MICRO-MECHANICS OF FRACTURE : EXPERIMENTS AND SIMULATIONS

LABORATORY : Institut Lumière Matière

LEVEL : M1 / M2 / L3
TEAM(S) : MMCI

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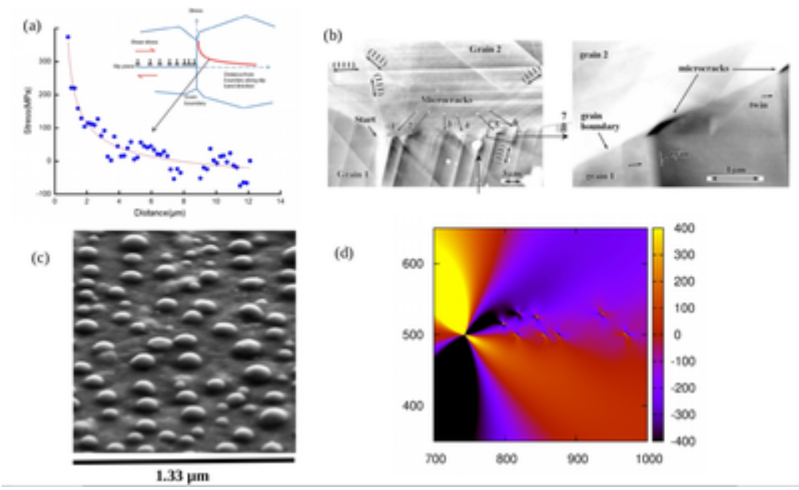
KEYWORD(S) : multiscale simulations / sub micron scale experiments / fracture physics

SCIENTIFIC CONTEXT :



(a, b) stress concentration and cracks, (c) gold nano droplets, (d) simulation

Context : Fracture initiation in solids is linked to the formation of stress concentrators which activate locally fracture processes such as : breaking of "atomic bonds" in brittle cases (Si [1], Fe [2] and W [3] at low temperature, ceramics [4]), the formation of nano scale cavities (Fe-H at room temperature [5], fracture of amorphous solids [6], ductile crack embryos in pure metals [7], fatigue crack initiation [8]), as well as thermally activated subcritical crack propagation [9]. These mechanisms might be activated at the tip of slip bands when those are blocked by obstacles, such as grain boundaries (Fig. 1) and lead to the formation of crack embryos [10-12]. Even if the existence of stress concentrators is well known, in situ observations are scarce [12,13].

In this internship, we plan to observe or model such mechanisms. Experimentally, an original method has been developed to measure deformation at high magnification by following, on the surface, the displacement of gold nano droplets (Fig. 1c) [14]. It uses a micro-tensile stage within a scanning electron microscope. Computationally, a discrete dislocation dynamics simulation has been set up to simulate plastic deformation generated by the stress concentration at a pre-existing crack tip [15].Previous studies have shown that the number of dislocations within such simulation should be enlarged to enable a direct comparison with experiments.

MISSIONS :

In particular, we would like to study the onset of secondary plasticity, ahead of a crack tip, a phenomenon that we have already observed experimentally [16] but which is not understood and is potentially essential to understand embrittlement at the nanoscale.

[1] "Role of Surface Reconstructions in (111) Silicon Fracture" D. Fernandez-Torre et al., Phys. Rev. Lett. 105 185502 (2010)

[2] "Cleavage Oriented Iron Single Crystal Fracture Toughness" M. L. Hribernik, PhD thesis UC Santa Barbara (2006)

[3] "Cleavage Anisotropy in Tungsten Single Crustals" J. Riedle et al. Phys. Rev. Lett. 76 3594 (1996)

[4] "In situ stable crack growth at the micron scale" G. Sernicola et al. Nat. Comm. 8 108 (2017)

[5] "Hydrogen embrittlement understood" I.M. Robertson, Met. Mat. Trans. A 46A 2323 (2015)

[6] "Quantitative prediction of the fracture toughness of amorphous carbon from atomic-scale simulations" S. Mostafa Khosrownejad et al. Phys. Rev Mater. 5 023602 (2021)

[7] "Do voids nucleate at grain boundaries during ductile rupture?" P. Noell et al. acta mater. 137 103-114 (2017)

OUTLOOKS :

L3 and M1 internships are for 8 weeks

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BIBLIOGRAPHY :

[8] "On the mechanism of fatigue crack initiation in high-angle grain boundaries" V. Mazánová et al. Int. J. Fatigue 158 106721 (2022)

[9] "How heat controls fracture: the thermodynamics of creeping and avalanching cracks", T. Vincent-Dospital et al. Soft Matter 16 9590-9602 (2020)

[10] "The equilibrium of linear arrays of dislocations", J.D. Eshelby et al. Phil. Mag. 42 351-364 (1951)

[10b] "A theory of the fracture of metals" A.N. Stroh Advances in Physics 6 418-465 (1957)