MM 2: SYM Micro- and Nanomechanics I

Time: Monday 10:15–12:15 Location: H16

Invited Talk MM 2.1 Mon 10:15 H16

Effect of hydrogen and grain boundaries on dislocation nucleation and multiplication examined with a Ni-AFM — •Horst Vehoff and Afrooz Barnoush — Institut für Werkstoffwissenschaft, Universität des Saarlandes, 66041 Saarbrücken

A nanoindenting AFM with an environment chamber was constructed to study the effect of hydrogen on decohesion and dislocation nucleation and the effect of grain boundaries on dislocation nucleation. Ultra fine grained Ni and Ni single crystals were examined. It could be clearly shown that hydrogen influences the pop in width and length. Testing single grains with grain sizes below one micron at different rates inside a Ni-AFM showed that the rate dependence of UFG Ni is a result of the interaction of the growing dislocation loop with the boundary. The results will be discussed in the talk.

MM 2.2 Mon 10:45 H16

Size effects observed during indentation testing — •Karsten Durst — Institut für Werkstoffwissenschaften 1, Universität Erlangen-Nürnberg, Erlangen

Nanoindentation allows probing the mechanical response of materials from the nanoscale to the macroscale. It is found that strength of crystalline materials is size dependent and the size dependence is influenced by i.e. grain size, dislocation density and solid solution strengthening. Initially, materials deform purely elastically, supporting loads up to their theoretical strength. The nucleation and multiplication of dislocations leads to a discontinuity in the load displacement data, marking the transition from elastic to plastic deformation. After pop-in, a high hardness is observed, which decreases with increasing indentation depth until a constant hardness is found for large indentation depths. The experimental observations can be modeled within the framework of Taylor hardening, considering geometrically necessary dislocations (GND) and statistically stored dislocations (SSD). The statistically stored dislocation density is derived from uniaxial stress-strain data applying the Tabor concept of the representative strain. The GNDs are necessary for providing the lattice rotation underneath the indenter and for forming the residual impression. Their density is calculated for conical and spherical indenters, using the storage volume of GNDs as a fitting factor for describing the experimental observations. Hertzian contact theory is used to describe the initial elastic deformation of the material, whereas the critical pop-in load is derived from the theoretical strength of the material.

MM 2.3 Mon 11:15 H16

Micro-Compression Testing of Metals — •Cynthia Volkert — Institut für Materialforschung II, Forschungszentrum Karlsruhe, 76021 Karsruhe, Germany

Smaller is stronger, at least for most metals. When either the sample size or grain size of a metal is decreased below one micrometer, the underlying mechanisms for deformation are changed and almost all mechanical properties, strength in particular, are influenced. The opportunity to tailor mechanical properties by changing the material length scale, and to combine this with desired electrical, magnetic or chemical properties, has been a major incentive for the development of nanostructured metals and composites for technological applications.

Recent developments in micro-mechanical testing methods using focused ion beam machining offer unique opportunities to systematically study deformation of small samples. This talk will focus on results from uniaxial compression tests on sub-micron columns of single crystal Au and nanoporous Au. The experiments confirm that *smaller is stronger*, with sub-micron specimen strengths close to theoretical values. In addition to high strength, the nanoporous Au exhibits macroscopic brittle behavior. Results from fracture testing of micron-sized, notched cantilever beams fabricated in nanoporous Au with a focused ion beam reveal that the material has mechanical properties similar to those of a porous ceramic. These trends will be discussed in terms of the inhibition of defect creation and motion in small volumes. Finally, an outlook of what can be achieved by tailoring length scales in various materials will be presented.

MM 2.4 Mon 11:45 H16

Of Pillars and Bridges, Mechanical Testing of Micro and Nano Structures — •Holger Pfaff[1] and Erik Herbert[2] — [1]Surface, Rheinstrasse 7, 41836 Hückelhoven — [2]MTS Nano Instruments, 1001 Larson Drive, Oak Ridge, TN 37830

Successive miniaturization in technology and science has created a strong need for testing materials and structures in the nano scale. As microscopic structures and thin coatings often behave significantly different from bulk materials, a detailed understanding of the underlying mechanisms is crucial for the fabrication of reliable micro products and for further technological and scientific progress.

Surface detection, accurate displacement and load control, as well as precise lateral positioning are critical issues for investigating the mechanical behavior of micro and nano structures. Hence insensitive surface detection would damage the specimen before the test. By measuring the dynamic contact stiffness, the sensitivity of surface detection is increased significantly.

The requirements of locating and addressing submicron scale features on a surface are met by scanning the specimen with the very probe used for the mechanical testing.

Several methods, combining the mentioned techniques, were developed for automatically testing fragile structures in a complex sequence of testing steps. The methods were used for investigating the mechanics of MEMS devices and fibrillar polymer structures.

MM 2.5 Mon 12:00 H16

Investigation of the size dependent plasticity of micro-pillars by discrete dislocation dynamics — •Daniel Weygand[1], Jochen Senger[1], Oliver Kraft[1,2], and Peter Gumbsch[1,3] — [1]IZBS, University of Karlsruhe, Karlsruhe, Germany — [2]IMF II, Forschungszentrum Karlsruhe, Germany — [3]IWM, Fraunhofer Institut, Freiburg, Germany

The understanding of the plasticity of sub-micrometer sized metallic components is of relevance due to the increasing use of small scale devices. The reliability of such structures is of importance for technical applications. As indicated by many experimental studies on sub-micron sized samples, crystalline materials in general display pronounced size effects regarding their mechanical behavior. In order to investigate the microstructural origin of the size effect the plastic flow of uniformly loaded pillars is modelled using a three dimensional discrete dislocation dynamics tool. Starting from Frank-Read sources of given length and random orientation, the simulated flow stress at 0.2% plastic strain shows a size effect, quite similar to experimental findings for larger strains. Furthermore the scattering in the simulated stress-strain curves decreases with increasing sample size, which reflects that plasticity of small scale samples is very sensitive to the underlying dislocation microstructure. Statistical properties of the resulting dislocation microstructure are discussed as well.