# MM 17: Mechanical Properties III

Time: Tuesday 10:15–11:45 Location: IFW D

MM 17.1 Tue 10:15 IFW D

**Change of deformation mechanism in nanocrystalline nickel at very low temperatures** — •Lutz Hollang, Suhash Ranjan Dey, and Werner Skrotzki — Institut für Strukturphysik, Technische Universität Dresden, 01062 Dresden

Pure nanocrystalline nickel was produced by pulsed electro-deposition without additives for grain refinement. The average grain size of the material is d(EBSD) = 150 nm and d(XRD) = 25 nm if determined by electron backscatter diffraction (EBSD) and X-ray diffraction (XRD), respectively. Tensile tests with constant deformation rate were performed at temperatures between 4 K and 320 K. The stress-strain curves are parabolic with the ultimate stress strongly decreasing with increasing temperature. Stress relaxation experiments reveal that dislocation interaction governs the plastic behaviour of the material at low temperatures. However, if the stress reaches the threshold of 2400 MPa, as it is the case between 4 K and 9 K, the deformation mode suddenly changes towards 'catastrophic' shear. The shear events are characterized by substantial stress drops accompanied by acoustic emission. The nature of the shear events will be discussed on the basis of microstructural investigations performed by electron microscopy.

MM 17.2 Tue 10:30 IFW D

**Deformation behavior of nanocrystalline Pd and Pd-10 at. % Au alloy investigated by mini-compression test** — •Lilia Kurmanaeva[1], Yulia Ivanisenko[1], Jürgen Markmann[2], and Hans-Jörg Fecht[3] — [1]Institute für Nanotechnology (INT), Forschungszentrum Karlsruhe, Karlsruhe, Germany — [2]Universität des Saarlandes, FR7.3 Technische Physik, Saarbrücken, Germany — [3]Institute of Micro and Nanomaterials, University of Ulm, Ulm, Germany

Investigations of mechanical properties of nanocrystalline (nc) materials are still in interest of materials science. The method of inert gas condensation (igc) allows to produce nc samples having uniform equiaxed microstructure with the mean grain size of 5-10 nm, and of very high purity. Here, we present results of the microstructure and mechanical properties investigation of nc as-igc Pd and Pd-10 at. % Au alloy. The specimens' microstructure was analysed by means of XRD and TEM, and mechanical properties were studied in compression tests using a dedicated testing stage for miniature specimens. Conventional compression tests showed that samples demonstrate high stress (the yield strength were 0.95 GPa and 1.12 GPa for as-igc Pd and Pd-10%Au, respectively) with significant ductility. Strain-rate jump compression tests revealed high strain rate sensitivity in nc Pd and Pd-Au alloy, strain rate sensitivity parameter (m) was 0.067 and 0.034, and activation volume was 4 and 7 burgers vectors for Pd and for Pd-10%Au, respectively. The obtained results of mechanical properties and microstructure are discussed.

MM 17.3 Tue 10:45 IFW D

**Metals Plasticity: Interrelating Different Levels of Description** — •Markus Hütter[1], Miroslav Grmela[2], and Hans Christian Öttinger[1] — [1]ETH Zürich, Department of Materials, Polymer Physics, CH-8093 Zürich, Switzerland — [2]Ecole Polytechnique de Montreal, Montreal, Quebec, Canada H3C 3A7

The behaviour of crystalline metals under applied mechanical load can be described on different levels of description, namely, (i) the microscopic constituent particles, (ii) the dislocations on mesoscopic scales, and (iii) the macroscopic continuum. The most one benefits from these separate pieces of information once they are related to each other. In this contribution, we offer some insight in how to achieve these relations. First, coarse-graining is used to constrain the constitutive relation for plastic flow on the macroscopic scale based on the microscopic dynamics of the constituent particles. However, as this approach does not adequately represent the origin of plastic deformation, in a second step, the mesoscopic level of dislocations and their dynamics are taken into account in due detail by the following steps. A kinetic toy model is introduced that can be interpreted as modelling the dynamics of a single dislocation. In contrast to most approaches in literature, our kinetic toy model describes not only the irreversible (plastic) but also the reversible dynamics of the dislocations. Subsequently, we discuss how the effect of multiple dislocations and the interactions between them, that lead to strain hardening, can be taken into account. Finally, we comment on how our approaches of modelling dislocations can be related to the macroscopic description of elasto-viscoplasticity.

MM 17.4 Tue 11:00 IFW D

**Multi-scale phase composites in high strength hypoeutectic FeCo-based alloys with large plasticity** — •Ran Li[1], Gang Liu[1], Mihai Stoica[1], and Jürgen Eckert[1,2] — [1]IFW Dresden, Institut für Komplexe Materialien, P.O. Box 27 01 16, D-01171 Dresden, Germany — [2]TU Dresden, Institute of Materials Science, D-01062 Dresden, Germany

Near-equiatomic FeCo alloy is a famous conventional magnetic material ideally suitable for the applications of high magnetic flux density such as electromagnetic system in aircraft industry. However, notorious brittleness of this alloy obstructs its industrial application. By controlling rapid-solidification condition and designing multicomponent alloying, we produced a family of FeCo-based multi-scale phase composites with good mechanical properties. Comparing with equiatomic FeCo alloy, the designed alloys exhibit 3-7 times improvement of yield stress and plastic deformation of 3-18 % during compressive test. The structural analysis indicated that fined grains induced by the control of liquid solidification and morphologic construction of multi-scale phase composite endow these alloys with good mechanical properties. Although the alloying slightly decreased the saturation magnetization of resulting alloys, it still remains around 2 T as high as the result of pure iron. Furthermore, the strength and deformation behavior are quantitatively related to the volume fraction and size of the multi-scale phases via modeling, which can give a useful guideline to design this kind of composite alloys.

MM 17.5 Tue 11:15 IFW D

**Measurement of mechanical properties for materials of interest in microelectronics using indentation methods: porous low-k dielectric and soft metallic thin films as examples** — •Matthias Herrmann and Frank Richter — Institute of Physics, Chemnitz Univ. of Technol., 09107 Chemnitz, Germany

For the characterisation of the mechanical behaviour of bulk and thin film materials, physical quantities like Young's modulus $E$, Poisson's ratio $\nu$, or yield strength $Y$ are most appropriate and can principally be used for modelling and/or predicting materials under load. In contrast to these quantities, the often used hardness depends on the applied measuring method and is less suited for modelling. However, the determination of these properties is difficult because it is distorted by the influence of the substrate. Additionally, problems can arise when the investigated materials start to plastically deform already at very low loads.

In this contribution, indentation methods have been applied to two such special cases: mesoporous $SiO_2$ as well as MSQ-based films with porosities of 0.30-0.57 and copper films. To determine their $Y$ and $E$, e.g. elastic-plastic indentations using spheres and sharp tips have been performed, which were analysed by Pharr's concept of the effective indenter. We found $Y$ values between 75-150 MPa for $SiO_2$ and MSQ films which decreased with increasing porosity. They indicate a tendency to easily plastically deform. The $E$ of these films were between 1-4 GPa. General difficulties with the measurement of plastically deforming materials are exemplarily discussed for the copper films.

MM 17.6 Tue 11:30 IFW D

**Elasticity of Porous Materials with Multicontinuous Microstructure** — •Sebastian C. Kapfer[1], Christoph H. Arns[2,3], Klaus R. Mecke[1], Stephen T. Hyde[3], and Gerd E. Schröder-Turk[1] — [1]Friedrich-Alexander-Universität, Erlangen, Germany — [2]University of New South Wales, Sydney, Australia — [3]Australian National University, Canberra, Australia

Porous microstructure models reminiscent of existing biomaterials are derived from minimal surfaces of cubic symmetry. The microstructures are composed of a linear elastic solid and a void phase, both of which are continuous. The effective elastic properties of these structures are calculated using a voxel-based finite element method. It is found that effective bulk and shear moduli of the microstructures can be related to the porosity by a power law with fractional exponent. The exponent is found to depend on the topology of the material. Results of similar functional form have previously been reported by A. P. Roberts and

E. J. Garboczi for random porous material models (cf. Proc R Soc Lond A (2002) 458 pp. 1033–1054).