Copper electropolishing studies for the FCC-ee SC-RF cavities

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Outline

- Copper surface finishing
- New electrochemical polishing facility
- Electrochemical polishing optimisation work

Copper surface finishing

Chemical polishing (SUBU):

Sulfamic acid (85% w/w) – 5 g/l
n-Butanol (99% w/w) – 5 % v/v
Hydrogen peroxide (35 % w/w) – 5% v/v
Ammonium citrate dibasic (98% w/w) – 1 g/l

Electrochemical polishing (EP):

Phosphoric acid (85% w/w) – 55 % v/v
n-Butanol (99% w/w) – 45 % v/v

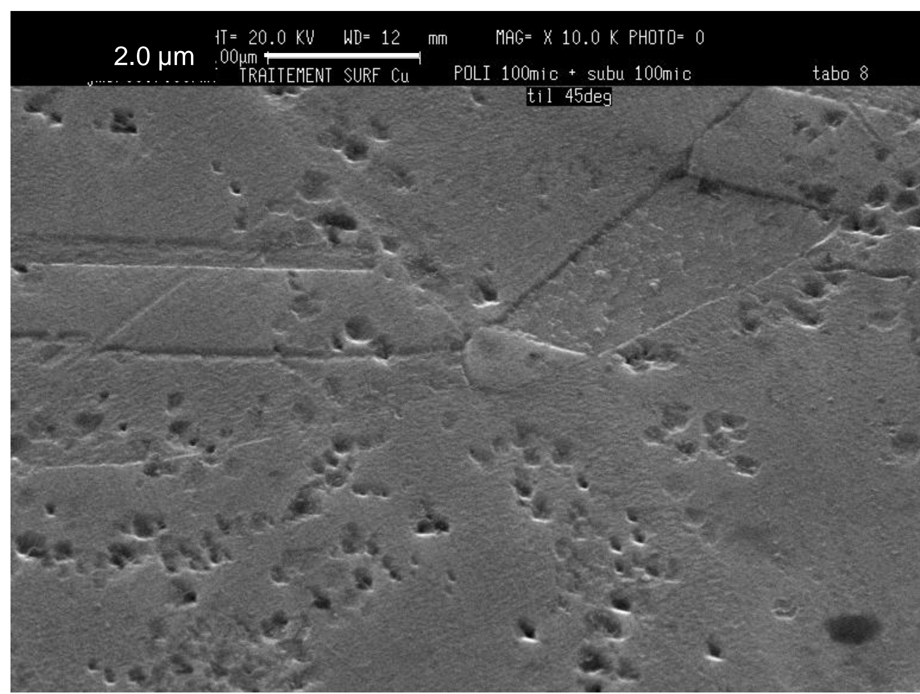
SUBU vs EP

Easier to setup

Improved surface finishing (↓Ra…)

Copper surface finishing

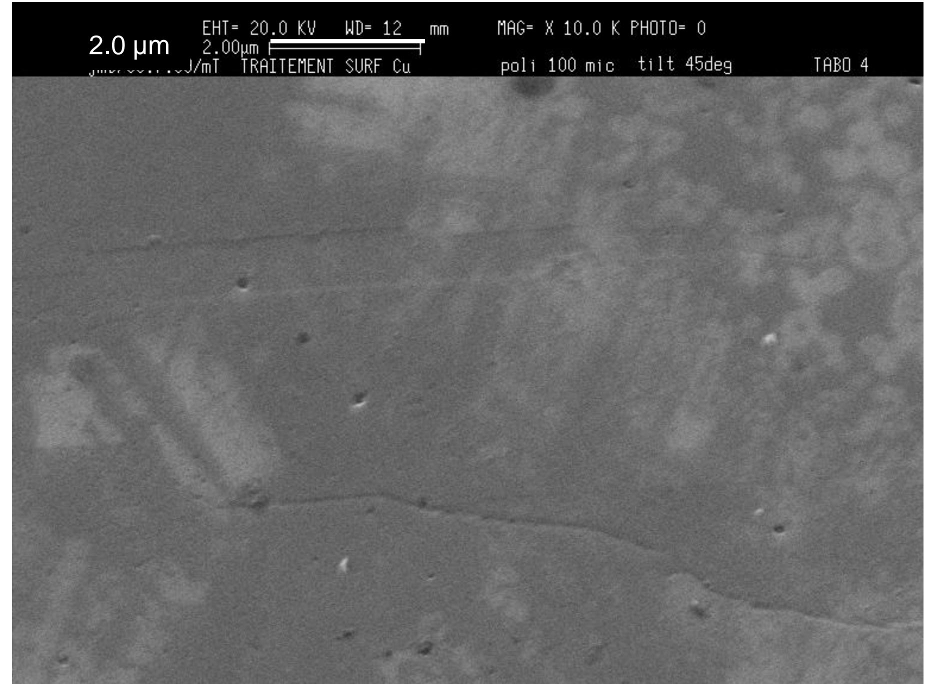
Chemical polishing (SUBU):



Chemically polished copper

- average roughness: 0.2 µm
- pinholes of 0.3 mm

Electrochemical polishing (EP):

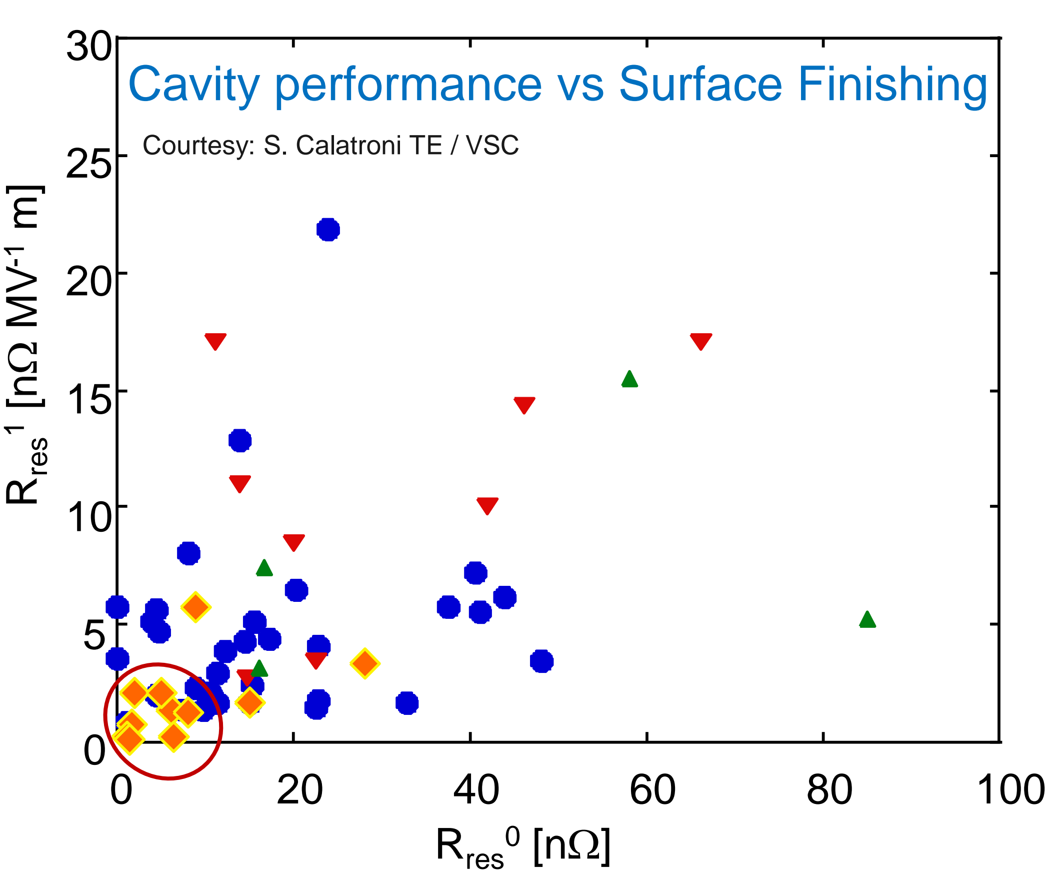


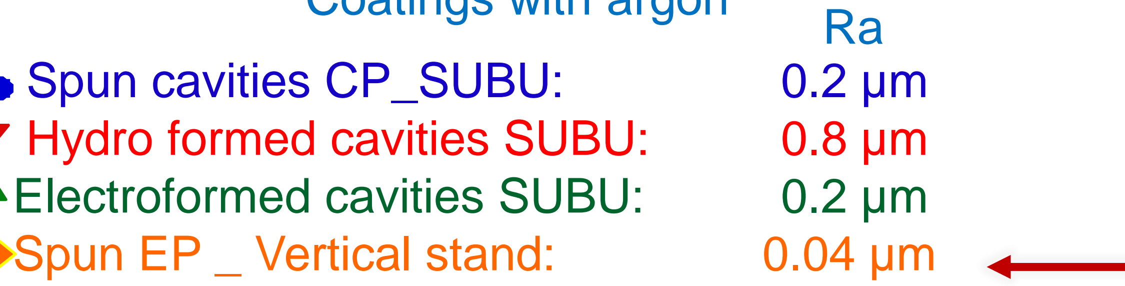
Electropolished copper

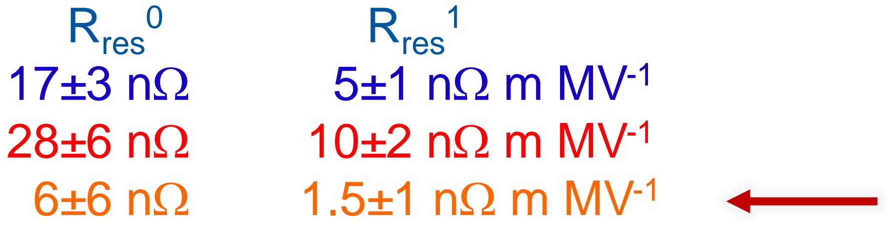
- average roughness: 0.02 µm
- nearly no defects

Courtesy: S. Calatroni TE / VSC

Copper surface finishing







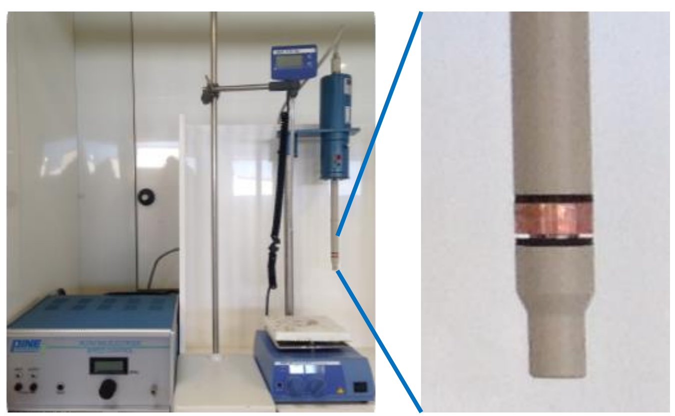
Copper surface finishing

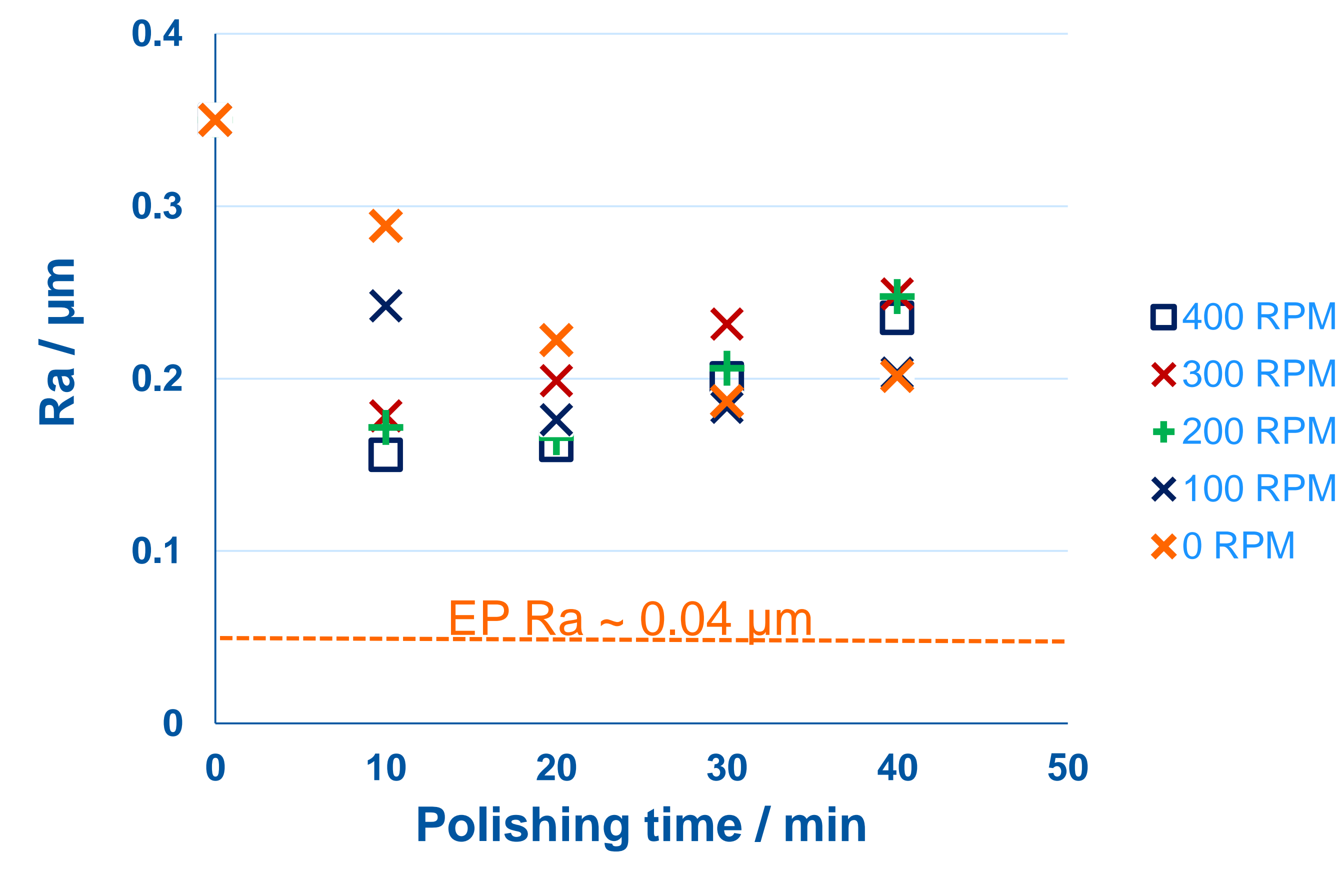
SUBU optimisation work

1st set of trials on samples:

- Surface sample / bath volume ratio:
  0.23 dm²/dm³ (0.23 dm⁻¹);
  HIE-ISOLDE = 0.25 dm⁻¹
  400 MHz = 0.28 dm⁻¹

- Initial surface roughness:
  Ra = 0.35 µm
  Rt = 4.40 µm





Copper surface finishing

Chemical polishing (SUBU):

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Baseline

SUBU vs EP

Easier to setup

Improved surface finishing (↓Ra…)

New EP facility

New electropolishing facility

Main requirements:

- Electropolishing of bare cavities

- 1.3 GHz to 400 MHz compatible

- Working bench enabling either vertical and horizontal processing

New electropolishing facility

Planning

Time frame to put in place new electropolishing installation:
Ready for the 1st 400 MHz seamless cavity ~ end of 2017

	2017				2018			
Task	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q
Concept								
Supplier survey								
Design								
Purchasing								
Assembly								
Commissioning								
Preliminary tests								

New electropolishing facility

Design status

Defining the flow diagram and populating information on equipment suppliers (cost and technical specifications)

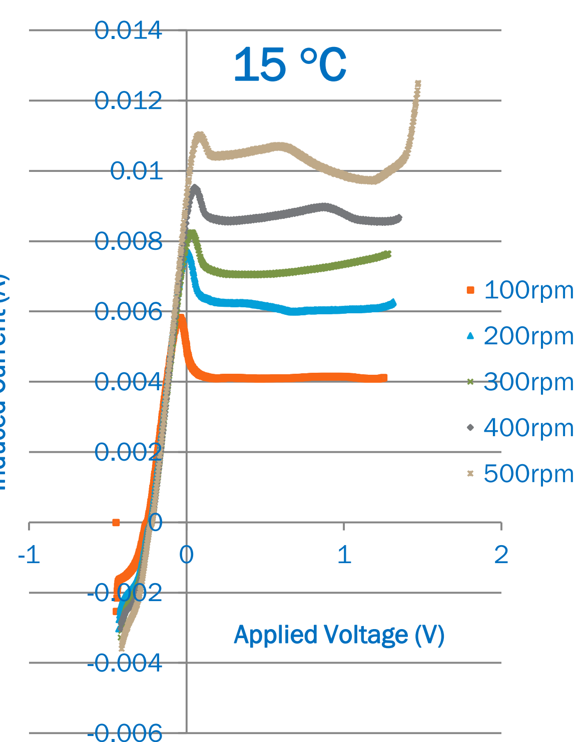
Equipment	Supplier	Ref. name	Material	Type/ dimensions	Integrated equipment	Comments	Estimated cost	Real cost

Electrochemical polishing optimisation work

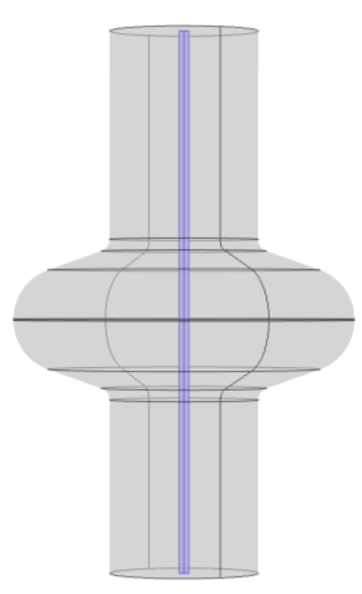
Electrochemical parameters assessment

Laboratorial setup

Extract data

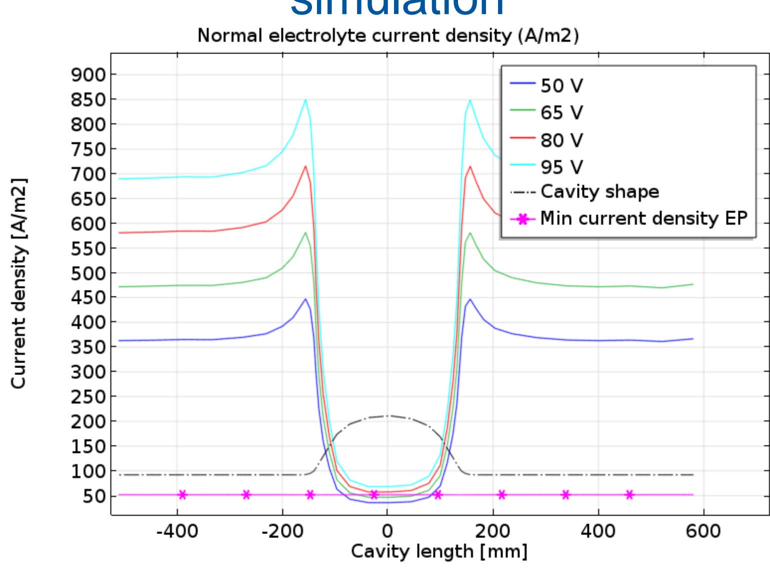


Define a model



400 MHz with 2cm Ø rod cathode geometry

Output from electrochemical simulation

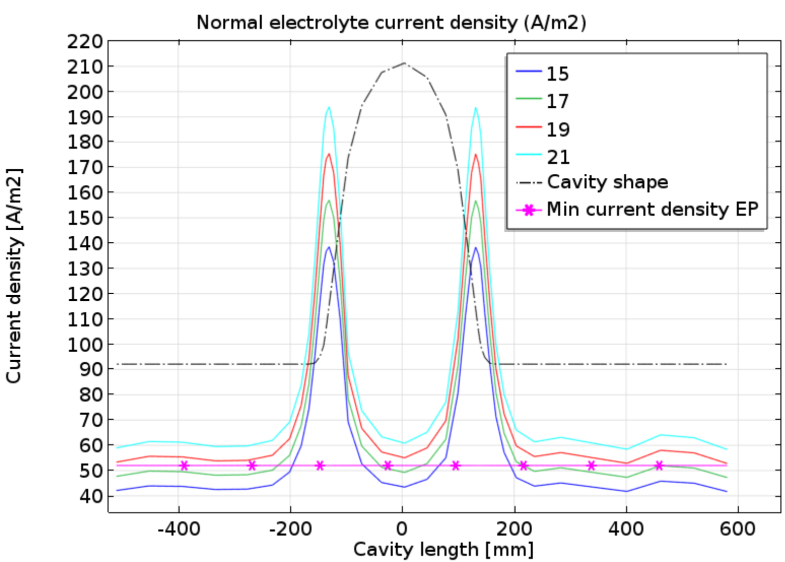


- Minimum voltage to EP the cavity ≈ 80 V
- Total current ≈ 652 A

Electrochemical polishing optimisation work

Electrochemical parameters assessment

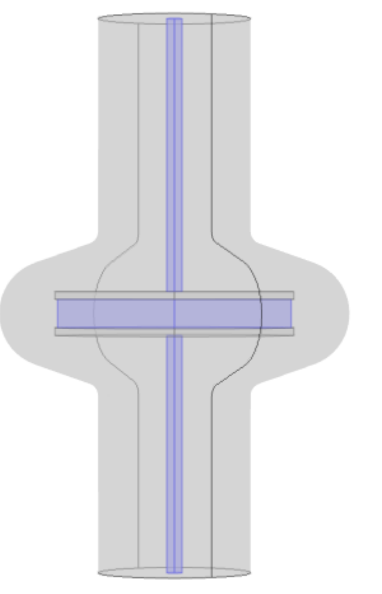
“Optimum” cathode



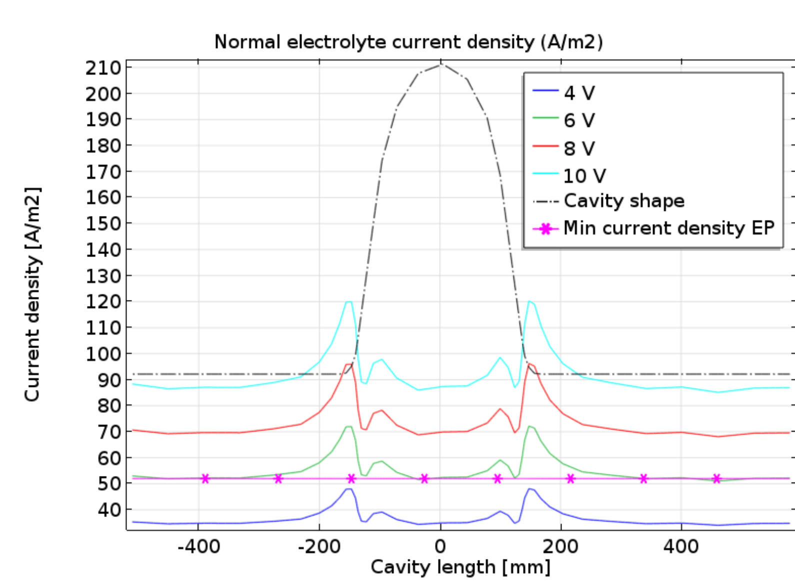
400 MHz with improved cathode geometry

- Minimum voltage to EP the cavity ≈ 19 V
- Total current ≈ 148 A

“Ideal” cathode



400 MHz with “ideal” cathode geometry



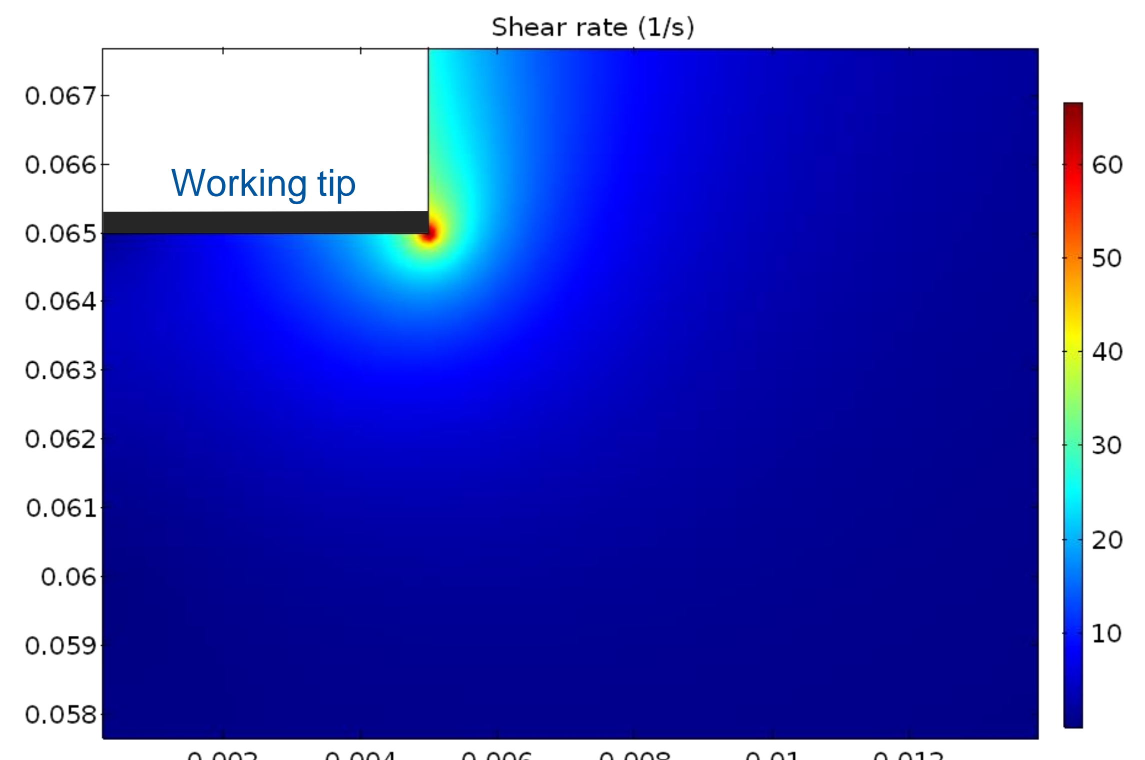
- Min voltage to EP the cavity ≈ 6 V
- Total current ≈ 100 A

Electrochemical polishing optimisation work

Fluid dynamics impact on the etching rate

Laboratorial RDE setup

Create a model of the RDE



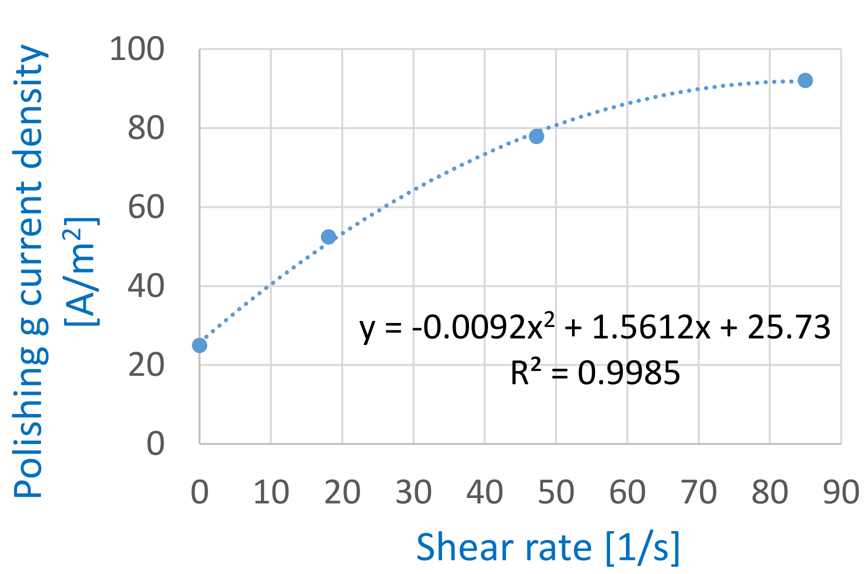
Output from RDE model

Speed of the RCE (rpm)	polishing current density (A/m^2)	**Shear rate (1/s)**
0	25	**0**
100	52	**18**
200	78	**47**
300	92	**85**

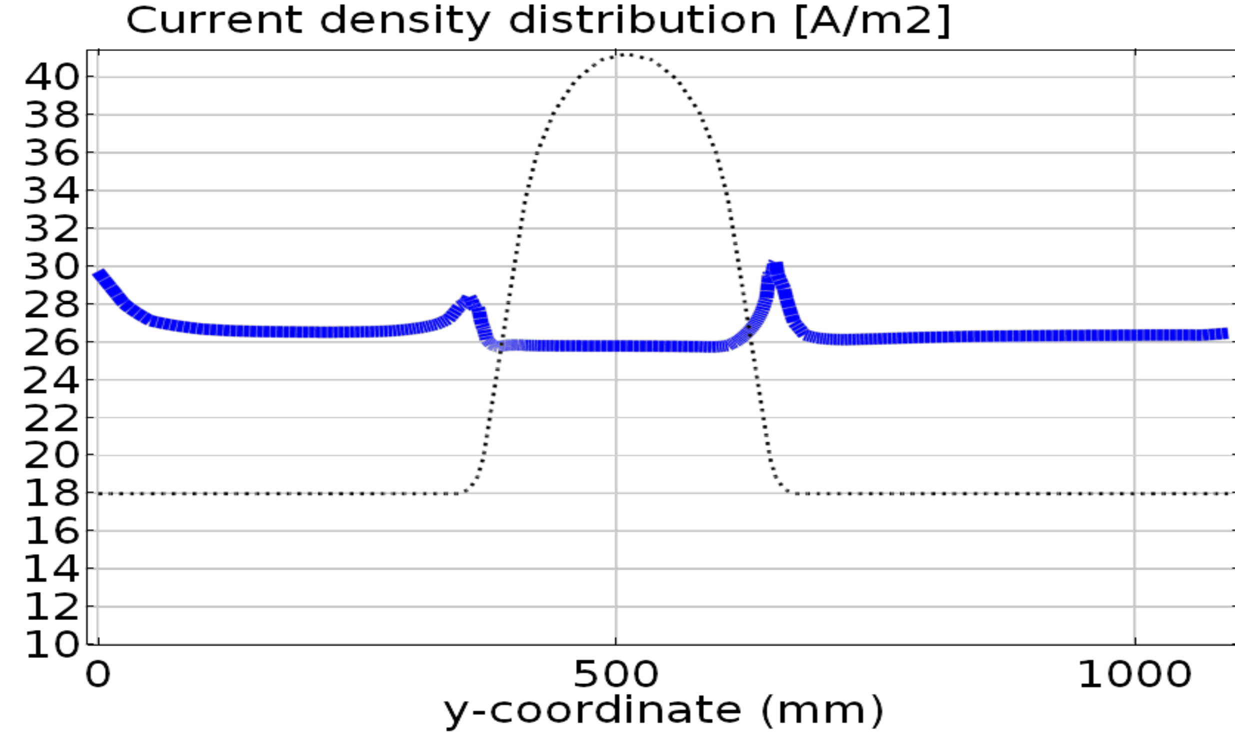
Electrochemical polishing optimisation work

Fluid dynamics impact on the etching rate

Output from RDE becomes FD input



Output from FD



Summary

- Past experience proves that copper electropolishing provides superior accelerating performances if compared with copper chemical polishing (SUBU)
- Electropolishing is the baseline surface treatment for the FCC 400 MHz, niobium on copper cavities
- Copper electropolishing is a missing facility
- New facility:
  - schedule is very tight (commissioning/reception of 1st 400 MHz cavity);
  - manpower is allocated;
  - Budget is assured.
- Optimisation work is ongoing through simulation and using 1.3 GHz cavity as validation and benchmark model

Thank you for your attention