IN SITU NANO-MECHANICAL TESTS IN THE LIGHT OF µLAUE DIFFRACTION

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In the recent past, low-dimensional materials attracted enormous attention due to the extraordinary properties found for nanostructures compared to their bulk counterparts. For instance, micro- and nano-mechanical tests revealed an increasing yield strength with decreasing size of the structure reaching the ultimate limit of the material for nanowires. While bulk fcc metals fail at stresses of few MPa, ultra-high strengths were demonstrated for gold nanowires with an elastic limit of few GPa [1, 2]. Additionally, while semiconductors such as Si and InSb are brittle at room temperature and become ductile at elevated temperatures of few hundred degrees Celsius, pillars of sufficiently small diameters are ductile under ambient conditions [3].

To shed additional light on the mechanical behavior of low-dimensional materials, in situ experimental setups are being designed for imaging the deformation process as well as the nucleation and evolution of defects induced by the mechanical loading. Recently, we have developed a scanning force microscope (SFINX) which may be installed at 3rd generation synchrotron beamlines for in situ nano-mechanical tests in combination with nano-focused X-ray diffraction techniques such as coherent X-ray diffraction and µLaue diffraction [4, 5].

So far, in situ mechanical tests coupled with diffraction techniques concentrated on micrometric samples [6, 7]. We have recently reported the first successful coupling of atomic force microscopy with µLaue diffraction for in situ three-points bending tests on single self-suspended gold nanowires pushing the well-established µLaue diffraction technique from the micro- to the nanoscale [5]. A sequence of µLaue diffraction patterns of the central Laue spots (Si004 and Au222) is presented in Fig. 1(a). For the pristine nanowire the two Laue spots are superimposed. With increasing applied force the Au222 spot is displaced on the detector, moves further away from the Si004 spot and returns towards its original position until the two spots are again superimposed when unloading the wire. This reversible behavior indicates a fully elastic behavior of the Au nanowire.

By scanning the X-ray beam along the nanowire during the deformation process the complete profile of the nanowire under load is accessible. This technique allows for defining the boundary conditions, i.e. whether the nanowire is thoroughly or partially clamped or simply supported. Additionally, the applied load was extended until plastic deformation of the nanowire occurred and, thus the onset of plasticity was studied.

This work was funded by the French National Research Agency through project ANR-11-BS10-01401 MecaniX.