MM 8: Interface Controlled Properties, Nanomaterials and Microstructure Design II

Time: Monday 11:45–13:00 Location: C 230

MM 8.1 Mon 11:45 C 230

Topology-dependent scaling behavior of stiffness and strength of hierarchical nanoporous metals — •Lukas Riedel[1], Jürgen Markmann[1,2], and Shan Shi[3,1] — [1]Institute of Materials Mechanics, Helmholtz-Zentrum Hereon, Geesthacht, Germany — [2]Institute of Materials Physics and Technology, Hamburg University of Technology, Hamburg, Germany — [3]Research Group of Integrated Metallic Nanomaterials Systems, Hamburg University of Technology, Hamburg, Germany

Structural hierarchy in nanoporous metals allows optimized functional and mechanical properties in lightweight materials. In this work, hierarchical nanoporous gold with two distinct length scales is synthesized via a dealloying-coarsening-dealloying method. This method enables tuning the structure of the lower and upper hierarchy level independently. The structural parameters including ligament diameter, ligament distance, solid fraction, and topological connectivity are characterized by combining focused ion beam tomography with small- and ultra-small-angle X-ray scattering. The mechanical studies indicate that consistent with the connectivity, the effective macroscopic Young's modulus and the normalized strength also highly depend on the ligament size of both the upper and the lower hierarchy level. These experimental findings serve as basis for the development of a topology-dependent scaling law for the stiffness and strength of random hierarchically nested-network nanomaterials.

MM 8.2 Mon 12:00 C 230

In-situ studies on the formation of nanoporous copper during electrochemical dealloying — •Samuel Graf[1], Eva-Maria Steyskal[1], Elisabeth Hengge[2], Tatiana Kormilina[3], and Roland Würschum[1] — [1]Institute of Materials Physics, NAWI Graz, Graz University of Technology, Austria — [2]Insitute of Biotechnology and Biochemical Engineering, NAWI Graz, Graz University of Technology, Austria — [3]Austrian Centre of Electron Microscopy and Nanoanalysis, Steyrergasse 17, 8010 Graz, Austria

Nanoporous metals formed by dealloying, a selective etching process which removes the less noble component(s) from an alloy, are versatile systems due to their self-similar, free-standing, conductive structure with very high surface-to-volume ratio. The here presented bulk nanoporous copper (np-Cu), produced from Mn-Cu [1] and Al-Cu alloys, represents a highly interesting alternative to the well-known nanoporous gold structure, both from an economic as well as a sustainability persperspective. Insights to the formation process of np-Cu are provided by in-situ resistometry during the electrochemical dealloying process, and supported by ex-situ scanning electron microscopy imaging after dealloying. The results show that compared to more noble metals, the surface reordering during nanoporous structure formation is suppressed on np-Cu. This is assigned to the stronger formation of oxides, which yields interesting properties for possible future applications. Financial support by the FWF project P 36409 is appreciated. [1] Hengge et al. Nanoscale Advances **5** (2023) 393-404

MM 8.3 Mon 12:15 C 230

In-situ xray nanotomography of the isothermal structural-topological evolution of nanoporous gold — •Markus Ziehmer[1,2], Kate L.M. Elder[3,4], Jürgen Markmann[2], Yijuan Wu[2], Tiberiu Stan[4], Jin Zhang[4], Xianghui Xiao[5], Erica T. Lilleodden[6,2], and Peter W. Voorhees[4] — [1]Universität Ulm, Institut für Funktionelle Nanosysteme, — [2]Helmholtz-Zentrum Hereon, Institut für Werkstoffmechanik — [3]Lawrence Livermore National Laboratory — [4]Northwestern University, Department of Materials Science and Engineering — [5]Brookhaven National Laboratory, National Synchrotron Light Source II — [6]Fraunhofer IMWS, Fraunhofer-Institut für Mikrostruktur von Werkstoffen und Systemen

The structural coarsening of nanoporous gold and other metallic, bicontinuous systems is inherently linked to topological transitions. These transitions do not only act on the global topological parameters, but also on local descriptors, as well as on the crystallographical evolution.

Various types of topological transitions have been identified experimentally recently: pinch-off, ring collapse, ligament reattachment, and particle detachment and reattachment. The relative weight of such transitions to happen, seems to depend strongly on the material's solid volume fraction, but also on the coarsening stage.

We report on in-situ xray nanotomography experiments, that allowed for tracking same sample subvolumes, in order to further elucidate aspects of the topological evolution in bicontinuous metallic materials.

MM 8.4 Mon 12:30 C 230

Reversible mechanical actuation of nanoporous gold modified by electroactive self-assembled monolayers: Impact of the surface stress — •Olga Matts[1], Xinyan Wu[2], and Nadiia Mameka[1] — [1]Helmholtz-Zentrum Hereon, Geesthacht, Germany — [2]Hamburg University of Technology, Hamburg, Germany

Hierarchical nanoporous (hc np) metals made by dealloying present novel opportunities for the development of light-weight, high surface-area materials with diverse functionalities in the fields of catalysis, energy storage, sensing, and actuation. Most hc np metals possess a bimodal pore size distribution, featuring pores of hundreds of nanometers with nanometer-sized pores located within their walls. Understanding the impact of the porous hierarchy on functional behavior of hc np materials is crucial to further enhance their performance. This work reports the actuation in np-Au with single and bimodal size distributions modified by ferrocene-terminated alkanethiol self-assembled molecules (SAMs). For this, in situ dilatometry and cantilever bending are employed in electrolyte under potential control, exploiting the ability of the electroactive molecules to undergo reversible redox reactions. Pronounced variations in the macroscopic length change of the hybrids are revealed in response to the voltage-induced redox transformations. The phenomenon can be explained by a reorientational motion of the alkyl chains and the ferrocene-moiety due to uptake of electrolyte's anions. The steric hindrance and local disorder in the SAM clamped to the gold surface induces the surface stress, that is compensated by the bulk stress, and results in the actuation of the hybrid.

MM 8.5 Mon 12:45 C 230

Mitigation strategies for self-detachment of nanoporous thin films — •Gideon Henkelmann[1], Xinyan Wu[1,2], and Jörg Weissmüller[1,3] — [1]Institute of Materials Physics and Technology, Hamburg University of Technology, Germany — [2]Institute of Optical and Electronic Materials, Hamburg University of Technology, Germany — [3]Institute of Materials Research, Materials Mechanics, Helmholtz-Zentrum Geesthacht, Germany

Experiment shows thin films of dealloyed nanoporous gold (NPG) spontaneously detaching from massive gold base layers. NPG can also densify near its external surface. This is naturally reproduced by kinetic Monte Carlo (KMC) simulations of dealloying and coarsening and so appears generic for nanoscale network materials evolving by surface diffusion. This talk focuses on how the KMC simulation manages to predict intricate physical phenomena with few and simple assumptions to the kinetics. Finally, we provide strategies to mitigate the self-detachment effect supported by both simulation and experimental results.