Recent Advances In **Metallographic Polishing** For SRF Application

Oleksandr "Sasha" HRYHORENKO

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Acknowledgments

- **CEA-IRFU**
  Claire Antoine
- **IJCLab**
  David Longuevergne
- **KEK**
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- **HZB**
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  Oliver Kugeler
- **STFC**
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  Reza Valizadeh
  Oleg Malyshev
- **LAM PLAN**
  William Magnin
  Monish Rajkumar

Outline

2. MP on small samples

4. Cavity fabrication

1. Introduction & Goals

3. MP on large disks

5. Conclusions & Future

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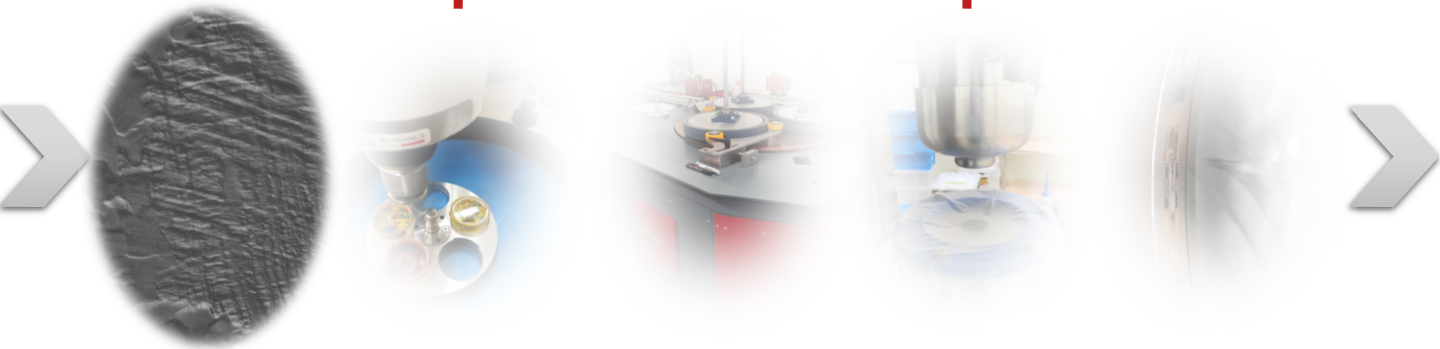
4. Cavity fabrication



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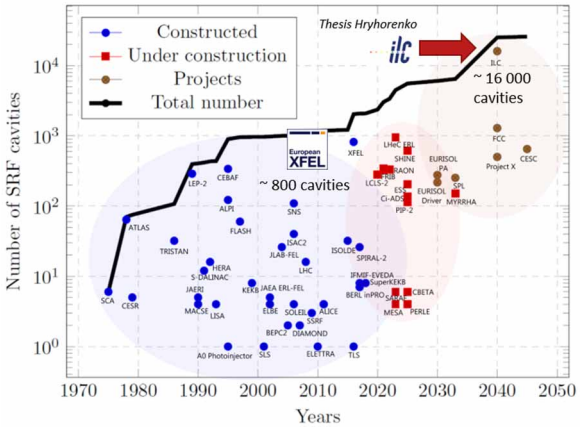
Introduction & Goals

- Why alternative polishing for SRF cavities?
- Mechanical polishing as an alternative
- Goals

Introduction & Goals

- Why alternative polishing for SRF cavities?



Improve production yield

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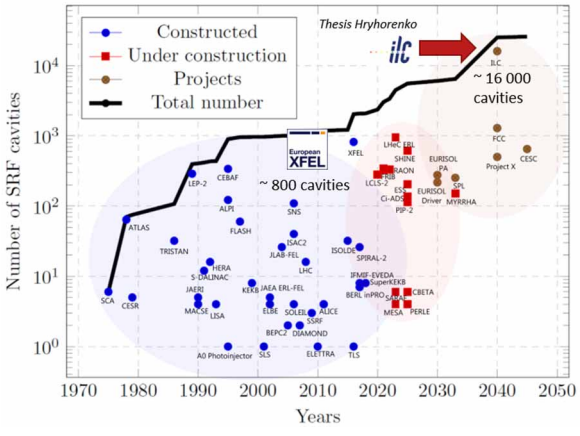

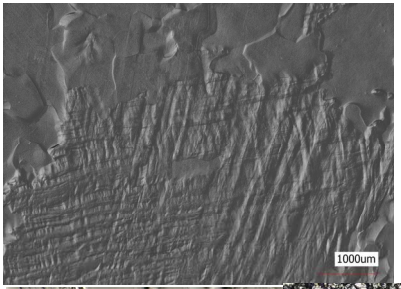

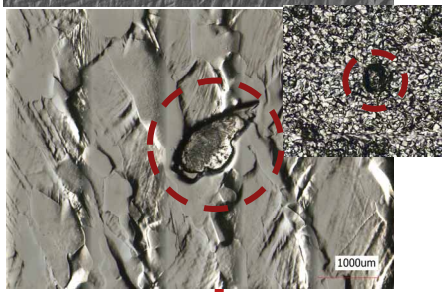

Improve production yield

- *Uniform surface preparation*
- *Prepare better substrate for thin film deposition*

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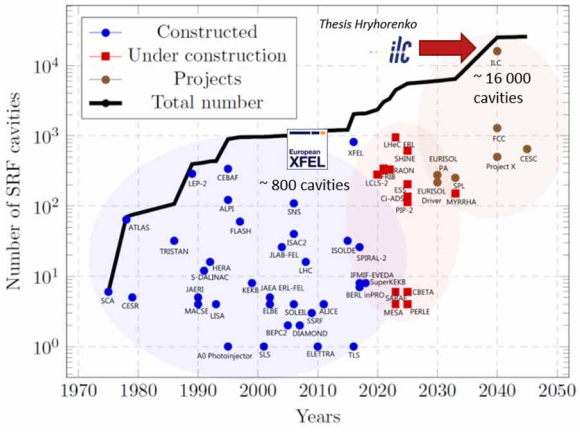

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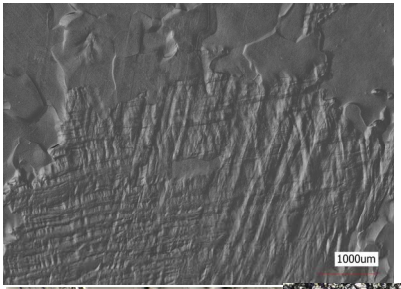

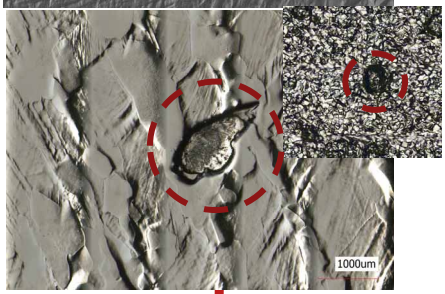

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Safety concerns

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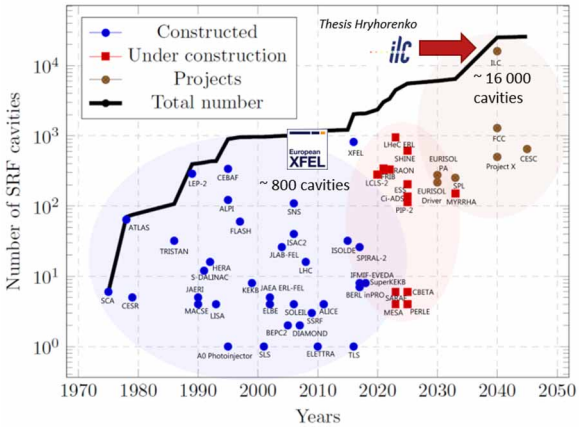

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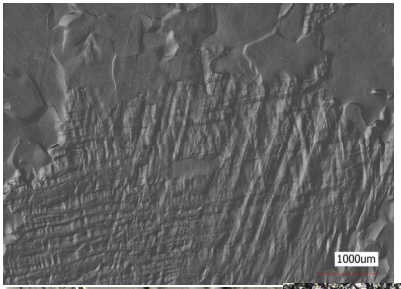

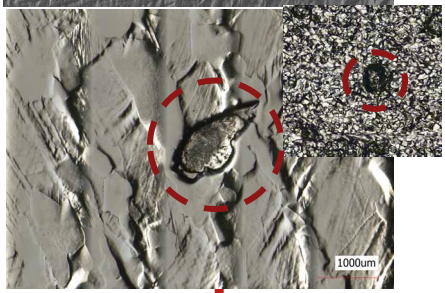

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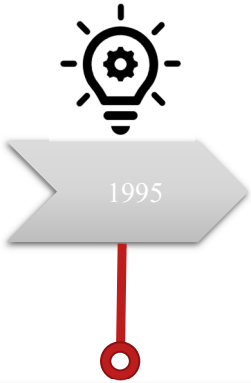
Mechanical polishing as alternative

Mechanical polishing history in SRF field



Barrel polishing (tumbling) was pioneered by Tamawo Higuchi, Kenji Saito and others. Presented at SRF 95

SUMMARY:

- *Removed 30 um by tumbling (week)*
- *After annealing and EP (10 um) improved performance*

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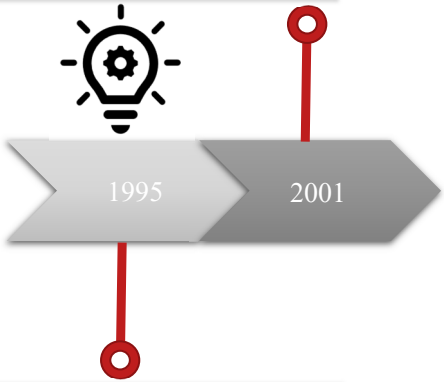

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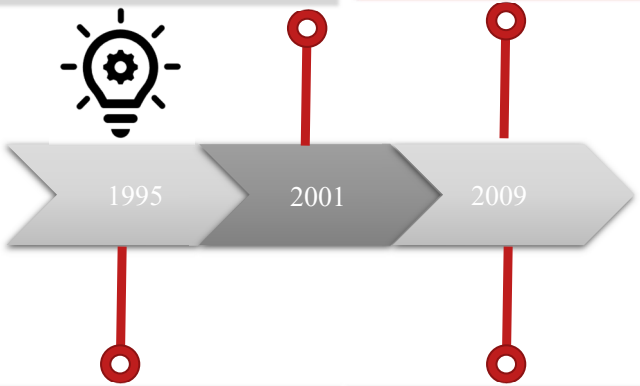

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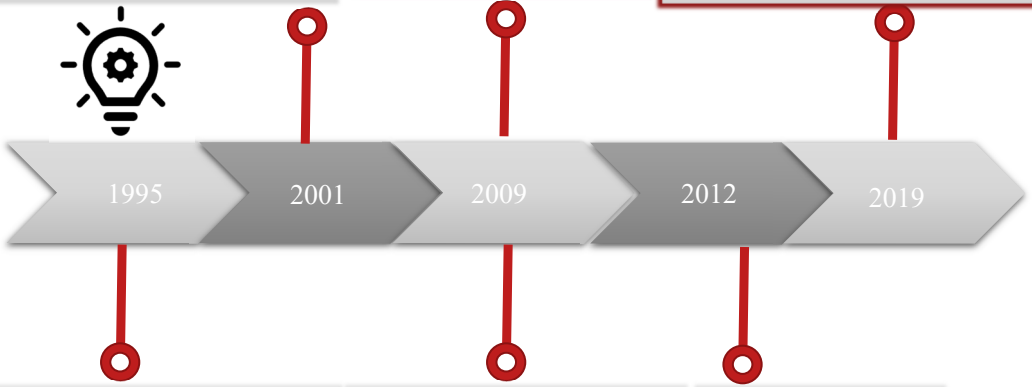

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SUMMARY:
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Eduard Chyhyrynets performed vibro-tumbling on 6 GHz cavities (INFN). Presented at SRF 19

SUMMARY:
2 steps/removal rate 3.2 um/h

2021

First attempts to transfer MP protocol to large areas compatible for 1.3 GHz cavity fabrication and forming studies on samples. Presented at SRF 2021

2023

To be presented at SRF23…

Goals

- Remove damaged layer 100-200 um before cavity fabrication
- Get superior smoothness and flatness compared to conventional polishing
- Limit manipulations and process time (industrialization concern)
- Fabricate three 1-cell cavities with pre-polished disks
- Measure their performances

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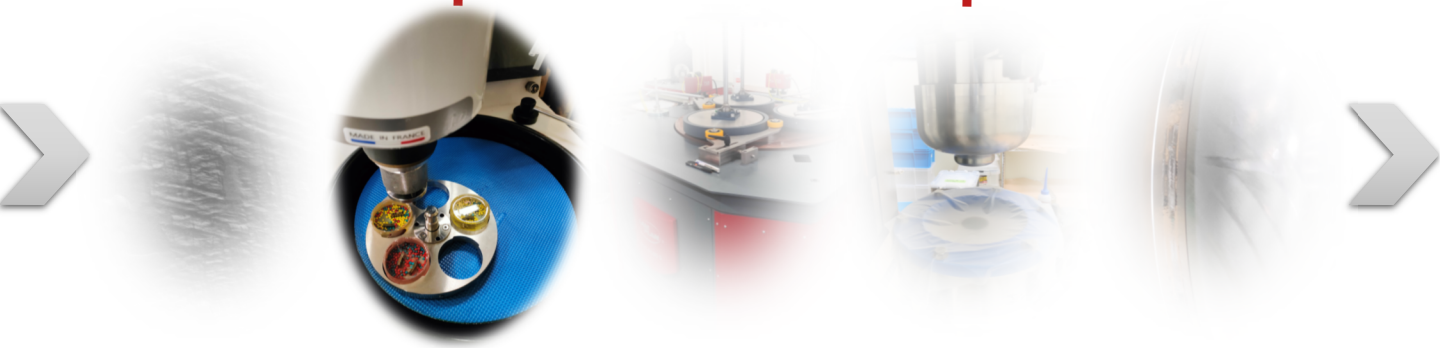

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Superconducting RF evaluation

- *RF disks used at STFC*
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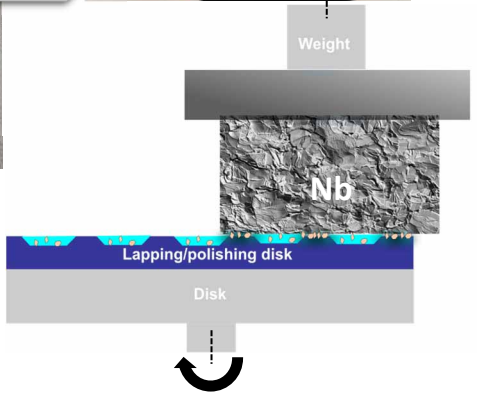
Surface preparation



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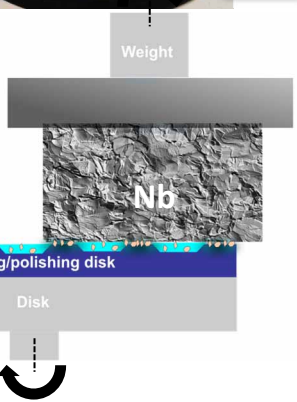
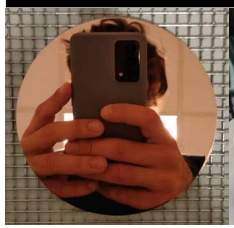
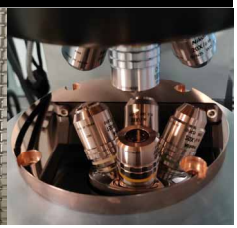


Visual characterization





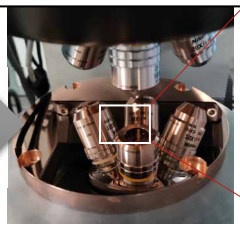
Polishing technology	Removal rate, um/min	Time to remove 100-200 um
Tumbling	*0.008*	*weeks*
CBP	*0.08*	*days*
Vibro-tumbling	*0.05*	*days*
BCP	*1*	*4-8 h*
EP	*0.5*	*8-16 h*
MP	*1.5*	*1-3 h*

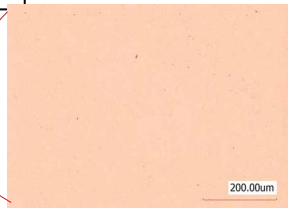
Results on Cu/Nb disks

Sa = 1.24 µm, Sz = 14 µm

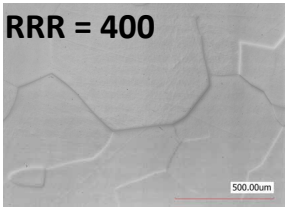
300 um removal

Sa = 20 nm, Sz = 2.5 µm

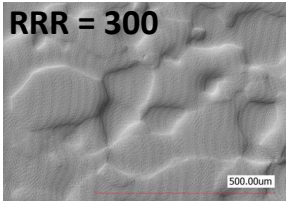




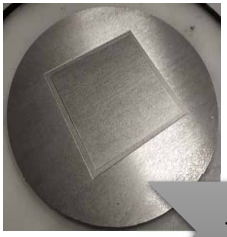
RRR = 400



RRR = 300



Sa = 2.2 ± 0.3 µm , Sz = 21 ± 4 µm



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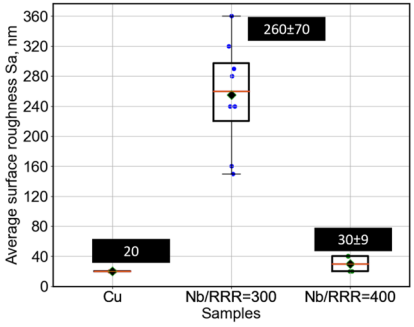

- *4 Cu disks and 1 Nb disk polished so far in the framework of the iFast project*

Jefferson Lab

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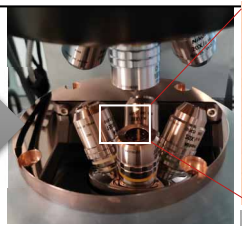

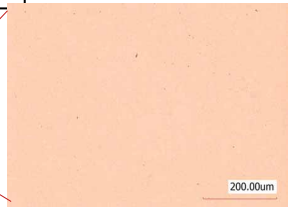

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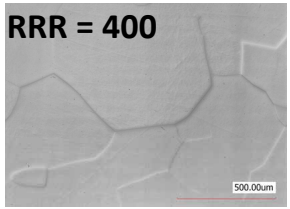

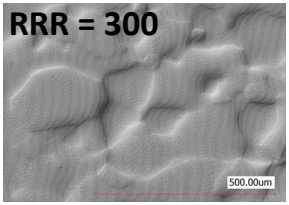

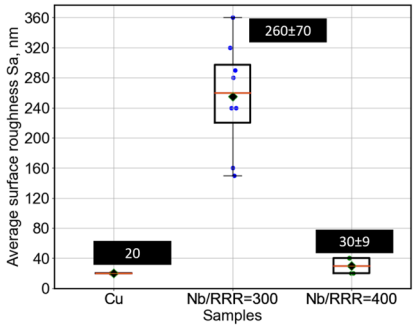

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Superconducting RF evaluation at STFC

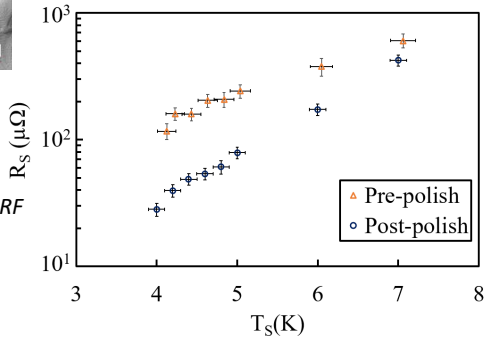
- *Cavity frequency = 7.8 GHz*
- *TM_{010} mode*
- *Sample temperatures, $T_S \geq 4$ K*
- *Sample $B_{peak} \leq 1.1$ mT*
- *Low RF powers ≤ 1 W*
- *Fast and qualitative analysis*

Choke cavity

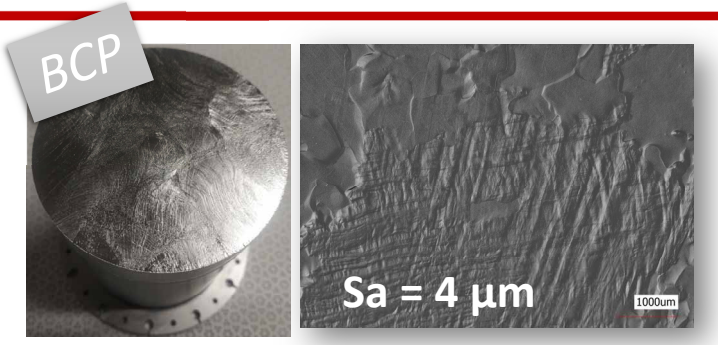
Courtesy of Daniel Seal, Oleg Malyshev from STFC

- *Nb disk is evaluated under RF*
- *R_{BCS} (4.2 K) ~ 15.3 µΩ*
- *Improvement in Rs*

Daniel Seal et al.
DOI: 10.18429/JACoW-LINAC2022-THPOGE10



Results on QPR disks



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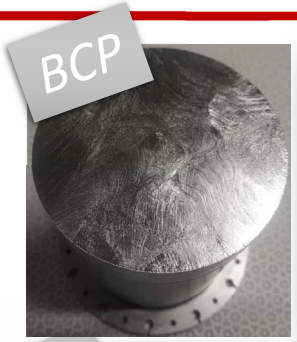
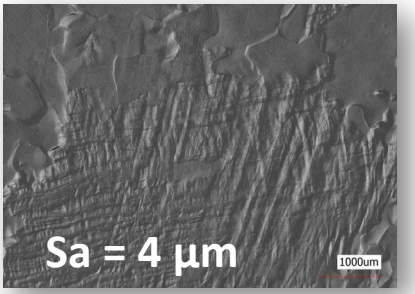
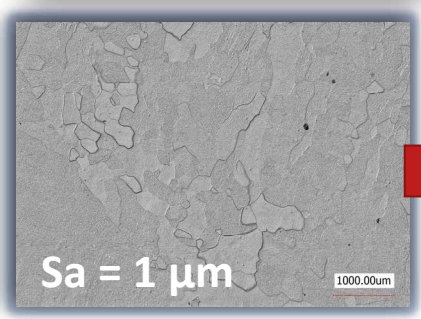
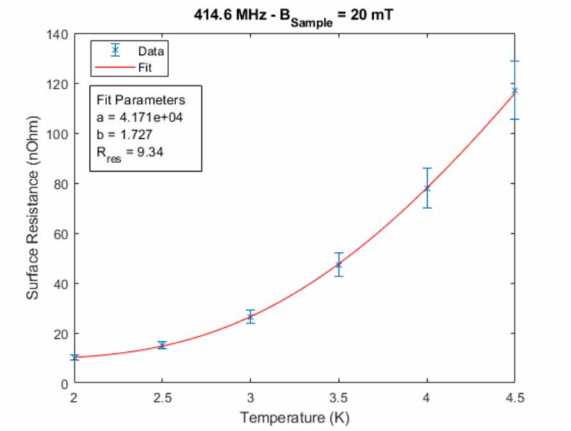






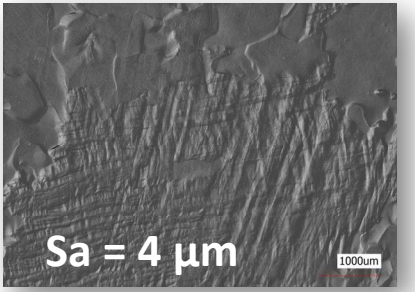
Baseline:
- *EP removal of 100 um*
- *Heat treatment at 900 C for 3 h*
- *EP 20 um*



Courtesy Sebastian Keckert, Oliver Kugeler from HZB

Results on QPR disks

BCP



EP

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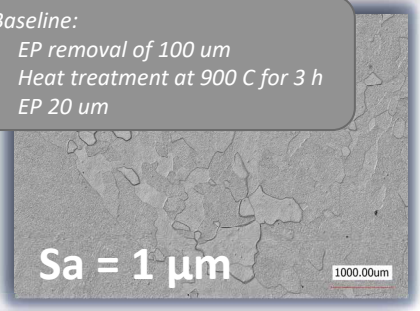
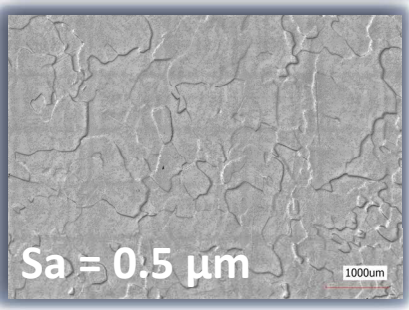
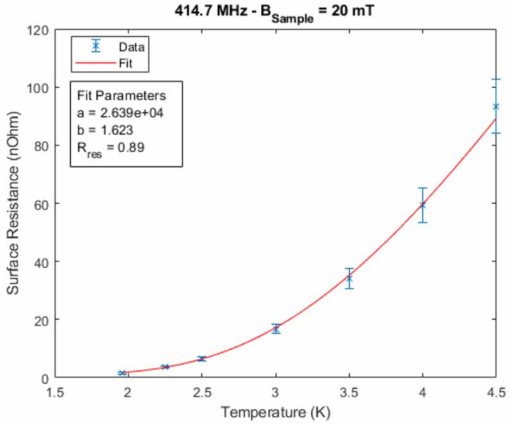


MP



Polished:
- *MP removal 25 um in 2 step protocol*
- *Heat treatment at 600 C for 10 h*
- *No EP*



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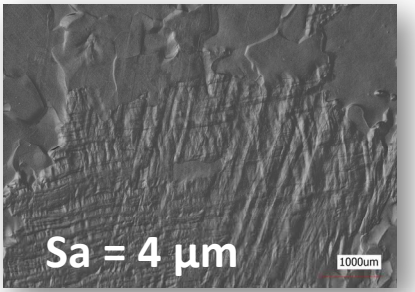

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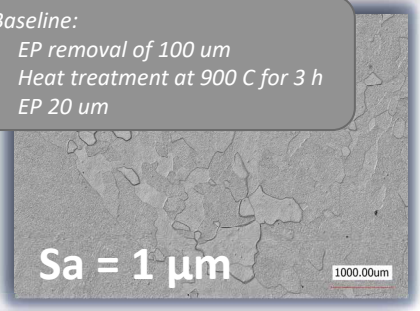
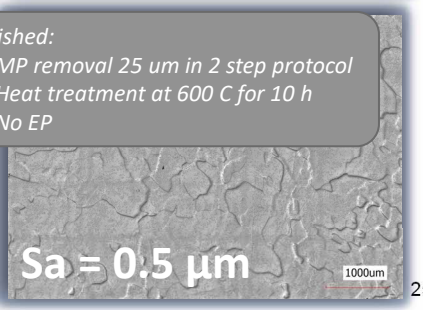
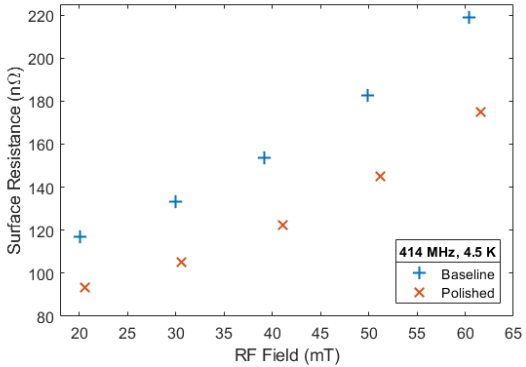
- *EP removal of 100 um*
- *Heat treatment at 900 C for 3 h*
- *EP 20 um*

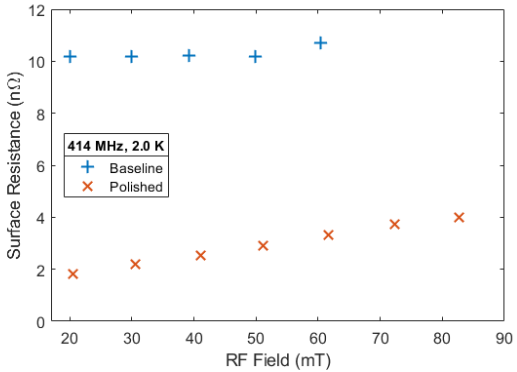


MP

Polished:
- *MP removal 25 um in 2 step protocol*
- *Heat treatment at 600 C for 10 h*
- *No EP*







Courtesy Sebastian Keckert, Oliver Kugeler from HZB

- *Improved surface preparation pushed the RF fields above 80 mT.*
- *Measurement of Rres resistance below 1 nOhm.*
- *Reproducible results (x2 QPR so far).*

Jefferson Lab

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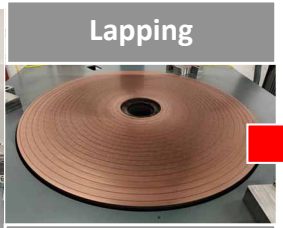
5. Conclusions & Future

MP transfer to disks for fabrication 1.3 Ghz cavities

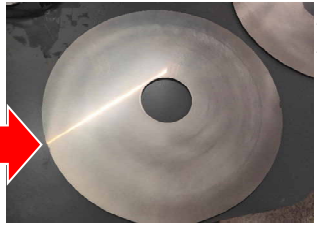
Lapping device

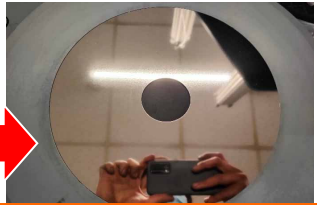


Lapping

Polishing

2-3 steps protocol





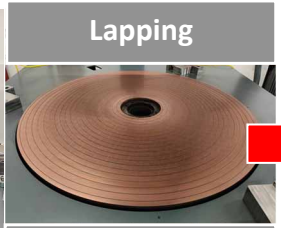
Visual inspection

Lapping: removal of 200 um in 3h
Polishing: recover SRF properties for 2h

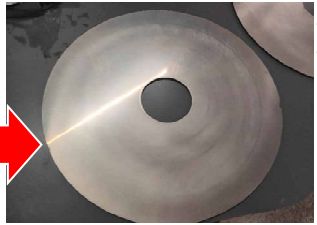
O. Hryhorenko, C. Z. Antoine, W. Magnin, M. Rajkumar, F. Brisset, S. Guilet, and D. Longuevergne, "An innovative approach of surface polishing for srf cavity applications," *Journal of Manufacturing and Materials Processing*, vol. 7, no. 2, 2023.

MP transfer to disks for fabrication 1.3 Ghz cavities

Lapping device



2-3 steps protocol



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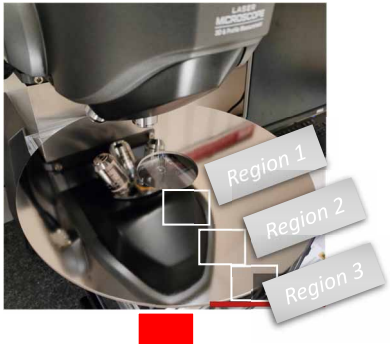

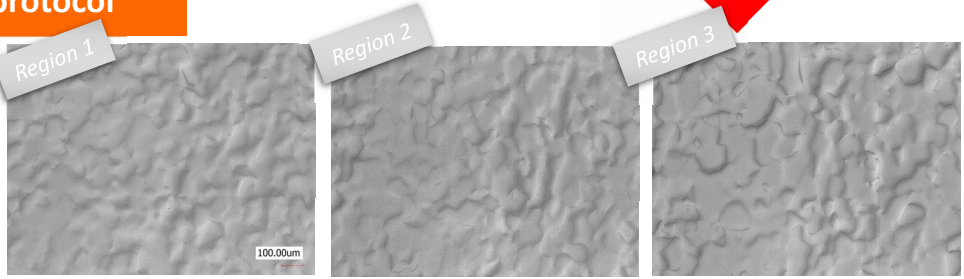

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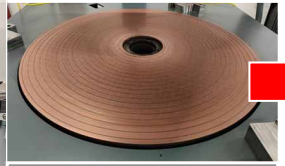
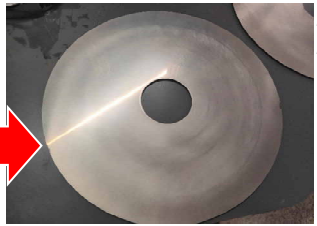
MP transfer to disks for fabrication 1.3 Ghz cavities

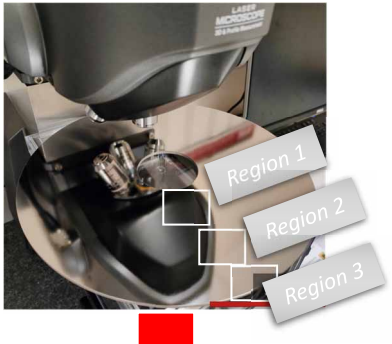
Lapping





Polishing

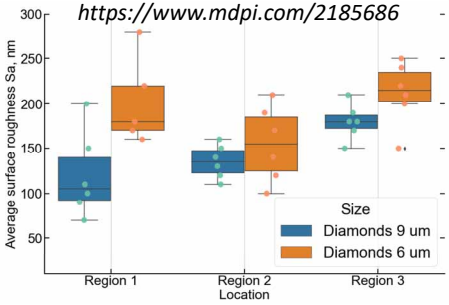
Lapping: removal of 200 um in 3h
Polishing: recover SRF properties for 2h

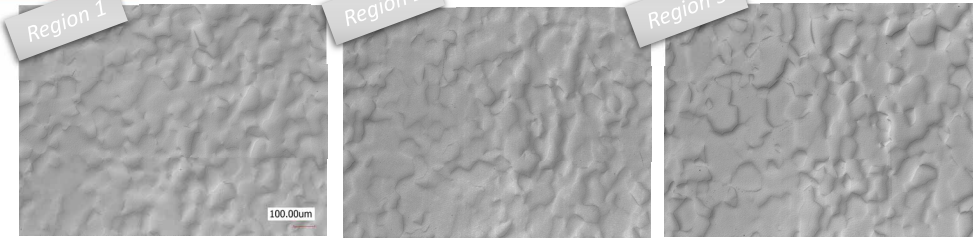


Lapping device

2-3 steps protocol

Visual inspection





O. Hryhorenko, C. Z. Antoine, W. Magnin, M. Rajkumar, F. Brisset, S. Guilet, and D. Longuevergne, "An innovative approach of surface polishing for srf cavity applications," *Journal of Manufacturing and Materials Processing*, vol. 7, no. 2, 2023.

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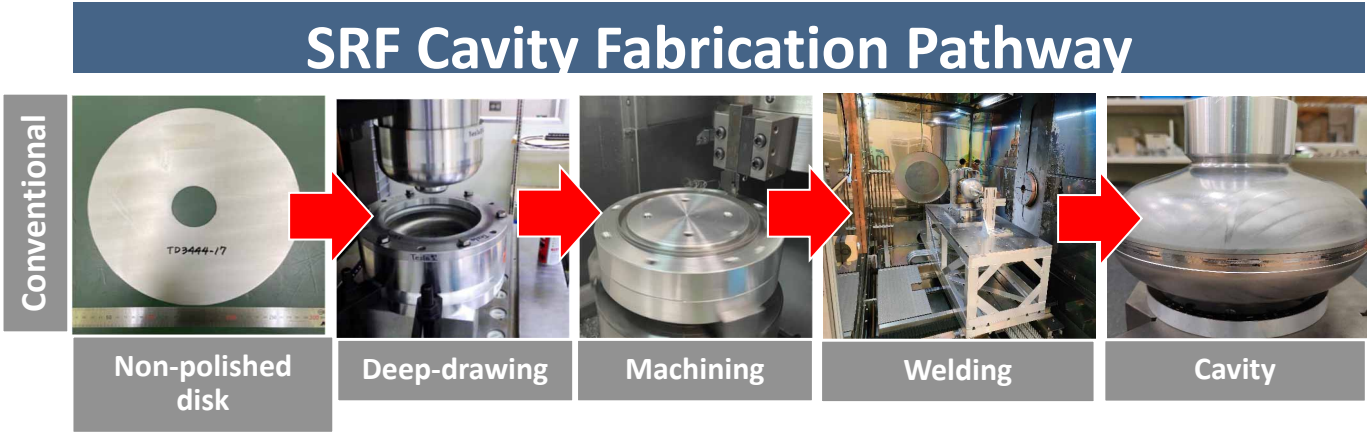
Conventional cavity fabrication route

Poster: WEPWB050

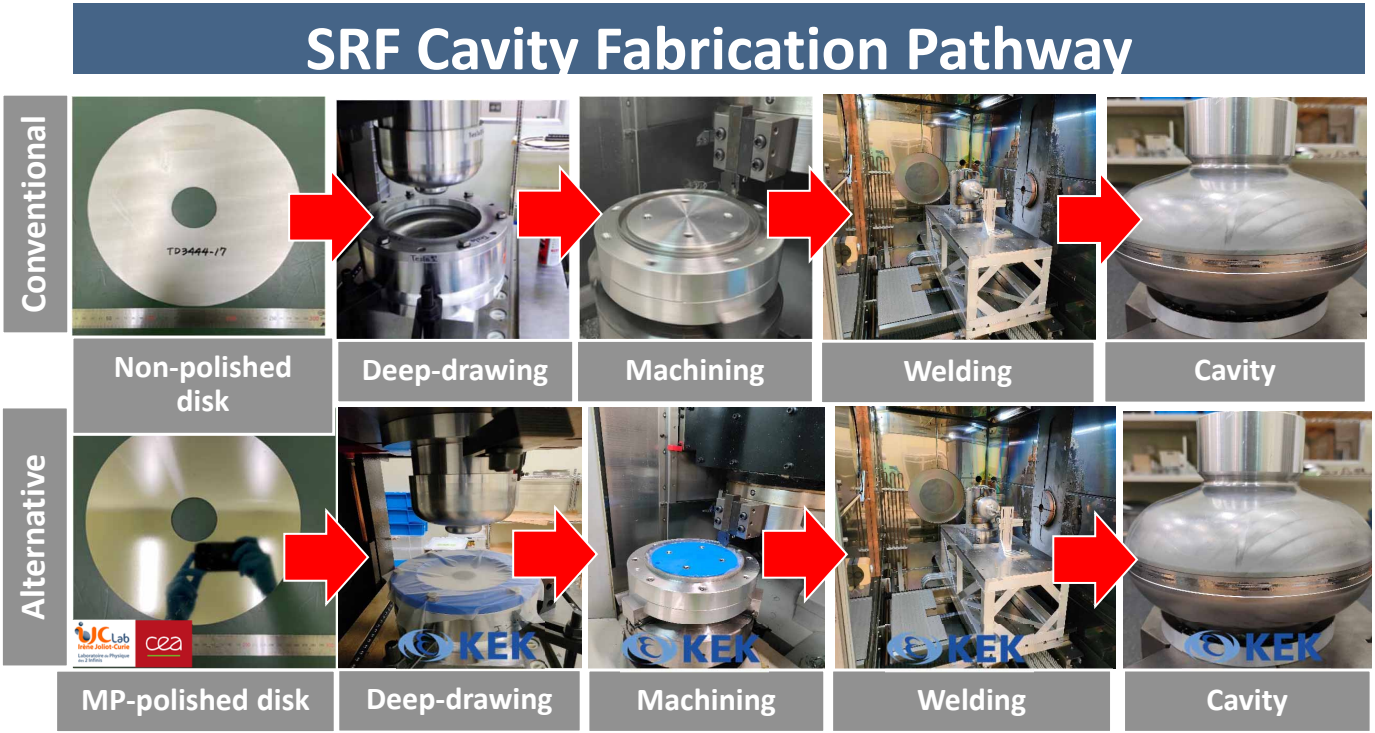
"Exploring innovative pathway of cavity fabrication for SRF application", presented by Oleksandr Hryhorenko (JLAB)



Alternative cavity fabrication route

Poster: WEPWB050

"Exploring innovative pathway of cavity fabrication for SRF application", presented by Oleksandr Hryhorenko (JLAB)

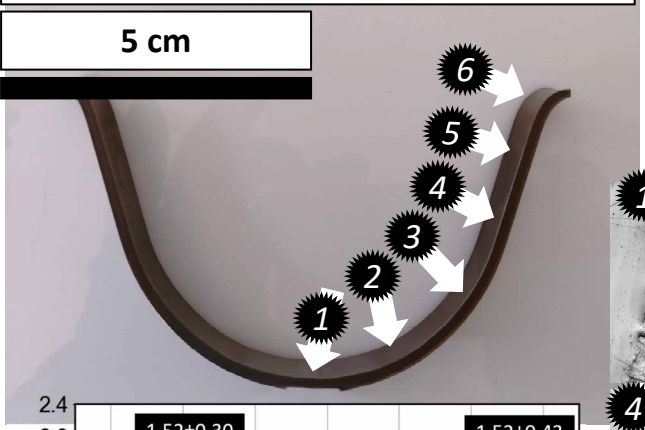


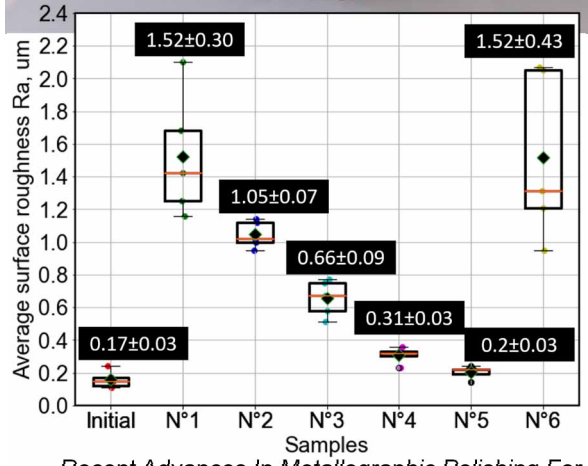
Material analysis: Inner surface

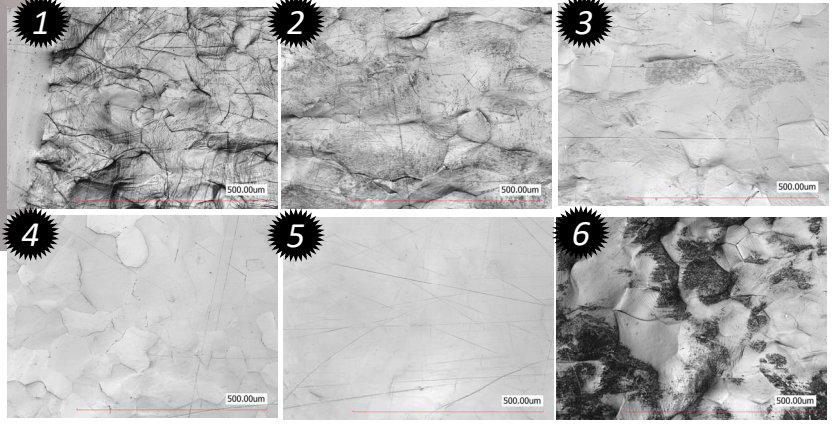
Material analysis: Inner surface

Cut-outs samples

5 cm

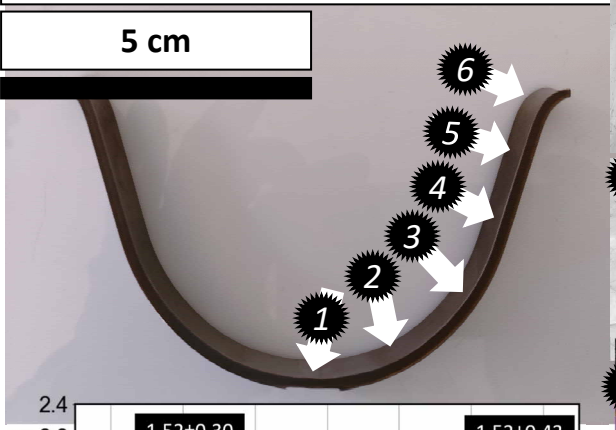


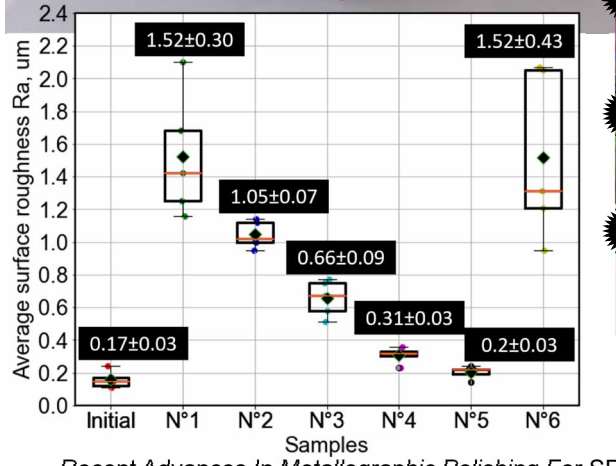


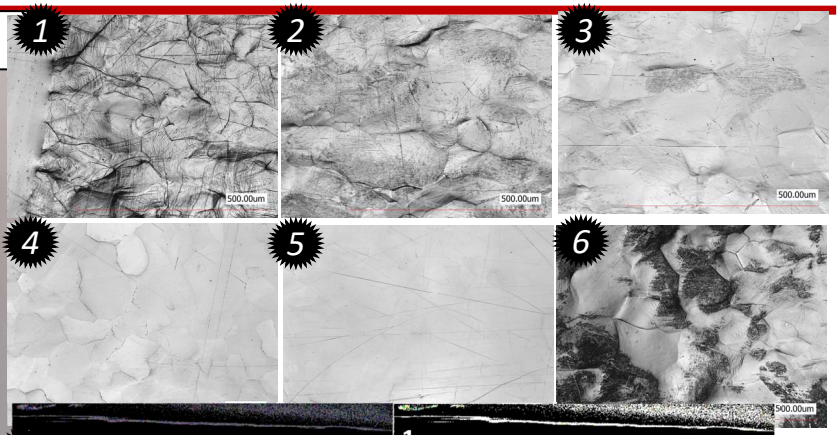


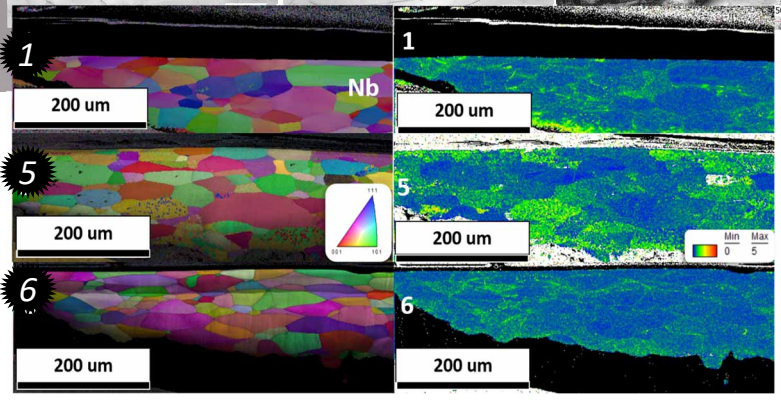
Material analysis: Inner surface

Cut-outs samples

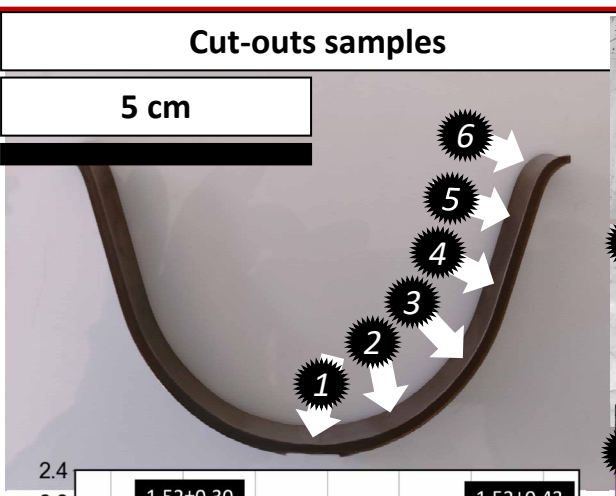


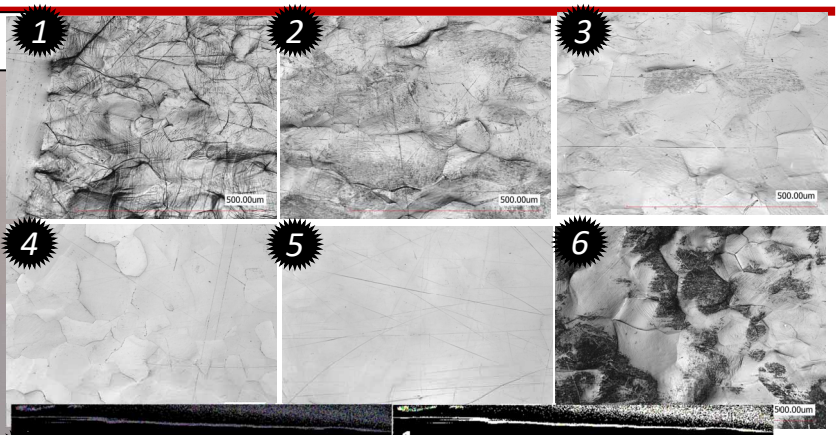


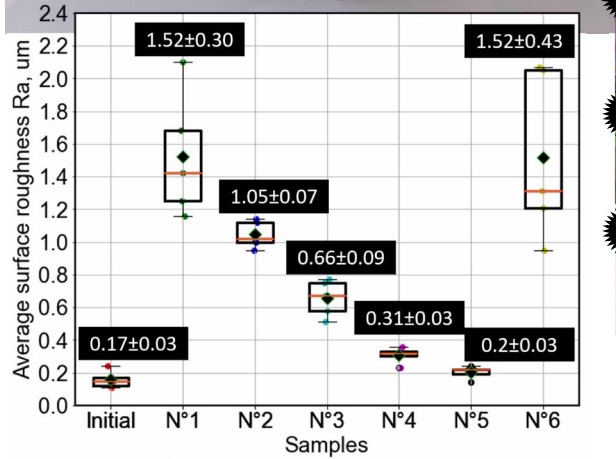


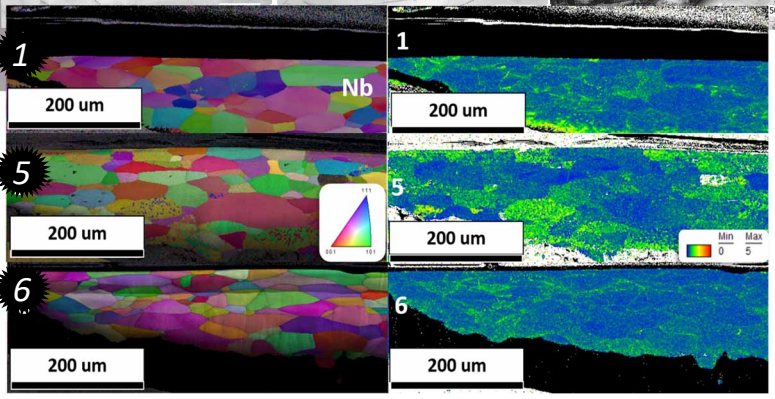


Material analysis: Inner surface









Combined action of an intermediate layer at the interface between dies and disk, and improved final internal surface resulted that the load being better distributed during deep drawing, as well as the better-distributed and reduced friction.

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Conclusions & Future

- MP polishing is a great method to prepare substrates for thin deposition
- MP polishing protocol successfully transferred to large disks
- We fabricated dummy 1.3 GHz cell with a novel approach, applying polishing before fabrication, to study material properties.
- Damages after cavity fabrication are considered to be less than 1 μm and located at revealed new grain GBs.
- Superior level of smoothness and flatness before forming compared to conventional polishing.
- High residual strain at GB might be removed via recrystallization (800 °C, 2h).
- Three additional cavities will be fabricated in the framework of the FJPPL program (one is welded, and 4 half-cells are ready), to study RF performance.

Thank you all for listening !

- Special thanks to Kenji Saito and Ting Xu for hosting SRF 2023