

Investigation of an alternative path for SRF cavity fabrication and surface processing

2024 Joint Workshop of FKPPN and TYL/FJPPN2024/5/22

David Longuevergne, IJCLab/IN2P3

Claire Antoine, IRFU/CEA

Takeshi Dohmae†, Kensei Umemori, iCASA/KEK



Prologue -SRF cavity fabrication-

Nb material manufacturing

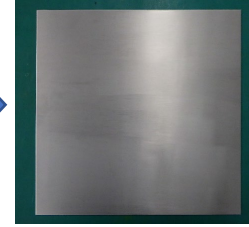
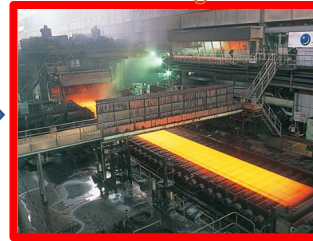
Melting



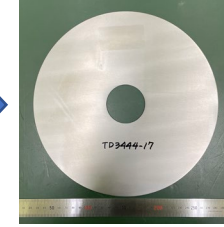
Forging



Rolling



Cutting

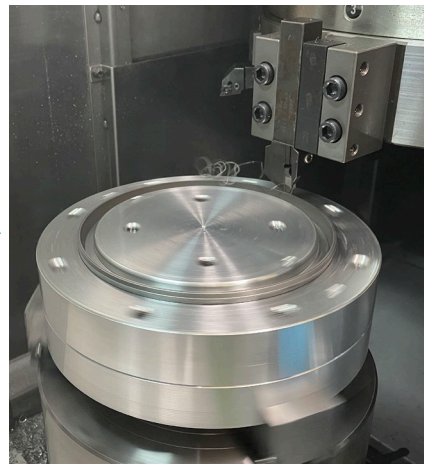


Cavity production

Forming



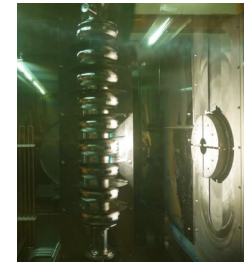
Machining



Chemical polishing



Welding



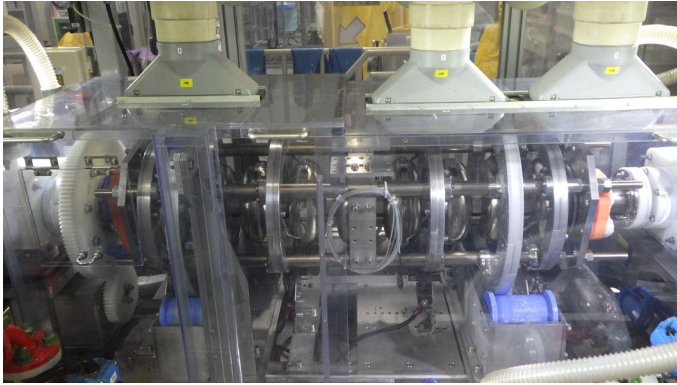
Complete



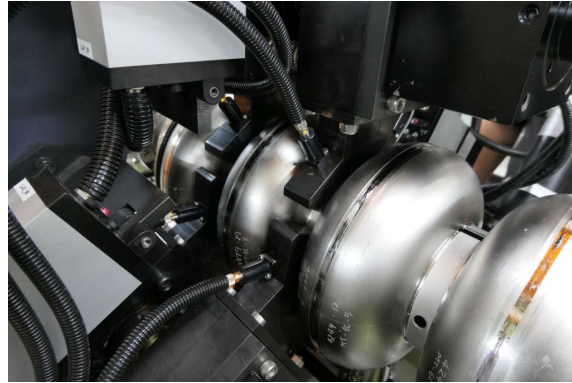
9-cell SRF cavity

Prologue -Surface treatment and preparation for the test-

Electro polishing
100~120 μ m



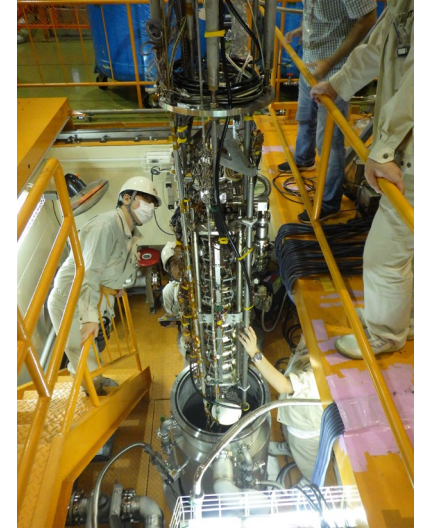
Frequency tuning



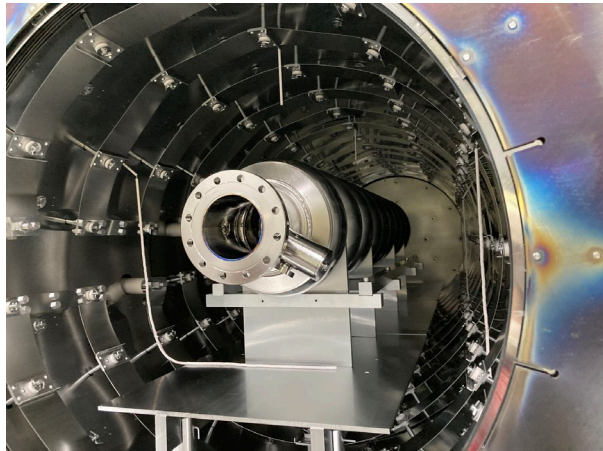
Clean room assembly



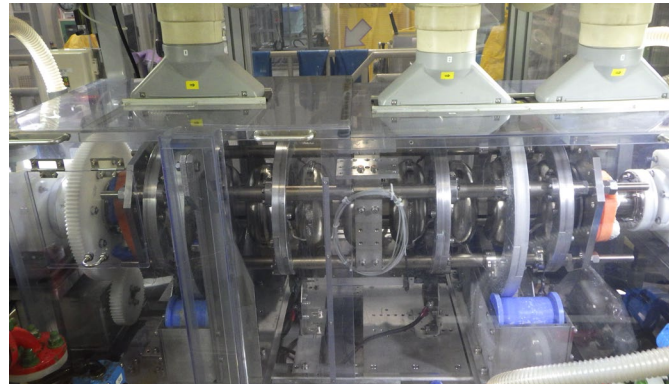
Performance test



Degassing in the vacuum furnace



Electro polishing (20~30 μ m)
Rinsing with UPW



Baking



Motivation

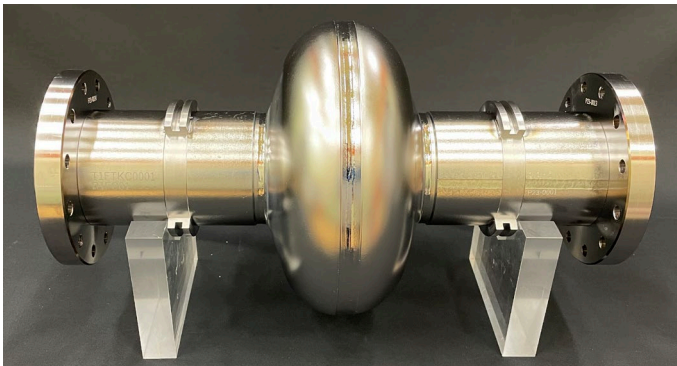
In current surface treatment recipe of SRF cavity, more than 100 μm of the material is removed by electro (or chemical) polishing which uses several **deleterious chemicals** to remove damaged layer produced during Nb sheet manufacturing. (Damaged layer degrades cavity performance.)

In this study, **surface of Nb sheets are previously polished with newly optimized metallographic polishing procedure before forming** to skip (reduce) the electro polishing in the surface treatment process.

This results;

- **reduction of the cost of the conventional electro polishing,**
- **improvement of environmental footprint and worker safety,**
- **preparation of the substrate for superconducting thin film coated cavities,**
- **push up the cavity performance.**

Example of 1-cell cavity

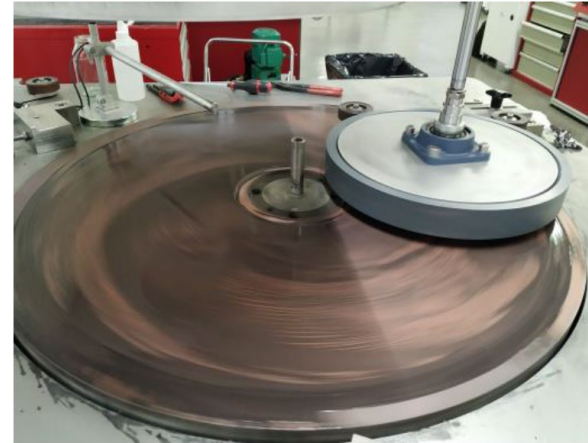


Our goal in this collaboration;

- **Fabricate three 1-cell cavities with pre-polished discs.**
- **Measure their performances.**

Metallographic polishing

Metallographic polishing removes the damaged layer produced during Nb sheet manufacturing but creates localized minor damages on a surface (significantly lower than standard mechanical polishing).



Cavity fabrication with metallographic polishing

Nb material manufacturing

Melting



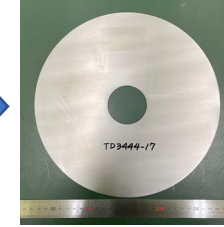
Forging



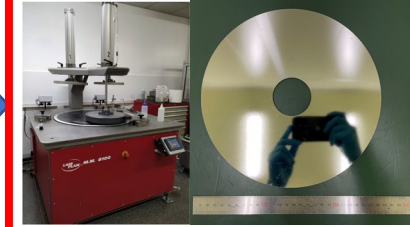
Rolling



Cutting



Polishing



Cavity production

Forming

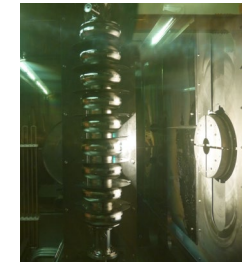


Machining



half-cell

Welding



Light chemical polishing

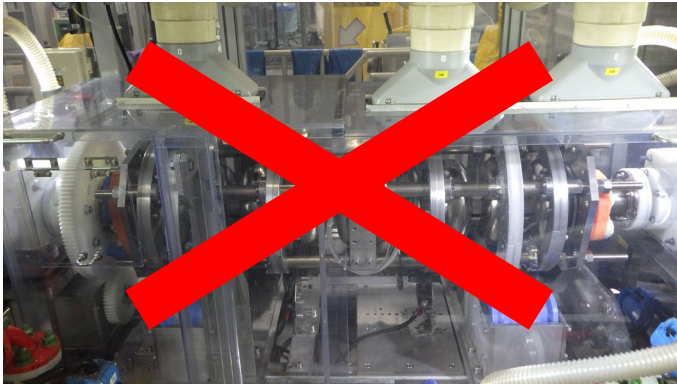


Complete

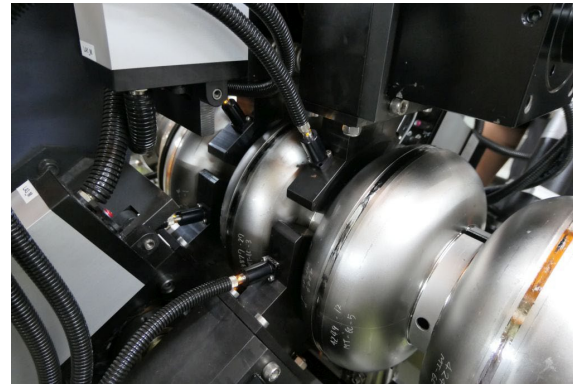


Preparation for the test with metallographic polishing

Electro polishing
100~120 μ m



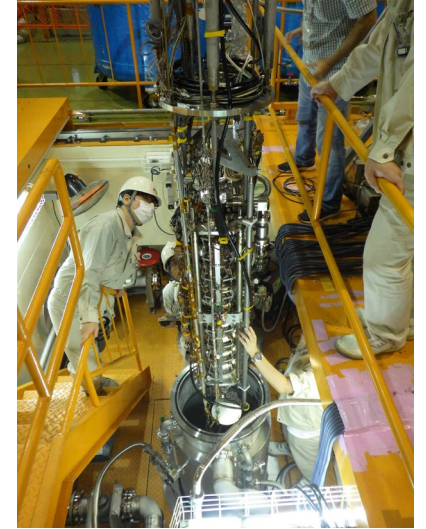
Frequency tuning



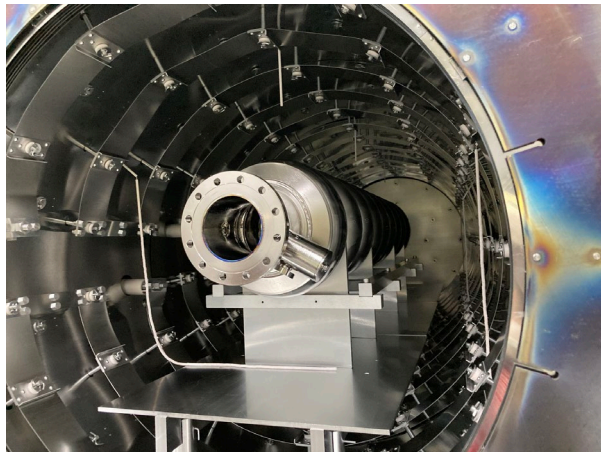
Clean room assembly



Performance test



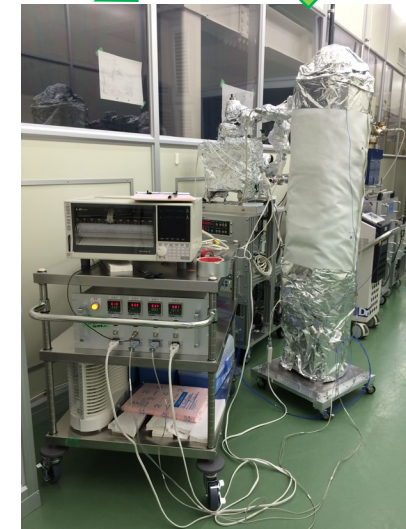
Degassing in the vacuum furnace



Electro polishing (20~30 μ m)
Rinsing with UPW



Baking

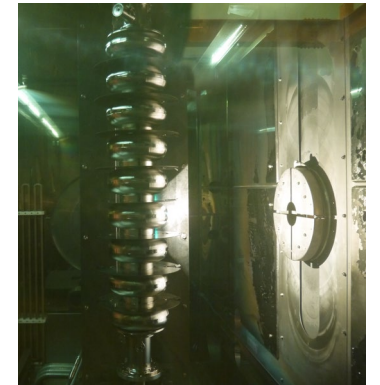
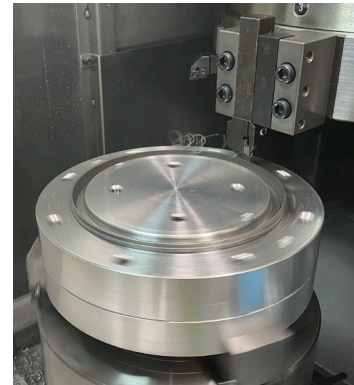
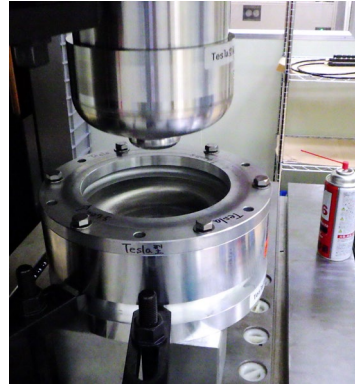


Our roles

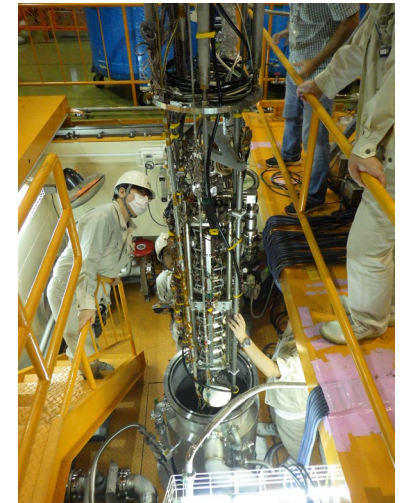
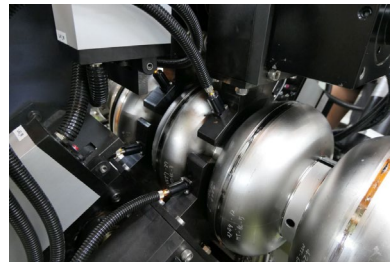
IJCLab/IRFU: Polishing, Analysis



KEK: Fabrication



IRFU/KEK: Surface treatment, Performance test

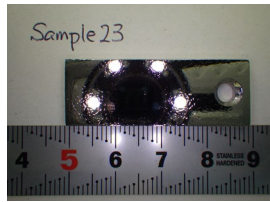
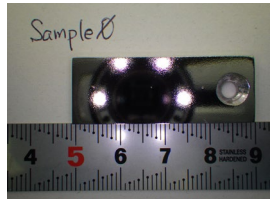


Our activities

Activities in 2020-2021

Sample test was performed in the first year.

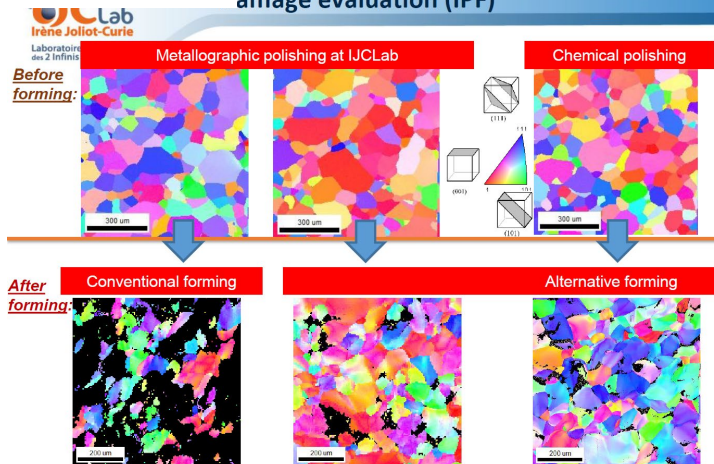
IJCLab/IRFU



Polishing

Analysis

Damage evaluation (IPF)



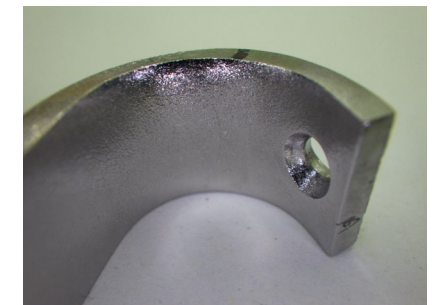
11/05/2021

Oleksandr Hryhorenko, TYL/FJPL & FKPL, 10-12th of May 2021

KEK



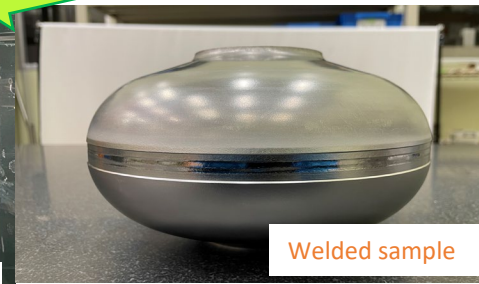
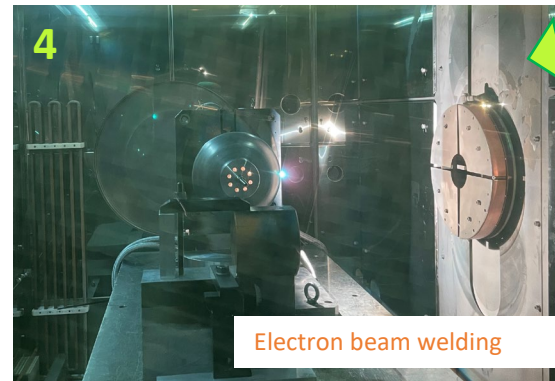
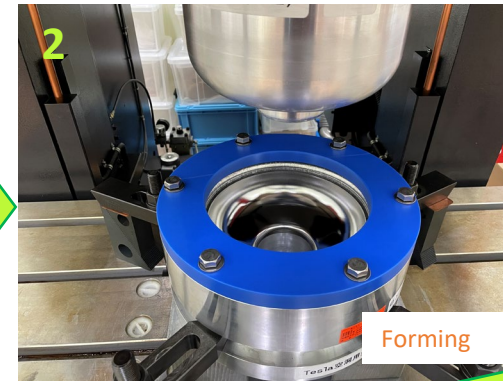
Forming



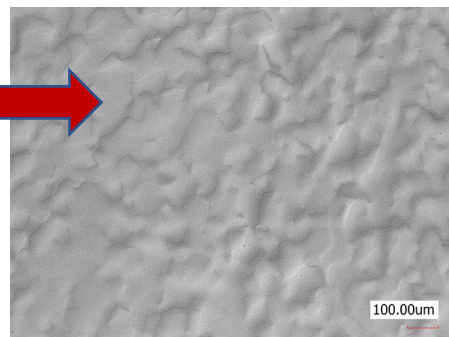
Activities in 2021-2022

Simulation of cavity fabrication

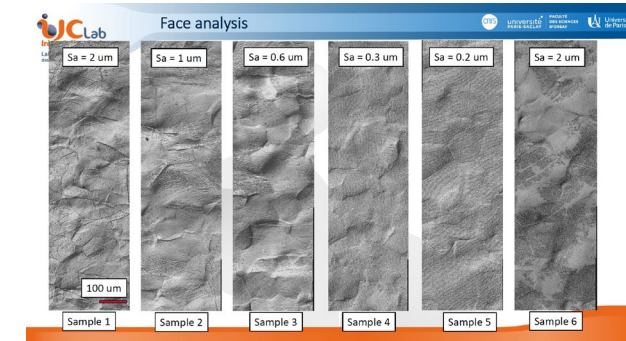
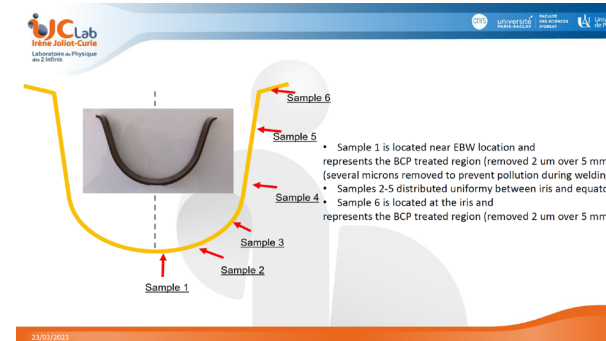
1. A niobium disc was polished.
2. Disc was formed into half-cell shape of cavity.
3. Edges of half-cell were machined.
4. Half-cell was electron beam welded (typical welding procedure) with another dummy half-cell.
5. Welded sample is now under characterization.



Observation of polished disc by laser microscope



5. Characterization



Activities in 2022-2023 (Materials)

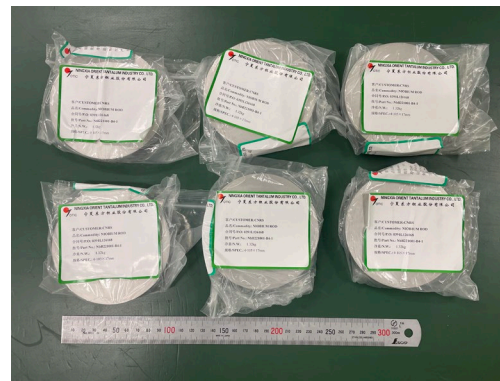
Six discs for three 1-cell cavities were polished at LAM PLAN (France).
Other materials for parts of 1-cell cavities were also prepared by France.



NbTi for flange



Nb for fixture ring



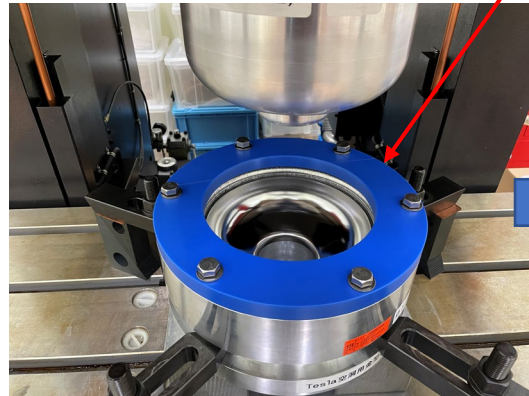
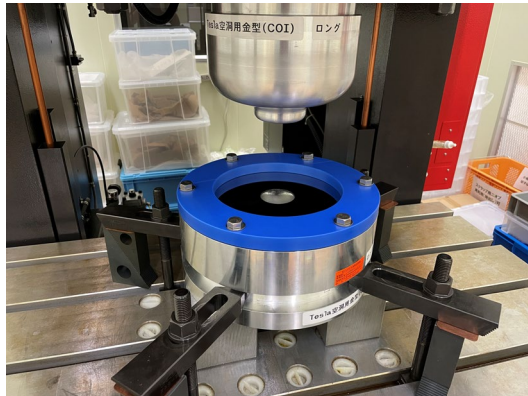
Beam tube



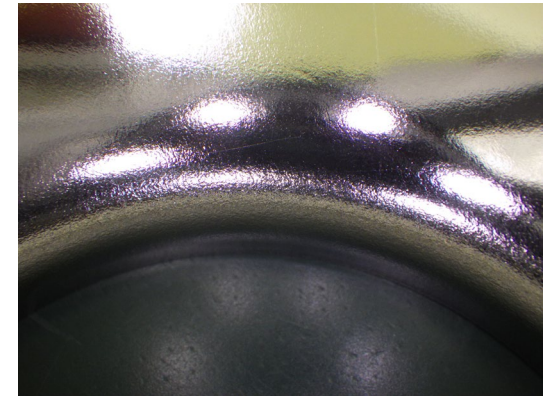
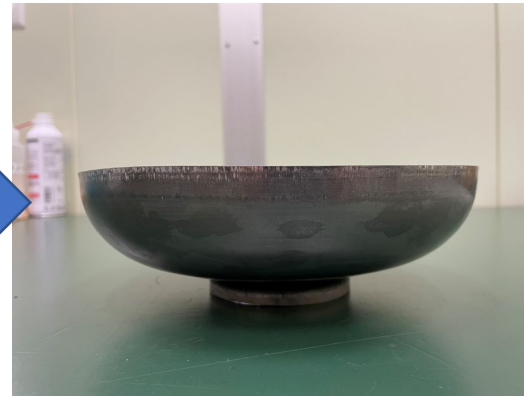
Activities in 2022-2023 (Fabrication1)

Polished discs were shipped to Japan (KEK).
They were then press-formed into half-cell shape.
A special tooling which does not scratch Nb surface was additionally produced.

Oleksandr Hryhorenko visited KEK and worked together

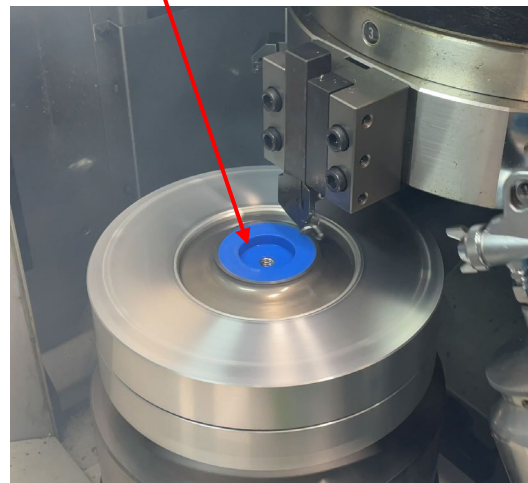


Special tooling



Edges of formed half-cell were then machine processed.
A special tooling was also employed not to scratch Nb surface.

Special tooling



A special care is necessary when we treat these half-cells.

Activities in 2022-2023 (Fabrication 2)

Reported at the joint workshop in 2023

Machine processed half-cells were washed in the ultra-sonic bath and edges were chemically polished to remove oil used during machine processing.

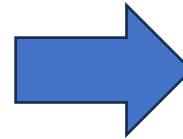
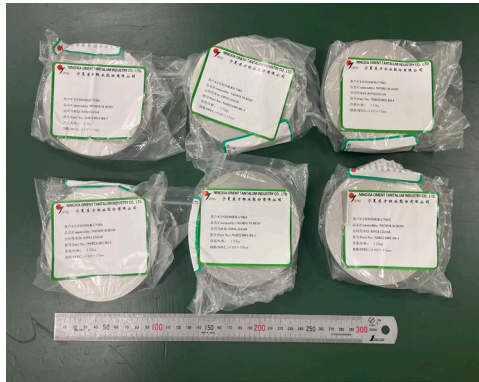
Two half-cells were assembled and welded by electron beam welding in the vacuum chamber.

Four half-cells were left un-welded.



Activities in 2023-2024 (Fabrication 1)

All materials were machined into final shape.



Activities in 2023-2024 (Fabrication 2)

Some parts were welded together.



Three cavities were named “Eclat”, “Kagayaki” and “SHINE”.



The latest situation

The 1st cavity “Eclat” will be completed soon.



Epilogue -Summary and future plan-

- We are aiming to fabricate SRF cavity with Nb discs which are metallographically polished before fabrication.
- Cost reduction of cavity polishing, improvement of environmental footprint and worker safety can be achieved using polished discs for the cavity.
- Six polished discs were already formed, and two of them were already welded.
- Parts for the cavity were already machined, and some of them were already welded.
- **The 1st cavity “Eclat” will be completed soon.**

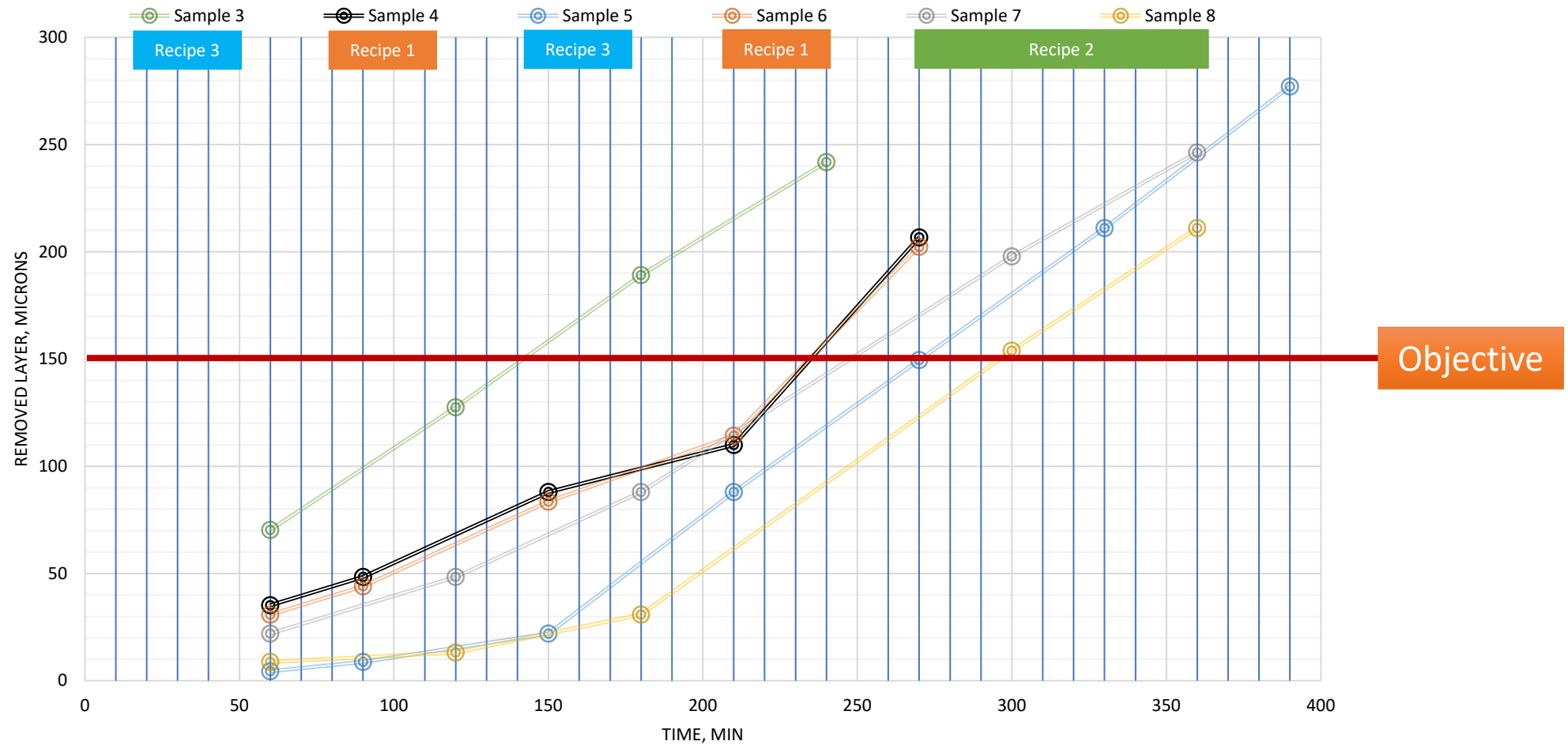
Future plan

- Three 1-cell cavities will be fabricated at KEK in FY2024.
- Some of them will be sent back to France, and their performance will be measured after minimum surface treatment process.
- The performance of left cavity will be also measured at KEK after minimum surface treatment process.

Backup

Activities in 2022-2023 (polishing of discs)

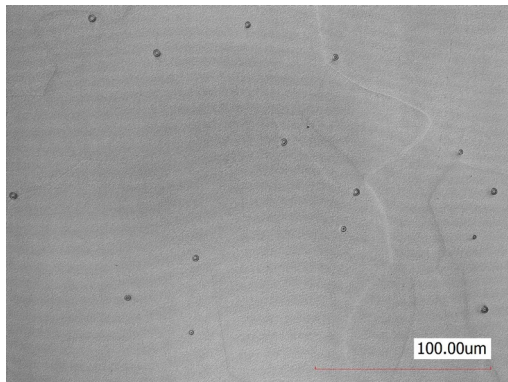
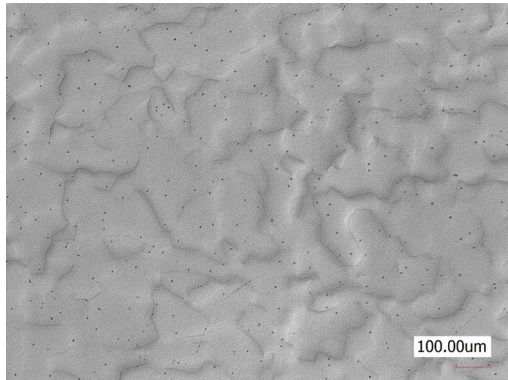
Removed layer vs time



Activities in 2022-2023 (Cleaning of discs)

Discs were then cleaned for surface analysis.

Before cleaning

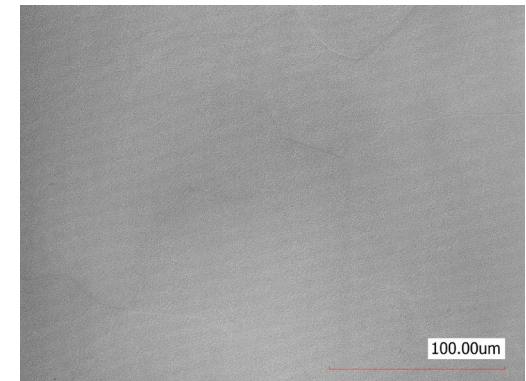
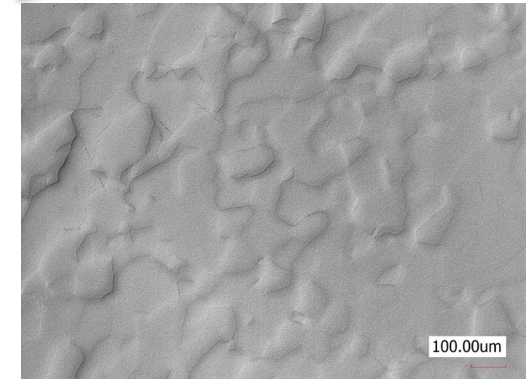


IJCLab procedure of cleaning recipe

1. Ultrasonic cleaning with UPW, 20 minutes, 50°C
2. Rinsing with UPW, 2 minutes
3. Drying with N spray gun
4. Disk ready for analysis



After cleaning



Activities in 2022-2023 (Polishing of discs)

Nb discs for 1-cell cavities were polished at France.
Three recipes were performed.

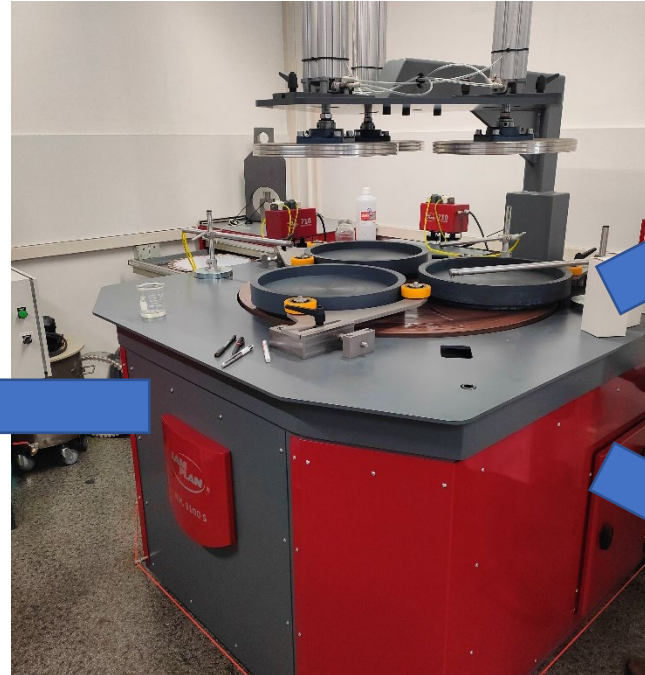
Recipe 1 (2 steps)

Lapping

Patented disk NEW LAM VERT
+ polycrystalline diamonds of
9 μ m

Polishing

Adhesive cloth 4MP2 + liquid
final (SiO₂ + chemical
compound) – 150 minutes



Recipe 2 (2 steps)

Lapping

Patented disk NEW LAM VERT
+ polycrystalline diamonds of
6 μ m

Polishing

Adhesive cloth 4MP2 + liquid
final (SiO₂ + chemical
compound) – 150 minutes

Recipe 3 (3 steps)

Lapping

1. Patented disk NEW LAM VERT + polycrystalline diamonds of 9 μ m
2. Patented disk NEW LAM VERT + polycrystalline diamonds of 6 μ m

Polishing

Adhesive cloth 4MP2 + liquid
final (SiO₂ + chemical
compound) – 150 minutes

Sample



NEW LAM VERT

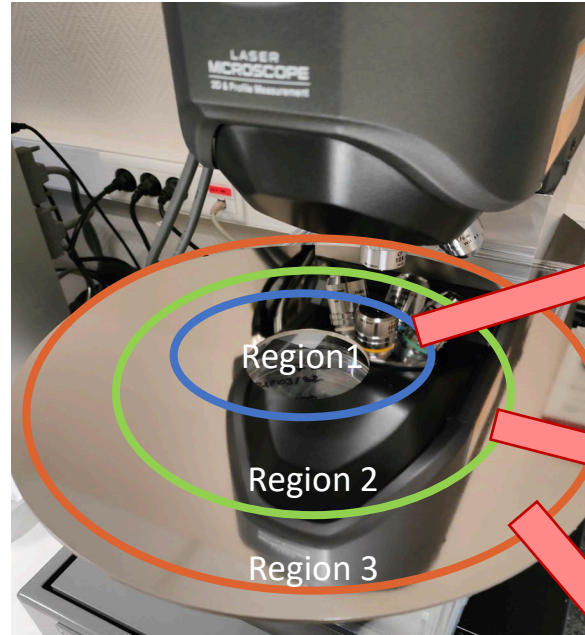
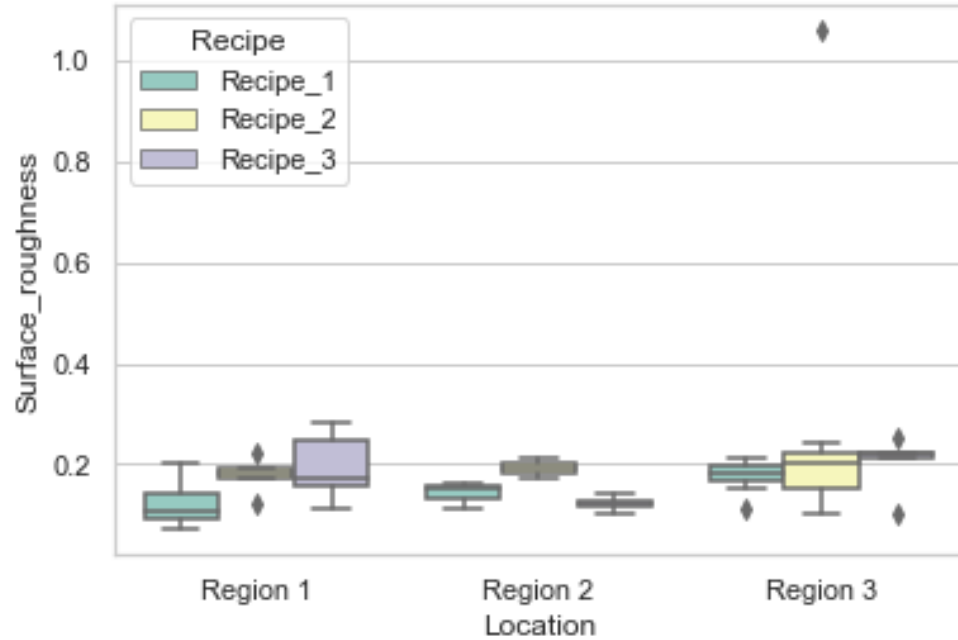


Cloth 4MP2



Activities in 2022-2023 (Surface analysis)

Surfaces of polished discs were then observed.



Recipe 2 and 3 result in a less scratched surface, more uniform grain size revealed, more uniform surface, but some of defects are incredibly huge, and localized at the edge of the disks.