



Essais in-situ et mesures de champs cinématiques sous MEB

E. Héripré, D. Caldemaison

*J. Crépin, M. Bornert, T. Bretheau, A. Zaoui, G. Bertolino, J.M. Allain, M.
Bourcier, L.L. Wang, O. Lopez*

Laboratoire de Mécanique des Solides, UMR 7649,
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Palaiseau, France

Bibliographie



Web of Science : Topic = (scanning electron microscop*) AND (in situ test)

165

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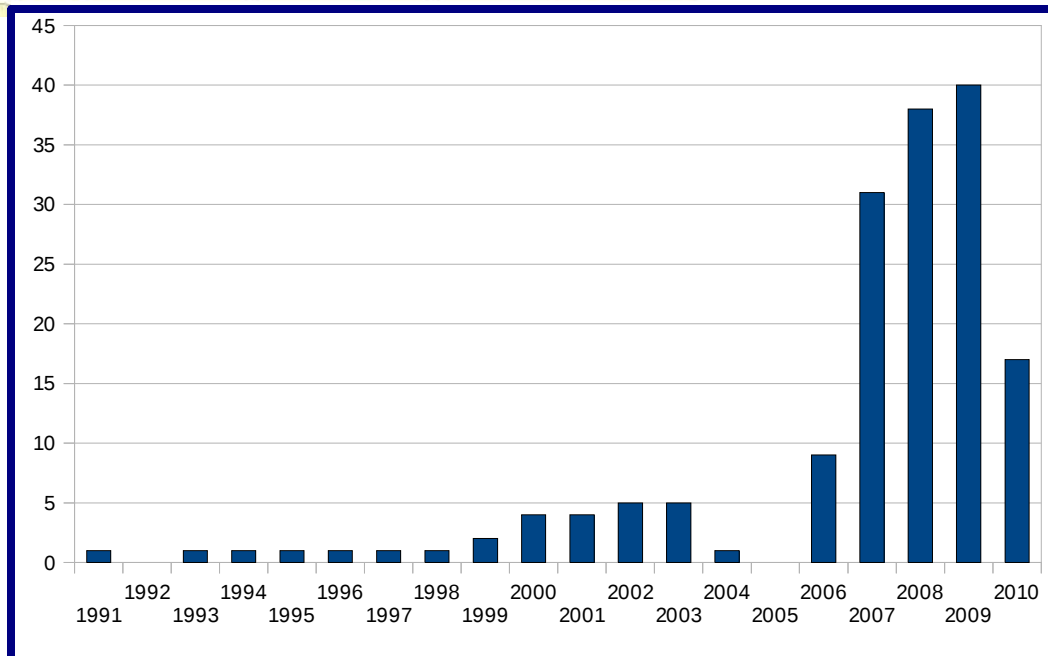
Results Topic=(scanning electron microscop*) AND Topic=(in situ test)
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Timespan=All Years.

Results: **165**

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Bibliographie

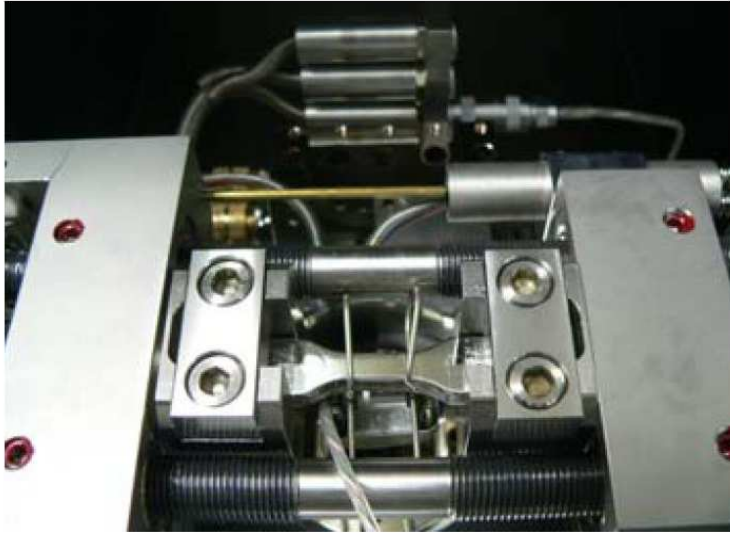


Fig.2. Push-pull loading stage with mounted specimen and extensometer on the backside of the specimen.

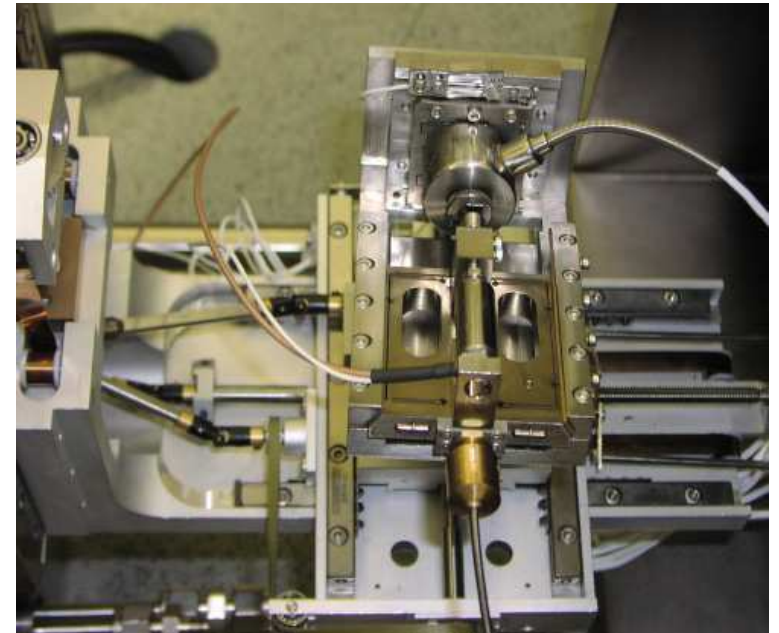
Weidner et al. (2010), Proc Eng 2



Fig. 3. Loading device with a sample to be furnished inside the SEM.

Song et al. (2008), Comp Sc. Tech.

Essentiellement fissuration
+ scratching tests



COMPACT TEST PLATFORM FOR IN-SITU INDENTATION
AND SCRATCHING INSIDE A SCANNING ELECTRON
MICROSCOPE (SEM)

Thèse R. Rabe, EPFL (2006) 3

Bibliographie

Mais aussi :
Essais à chaud ou sous environnement

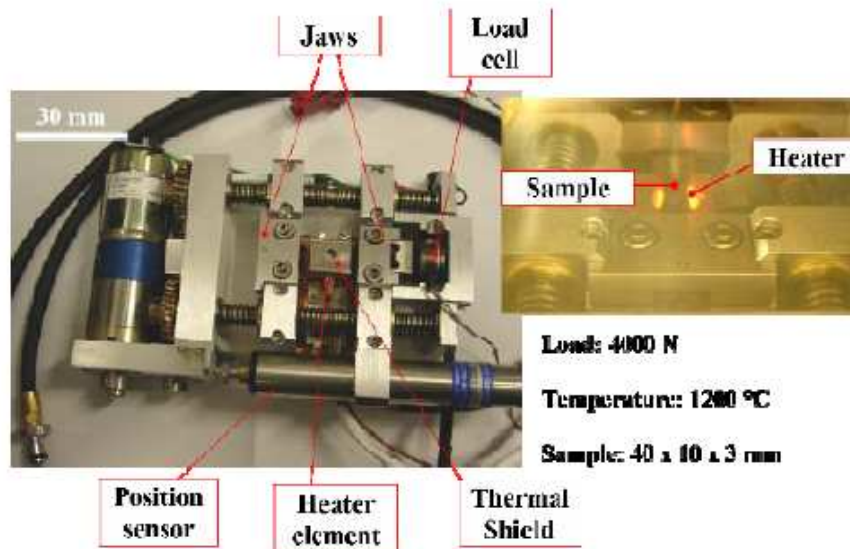


Figure 1. High-temperature-tensile mini-stage.

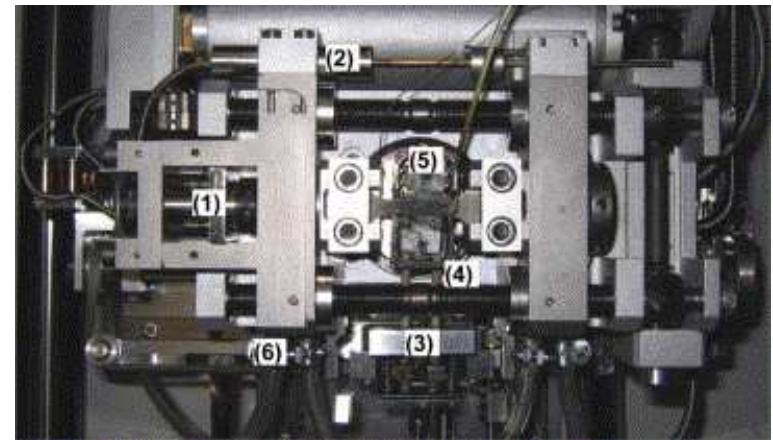


Fig. 1. Miniature load frame used for in situ fatigue testing in the ESEM (the heat shield that covers most of the specimen and the furnace has been removed). See main text for details.

Torres et al. (2009)
Proc. 8th Conf. Trends in Welding Research

Biallas et al. (2007) Int. J. Frac.

Bibliographie



Topic=(scanning electron microscop*)

AND (in situ test) AND (digital image correlation)

Results Topic=(scanning electron microscop*) AND Topic=(in situ test) AND Topic=(digital image correlation)
Timespan=All Years.

Scientific WebPlus BETA View Web Results >>

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Subject Areas Refine

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 AUTOMATION & CONTROL SYSTEMS (1)
 ENGINEERING (1)
 INSTRUMENTS & INSTRUMENTATION (1)
 MECHANICS (1)
[more options / values...](#)

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Authors

Source Titles

Publication Years

Languages

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Analyze Results

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Analyze Results

1. Title: [Micro-scale deformation measurement using the digital image correlation technique and scanning electron microscope imaging](#)
Author(s): Jin, H; Lu, WY; Korellis, J
Source: **JOURNAL OF STRAIN ANALYSIS FOR ENGINEERING DESIGN** Volume: 43 Issue: 8 Pages: 719-728 Published: 2008
Times Cited: 1
2. Title: [Digital image correlation of nanoscale deformation fields for local stress measurement in thin films](#)
Author(s): Sabate, N; Vogel, D; Gollhardt, A, et al.
Source: **NANOTECHNOLOGY** Volume: 17 Issue: 20 Pages: 5264-5270 Published: OCT 28 2006
Times Cited: 6
3. Title: [Tensile test apparatus for micro-scale specimens on scanning electron microscope using sub-pixel digital image correlation](#)
Author(s): Pradhan, S; Chu, TC
Conference Information: **ASME International Mechanical Engineering Congress and Exposition**, Date: NOV 05-11, 2005 Orlando FL
Source: **Proceedings of the ASME Dynamic Systems and Control Division 2005, Pts A and B** Pages: 1769-1772 Published: 2005
Times Cited: 0
4. Title: [Microscopic strain mapping using scanning electron microscopy topography image correlation at large strain](#)
Author(s): Kang, J; Jain, M; Wilkinson, DS, et al.
Source: **JOURNAL OF STRAIN ANALYSIS FOR ENGINEERING DESIGN** Volume: 40 Issue: 6 Pages: 559-570 Published: AUG 2005
Times Cited: 11
5. Title: [Interfacial adhesion of laser clad functionally graded materials](#)
Author(s): Ocelik, V; Pei, YT; De Hosson, JTM
Conference Information: **International Surface Engineering Congress and Exposition**, Date: OCT 07-10, 2002 COLUMBUS OH
Source: **SURFACE ENGINEERING: COATING AND HEAT TREATMENTS, PROCEEDINGS** Pages: 216-225 Published: 2003
Times Cited: 0

Bibliographie



2010



International Journal of Plasticity 26 (2010) 93–106



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journal homepage: www.elsevier.com/locate/ijplas



Multiscale strain measurements of plastically deforming polycrystalline titanium: Role of deformation heterogeneities

C. Efstathiou^{a,*}, H. Sehitoglu^a, J. Lambros^b

^aUniversity of Illinois at Urbana-Champaign, Department of Mechanical Science and Engineering, 1206 W. Green St., Urbana, IL 61801, USA

^bUniversity of Illinois at Urbana-Champaign, Department of Aerospace Engineering, 104 South Wright Street, Urbana, IL 61801, USA

Bibliographie



Biblio probablement non complete ... mais intéressante ...

Table 1

A list of experimental parameters for previous investigations and the current investigation which obtained sub-grain or grain scale measurement resolution. The table is sorted according to the metrology method. Note that the approximate number of grains is listed for the field-of-view (FOV).

	Imaging technique	Material	Avg. grain size	FOV studied	Approx. No. of grains	Ref.
DIC	SEM	Al	3.5 mm	8 × 6 mm ²	20	Zhao et al. (2008)
	SEM	Cu	50 μm	250 × 200 μm ²	16	Tatschl and Kolednik (2003b)
	SEM	Cu	100 μm	180 × 130 μm ²	1	Tatschl and Kolednik (2003a)
	SEM	Al	3.5 mm	15 × 10 mm ²	18	Raabe et al. (2001)
	Optical	Ti	30 μm	450 × 300 μm ²	150	Current
	Optical	Fe-Cr-C	10 μm	160 × 140 μm ²	14	El Bartali et al. (2008)
	Optical	Al-Mg	3 mm	4 × 3 mm ²	10	Zhang and Tong (2004)
	Optical	Al	3.5 mm	5 × 5 mm ²	9	Sachtleber et al. (2002)
Grid method	SEM	Zr	50 μm	500 × 500 μm ²	100	Crepin et al. (2007)
	SEM	Fe	2 mm	16 × 4 mm ²	27	Hoc et al. (2003)
	SEM	Fe	20 μm	175 × 175 μm ²	87	Hoc et al. (2003)
	SEM	Cu	70 μm	200 × 400 μm ²	20	Schroeter and McDowell (2003)
	SEM	Cu	1 cm	3.5 × 1.75 cm ²	9	Delaire et al. (2000)
	SEM	Fe-C	20 μm	175 × 175 μm ²	76	Hoc et al. (2000)
	SEM	Fe-C	20 μm	300 × 225 μm ²	114	Hoc and Rey (2000)
	SEM	Fe-C	30 μm	260 × 130 μm ²	76	Lineau et al. (1997)

Bibliographie



Biblio probablement non complete ... mais intéressante ...

Table 1

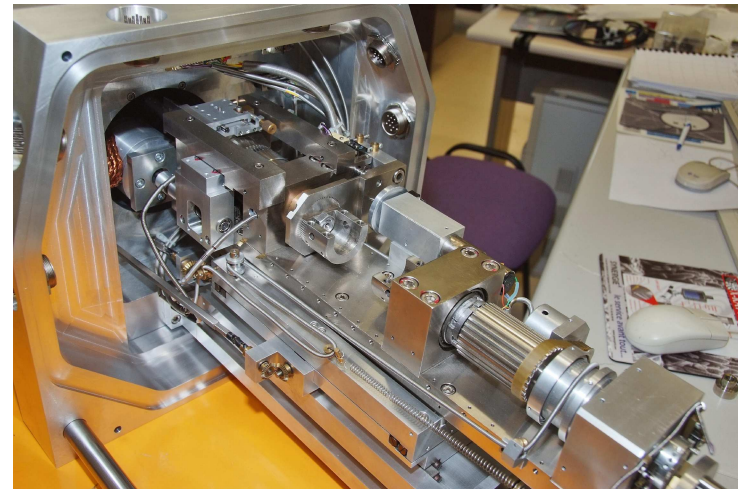
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	SEM	Fe–C	20 μm	175 × 175 μm ²	76	Hoc et al. (2000)
	SEM	Fe–C	20 μm	300 × 225 μm ²	114	Hoc and Rey (2000)
	SEM	Fe–C	30 μm	260 × 130 μm ²	76	Lineau et al. (1997)

Bibliographie

Petit historique sur les essais in-situ en région parisienne

- 1986 : Machine d'essai traction (Raith) LPMTM, Villetaneuse
- 1988 : Modification maison
- 1994 : Prototype Fatigue Traction/Torsion (Raith)



Et maintenant : Machine pour essais in situ en vente
(Deben/Gatan, Kammrath & Weiss/Raith, ...)



En France : Poitiers, Metz, Nancy, Albi, ...

IdF : LMS-X, LPMTM-Villetaneuse, LMT-ENS Cachan, ONERA, SNECMA, EDF, ...

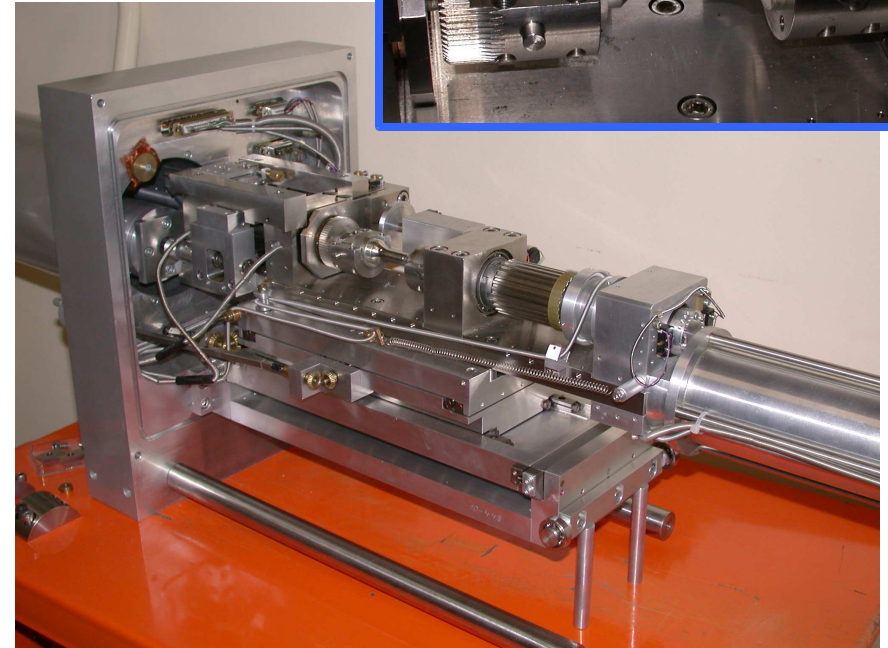
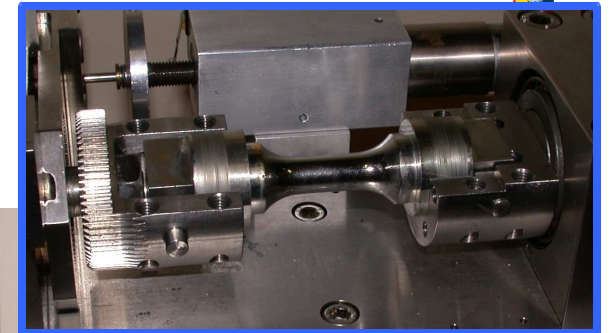
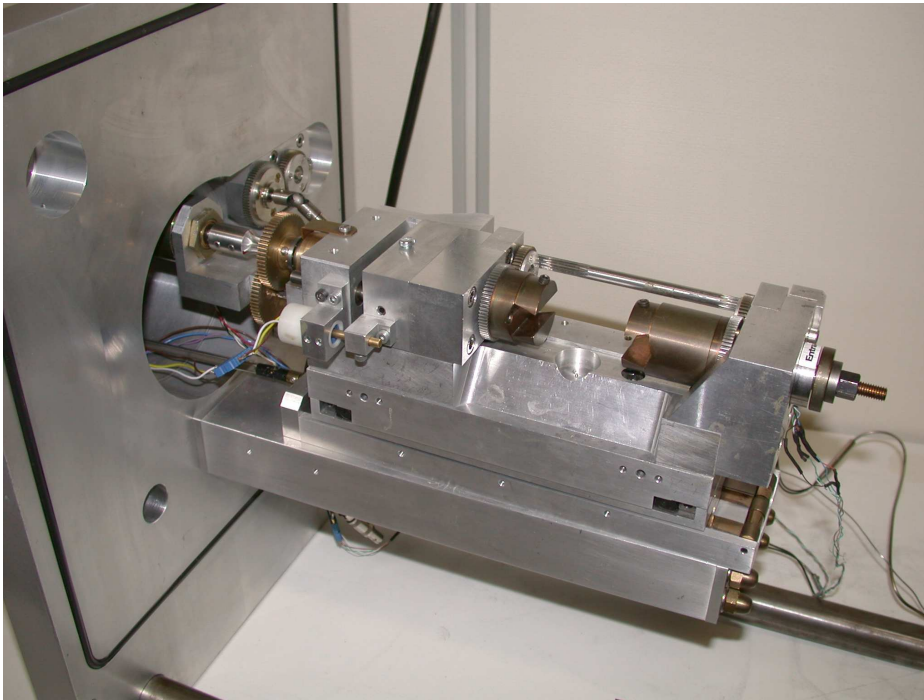
Plan



- Mesure de champs cinématiques : Comment ?
- Pour quoi faire ? Quelques exemples
- Quelques mots sur la précision de la mesure

Essais in-situ au LMS

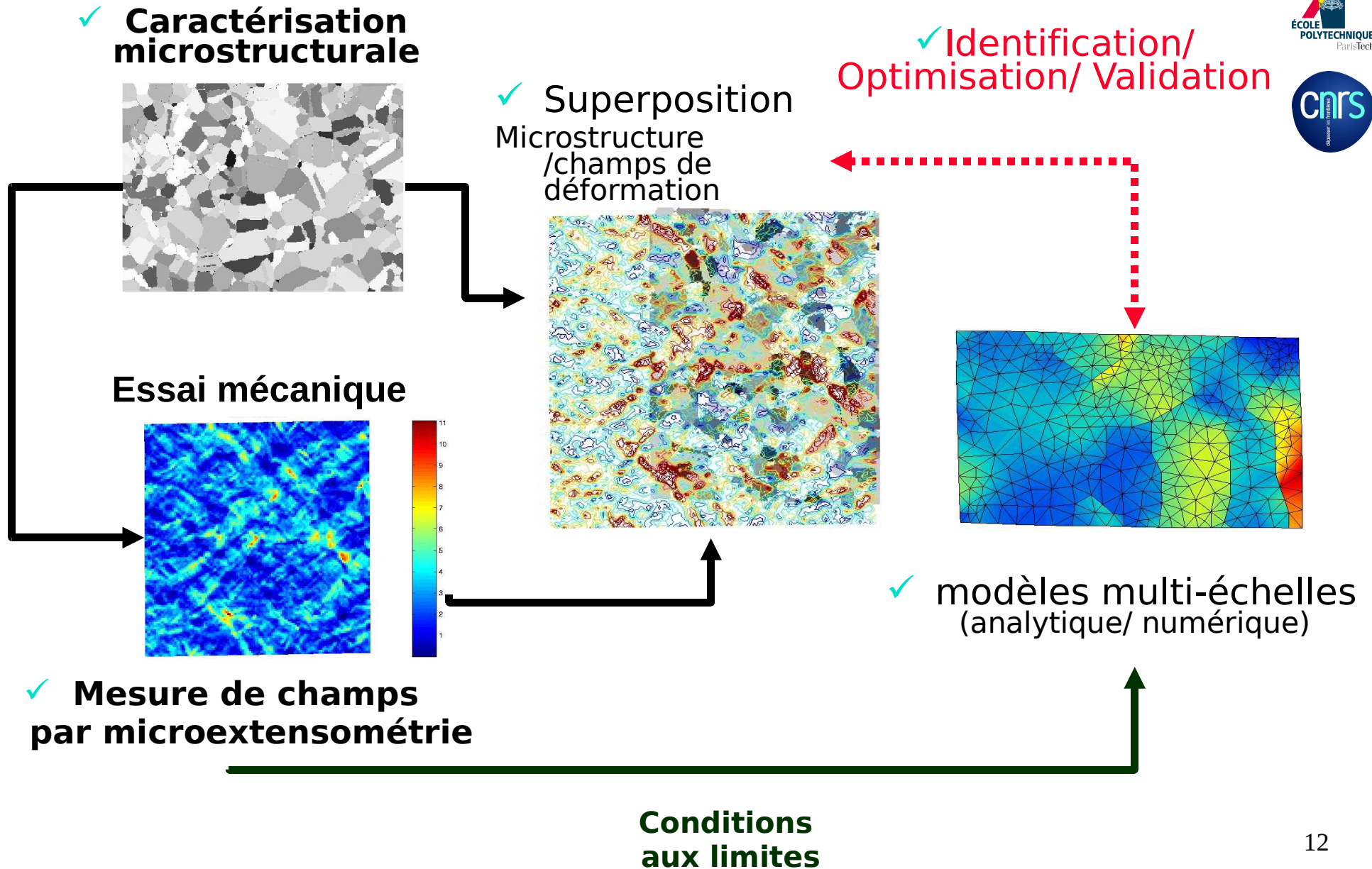
traction ou compression ou flexion
(Raith, 5kN, 500°C)



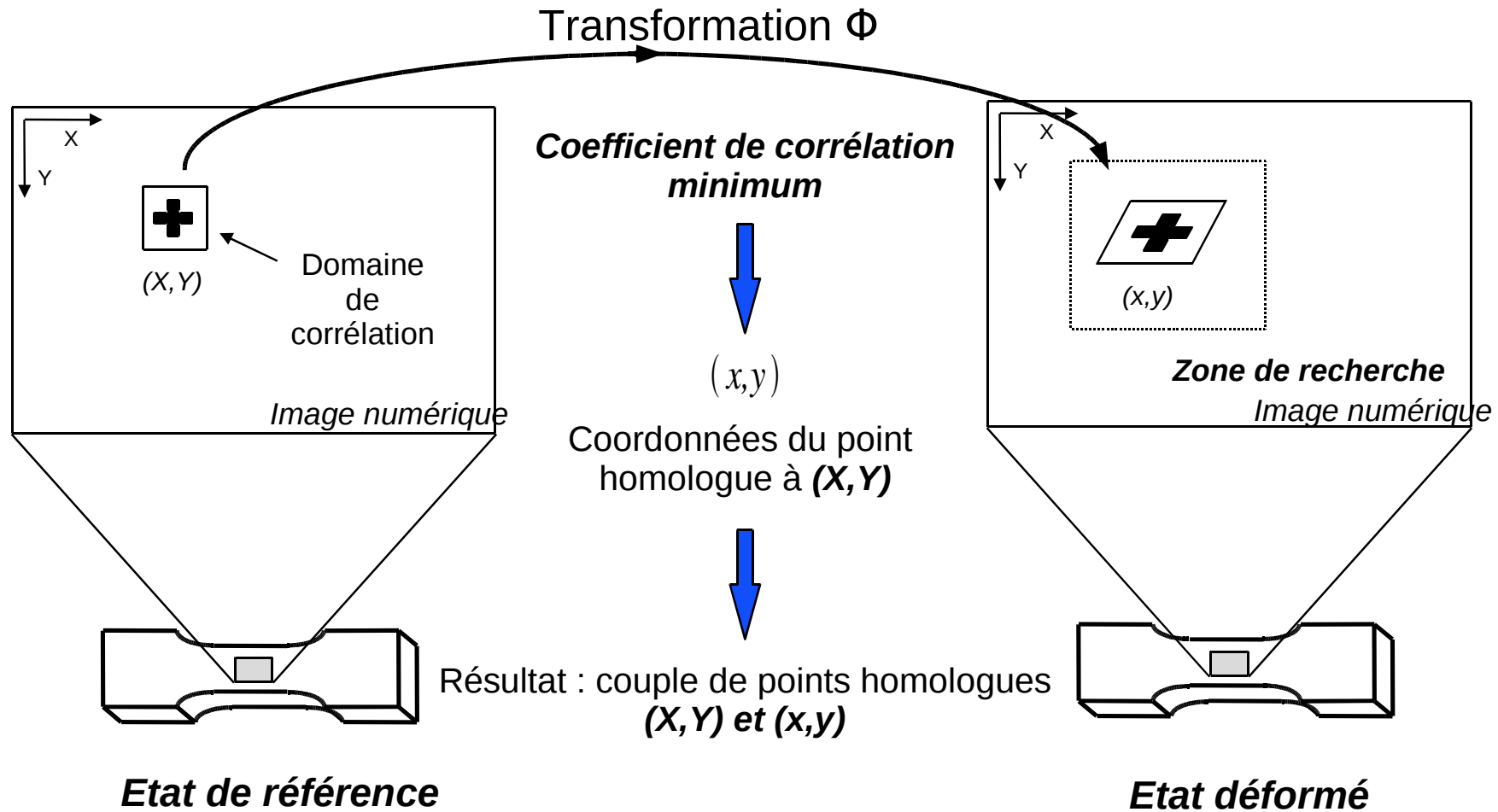
traction/compression/torsion
cyclique
(Raith, 10kN, 50Nm, 1Hz)

+ Essai mécanique sous MO (sous atmosphère)

Démarche adoptée

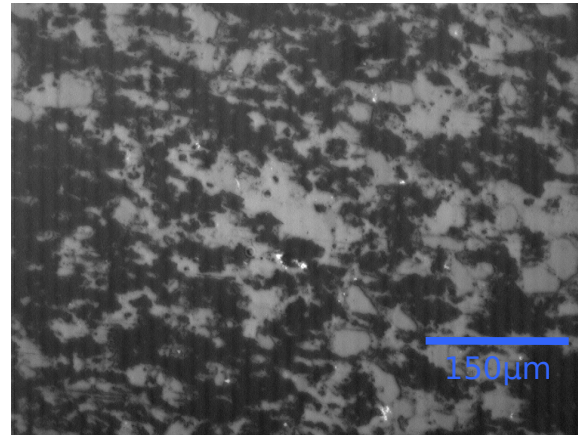
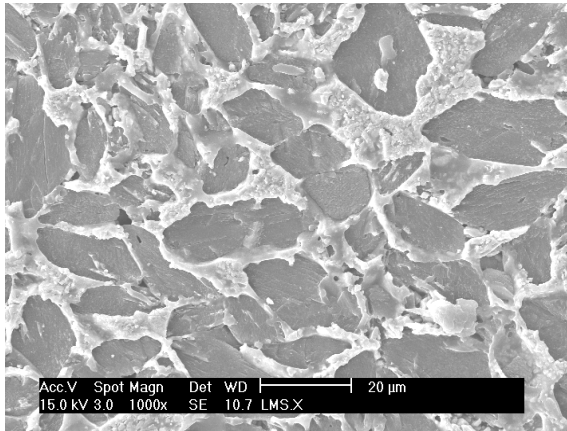


Principe de la corrélation d'images

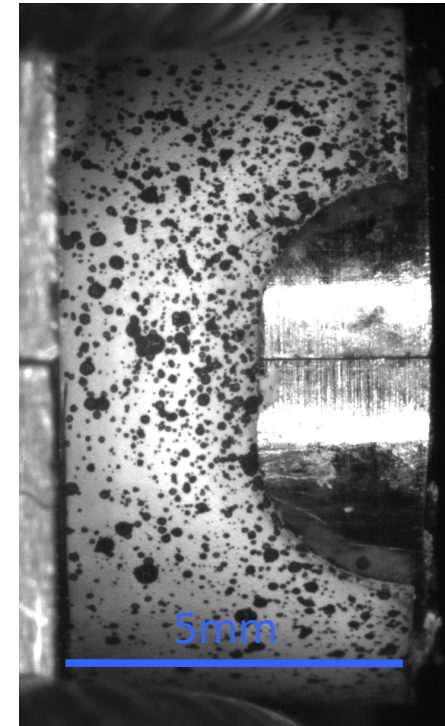


Nécessité de Contraste

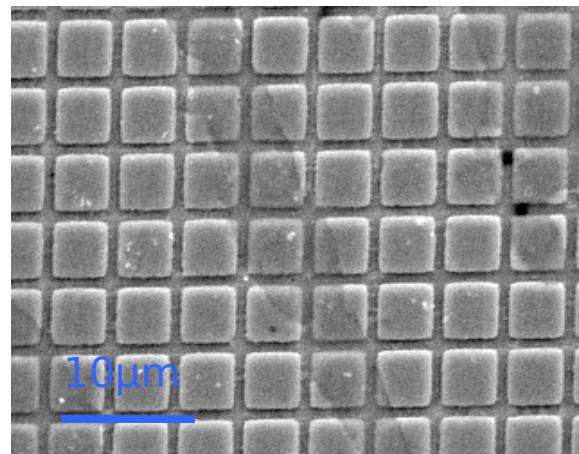
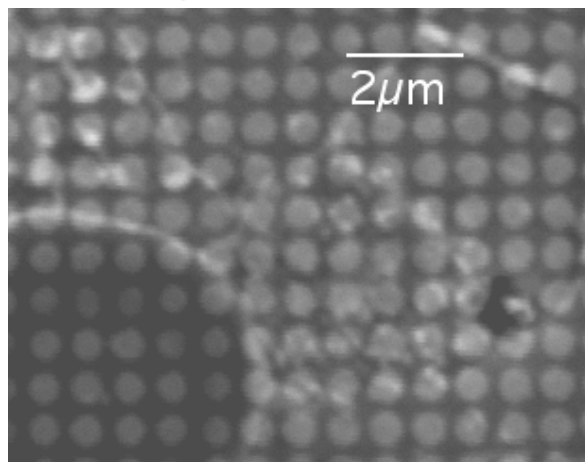
- Naturel



- Mouchetis



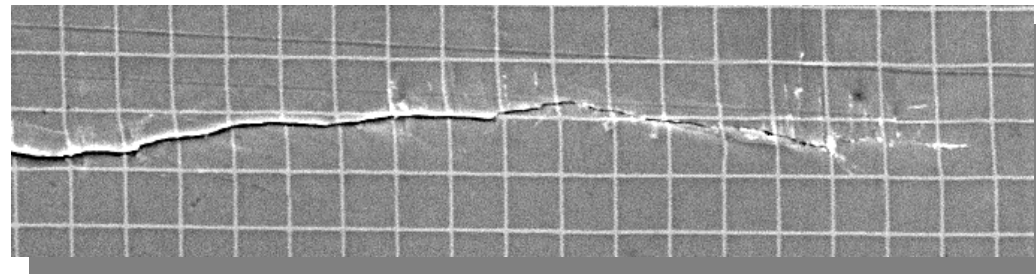
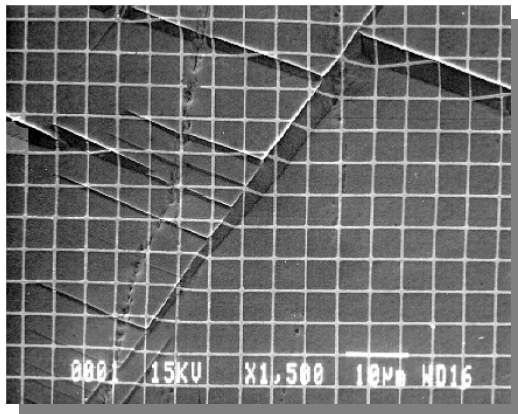
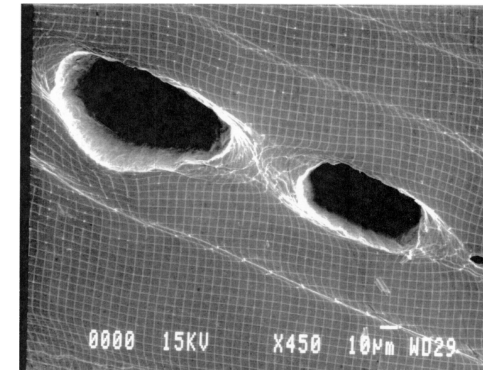
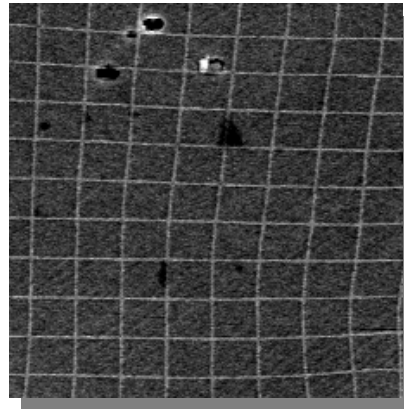
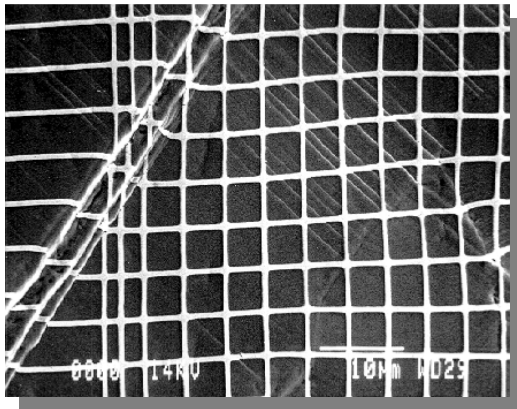
- **Microgrille** : dépôt métallique ou attaque chimique



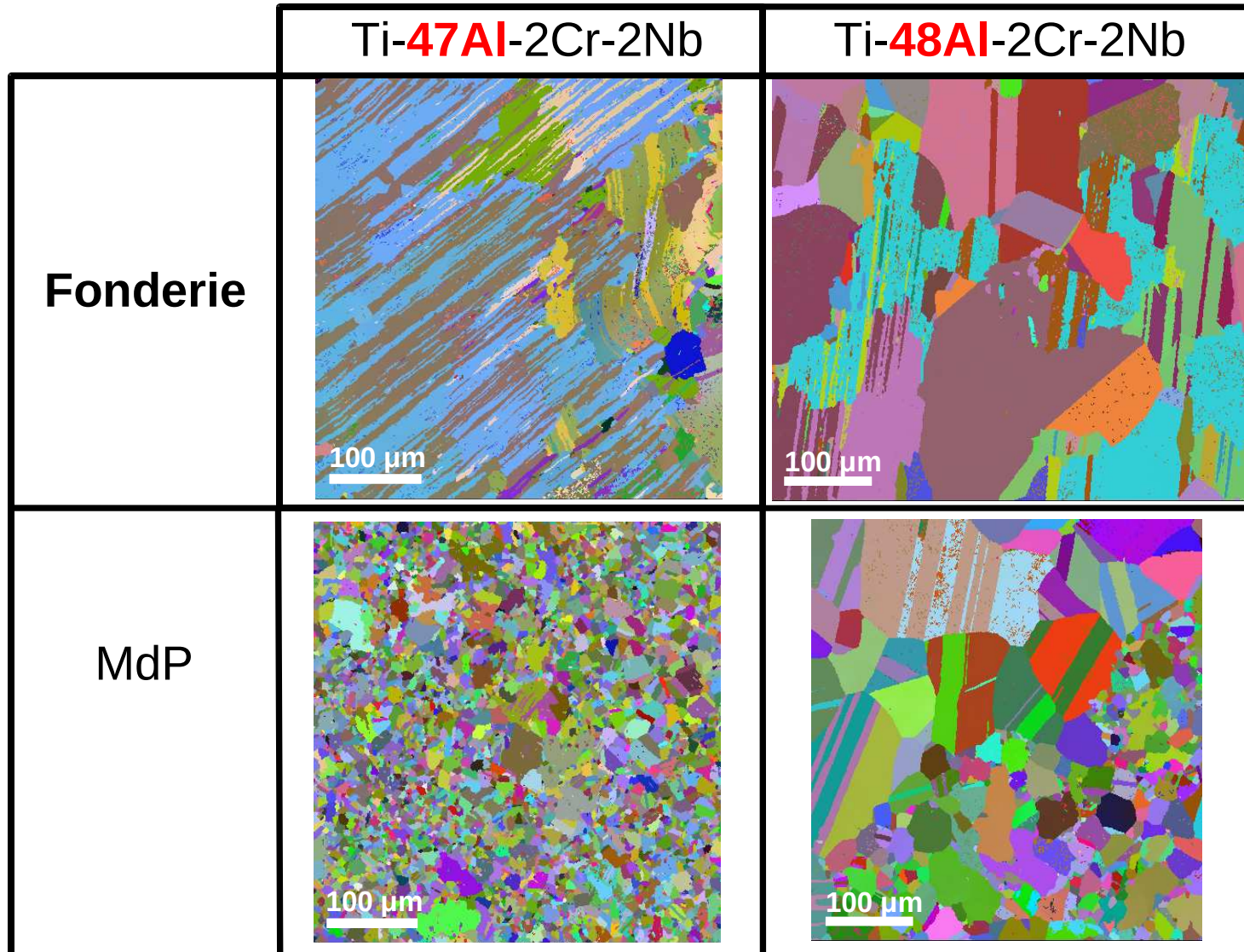
Pas 0,5 à 20µm

Domaines marqués centimétriques

Technique de grilles

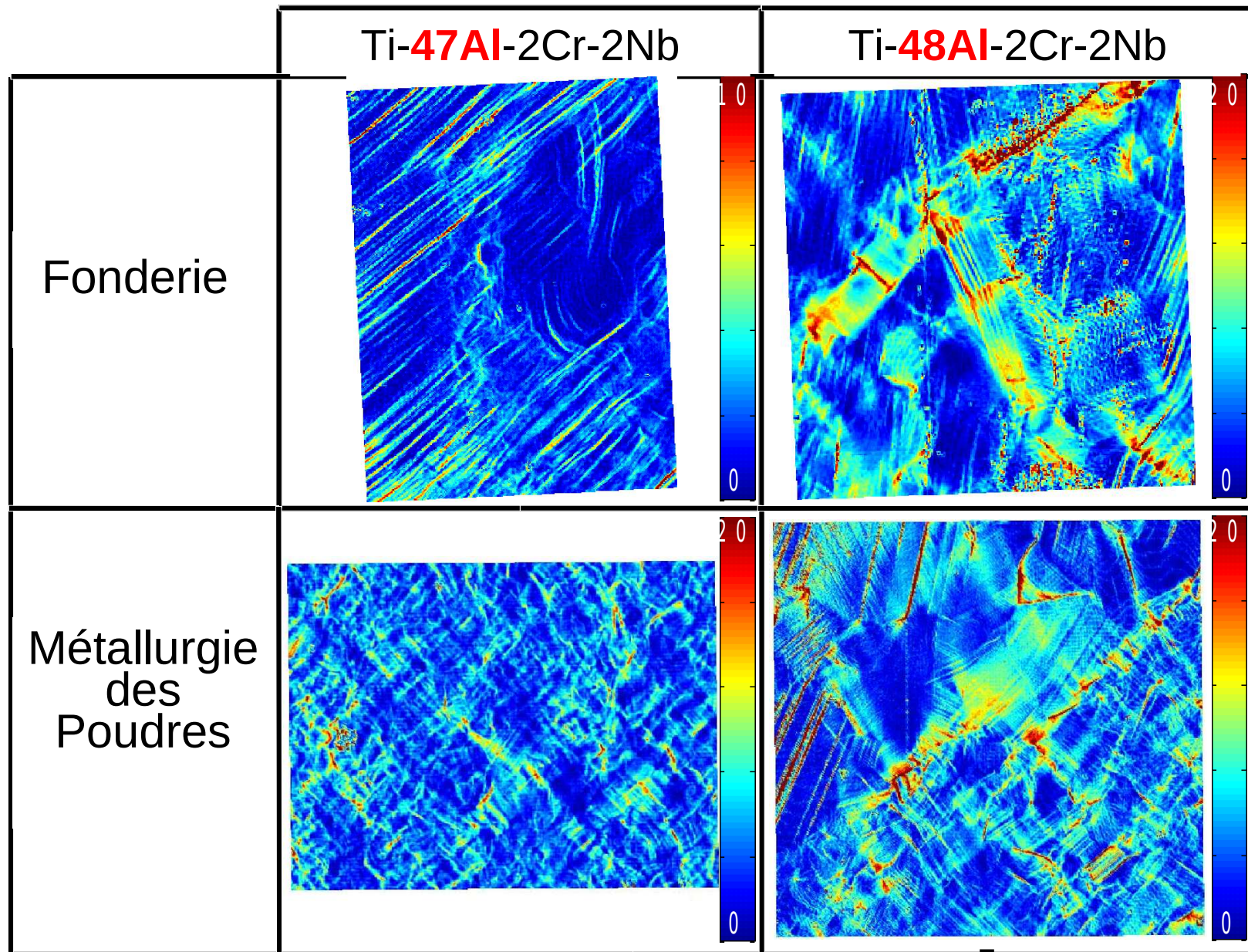


Exemple : les alliages TiAl

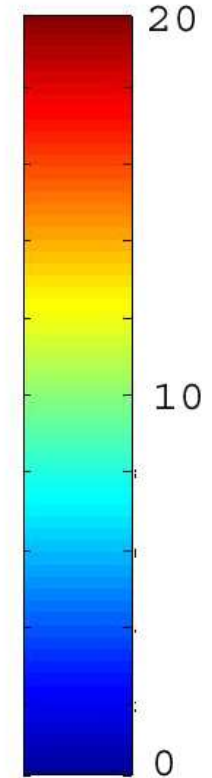
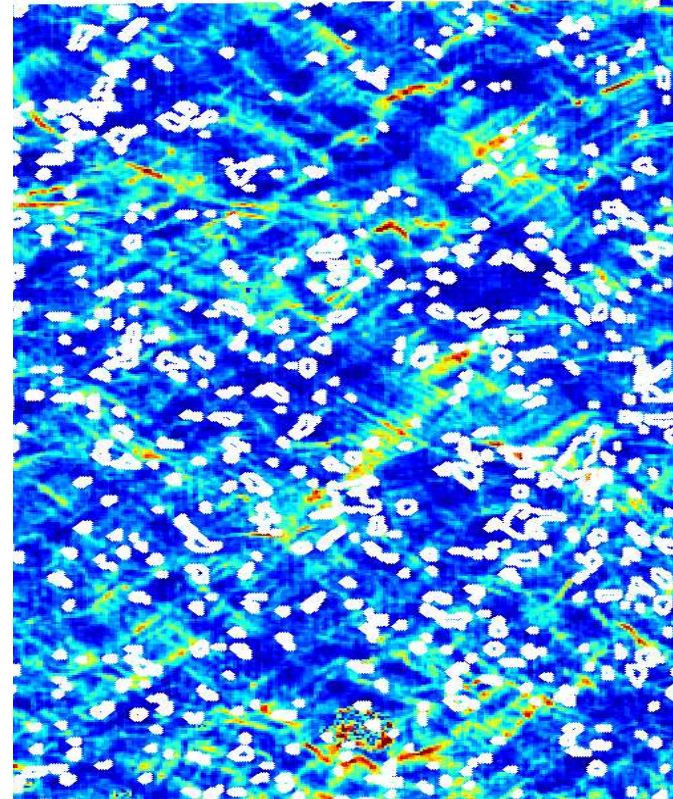
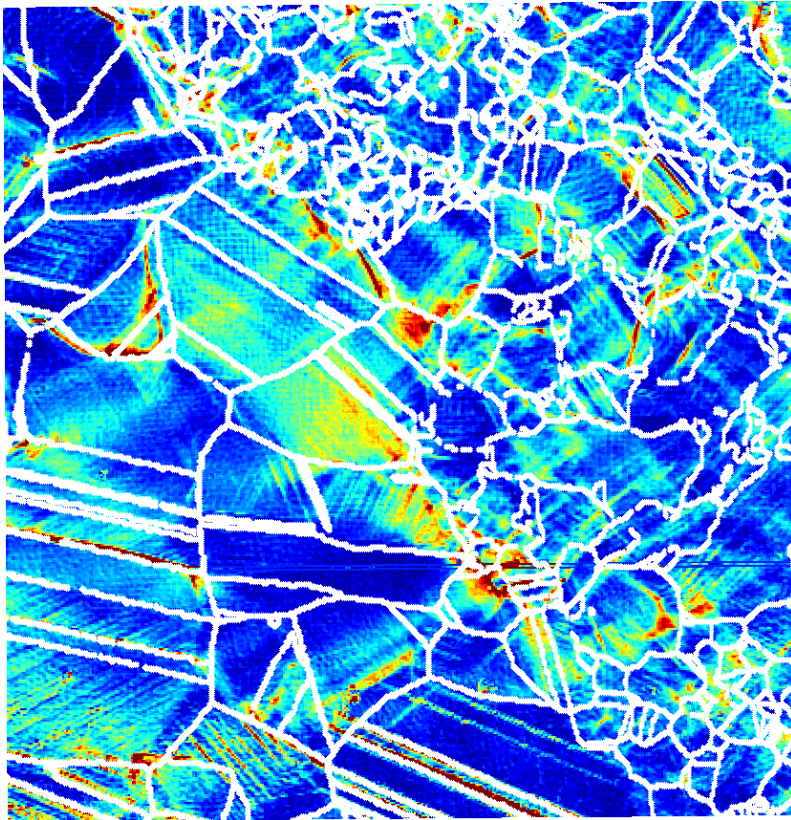


(DMMP /
ONERA)

Exemple : les alliages TiAl



Exemple : les alliages TiAl



Ti-48Al-2Cr-2Nb MdP

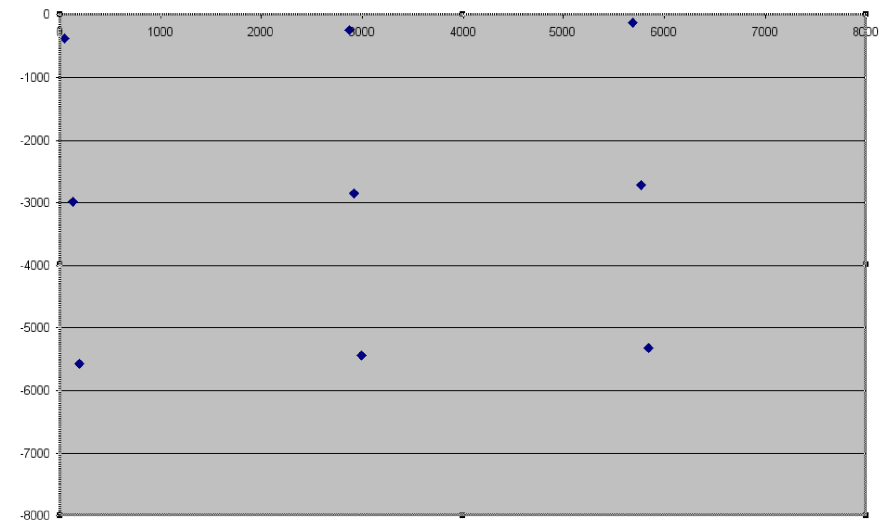
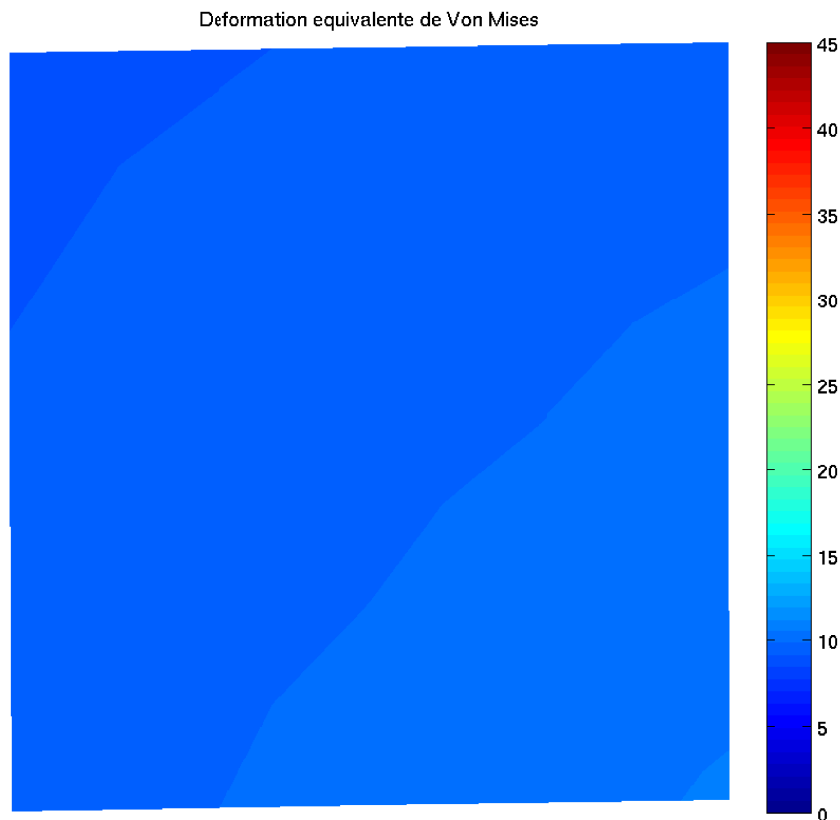
Ti-47Al-2Cr-2Nb MdP

Superposition à la microstructure

Effet de la base de mesure ?

Surface analysée 300x 300 μm

Variation de la base de mesure de 150 à 2 μm



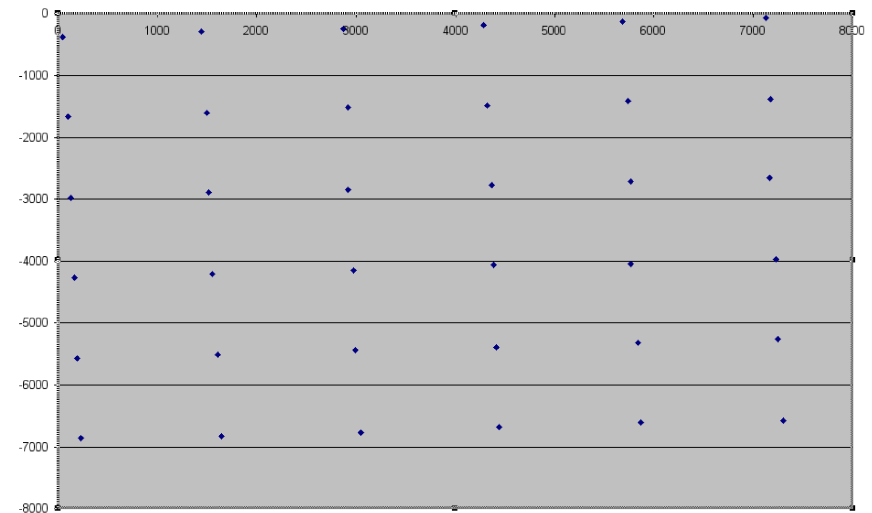
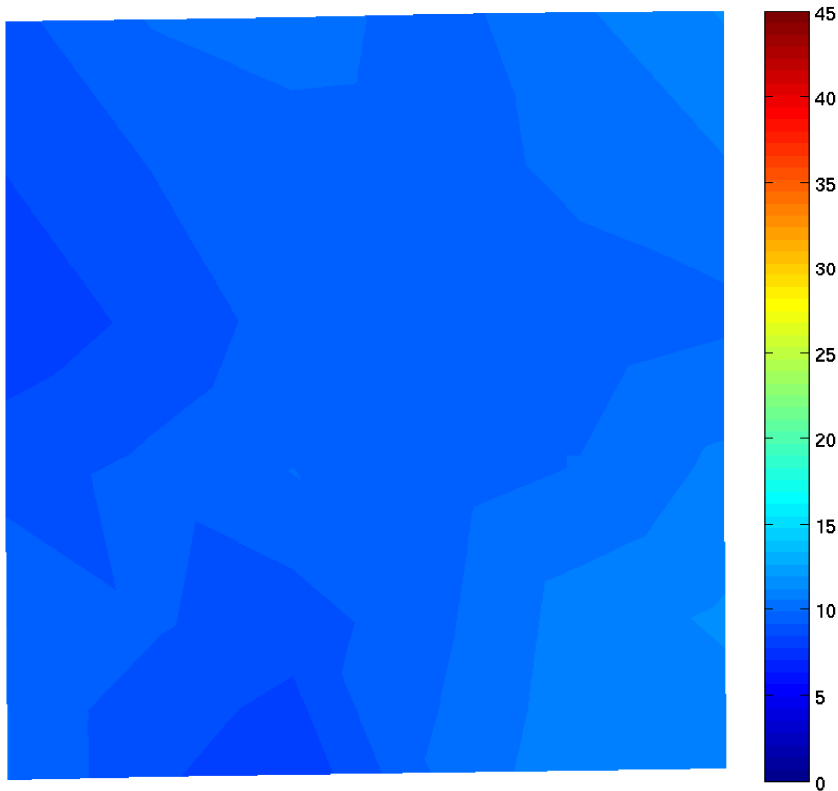
Base de mesure : 150 μm

Effet de la base de mesure ?

Surface analysée 300x 300 μm

Variation de la base de mesure de 150 à 2 μm

Déformation équivalente de Von Mises



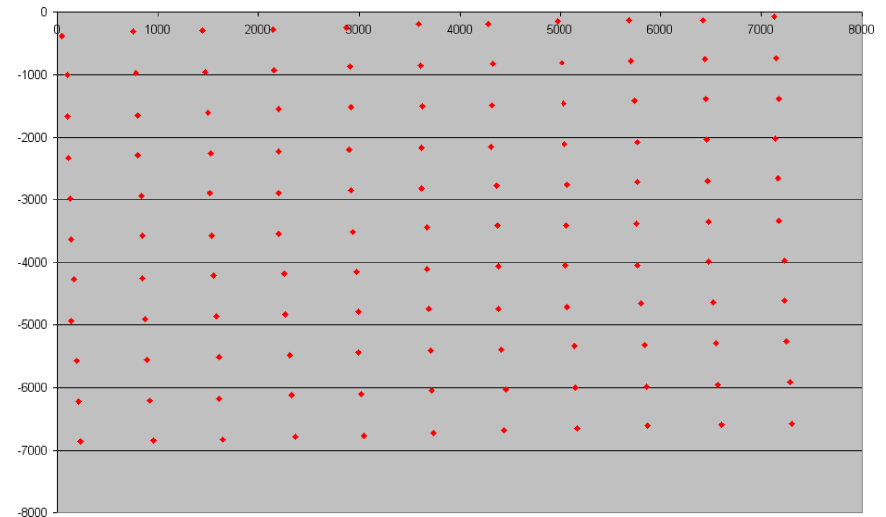
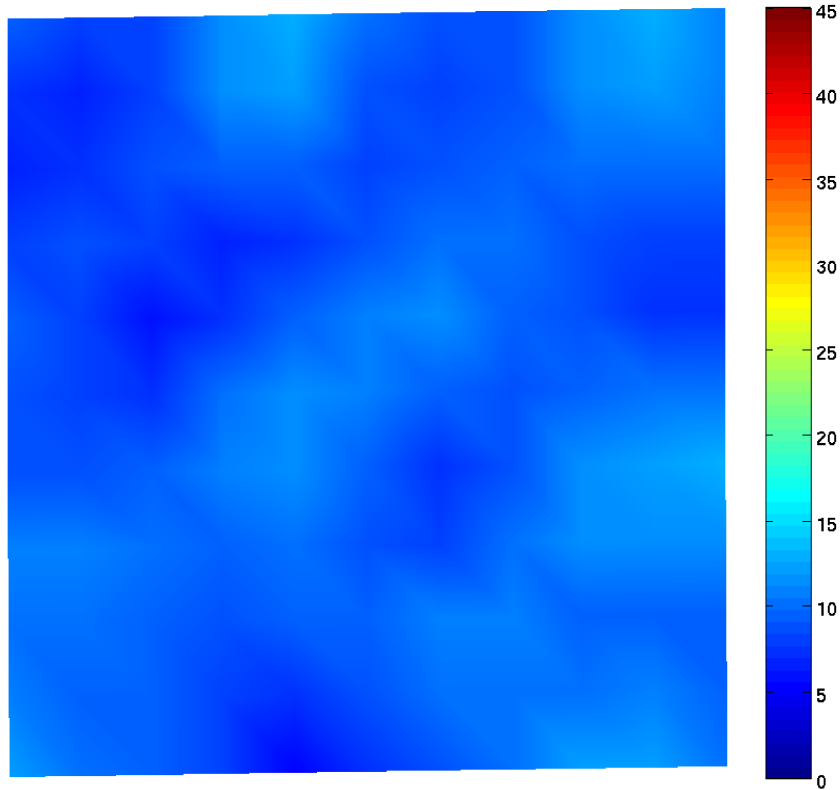
Base de mesure : 60 μm

Effet de la base de mesure ?

Surface analysée 300x 300 μm

Variation de la base de mesure de 150 à 2 μm

Deformation equivalente de Von Mises



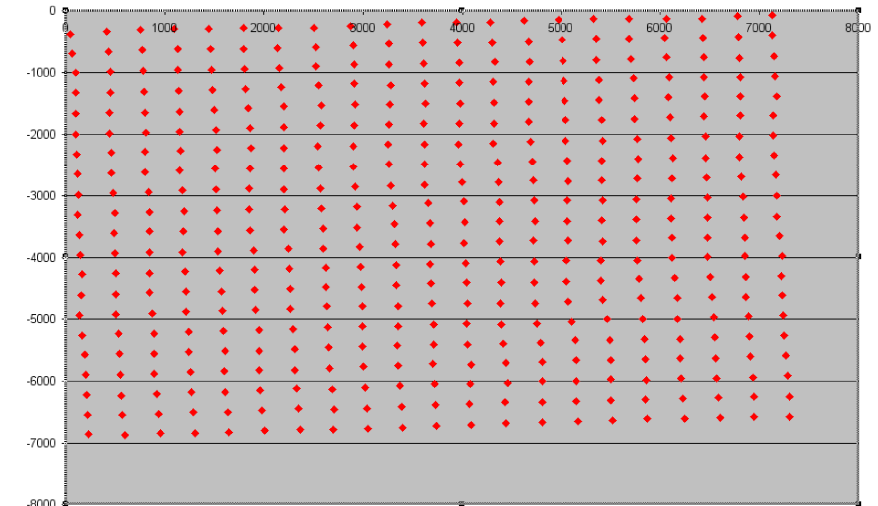
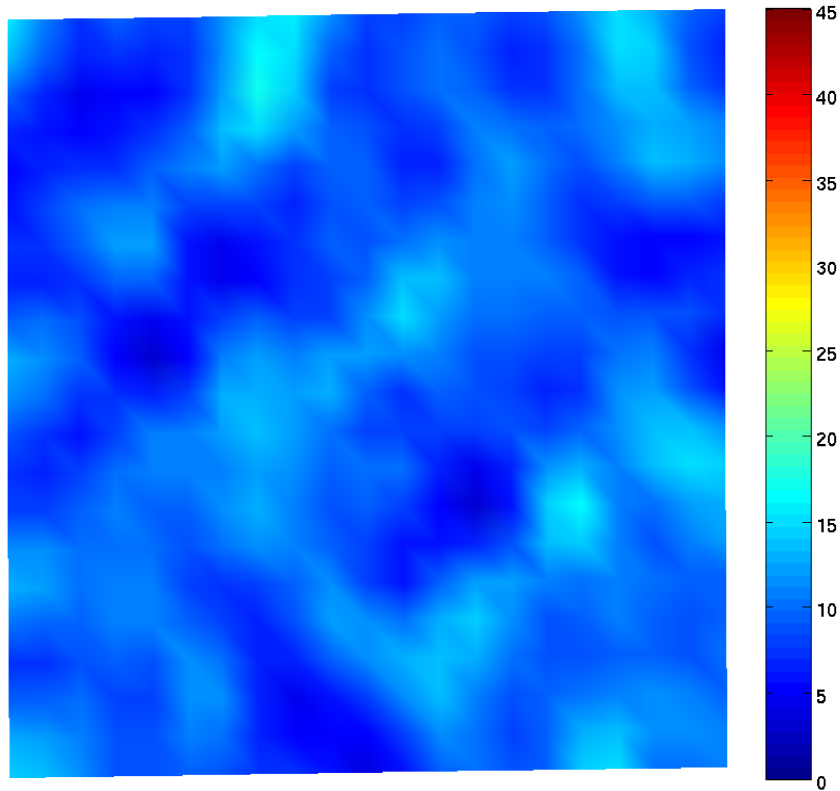
Base de mesure : 30 μm

Effet de la base de mesure ?

Surface analysée 300x 300 μm

Variation de la base de mesure de 150 à 2 μm

Deformation equivalente de Von Mises



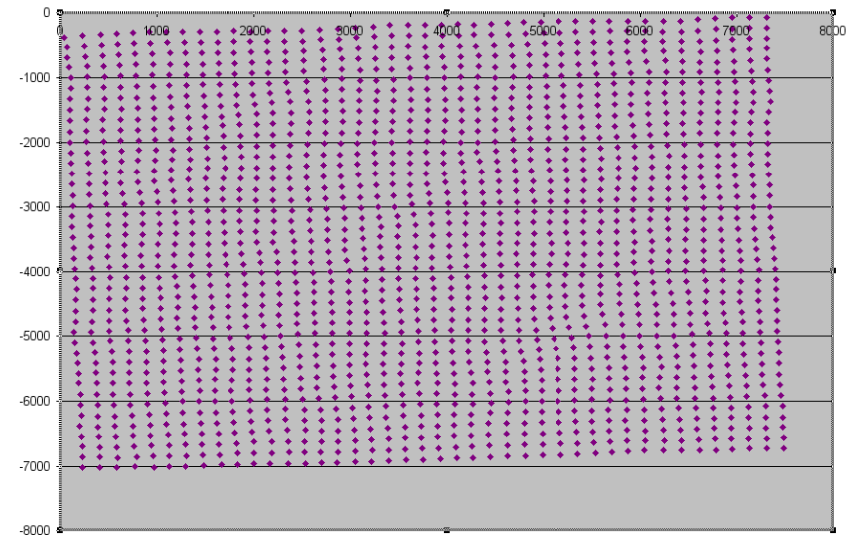
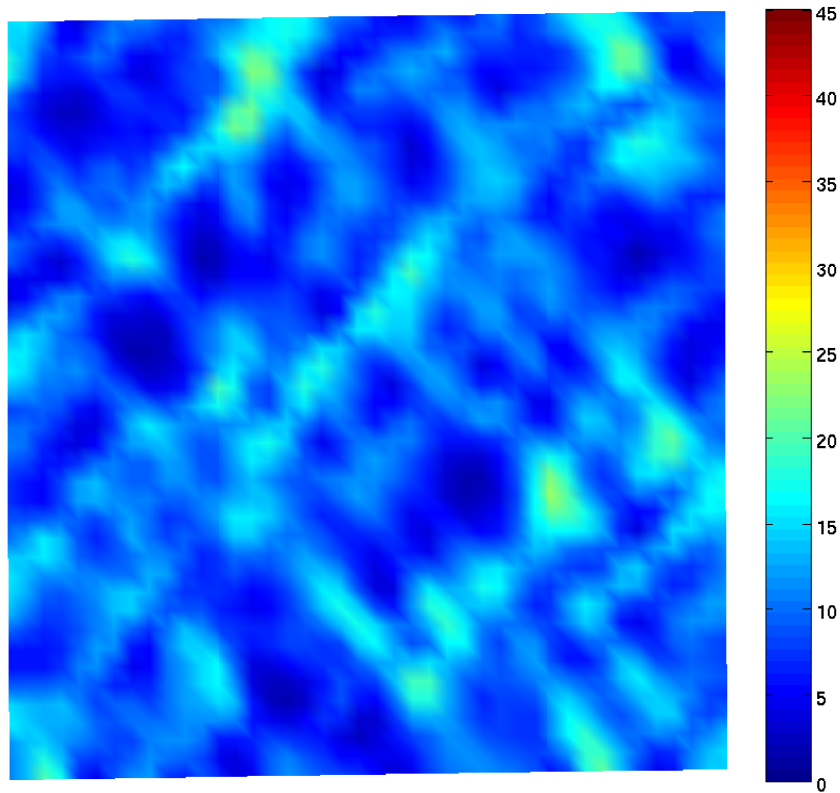
Base de mesure : 15 μm

Effet de la base de mesure ?

Surface analysée 300x 300 μm

Variation de la base de mesure de 150 à 2 μm

Deformation equivalente de Von Mises



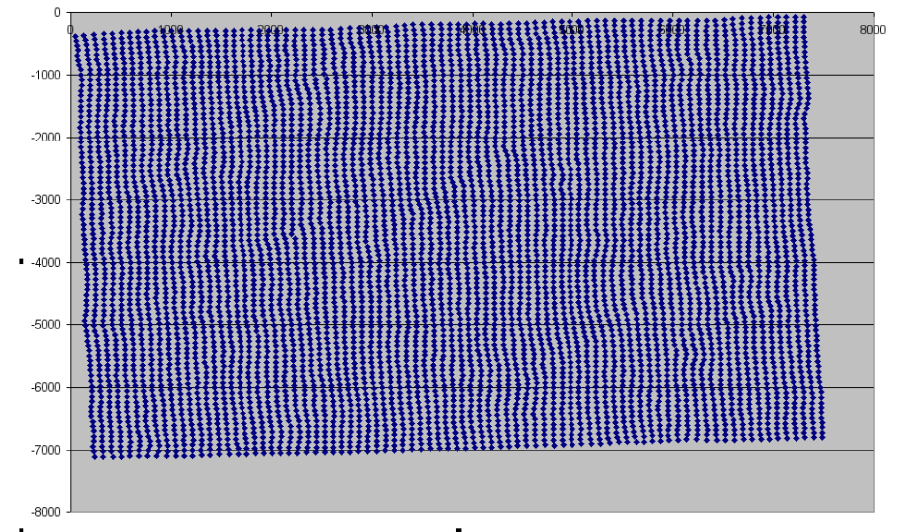
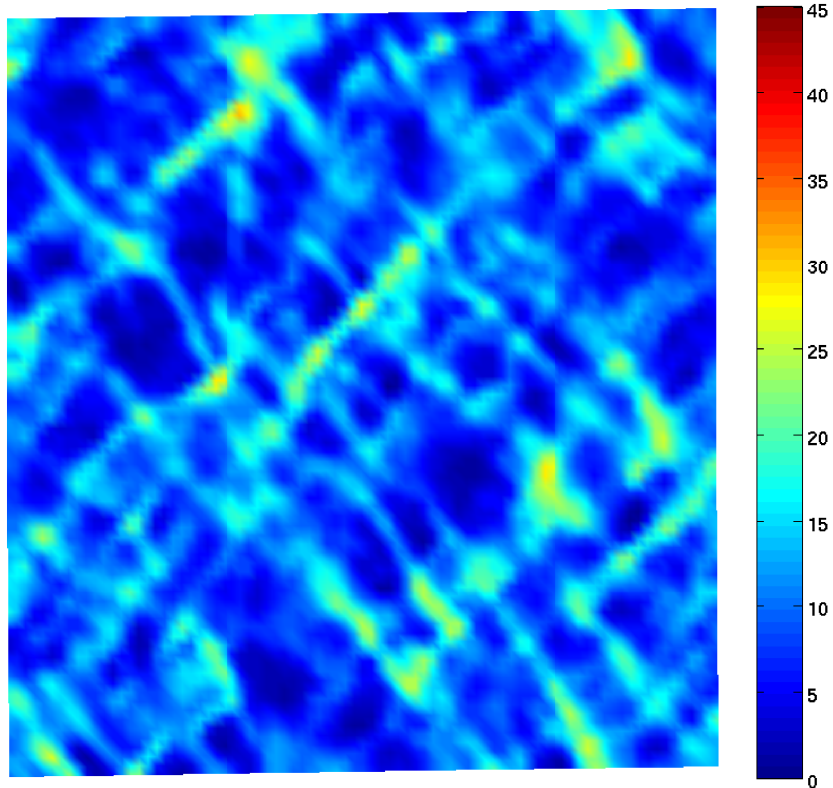
Base de mesure : 7 μm

Effet de la base de mesure ?

Surface analysée 300x 300 μm

Variation de la base de mesure de 150 à 2 μm

Déformation équivalente de Von Mises



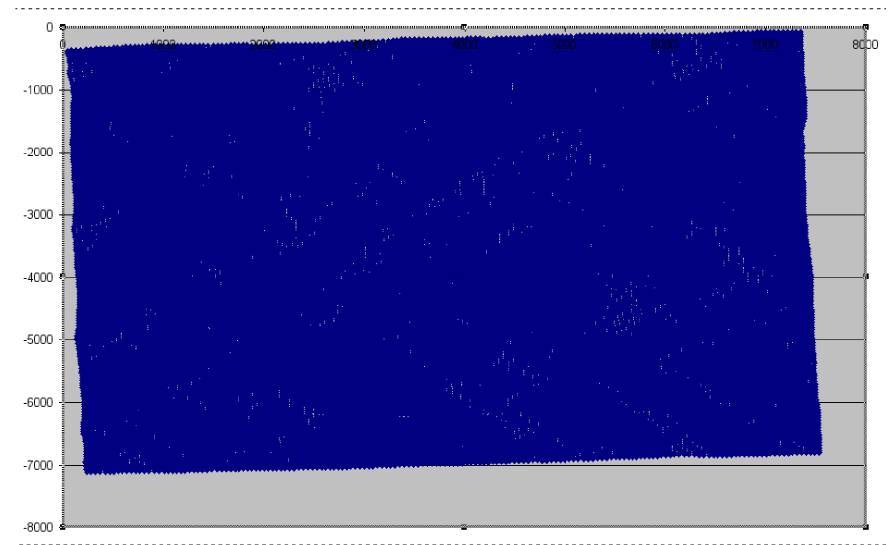
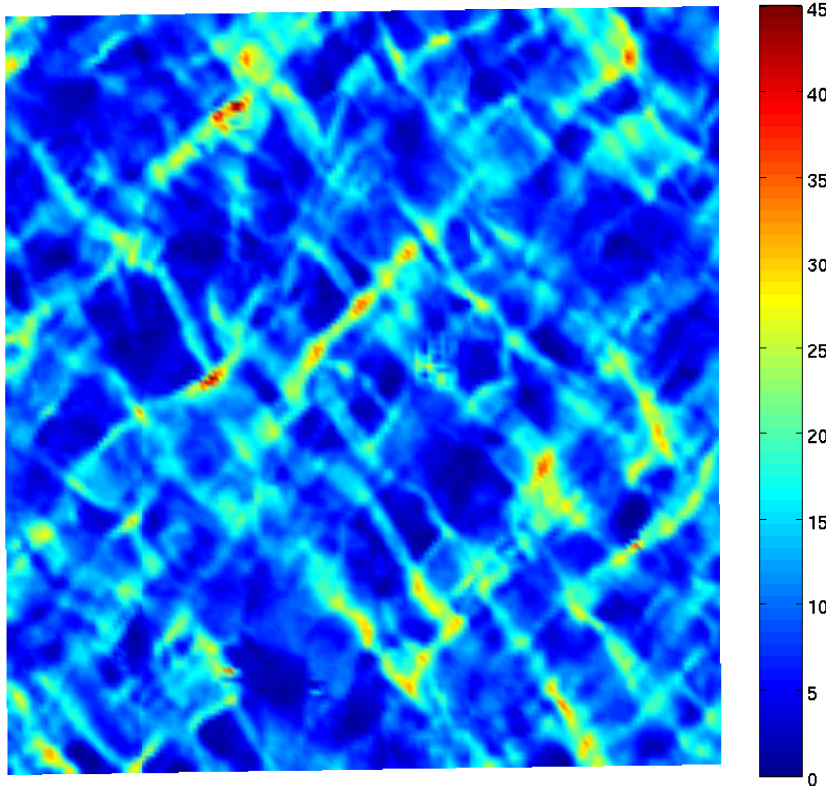
Base de mesure : 4 μm

Effet de la base de mesure ?

Surface analysée 300x 300 μm

Variation de la base de mesure de 150 à 2 μm

Deformation equivalente de Von Mises



Base de mesure : 2 μm

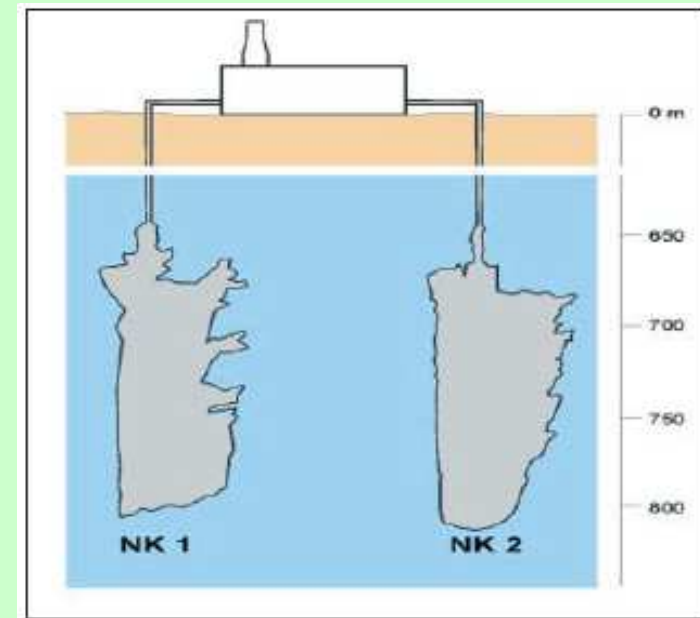
Comportement viscoplastique du sel : étude multi échelles

1-Contexte de l'étude : Stockage d'énergie sous forme d'air comprimé dans les cavernes de sel.

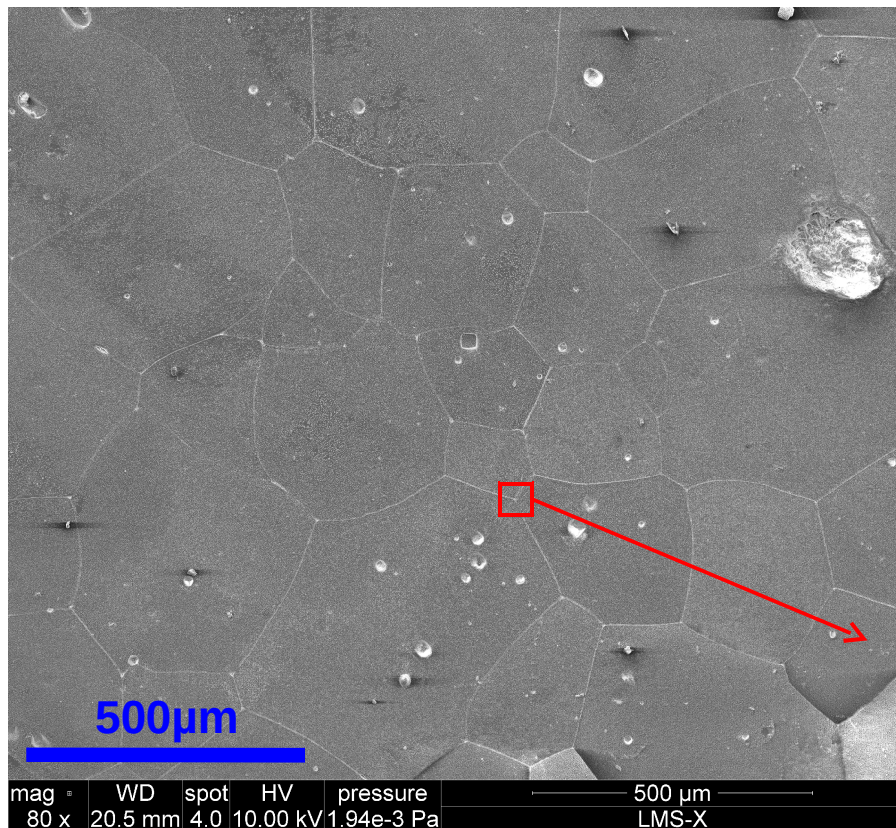


Centrale Gaz
2 cavités, 300 000 m³,
 $P_{\min} = 4 \text{ MPa}$, $P_{\max} = 7 \text{ MPa}$.

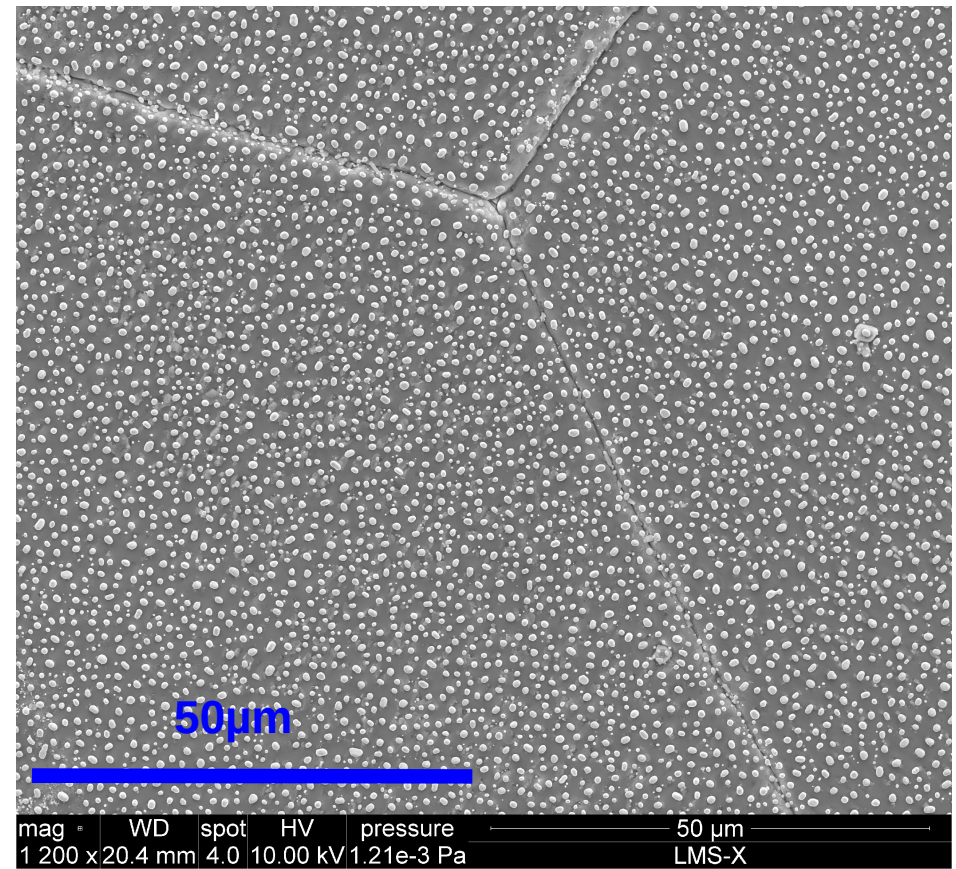
Usine CAES de
Huntorf, Allemagne (1978)
(E.N. Kraftwerke)

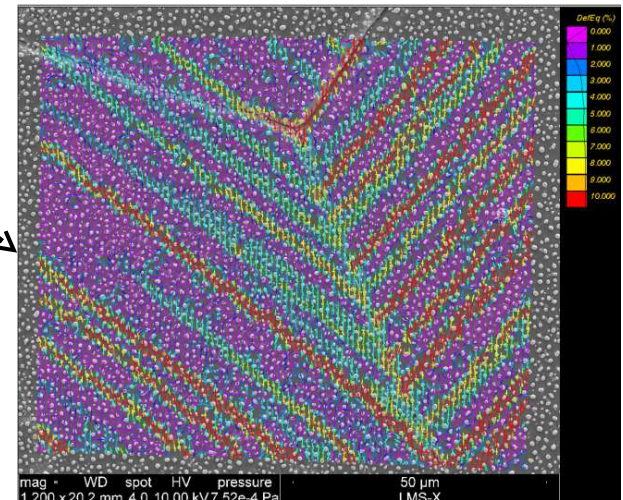
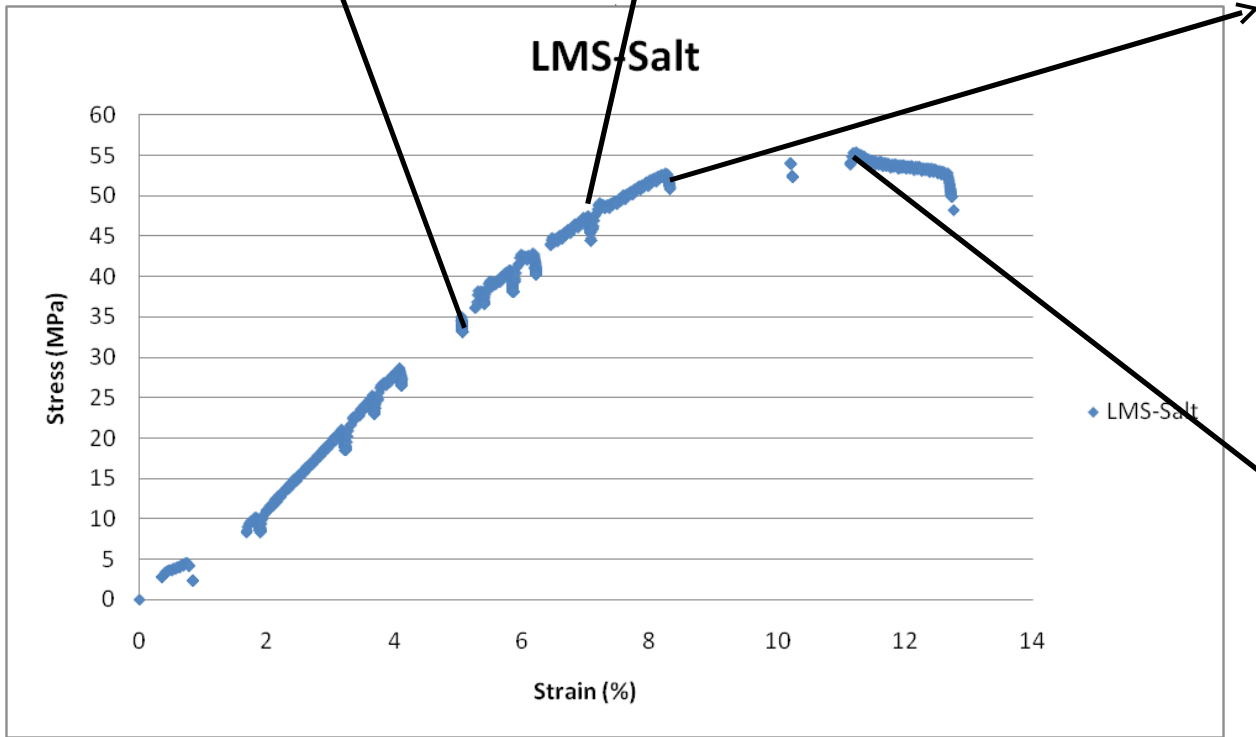
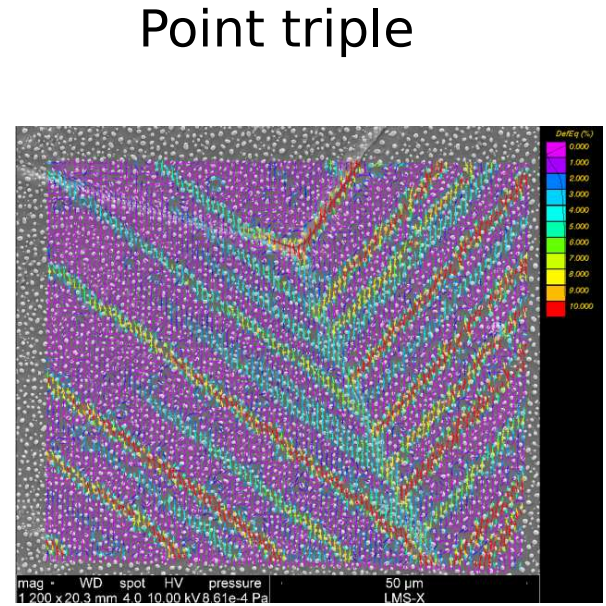
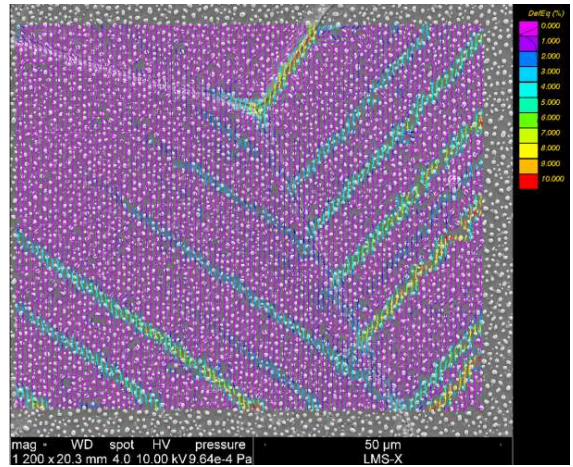
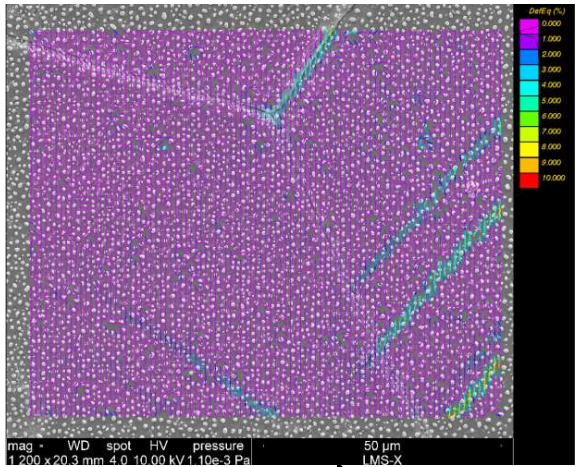


2 - Echelle microscopique



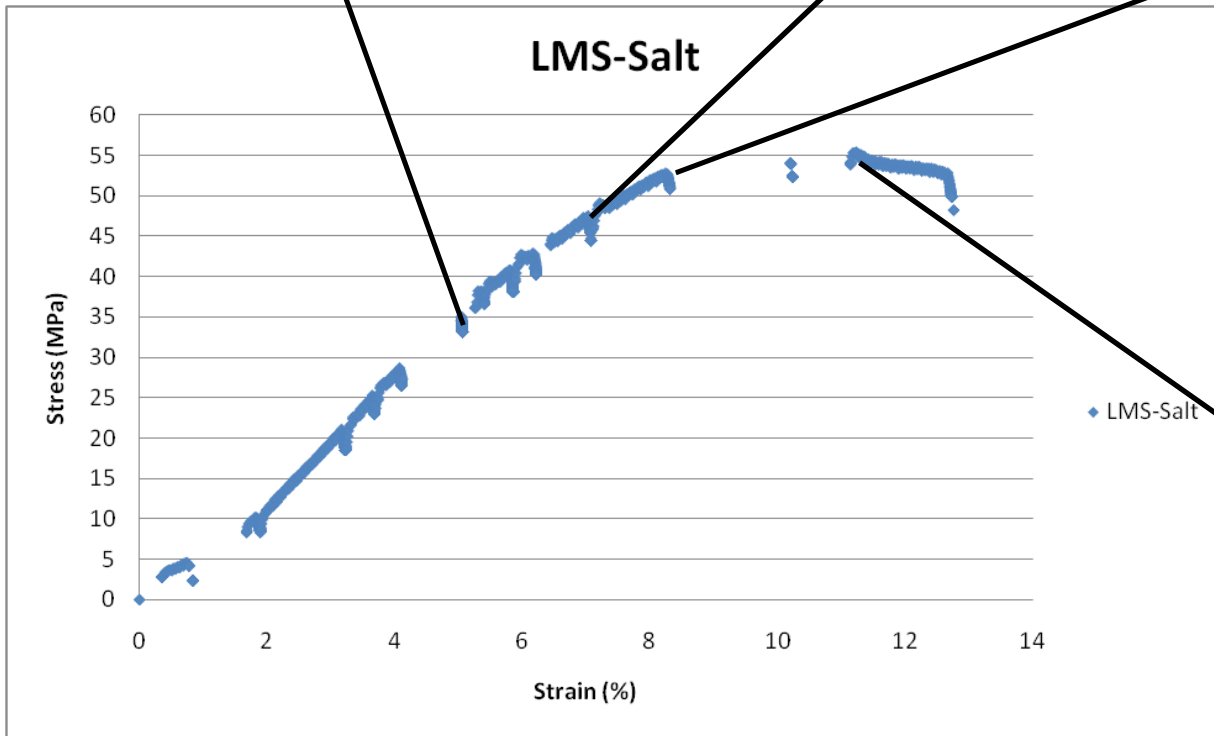
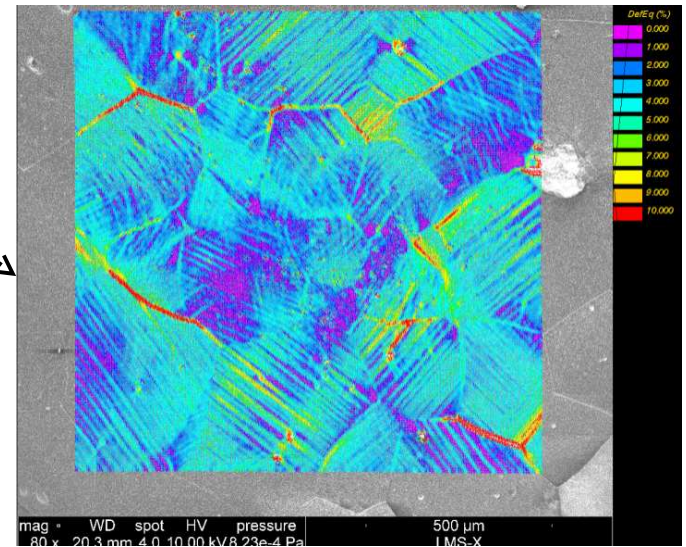
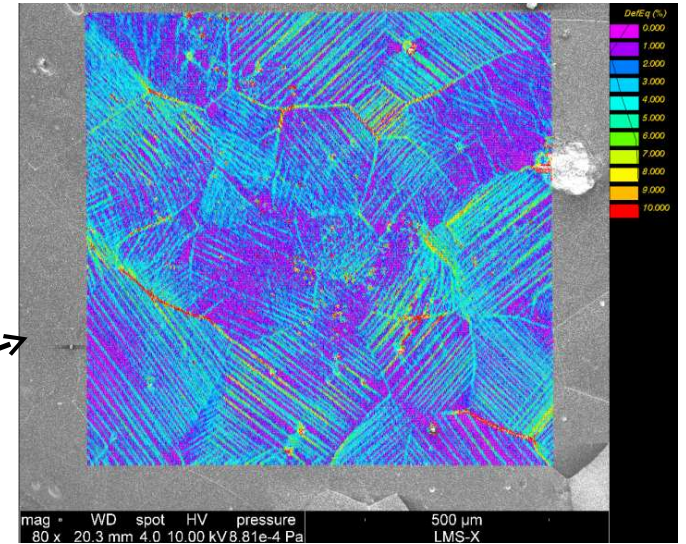
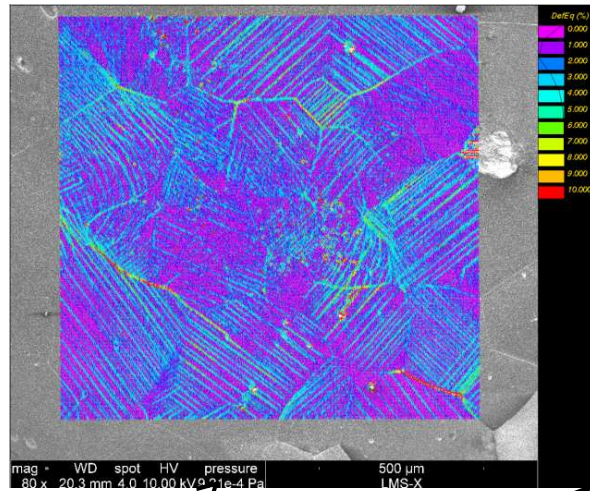
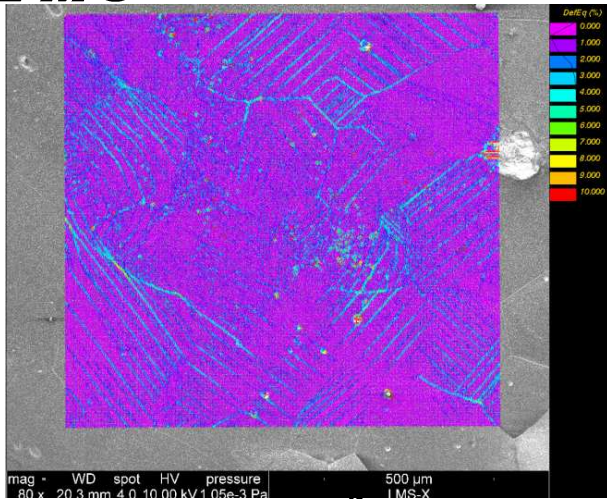
Point triple



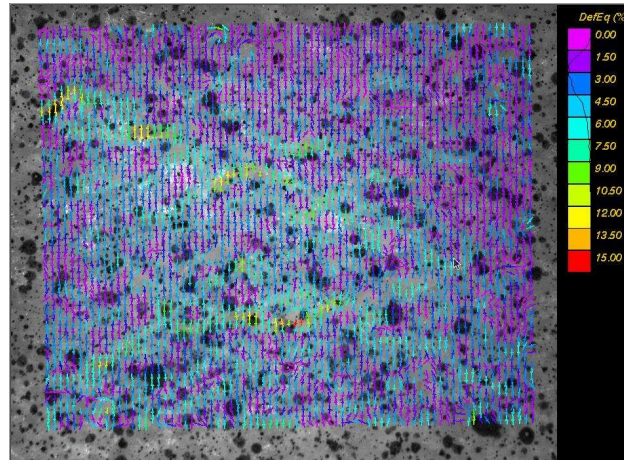
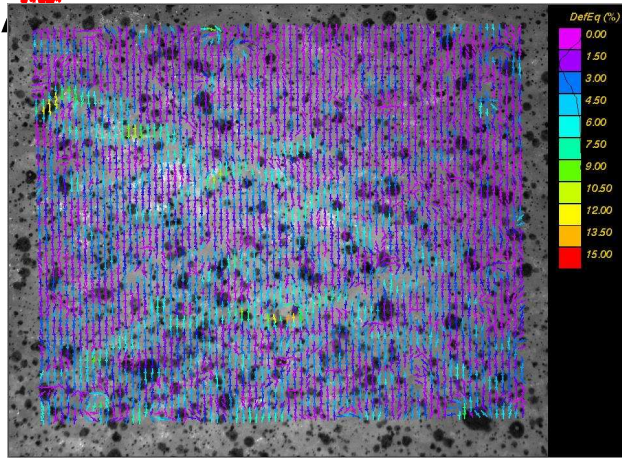


Essai In-situ MEB : Compression Uniaxiale

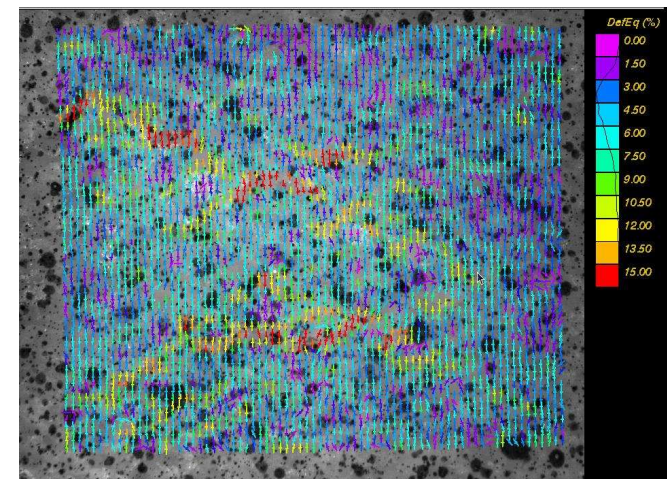
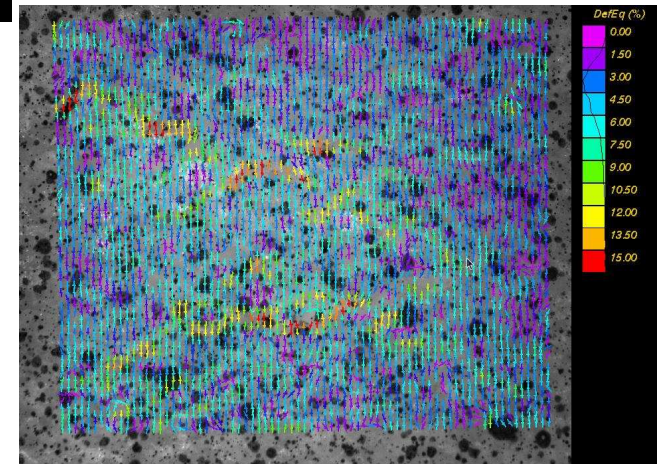
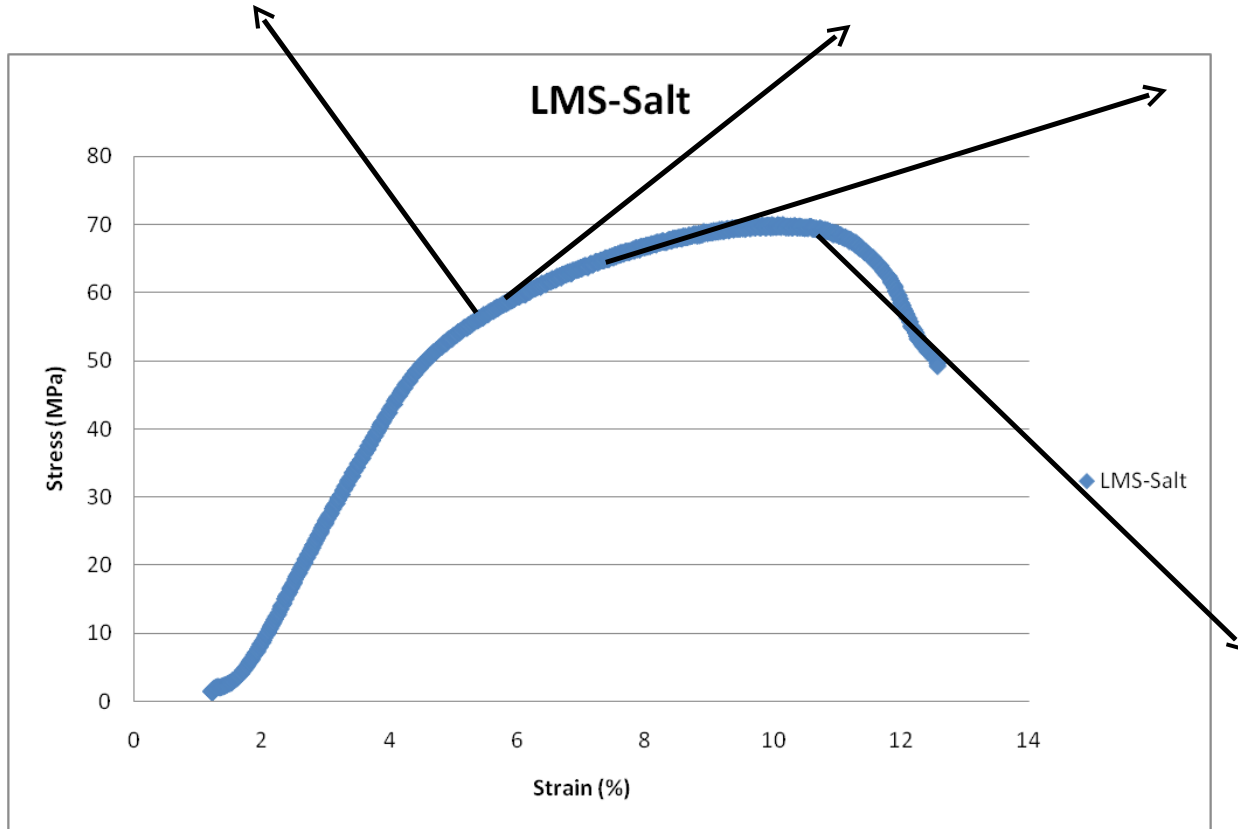
Gx80 - 1mm²
 Taille de grains : 200µm



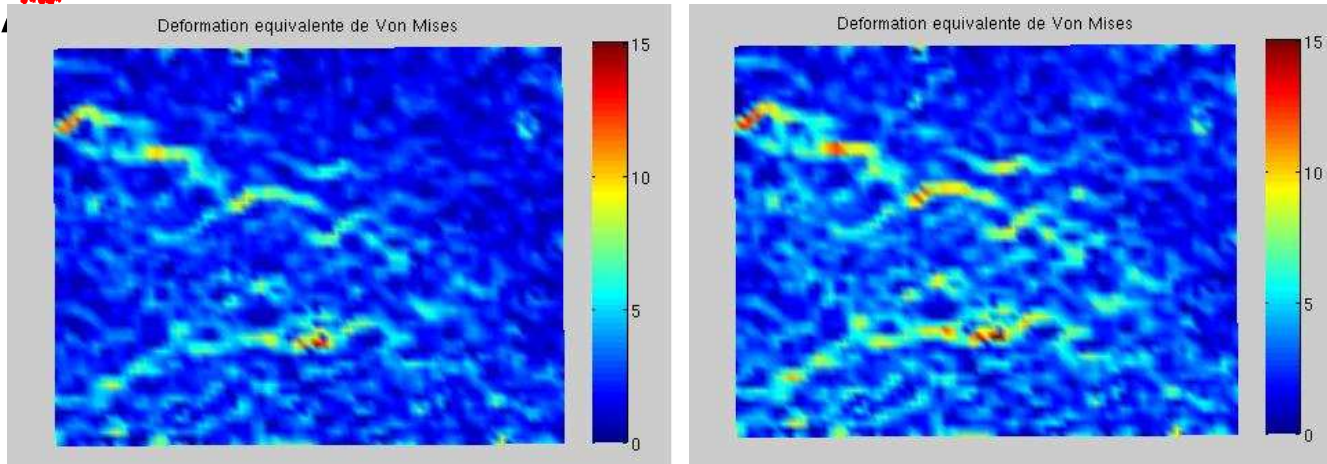
3- Echelle mesoscopique



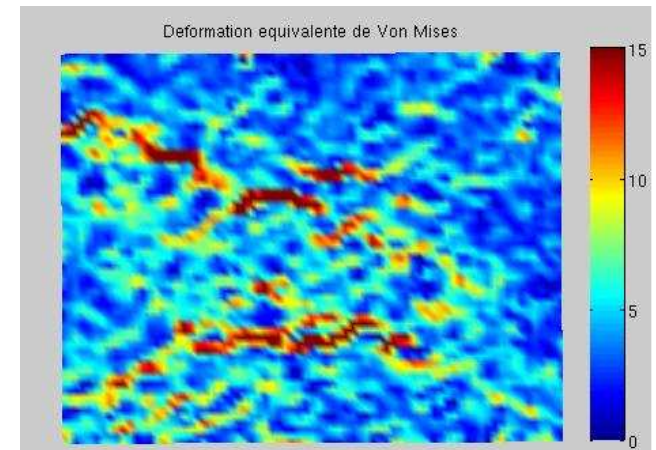
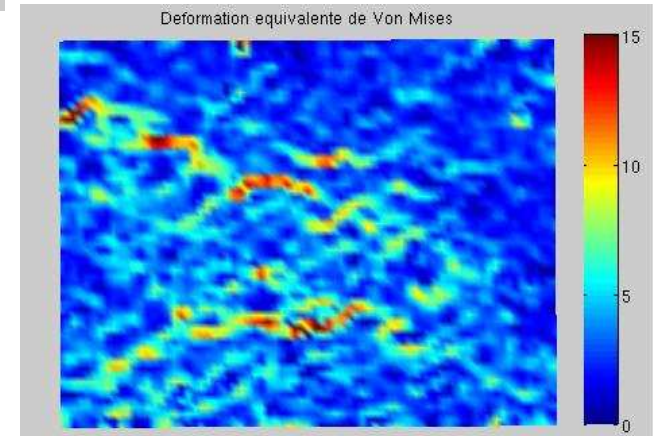
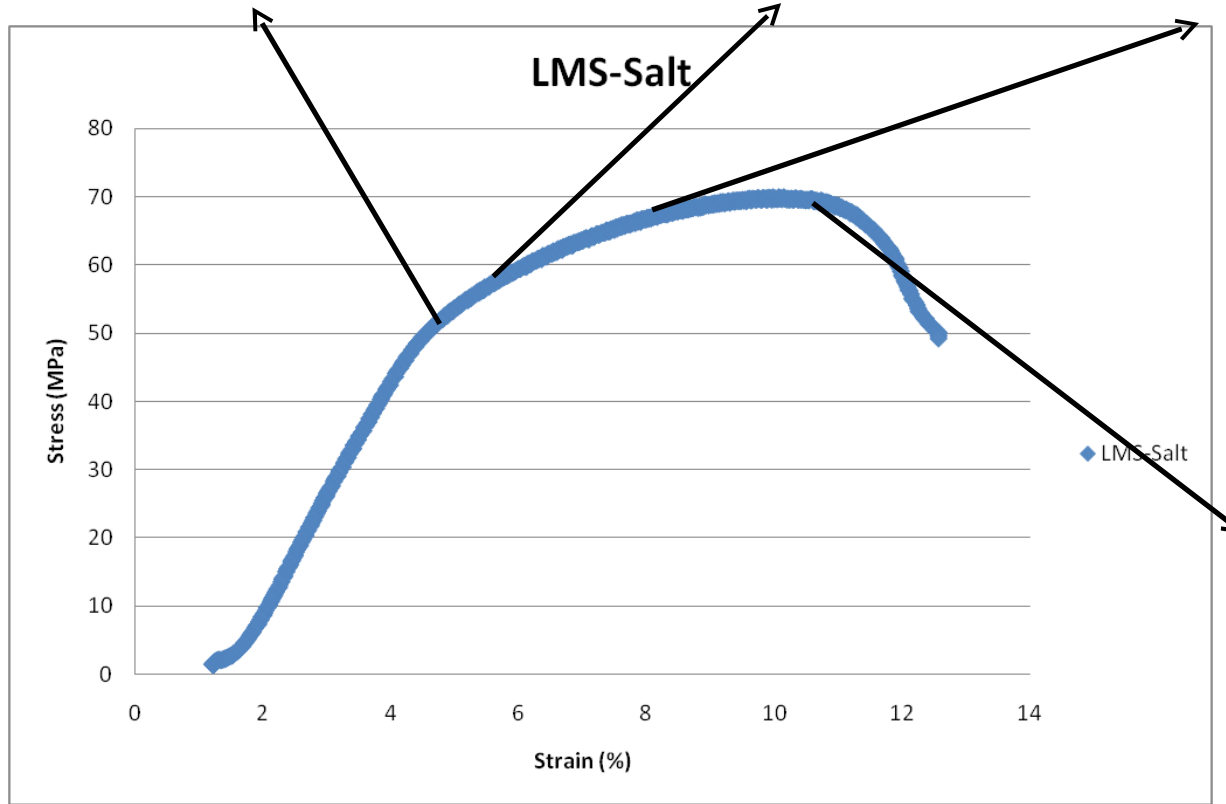
5x6mm²



3- Echelle mesoscopique



5x6mm²



Suivi de déformations de l'os << in-situ >>

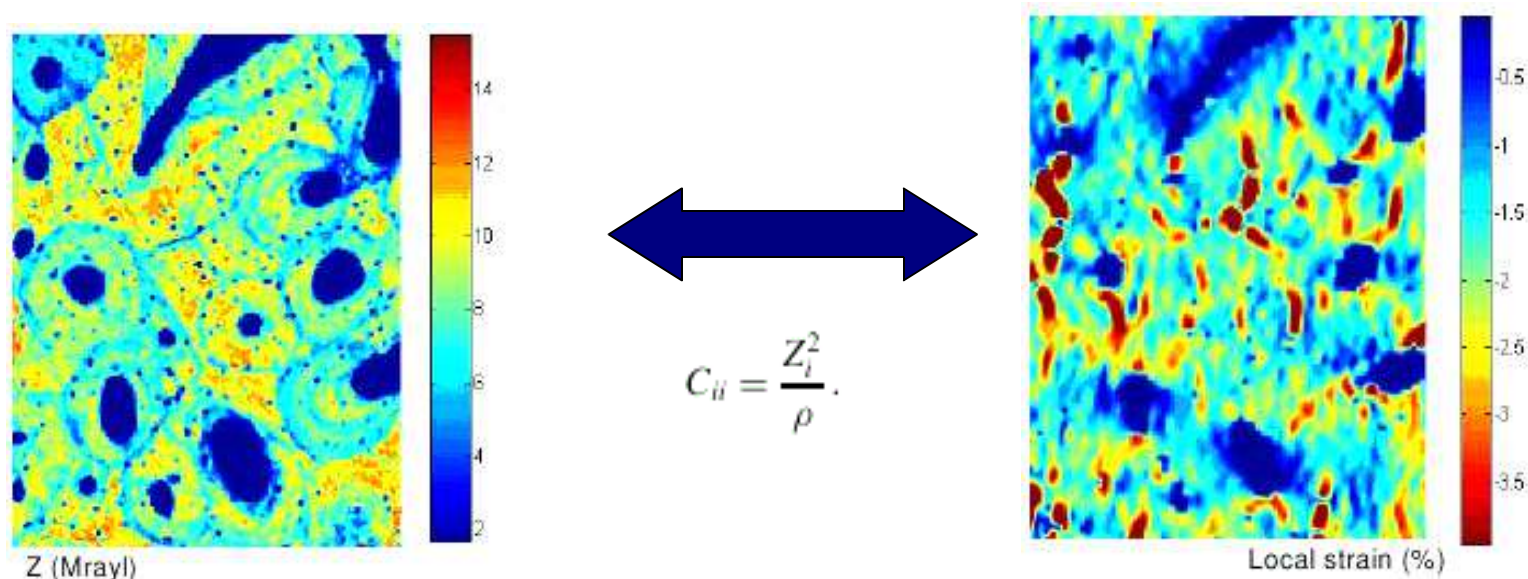
Stage Oliver Lopez (encadrant : J.M. Allain)

Contexte de l'étude

L'**ostéoporose** est une maladie liée à l'âge et un problème de santé publique de grande ampleur.

Objectifs :

- Comprendre du comportement mécanique de l'os à différentes échelles.
 - Choix des **techniques ultrasonores** pour évaluer les propriétés mécaniques de l'os de manière non destructive.
- (F. Rupin)



Étude de l'impédance acoustique par microscopie acoustique.

Étude des déformations de l'os en compression

(M. Mouchet et al.)

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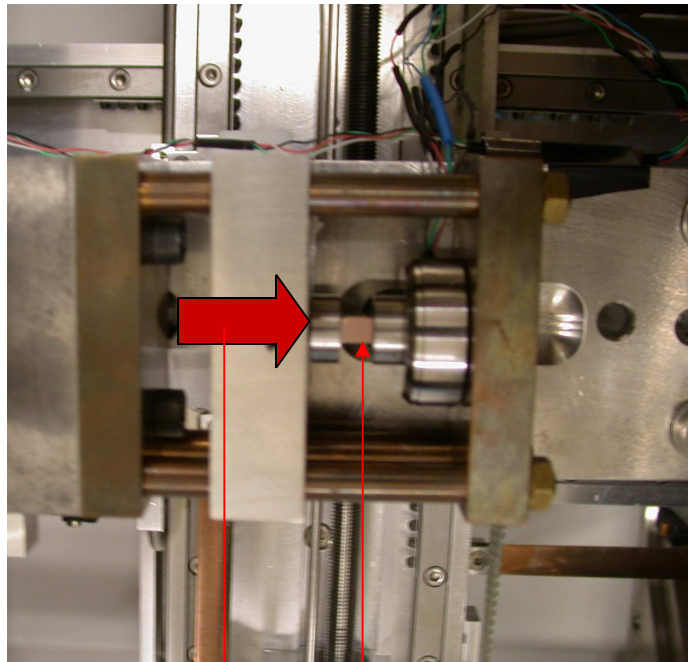
Suivi de déformations de l'os << in-situ >>

Échantillons d'os cortical humain (fémur), cube de 4x5x7 mm³

Préparation :

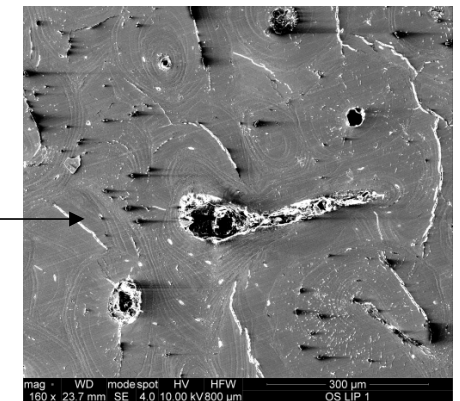
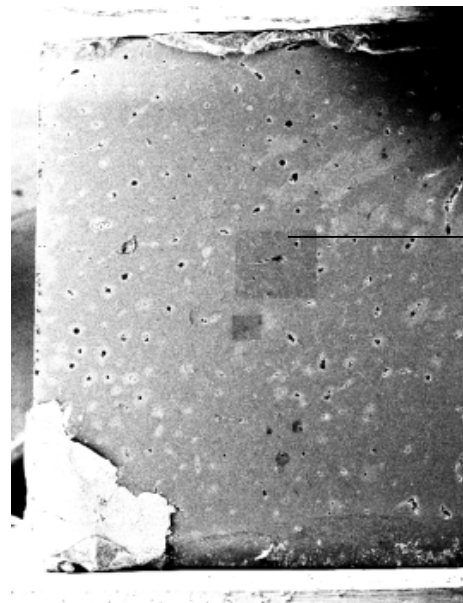
- > *Polissage* (grains de 5µm de diamètre)
- > Metallisation (couche métallique de 10nm d'épaisseur)

Essai de compression dans un microscope électronique à balayage



Échantillon

Déplacement imposé (1µm/s)

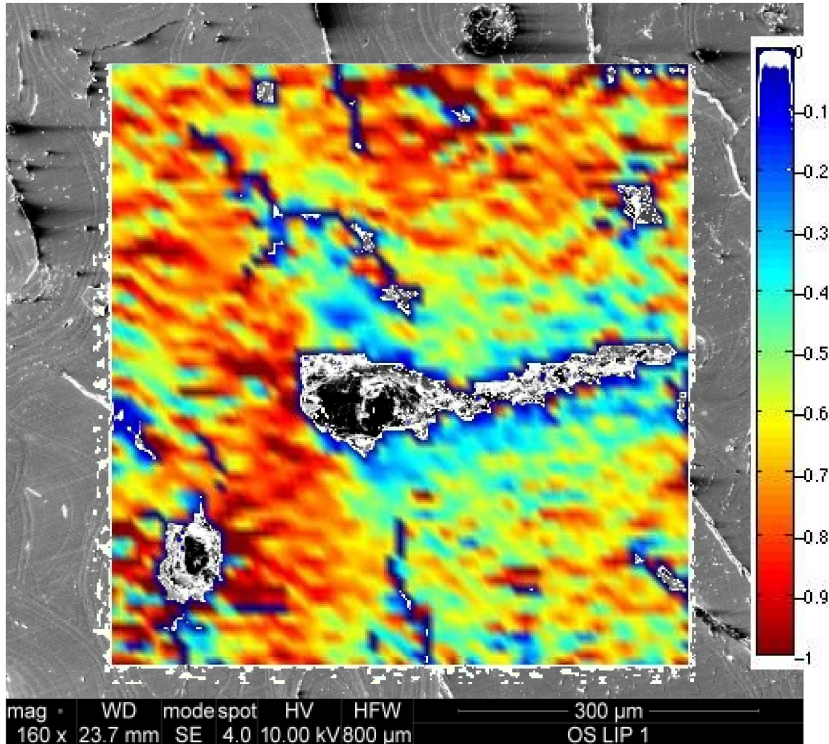


Zone de l'échantillon
imagée
(HFW de 800µm)

Obtention de la carte des déformations à l'aide d'un logiciel de corrélation des images (correlmanuv)



Contrainte de 72MPa
Déformation de 0.78%



Selon biblio, Module d'Young plus faible dans les lamelles autour des trous/ostéons que dans la matrice

Module d'Young obtenu d'accord avec la littérature

Magnification	HFW	E [Gpa]	
160x	800 μm	14.47	+1.77
450x	284 μm	18.85	+0.86

Observation en microscopie acoustique (Laboratoire d'Imagerie Paramétrique de l'université Paris 6)

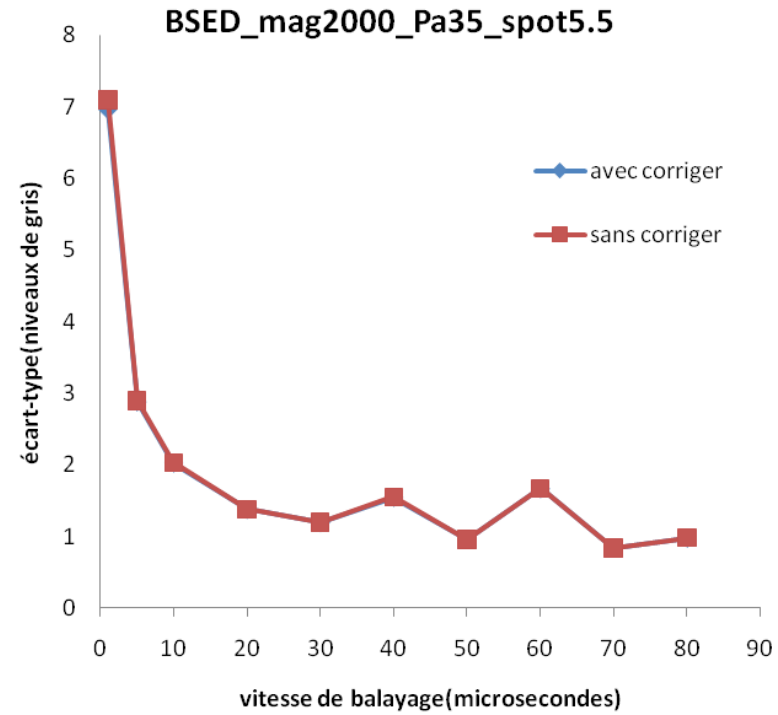
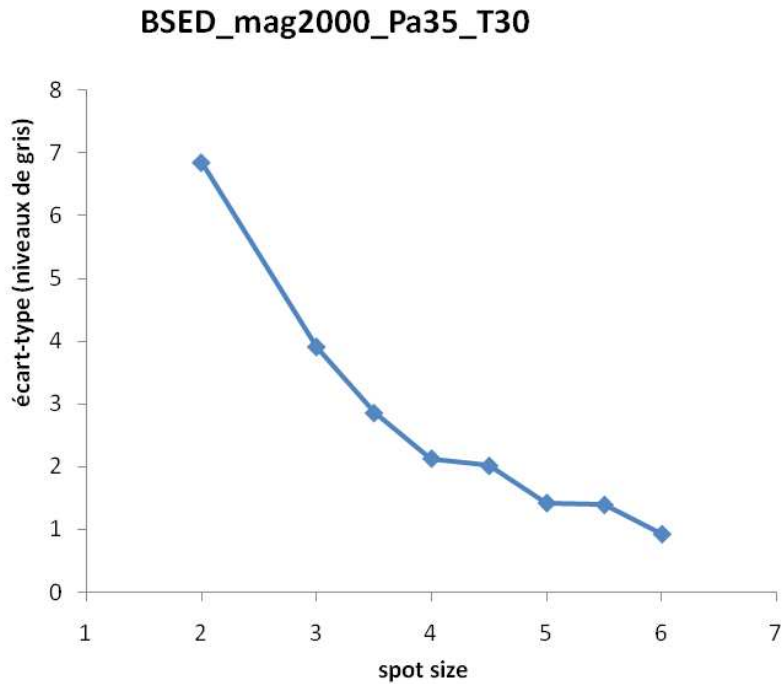
Obtention de la carte d'impédance acoustique (liée à la déformation par la densité) dans le même échantillon.

> Correlation de ces cartes (travail actuel)

Précision de la mesure ?



■ Erreurs intrinsèques : Bruit d'image

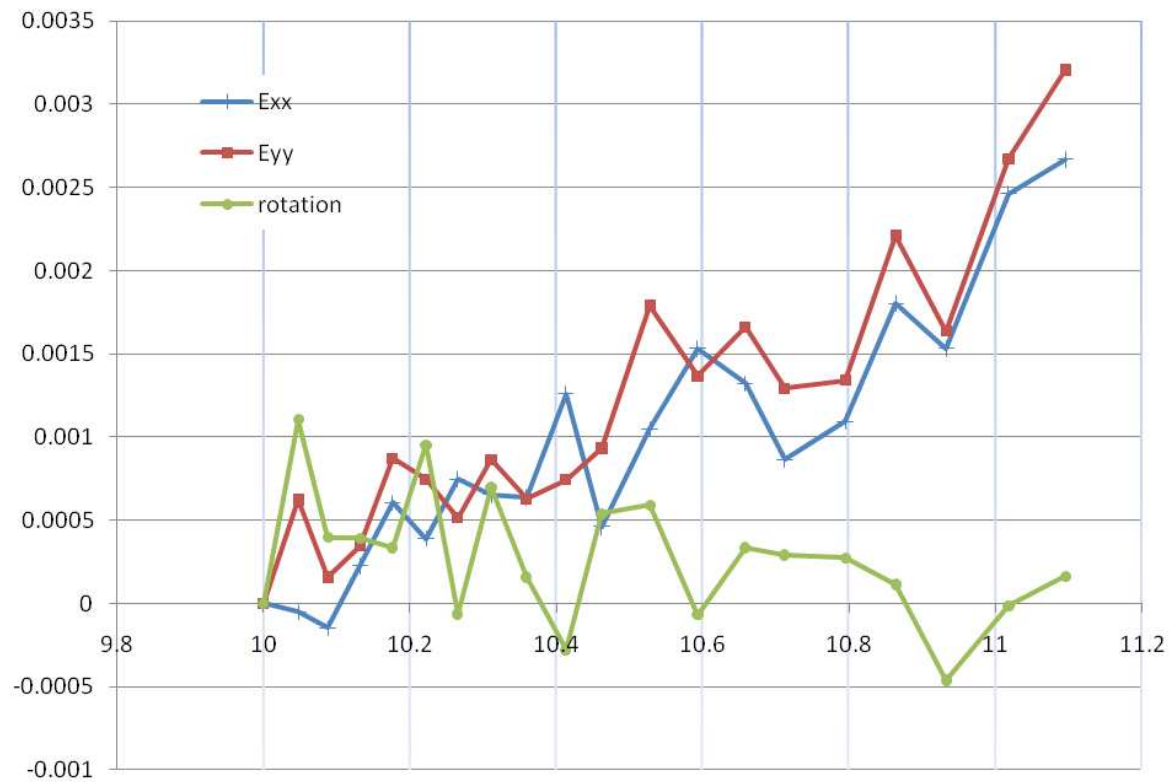


■ Erreurs extrinsèques : Variation de grandissement

Précision de la mesure ?



- Erreurs intrinsèques : Bruit d'image
- Erreurs extrinsèques : Variation de grandissement



Conclusions et perspectives



Evolutions des essais mécaniques in-situ :

- Observation
- Mesure
- Couplage avec d'autres techniques
- Calculs polycristallins / changement d'échelles
- Statique – Dynamique

Perspectives :

- Essais et Mesures de champs en mode ESEM
- 3D