SINGLE AND LARGE GRAIN ACTIVITIES AT FERMI

Single Crystal Niobium Technology Workshop

Araxia, Brazil

Claire Antoine + Fermi teams…

10/31/2006

Layout

- Large grain / Monocrystal Cavities development
  - Fabrication process
  - 1cell program
- Sample R&D to support cavities fabrication
  - Recrystallization study
  - Cold and room temperature properties
  - Magnetic properties
- Sample R&D to understand SRF issues
  - Grain boundaries and roughness
  - GB and field enhancement
  - GB and weak superconductivity

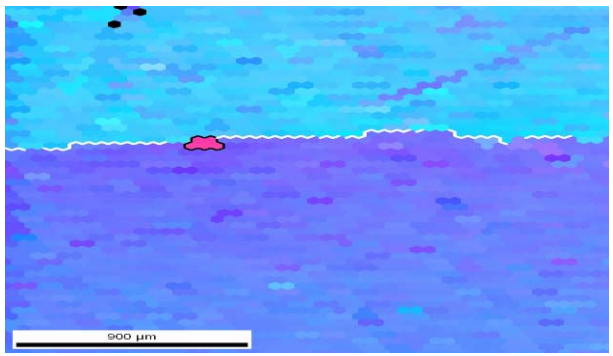
Collaboration with MSU

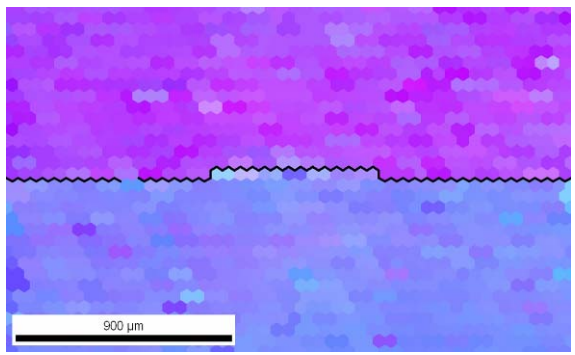
Collaboration with FSU

FNAL monocrystal Nb program

- Interest :
  - Fewer fabrication steps => starting material should be less expansive
  - No/few recrystallization @ welding => BCP instead of EP
  - Possibility to choose the proper orientation for :
    - Formability ? *e.g. (111) = more favorable for small grain textures*
    - Oxygen diffusion ? *(111) = close packed/ (001) = loose packed*
    - Oxide thickness ? *(idem)*
    - Surface B_C ? *(B_{C3})*
    - Recrystallization @ welding…

grain orientations: asymmetric ↓ *symmetric ↓* *triple point ↓* *[H. Jiang et al, MSU]*





Monocrystal Nb program…

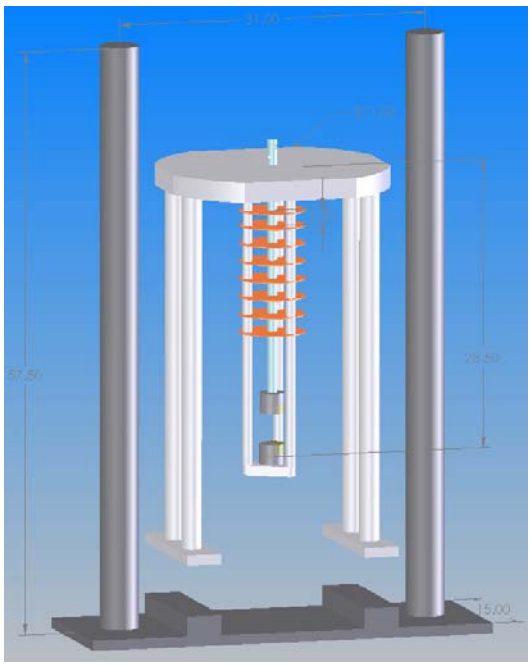
2 complementary goals :

- Developing local expertise on the fabrication process :
  - ~ 10-15 1-cell cavities project
  - 3.9 GHz :
    - Easier to get 1! -grain material
    - Sufficient to determine the fabrication steps
    - Can be used to test EP, and other behaviors
    - High R_{BCS} losses => limited RF testing ?
  - Then 1.3 GHz
    - RF testing once the fabrication process is mastered
- R&D program on sample:
  - Sensitivity of the crystalline orientation to :
    - EP vs BCP
    - Baking/Oxygen diffusion
    - Hydrogen loading
    - …
  - Bi-crystal studies… [see P. Lee talk]

Mechanical properties: cold and RT

Tensile test from 4 K – 300 K

- Minor investment and time required
- QA: Systematic testing of Nb batches : RT and Cold mechanical properties => **data for modeling** (forming, mechanical resistance , RF behavior…)
- **Recrystallization study**

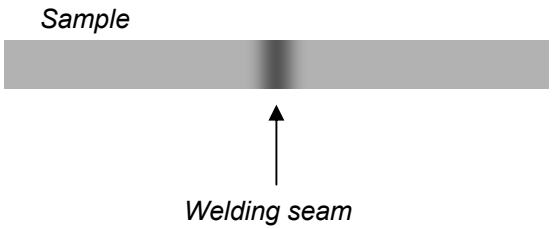


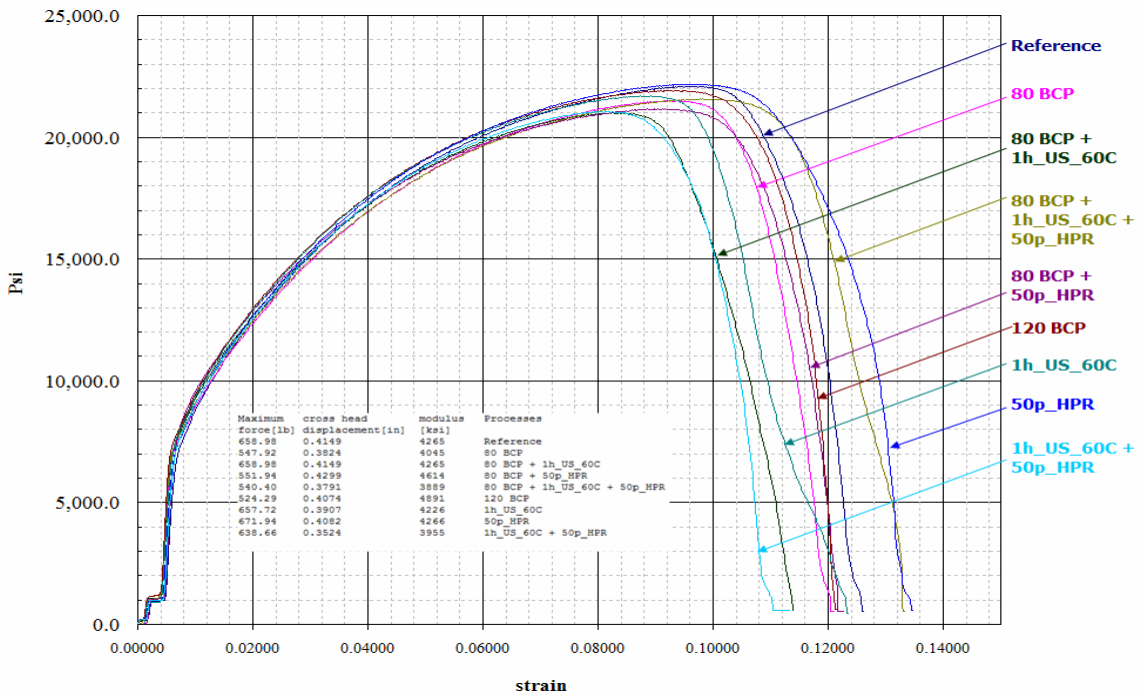
2 Priority : cold testing upgrade of the Instrom

Possible developments (mid term)

- Hydrogen, oxygen embrittlement at low temperature
- Effect of welding
- Grain boundary strength,
- Crystal orientation/texture effects
- …

Study of the mechanical behavior of welded Nb : note that the elongation is only 12-14 % (compare to bulk Nb ~ 30 %)

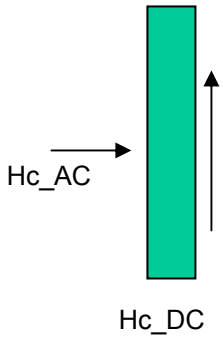


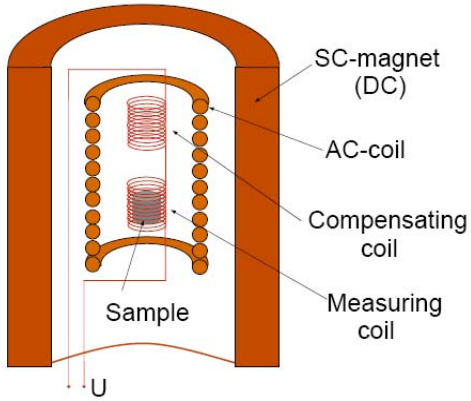


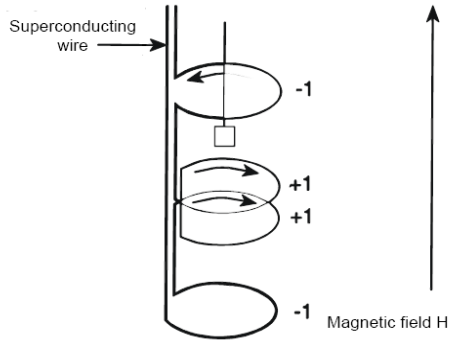
Monocrystal Nb program…

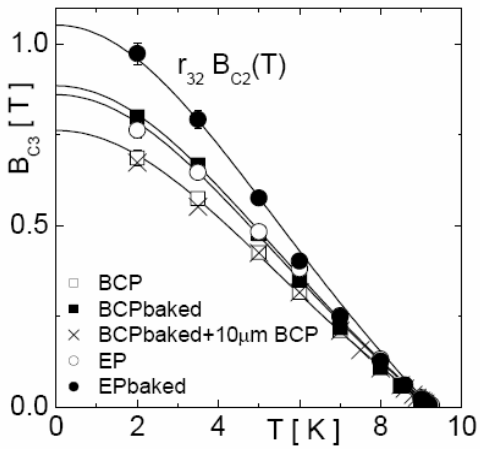
AC susceptibility, magnetization measurement

- 1rst step: buy a commercial magnetometer for B_{C3} measurement/ or collabn
- It is the only technique sensitive enough to baking/surface processing !



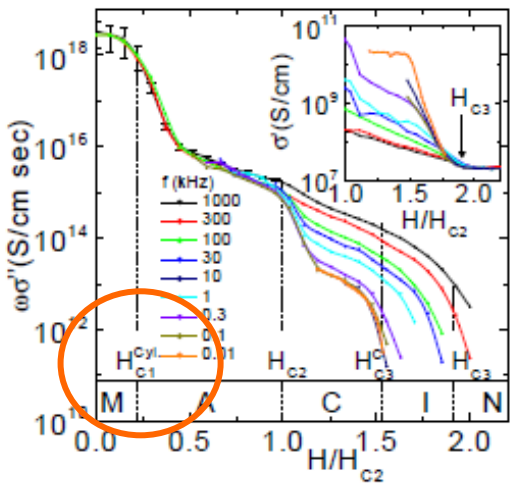






[S. Casalbuoni et al, Hamburg]

- 2nd step : try to measure H_{C1}.
- ∃ very few information on H_{C1}

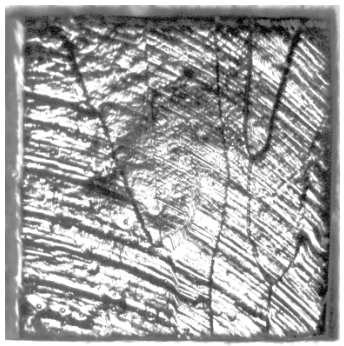


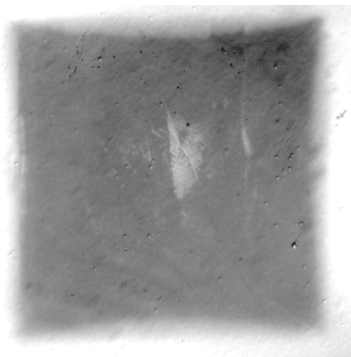
What is the problem with GB ?

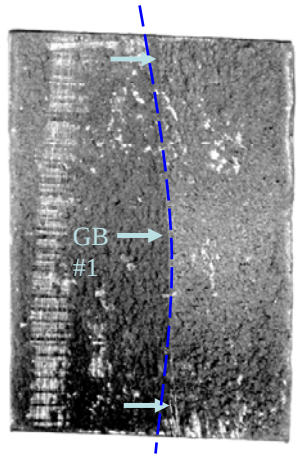
Morphological effect or depleted SC ?

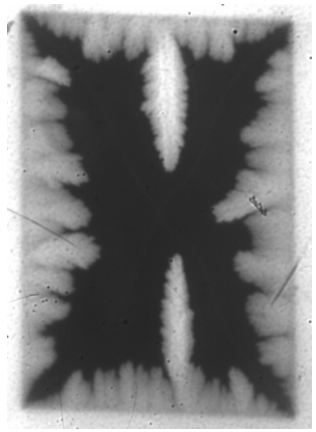
Flux penetration @ GB

[A. Polyanskii et al, WU/FSU]

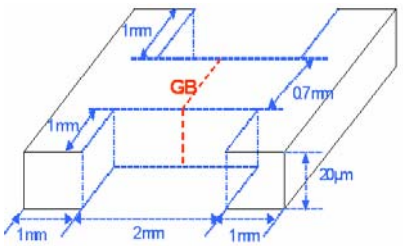




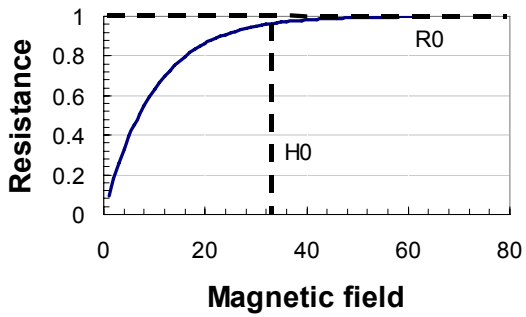


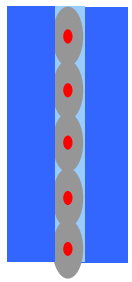


[P. Lee, next talk]



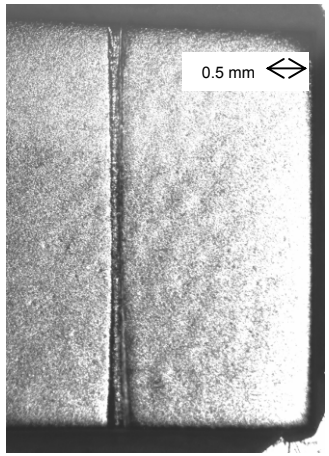
[Sung Hawn]

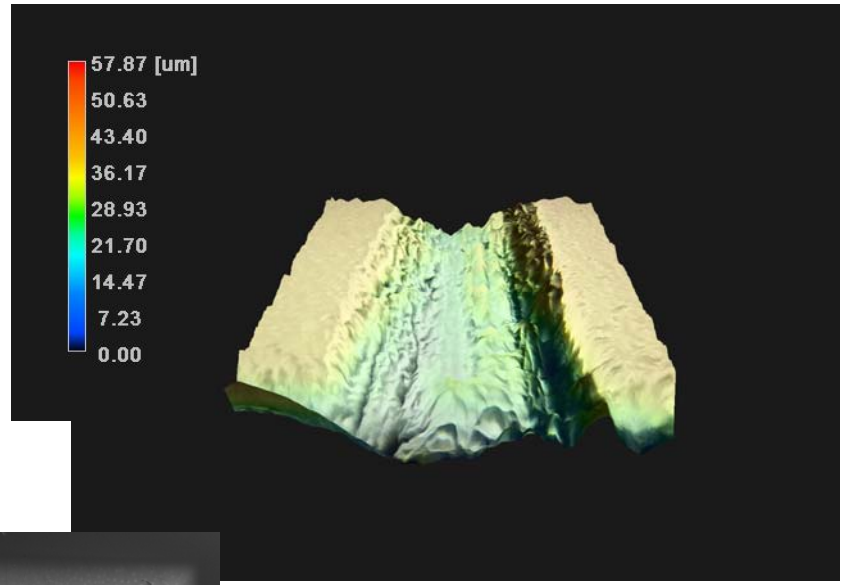


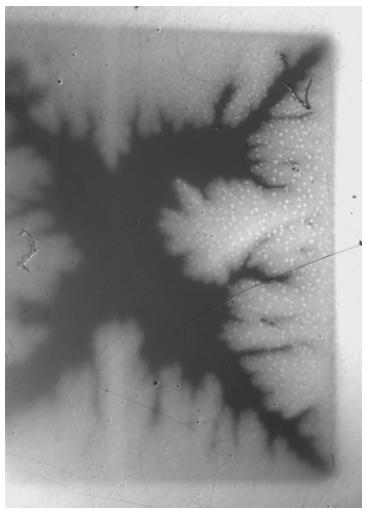


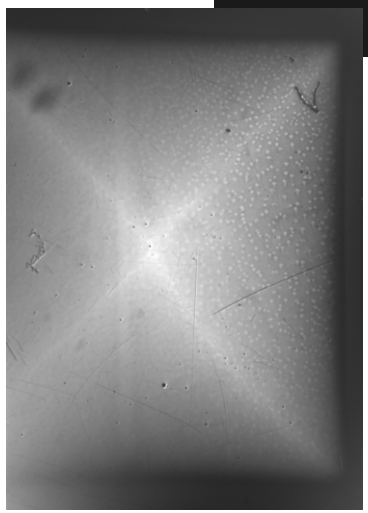
Saturation-field H0 gives information on de-pairing J_d of SC GB

Single crystal with artificial defect (notch) on the surface









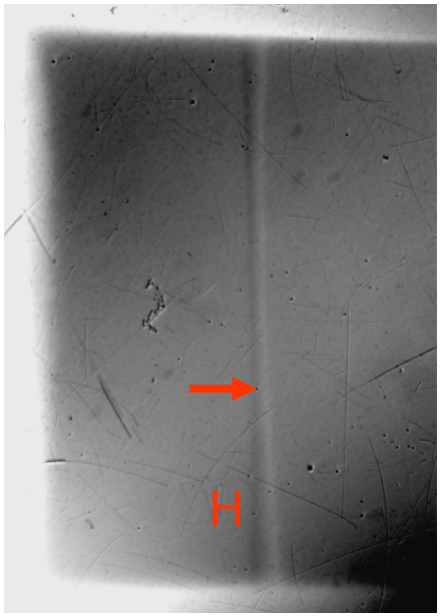
#52 ZFC H=40 mT T=7K

#62 Remn H=80 mT T=7K

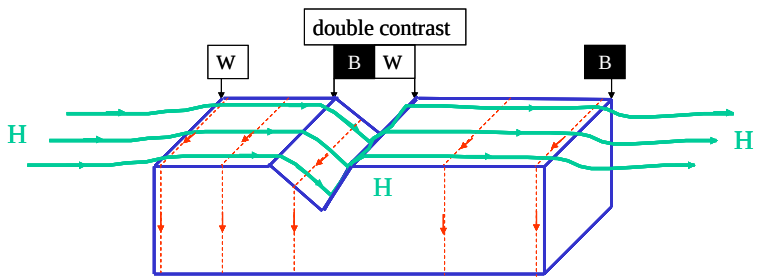
[A. Polyanskii et al, WU/FSU]

- H ⊥ surface: notch has small impact on flux distribution even at higher T

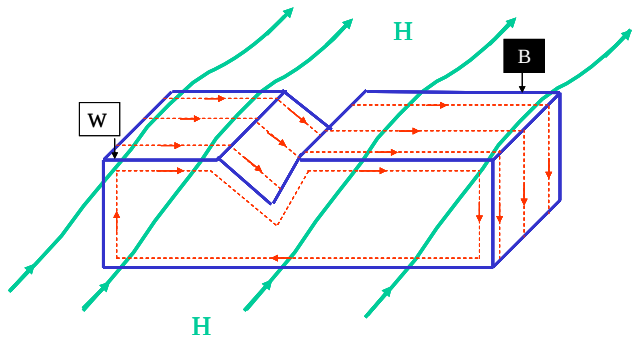
Single crystal with notch on the surface : H // surface



T=5.6K



MO contrast is double at the groove, when in-plane field perpendicular to groove

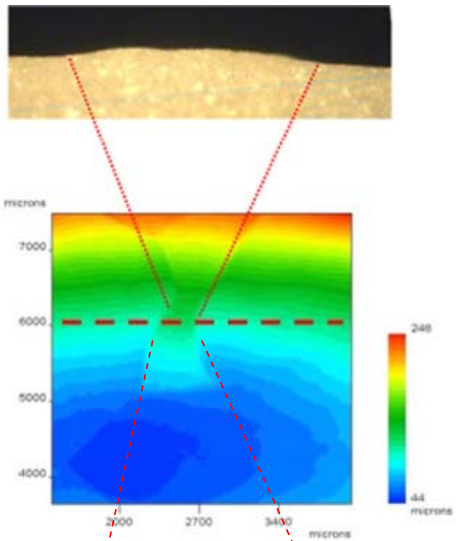


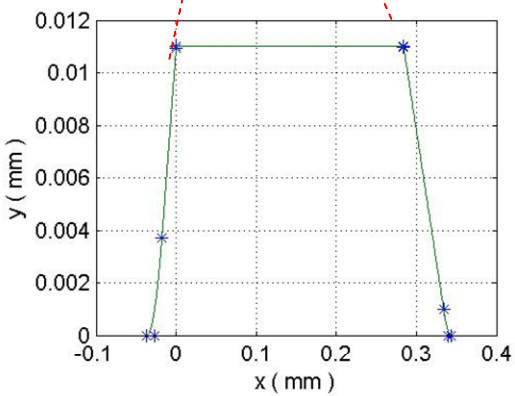
No MO contrast at the groove, when in-plane field parallel to groove

Morphological effect … Roughness

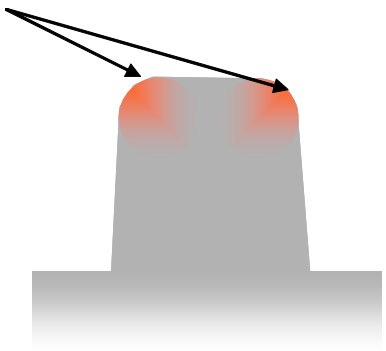
Working hypothesis: morphology => quench

- Steps perpendicular to H produce field enhancement
- It triggers quench
- This phenomena is different from the hot spots observed when ∃ Q-drop

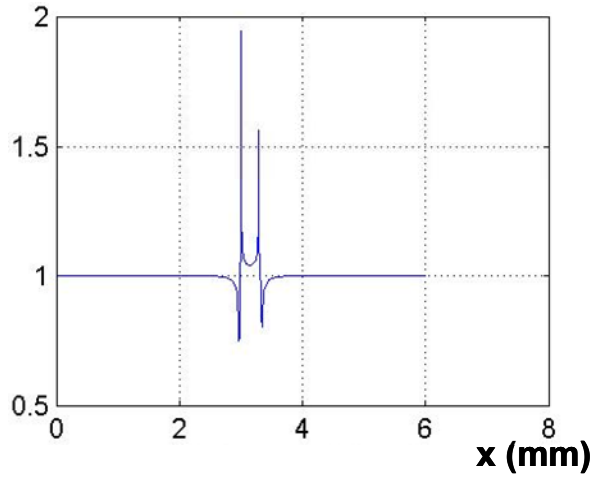




Normal conducting zones

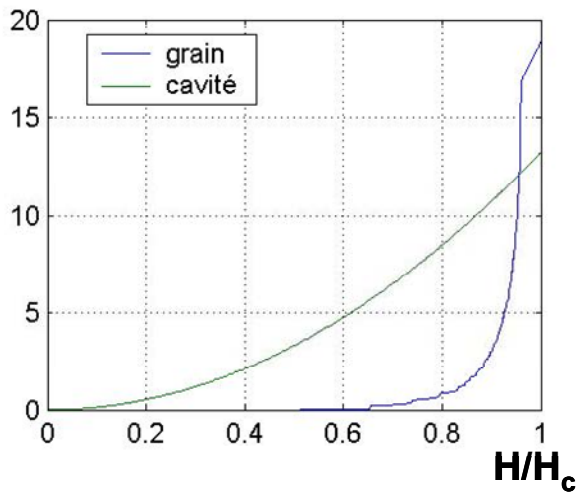


H/<H>



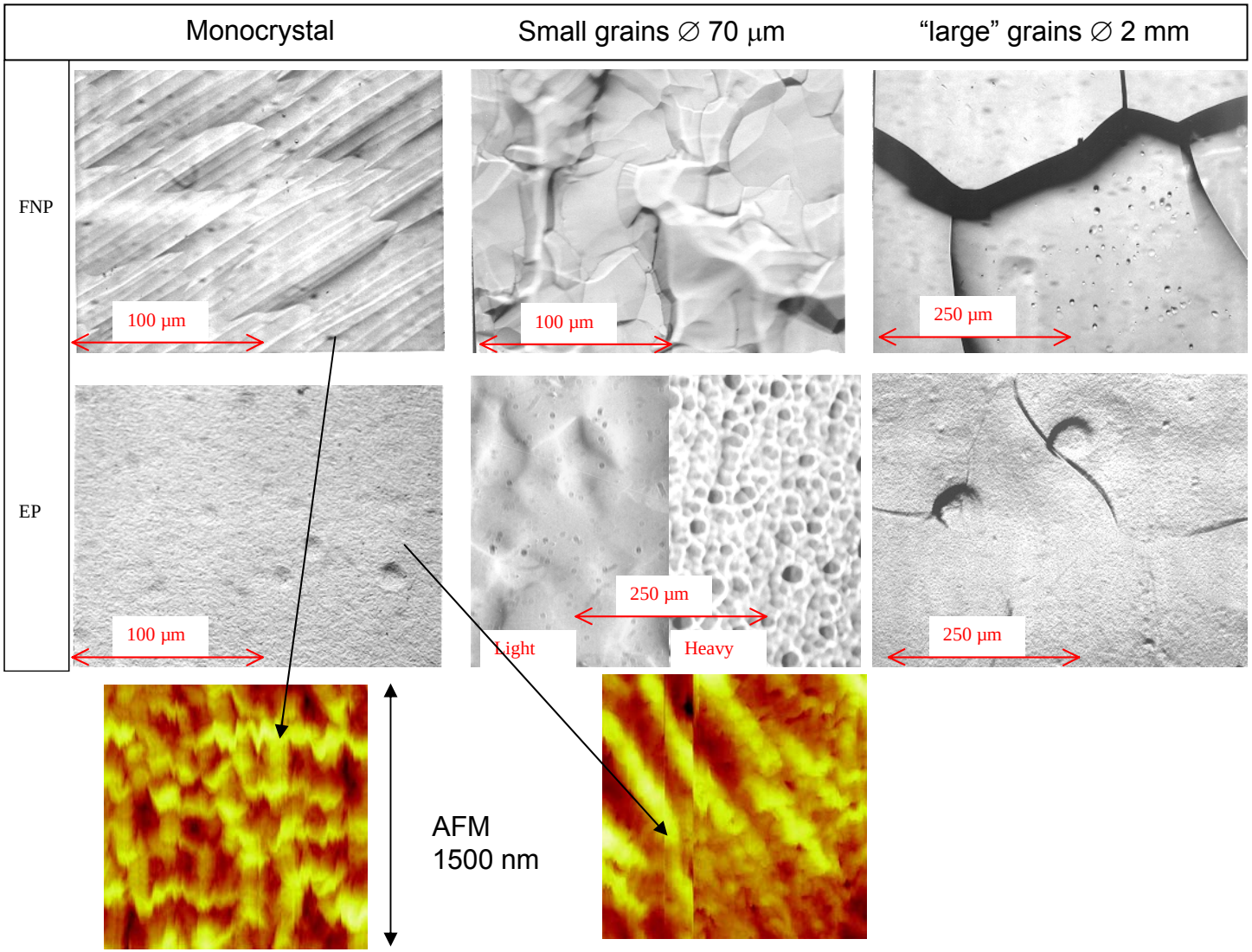
P (W)

Dissipated power (Rs ~ 2mΩ)



Influence of GB on roughness

- Roughness depends on grain ∅



Roughness depends on observation scale

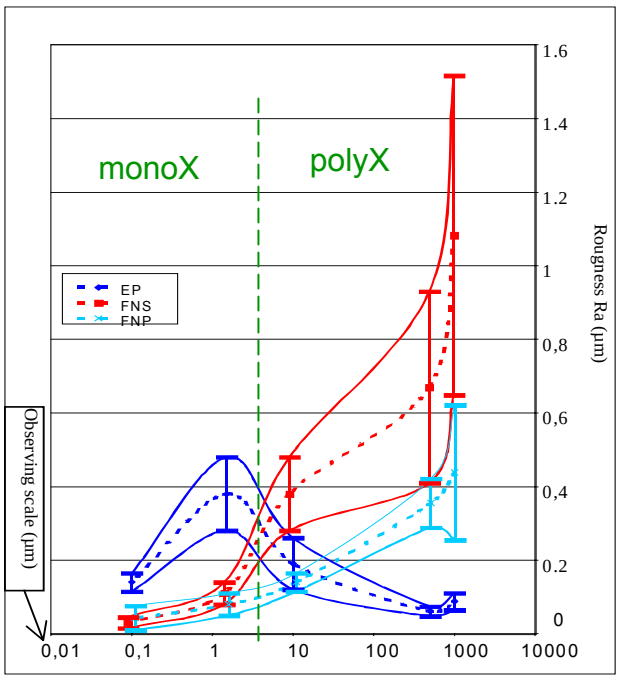
On Silicon (monoXstal)

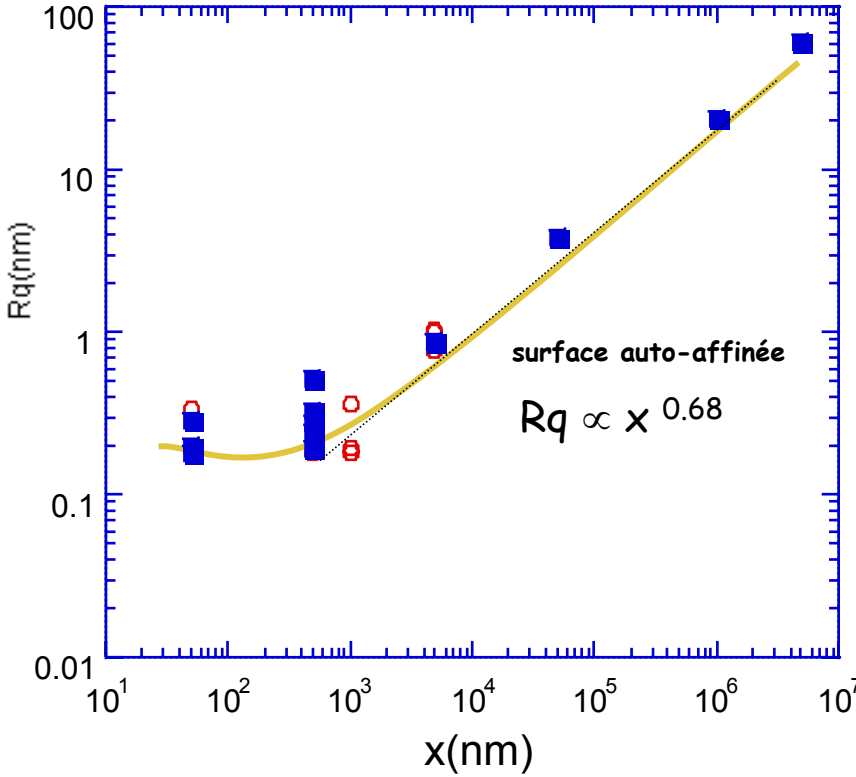
[J. Amrit et al, Orsay]

"Most polished crystal surfaces, including silicon crystal surfaces, display a fractal behavior [6], that is, the root-mean-squared roughness height varies as

$$\sigma \approx bx^{\alpha},$$

where b is a constant and α the roughness exponent."

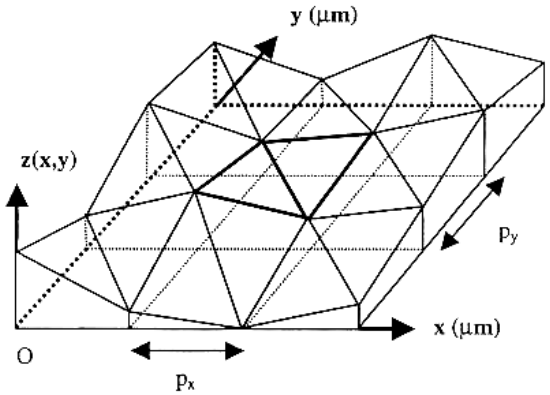




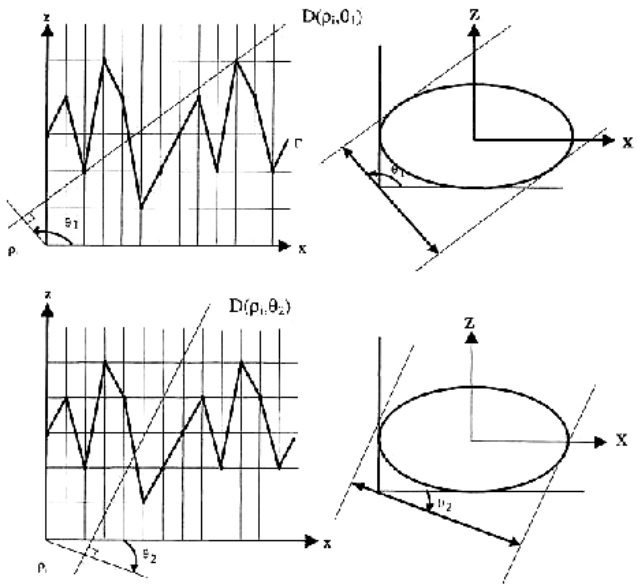
On Nb (mono/polyXstal)

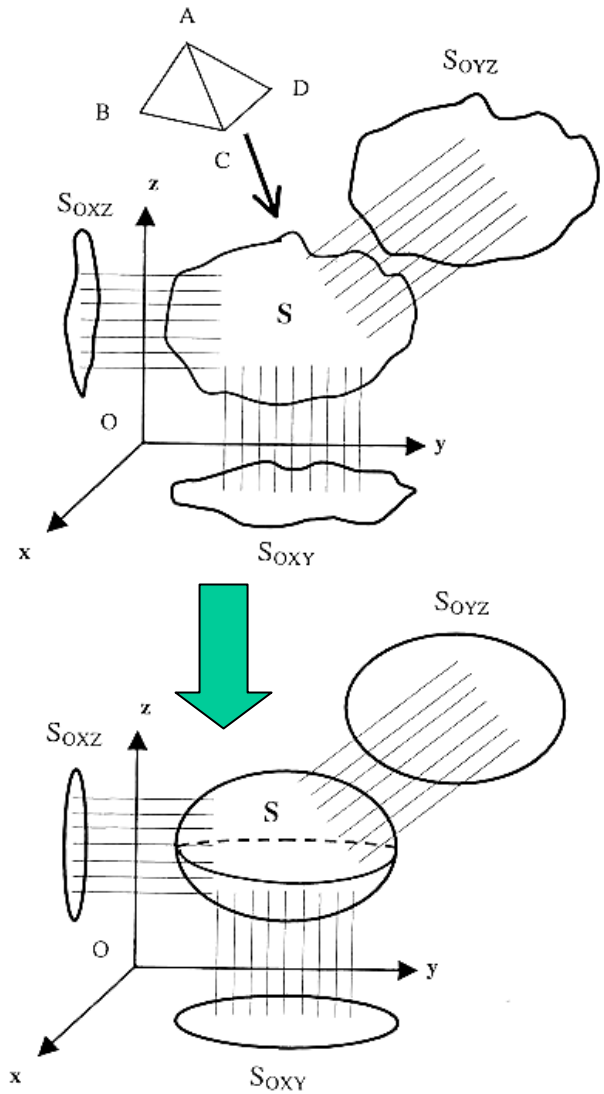
←

« conformal equivalent structure » concept



1. Decomposition of a sampled surface into elementary segments mode) or elementary micro-triangles (3D mode).



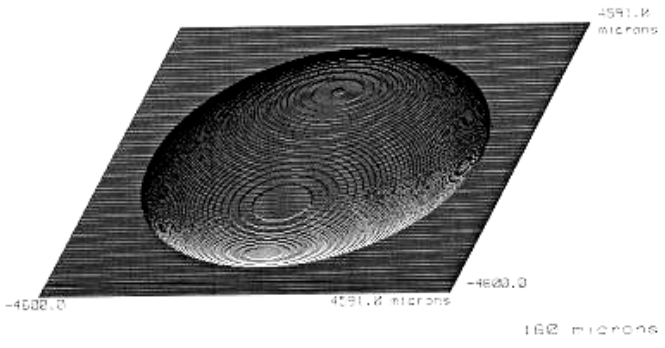


On Nb samples

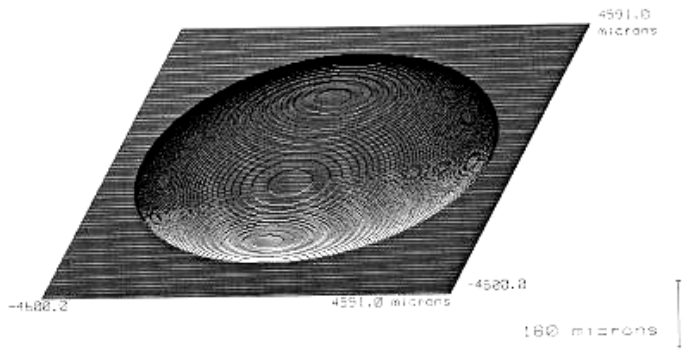
a) Annealed ~ 1 grain

b) not annealed ~ 15 grains

EP

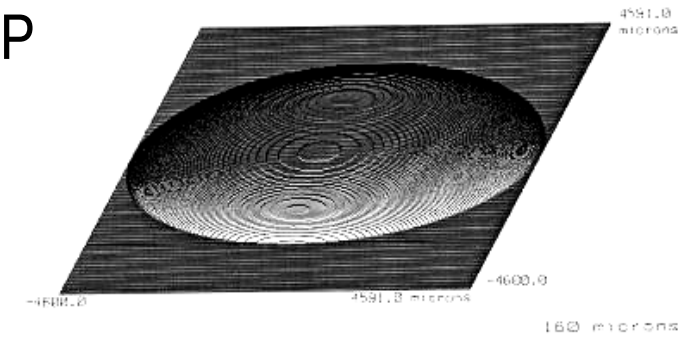


7R.A-EP recuit

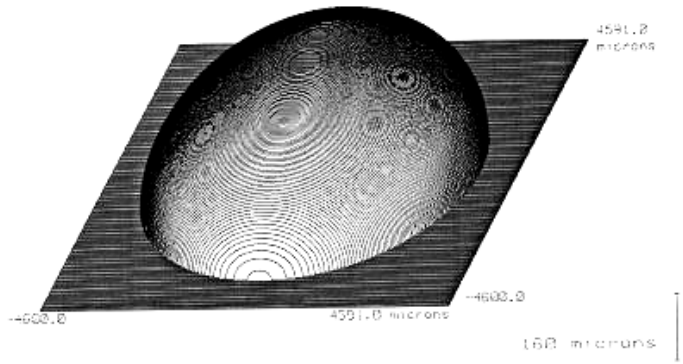


7B-EP non recuit

BCP



1R.A-FNP recuit



7F-FNP non recuit

a)Annealed material with grain ∅ ~ 1-2 mm
b) Small grain material with ∅ ~ 70 μm

Grain boundaries and roughness

Scanned surface	Step size	Average grain #	Process	Ra	C	β
1 mm²	1 μm	1 [a]	EP	0.69	9.3	
			BCP	2.9	12.1	
		~15 [b]	EP	0.8	13	
			BCP	2.2	49	
85 mm²	9 μm	8-9 [a]	EP	0.8	63.2	1.0135
			BCP	5	98	1.0283
		~ 1250 [b]	EP	4.33	78.5	1.0182
			BCP	1.9	313	1.0651

a) Annealed material with grain ∅ ~ 1-2 mm
b) Small grain material with ∅ ~ 70 μm

Parameter	out of welding seam	on welding seam
R_a (μm)	6.1±1.8	60.6±23.4
c (μm)	96.5±3.6	354.3±7.2

β ~ 1.4

Conclusion/ Proposal

Hypothesis:

- GB are harmful only because of BCP differential etching rate with orientation
- The field enhancement factor ↑ with ↑Ø of grains

Then

- Only GB to ⊥ H are dangerous
- Cavities with a GB // to the welding seem should be OK
  - Less fabrication steps
  - Delicate crystallographic alignment of the 2 half cells would not be necessary
  - Let's discuss that at the next coffee break !