MM 13: Topical Session: Nanomechanics of nanostructured materials and systems III - Small scale plasticity

Time: Monday 15:45–17:45 Location: BAR 205

Topical Talk MM 13.1 Mon 15:45 BAR 205
Elevated Temperature, In-situ Microcompression Methods — •Johann Michler, Rejin Raghavan, and Jeffrey Wheeler — EMPA,Thun, Switzerland

The small size of nano-mechanical testing equipment creates opportunities for incorporating the equipment into different micro-analysis instruments: SPM, SEM, EBSD, optical probes, etc. This allows in situ sample surface imaging and in-situ microstructure analysis during mechanical testing. In the first part of the talk, we will describe a general nano-mechanical test platform capable of performing variable temperature and variable strain rate testing of micropillars in situ in the scanning electron microscope. Stable, elevated temperature indentation/micro-compression requires the indenter tip and the sample to be in thermal equilibrium to prevent thermal displacement drift due to thermal expansion. This is achieved through independent heating and temperature monitoring of both the indenter tip and sample. Furthermore, the apex temperature of the indenter tip is calibrated, which allows it to act as a referenced surface temperature probe during contact. In the second part of the talk, several case studies based on elevated temperature microcompression experiments will be presented: shear band kinetics in amorphous metals, brittle ductile transitions in Silicon, GaAs, GaN and InSb micropillars, and mechanical behaviour of nanolaminates.

MM 13.2 Mon 16:15 BAR 205
Finite volume effects on dislocation organization and associated size effects in strength — •Erica Lilleodden and Henry Ovri — Institute of Materials Research, Materials Mechanics, Helmholtz-Zentrum Geesthacht

The nearly universal observation of size effects from nanoindentation and microcompression experiments in metals has led to heated debate regarding the physical basis of such behaviors. Much research in this area has focused on the scaling of stress with deformation length scale, and largely ignores the important observation of the inherently jerky load-displacement response common to both experiments. Borrowing ideas from self-organized criticality, it is argued here that consideration of the displacement bursts in relation to the deformation and microstructural length-scales can help provide a framework for understanding size effects in plasticity. The talk will focus on single crystalline high purity Mg and the Mg alloy AZ31 of two orientations associated with dislocation plasticity (i.e., no twinning), where the active slip systems for the two orientations have significantly different Peierls barriers. In this way, we are able to differentiate the influence of intrinsic lattice strength and alloying content. It will be shown that the distribution of displacement bursts and their associated stresses can be used to investigate the combined influences of finite volumes and material & microstructural parameters on the organization of dislocation structure and resultant stress-strain response.

MM 13.3 Mon 16:30 BAR 205
Size-dependent plasticity in KCl and LiF single crystals: Influence of orientation, temperature, pre-straining and doping — •Yu Zou and Ralph Spolenak — Laboratory for Nanometallurgy, Department of Materials, ETH Zurich, Zurich, Switzerland

Size dependence of plasticity is generally observed and intensively studied in metallic systems, but it is rarely investigated in ionic crystals. In this work, two typical ionic crystals with the rocksalt structure, KCl and LiF, were investigated using micro-compression technique. Single-crystalline KCl and LiF pillars with diameters ranging from four microns to two hundred nanometers were produced by focused ion beam milling. The pillars were compressed using a flat-punch tip in a nanoindenter, along [001]- and [111] orientations and at both room temperature and ˜200 °C. Pre-strained [111] LiF and CaCl2 doped [001] KCl pillars were compressed as well. We found that, in contrast to KCl, the size-dependence in LiF pillars is more sensitive to the orientation and temperature change. [111] LiF exhibit smaller size dependence and displacement bursts than the other pillars measured. The results also show that the pre-straining strengthens [111] LiF pillars in micron-sized range but weakens them in submicron-sized range, resulting a reduced size-effect exponent. The doping in [001] KCl slightly increases strength levels and decreases the size dependence. Generally, in terms of size-effect phenomenon, [111] LiF is similar as body-centered-cubic metals, while [001]- and [111] KCl and [001] LiF are comparable with face-centered-cubic metals. The additivity of strengthening mechanisms is critically discussed.

15 min break

MM 13.4 Mon 17:00 BAR 205
Influence of microalloying on the mechanical properties of molybdenum disilicide — •Carolin Puscholt[1], Steffen Neumeier[1], Mathias Göken[1], and Sandra Korte-Kerzel[2] — [1]FAU Erlangen-Nürnberg, Germany — [2]RWTH Aachen, Germany

Molybdenum disilicide (MoSi2) is a very promising candidate material for high temperature structural applications due to its high melting point (2030°C), low density and good oxidation resistance. However, the use of the pure material is limited by its low fracture toughness below 900°C which is associated with the plastic anisotropy and the high critical resolved shear stress on particular slip systems.

Microalloying of MoSi2 clearly enhances the room temperature ductility. For example, Ta, Al and Nb increase the ductility due to the activation of an additional slip system. However, the underlying mechanisms by which ductility is improved remain poorly understood, predominantly due to the difficulties encountered in low temperature experiments along the most brittle crystal orientation [001].

Here, this problem is overcome by using characterization methods at the microscale. A combination of uniaxial testing, where cracking is suppressed and hence the critical resolved shear stresses in specific crystal orientations can be determined individually, and nanoindentation in conjunction with EBSD and TEM was used. Results on pure and microalloyed MoSi2 with Tantalum will be presented, focusing on the influence of microalloying on the critical resolved shear stresses of particular slip systems.

MM 13.5 Mon 17:15 BAR 205
On The Importance Of Twinning Wedges in Nanowhisker Bending — Johannes J. Möller, Wolfram Nöhring, and •Erik Bitzek — Department of Materials Science and Engineering, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)

Single crystalline metallic nanowhiskers have attracted substantial interest due to their special mechanical behavior. Similar to other nanostructured metals, like nano-pillars, thin films and nanocrystalline samples, they show a pronounced "smaller is stronger"-effect. However, not only the strength but also the deformation mechanisms can be size-dependent. Recently, twinning has been observed to be the governing deformation mechanism of <110>-oriented gold nanowhiskers under tension, whereas under compression they deform by nucleation and glide of full dislocations. Here, we address the question how nanowhiskers deform under bending loads. For this purpose we performed atomistic simulations of Au, Cu and Mo nanowhiskers using set-ups modeling three-point bending and the bending of a clamped cantilever beam. Independent on temperature, deformation rate, size and aspect ratio, the occurrence of wedge-shaped twins in the tensile region of the bent whisker was a characteristic feature in all simulations. Whereas the tendency for twinning can be explained by analyzing the generalized stacking fault energy and the resolved shear stresses on the partial dislocations, the particular wedge shape of the twins can be directly rationalized by the strain gradient within the bent whiskers.

MM 13.6 Mon 17:30 BAR 205
Mechanical stability of quasi one-dimensional nanostructures (nanowires) — •Charlotte Ensslen, Oliver Kraft, and Reiner Mönig — Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen, Germany

Nanostructured materials are of interest for both fundamental scientific and applied research which can be ascribed to their outstanding mechanical properties, e.g. Au nanowires can exhibit high strength and ductility. In general, it can be observed that a decrease in the sample dimension results in an increase in strength known as mechanical size effect. However, data considering the mechanical properties of nanostructures with dimensions smaller than 100 nm are still rare and the corresponding deformation mechanisms and the interrelations of the microstructure, e.g. the role of inherent defects, have not been fully understood. In order to develop a profound understanding of the role of defects for the deformation mechanisms of single- and polycrystalline nanowires we make use of a helium ion microscope. It offers the possibility to design and modify nanostructures, altering the surface characteristics or creating nanopores in the nanowire prior to mechanical testing. The stress-strain curves and the deformation mechanisms of pristine and modified Au and Si nanowires are presented as recent examples. Whereas modified Si nanowires show a decreased tensile strength and a brittle failure at the defects, the mechanical behavior of modified Au nanowires seems to be independent of the defects.