DEVELOPMENTS ON SRF COATINGS AT CERN

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Introduction

The thin films techniques applied to Superconducting RF (SRF) have a long history at CERN. A large panel of cavities has been coated from LEP, to LHC. For the current and future projects (HIE-ISOLDE, HL-LHC, FCC) there is a need of further higher RF-performances with focus on minimizing residual resistance Rres and maximizing quality factor Q0 of the cavities. This paper will present CERN's developments on thin films to achieve these goals through the following main axes of research. The first one concerns the application of different coating techniques for Nb (DC-bias diode sputtering, magnetron sputtering and HiPIMS). Another approach is the investigation of alternative materials like Nb_3Sn. These lines of development will be supported by a material science approach to characterize and evaluate the layer properties by means of FIB-SEM, TEM, XPS, XRD, etc. In addition a numerical tool for plasma simulation will be exploited to develop adapted coating systems and optimize the coating process, from plasma generation to thin film growth.

Motivation

Limitation of the Nb thin films with respect to the Nb bulk is the large surface resistance Rs that leads to the Q-slope of the RF characteristic of a cavity.

The main drivers for the SRF thin film developments at CERN are:

- Short term: HIE-ISOLDE high-beta Quarter Wave Resonators (QWR) cavities (100 MHz), 20 cavities in total.
- Medium term: HL-LHC Crab Nb/Cu Wide Open Waveguide (WOW) cavities (400 MHz), 16 cavities
- Long term: LHC upgrade, ERL, FCC cavities (400/800 MHz)

Plasma simulation

Goals:

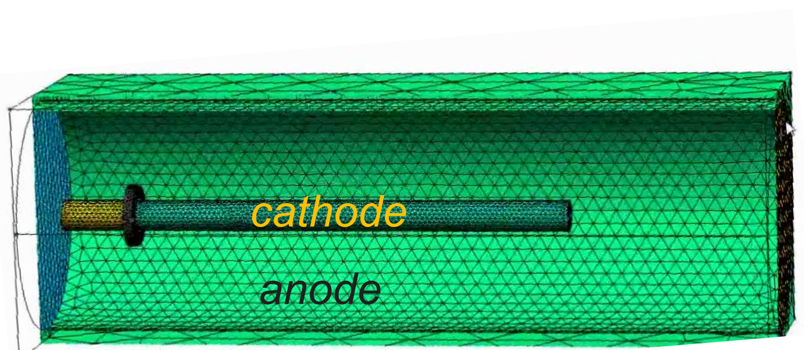
- increase the understanding of coating processes from plasma generation to thin film growth
- converge in a faster way to the best coating setup design for a given cavity geometry

Methodology:

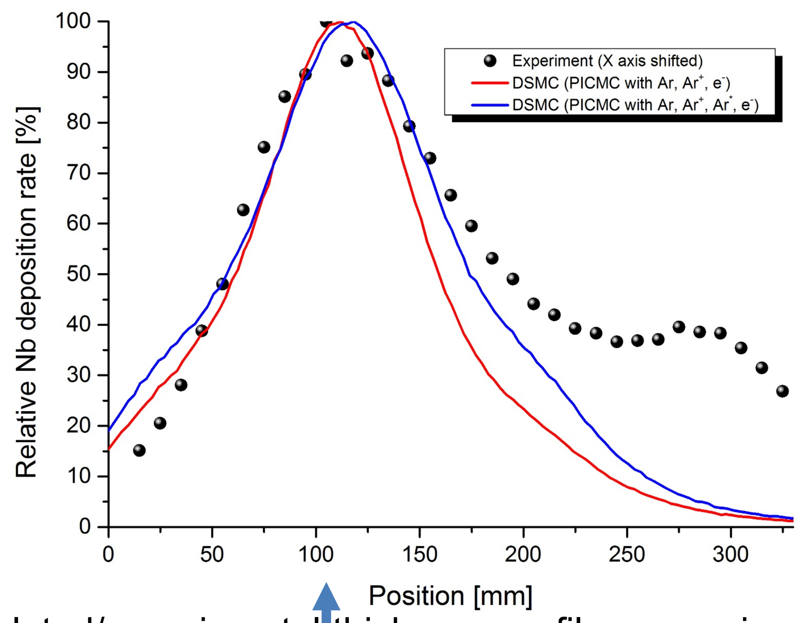
1. Compare numerical simulations obtained with a DSMC-PIC (Direct Simulation Monte Carlo – Particle in Cell) code from Fraunhofer IST with the plasma test bench experiments, in DC bias diode and DC magnetron sputtering modes to confirm the functionality of the code
2. Use the code to simulate complex geometries like HIE-ISOLDE QWR or LHC Crab WOW cavities to understand plasma behavior and thin film growth and apply it to coating system and cathode design or improvement
3. Use the output deposition profiles as inputs for thin film growth simulation with code like NASCAM developed by Namur University

Example:

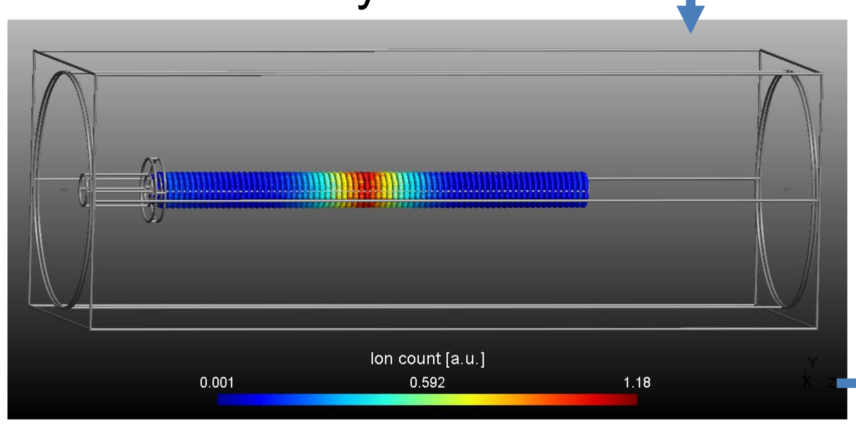
→ plasma test bench case study



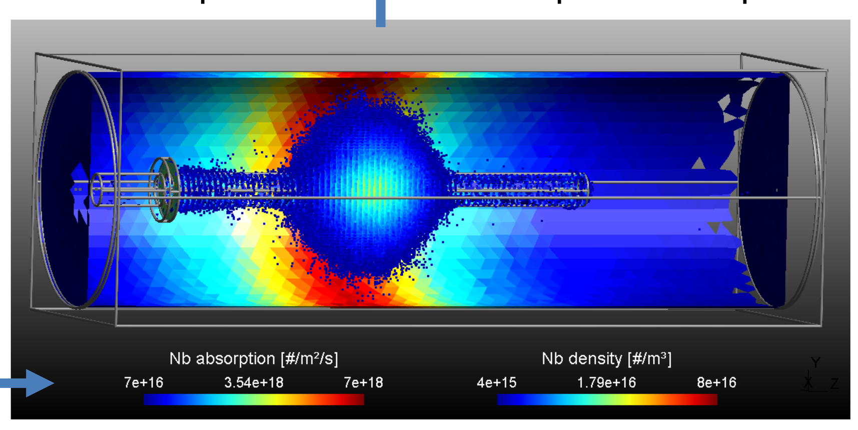
Geometry and mesh



simulated/experimental thickness profile comparison



Ar+ flux on the cathode



Sputtered Nb distribution

Coating, SC material and layer characterization

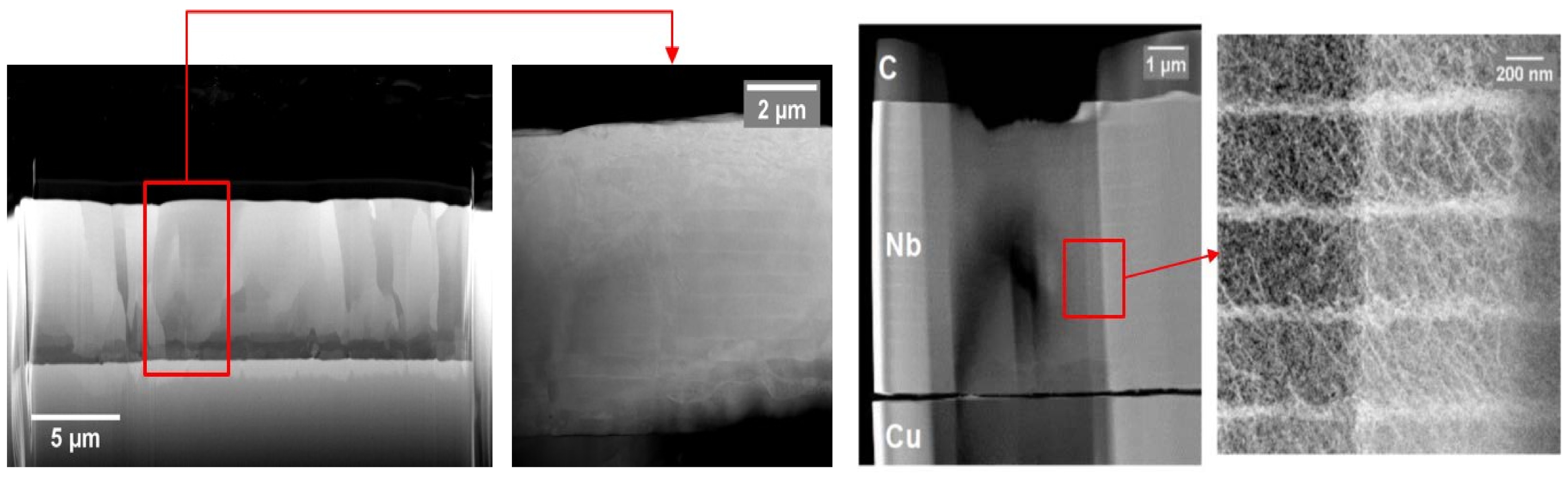
The thin film developments at CERN are oriented along three axes referring to the different coating process steps:

1. Substrate preparation, surface and interface
2. Thin film production
3. Top layer surface properties

→ target: grow a smooth, pure, defect free, dense layer of uniform thickness

HIE-ISODLE example:

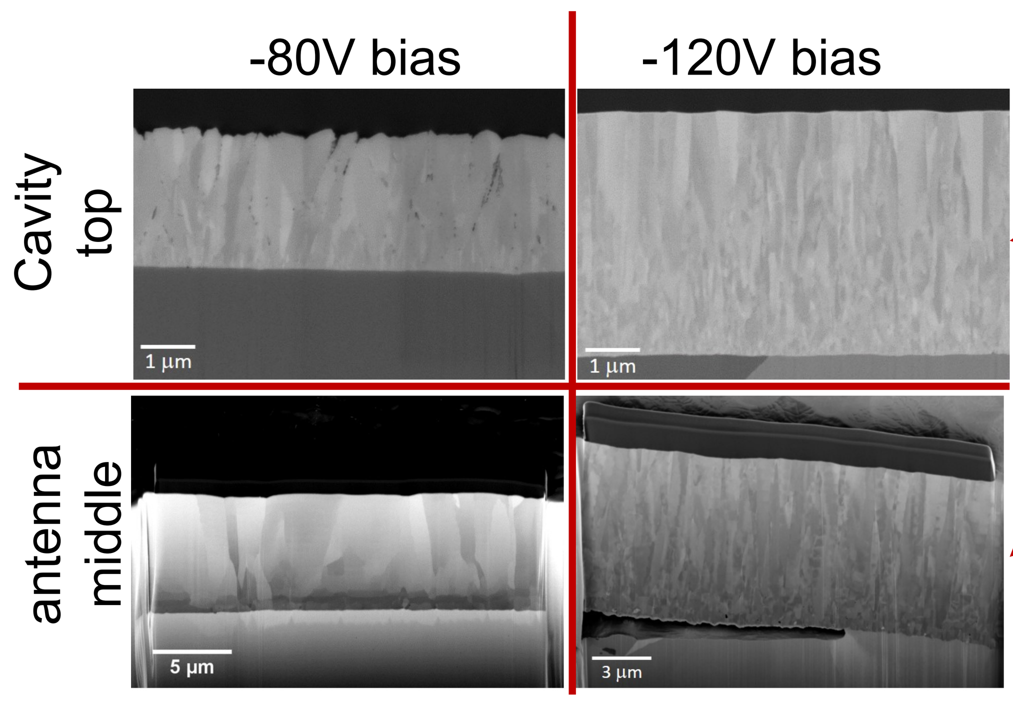
Substrate temperature effect:

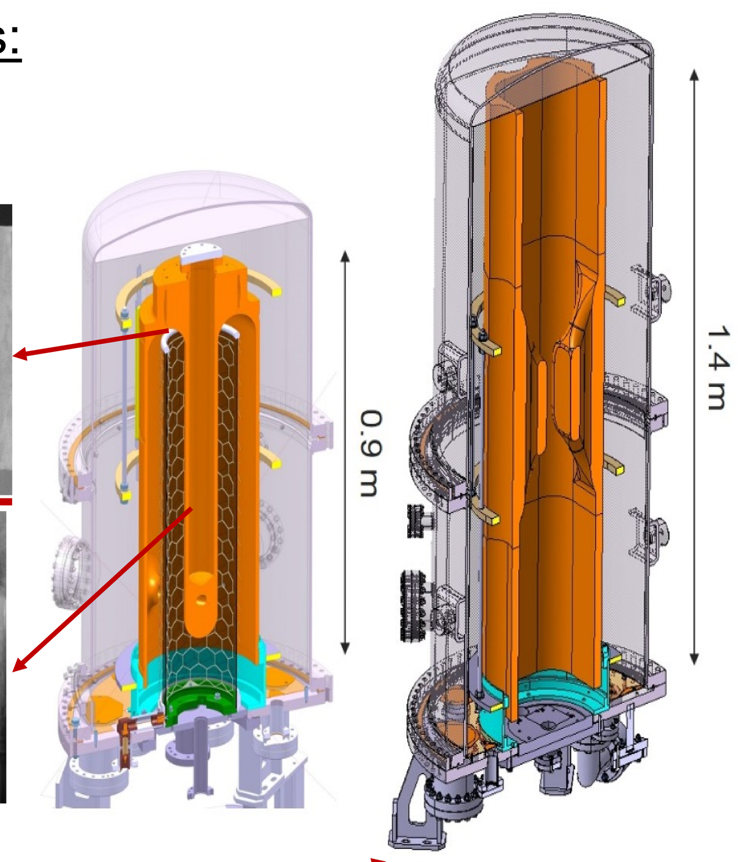


dense layer at the antenna middle and visualization of the 15 deposited layers

dislocation concentration gradient induced by the 15 high temperature coating/cool down cycles

Substrate bias and cathode geometry effects:





→ Challenges in coating complex geometries HIE-ISOLDE QWR and Crab-cavities WOW

Investigation of

→ Substrate/layer interface: substrate annealing, copper diffusion, surface impurities segregation, thermal contact and adhesion

→ Top layer interface: characterization of surface and intergranular oxidation, study of protection by passivation layer

To counteract the Rres limitation of niobium film an alternative is to use A15 compounds offering a smaller BCS surface resistance like Nb_3Sn or V_3Si

→ More details: TUPB051

Conclusion

Thin film SRF is the most promising approach for large scale project like FCC. The recently started second run of LHC will determine the direction accelerator technology should take for its future developments. Thus, SRF thin film technology must be mature by that time and extensive developments in collaboration with worldwide institutes started.

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SRF 2015 WHISTLER