Laboratoire des Sciences des Procédés et des Matériaux – UPR 3407
Institut des Sciences de l'Ingénierie et des Systèmes (INSIS)

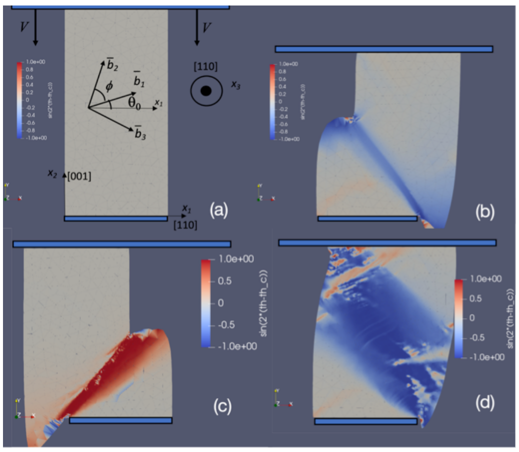
University Sorbonne-Paris-Nord 3years PhD grant

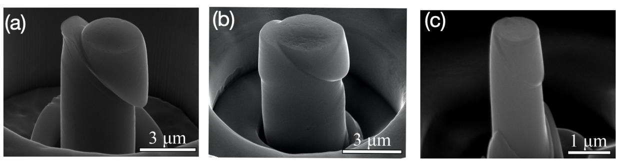
Eulerian modeling of large plastic deformation of crystals with applications to micro-pillars

The Eulerian rate-dependent single crystal models (as proposed in [1]) is particularly suitable for solving boundary-value problems involving large strains and strain rates. They are able to describe both the lattice rotations and the rate-dependent plastic flow.

The first objective of the thesis is to develop the numerical scheme for Eulerian rate-dependent crystal plasticity (firstly proposed in [2]) and to increase the its robustness and its computational efficiency. To handle the non-differentiability of the plastic terms an iterative decomposition/coordination formulation coupled with the augmented Lagrangian method will be used. For the spatial discretization a mixed FE (Finite Element)- DG (Discontinuous Galerkin) strategy was adopted. The final result of this objective will be a user-friendly *3D-code of crystal plasticity* implemented in FreeFem++.

The second objective will be the applications of the model and of the code to *micro-pillars* [3]. The mechanical response of single-crystal micro-pillars under compression shows a highly localized behavior in the form of shear bands that can endanger the structural stability of a sample. Experiments suggest that introducing an artificially tailored quenched disorder (precipitates and solutes) embedded into the sample or changing the orientation of the crystal, a more homogeneous mechanical response can be achieved, which is highly beneficial in practical applications. In this thesis, we continue the work [4] to study the mechanical response of a 3D FCC crystals when it is compressed through 3-D FE computations taking into account the geometry and the underlying crystal lattice of pillars.





Left : Compression of a 2D nano-pillar using Eulerian plasticity approach (Free-Fem++ computations) for three different initial orientation of the crystal with the orientation misfit in color scale (from [4]). Right : Scanning electron microscopy images showing the deformed states pillars (experiments from [3])

[1] O. Cazacu and I. R. Ionescu, "Dynamic crystal plasticity: An eulerian approach," J.Mech. Phys. Solids , vol. 58, pp. 844–859, 2010 [2] Cazacu, O. and I. R. Ionescu., Augmented Lagrangian method for Eulerian modeling of viscoplastic crystals, Computer Methods in Appl. Mech. and Engng. vol. 199, 688—699, 2010 [3] P. Zhang,O.U. Salman, J.-Y. Zhang, G. Liu, J.Weiss, L. Truskinovsky, and J. Sun, "Taming intermittent plasticity at small scales," Acta Materialia, vol. 128, pp. 351 – 364, 2017 [4] O.U. Salman and Ioan R. Ionescu, Tempering the mechanical response of FCC micro-pillars: an Eulerian plasticity approach, Mech. Res. Comm. 2021

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***Starting date:* October 1st 2021**

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