Examples of application in metallurgy

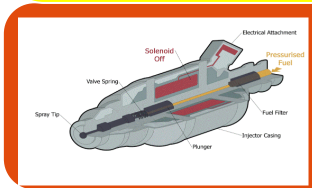
1) Ferrite nucleation in deformed austenite

(M. Veron & S. Lacroix, 2003)

2) TRIP Steels

Multiphased TRIP steels, Nippon Steel, E Rauch @SIMaP

Stainless austenitic TRIP steels, M. Véron Coll. D. Embury, K. Spencer, P. Jacques



3) Recrystallization of ferritic stainless steels

Collaboration with N. Meyer, Ugitech

4) Thin Films

S. Lay, SIMAP. + Collaboration with S. Godet, ULB, Bruxelles

5) Sintered materials : WC-Co

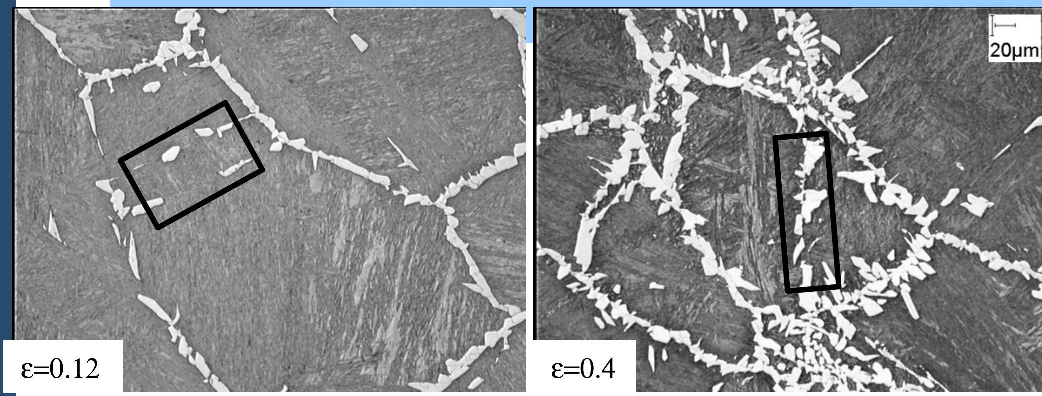
S. Lay, SIMAP. Pr JIN, Pekin, Mat science lab.

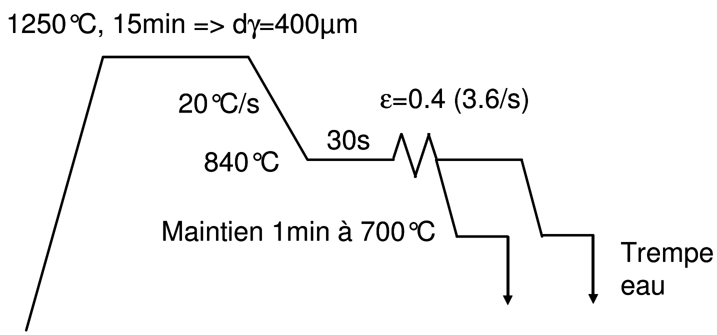
Grenoble INP

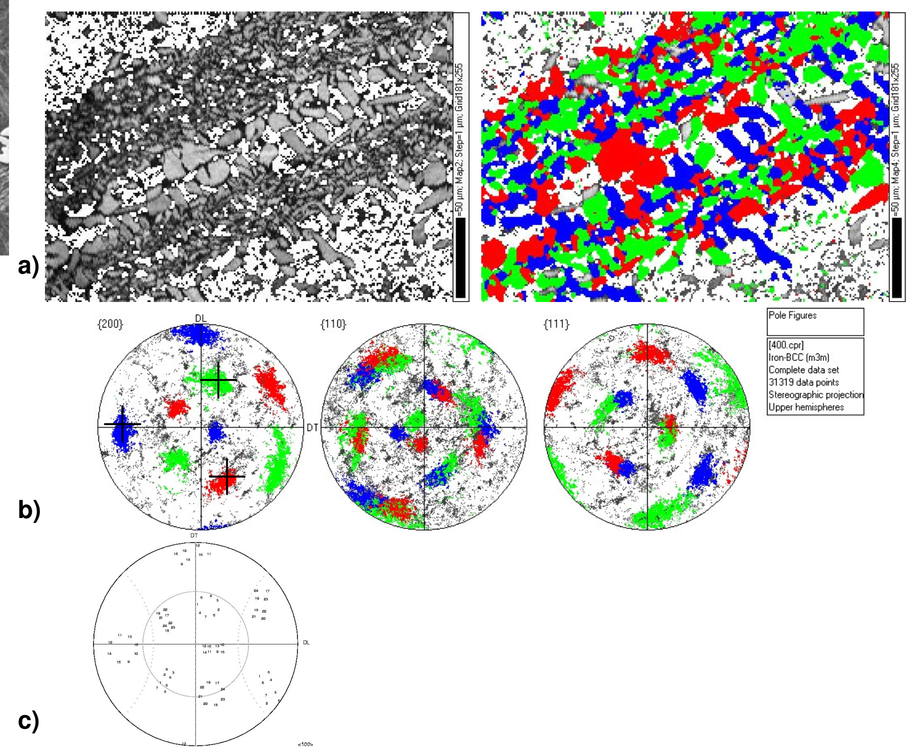
Muriel VERON,

SIMAP-Phelma, Grenoble

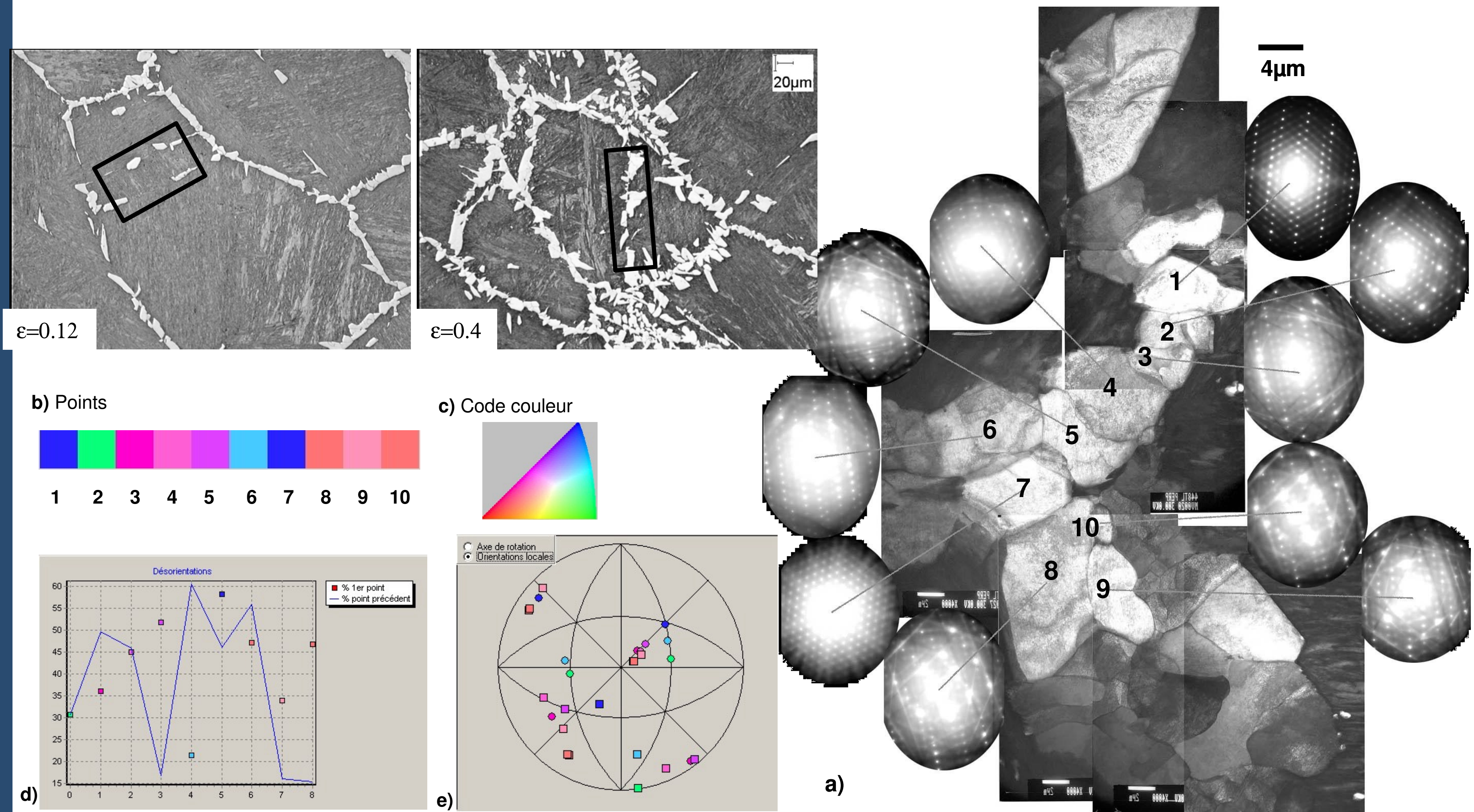
1) Ferrite nucleation in deformed austenite
(M. Veron & S. Lacroix, 2003)



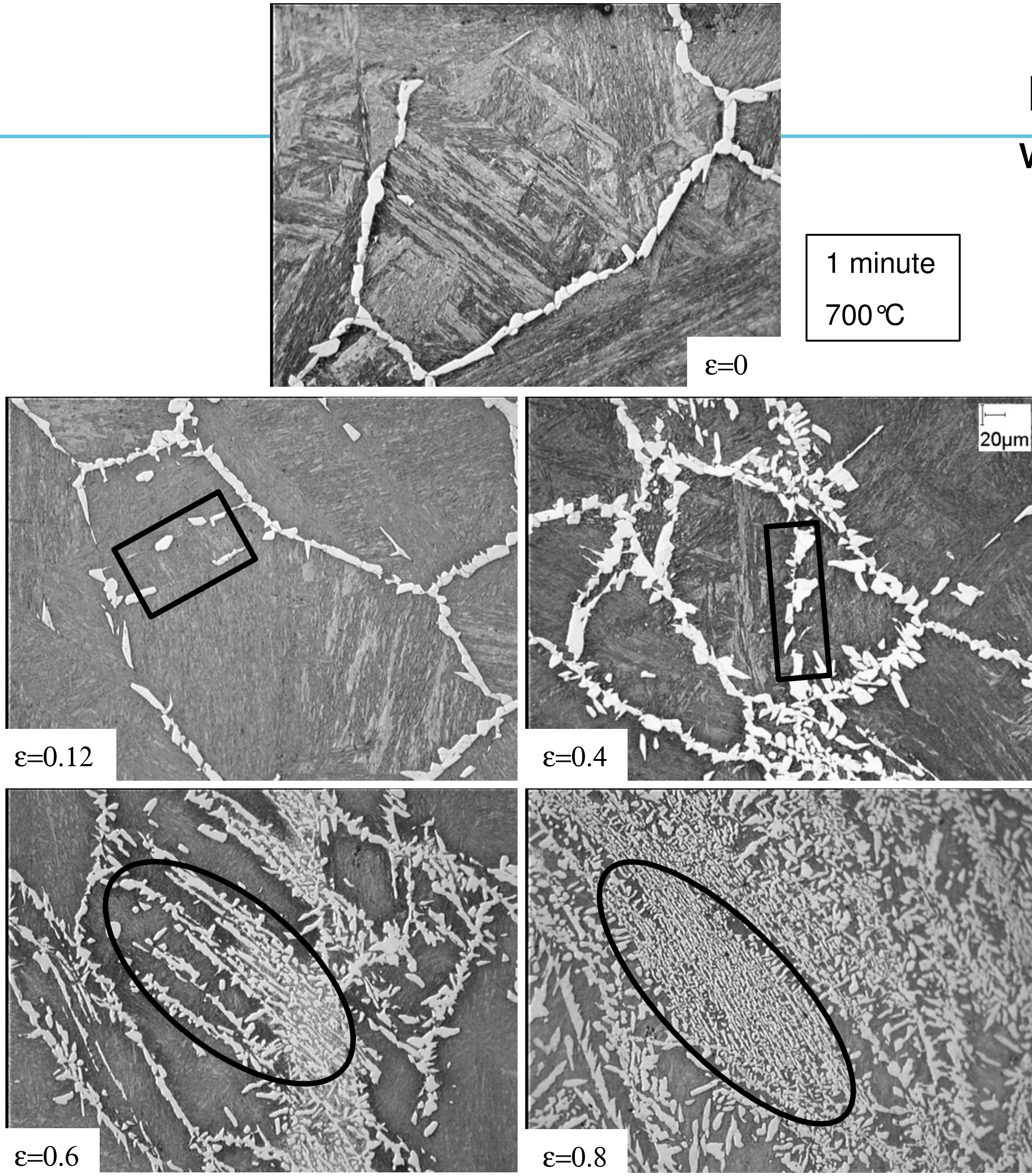




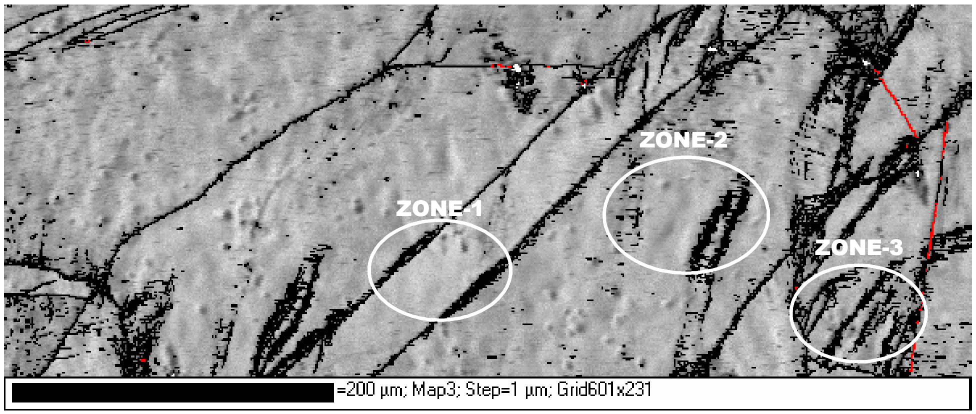
Sample strained of 40% in torsion


ε=0.12
ε=0.4
20µm
b) Points
1 2 3 4 5 6 7 8 9 10
c) Code couleur
Désorientations
% 1er point
% point précédent
d)
Axe de rotation
Orientations locales
e)
4µm
1
2
3
4
5
6
7
8
9
10
a)

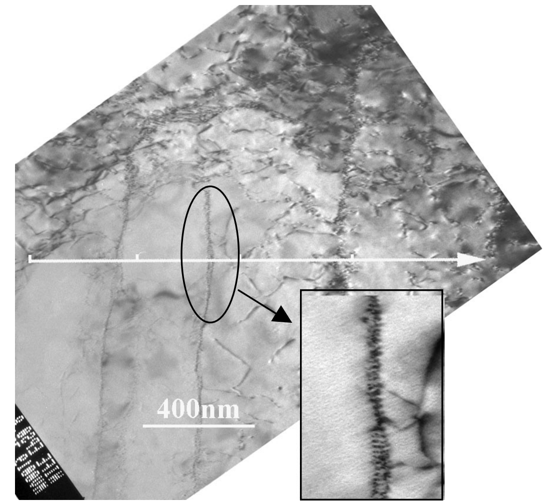
Microstructural evolution with austenite strain level

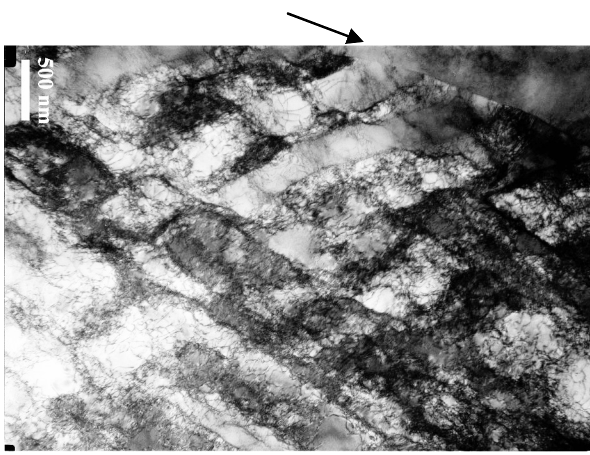


Deformed austenite (Fe-Ni alloy), EBSD quality contrast, and TEM observations

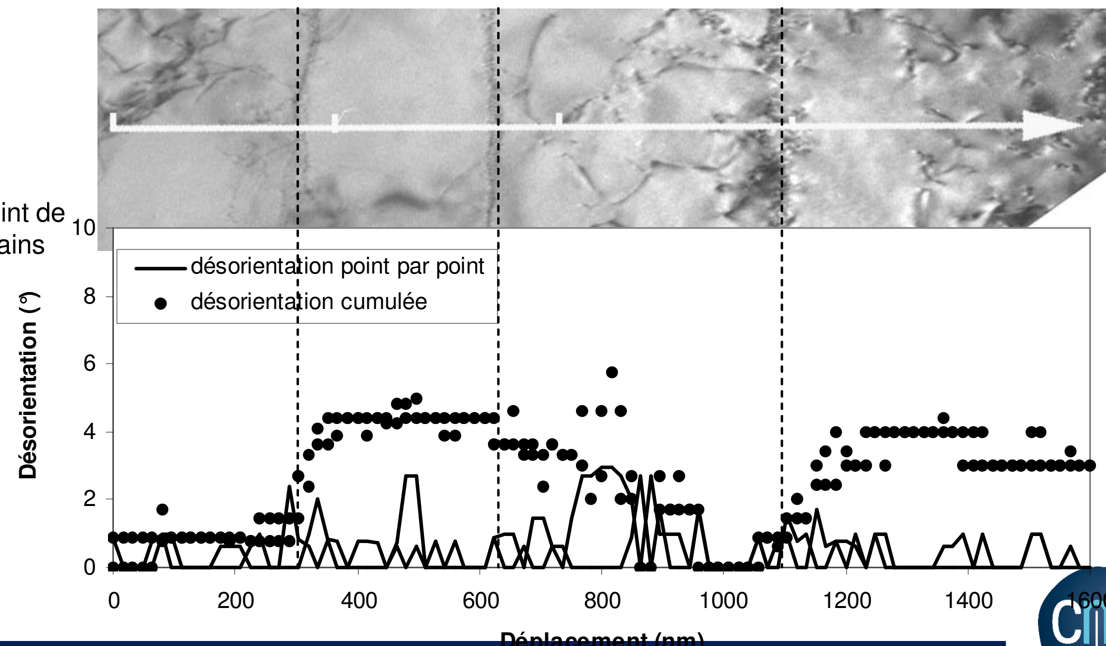


EBSD index quality contrast



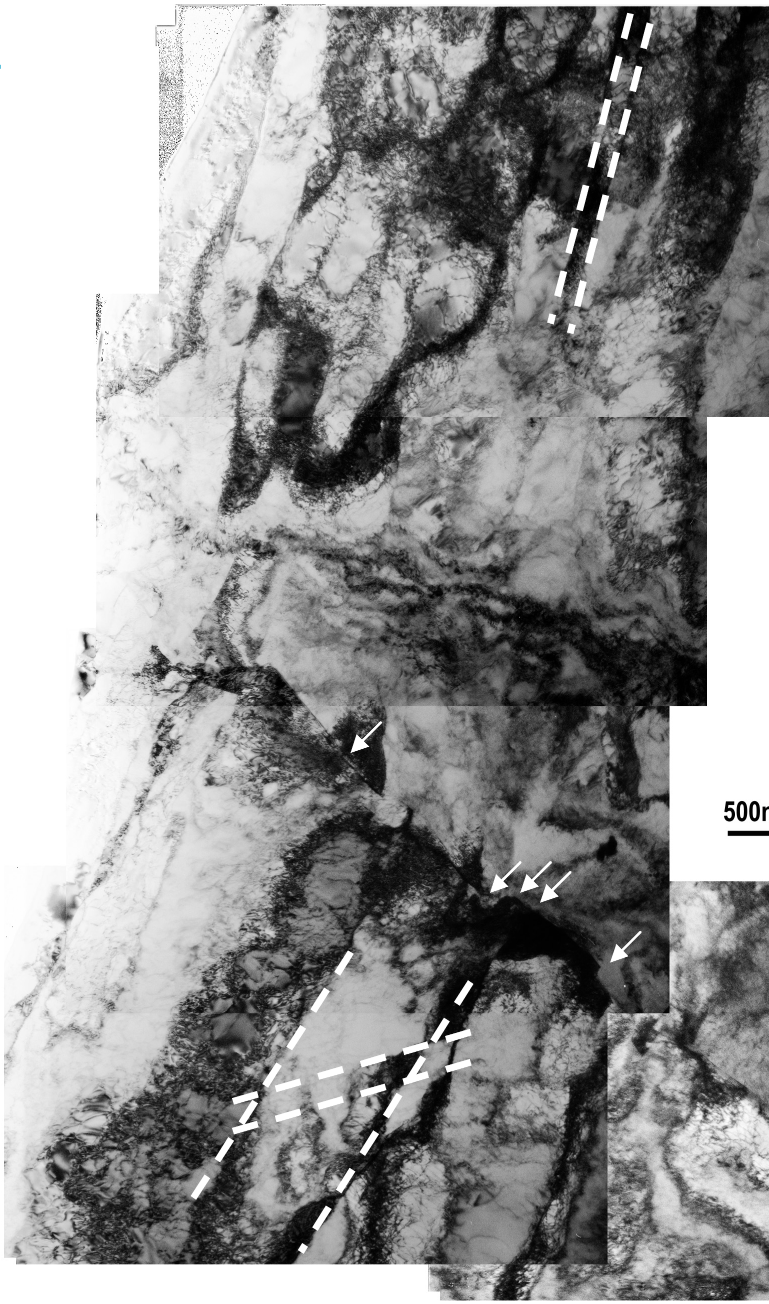


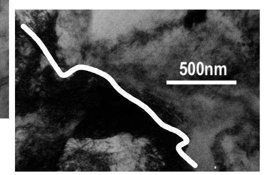
Joint de grains



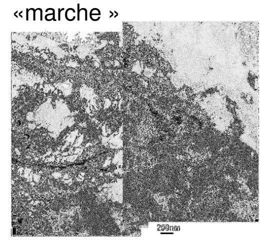
BF TEM observations

Grenoble INP

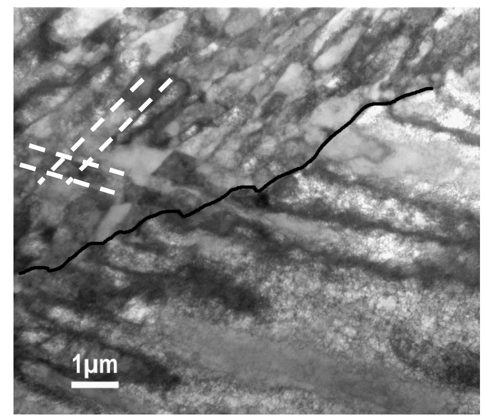




Vue de détail montrant des serrations en «marche »



Vue de détail montrant une serration en « pointe »



2) TRIP Steels

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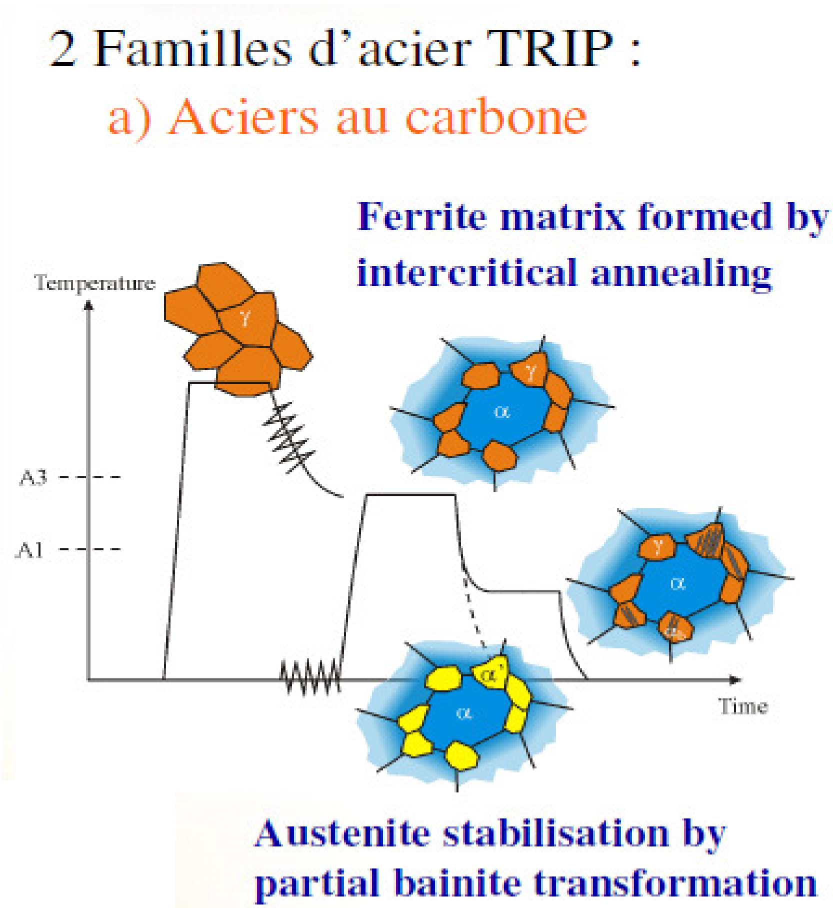
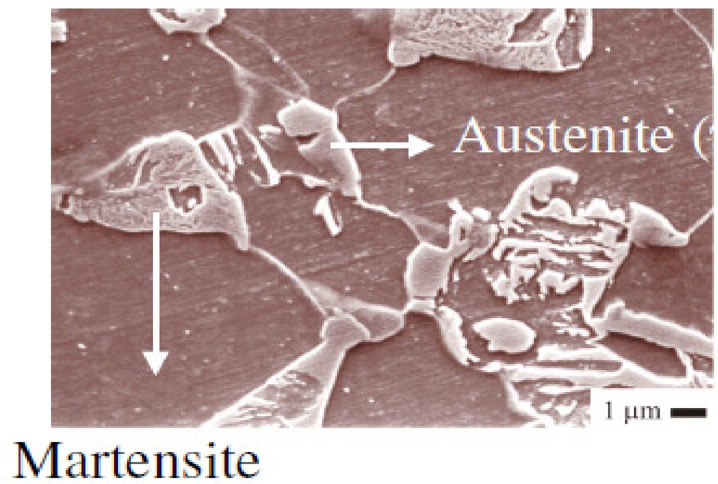




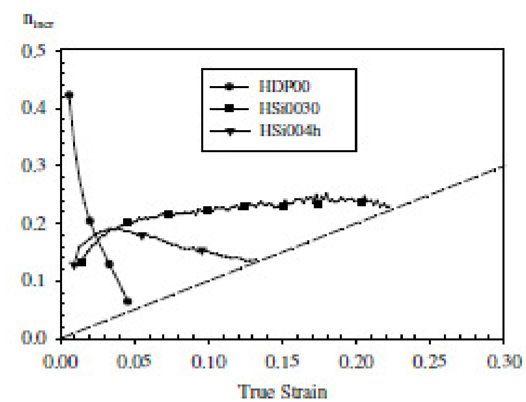
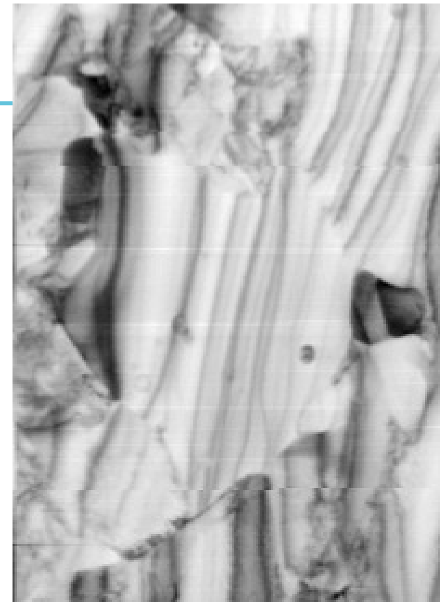


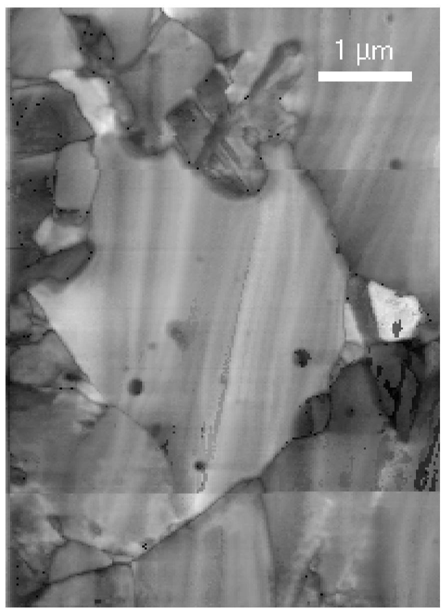
Image MET BF



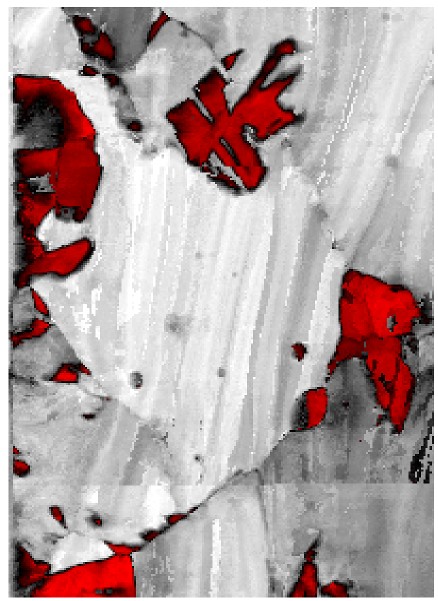
Virtual Bright Field

JEOL, 3010 LaB6, Spot 25nm, Step 25nm

Carte d'orientation



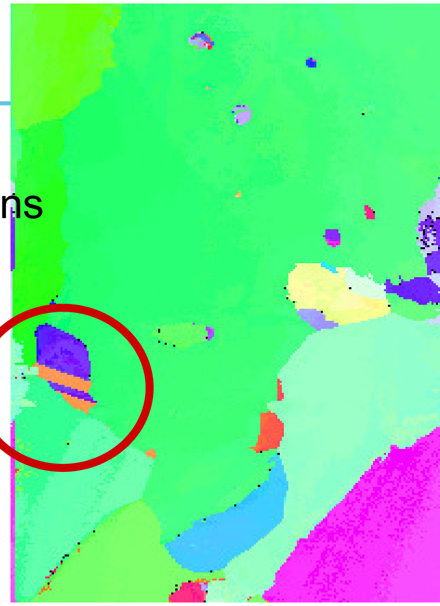
Robustesse

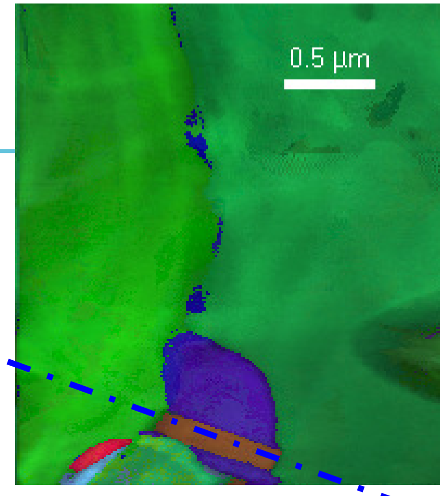


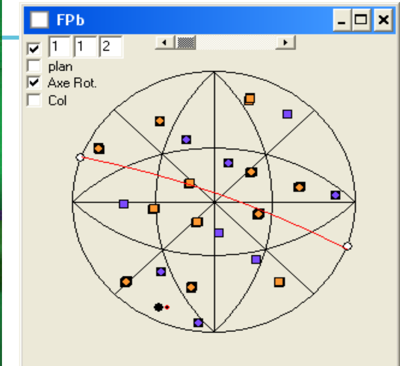
identification des phases : cfc

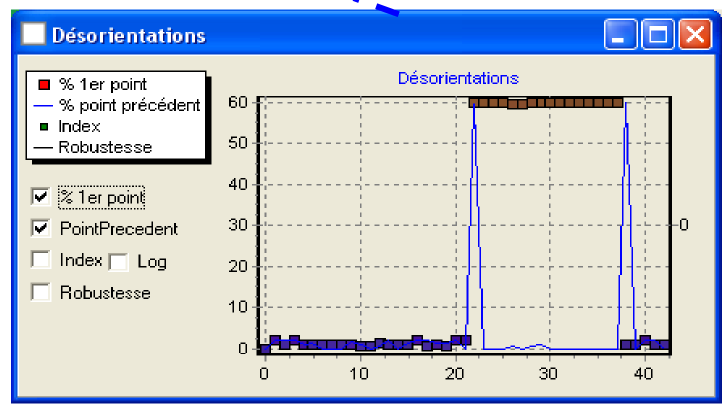
Complementary observations

Twin observations

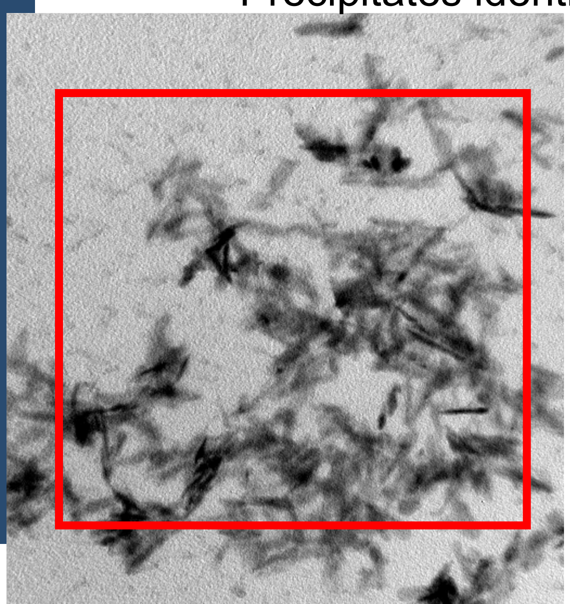


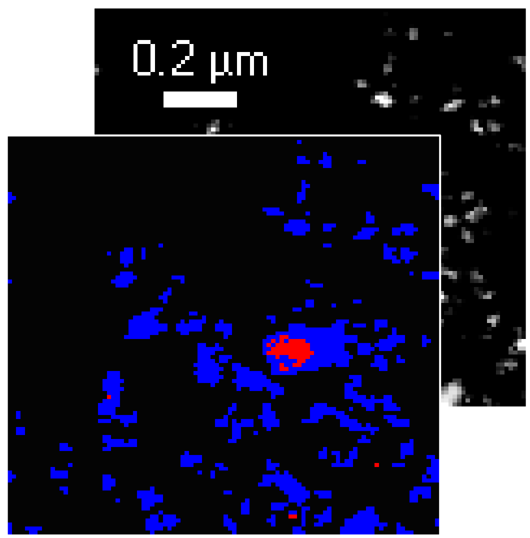






Precipitates identification





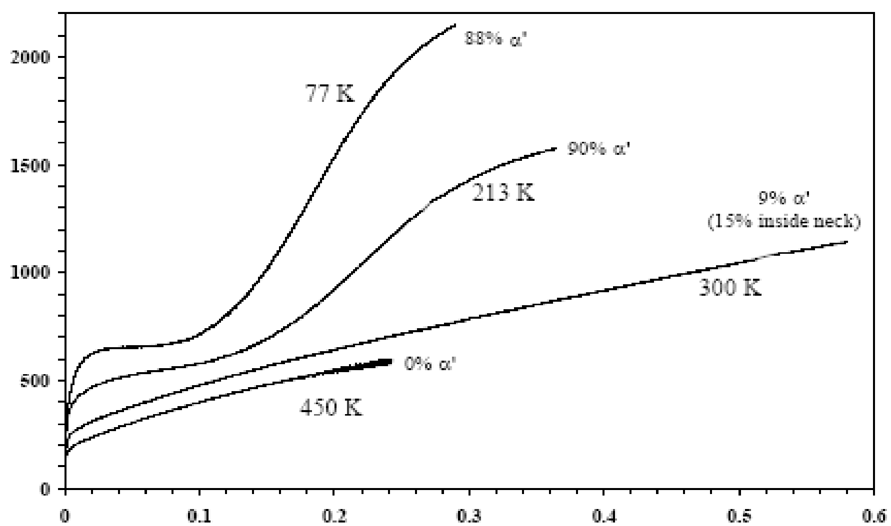
Blue : cementite

Red : TiN

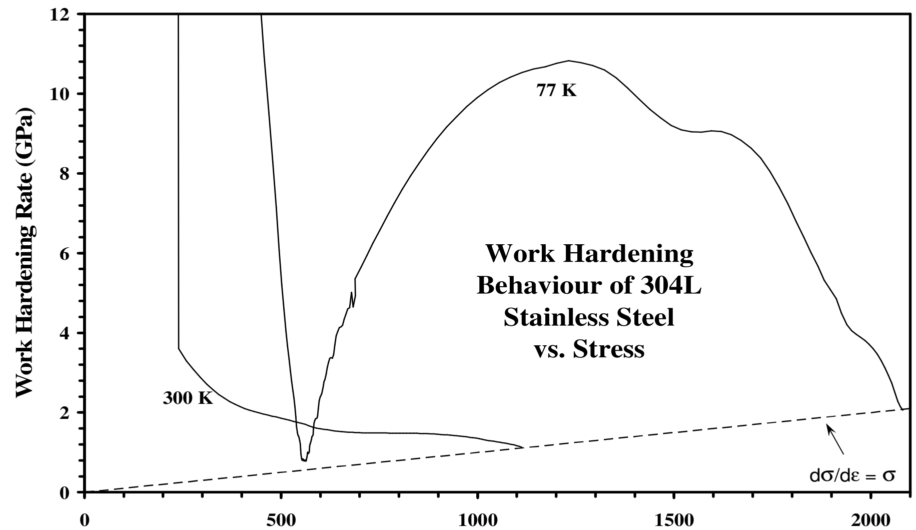
100x100 scanned at a rate of 44 fps (23 min). Step size 12 nm

b) Austenitic stainless trip steels: deformation mechanisms

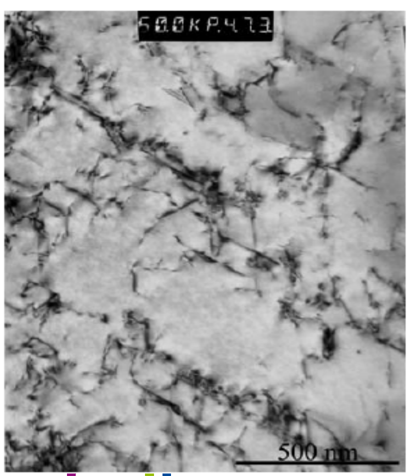
Contrainte vraie

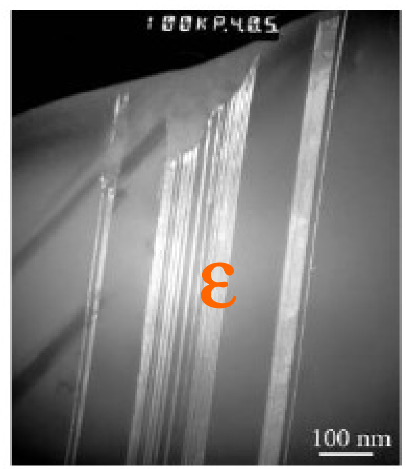


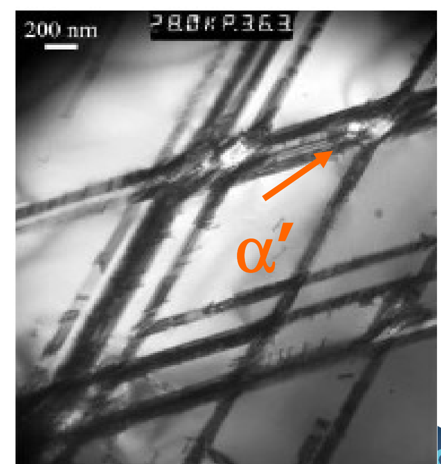
Déformation vraie



Contrainte vraie







RT

A 77K, law ε

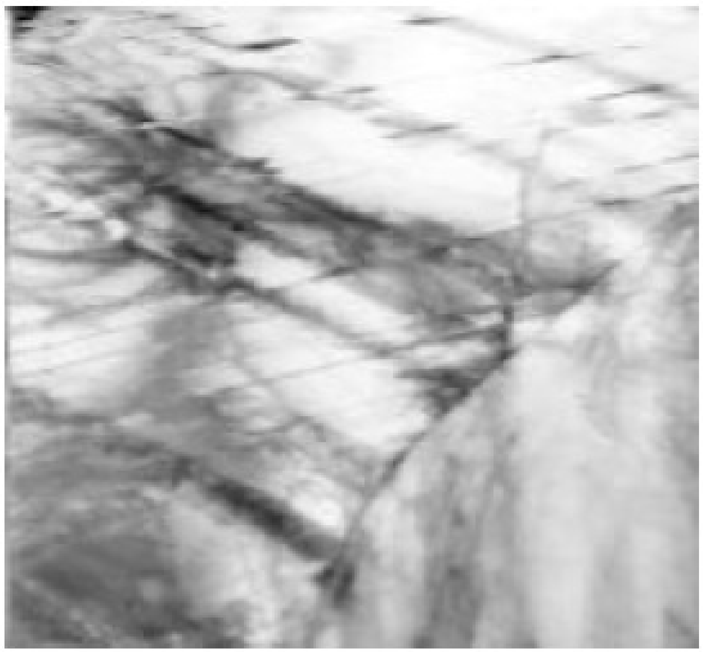
A 77K, ε= 5%

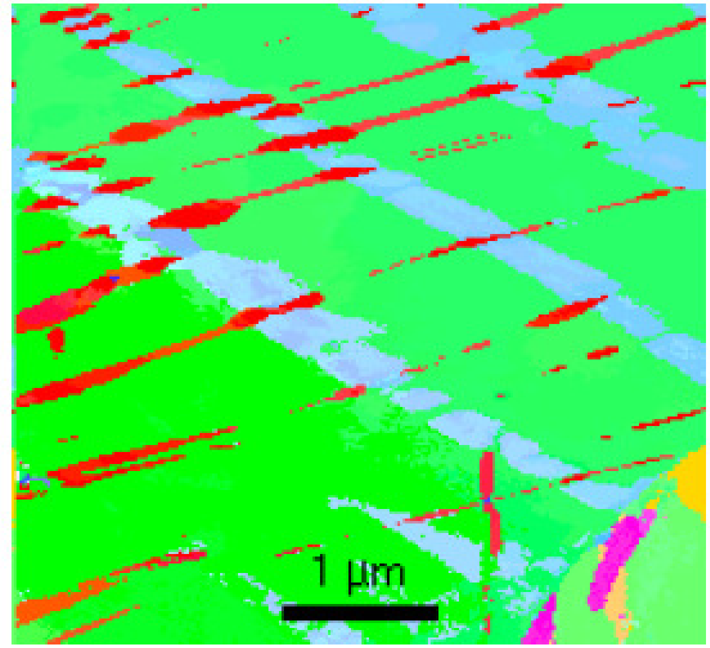
A 77K, ε= 10%

Grenoble INP

Phase identification

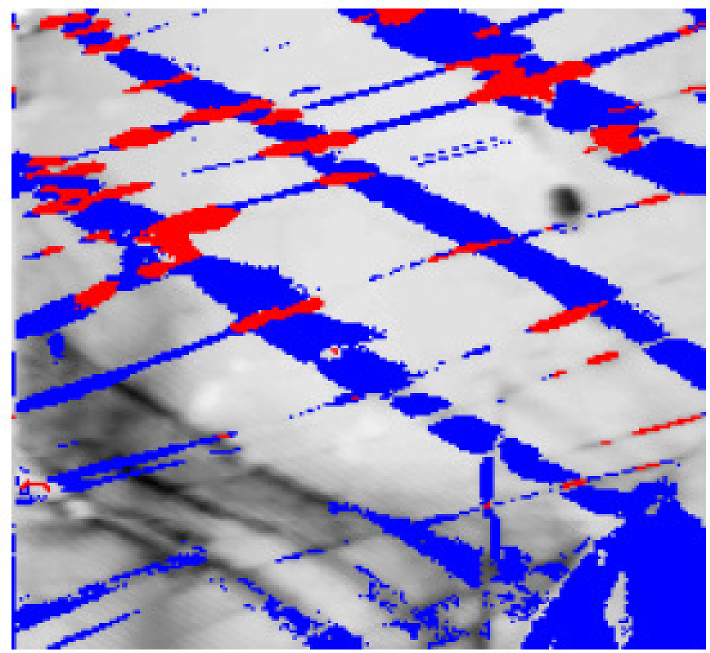
+ orientation of phase relationships





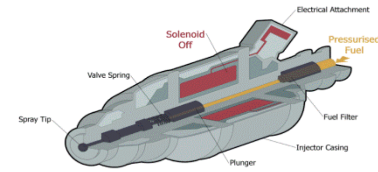
JEOL, 3010 LaB6, Spot 25nm, Step 25nm

+ precession angle 0,4°



Grenoble INP

3) Microstructural optimization for magnetic actuators



- Alloys compositions

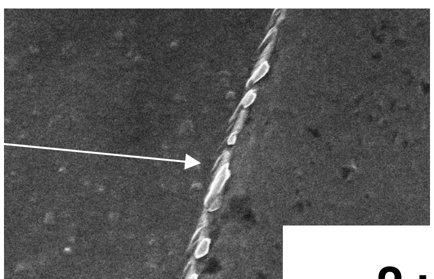
AISI	EN	C	N	Cr	Nb
430	1.4016	0.017	0.028	16.083	0.004
430Nb	1.4511	0.015	0.012	16.284	0.27

- Ferritic Stainless steel 430 (A1 = 880℃)

- Stabilized Ferritic stainless steel: 430Nb (feriitic at all T)

Cr_2N

% Cr

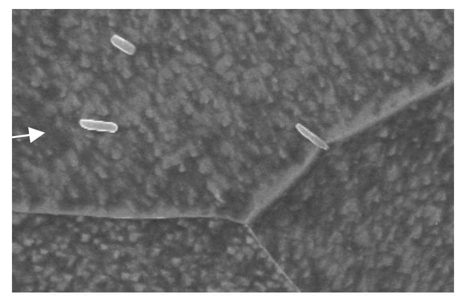


2 µm

Area without Chromium

Nb(C,N)

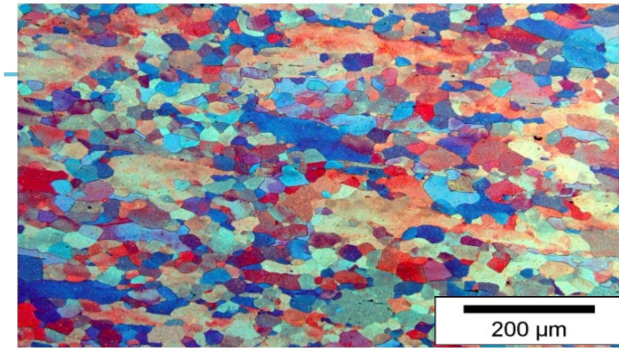
% Cr

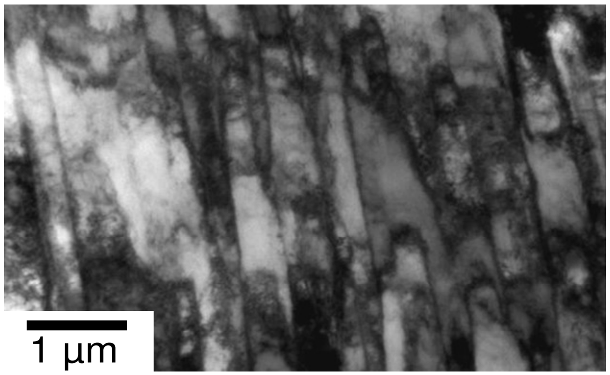


Grain scale

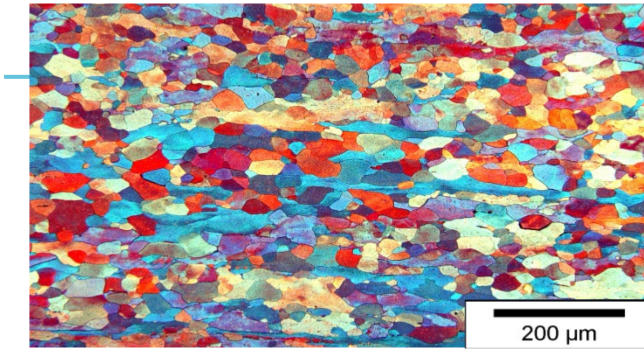
Subgrains

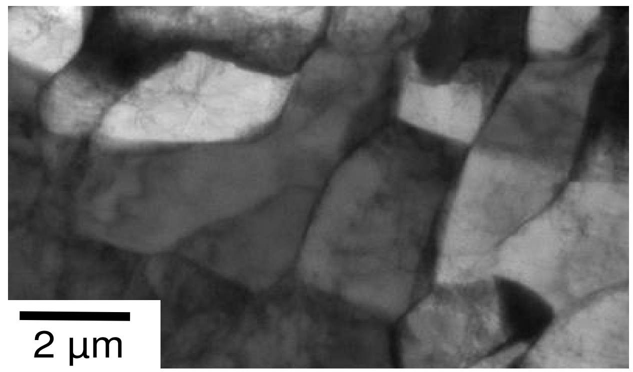
Deformed state



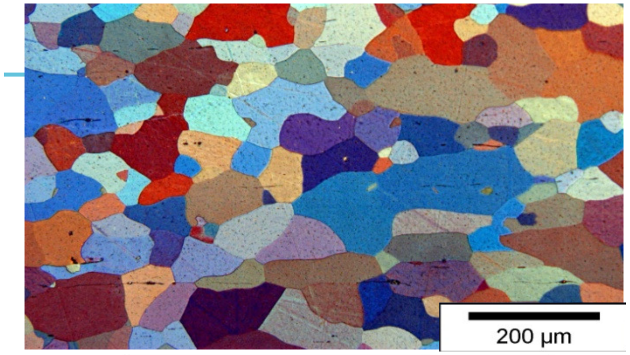


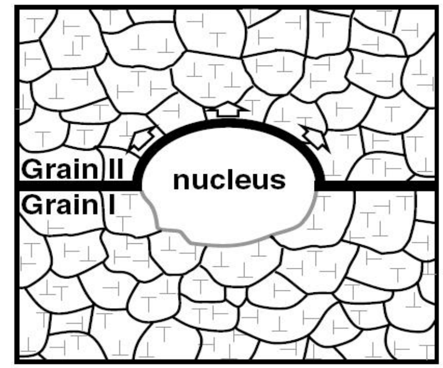
Static recovery



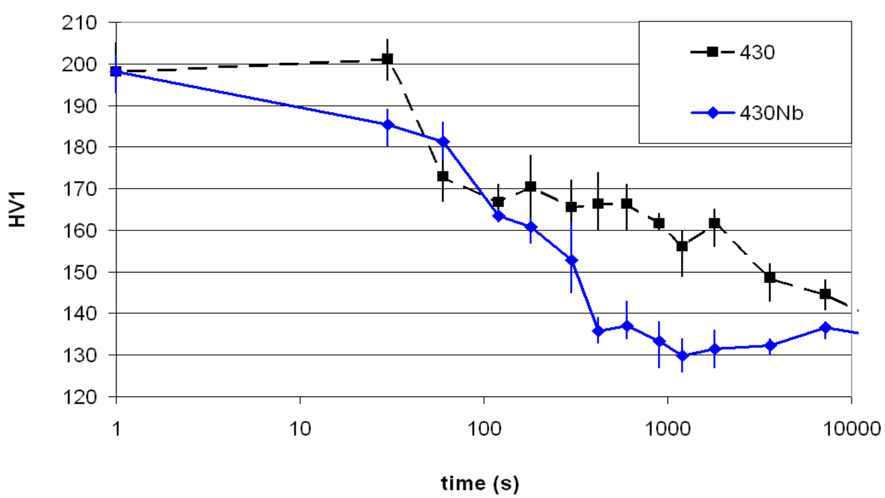


Static recrystallization

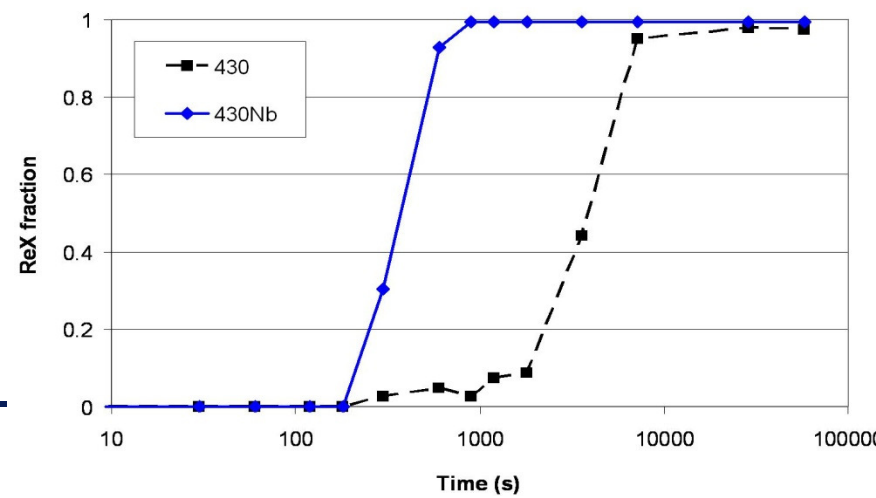




Recovery

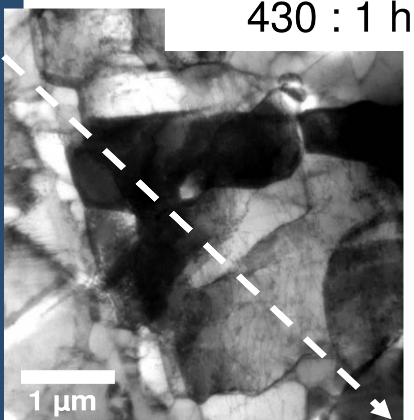


Recrystallized fraction

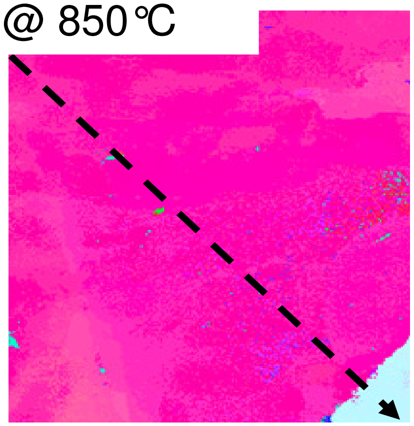


- Recrystallization mechanism
  - Nucleation
    - We did not observed large misorientation, even in recovered area

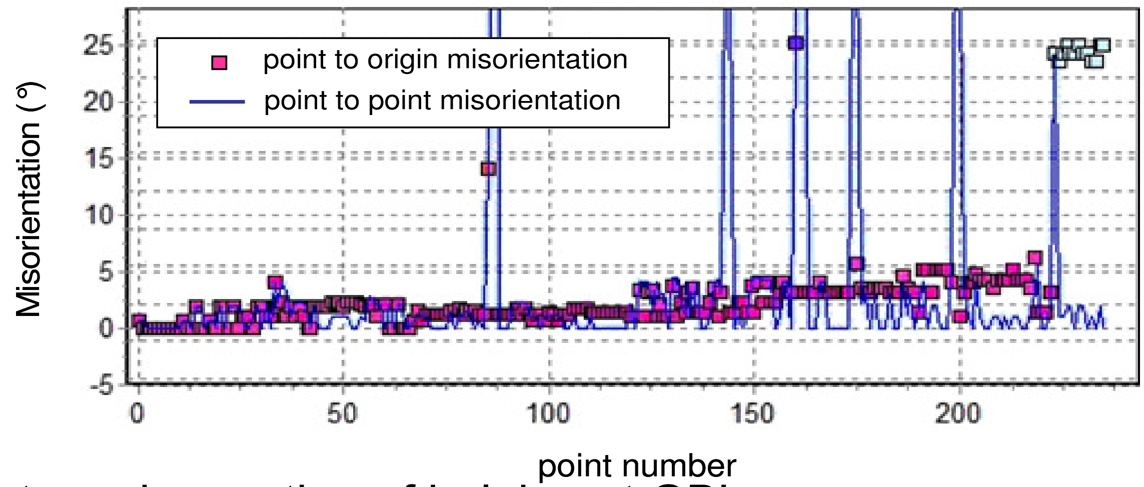
430 : 1 h @ 850℃



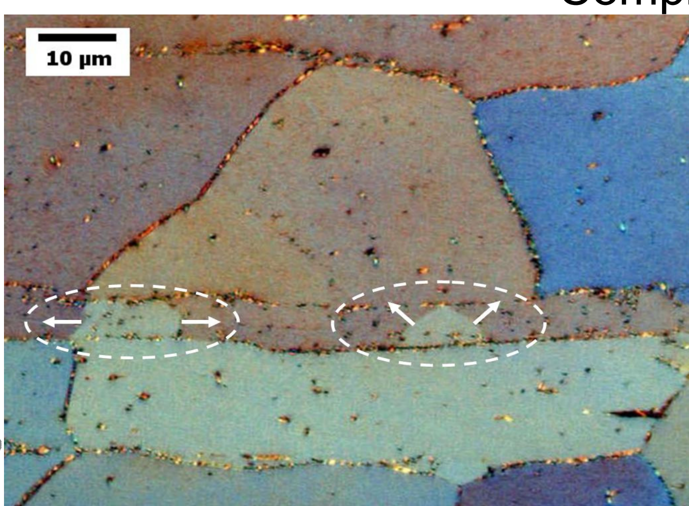
Bright Field



Orientation map



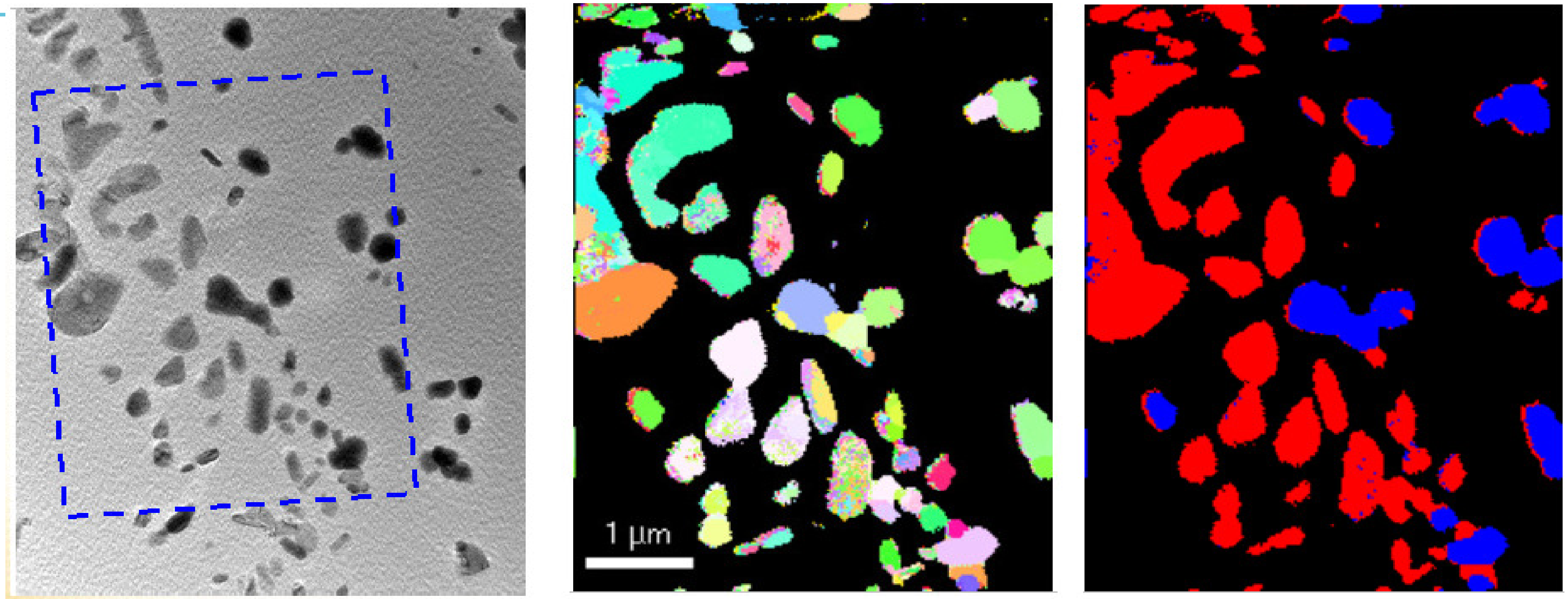
Complementary observation of bulging at GB's



430 : 7 min @ 850℃

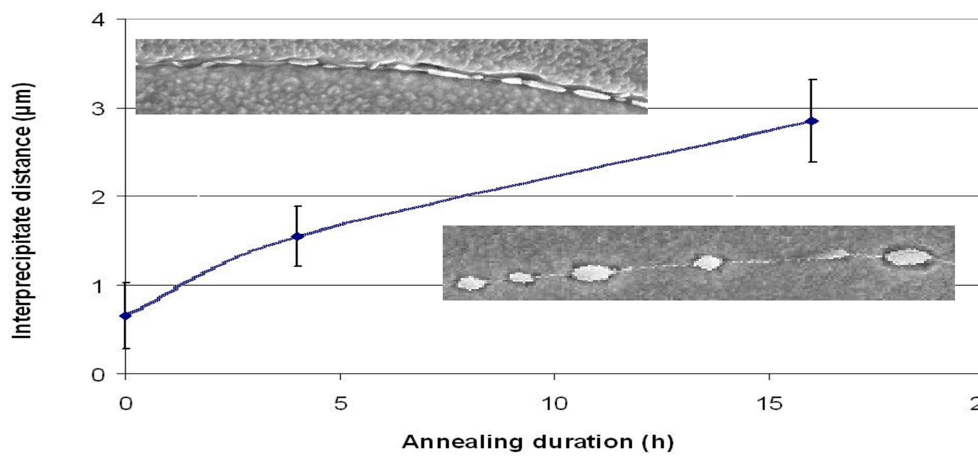
Nucleation mecanisms : SIBM, typical for law strain level

- Identification of the precipitation at the GBs (alloy 430) :



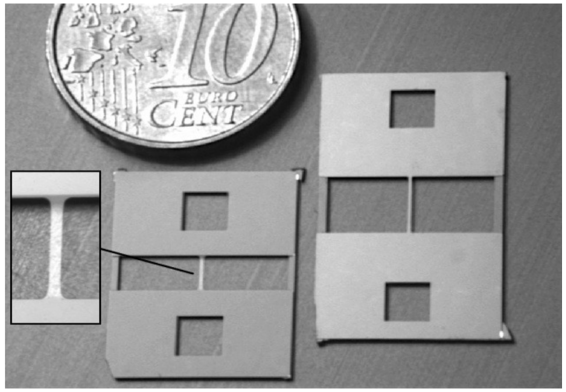
Phase identification: carbides (blue), and nitrides (red)

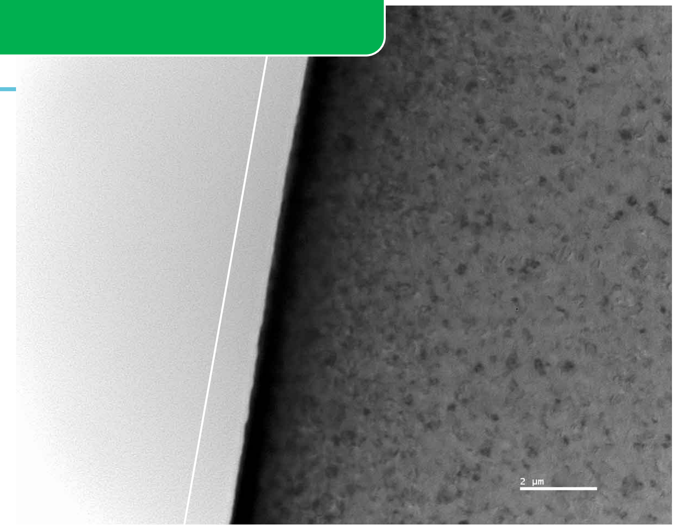
Recrystallization starts when precipitates have coarsened



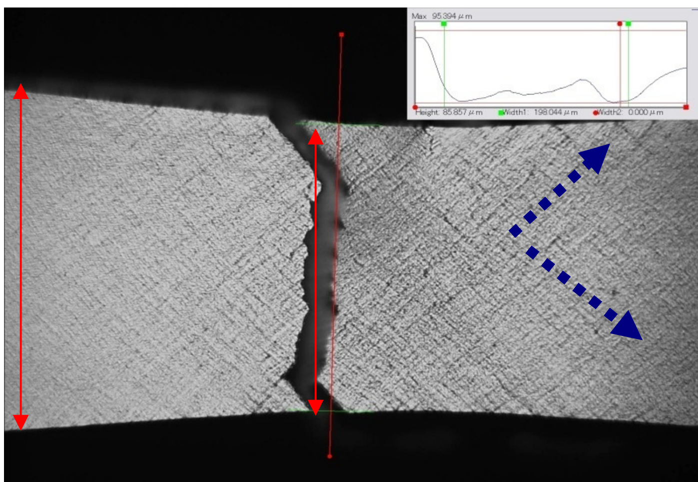
4) Thin Films

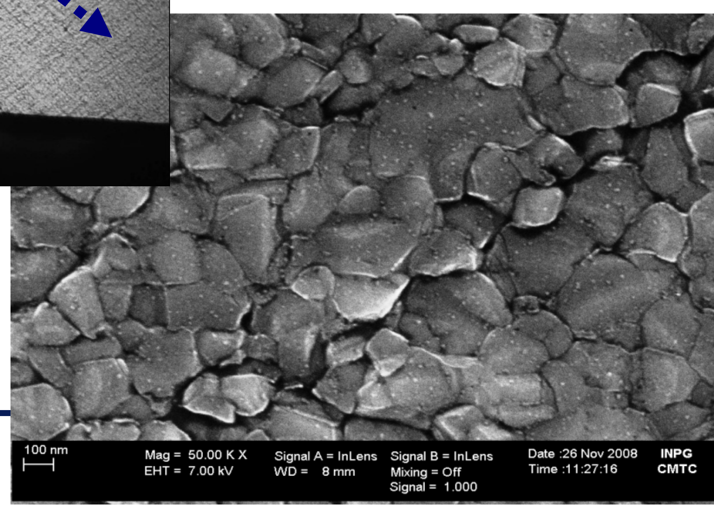
4) Thin Films : S. lay, Grenoble

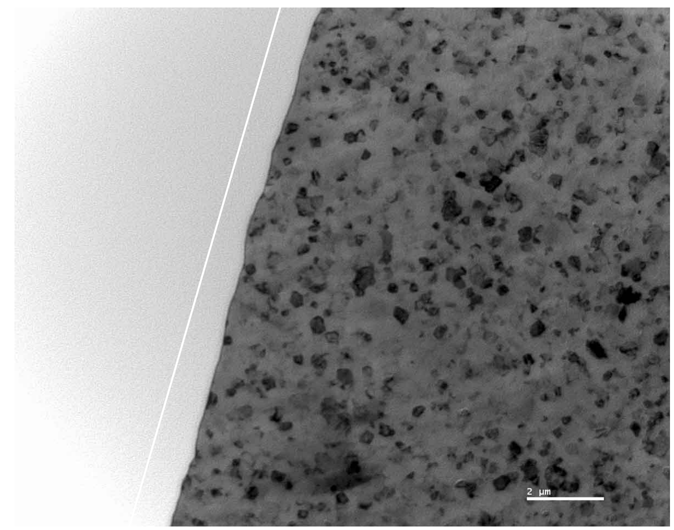




Non déformé

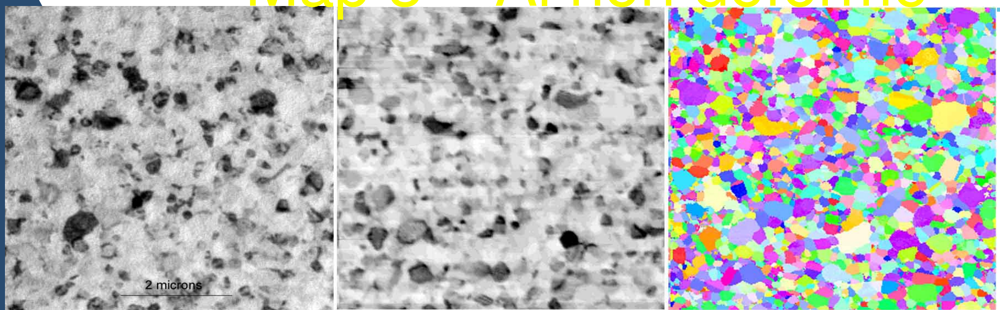






déformé

Map 3 – Al non déformé



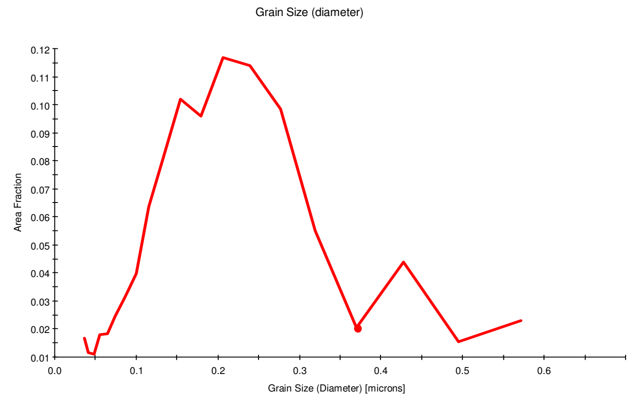
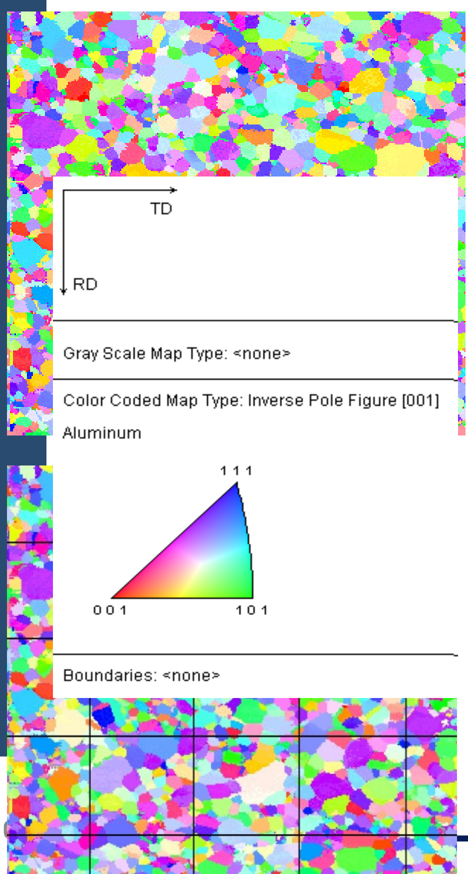


Chart: Grain Size (diameter)

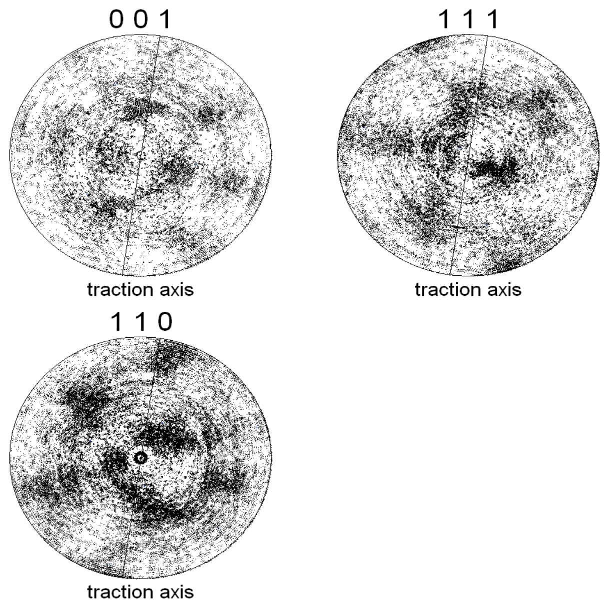
Edge grains excluded from analysis

Diameter [microns]	Area Fraction
0.03604	0.0165494
0.0416846	0.0116688
0.0482132	0.0108017
0.0557644	0.0179987
0.0644982	0.0181226
0.0745999	0.0244773
0.0862838	0.0312035
0.0997975	0.0398375
0.115428	0.0634848
0.133506	0.0810004
0.154416	0.101873
0.178601	0.0960262
0.206573	0.116973
0.238927	0.113876
0.276347	0.0984417
0.319629	0.0550986
0.369689	0.0203399
0.42759	0.043789
0.494559	0.0154841
0.572017	0.0229536

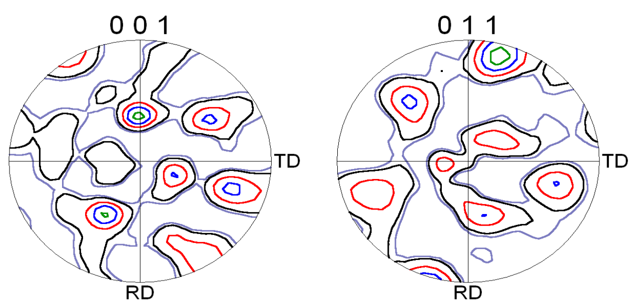
Average
Number 0.0940347
Area 0.206213

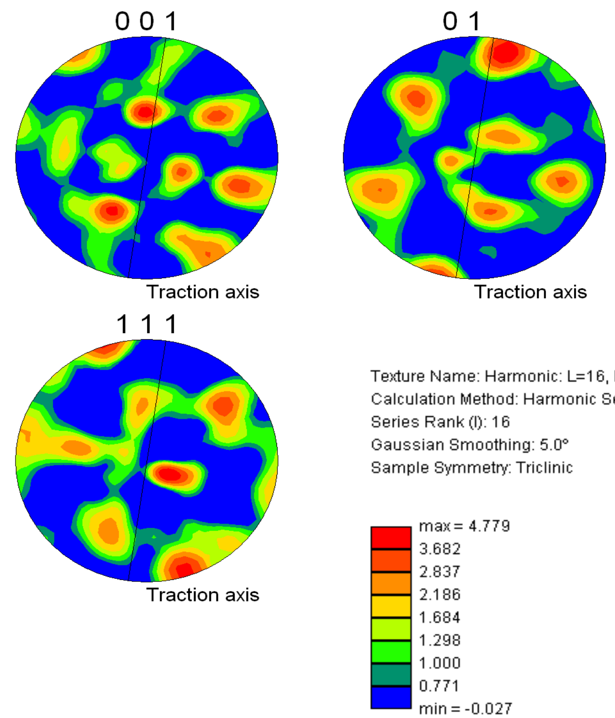


ACOM



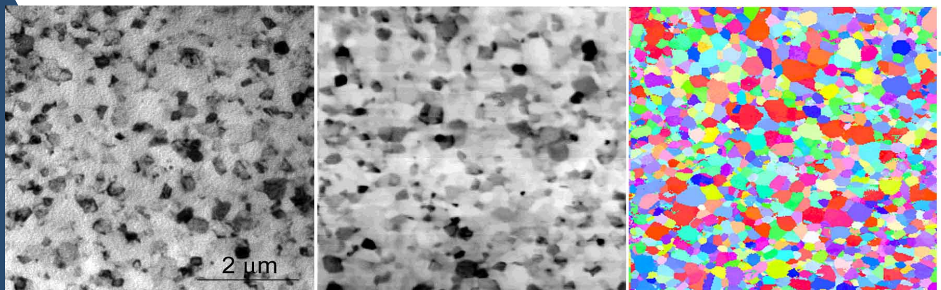
OII





Texture Name: Harmonic: L=16, HW=5.0
Calculation Method: Harmonic Series Expansion
Series Rank (l): 16
Gaussian Smoothing: 5.0°
Sample Symmetry: Triclinic

Map 3 Al déformé



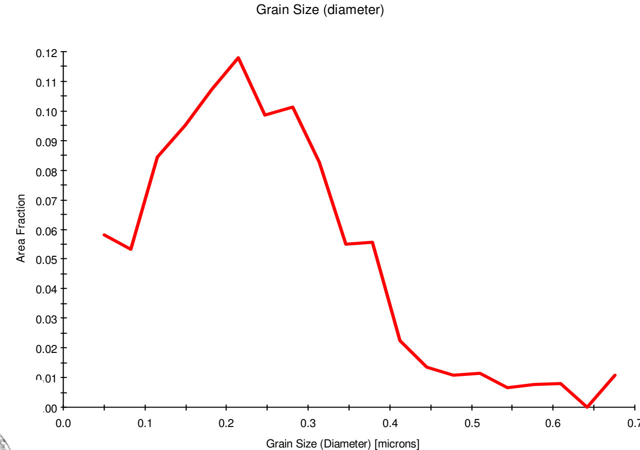


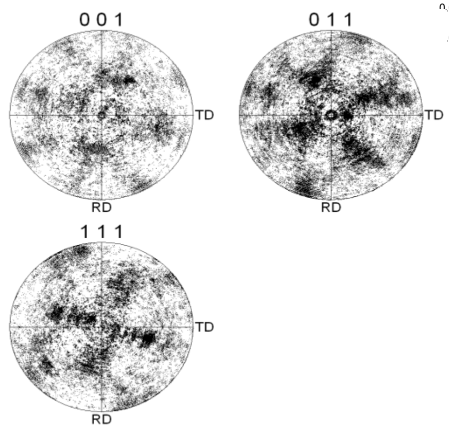
Chart: Grain Size (diameter)

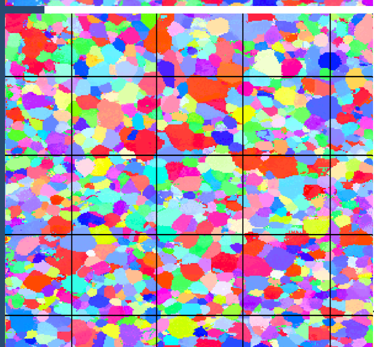
Edge grains excluded from analysis

Diameter [microns]	Area Fraction
0.0499649	0.057976
0.0828725	0.0531521
0.11578	0.084316
0.148688	0.0952016
0.181595	0.107325
0.214503	0.11807
0.24741	0.0984303
0.280318	0.1012
0.313225	0.0825549
0.346133	0.0549387
0.379041	0.0555768
0.411948	0.0225625
0.444856	0.0135528
0.477763	0.0106687
0.510671	0.0114599
0.543578	0.00653395
0.576486	0.00749107
0.609393	0.00811639
0.642301	0
0.675209	0.0108729

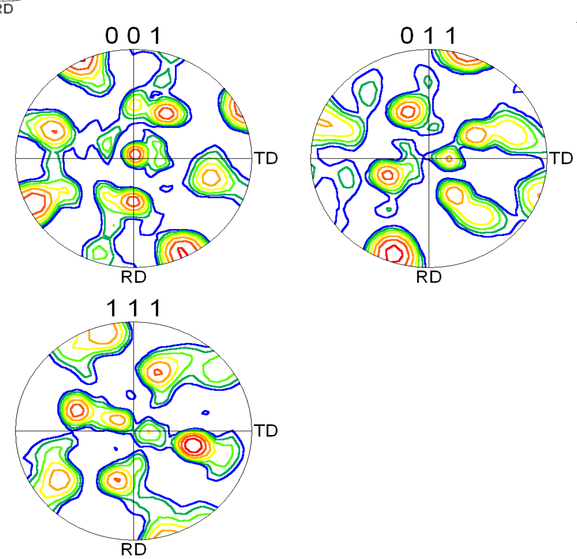
Average	
Number	0.0979333
Area	0.241055

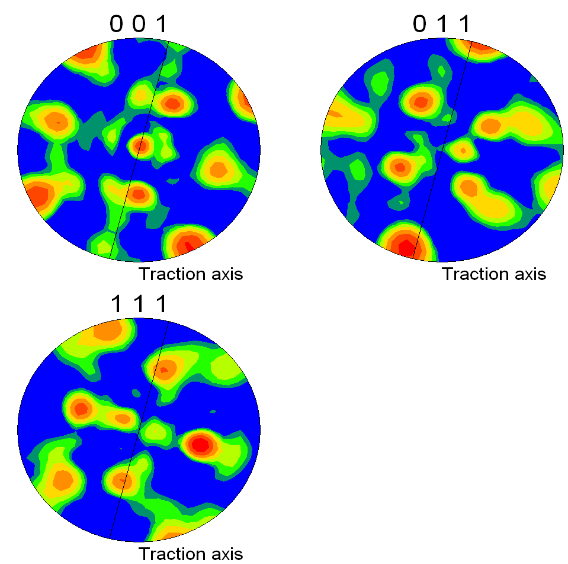
ACOM





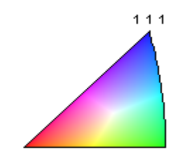
OIM





Color Coded Map Type: Inverse Pole Figure [001]

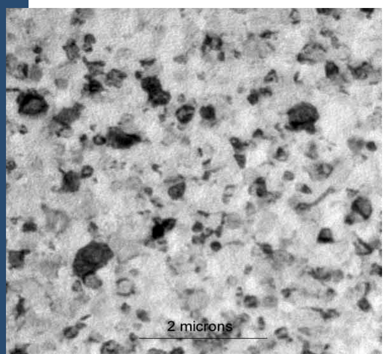
Aluminum

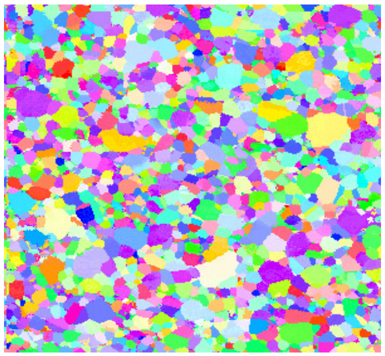


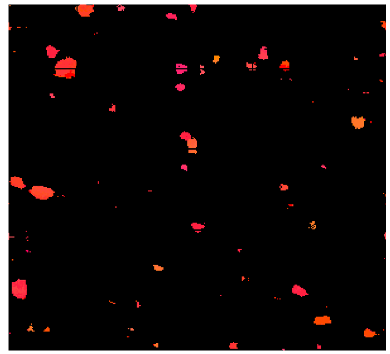
Boundaries: <none>

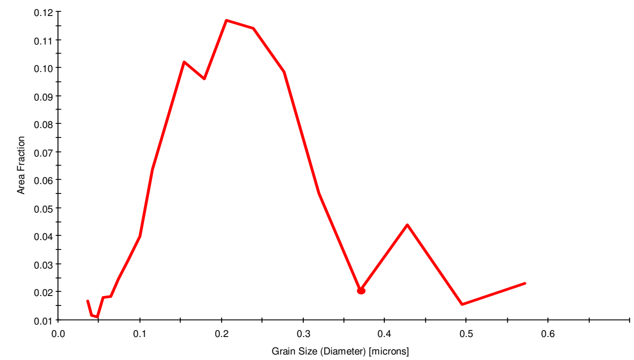
Aluminium before deformation

TEM image | Orientation map | Grains close to <001> direction | Grain size distribution

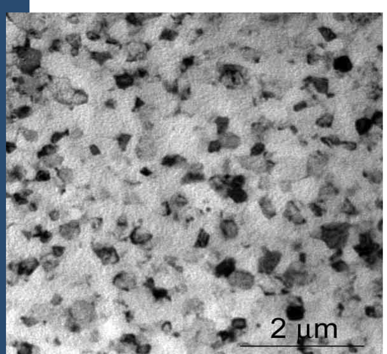


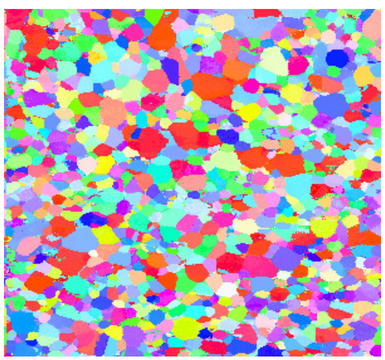


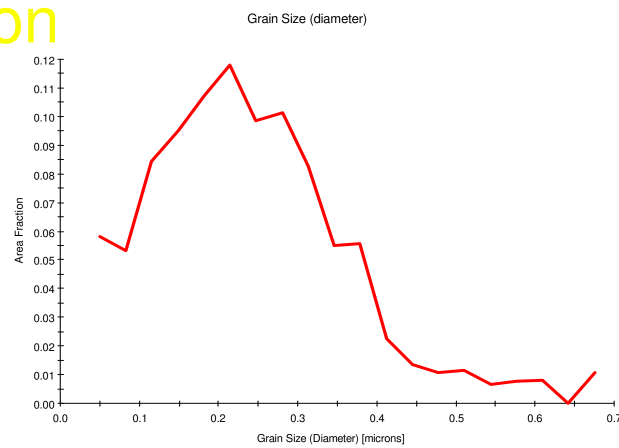




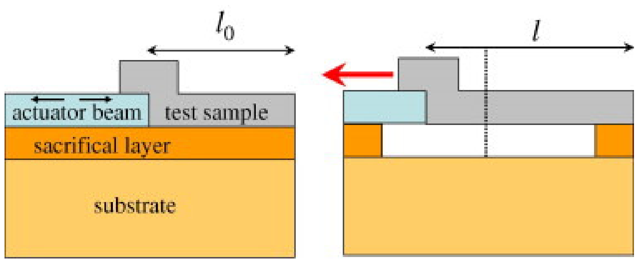
Aluminium after deformation







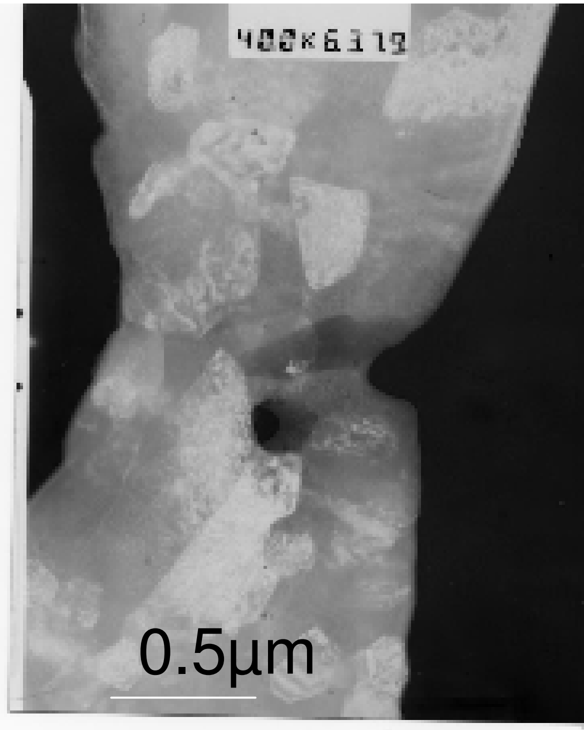
4) Thin Films : S. Godet, Bruxelles

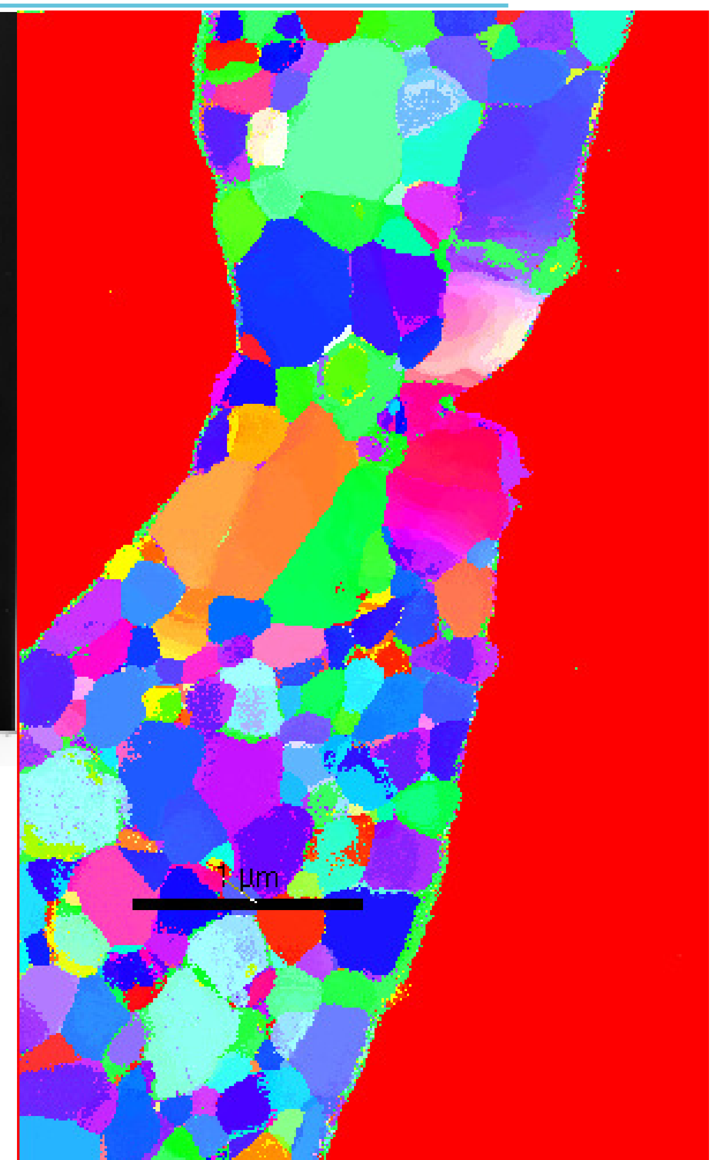


$$\varepsilon^{mech} = \ln\left(1+\frac{\Delta l}{l_0}\right) + (\alpha_{sub} - \alpha)\Delta T$$

$$\varepsilon_{act}^{mech} = \ln\left(\frac{l_{0act} - \Delta l}{l_{0act} - \Delta l_{free}}\right)$$

$$\sigma_{act} = E_{act}\varepsilon_{act}^{mech} \qquad \sigma = \sigma_{act}\frac{S_{act}}{S}$$

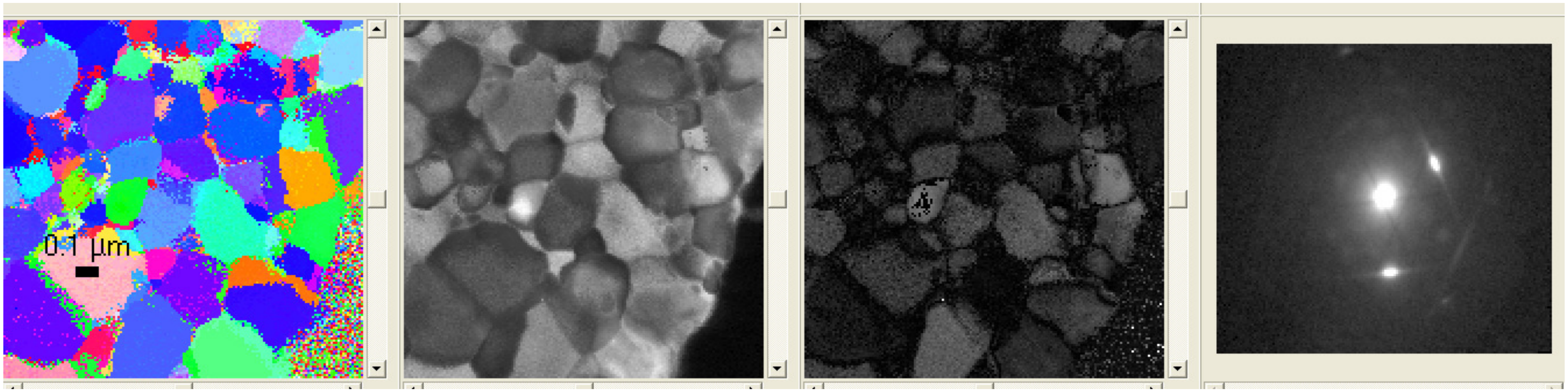




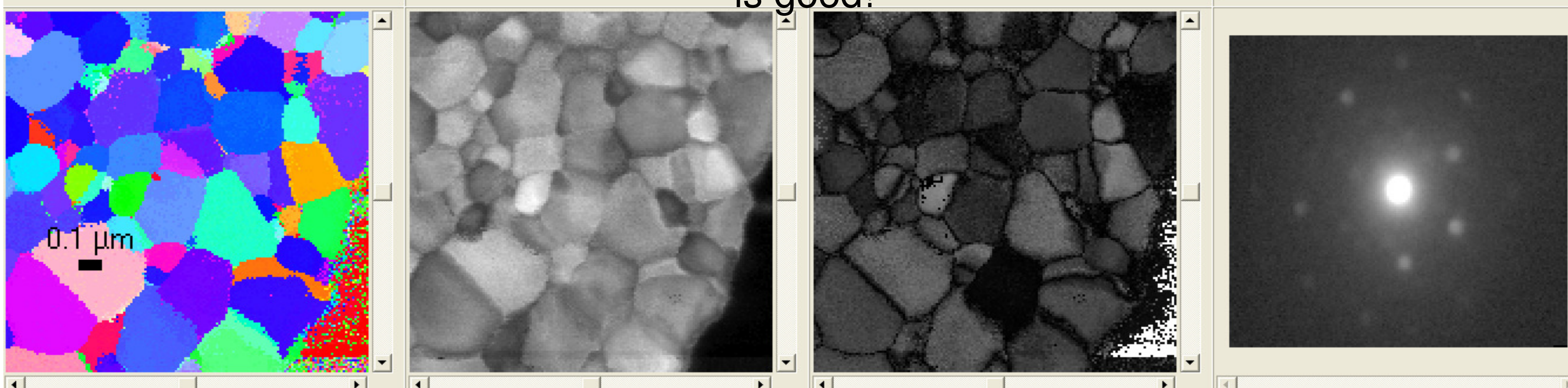
CM20, LaB6,

Spot size 10nm,Step 10nm, 50fps, precession 0.9

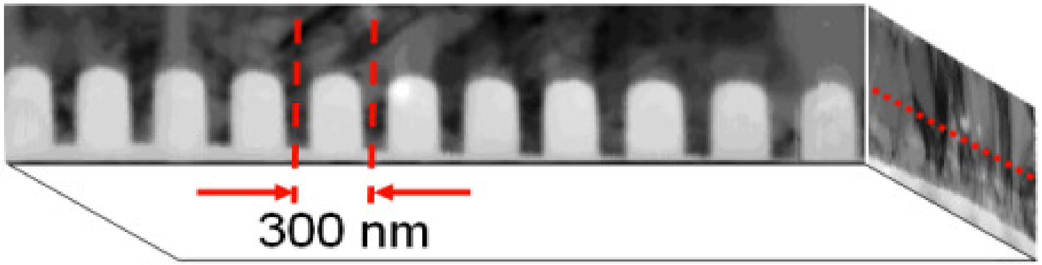
Good results were obtained with a precession angle α= 0.9°



Thick sample, same area, diffraction patterns with kikuchi lines. Without precession, quality is poor, with precession α= 0.9°, diffraction patterns are « cleaned », and indexing is good!



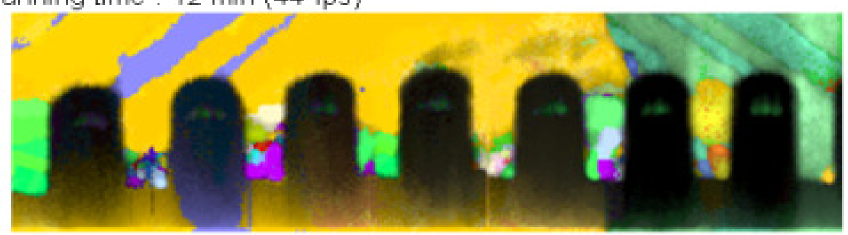
Tailles de grains et désorientation dans des lignes de Cu de 80nm



500x100 steps (6.5 nm each) , Spot size 25 nm
Scanning time : 19 min (44 fps)

Side view

300x100 steps (6.5 nm each), spot size 15 nm
Scanning time : 12 min (44 fps)

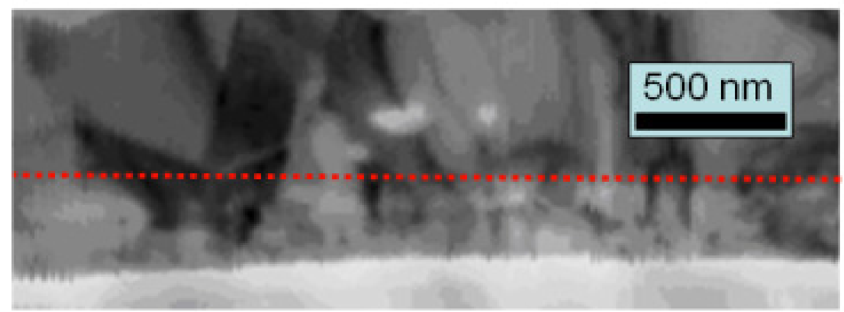


SIDE VIEW (orientation and index superimposed map)
The two scans were performed with different settings
They demonstrated the reproducibility of the identification

CROSS VIEW (orientation map)

Grain size of the order of 30 nm may be identify despite the use of a conventional LaB6 equipped Jeol 3010 TEM (spot size 25 nm)

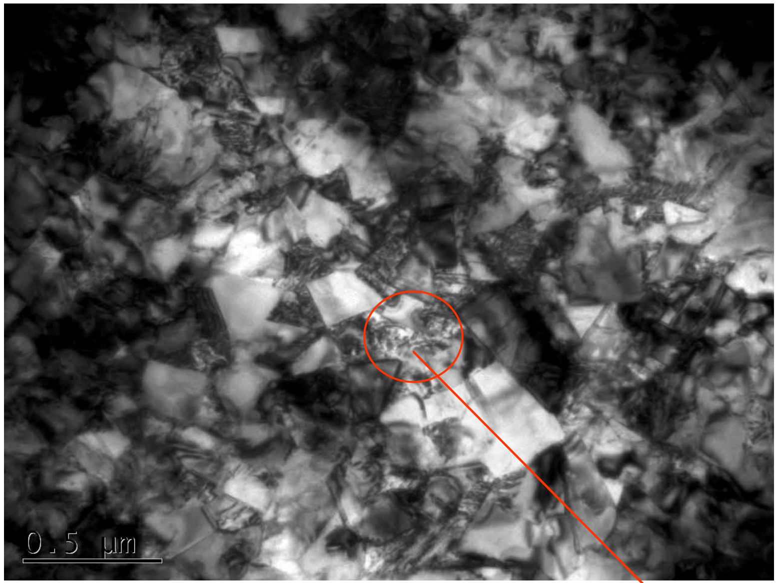
250x100 steps (13 nm each)
LaB6 equipped Jeol 3010 TEM (spot size 25 nm)
Scanning time : 10 min (44 fps)



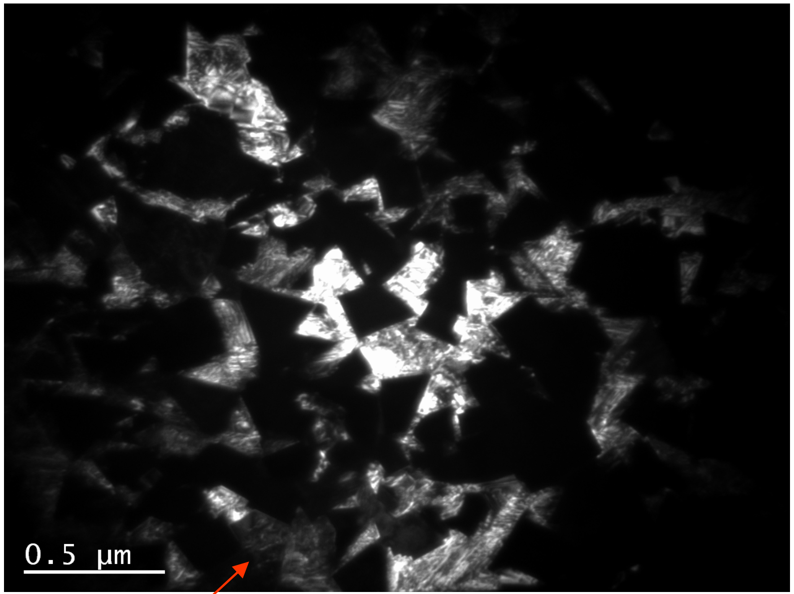
Credits:
- Stefan BRANDSTETTER SIMaP - Grenoble INP

5. Identification des phases et des orientations dans les matériaux frittés WC-Co

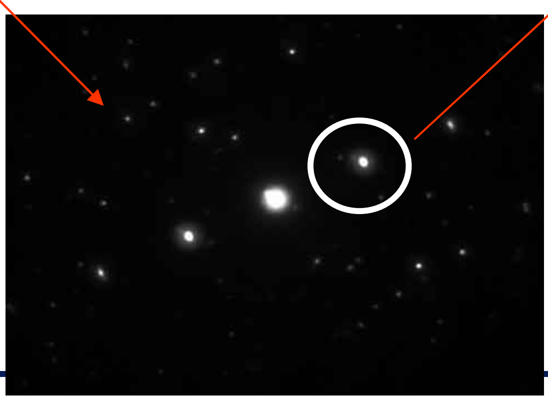
S. Lay @SIMaP



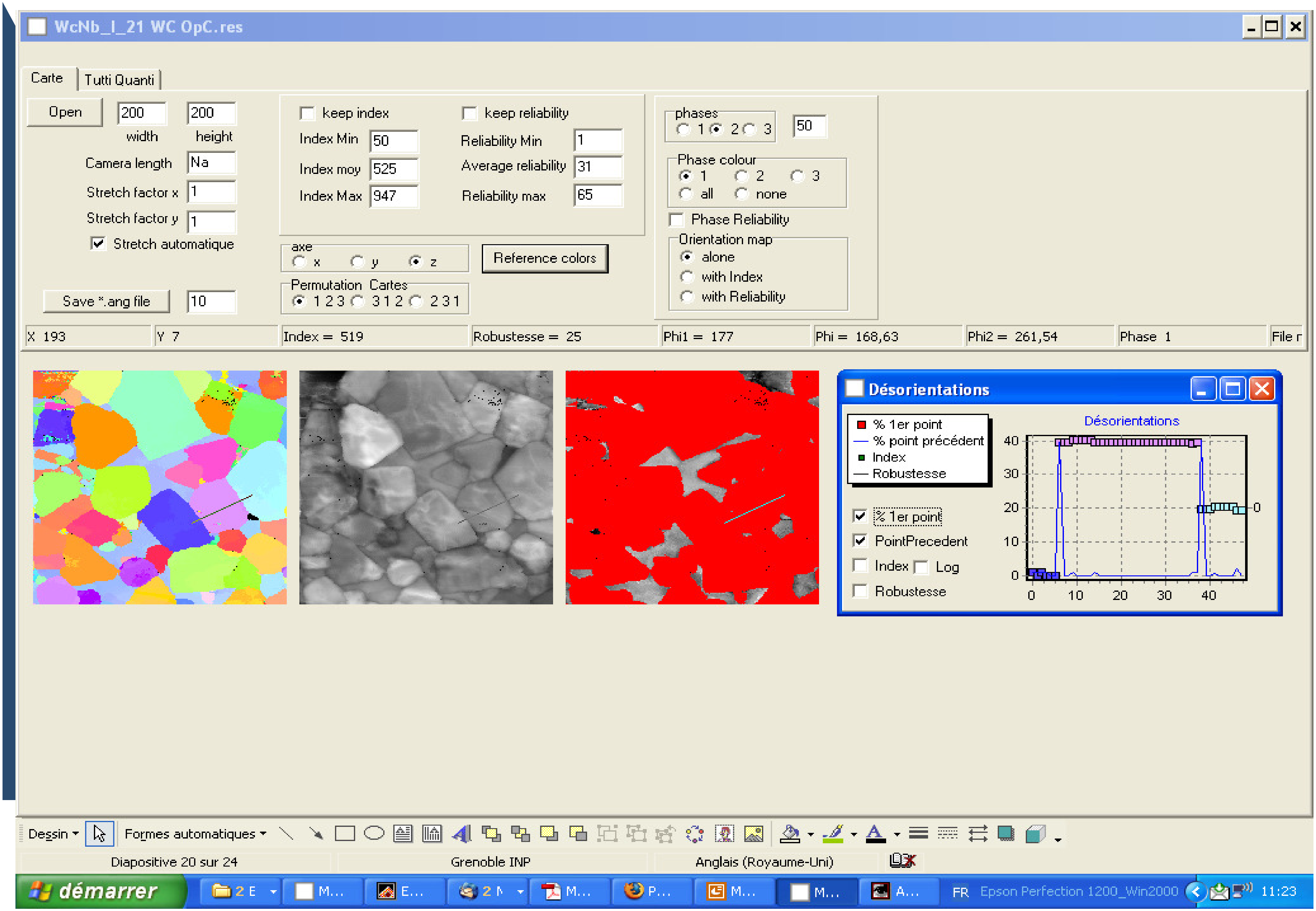
Bright field image



Dark field image : same orientation for all Co pools (Co in bright)



DP of Co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Reliability max
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z
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3 1 2
2 3 1
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3
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2
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all
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with Reliability
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Robustesse = 25
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Phi2 = 261,54
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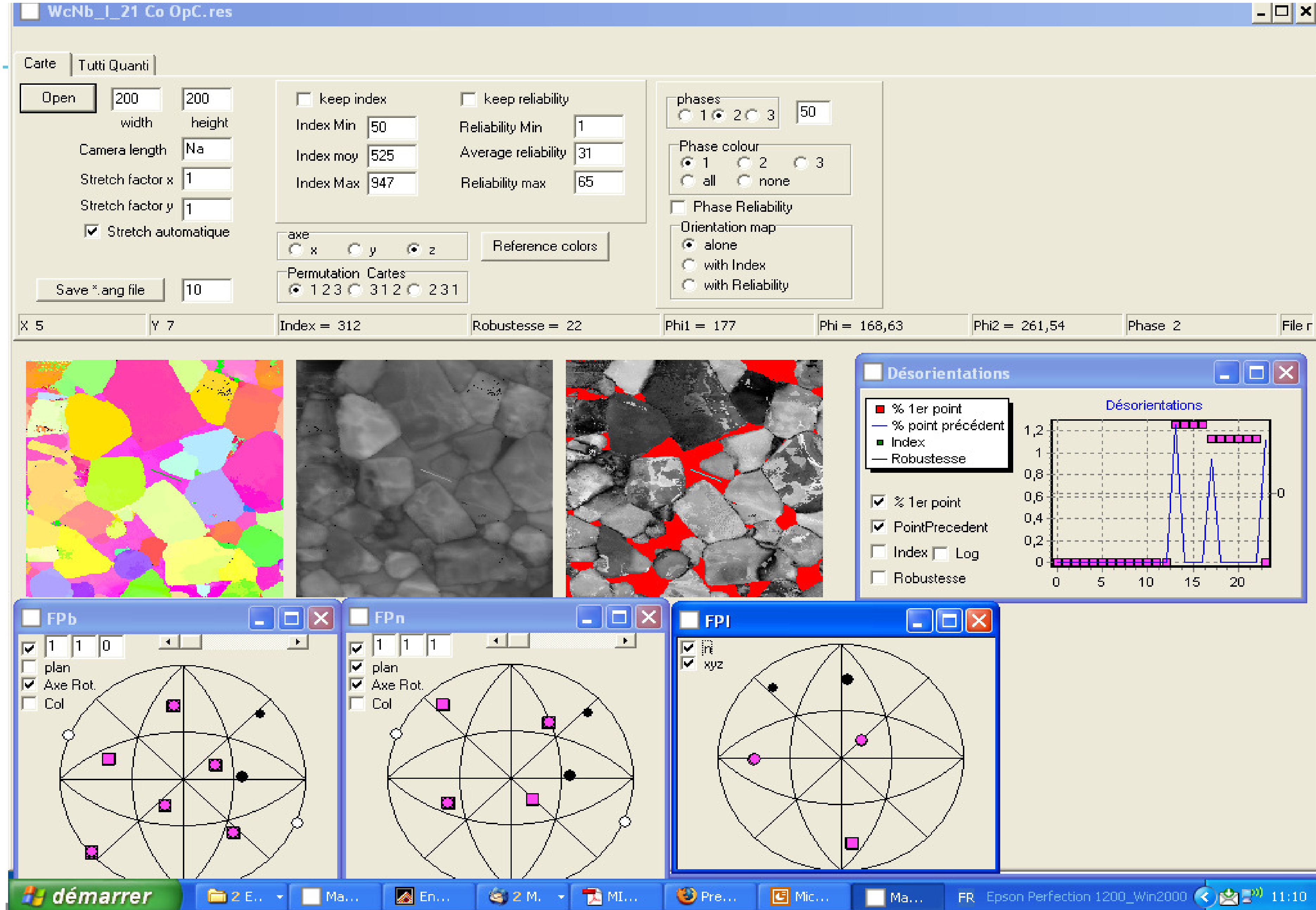

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Robustesse = 22
Phi1 = 177
Phi = 168,63
Phi2 = 261,54
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