SUPERCONDUCTING THIN FILMS STUDIES AT CERN

on behalf of FCC SRF WP3
Outline

1. WP3 Objectives
2. R&D Status
3. Short/Mid term plans
4. Conclusion
WP3 OBJECTIVES
Overview

Improve Substrate Surface Preparation

Improve coating technique / recipe

Qualify SRF cavities performance / sensitivity

Delivery of prototype cavities for CM

Set-up collaboration with international partners
Surface Treatments

Develop and optimize 1.3GHz substrates electropolishing

Optimize Cu passivation (adhesion)

Scale-up to 400MHz / SWELL cavities
Surface Treatments

Develop and optimize 1.3GHz substrates electropolishing
Optimize Cu passivation (adhesion)
Scale-up to 400MHz / SWELL cavities

Coatings

Optimize HiPIMS recipe
Reduce gas incorporation
Predict RF performance based on DC characterization
Mitigate Q-slope
Investigate alternative materials to Nb
Scale-up to 400MHz and SWELL cavities
Surface Treatments

- Develop and optimize 1.3GHz substrates electropolishing
- Optimize Cu passivation (adhesion)
- Scale-up to 400MHz / SWELL cavities

Coatings

- Optimize HiPIMS recipe
- Reduce gas incorporation
- Predict RF performance based on DC characterization
- Mitigate Q-slope
- Investigate alternative materials to Nb
- Scale-up to 400MHz and SWELL cavities

RF Testing

- Assess Cavities’ performance
- Assess Cavities’ sensitivity to trapped flux
- Assess Cavities’ sensitivity to thermal gradient
- Develop thermal mapping for defect localization

https://indico.frib.msu.edu/event/38/attachments/158/1065/THPCAV007.pdf
Electropolishing

Bench commissioned
Removal rate profile qualified
Currently processing 1 cavity / week
Optimization on-going
Coatings

Nb/Cu

Bias optimized based on Jc lowering

![Graph showing Jc (A/mm²) vs. Thickness (µm) for different biases with Tsample = 150°C.](image)

-50V
-75V
-85V
-100V
-125V
Bulk

Thickness (µm)
Coatings

Nb/Cu

Bias optimized based on Jc lowering

Neutral atmosphere housing for high temperature coatings
Coatings

Nb/Cu

Bias optimized based on Jc lowering

Neutral atmosphere housing for high temperature coatings

Promising performance obtained on QPR
Coatings

Nb/Cu

Bias optimized based on Jc lowering
Neutral atmosphere housing for high temperature coatings
Promising performance obtained on QPR
Coatings on
- bulk machined seamless cavity
Coatings

Nb/Cu

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Promising performance obtained on QPR

Coatings on

- bulk machined seamless cavity
- internal e-beam welded cavity

Cf S. Atieh talk (FCC week 2021)
Coatings

Nb/Cu

Bias optimized based on $J_c$ lowering

Neutral atmosphere housing for high temperature coatings

Promising performance obtained on QPR

Coatings on

- bulk machined seamless cavity
- internal e-beam welded cavity
- electroformed cavities

https://indico.cern.ch/event/817780/contributions/3716458/
Coatings

Nb/Cu

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Coatings on

- bulk machined seamless cavity
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- electroformed cavities
- spun seamless cavities

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Coatings

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Promising performance obtained on QPR

Coatings on

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Quantify the effect of surface damaged layer

- by surface machining
- by forming

All cavities electropolished
Coatings

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Promising performance obtained on QPR

Coatings on

- bulk machined seamless cavity
- internal e-beam welded cavity
- electroformed cavities
- spun seamless cavities

R_{res} of \sim 4nOhms achieved on 1.3GHz with

Q > 1.10^{10} up to 15MV/m

Cf: P. Vidal-Garcia talk
and:
https://indico.frib.msu.edu/event/38/attachments/158/1275/TUPTEV09_rev_3.pdf
Coatings

Nb/Cu

Bias optimized based on Jc lowering

Neutral atmosphere housing for high temperature coatings

Promising performance obtained on QPR

Coatings on

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Scale-up to 400MHz
Coatings

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Promising performance obtained on QPR

Coatings on

- bulk machined seamless cavity
- internal e-beam welded cavity
- electroformed cavities
- spun seamless cavities

Scale-up to 400MHz – First HiPIMS coating of a 400MHz cavity

F. Avino et al. 2019 Plasma Sources Sci. Technol. 28 01LT03
Coatings

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Coatings on

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Scale-up to 400MHz
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Coatings on

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Scale-up to 400MHz Layer densification
Coatings

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Coatings on

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Scale-up to 400MHz Layer densification
Coatings

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Coatings on

- bulk machined seamless cavity
- internal e-beam welded cavity
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- spun seamless cavities

Scale-up to 1.3GHZ SWELL

QPR test pending for setup qualification
Coatings

Nb/Cu

Bias optimized based on Jc lowering

Neutral atmosphere housing for high temperature coatings

Promising performance obtained on QPR

Coatings on

- bulk machined seamless cavity
- internal e-beam welded cavity
- electroformed cavities
- spun seamless cavities

Scale-up to 400MHz Layer densification

A15/Cu

Nb$_3$Sn and V$_3$Si
Coatings

**Nb/Cu**

- Bias optimized based on Jc lowering
- Neutral atmosphere housing for high temperature coatings
- Promising performance obtained on QPR
- Coatings on:
  - bulk machined seamless cavity
  - internal e-beam welded cavity
  - electroformed cavities
  - spun seamless cavities
- Scale-up to 400MHz Layer densification

**A15/Cu**

**Nb$_3$Sn and V$_3$Si**

- Substrate has a fundamental effect

Graph:

- Moment / Moment$_{transition}$ vs Temperature (K)
- P = 1*10$^{-3}$ mbar
- P = 5*10$^{-3}$ mbar

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Coatings

**Nb/Cu**

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**A15/Cu**

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Scale-up to 400MHz Layer densification

**A15/Cu**

Nb$_3$Sn and V$_3$Si

Substrate has a fundamental effect

Diffusion Barrier Layer use

![Graph showing critical temperature vs. atomic tin content](image-url)
Coatings

Nb/Cu

Bias optimized based on Jc lowering

Neutral atmosphere housing for high temperature coatings

Promising performance obtained on QPR

Coatings on

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Scale-up to 400MHz Layer densification

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Nb$_3$Sn and V$_3$Si

Substrate has a fundamental effect

Diffusion Barrier Layer use

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Coatings

**Nb/Cu**
- Bias optimized based on Jc lowering
- Neutral atmosphere housing for high temperature coatings
- Promising performance obtained on QPR
- Coatings on
  - bulk machined seamless cavity
  - internal e-beam welded cavity
  - electroformed cavities
  - spun seamless cavities
- Scale-up to 400MHz Layer densification

**A15/Cu**
- Nb$_3$Sn and V$_3$Si
- Substrate has a fundamental effect
- Diffusion Barrier Layer use
- More QPR testing on their way
- Scale-up to 1.3GHz
  - Process temperature
  - Structural stability
Coatings

**Nb/Cu**
- Bias optimized based on $J_c$ lowering
- Neutral atmosphere housing for high temperature coatings
- Promising performance obtained on QPR

**A15/Cu**
- $Nb_3Sn$ and $V_3Si$
- Substrate has a fundamental effect
- Diffusion Barrier Layer use
- More QPR testing on their way
- Scale-up to 1.3GHz
  - Process temperature
  - Structural stability

Coatings on
- bulk machined seamless cavity
- internal e-beam welded cavity
- electroformed cavities
- spun seamless cavities

Scale-up to 400MHz Layer densification

Achieved $T_c$ of 15K on $Nb_3Sn$
Coatings

Plasma simulations

Optimization of plasma coating sources
https://indico.jlab.org/event/405/contributions/8107/
Coatings

Plasma simulations

Optimization of plasma coating sources
https://indico.jlab.org/event/405/contributions/8107/

WOW Cavity (FCC hh)

F. Manke Talk
RF Testing
1.3GHz elliptical cavities

Please stay for P. Vidal-Garcia talk

1.3GHz SWELL Cavity

Cryogenics studies and simulation on going

Cf: F. Peauger and S. Atieh talks
SHORT/MID TERM PLANS
Plans

**Nb/Cu**
- push 1.3GHz cavities toward $Q \sim 1.10^{10}$ @ 20MV/m
- assess the performance of various manufacturing techniques
- Produce additional electroformed cavities
- fundamental understanding of process parameters effect on Nb layer properties
- Q4 2021: First HiPIMS coating on 400MHZ cavity for RF testing / transfer 1.3GHz recipe
- First coating of a 1.3GHz SWELL prototype
- Q4 2021: First coating test on WOWcc

**A15/Cu**
- Optimization of bi-polar HiPIMS coatings
- Increase QPR coating rate
- Propose a scale-up strategy

**RF Testing:**
- Evaluate the full potential of the first successful 1.3GHz cavity
- Sustain strong diagnostic capability

**Expanding collaborations** (TU Wien, Helsinki University, UniGe…) for more fundamental studies
Conclusion

Significant progress on 1.3GHz Nb/Cu cavities
- No fundamental limit of that technology
- Strong synergy between the actors is key to success (manufacture, surface treatments, RF testing, collaborators)

A15/Cu: Still strong efforts needed – more complex than Nb/Cu (… and it is already a hard task)

Scale-up on going and encouraging

Solid basis for SWELL demonstrator.
Thank you for your attention.
Acknowledgements