In-situ nano-mechanical tests in the light of μLaue diffraction

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In situ three-points bending tests of Au nanowires in the light of µLaue diffraction

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Scanning Force microscope for In situ Nanofocused X-ray diffraction

Z. Ren et al., J. Synchrotron Radiat. 21 (2014) 1128
in situ μLaue diffraction

setup at BM32 @ ESRF
Au nanowires

Si(hkl) cleaned by rinsing in acetone, ethanol

cathodic etching + 30 nm C sputtering

transfer to UHV annealing at 680°C, 5 min

nanowire growth by physical vapor deposition

G. Richter, MPI Stuttgart
µLaue diffraction

SEM

5 µm

topography

6.0 µm

Au-L\text{\textsubscript{III}} fluorescence

6.0 µm

shadow from AFM head

red circles indicate Laue spots from Au nanowire

nanowire bending

- UB matrix computed from position and displacement of Laue spots
- calculation of crystal orientation – bending + rotation

bending angle $\beta$ increases up to $3.5^\circ$ for [111] and [0-11] direction, while for [2-11] $\beta < 1^\circ$  
$\Rightarrow$ force not perfectly vertical but finite lateral force exist due to cantilever deflection
FEM simulation

experiment well described by FEM simulations

- bulk elastic constants
- geometric non-linearities due to strain inhomogeneity
- $\sigma_{\text{max}} > 450 \text{ Mpa} \gg \text{bulk yield strength}$
- max. theoretical shear stress for Au $\tau_{\text{max}} = G/2\pi \approx 4.8 \text{ GPa}$

Au nanowires plastically deformed using AFM

Ex situ scans with μLaue diffraction along nanowire
plasticity

![Graph showing bending angle vs. motor position and deformation vs. motor position. The graph includes data points and lines indicating changes in bending angle and deformation with motor position.]

- Bending angle vs. motor position with data points and lines indicating changes in bending angle with motor position.
- Deformation vs. motor position with data points and lines indicating changes in deformation with motor position.

- The graph highlights a consistent 10 µm change in deformation as the motor position varies.

- Key values: bending angle (deg) and motor position (mm).
identifying slip systems

experiment
inverse pole figure

theory
Stress distribution

- compression
- tensile

- GNDs expected

- mainly activated slip system: (0-11),[111]
- slight deviation observed
  ⇒ second slip system
- calculated geometry
  ⇒ clamped boundary conditions

- expected slip system: (0-11),[111]
- dislocation stored for compatible deformation of crystal (GNDs)

in situ KB scan

C. Leclere et al., in preparation
in situ KB scan

C. Leclere et al., in preparation
in situ KB scan
in situ plasticity

loading-unloading cycle

piezo movement

KB

KB

KB

KB

KB

KB +
normal scan

time

peak splitting

AFM-tip

peak splitting

beam profile
rotation due to dislocations

bending angles: 
(11-2)=0.13°, (1-10)=1.05°, 
(111)=0.93°

inverse pole figure indicates 
single slip oriented

facilitates « counting » number of dislocations

Geometrically necessary boundary 
(GNB) with 20 dislocations

rotation ~ 1°
conclusions

Scanning force microscope for in situ nanofocused XRD
✓ Combination with μLaue diffraction
✓ In-situ imaging
✓ Elastic bending of NWs
✓ Plastic deformation of NWs

In situ studies
✓ Elastic properties of NWs
✓ Defining activated slip system
✓ « counting » number of dislocations
General Meeting

on the Mechanics of Nano-objects

Marseille, November 5-6, 2015

Organizing Committee: Olivier Thomas, Cathy Paitel (IM2NP Marseille)

Registration deadline: October 11th, 2015
Thanks for your attention!