Copper electropolishing studies for the FCC-ee SC-RF cavities
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):
- average roughness: 0.2 µm
- pinholes of 0.3 mm

Electrochemical polishing (EP):
- average roughness: 0.02 µm
- nearly no defects
Copper surface finishing

Cavity performance vs Surface Finishing

Coatings with argon
- Spun cavities CP_SUBU: 0.2 µm
- Hydro formed cavities SUBU: 0.8 µm
- Electroformed cavities SUBU: 0.2 µm
- Spun EP _ Vertical stand: 0.04 µm

R_{res 0} [nΩ MV^{-1} m]

R_{res 1} [nΩ MV^{-1} m]

R_{res 0}
- 17±3 nΩ
- 28±6 nΩ
- 6±6 nΩ

R_{res 1}
- 5±1 nΩ m MV^{-1}
- 10±2 nΩ m MV^{-1}
- 1.5±1 nΩ m MV^{-1}
Copper surface finishing
SUBU optimisation work

1st set of trials on samples:
• Surface sample / bath volume ratio:
  0.23 dm$^2$/dm$^3$ (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

EP Ra ~ 0.04 µm
Copper surface finishing

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SUBU vs EP

Easier to setup

Improved surface finishing (↓Ra…)
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

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

<table>
<thead>
<tr>
<th>Task</th>
<th>2017</th>
<th>2018</th>
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<tbody>
<tr>
<td></td>
<td>1Q</td>
<td>2Q</td>
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<tr>
<td>Concept</td>
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<td>Supplier survey</td>
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<td>Purchasing</td>
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<td>Commissioning</td>
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<td>Preliminary tests</td>
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- Ready for the 1\textsuperscript{st} 400 MHz seamless cavity ~ end of 2017
New electropolishing facility

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

![Flow diagram](image)

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Supplier</th>
<th>Ref. name</th>
<th>Material</th>
<th>Type/dimensions</th>
<th>Integrated equipment</th>
<th>Comments</th>
<th>Estimated cost</th>
<th>Real cost</th>
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</thead>
<tbody>
<tr>
<td>E-2</td>
<td>TE-VSC A. Pérez &amp; L. Ferreira FCC Berlin 05.2017</td>
<td>New electropolishing facility</td>
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Electrochemical polishing optimisation work

Electrochemical parameters assessment

Laboratorial setup

Extract data

- **15 °C**

- Applied Voltage (V)
  - Induced Current (A)
  - 100rpm
  - 200rpm
  - 300rpm
  - 400rpm
  - 500rpm

- **400 MHz with 2cm Ø rod cathode geometry**

Define a model

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

Output from electrochemical simulation

- **400 MHz with 2cm Ø rod cathode geometry**
Electrochemical polishing optimisation work

Electrochemical parameters assessment

**“Optimum” cathode**
- Minimum voltage to EP the cavity ≈ 19 V
- Total current ≈ 148 A

**“Ideal” cathode**
- 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

<table>
<thead>
<tr>
<th>Speed of the RCE (rpm)</th>
<th>Polishing current density (A/m²)</th>
<th>Shear rate (1/s)</th>
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<tbody>
<tr>
<td>0</td>
<td>25</td>
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<tr>
<td>100</td>
<td>52</td>
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<tr>
<td>200</td>
<td>78</td>
<td>47</td>
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<tr>
<td>300</td>
<td>92</td>
<td>85</td>
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</table>
Electrochemical polishing optimisation work

Fluid dynamics impact on the etching rate

Output from RDE becomes FD input

Output from FD

$y = -0.0092x^2 + 1.5612x + 25.73$

$R^2 = 0.9985$
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