

Institut Matériaux Microélectronique  
Nanosciences de Provence

## Mechanical properties at small scales

---

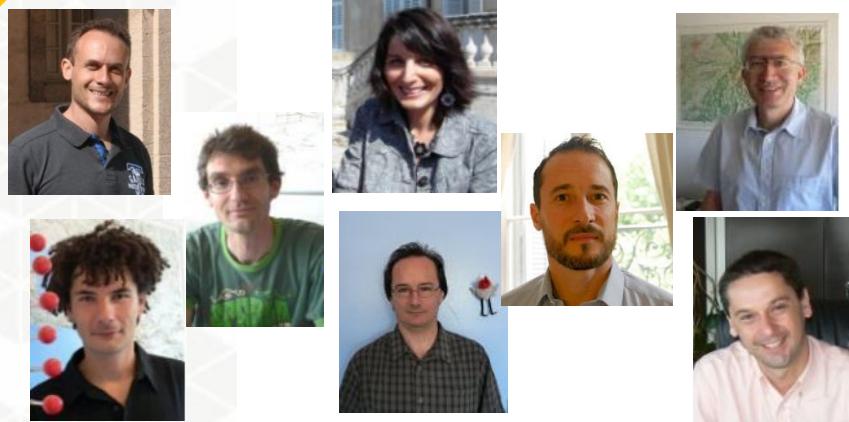
Thomas W. Cornelius ([thomas.cornelius@im2np.fr](mailto:thomas.cornelius@im2np.fr))  
CNRS Researcher  
Co-responsable of Mechanics of Nano-Objects (MNO) research team



Institut Matériaux Microélectronique Nanosciences Provence  
UMR 7334, CNRS, Universités d'Aix-Marseille (AMU) et de Toulon (UTLN)



# Mechanics of Nano-Objects



## Research topics

- Mechanics of nano-objects
- Strain in microelectronic devices

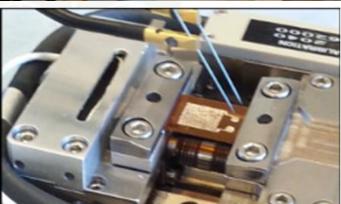
## Techniques/Methods

- (Synchrotron) X-ray diffraction
- Transmission electron microscopy (TEM)
- MD simulation

CNRS funded IRP « DASEIN » with University of California Santa Barbara (UCSB) on defect and strain engineering in materials for new and improved properties



4-circle diffractometer



Tensile stage Deben

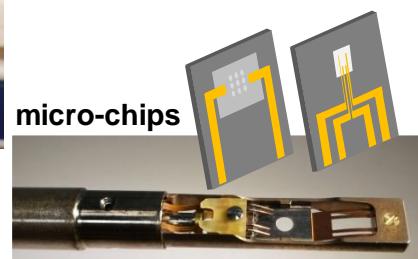


Anton Paar furnace



In-situ AFM SFINX

Z. Ren et al., *J. Synchrotron Radiat.* 21 (2014) 1128



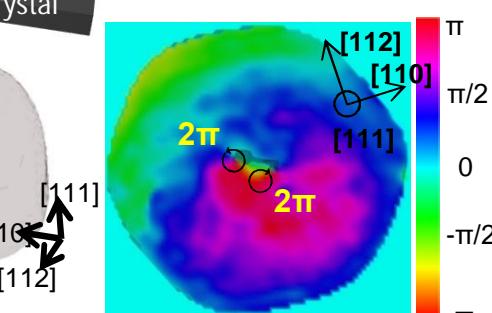
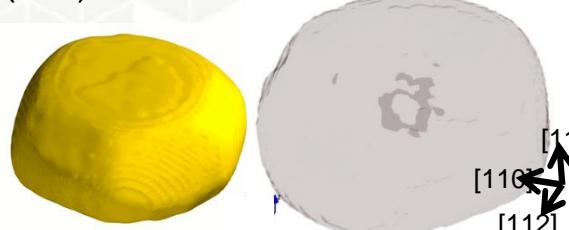
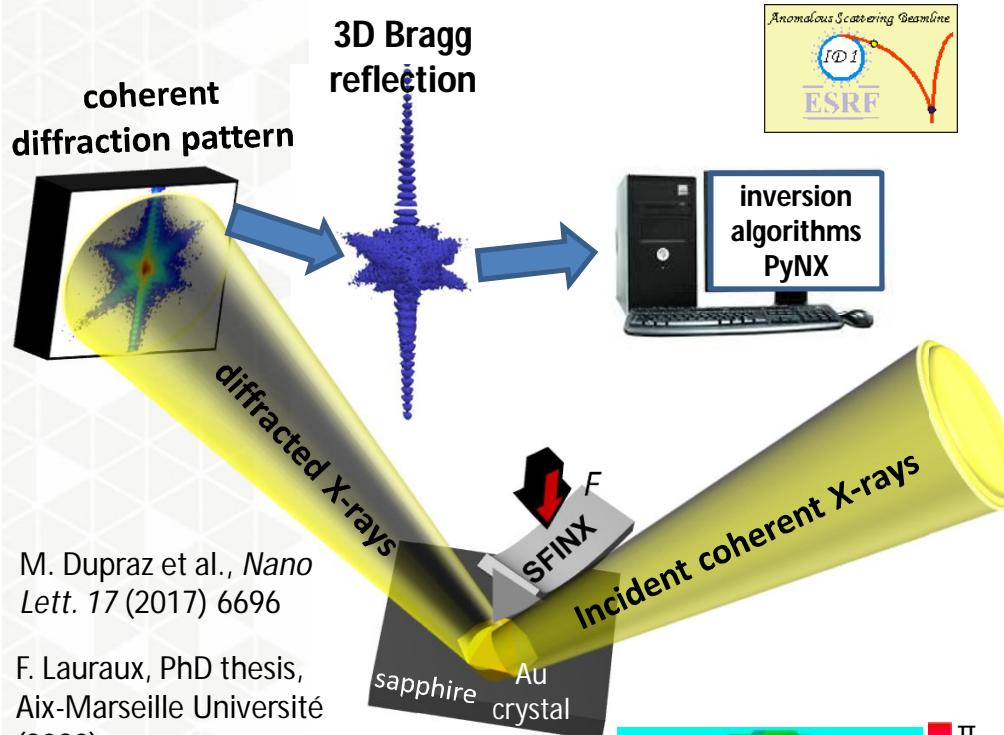
In situ biasing / heating  
TEM sample holder



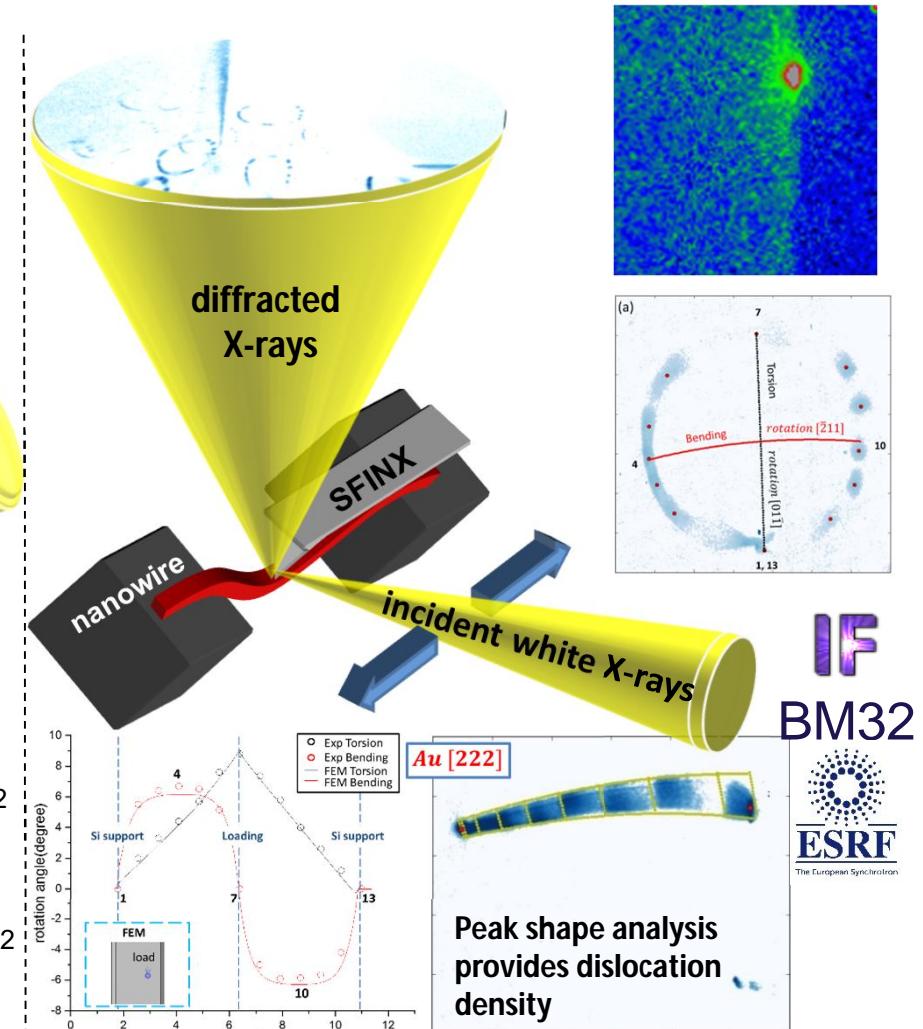
Optical curvature  
measurement

# *in situ* nano-mechanics

## Bragg coherent X-ray diffraction imaging

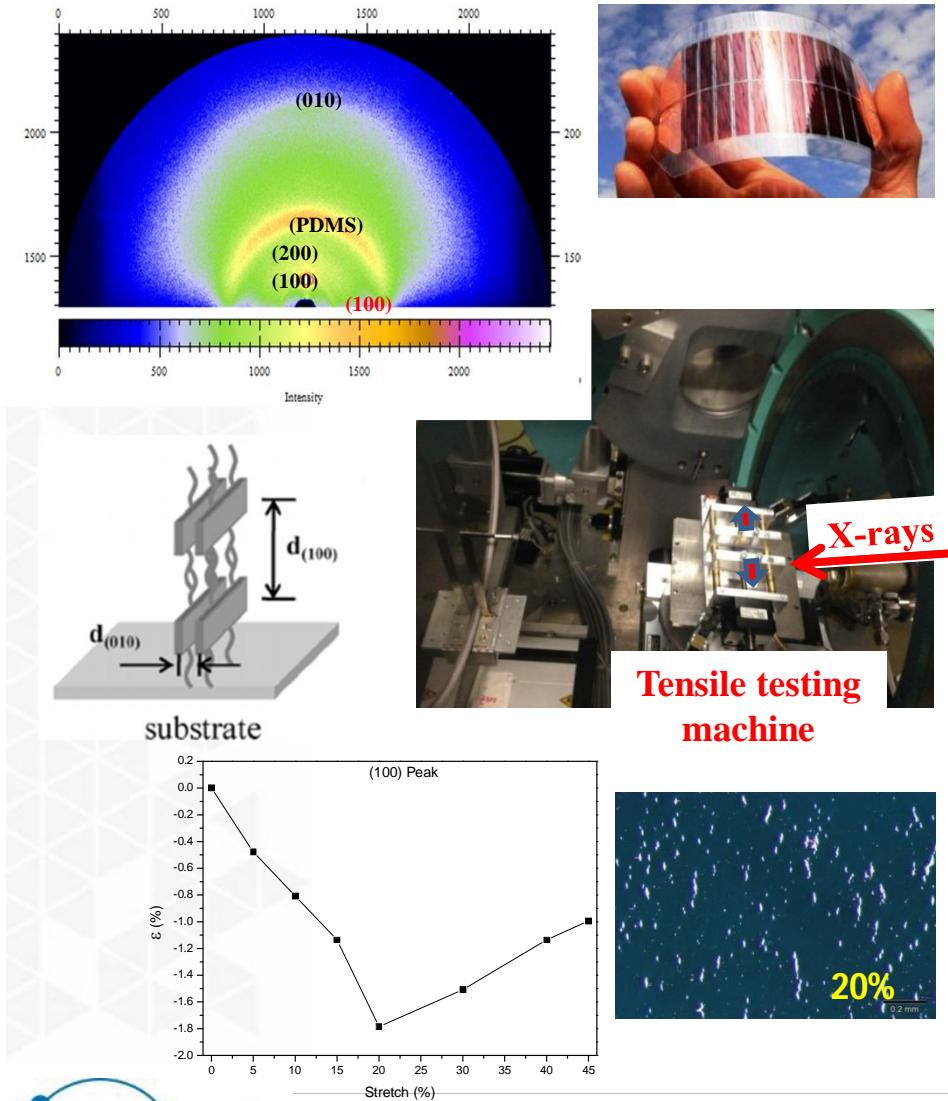


## Laue microdiffraction

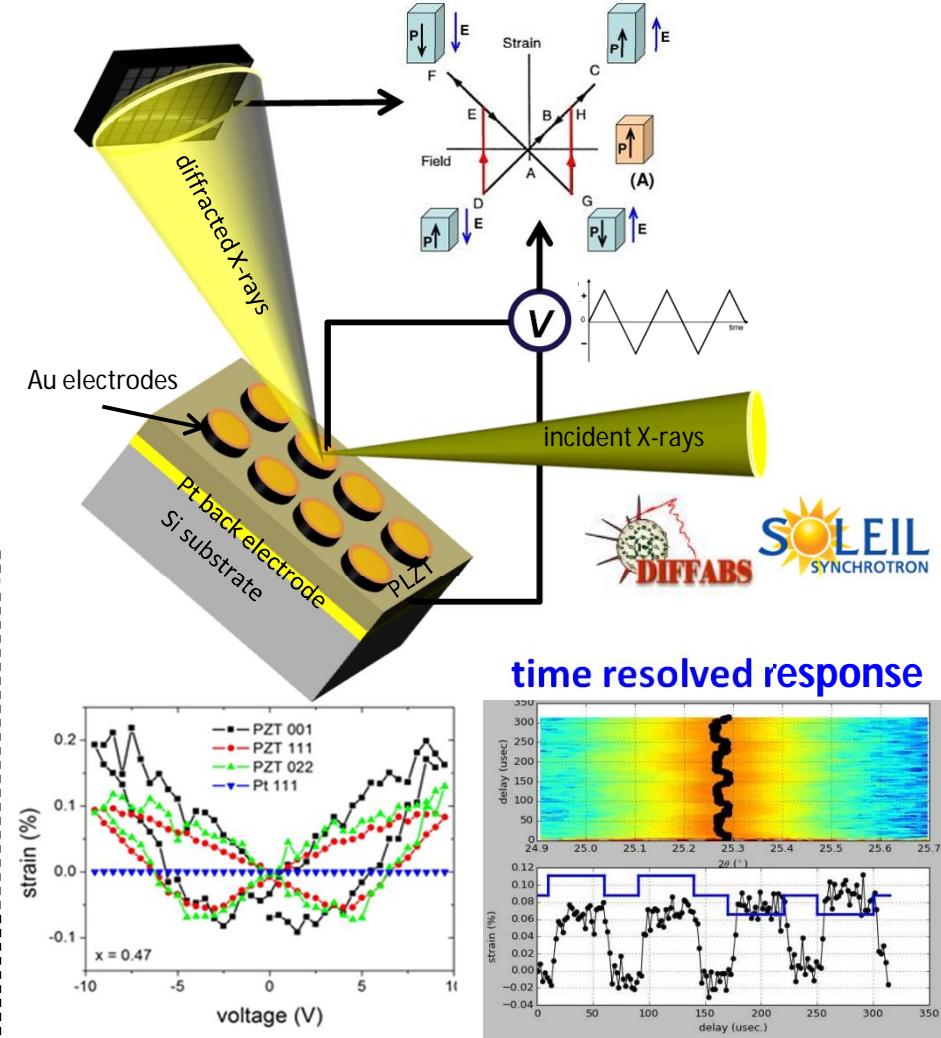


# *in situ* X-ray diffraction

mechanics of polymers on flexible substrates



piezoelectric ferroelectric thin films

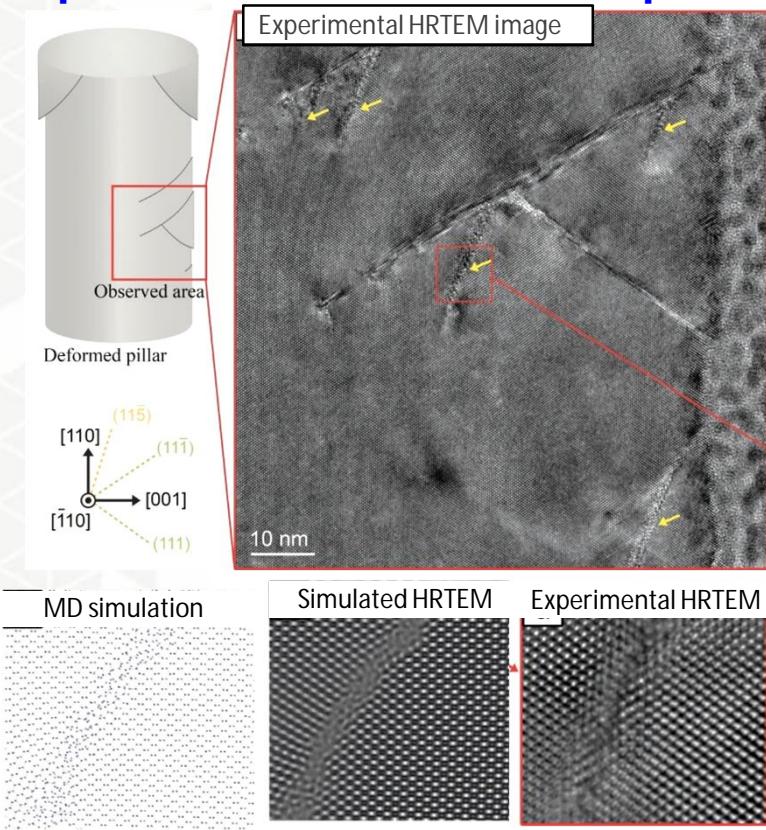


T.W. Cornelius et al., *J. Appl. Phys.* 122 (2017) 164104

T.W. Cornelius et al., *Materials* 13 (2020) 3338

# dislocation microstructure

HRTEM of dislocation microstructures in Si nanopillars deformed at room temperature



Observation of unusual defects located in {115} planes

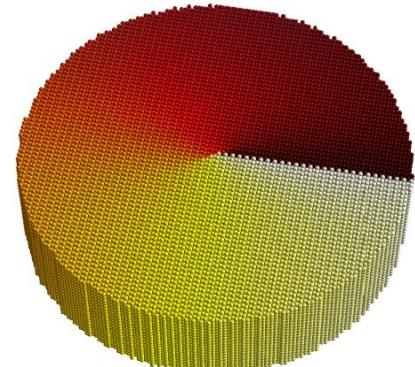
Depending on loading conditions (notably compression axis), various types of defects are produced: perfect and partial dislocations, nano-twins, {115} defects,...

Comparison between experimental image and MD

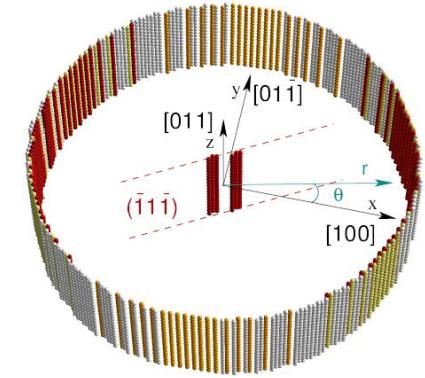
A. Merabet et al. *Acta Mater.* 161 (2018) 54

Molecular static simulation of screw dislocation in Cu nanowire

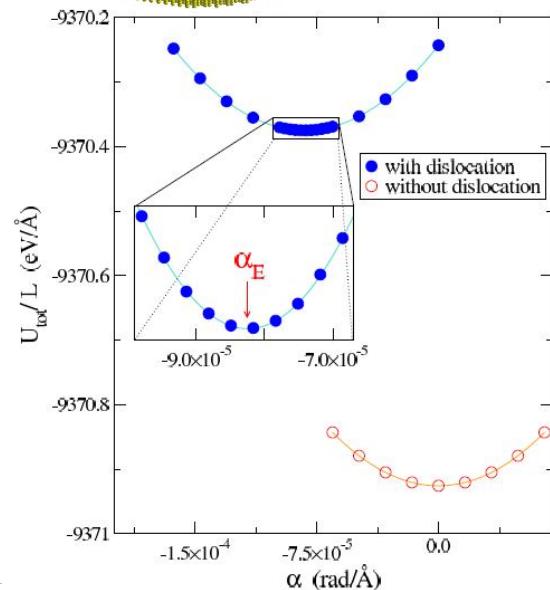
total displacement field  $u$ ,



energy



separation into two  
Shockley partials

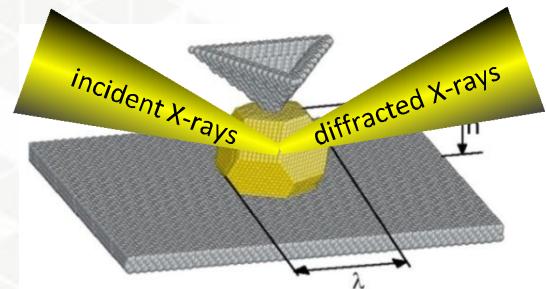


M. Gailhanou, J.-M.  
Roussel, *Phys. Rev.*  
*B* 88 (2013) 114101

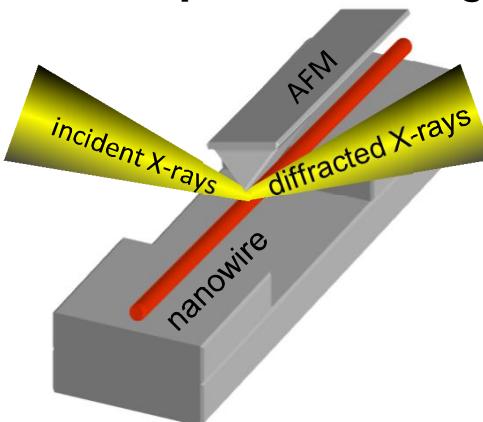
# internship / expertise

## Mechanical properties at small scales

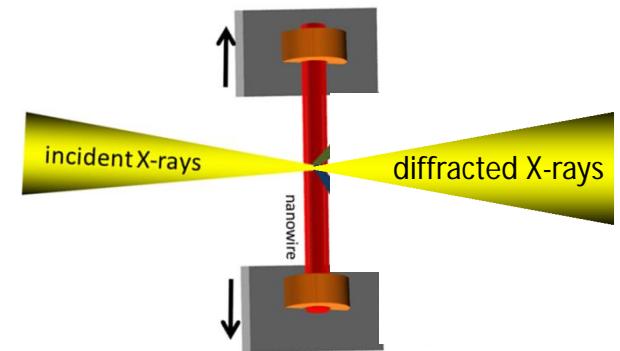
nano-indentation



three-point bending



tensile testing



(Synchrotron) X-ray diffraction

nanofocused  
X-ray diffraction  
mapping

Bragg coherent X-ray  
diffraction imaging

Laue micro-  
diffraction

high-resolution TEM

*understanding of defect nucleation and evolution in defect scarce nanostructures*