MM 1: HV Lilleodden

Time: Monday 9:30–10:00 Location: H16

Invited Talk MM 1.1 Mon 9:30 H16

Size Effects in Metal Plasticity — •Erica Lilleodden — GKSS Forschungszentrum, Institut für Werkstoffforschung, Max-Planck-Straße 1, D-21502 Geesthacht

Size effects in plasticity have received much attention in recent years, due to increased resolution in experimental capabilities, and the development of materials at small geometric and microstructural length scales. Nanoindentation, wafer curvature and, more recently, micro-compression tests have all shown such size effects. To date, a multitude of theories for the observed behaviors exist based on the evolution of dislocation distributions, and are often conflicting. This talk will provide an overview of recent experimental studies of size effects in materials, particularly those which combine nanoindentation-based techniques with microstructural characterizations (e.g., transmission electron microscopy, orientation imaging microscopy and x-ray microdiffraction). The overwhelming observation of "smaller is stronger" will be discussed in terms of the volume of deformation, the presence of strain gradients, and the evolution of dislocation structure.

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.

MM 3: Liquid and amorphous materials I

Time: Monday 10:15–11:15 Location: H4

MM 3.1 Mon 10:15 H4

Neutron scattering investigatons on melts of Al-Ni and Zr-Ni alloys — •Dirk Holland-Moritz[1], Andreas Meyer[1], Helena Hartmann[1], Sebastian Stüber[2], and Fan Yang[2] — [1]Institut für Materialphysik im Weltraum, DLR-Köln, Germany — [2]Physik Department E13, TU-München, Germany

This work presents investigations on the short-range order of stable and deeply undercooled melts of binary Al-Ni and Zr-Ni alloys. The liquids were containerlessly processed and undercooled by use of the electromagnetic levitation technique which was combined with the technique of elastic neutron scattering at the diffractometer D20 of the Institut Laue-Langevin (ILL) in order to determine the static structure factor. The scattering contrast was varied by isotopic substitution. By means of this partial structure factors were determined. For the case of $Zr_{64}Ni_{36}$ alloys strong indications for the existence of a chemical order are found.

This work was supported by DFG under contracts No. Ho1942/6-3 and Me1958/2-3.

MM 3.2 Mon 10:30 H4

Interplay of Structure and Dynamics in liquid and undercooled AlNi melts — •Sebastian Stüber[1], Andreas Meyer[2], Dirk Holland-Moritz[2], Helena Hartmann[2], and Tobias Unruh[3] — [1]Physik Department E13, TU München — [2]Institut für Materialphysik im Weltraum, DLR Köln — [3]Forschungsneutronenquelle Heinz Maier-Leibnitz (FRM II), Garching

AlNi melts show a chemical short-range order (CSRO), dependent on the Ni concentration [1]. For lower temperatures, this CSRO becomes more pronounced. To increase the available temperature range further, we used electromagnetic levitation. This container-free method enabled significant undercooling (up to 266 K) for several hours.

The AlNi melts were studied using inelastic neutron scattering. The quasielastic line was fitted by a scaled Lorentzian, whose HWHM corresponds to the inverse of the mean relaxation time τ_q. With this a q-dependent diffusivity $D(q) = 1/(\tau q^2)$ can be defined, for the hydrodynamic limit $q \to 0$ one gets the (Ni) self-diffusion coefficient D as a function of temperature.

The q-dependent diffusivity $D(q)$ provides information about the correlation between the diffusive motion and the CSRO, visible at intermediate q values. Using $D(q)$ we will discuss the process of diffusive atomic motion in AlNi melts, under the pronounced influence of CSRO.

[1] S.K. Das *et al.*, Appl. Phys. Lett. **86**, 011918 (2005).

MM 3.3 Mon 10:45 H4

Struktur und Dynamik von flüssigem Titan: Computersimulation, Modenkopplungstheorie und Experiment — •Jürgen Horbach — Institut für Physik, Universität Mainz, Staudinger Weg, D-55099 Mainz

Mittels Molekulardynamik-Computersimulationen wird die Struktur und Dynamik von Titan in der Nähe des Schmelzpunktes, d.h. bei der Temperatur $T = 1970\,\mathrm{K}$, untersucht. Dabei verwenden wir als Modell ein Potential vom "embedded atom"-Typ [1]. Der statische Strukturfaktor $S(q)$ aus der Simulation ist in sehr guter Übereinstimmung mit experimentellen Daten [2,3]. Wir verwenden den simulierten Strukturfaktor $S(q)$ als Input für eine Rechnung im Rahmen einer Modenkopplungstheorie, aus der die von der Frequenz ω abhängigen, dynamischen Strukturfaktoren $S(q,\omega)$ vorhergesagt werden. Wir zeigen, dass die dynamischen Strukturfaktoren aus der Theorie in semiquantitativer Übereinstimmung mit der Simulation sind.

[1] R. Zope, Y. Mishin, Phys. Rev. B **68**, 024102 (2003).

[2] G. W. Lee, A. K. Gangopadhyay, K. F. Kelton, R. W. Hyers, T. J. Rathz, J. R. Rogers, D. S. Robinson, Phys. Rev. Lett. **93**, 037802 (2004).

[3] D. Holland-Moritz, O. Heinen, R. Bellissent, Th. Schenk, Mat. Sc. Eng. A, in press (2006).

MM 3.4 Mon 11:00 H4

Thermophysical properties of Si, Ge and Si-Ge melts under microgravity — •Suresh Mavila Chathoth, Bernd Damaschke, and Konrad Samwer — I. Physikalisches Institut, Universitaet Göttingen, 37077 Göttingen, Germany

The liquid Si and Ge are highly reactive materials. Especially the liquid Si is known to reactive with almost all materials. To have an accurate values of thermophysical properties of these melts container less processing is required. The container less processing can be realized by electromagnetic or electrostatic levitation. These ground based levitation techniques have demerits of gravity driven convection and accuracy of the data depend on convection currents. The thermophysical properties of Si, Ge and Si-Ge alloy melts have been investigated in the TEMPUS facility on board of Zero-G plane during the parabolic flights. Unlike metallic alloys [1] which can melt in a magnetic field, Si, Ge and Si-Ge are semiconductors in their sold state a laser pre-heating was necessary to melt these samples. The melted droplets were video taped and from the images the thermal expansion and surface tension of the samples were evaluated. Absence of gravity driven convection a separation of the influence of gravity induced convection become possible by comparing the data with ground based experiments. The work was supported by BMBF/DLR under grant No. 50WM0541.

[1] B. Damaschke, D. Oelgeschlaeger, J. Ehrich, E. Dietzsch, and K. Samwer, Rev. Sci. Instrum. **69**, 2110 (1998).

MM 4: Liquid and amorphous materials II

Time: Monday 11:45–13:00 Location: H4

MM 4.1 Mon 11:45 H4

Devitrification, consolidation and mechanical properties of ball milled Al-Y-Ni-Co glassy ribbons — •Kumar Babu Surreddi[1], Sascha Sager[2], Mira Sakaliyska[1], Sergio Scudino[1], and Jürgen Eckert[1] — [1]IFW Dresden, Institut für Komplexe Materialien, Postfach 27 01 16, D-01171 Dresden, Germany — [2]FG Physikalische Metallkunde, FB 11 Material- und Geowissenschaften, Technische Universität Darmstadt, Petersenstraße 23, D-64287 Darmstadt, Germany

In this work, glassy powders have been obtained by ball milling of Al-Y-Ni-Co glassy ribbons. The pulverization of the melt-spun ribbons was achieved by using proper milling conditions, i.e. interval-milling at low intensity, corresponding to a rather low kinetic energy, and performed at cryogenic temperature in order to retain their glassy structure and to avoid sticking of the material to the milling tools due to the high ductility of the ribbons. Due to the controlled milling conditions, the ball milled ribbons display a strikingly similar structure and crystallization behavior compared to the parent as-spun sample. The crystallization behavior and the temperature dependence of the viscosity of the as-spun and the milled ribbons were studied in order to select the proper consolidation parameters. Fully glassy and glassy-Al composite powders were then consolidated through uniaxial hot pressing and hot extrusion and finally the mechanical properties of the bulk specimens were evaluated via room temperature compression tests.