MM 4: Mechanical Properties II

Time: Monday 11:45–13:00 Location: IFW B

MM 4.1 Mon 11:45 IFW B

Crystal plasticity finite element study on small scale plasticity of micropillars — •D. Ma[1], D. Raabe[1], F. Roters[1], R. Maass[2], and H. Van Swygenhoven[2] — [1]Max-Planck-Institut für Eisenforschung GmbH, Max-Planck-Strasse 1, 402 37, Düsseldorf, Germany — [2]Paul Scherrer Institute, CH-5232 Villigen, Switzerland

Experimental studies on micro-compression testing on single crystals reveal that these samples are stronger than the respective bulk material. The onset of plasticity is hard to determine from the stress-strain curves, however, it can be associated with changes in in-situ taken Laue patterns. This method allows one to identify the true start of plastic yielding of such single crystals which is referred to as "Laue-yield". By applying this concept, recent experimental work discovered that the trend of smaller is stronger is considerably reduced (*Van Swygenhoven et al., in press*). In these experiments it has been observed that unexpected slip systems non-Schmid planes are activated prior to the geometrically predicted ones on Schmid planes. We use a crystal plasticity finite element method for investigating the details of the slip system activation under different boundary conditions, such as minor orientation and shape deviations of the crystals used, different contact conditions between sample and compression tools, and possible misalignments of the compression tools. In this study, we show how those boundary conditions influence the micro-compression test, the active slip system, and even the measured stresses. The results reveal that under certain small tool misalignments (ca. 2°) the activation of unexpected slip systems with small Schmid factors can be explained.

MM 4.2 Mon 12:00 IFW B

Evolution of Vickers hardness during room temperature grain growth of nanocrystalline Palladium — •Christian Braun[1], Jörg Schmauch[1], Jürgen Markmann[1,2], and Rainer Birringer[1] — [1]Universität des Saarlandes, FR 7.3 Technische Physik, Campus D2.2, 66123 Saarbrücken — [2]Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft, Institut für Nanotechnologie, 76344 Eggenstein-Leopoldshafen

Indentation methods provide a fast and reliable mean to characterize plastic deformation and hardness. Based on hardness values the Tabor relation allows one also to estimate yield strength. For polycrystalline coarse grained materials the Hall-Petch equation describes the relation between materials strength and its grain size. There are many studies, theory and experiment, around that corroborate that in nanometer-sized polycrystalline materials Hall-Petch behaviour prevails. Uncovering the physics of plastic flow in bulk nanocrystalline materials requires detailed studies of the scaling behaviour of yield stress versus grain size. With the recent discovery of room temperature grain growth in nc Palladium, it becomes feasible to investigate the scaling behaviour starting out from grain sizes below 10 nm up to the micrometer scale. In this study, we report about the evolution of Vickers hardness and strain rate sensitivity of nc Palladium during room temperature grain growth.

MM 4.3 Mon 12:15 IFW B

***In-situ* SEM micropillar compression of Zr-based bulk metallic glasses with different free volume content** — •Alban Dubach[1,2], Johann Michler[2], Upadrasta Ramamurty[3], and Jörg F. Löffler[1] — [1]Laboratory of Metal Physics and Technology, ETH Zurich, Wolfgang-Pauli-Str. 10, 8093 Zürich, Switzerland — [2]EMPA Materials Science and Technology, Feuerwerkerstrasse 39, 3602 Thun, Switzerland — [3]Department of Materials Engineering, Indian Institute of Science, Bangalore-560012, India

In contrast to crystalline metals, which exhibit dislocation-mediated deformation, bulk metallic glasses (BMGs) usually exhibit high yield strength and a plastic deformation which is triggered by free volume. Under an applied stress, clusters of atoms with high free volume (i.e. "shear transformation zones", STZs) accommodate shear strains locally. At room temperature these STZs coalesce along planes of maximum shear stress, leading to a deformation which is spatially and temporally restricted within narrow shear bands and therefore difficult to assess experimentally. In this study the uniaxial compression of micrometer-sized pillars has been investigated *in-situ* inside a scanning electron microscope. The micropillars, having diameters between 0.3 and 3 μm, were fabricated by focused-ion beam milling of a Zr-based BMG in three different conditions: as-cast, structurally-relaxed and shot-peened. Effects of different free volume content, sample size and applied strain rate have been analyzed. Shear band formation and stable propagation is observed to be the plastic deformation mode, with no difference in yield strength according to either size or condition.

MM 4.4 Mon 12:30 IFW B

Discrete dislocation dynamics study of the influence of boundary conditions in micro-samples — •Jochen Senger[1], Daniel Weygand[1], Oliver Kraft[1,2], and Peter Gumbsch[1,3] — [1]IZBS, Universität Karlsruhe (TH) — [2]IMF II, Forschungszentrum Karlsruhe — [3]IWM, Fraunhofer Institut für Werkstoffmechanik, Freiburg

Ongoing miniaturization in technical devices demands a better understanding of mechanical properties of metallic structures in micro-meter range. Compression and tension tests on single crystalline samples revealed a size-dependency of flow stress. With decreasing pillar diameter an increasing average flow stress and an increasing standard deviation. Experimental uncertainties in the control of the deformation, like misalignment between sample and loading device can occur, leading to more complex stress states than desired, e.g. superimposed torsion or bending moments. Three dimensional discrete dislocation dynamics simulations are performed to explore the effect of superimposed torsion moments on tensile experiments. Samples with variable diameters and aspect ratio are also loaded with uniaxial tensile stresses and different boundary conditions, different allowed displacements of the top surface of the micro pillars. Identical initial dislocation structure for different loading conditions shows clearly the impact of the boundary conditions on the observed plastic behavior and internal dislocation micro structure. Source activation and active glide planes are influenced by boundary conditions as torsion moments activate other sources than tensile stresses.

MM 4.5 Mon 12:45 IFW B

Research into the parallel determination of Young's modulus E and Poisson's ratio ν via normal and lateral nanoindentation experiments — •Andre Clausner and Frank Richter — TU-Chemnitz, Institut für Physik, Germany

In the case of a lot of materials used in various technical applications the assumption of isotropic behaviour can be made. For these materials the most important mechanical properties needed, for example for an FE-simulation of specific geometries, are the Young's modulus E and the Poisson's ratio ν. These material constants have to be determined experimentally on a existing structure which is most comparable with the later application. Therefore, as well as for small structures and thin film applications, a very small impact size and depth of the experiment on the structure is favoured. For this purposes instrumented nanoindentation experiments with different indenter shapes are used. In the case of the Young's modulus we can obtain the value of E via the well know Oliver and Pharr method for instrumented indentation experiments in normal direction. To obtain a second material constant, a second experiment is needed, independent from the normal one. A lateral displacement of a normal loaded spherical indenter in the range of sticking friction is used. For this mechanical loading situation there are some simplified analytical solutions in the elastic theory. Via comparison of the measured lateral data and the analytical model predictions the Poisson's ratio can be determined. The talk wants to show the possibilities and the recently obtained results of this proceeding to determine ν.