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Guy Oum, Jamal Fajoui, David Gloaguen, Vincent Legrand. Lattice strain evolution of a stainless steel during Bauschinger complex loading. 9th International Conference on Residual Stresses, 2012, Garmisch-Partenkirchen, Germany. 2012. hal-01007712

Institut de Recherche en
Génie Civil et Mécanique

Lattice strain evolution of a stainless steel during Bauschinger complex loading

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SCIENTIFIC CONTEXT

The stainless steel is a material widely used in heavy, naval, automobile and construction industry. With a Cubic Face Centered crystallographic structure, it undergoes important transformations as well as macroscopic level as mesoscopic (*grain* scale) and microscopic, while applying cyclic loading and many others. These mutations explain the appearance and the development of important internal *elastoplastic* deformations (or of order II) when those materials are subjected to a *given complexe loading* (*traction followed by uniaxial compression, Bauschinger type complex loadings…*).

The aim of this study is a better comprehension of microstructure mechanisms influences over the whole material behaviour in term of activated deformation mechanisms (*glides, dislocations*) depending on the crystallographic orientation and the micromechanic state of the crystallites forming the analyzed diffracting volume.

Purpose

To describe **Bauschinger Effect (BE)** we need to develop a more ***realistic*** and ***predictive multi-scale*** approach by integrating different microstructural aspects that influence the material whole behaviour.

This approach is based on:

- An **experimental study** based on deformation fields anlyzing using neutronic diffraction
- A **modelisation** based on a micromechanic approach using scale transitions like the self-consistent approach.

Study on large instruments (neutronic sources)

● ISIS Facility (Didcot, Angleterre)

ISIS

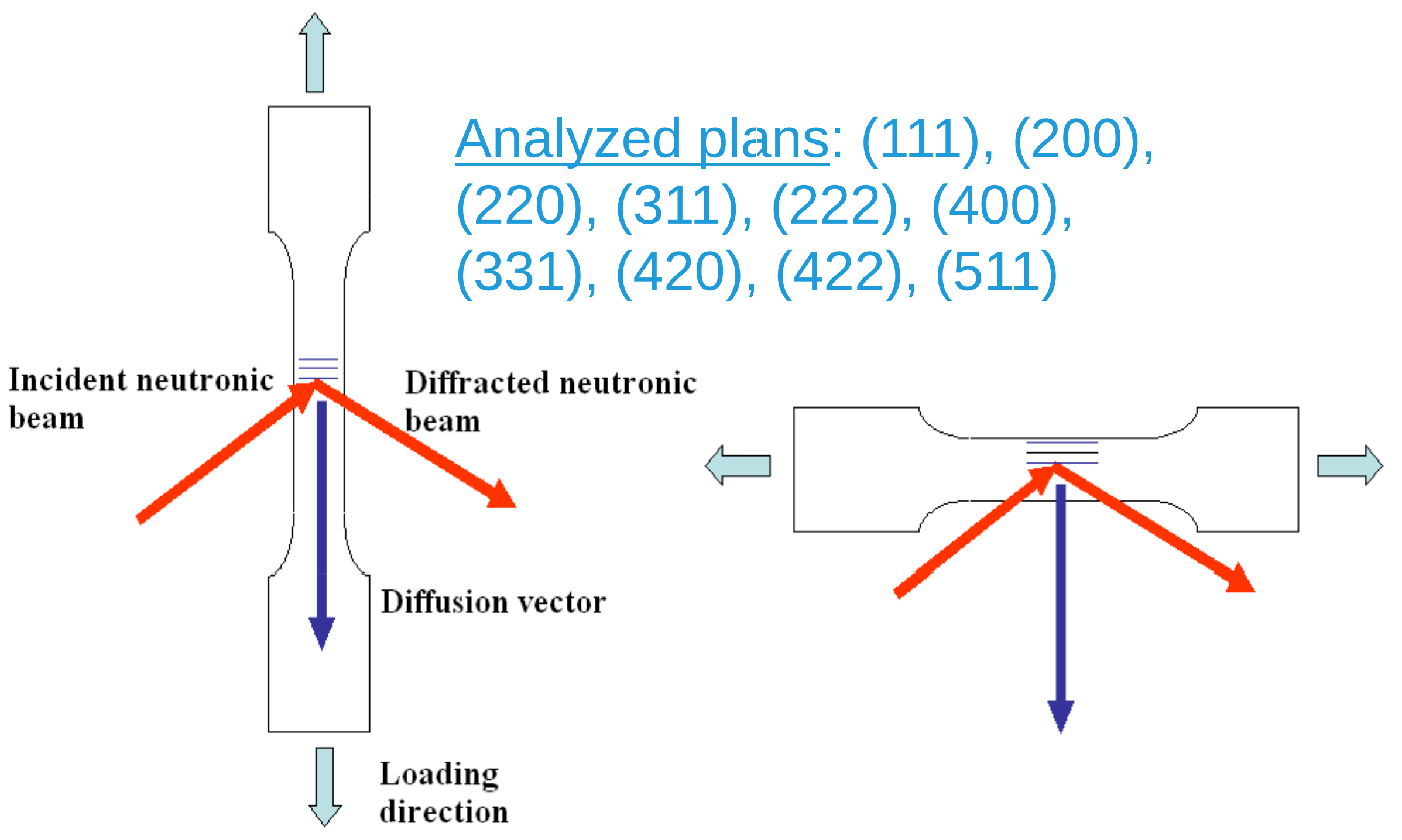
GEM : *General materials powder diffraction*, W. Kockelmann

Engin-X : *Engineering materials beamline*, J. Kelleher

EPSC APPROACH, MODULUS LOSS,CRITICAL SHEAR STRESS LOSS IN BE

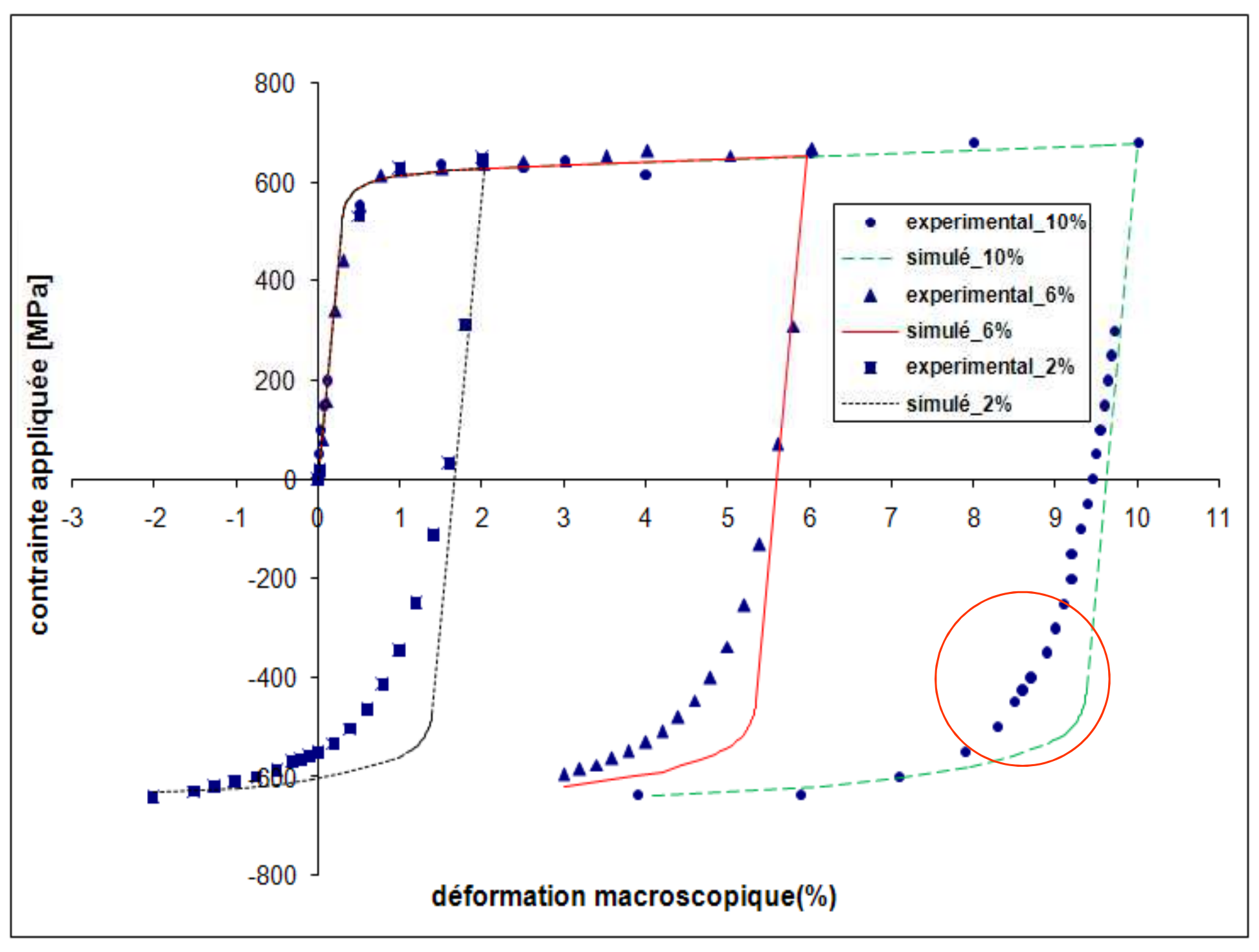
In situ measurements of intergranular longitudinal and transversal elastoplastic deformation using neutronic diffraction during Bauschinger type complex loadings at room temperature. Three prestrain rate : 2%, 6%, 10%. Volumic analysis (mm^3, statistically representative at macroscopic scale). Validation homogenisation method.

Neutronic diffractometer Engin-X (ISIS, UK)



Analyzed plans: (111), (200), (220), (311), (222), (400), (331), (420), (422), (511)

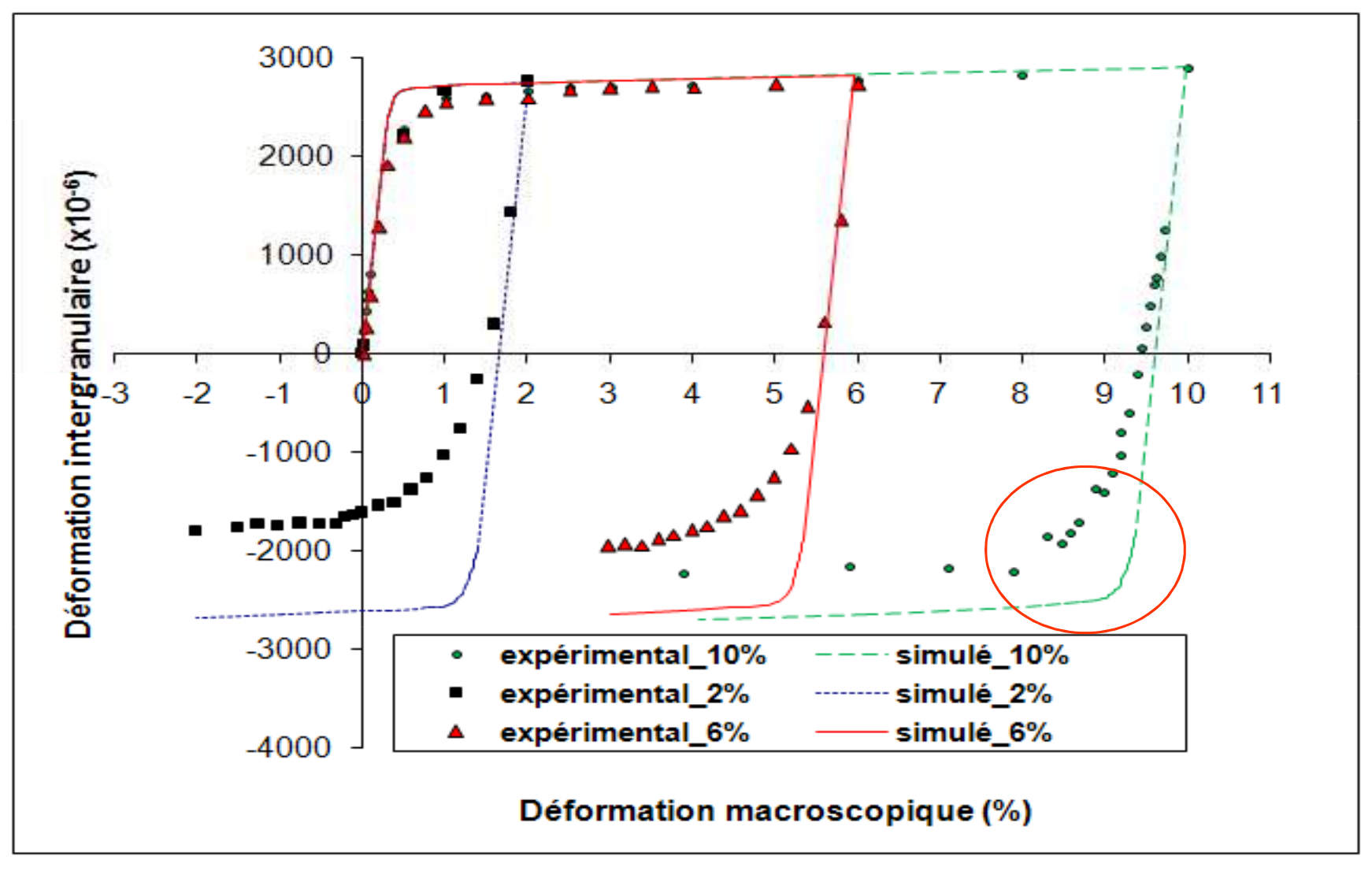
Longitudinal et transversal deformations



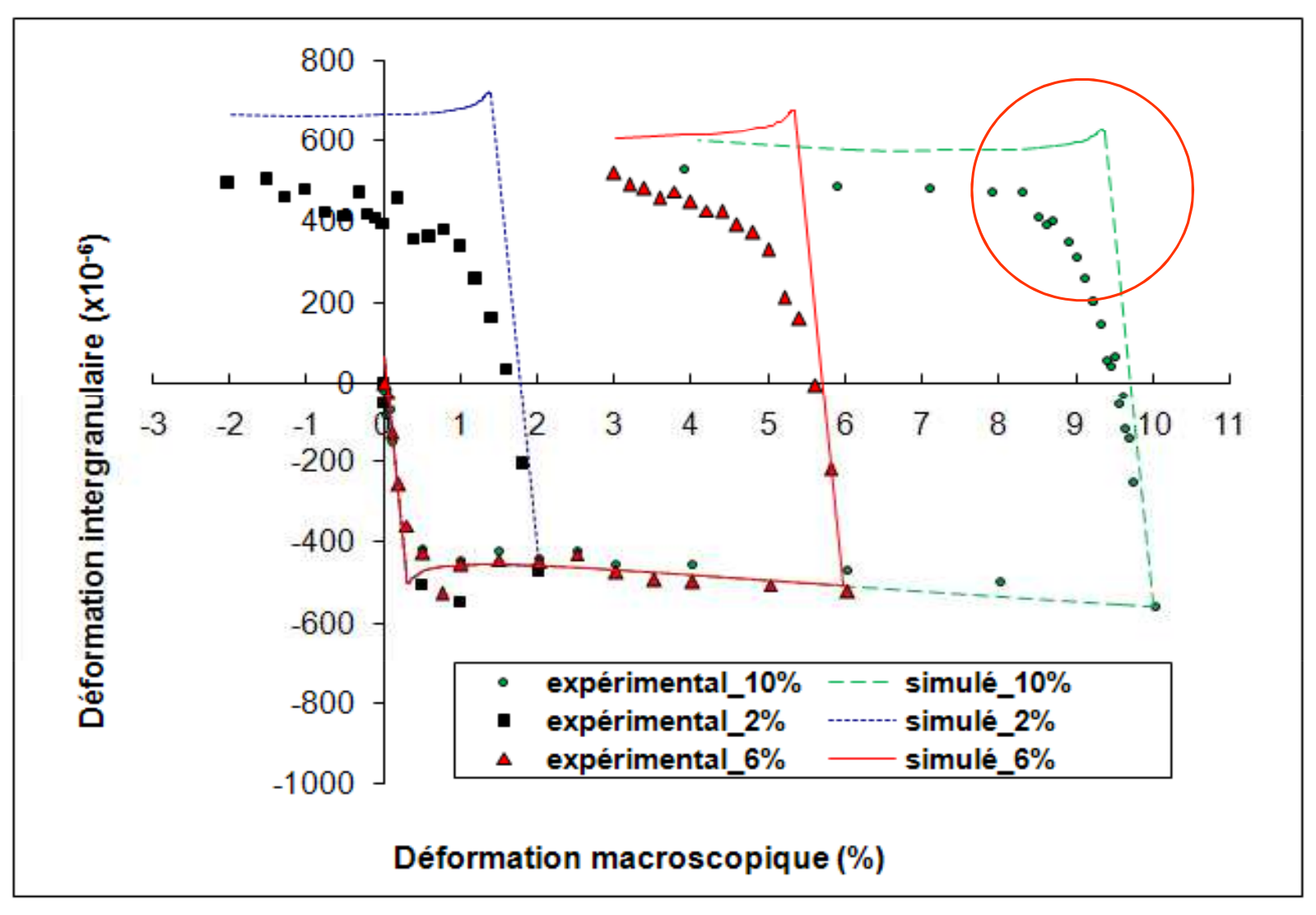
Macroscopic stress-strain curve

Evolution of intergranular deformation depending on the macroscopic strain: information over the deformation mechanisms on a fine scale of the diffracting volume

Longitudinal deformation

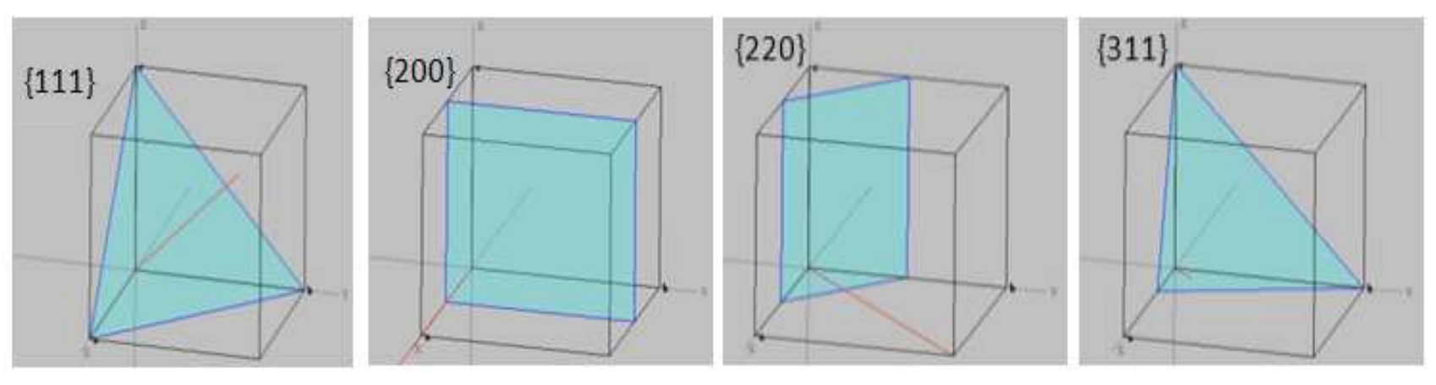


transversal deformation

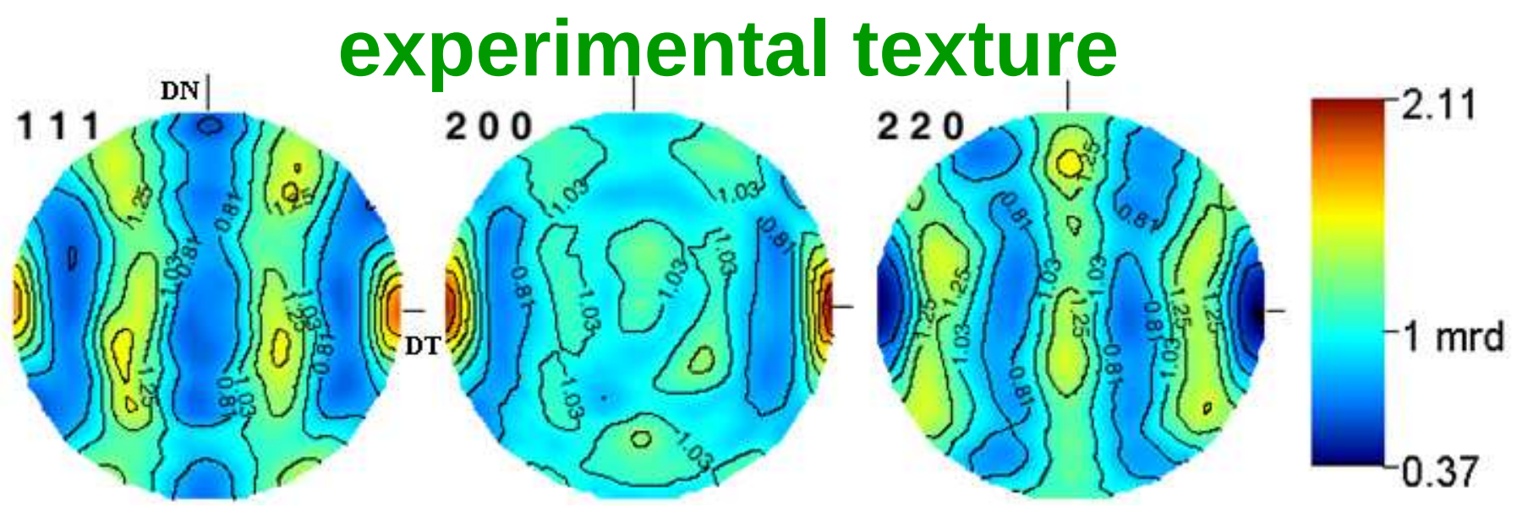


Plan (111)

Crystallographic plans



experimental texture



Work hardening evolution (biphased crsytal):

$$\dot{\tau}_c^r = \sum_{s=1}^{n} H^{rs} \dot{\gamma}^s$$

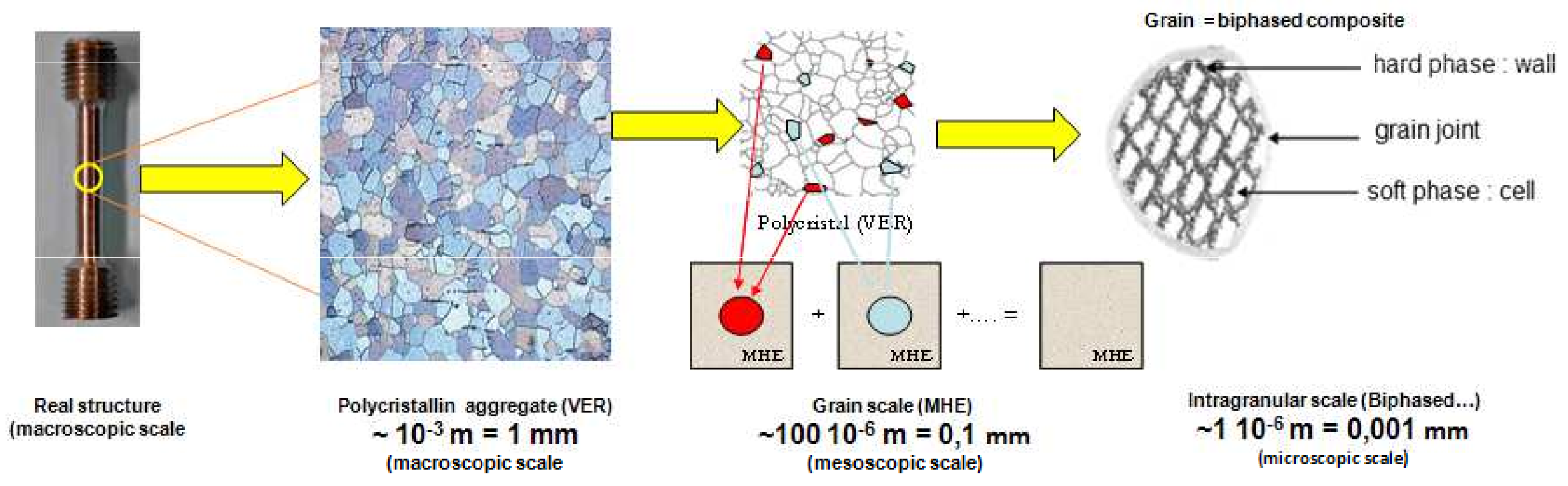
Glides description

Intergranular deformation:

$$\left\langle \varepsilon^{II}(\Phi,\Psi,hkl) \right\rangle = \sum_{j=1}^{n} \frac{f_j . \varepsilon_j^{II}(\Phi,\Psi,hkl)}{\sum_{i=1}^{n} f_i}$$

Double transition scales model:

behaviour prediction at micro- méso- and macroscopic scales



development

❑ Validation and model feeding
❑ Better description than the ONE scale transition over the microstructure evolution.
❑ Improvment of the model to better take into account intragranular heterogeneities.

Elements taken into account:

- *initial residual stresses,*
- *experimental crystallographic texture,*
- *deformation mechanisms (glides),*
- **starting scale : microstructure of dislocations,**
- **heterogeneities of deformation fields and of intragranular stresses,**
- **work-hardening: evolution of dislocation densities law.**

New elements added:

- ***pertelast** : a coefficient representing the percentage of modulus loss;*
- *incrcreasing of pertelast with the prestrain level,*
- *activation of cell systems first (reverse loading),*
- *activation of wall systems after most of cell systems (reverse loading),*
- *earlier activation of system in whole with the increasing prestrain*
- *microstructure reorganization and dislocation annihilation*

Mean free path of mobile dislocation:

$$L^g = D + \frac{k_L}{\sqrt{\sum_{l \neq g} (\rho_{wf}^l + \rho_{wr}^l)}}$$

Dislocation Density laws:

$$\dot{\rho}_{wf}^g = \frac{1}{b}\left(\frac{1}{L^{(g)}} - 2 y_c \rho_{wf}\right)\dot{\gamma}_r^g \qquad \dot{\rho}_{wr}^g = -\frac{1}{b}\left(\frac{1}{L^{(g)}} \frac{\rho_{wr}}{\rho_1^0}\right)\dot{\gamma}_r^g$$

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