Study of an Alternative Polishing Technique for SRF Cavities

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12^{th} of June 2018

Outline

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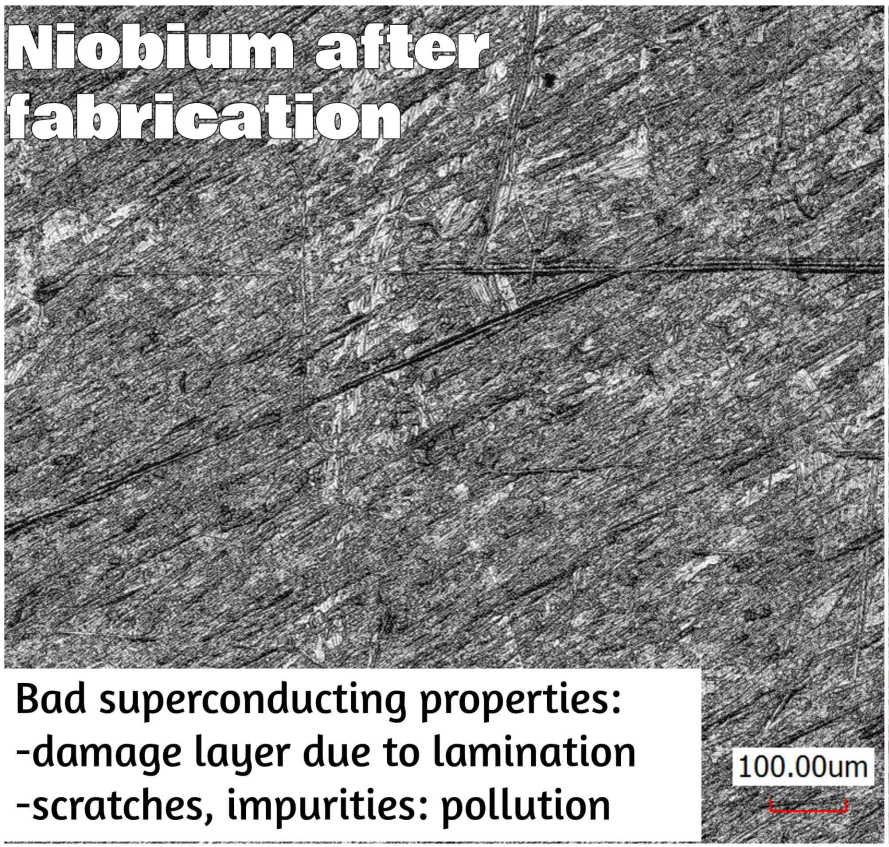
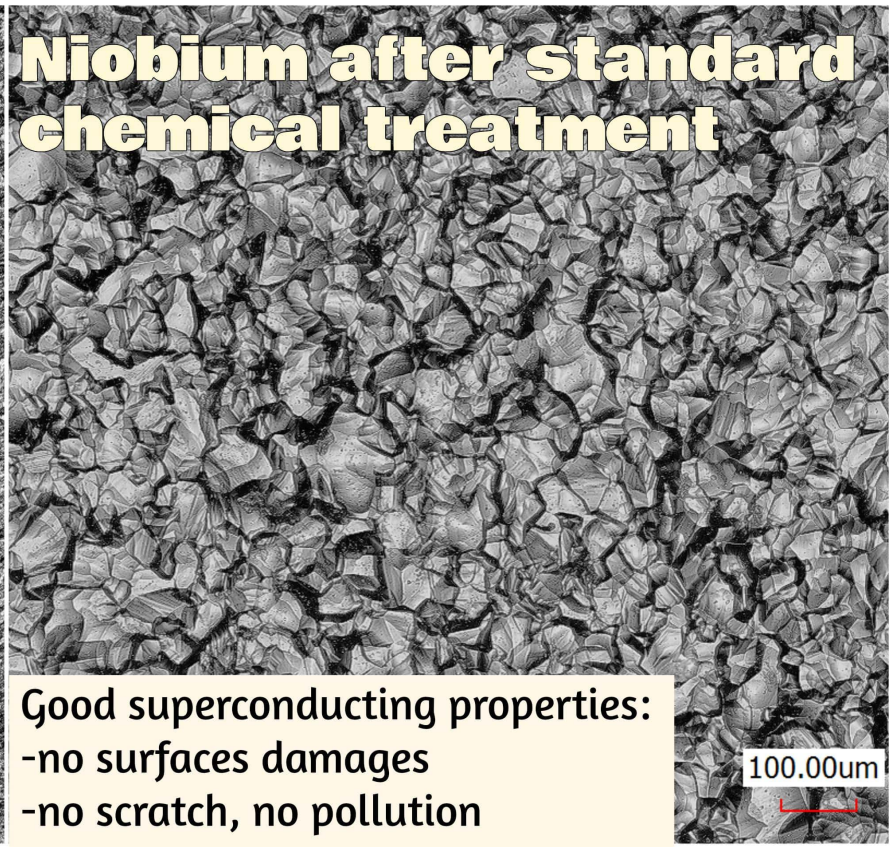
Why surface polishing for SRF cavities?



Bad superconducting properties:
-damage layer due to lamination
-scratches, impurities: pollution



Good superconducting properties:
-no surfaces damages
-no scratch, no pollution

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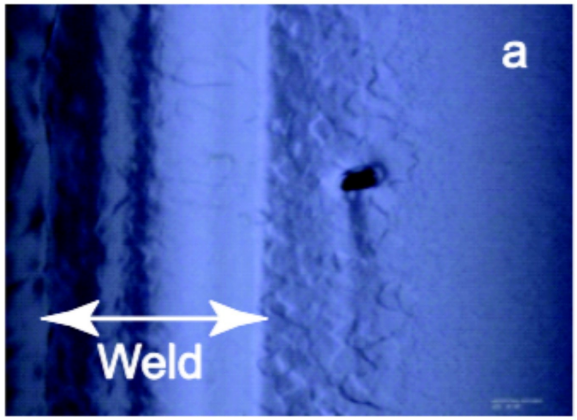
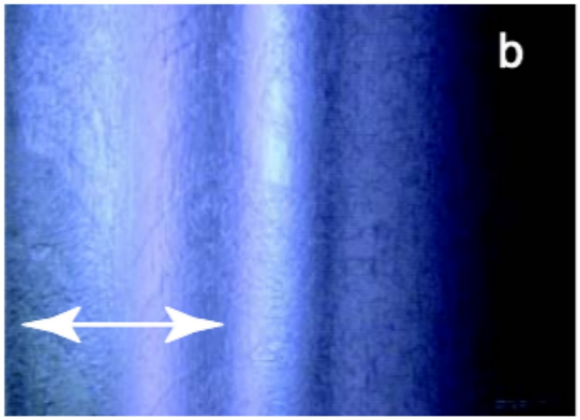
Motivation for alternative polishing





- Safety, recycling
- Possible reduction of the Niobium cavity processing cost
- Cure a surface where chemical polishing is inefficient (a-EP, b-CBP)
- Achieve better surface roughness (BCP $\sim$ 1 um, EP $\sim$ 100 nm, MP $\sim$ 10 nm)
- Surface preparation of substrates for alternative SRF material thin film deposition (Nb3Sn, multilayer ...)

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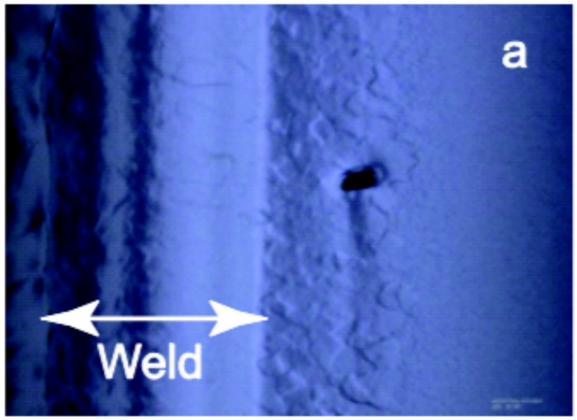

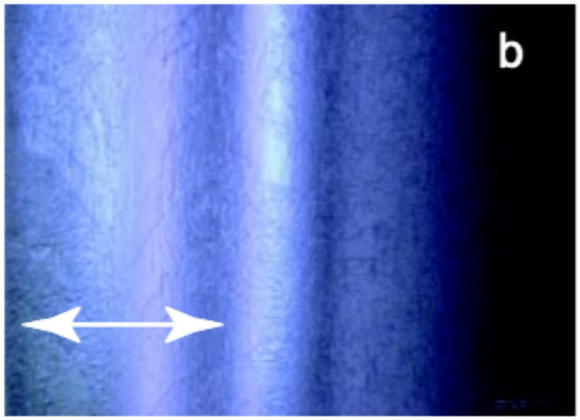

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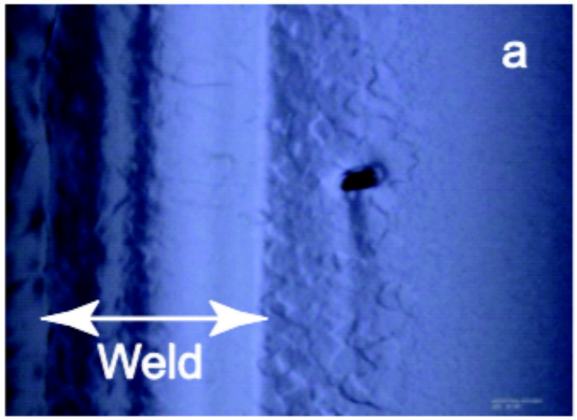

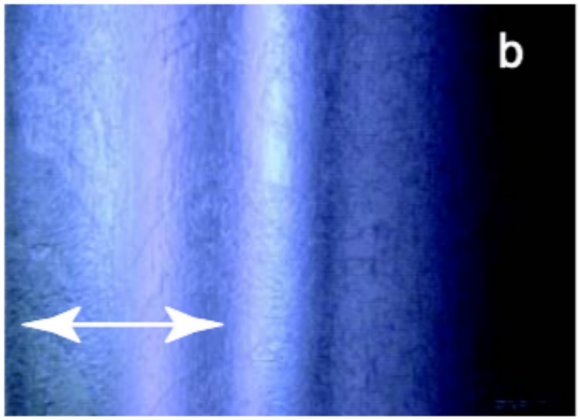

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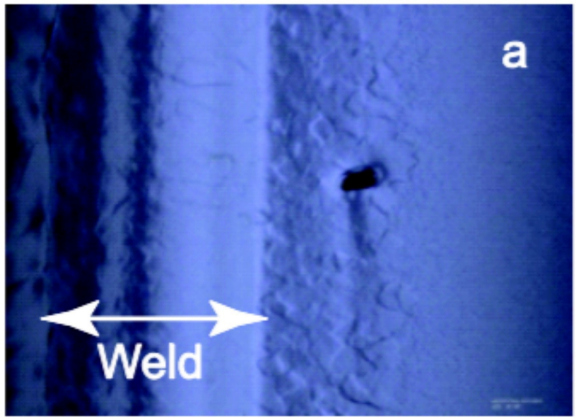

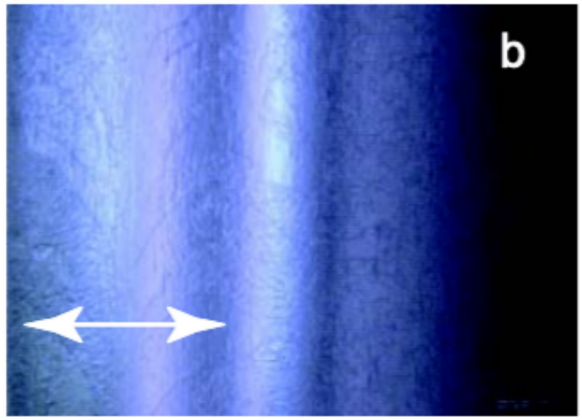

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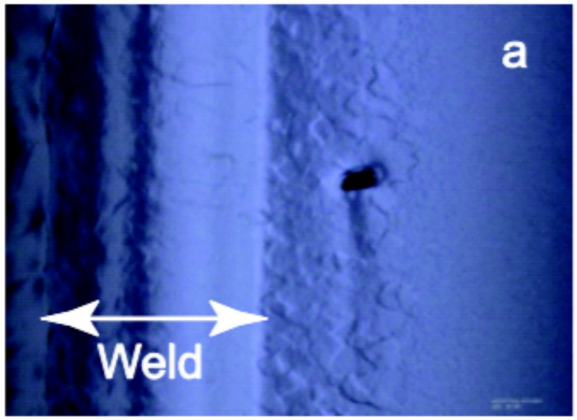

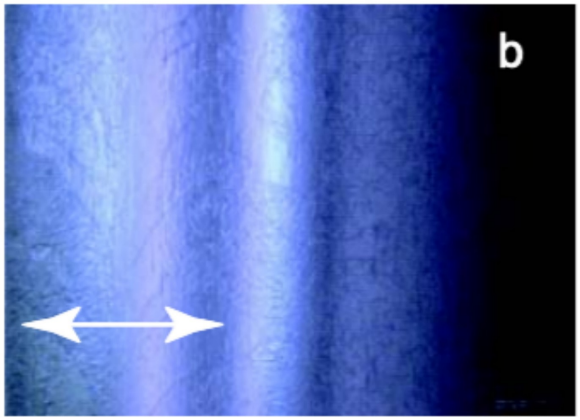

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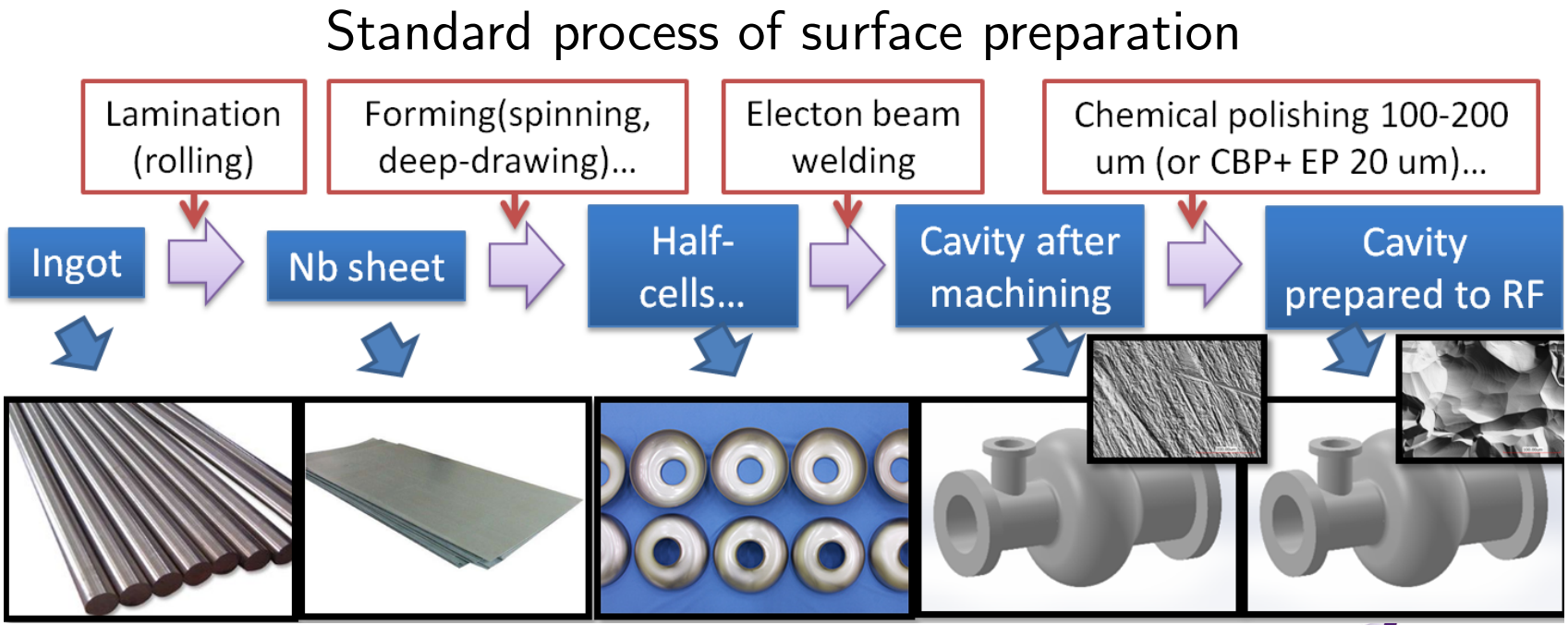
  1. abrasion step
  2. polishing step

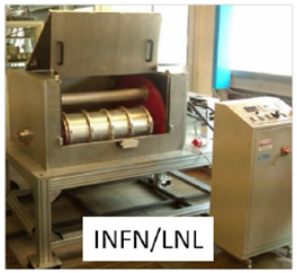
Scenario 1: Polishing after forming



Centrifugal Barrel Polishing (CBP): State of the art

CBP machines

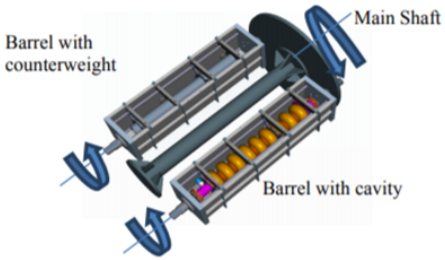
Custom built for 1.3 and 6GHz



Mass Finishing for 1.3GHz

Custom built for 1.3GHz

Mass Finishing for 0.65 and 1.3GHz



[A. D. Palczewskiy, C.A. Cooper et al., R&D progress in SRF Surface Preparation with Centrifugal Barrel Polishing (CBP) for both Nb and Cu]

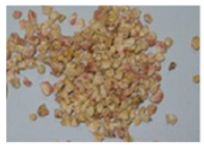
Standard CBP recipe

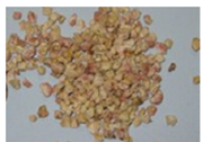
Course - K&M ceramic

Medium - RG-22 cones

Polish 1 - 800 mesh powder & carrier - hard wood blocks/corn cobs

Polish 2 - 40 nm colloidal silica & carrier - hard wood blocks/corn cobs



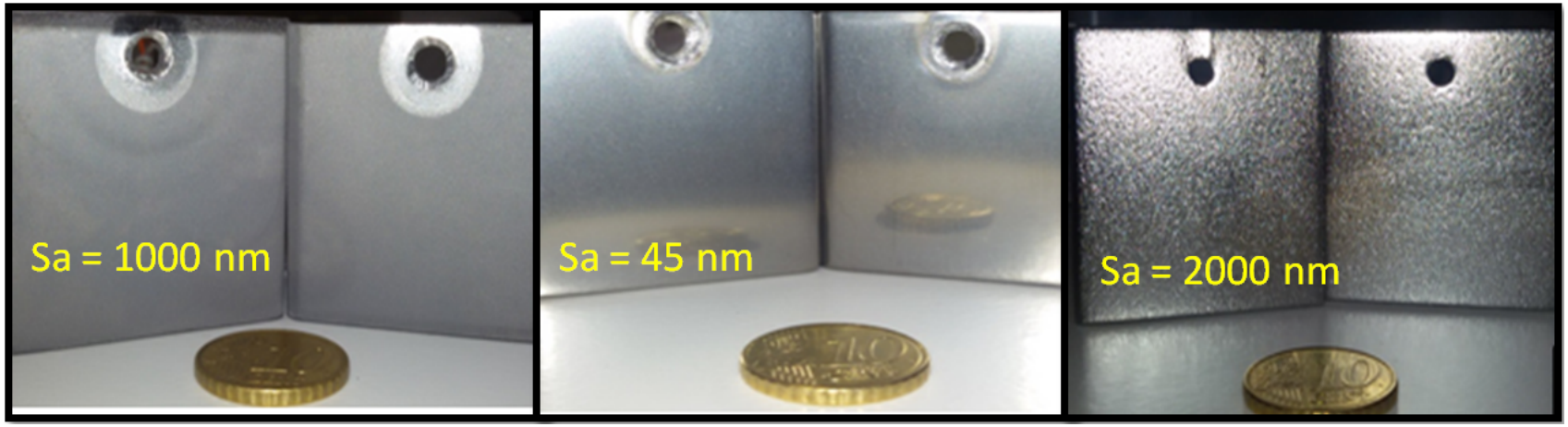


Outline

CBP at IPNO

Centrifugal Barrel Polishing machine with oblique axis

CBP at IPNO



Advantages

- Smoother surfaces compare to chemical treatment

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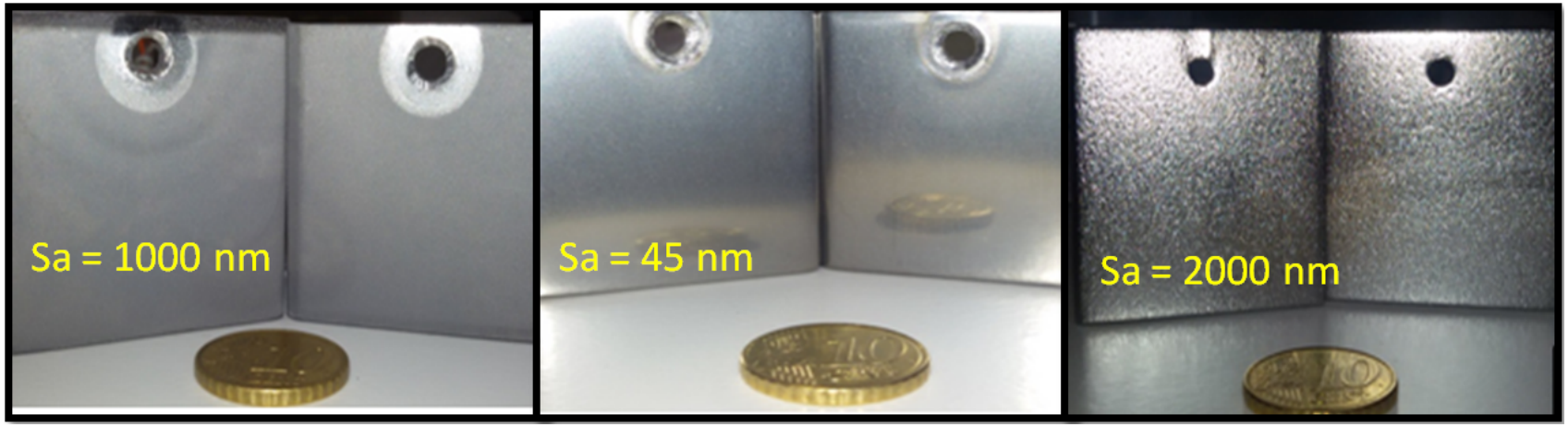
CBP at IPNO



Advantages

- Smoother surfaces compare to chemical treatment
- Safety-wise process

IPN
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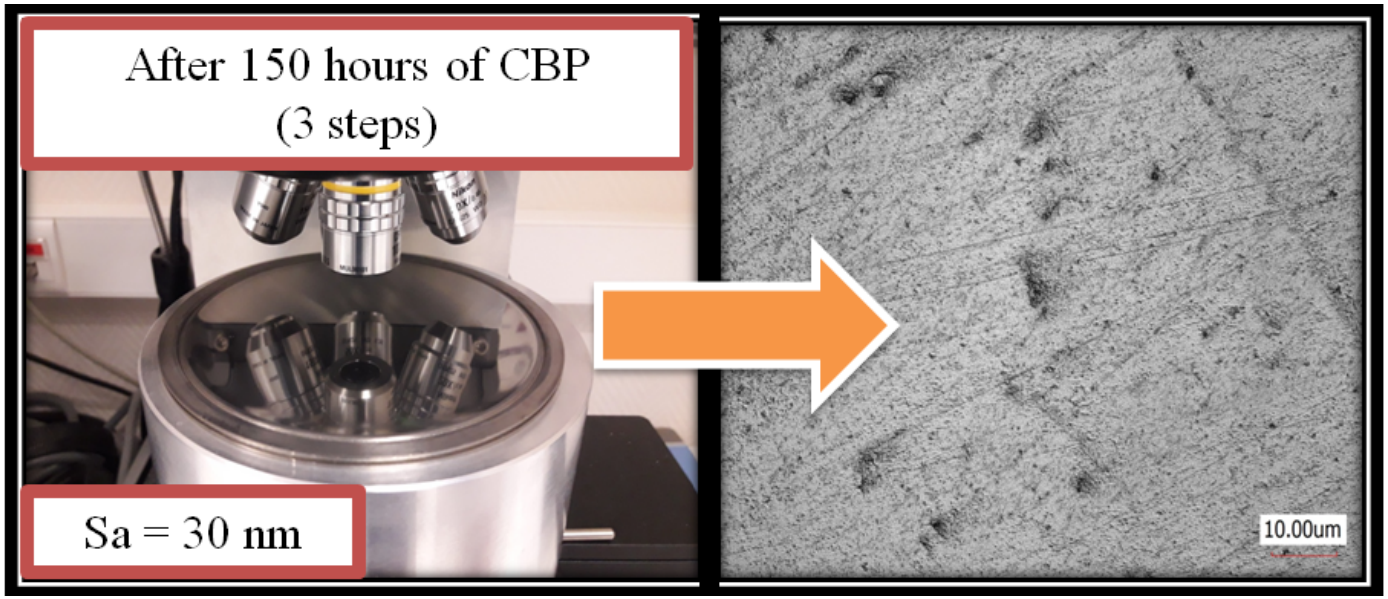
CBP at IPNO



Disadvantages

- Strong contamination of surface by abrasives particles

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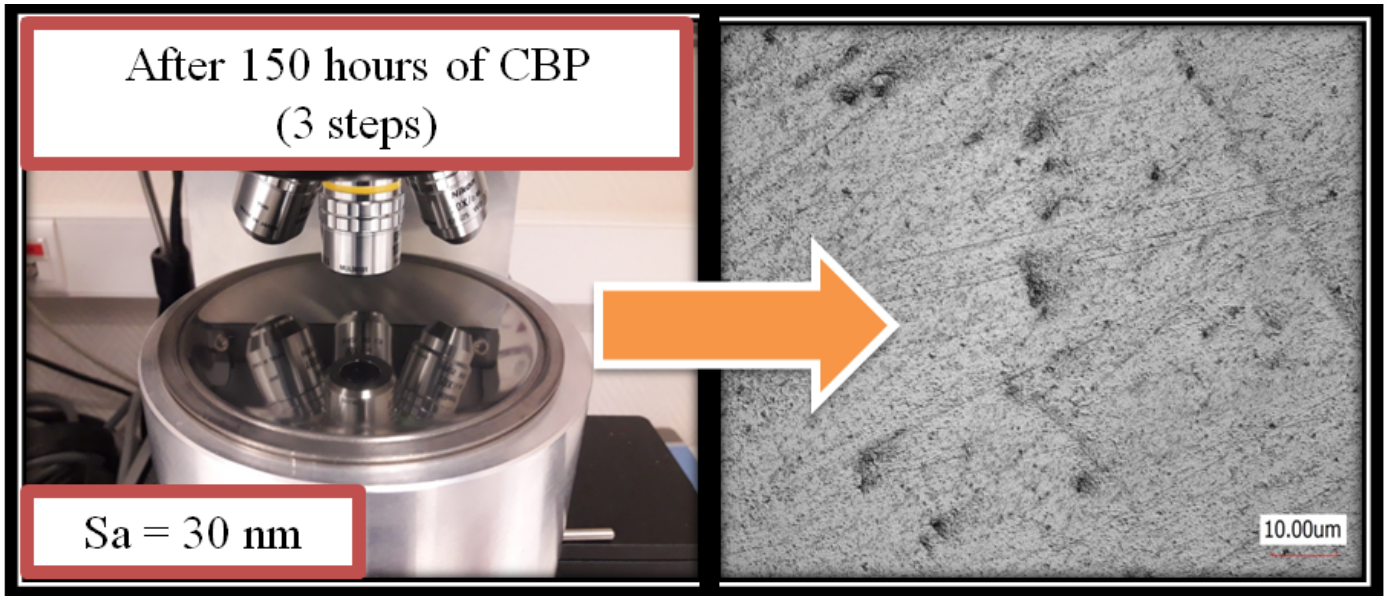

Disadvantages

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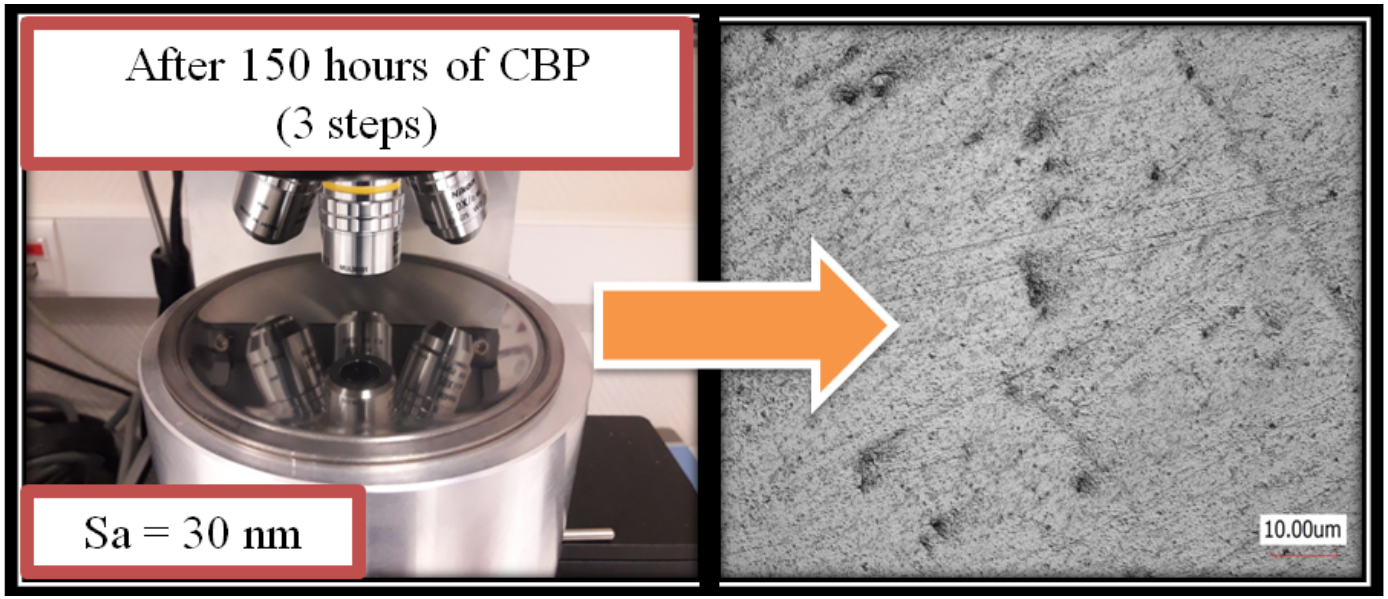

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- CBP at JLAB,... is 96 hours, at IPNO is 150 hours (3 steps)

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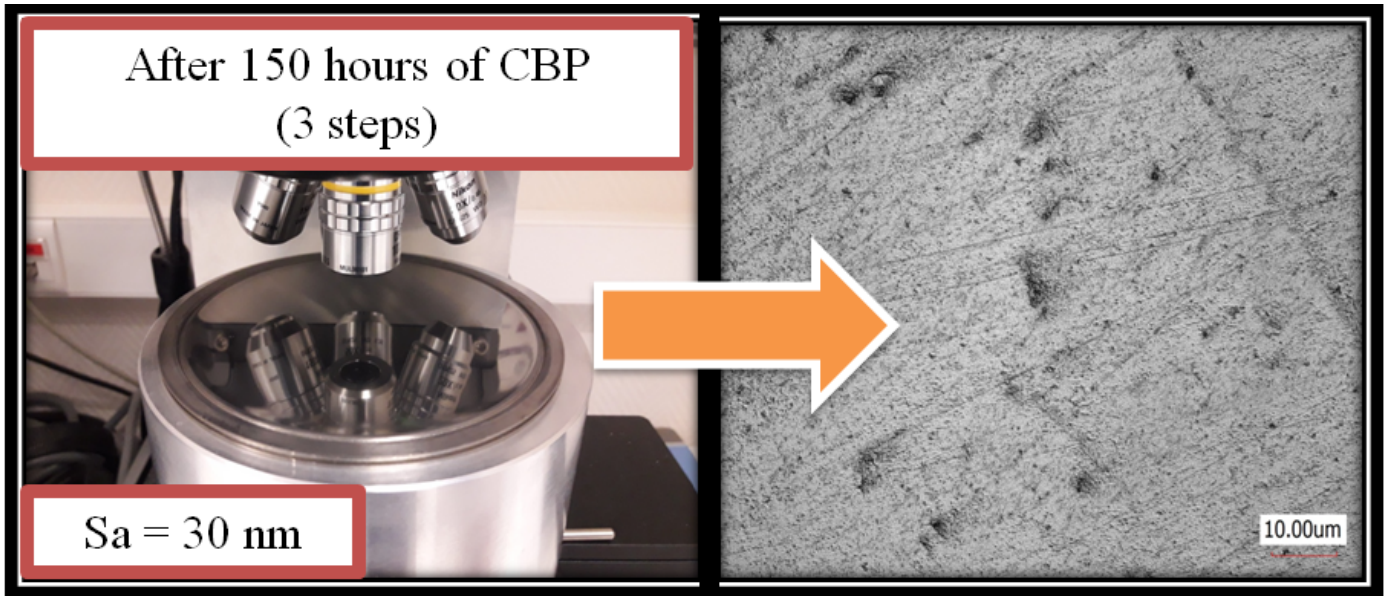
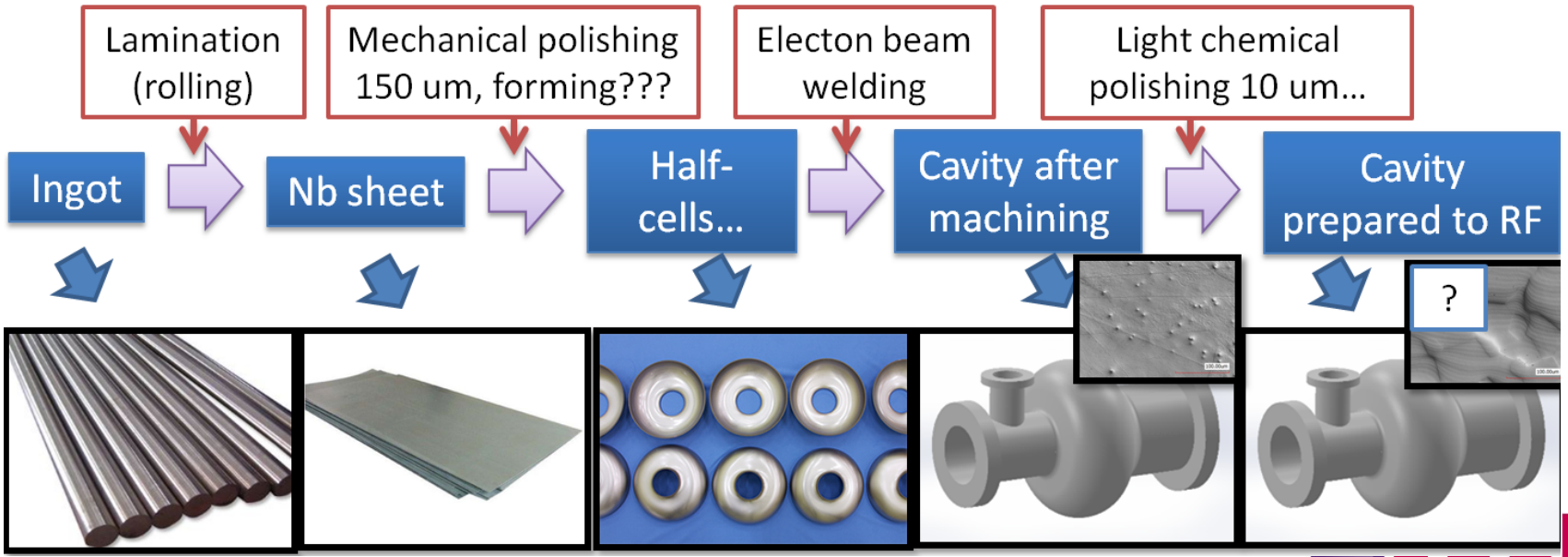


Disadvantages

- Strong contamination of surface by abrasives particles
- Time of treatment is considerably longer
- CBP at JLAB,... is 96 hours, at IPNO is 150 hours (3 steps)
- Non-uniform removal rate (Egor Tamashevich PhD thesis at DESY)

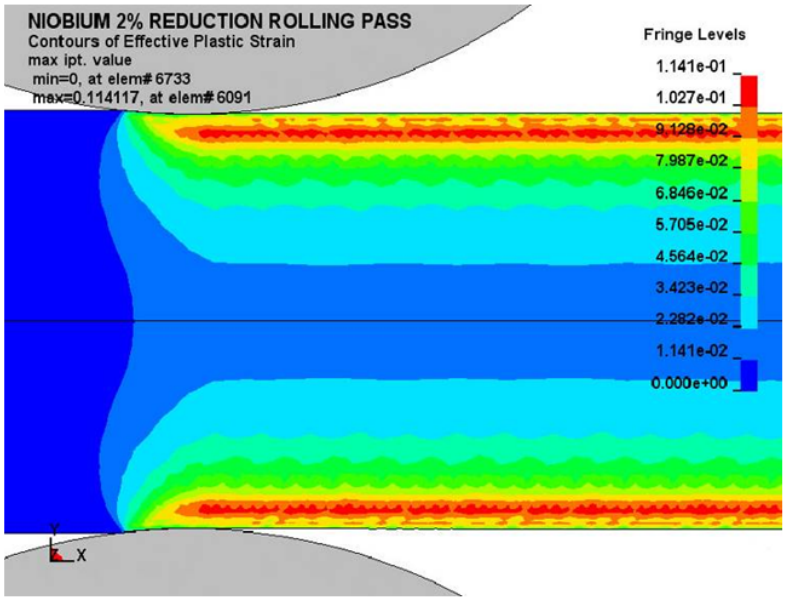
Scenario 2: Polishing before forming

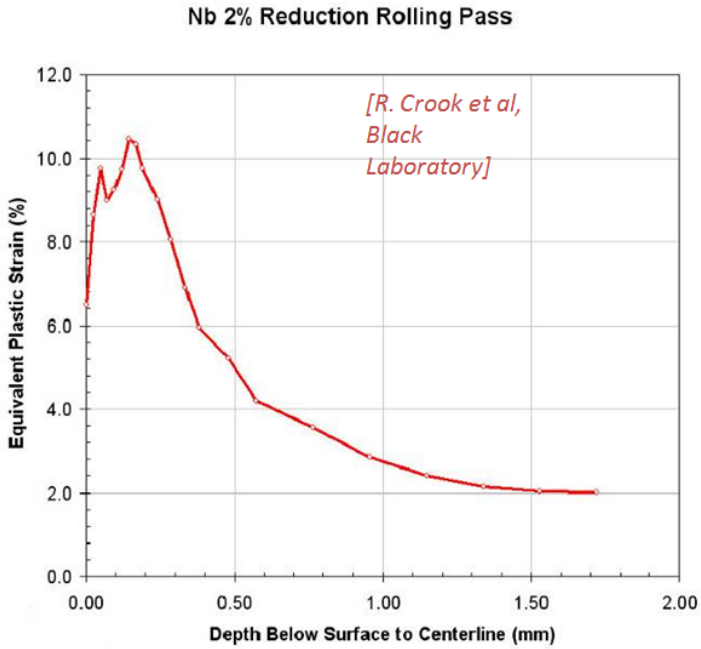
C.Z. Antoine proposed a new way of surface preparation for next generation of accelerator projects (ILC, FCC...)

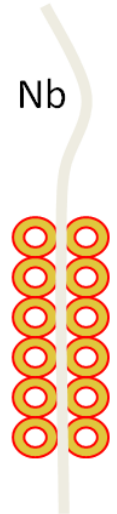


Scenario 2: Polishing before forming

Lamination leaves a damage layer approximately 150 microns with a structure resistant to recrystallization







Courtesy of C.Z. Antoine

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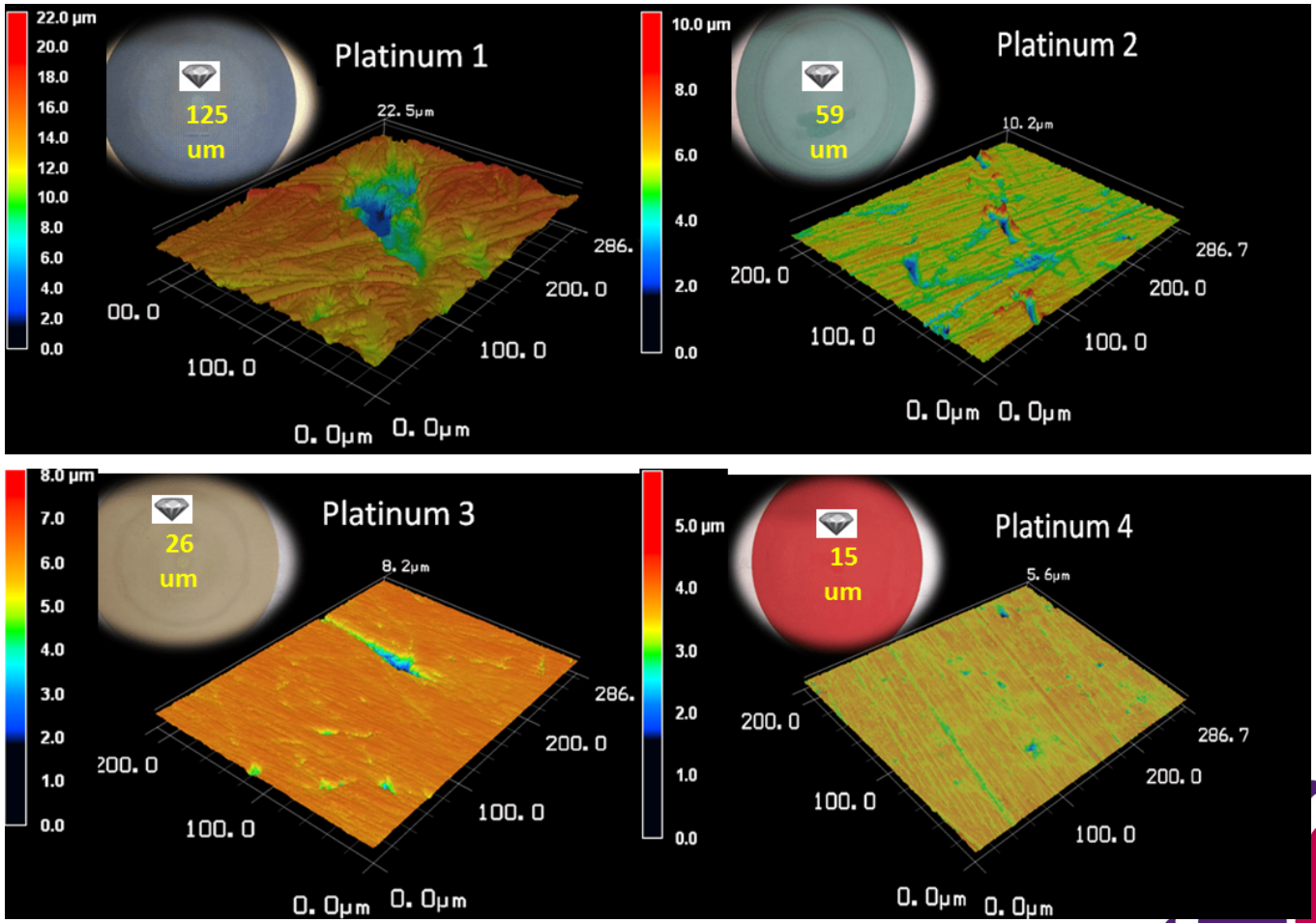
Second scenario: Metallographic flat polishing at IPNO

Mechanical polishing requirements

- Abrasion step
  1. High etching rate
  2. Limited pollution
  3. Limited surface damages (scratch, artifacts...)
- Polishing step
  1. Remove damages/pollution from previous step
  2. Decrease roughness to tens of nm

Study of abrasion step: diamonds as abrasives



Fixed abrasives

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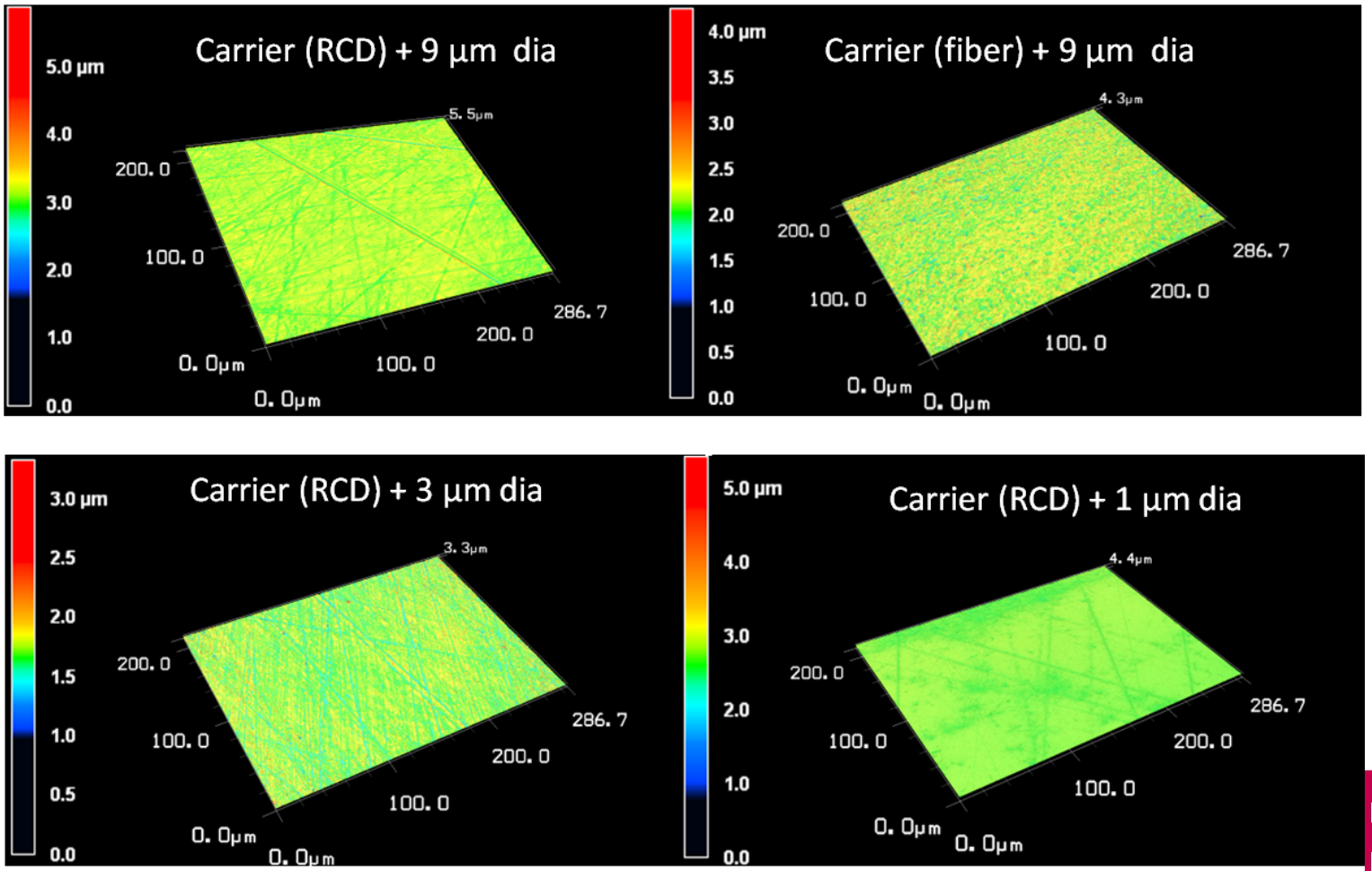
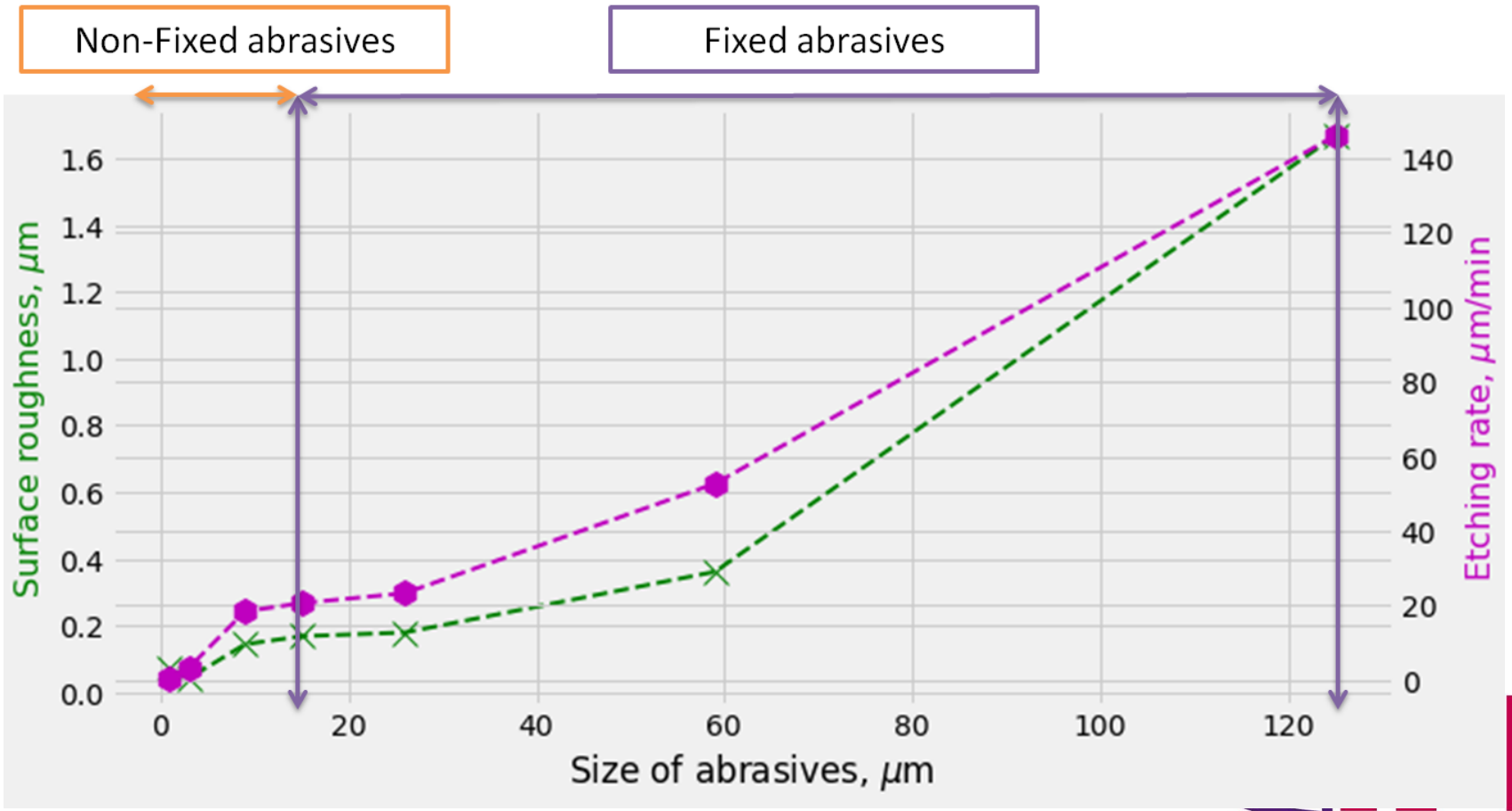
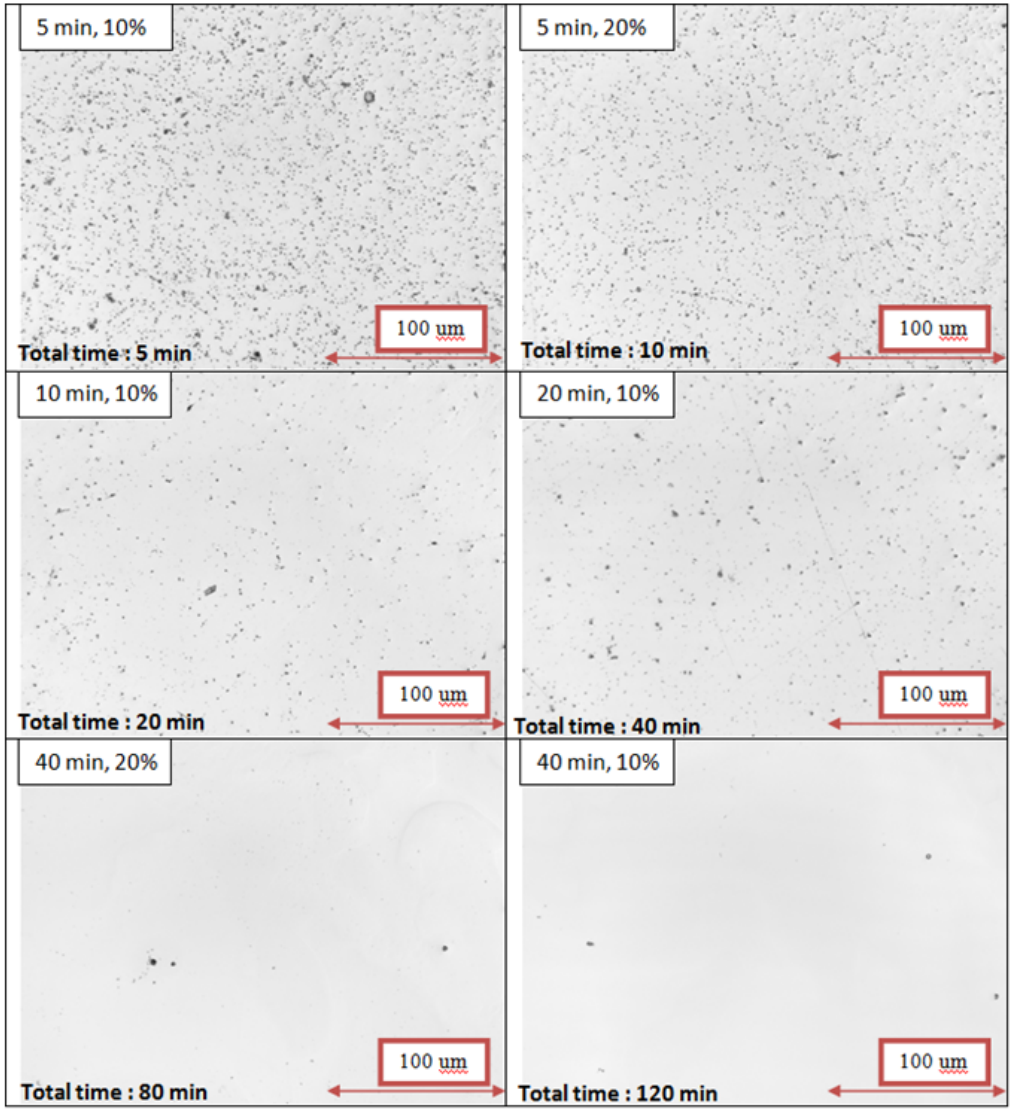


Non-Fixed abrasives

Etching rate and average surface roughness Sa



Study of polishing step: colloidal silica

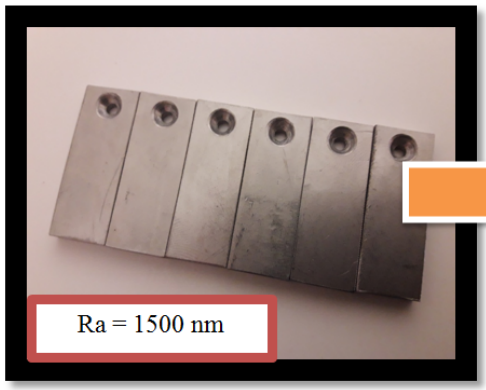


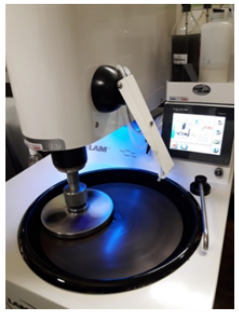
Study of polishing step: colloidal silica

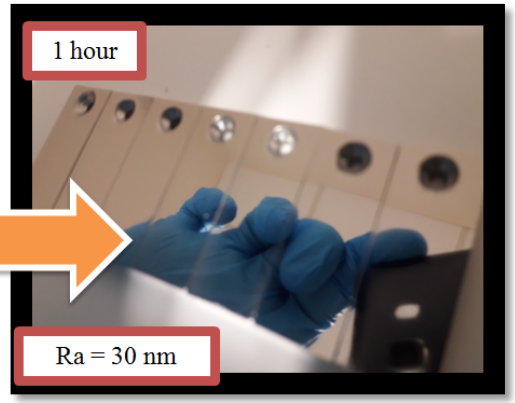
Final polishing recipe in 2 steps

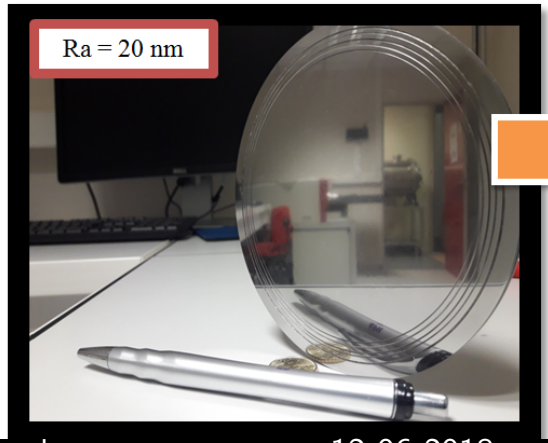
1. Rigid composite disk + non-fixed 3 um diamonds

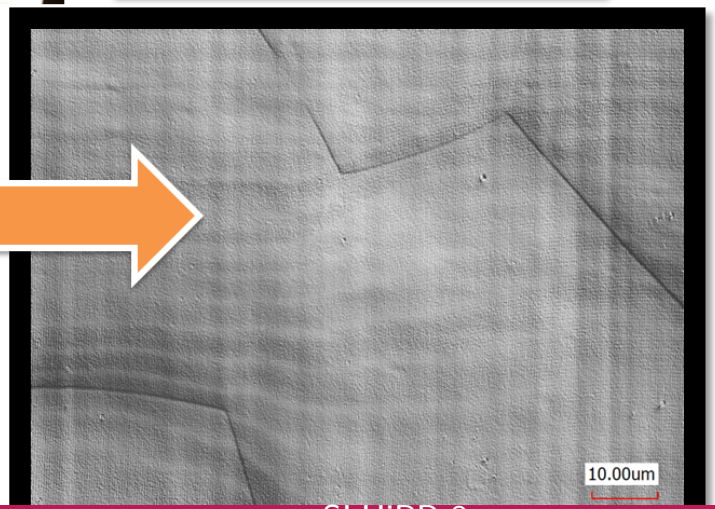
2. Polyurethane cloth + colloidal silica



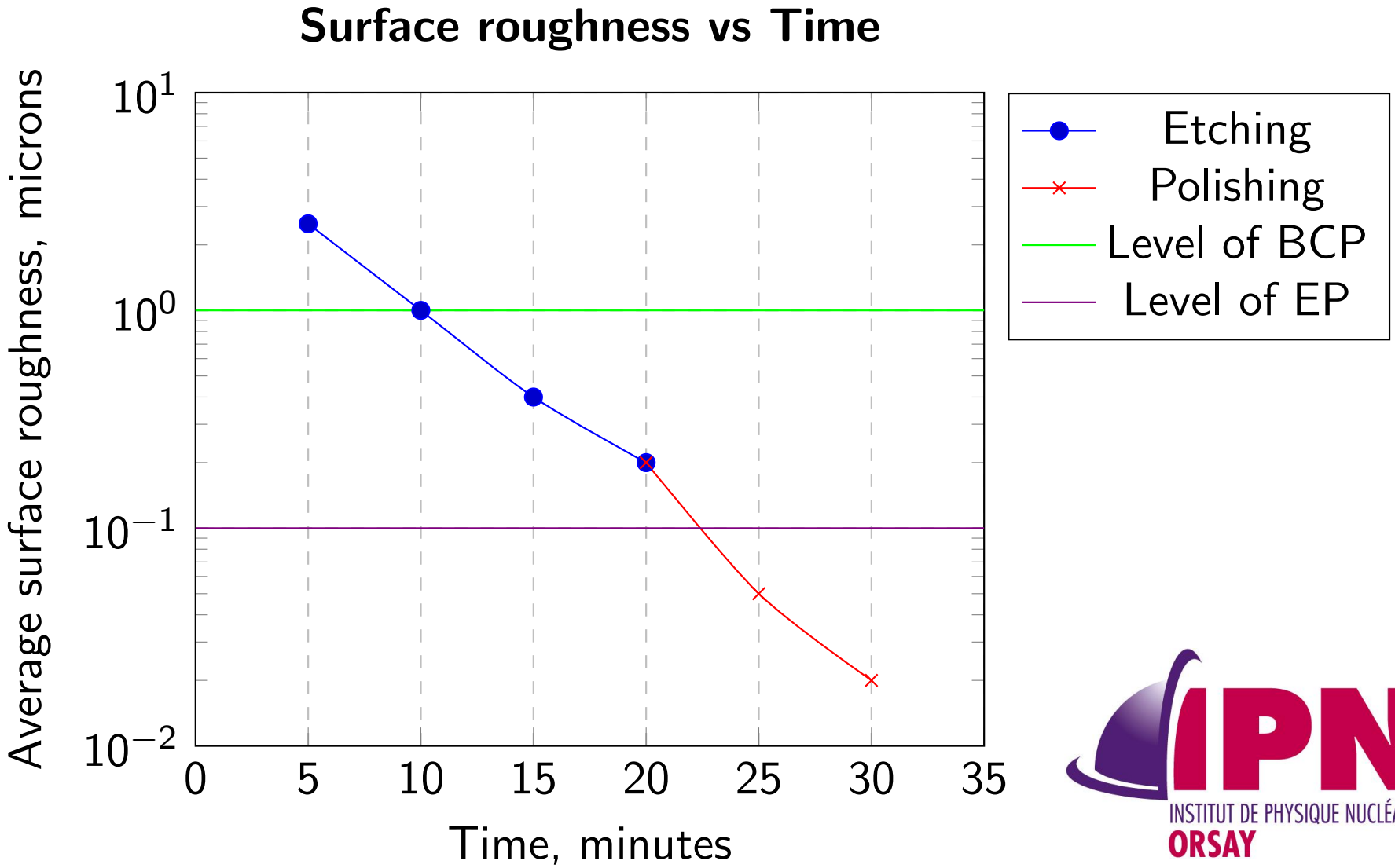




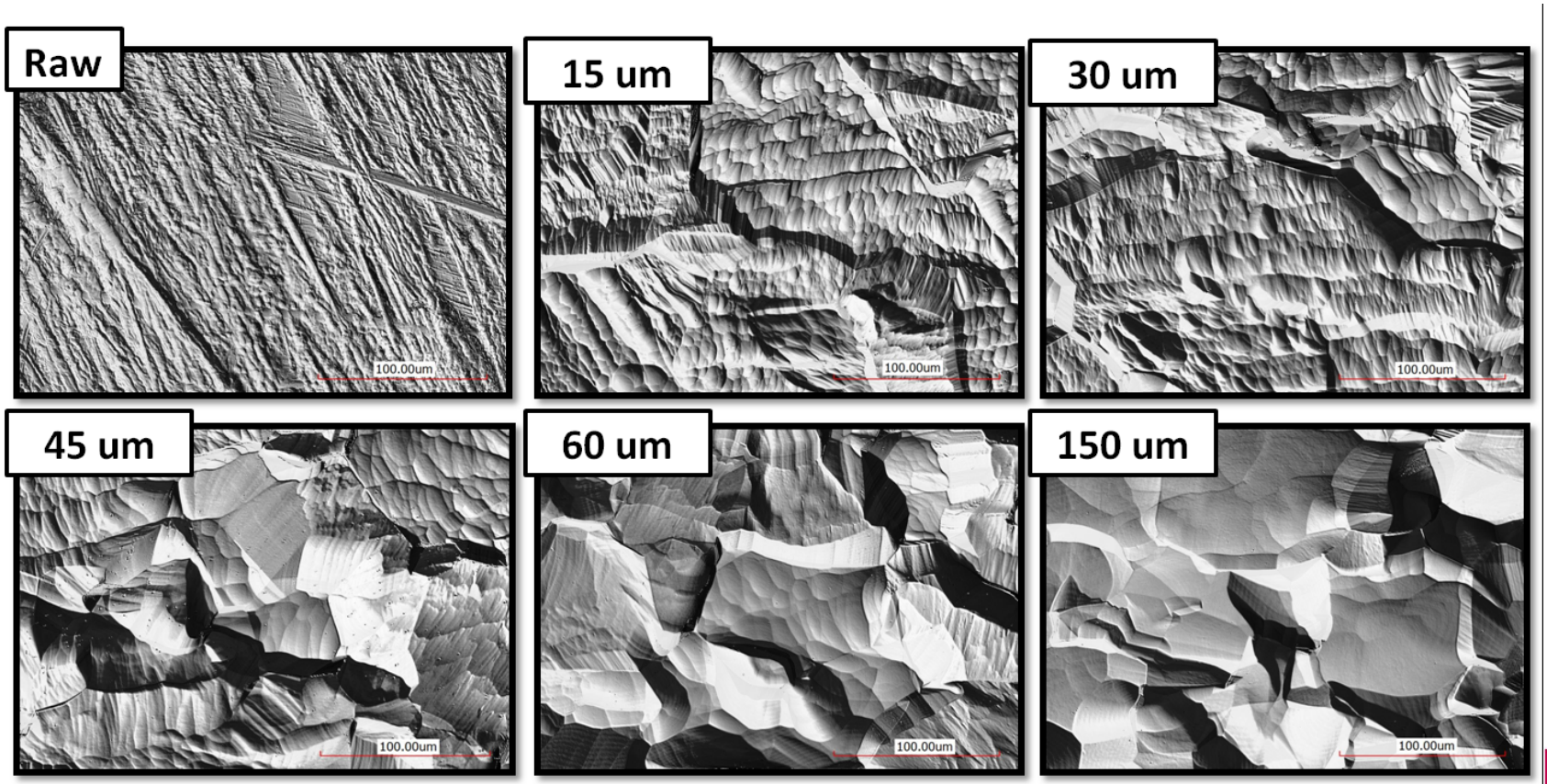




How long to polish Niobium to mirror like finish?



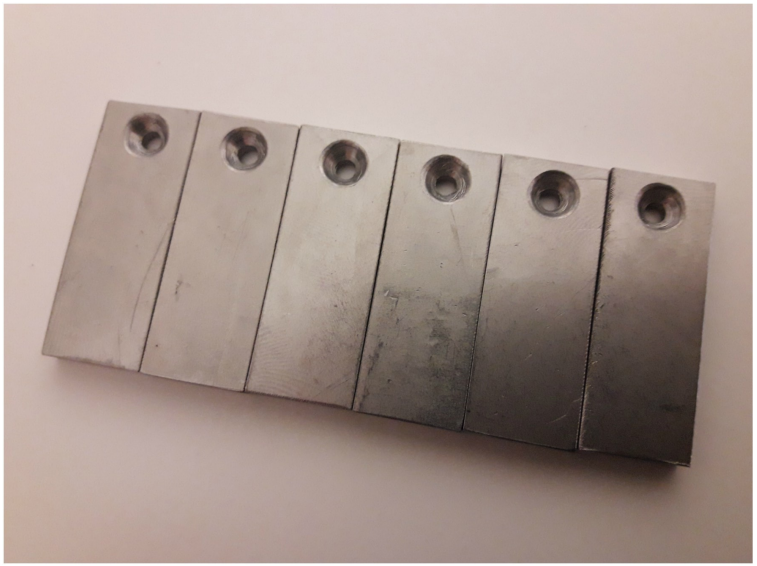
Damaged layer study



Damaged layer study with BCP...

Conclusion

- Hard abrasives could polish soft material
- Mirror-like finish surface (average surface roughness 20 nm compared to 100 nm achievable by baseline technique) was obtained
- Number of steps was optimized



Outline

What will be done?

- Characterize carefully surface pollution and damaged layer (SIMS, EBSD, Grazing X-Ray Diffraction)
- Characterize at cryogenic T and under RF (pill-box cavity)
- Apply optimized recipe to large sheets (LAMPLAN)
- Find a way to form a cavity from polished sheets
- Fabricate a real cavity (elliptical)

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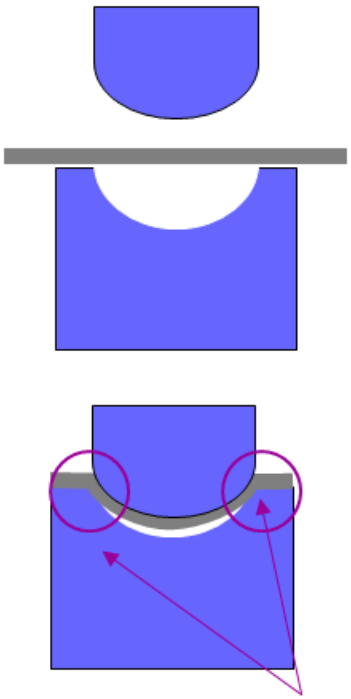
THANK YOU
FOR LISTENING

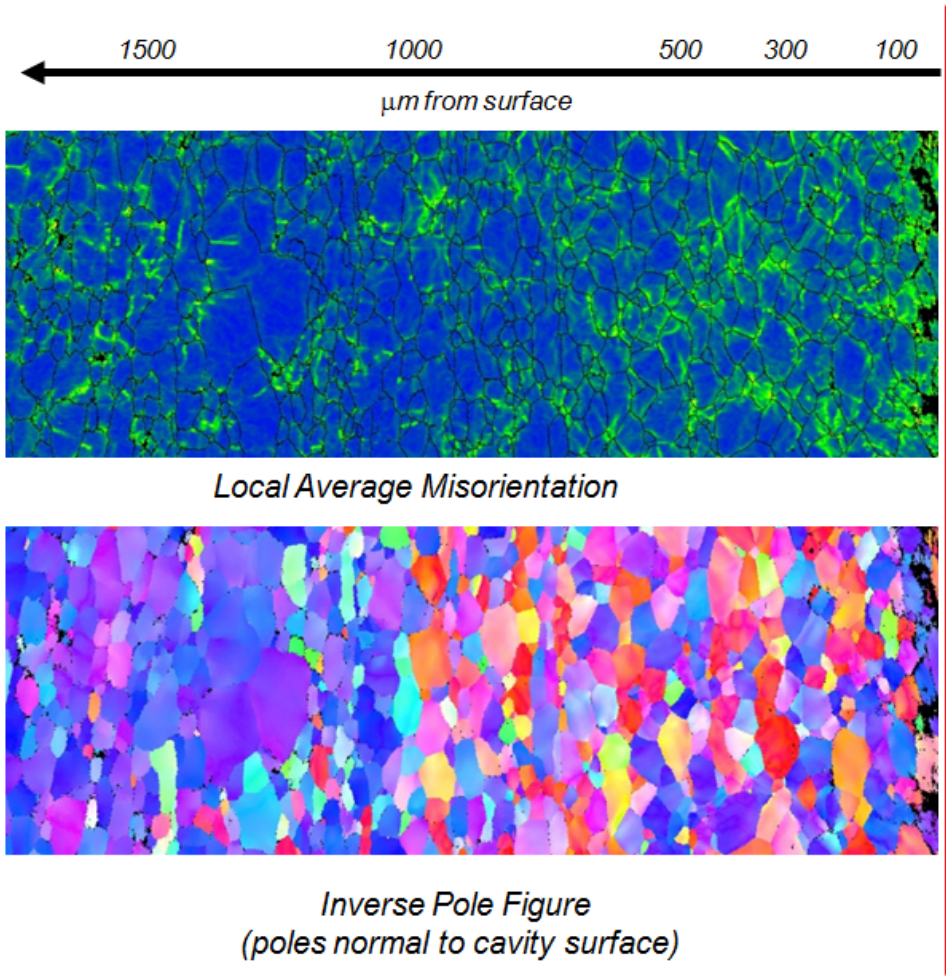
Half cell cutout

(just after deep drawing, before welding)



High friction area

NB, Average deformation ~30%
Easily recovered w. 800 ° C, 2 h annealing

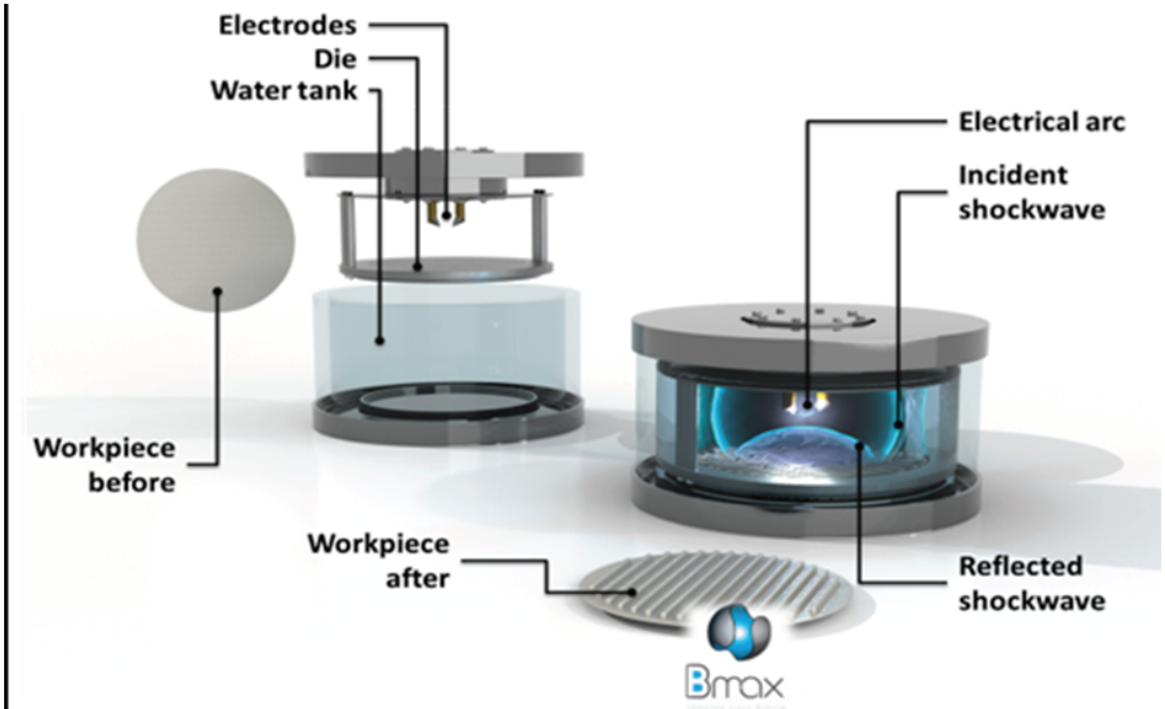


Local Average Misorientation

Inverse Pole Figure
(poles normal to cavity surface)

[courtesy : R. Crook et al, Black Laboratory]

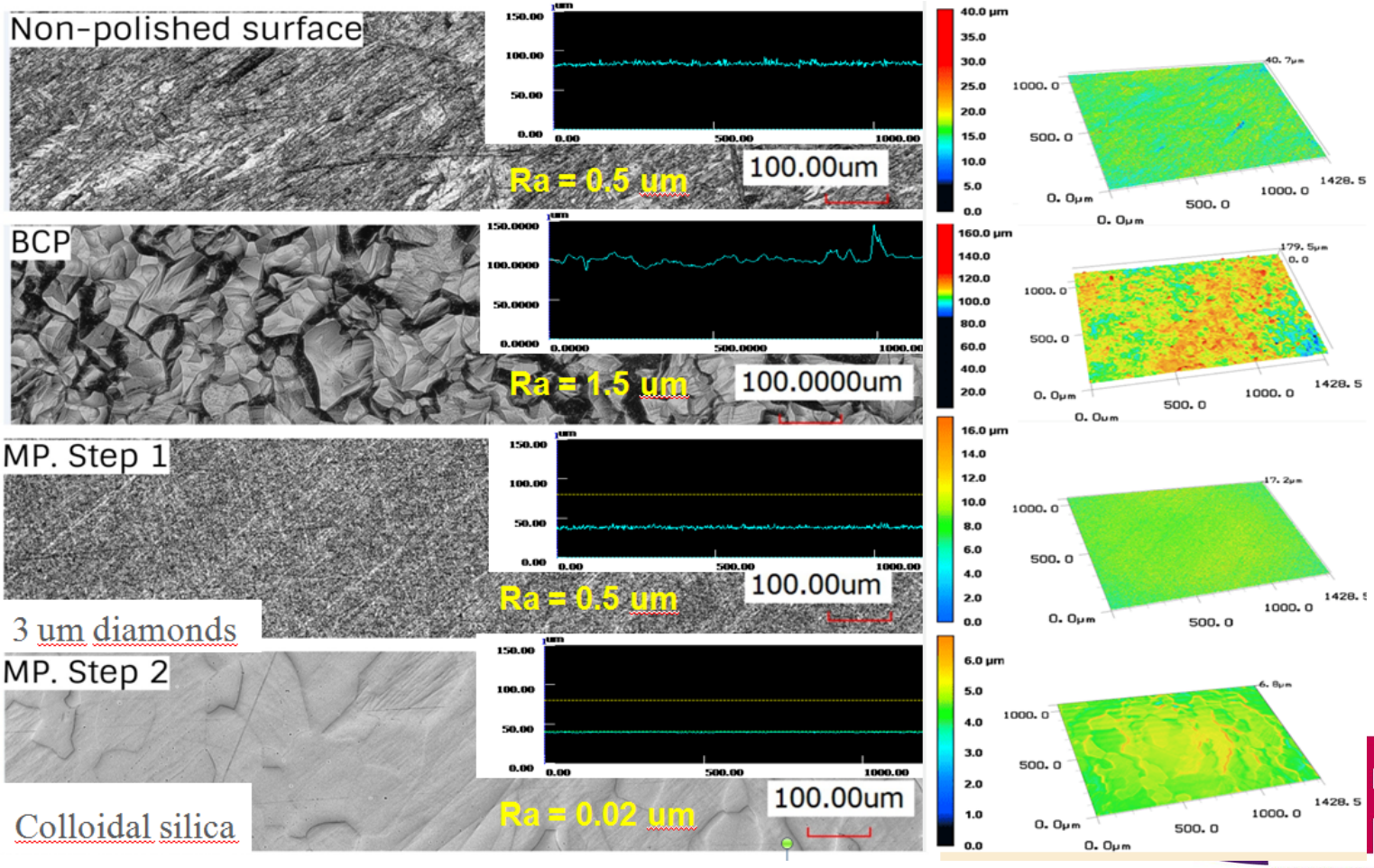
Electrohydraulic forming



S. Atiech et al., CERN, Geneva, Switzerland

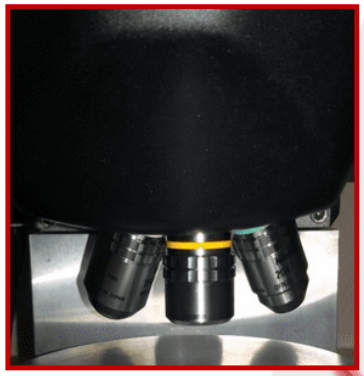
IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY

How is changed structure after final treatment?

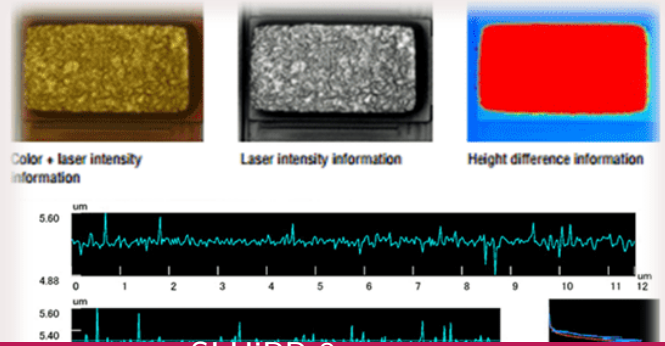


Back up slides: Laser confocal microscope

Laser Confocal Microscope



PLATEFORME D'ANALYSE
PANAMA



UE NUCLÉAIRE

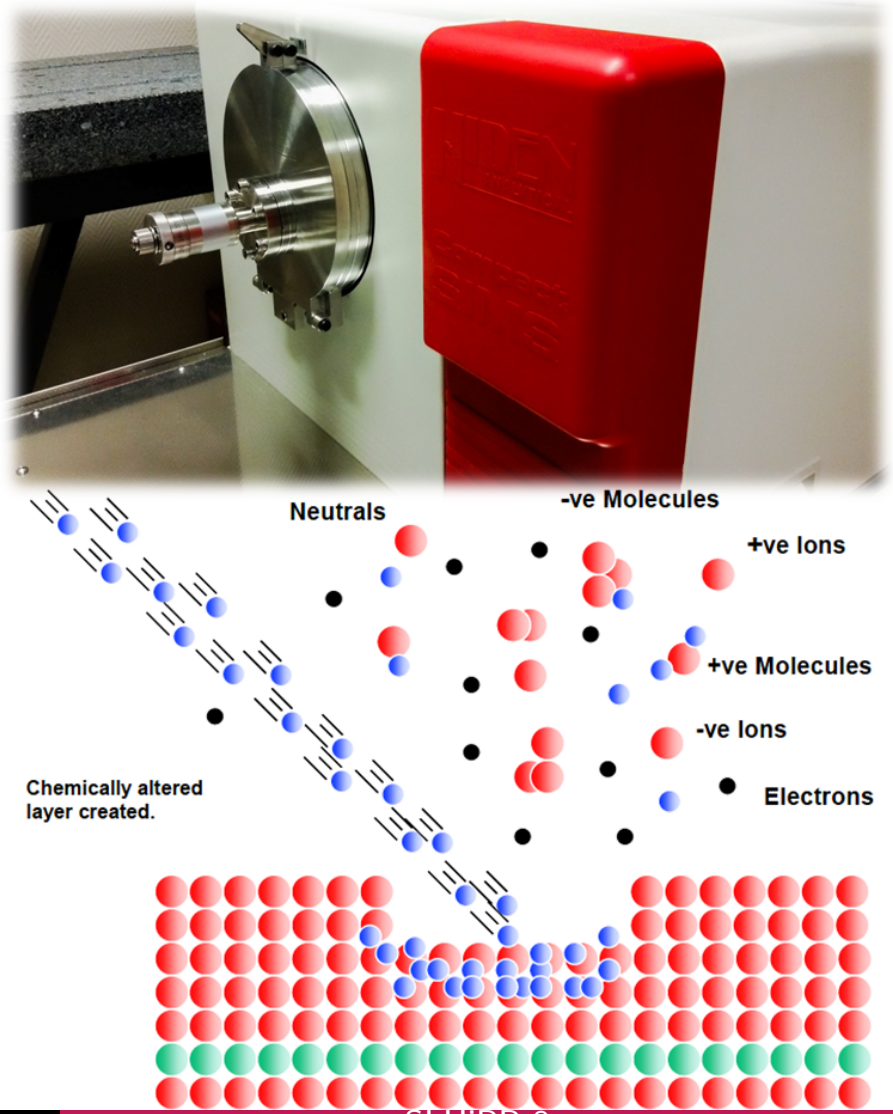
Back up slides: Secondary ion mass spectrometry

Beam:

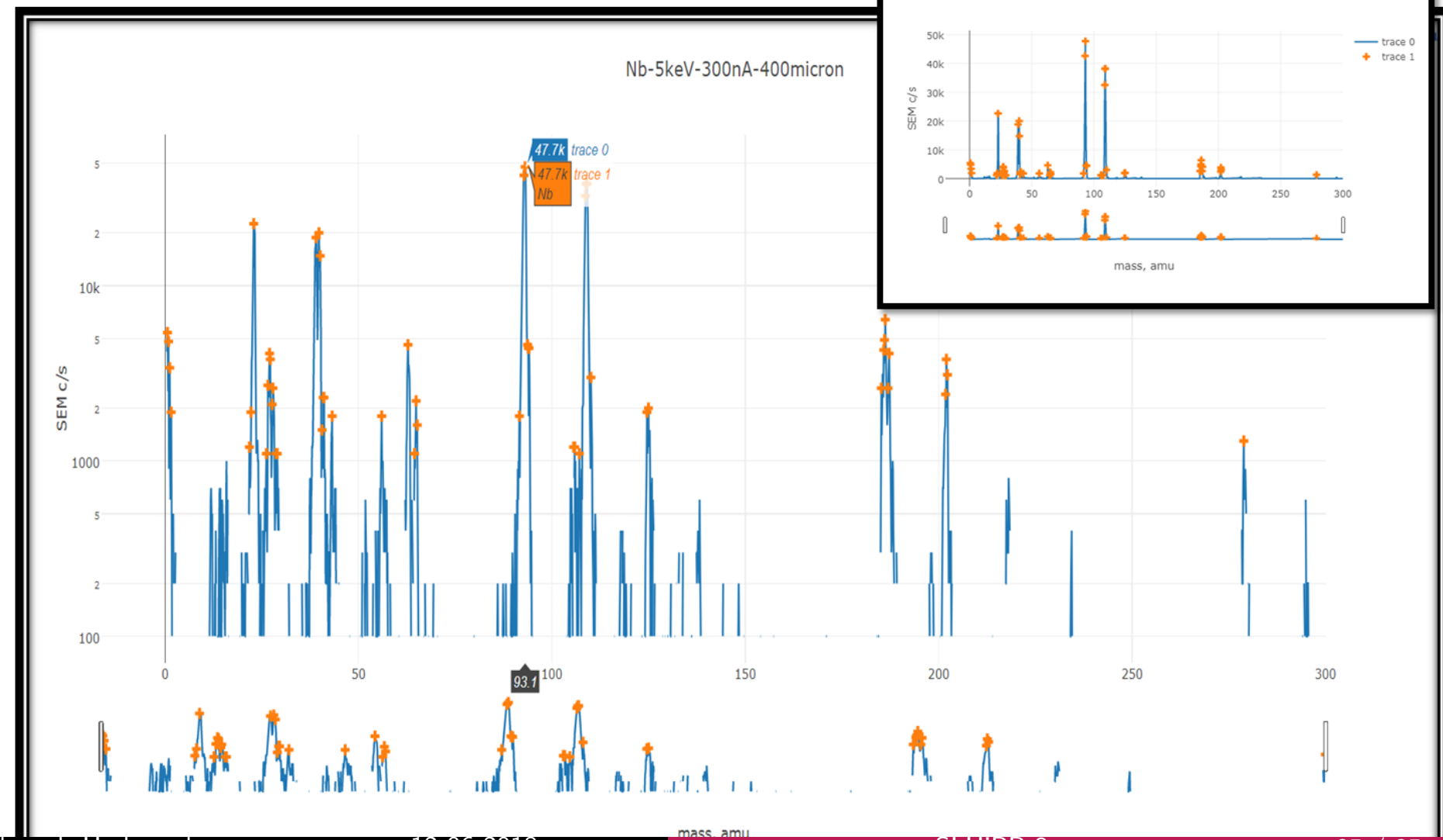
- Energy /current: 1 to 5 keV / up to 400nA
- Gaz: Oxygen or Argon
- Profilometry: 80 microns
- Resolution: 2 nm

Modes:

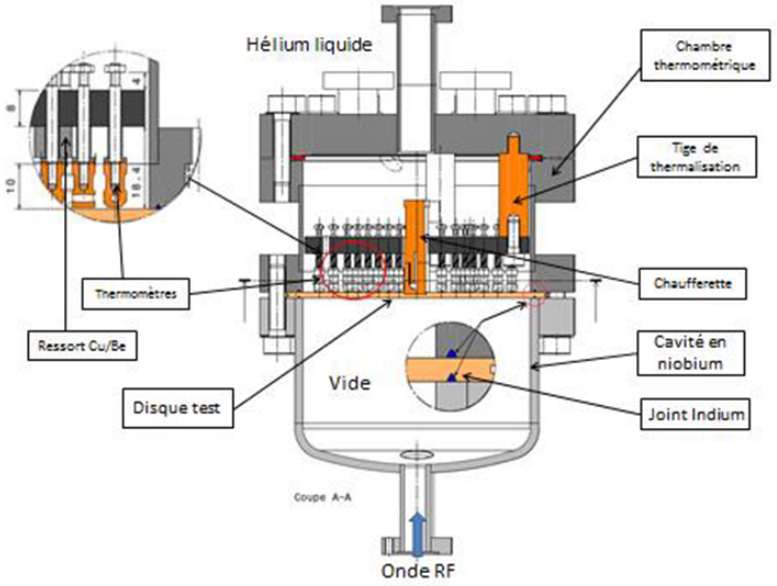
- SIMS static: chemistry composition
- SIMS dynamic: depth profile

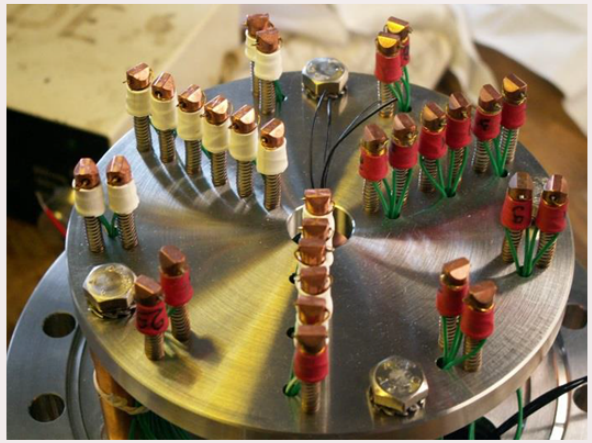


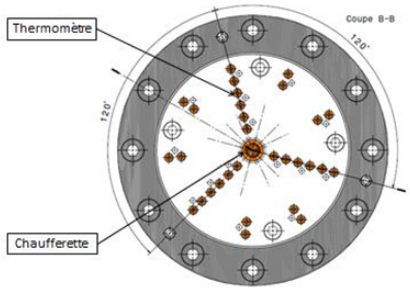
Back up slides: SIMS static

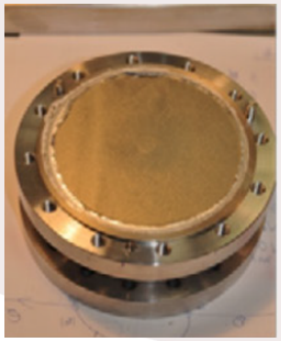


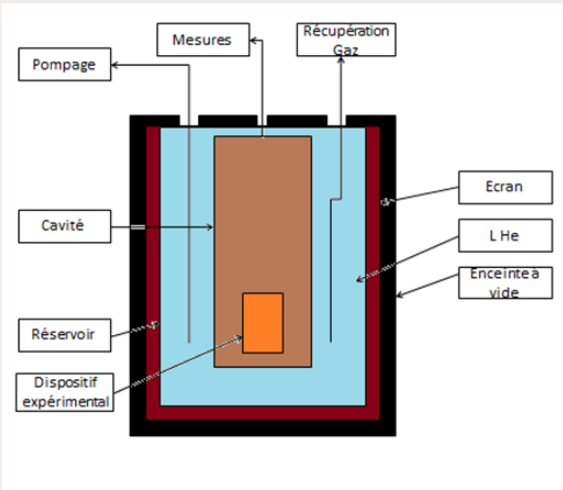
RF test: ECOMI



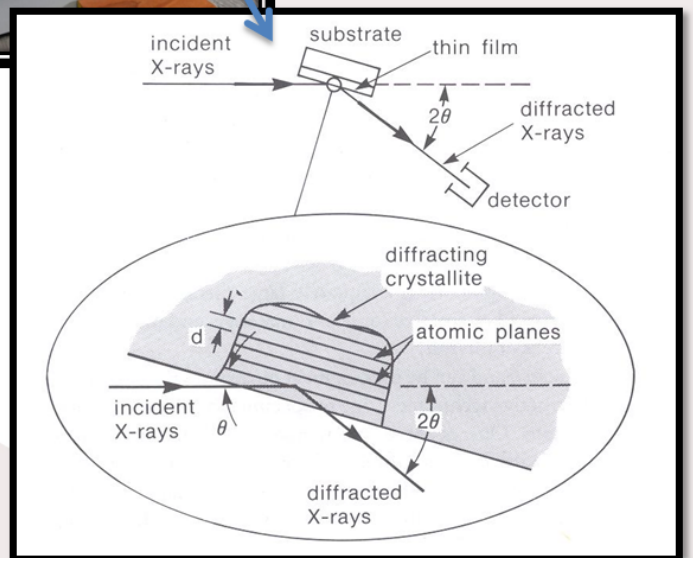








X-Ray diffraction



Panalytical X'Pert Pro X-ray diffractometer

- Preffered orientation
- Sample microstructure
- Residual stress analysis
- Analysis of changes in the crystal structure (deformation)
- Topology of the surface
- Depth control diffraction
- (2° - 650 nm, 10° - 2 micron, 20° - 2.5 um)