Nb/Cu thin film HiPIMS coatings optimization for SRF applications

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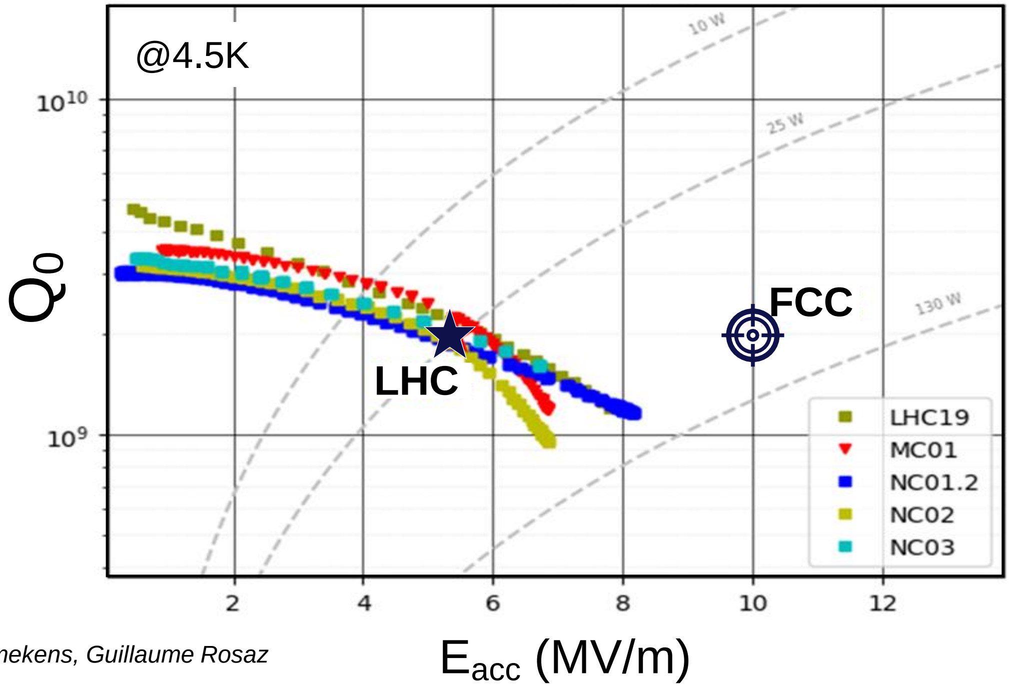
MOTIVATION

400MHz LHC cavities spares: last results



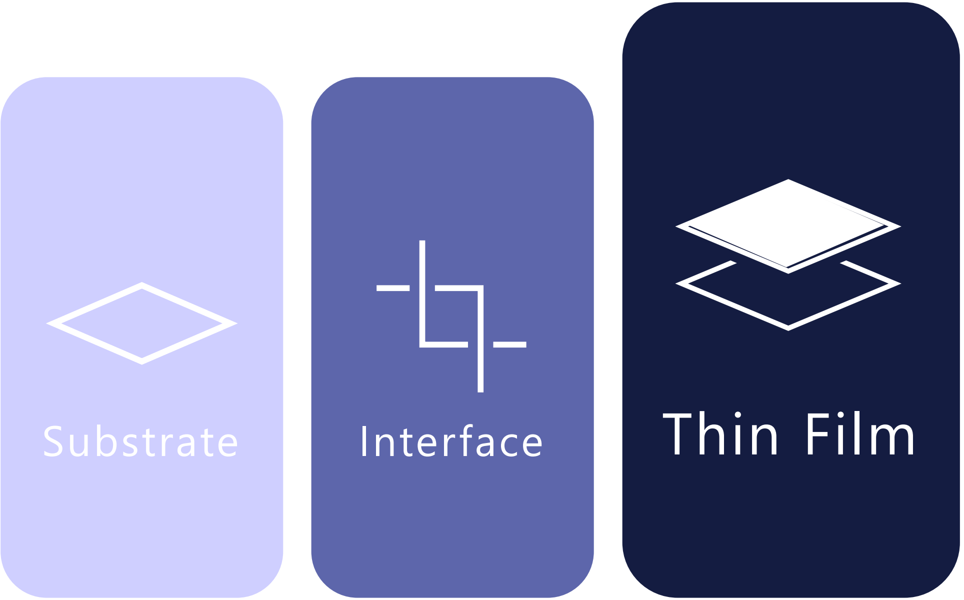
E_{acc} = 10 MV/m
Q_0 above $2x10^9$
@4.5 K

Jordan Walker, David Smekens, Guillaume Rosaz

R&D axis of research at CERN to improve the performance of SRF cavities

- Substrate
- Interface
- Thin Film

Optimization of thin film Nb/Cu coatings

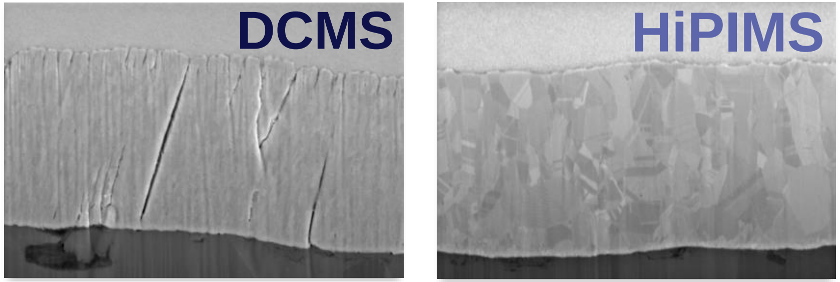


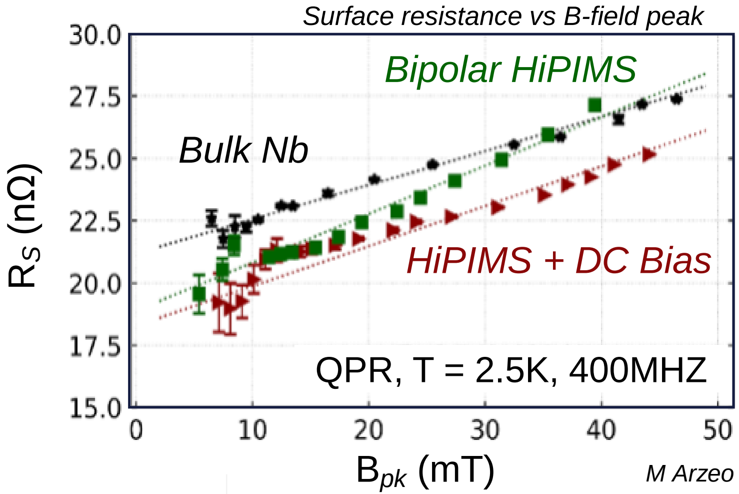
High Power Impulse Magnetron Sputtering (HiPIMS)

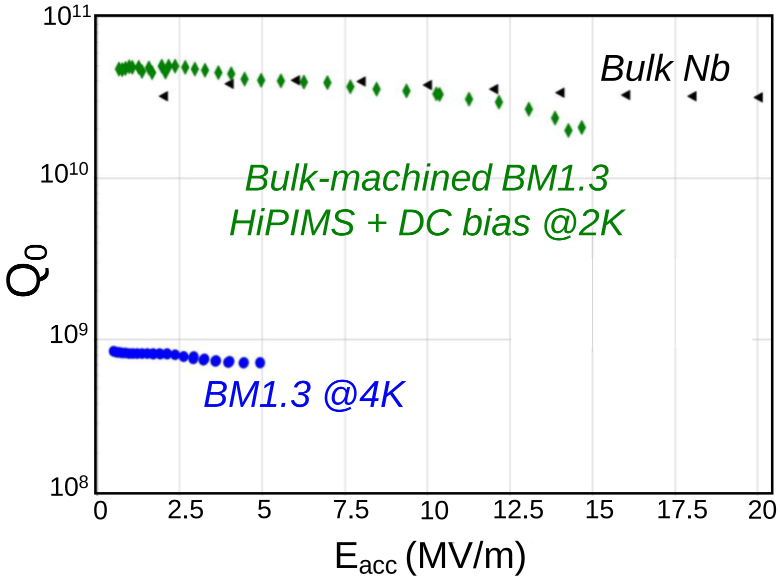
+

Substrate DC Bias
or
Bipolar HiPIMS

Why HiPIMS?





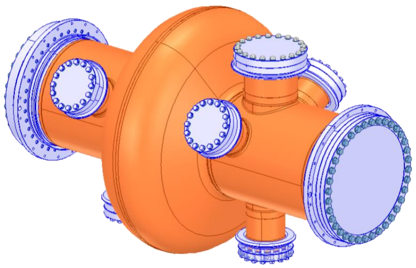


M Arzeo et al 2022 Supercond. Sci. Technol. 35 054008

Optimize Thin Film

?

Scale-up

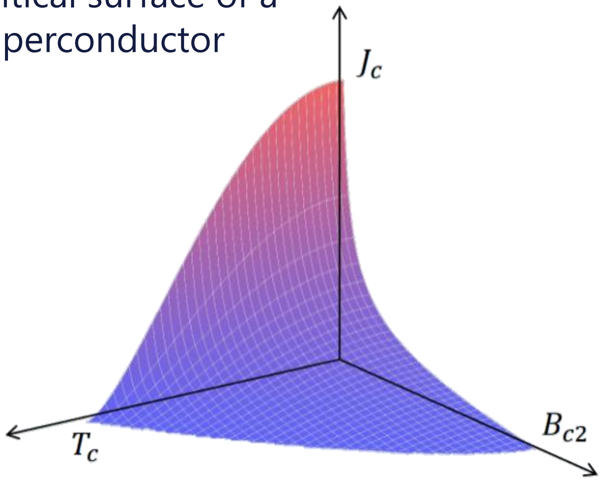


400 MHz

Correlate structural and morphological properties of HiPIMS Nb films with RF performance

CRITICAL CURRENT DENSITY J_C

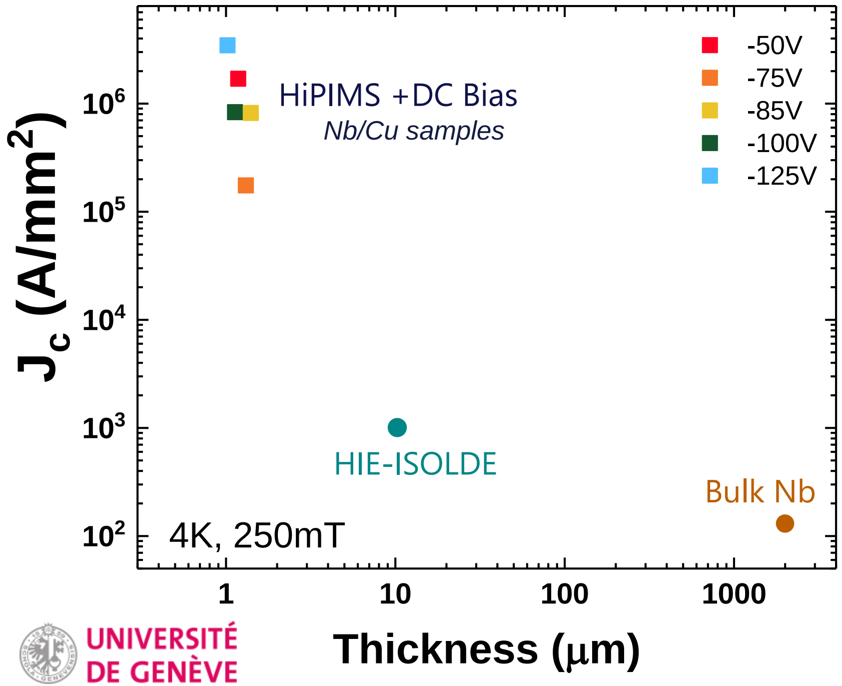
Critical surface of a superconductor



- Used to qualify the performance of superconductors, especially for magnets
- Depends on pinning centres (structural defects) – Lower J_c translates into a layer with less defects

CRITICAL CURRENT DENSITY J_C

Where are we?



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- J_C of our HiPIMS samples is orders of magnitude higher than HIE-ISOLDE (E_{acc} up to 120mT, corresponding to ~30MV/m in an elliptical cavity) and Bulk Nb (E_{acc} up to 49 MV/m with $Q_0 > 10^{10}$)

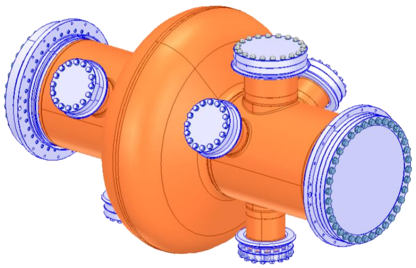
Lower J_C seems to result in better RF performance

There's room for improvement in our films

Optimize Thin Film

Lower J_C

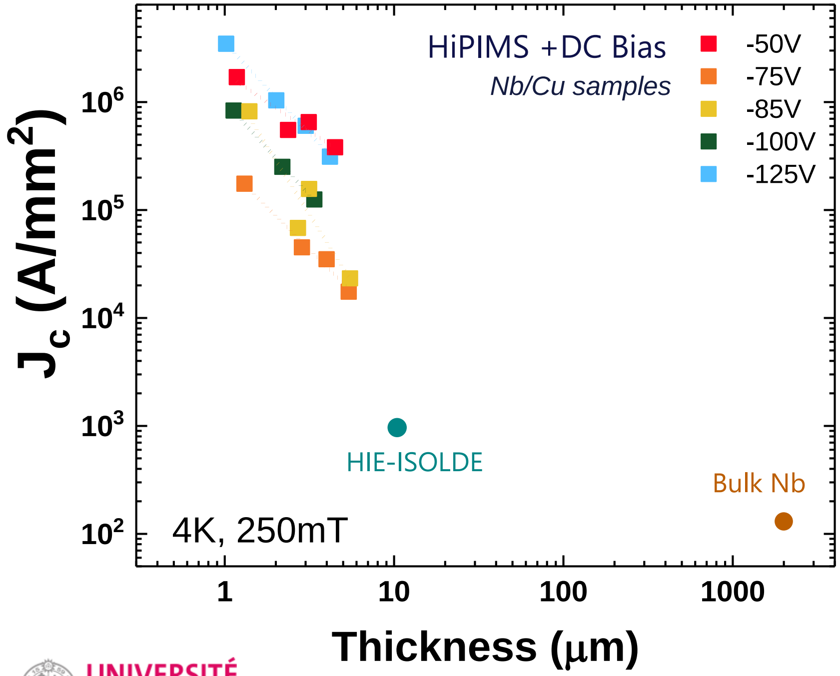
Scale-up



400 MHz

Series of measurements:
Tune coating parameters and study the effects on J_C

THICKNESS vs J_C



J_C decreases with increasing film thickness

Independently of bias

What morphological property is responsible for this?

i. e. which defect family disappears gradually with increasing thickness?

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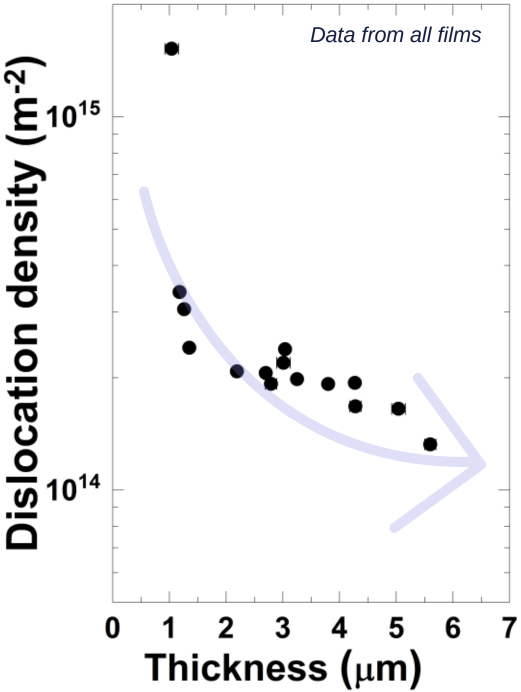
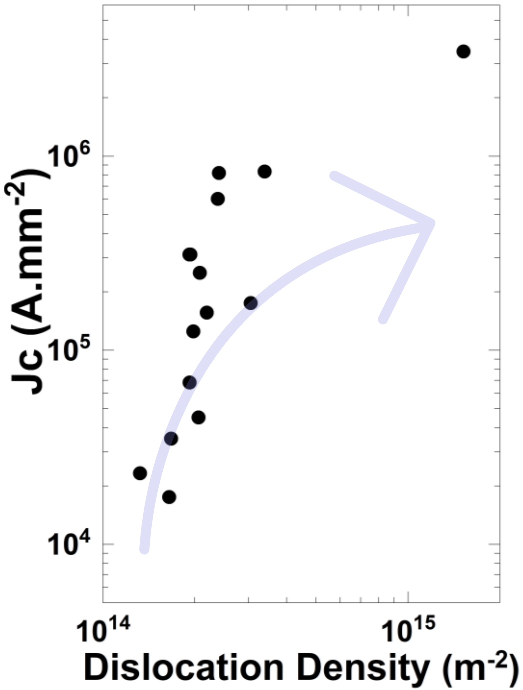
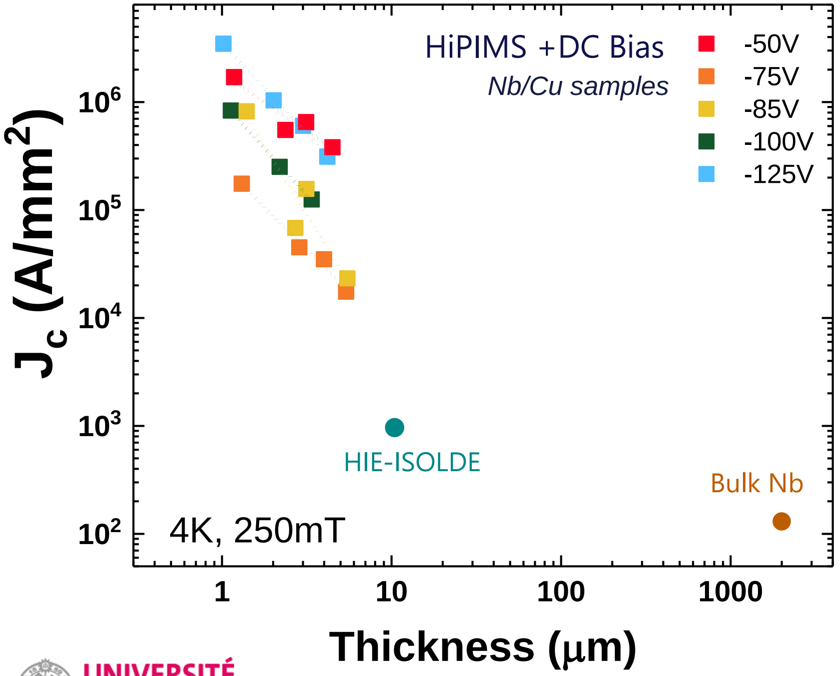
DISLOCATION DENSITY vs J_C





Dislocations seem to be driving defects for J_C optimization

ION BOMBARDMENT ENERGY vs J_C



Bias voltage applied corresponds to the ion energy impinging the surface

$$E_{ion} = |eV_B|$$

Nonlinear relation:

optimum J_C with -80V applied DC bias

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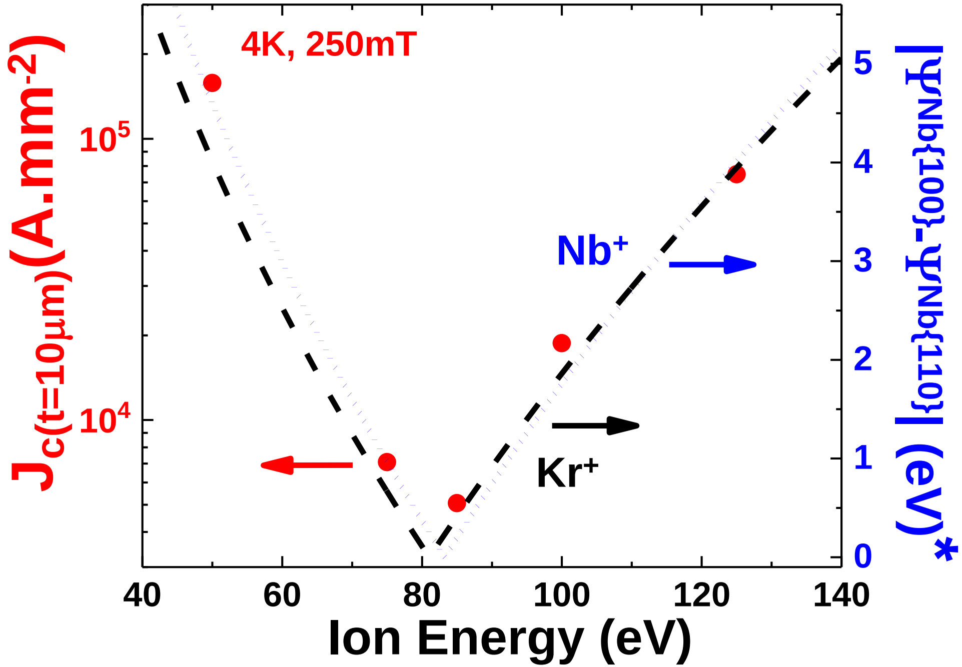
ION BOMBARDMENT ENERGY vs J_C



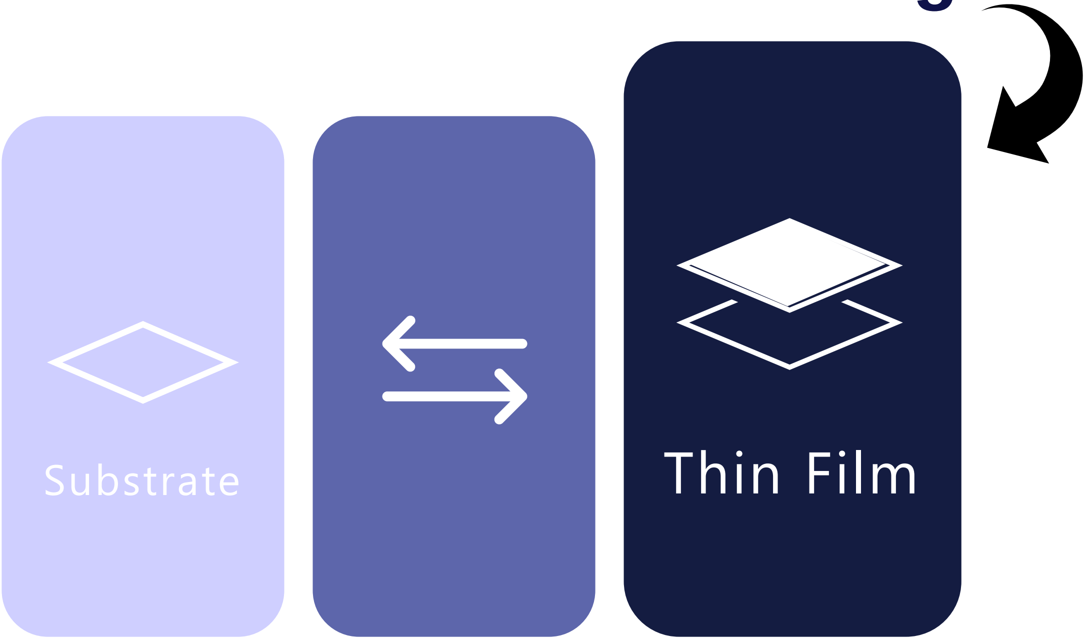
Optimum Jc when the energy is equally spread among the {100} and {110} crystalline planes

* binary collision approximation [1][2]

[1] D. K. Brrce et al. Nuclear Instruments and Methods in Physics Research, 44 1989 68-78
[2] Z.Q. Ma et al. Applied Surface Science 137 1999 184–190M

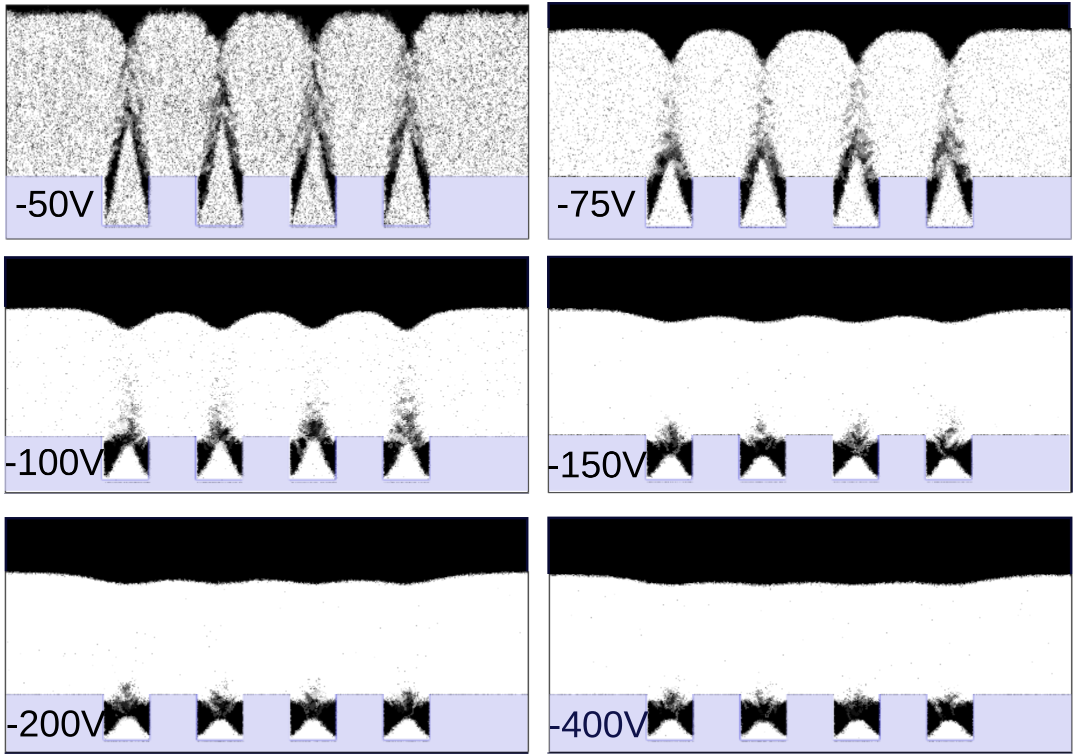
Optimization of thin film Nb/Cu coatings

Relax substrate quality requirements



Can we planarize a layer deposited on a very rough substrate with HiPIMS?

Nb PLANARIZATION



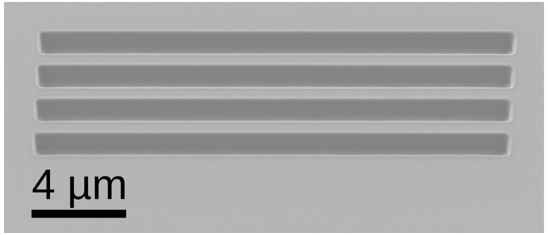
Planarization vs substrate DC bias

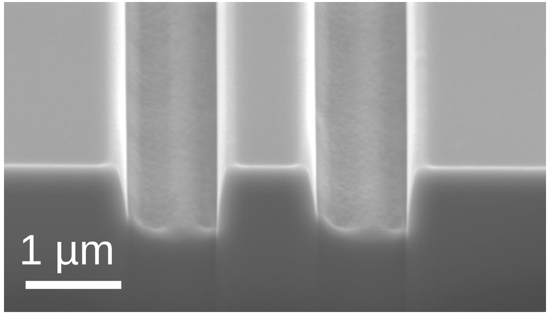
NASCAM simulations

Textured Si substrate
No surface diffusion (thermal effects neglected)
100% ionized Nb
Impinging angle: $(90\pm10)°$

Nb PLANARIZATION

FIB milling

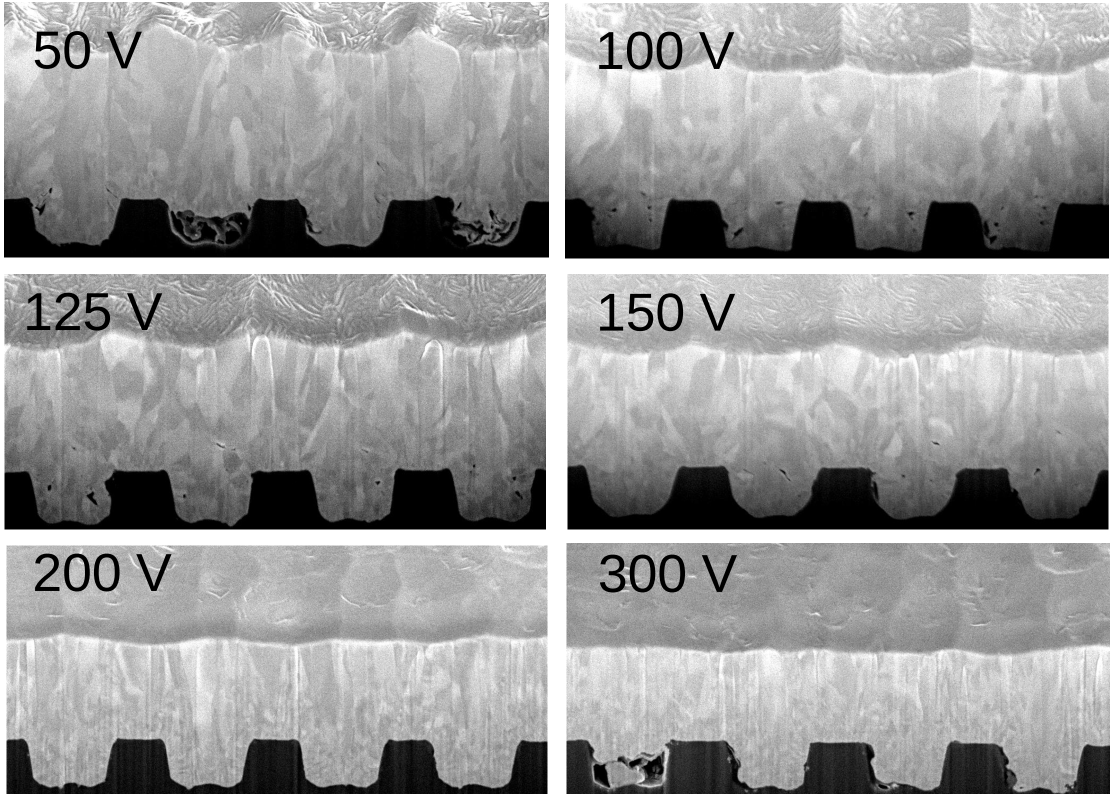




Si samples w/ 1x1x20 µm trenches

HiPIMS + substrate DC bias

1 µm



FUTURE WORK

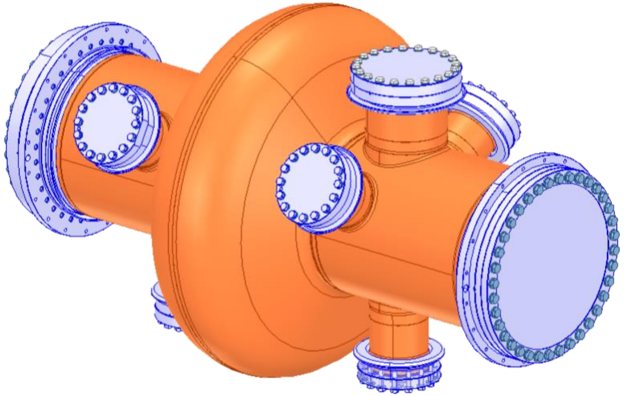
J_c

- Post coating annealing
- Coating temperature
- Substrate treatment

Nb planarization

- Coating Cu cavity first with a very thin Nb layer at high bias and then coat rest of the layer with optimal HiPIMS recipe

Scale-up HiPIMS

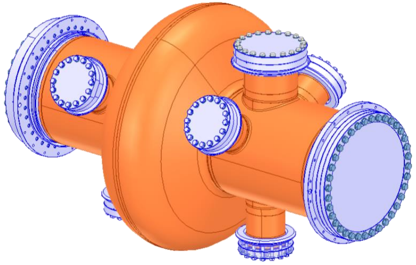


400 MHz cavities

Optimize
Thin Film

?

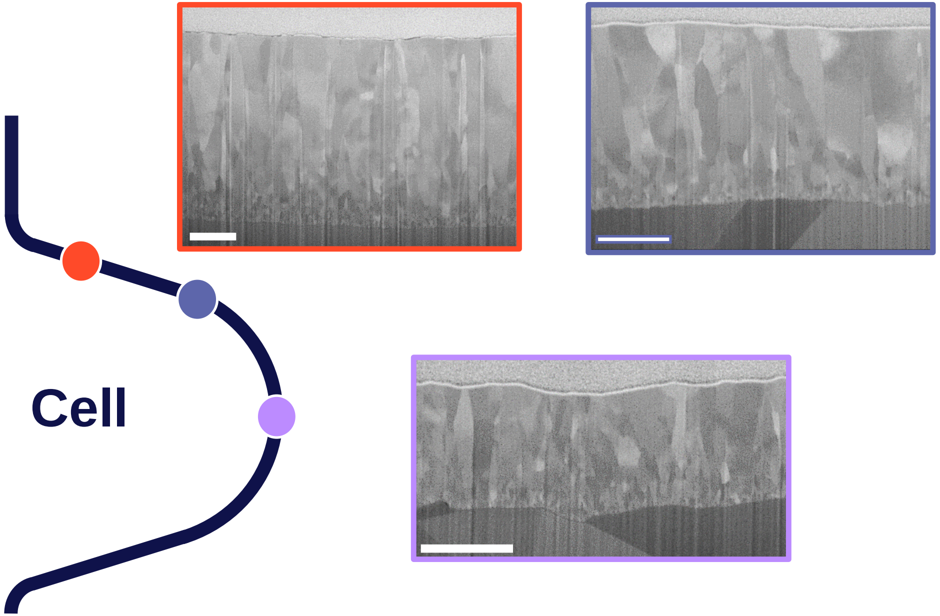
Scale-up



400 MHz

HiPIMS + substrate DC bias not yet possible
Bipolar HiPIMS compatible with current setup

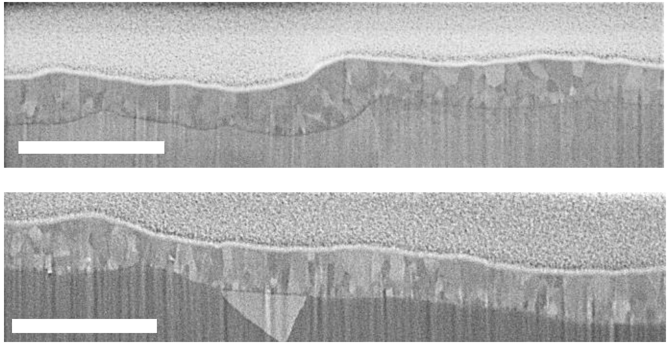
400 MHz ACTIVITIES



BIPOLAR HiPIMS (+80V)

coating trial on samples

Coating densification



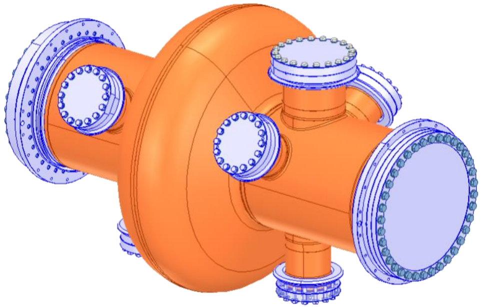
HOM ports

400 MHz ACTIVITIES

1^{st} BIPOLAR HiPIMS cavity coating on 05/2022

RF performance to be measured June/July 2022

FUTURE WORK



BIPOLAR HiPIMS

- RF performance of 1^{ST} test cavity to be measured
- Optimize coating setup and parameters

HiPIMS + DC bias

- Proven on 1.3GHz
  - Lot of RF data
- More complex coating setup
  - Upgraded cathode under study
  - Grid like anode needed + cavity insulation

- 3 RF tests / year foreseen

FCC

Thank you for your attention!