# MM 20: Topical Session: Nanomechanics of nanostructured materials and systems IV - Tribology/Composites

Time: Tuesday 10:15–12:00 Location: IFW A

**Topical Talk** MM 20.1 Tue 10:15 IFW A

**Nanometer-scale plasticity of (amorphous) metallic surfaces** — •Arnaud Caron, Johannes Maurer, and Roland Bennewitz — INM Leibniz-Institute for New Materials, Camnpus D2.2, 66123 Saarbrücken, Germany

The sub-micrometer-scale plastic deformation of Pt(111) and Pt57.5Cu14.7Ni5.3P22.5 metallic glass is discrete in nature and can be rationalized by the respective mechanisms for plastic deformation: burst-like activation and sliding of dislocation for crystalline metals and localized shear banding for metallic glasses. The discrete character of plastic deformation is conserved at the nm-scale for Pt(111). In contrast we observe a homogeneous flow in the case of Pt57.5Cu14.7Ni5.3P22.5 metallic glass at the nm-scale. On the one hand, the nm-scale plastic deformation of Pt(111) is mediated by the homogeneous nucleation and gliding of single dislocations. On the other hand, the nm-scale plastic deformation of Pt57.5Cu14.7Ni5.3P22.5 metallic glass involves the collaborative flow of structural unit, such as in the flow of viscous liquids and can be referred to as a structural collapse. Likewise, the nm-scale wear behaviour of Pt(111) occurs by dislocation-mediated homogeneous plastic deformation. In contrast, the wear of Pt57.5Cu14.7Ni5.3P22.5 metallic glass occurs through localized plastic deformation in shear bands that merge together in a single shear zone above a critical load and corresponds to the shear softening of metallic glasses.

MM 20.2 Tue 10:45 IFW A

**Grain size and orientation evolution of high-purity copper under reciprocating tribological loading** — •Christian Greiner and Zhilong Liu — IAM-ZBS, Karlsruhe Institute of Technology, Karlsruhe, Germany

One of the key questions in tribology is to correlate a material's microstructure with its friction and wear properties. However, there is still a significant lack of knowledge about the mechanisms for the evolution of the microstructure under a tribological load.

A reciprocating motion and high-purity copper in contact with a sapphire sphere was investigated. With an annealed initial microstructure, the energy dissipated during the sliding motion was varied by increasing the sliding distance up to several meters. A dual-beam microscopy system (FIB and SEM) was used to investigate the resulting grain size and to perform EBSD and (S)TEM measurements to follow the evolution of the microstructure in the wear track thoroughly. Results for the microstructure evolution, e.g. grain size and preferred orientation, with the sliding distance will be presented.

A long term goal of this study is to develop a model description for the microstructural changes in view of energy and mechanics in order to understand these changes and their influence on the tribological properties. In the future, this might allow for tailored microstructures combining low friction forces and very small wear rates.

MM 20.3 Tue 11:00 IFW A

**Nanoporous gold - polymer composites with strength and conductivity** — •Ke Wang[1] and Jörg Weissmüller[1,2] — [1]Institut für Werkstoffphysik und Werkstofftechnologie, Technische Universität Hamburg-Harburg, Hamburg, Germany — [2]Institut für Werkstoffforschung, Werkstoffmechanik, Helmholtz-Zentrum Geesthacht, Geesthacht, Germany

Nanoporous metal synthesis via dealloying provides mm- or cm-sized monolithic samples consisting of a homogeneous network structure of nanoscale "ligaments" with uniform size that can be controlled down to below 10 nm. The strength of the ligaments increases with decreasing size, attaining the theoretical strength at ligament diameters in the lower nanometer region. Here, we explore a novel materials design strategy that combines this high-strength and uniform metallic network structure with an interpenetrating polymer phase to obtain a strong, lightweight composite material. The porous metal was vacuum-impregnated with epoxy resin and tested for microhardness, macroscopic tensile and compressive stress-strain behavior. The results demonstrate that impregnation with a polymer is an efficient way of reducing the density change during plastic flow under uniaxial load. The composite is ductile in tension and compression, its strength considerably exceeds that of each of the constituent phases, and its electric conductivity reaches 1% of that of high-purity massive copper. The finding validates a novel materials design strategy that exploits the trend of "smaller is stronger" in metal nanostructures by incorporating them as reinforcement into a bulk composite material.

MM 20.4 Tue 11:15 IFW A

**Micromechanical characterization of nanoporous gold/epoxy composites** — •Kaixiong Hu[1], Ke Wang[2], Daniel Kupka[1], Markus Ziehmer[1], and Erica Lilleodden[1] — [1]Institute of Materials Research, Materials Mechanics, Helmholtz-Zentrum Geesthacht — [2]Institute of Materials Physics and Technology, Hamburg University of Technology

Nanoporous gold displays tunable mechanical behavior through the variation of internal length-scales, but it is severely limited by its lack of ductility in tension. By infiltrating the porous structure with epoxy, a composite material with tensile ductility and enhanced flow stress is achieved. Importantly, the infiltration of epoxy offers an advantage for 3D tomographic analysis by allowing "clean" cross sectioning with a focused ion beam. The resultant 3D reconstructions can be used to quantify characteristic structural parameters, and as direct input for finite element simulations of deformation. This, in turn, allows an improved description of the structure-property relations controlling this unique material. In the presented work, we have carried out a study of the micromechanical investigation of the nanoporous gold-epoxy composite using nanoindentation-based testing methods and finite element simulations, along with 3D tomographic characterization of the undeformed and deformed material. Results reveal how the 3D microstructure of the composite influences its mechanical behavior, and are discussed in terms of size-dependent plasticity and classical scaling laws for porous materials.

**Topical Talk** MM 20.5 Tue 11:30 IFW A

**Linking experiments and simulations to understand third body formation of tribologically stressed surfaces** — •Martin Dienwiebel[1,2], Pantcho Stoyanov[1,2], Pedro A. Romero[1,2], Rolf Merz[3], Priska Stemmer[4], and Michael Moseler[2,5] — [1]Karlsruhe Institute of Technology, MicroTribology Center, IAM-ZBS, Karlsruhe, Germany — [2]Fraunhofer IWM, Freiburg, Germany — [3]IFOS GmbH, Kaiserslautern, Germany — [4]University Duisburg-Essen, Duisburg, Germany — [5]University of Freiburg, Freiburg, Germany

In the present work we aim to link tribometry with atomistic simulations in order to improve our understanding of nanoscale interfacial processes of a tungsten-carbon-hydrogen tribo couple. Sliding induces severe changes of the material with respect to topography, composition and microstructure ( "third body", [1]). Experiments were performed using a novel experimental platform for the on-line correlation of friction, wear and topography under lubricated sliding [1]. Then, in order to elucidate the atomistic level processes which contribute to the observed microstructural evolution in the experiments, classical molecular dynamics are performed employing a bond order potential for the Tungsten-Carbon-Hydrogen system. The combined experimental and simulation data allowed a look at the third body formation of metals (tungsten), ceramics (WC) [3,4] and diamond-like carbon coatings [5].

[1] M. Godet, Wear, 100 (1984) 437-452. [2] S. Korres, M. Dienwiebel, *Rev. Sci. Instrum.*, **81** (2010) 063904. [3] P. Stoyanov et al., *Tribol. Lett.*, **50** (2013) 67-80. [4] P. Stoyanov et al., *ACS Appl. Mat. Int.*, **5** (2013) 6123-6135. [5] P. Stoyanov et al., *Acta mater.*, accepted (2013)