MM 50: Topical session (Symposium EPS and MM): Mechanical Properties at Small Scales

Plasticity and Fracture

Time: Thursday 10:15–11:30 Location: H 0106

Topical Talk MM 50.1 Thu 10:15 H 0106

New Insights into the Ductility of Freestanding Metallic Thin Films — •Benoit Merle — Department of Materials Science and Engineering, Institute I, Friedrich-Alexander-University Erlangen-Nürnberg, Germany

Little is known about the ability of freestanding films to accommodate plastic deformation, which is detrimental to the design of future generations of MEMS and integrated sensors. New insights are provided by investigations on 100-300 nm PVD copper, gold and silver thin films by means of in-situ tensile tests in a TEM and in-situ bulge tests in an AFM. They revealed that small specimens can accommodate a remarkable level of strain (10% or more) due to the grain-boundary mediated dominated deformation and the associated high strain-rate sensitivitya. This is in sharp opposition to the behavior of larger samples, which typically fail around 1% strain, because they contain defects that act as crack initiators. Suppressing them at all is hardly achievable in practice, which is why the most promising strategy to improve the ductility of thin films consists into improving their resistance to fracture. The bulge test offers a convenient way to measure the fracture toughness and observe the associated mechanisms. Against expectations, it was found that the thickness hardly influences the toughness of the films within the investigated range and that the microstructure does not play such a critical role as assumed. The resistance to fracture was shown to mostly depend on the resistance to necking ahead of a crack tip, suggesting new possibilities to increase the ductility of the films.

MM 50.2 Thu 10:45 H 0106

In situ TEM deformation studies of the Bauschinger effect in nanocrystalline thin films — •Ankush Kashiwar[1,2], Aaron Kobler[3], Horst Hahn[1,2], and Christian Kübel[1] — [1]Karlsruhe Institute of Technology, 76344 Eggenstein-Leopoldshafen, Germany — [2]Technische Universität Darmstadt, 64287 Darmstadt, Germany — [3]Nanoscribe GmbH, 76344 Eggenstein-Leopoldshafen, Germany

Nanocrystalline (nc) metals with grain sizes smaller than about 100 nm exhibit outstanding mechanical strength and fatigue properties compared to their coarse grained counterparts. Recent studies on this class of materials have reported an extended elastic-microplastic regime upon loading and unloading. With the aim of investigating the deformation mechanisms governing these elastic plastic transitions, we perfomed in situ cyclic loading-unloading experiments on sputtered nc Pd thin films inside a TEM. As the strain is progressively increased during each cycle, the stress strain curves show an increasingly non-linear unloading, deviating from an elastic unloading behavior, which is a characteristic of the Bauschinger effect (BE) in thin metal films. The corresponding ACOM-STEM series indicate local orientation changes in several grains, which are often fully or partially reversible. In addition, there is an evidence of partially reversible dislocation activity during loading and unloading from BF-TEM analysis. In our current experiments, we are combining the different imaging modes for the same sample in cyclic deformation experiments to correlate dislocation activity and grain orientation changes to systematically understand the deformation processes governing the BE in nc thin films.

MM 50.3 Thu 11:00 H 0106

Plasticity in three-point bent Au nanowires studied by in situ Laue micro-diffraction — •Thomas Cornelius[1], Zhe Ren[1], Gunther Richter[2], and Olivier Thomas[1] — [1]Aix-Marseille Univ, Univ Toulon, CNRS, IM2NP UMR 7334, Marseille, France — [2]Max-Planck Institute for Intelligent Systems, Stuttgart, Germany

In the recent past, in-situ experimental setups are being designed for monitoring the evolution of nanostructures during mechanical deformation. Compared to electron microscopy, X-ray diffraction has the benefit of being non-destructive, penetrating (no special need for sample pre-thinning) and extremely sensitive to elastic strains and defects. Thanks to the development of new synchrotron sources, increasingly efficient focusing optics, and advanced 2D detectors X-ray diffraction is becoming a major tool for investigating the structure of nano-objects in situ during mechanical deformation. In particular, Laue microdiffraction with its high sensitivity on crystal orientation and geometrically necessary dislocations (GND) is a predestined method for in-situ nano-mechanical testing. Here, we present in-situ Laue microdiffraction studies on the plasticity of three-point bent Au nanowires revealing the activation of unexpected slip systems and the storage of GNDs in contrast to MD simulations that predict the formation of wedge-shaped twins in purely bent nano-beams which escape the crystal after unloading.

MM 50.4 Thu 11:15 H 0106

X-ray nanodiffraction for in-situ mechanical studies — •Anton Davydok and Christina Krywka — Helmholtz-Zentrum Geesthacht, Hamburg, Germany

Huge scientific interest to mechanical properties of nano- and microscale non-organic materials requires appropriate experimental techniques with commensurate tools for detail investigations. For complete understanding of the deformation process in-situ experiments are necessary. P03 nanofocus endstation at PETRA III in DESY operated by Helmholtz Zentrum Geesthacht provides highly stabile experimental setup with high spatial resolution using a nanosized beam. It is one of only few places in the world where the experimental conditions for scanning X-ray nanodiffraction are provided and it offers a hard X-ray beam with a size of only 250 x 350 nm^2. The strong focus on materials science at P03 is demonstrated by the wide range of experiments already performed with in-situ sample environment including mechanical testing with strain resolution of 10^{-5}. In this presentation the setup for in-situ experiments at the Nanofocus Endstation of P03 beamline (PETRA III, DESY) will be presented with technical characteristic and examples of successful experiments will be shown.