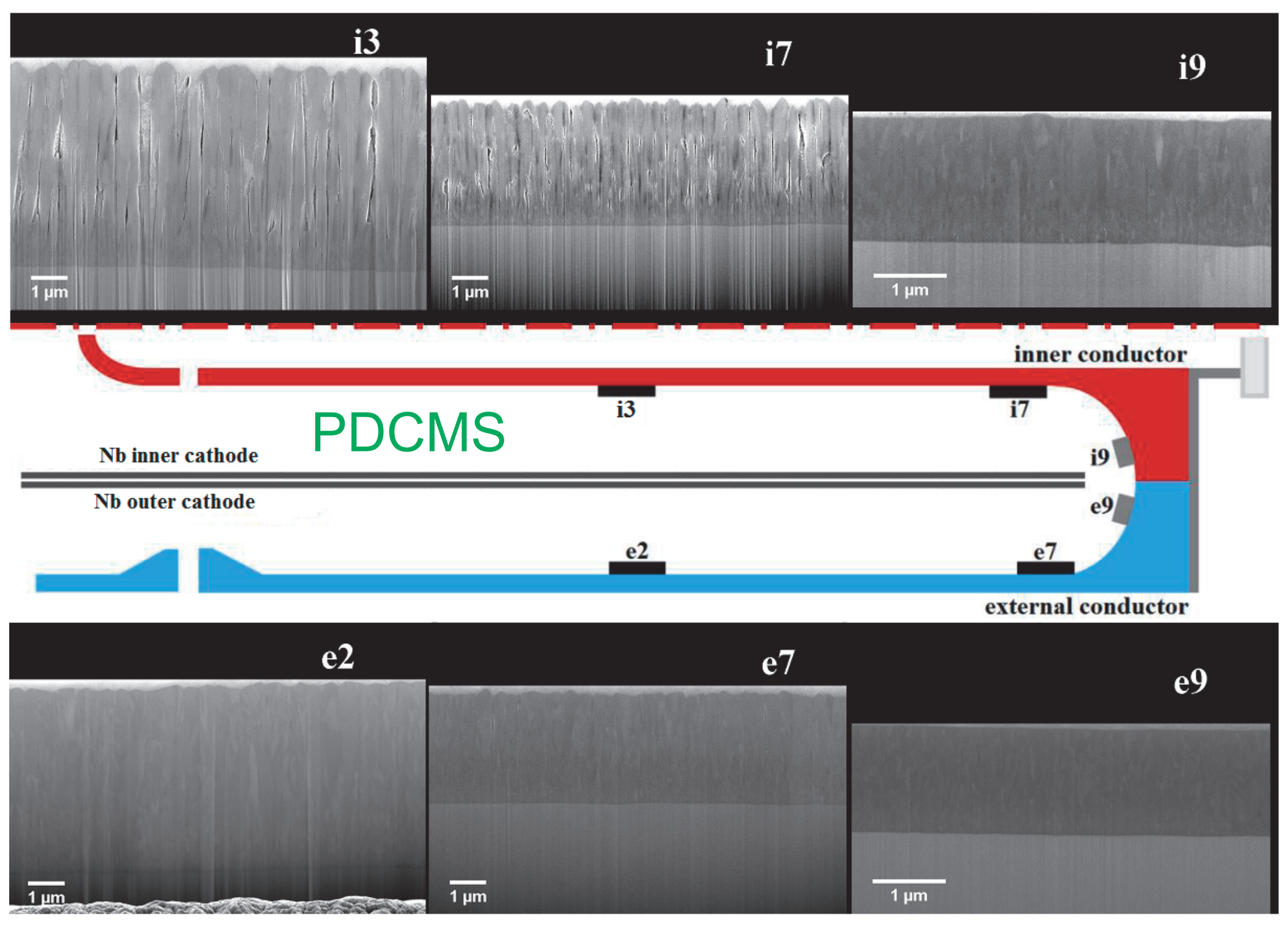
Good SRF properties rely on dense/ordered/impurities free layer.

DC-bias diode (single cathode) baseline : the film layer is dense through the whole cavity with nanoscale voids present only at the very top of the cavity.

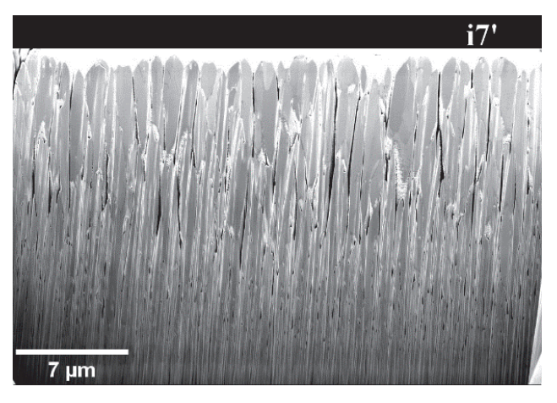
PDCMS (double cathode): layer is dense for outer conductor and top portion with small number of nanoscale voids, whereas porosity is present on the inner conductor.

DCMS (single cathode): similar inner porosity issue as for PDCMS.

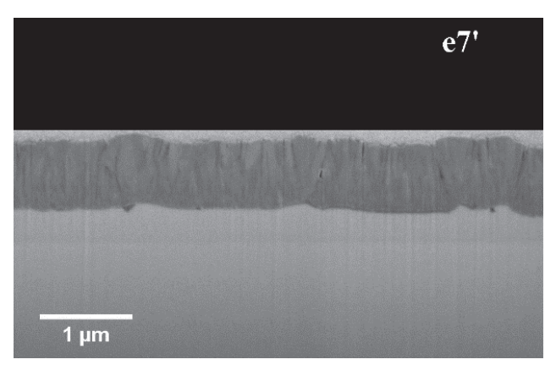




DCMS single in



DCMS single out



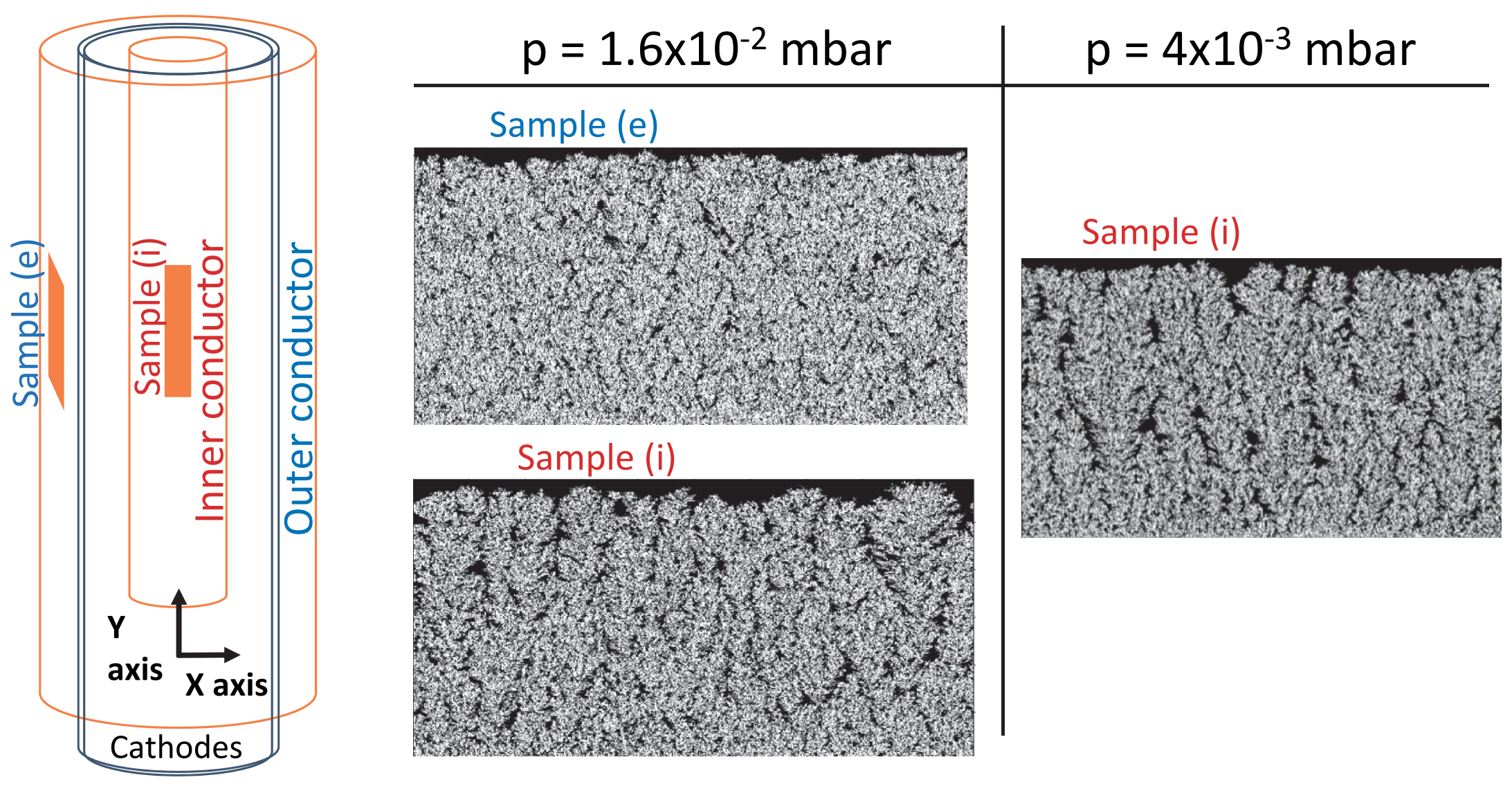
- → **Overall increased coating rate**
- → **Comparable coating rate profiles** achieved for inner and outer conductor with the double cathode.
- → **Lower coating rate at the top** of the cavity
- → **Porosity on inner conductor** with magnetron regime probably due to large mean free path and concave/convex geometry of inner cathode/conductor leading to large grazing angle of Nb atoms at the substrate.

Transport and thin film growth simulation

→ Simulation to try to understand the morphological issue on inner conductor with magnetron regime and evaluate influence of process pressure on film growth.

- **SRIM:** simulate the angular and energy distribution of Nb atoms sputtered at the target by Ar ions.
- **SIMTRA*:** simulate the transport and the energy and angular distributions of Nb atoms to the substrate.
- **NASCAM:** 3D Kinetic Monte Carlo code to simulate diffusion**, nucleation and growth of film on a surface.

*A uniform racetrack along the cathode is assumed
**The thermal diffusion and ion bombardment effect are neglected for simulation



→ In magnetron regime, no improvement in the morphology by lowering the process pressure with this particular geometry.

Conclusions and Prospects

- → Equal deposition rate profiles for inner and outer conductor is achieved using the double cathode scheme.
- → The overall coating time can be reduced, potentially lowering the amount of impurities in the film.
- → Porosity remains in the film on the inner conductor when using magnetron sputtering.
- → Transport and thin film growth simulation shows that changing process pressure would not help to cure the porosity issue.

Further development is needed to address this issue by implementing for instance an active bias to the substrate.