MM 5: Nanomaterials I: Mechanics

Time: Monday 10:15–11:30 Location: H53

MM 5.1 Mon 10:15 H53

Chemical crosslinking inside an organic/inorganic nanosupercrystal — •Axel Dreyer[1], Artur Feld[2], Andreas Kornowski[2], Ezgi D. Yilmaz[1], Heshmat Noei[3], Andreas Meyer[2], Andreas Stierle[3], Horst Weller[2], and Gerold A. Schneider[1] — [1]Technische Universität Hamburg-Harburg, Institut für Keramische Hochleistungswerkstoffe — [2]Universität Hamburg, Institut für Physikalische Chemie — [3]DESY, NanoLab

Natural hard tissues like nacre are characterized by outstanding mechanical properties. The key to their behavior is the combination of hard inorganic and soft organic constituents on the nanoscale. Our approach is to synthesize a bio-inspired material by self-organization of organic-coated Fe_3O_4 nanoparticles into a well-ordered superstructure. The inorganic particles are separated by a layer of surfactants that is about one nanometer thick. Therefore, the organic molecules play a prominent role by providing cohesion in the material via strong coordinative bonding of functional groups to the particles surface as well as weak van der Waals bonding between adjacent molecules. To improve the mechanical properties, we substitute the weak van der Waals interaction by strong covalent bonds through thermally induced crosslinking of unsaturated surfactants performed in the solid composite, which yields values of up to 3.4 GPa, 60 GPa, and 630 MPa for microscale hardness, modulus, and strength, respectively. We will discuss which chemical processes take place in the organic phase. This knowledge enables a tailor-made synthesis of surfactants for optimization of the mechanical properties.

MM 5.2 Mon 10:30 H53

Mechanical properties of amorphous/crystalline multilayer structures in the Fe-P system — •Timo Müller, Andrea Bachmaier, Manuel Pfeifenberger, Thomas Schöberl, and Reinhard Pippan — Erich Schmid Institute of Materials Science, Austrian Academy of Sciences, Leoben, Austria

Nanolamellar structures of alternating amorphous and crystalline layers are good candidates for combining high strength and ductility due to the combination of the different deformation mechanisms in the two components. In the present study, such structures were prepared in the Fe-P system using electrodeposition. The width of the individual layers was varied from about 250 nm down to a few nanometers. Microhardness testing revealed a Hall-Petch behavior with respect to the layer width for layers larger than 15 nm, whereas an approximately constant hardness of 6.7 GPa was observed for thinner layers. Nanoindentation and micromechanical testing was used to get further insights into the mechanical behavior of these materials.

MM 5.3 Mon 10:45 H53

Modeling the Mechanics of Metallic Nanolattices — •Alexander Stukowski[1] and Bernhard Eidel[2] — [1]Technische Universität Darmstadt — [2]Universität Siegen

Ultralight metallic lattices are a special form of cellular material with structural features on the micron and nanometer scales. Very recent advances in fabrication techniques and several promising applications have sparked great interest in the optimization of such materials and in developing an understanding of the underlying physical mechanisms that determine their stiffness and strength.

Continuum mechanics descriptions alone, however, are unable to describe important small-scale materials phenomena, most notably the transition from nanoelasticity to nanoplasticity. In this contribution we present results from fully atomistic simulations of metallic nanolattices, which have been performed for the first time to investigate the competing elastic and inelastic processes that determine the performance of these structural materials. Our large-scale simulations indicate that the prevailing plastic deformation mechanisms in thin-walled, Ni-based nanolattices is twinning while the deformation of full-profile lattice structures beyond the elastic regime is carried by dislocations. The extent of the elastic regime is controlled by the shape and architecture of the structures, but also local features such as notches and fillets that can induce or prevent stress concentrations.

MM 5.4 Mon 11:00 H53

Exploiting Electrocapillary Coupling at Metal Surfaces for Active Strain Sensing with Nanoporous Gold — •Charlotte Stenner[1], Lihua Shao[2], Nadiia Mameka[3], and Jörg Weissmüller[1,3] — [1]Institute of Materials Physics and Technology, Hamburg University of Technology, Germany — [2]Beijing Institute of Nanoenergy and Nanoscience, Chinese Academy of Sciences, China — [3]Institute of Materials Research, Materials Mechanics, Helmholtz-Zentrum Geesthacht, Germany

We investigate nanoporous gold (NPG) imbibed with electrolyte as a hybrid material, in which the metal acts as an electrode. Due to the large surface-to-volume ratio of NPG the properties of the hybrid material are particularly determined by the metal-electrolyte interface.

An applied strain on NPG is expected to cause measurable potential variations, since the impact of mechanical deformation of a planar gold electrode on its potential is large [1]. Our experiments demonstrate that NPG can be used for sensing elastic strain via measuring either current or potential response of the electrode. The electrochemical signals generated by cyclic straining are robust and sensitive, their magnitude increases with increasing strain amplitude. To connect strain-sensing and actuation measurements on the NPG-based hybrid material, we introduce a theoretical strain-sensing actuation relation that leads to excellent agreement with the experimental results. Thus, one can make predictions about sensing properties using effective actuation parameters and vice versa.

[1] M. Smetanin, Q. Deng and J. Weissmüller, PCCP 13 (2011) 17313

15 min. coffee break