MM 44: Topical session: Interface-Controlled Microstructures: Mechanical Properties and Mechano-Chemical Coupling - Nano-porous materials

Time: Wednesday 11:30–13:15 Location: IFW B

Topical Talk MM 44.1 Wed 11:30 IFW B

Manipulating interfaces in nanoporous metals: Towards robust nanostructured materials with novel functionalities — •Nadiia Mameka — Helmholtz-Zentrum Geesthacht, Institut für Werkstoffforschung, Werkstoffmechanik, 21502 Geesthacht, Germany

Nanoporous metals formed via dealloying emerge as a new class of nanomaterials in which high mechanical strength and stiffness can be successfully combined with diverse functional properties. The materials offer facile and controllable modification of their numerous internal interfaces through: *i)* tailoring size of their structural nanoscale constituents – nanoligaments – via thermal or electrochemical annealing, and *ii)* reversible altering of electronic and/or chemical structure of the nanoligaments by external stimuli.

The talk aims at demonstrating how imposing the consequences of both surface engineering approaches can be for actuation, strain sensing, and mechanical response of nanoporous metals with macroscopic dimensions. Here, the functionalities arise from electrocapillary coupling at the metal/fluid interface in hybrid composites made from nanoporous gold and aqueous electrolytes, where the control over the interface properties is realized by reversible changes of external control variables (surface charge density and/or adsorbate coverage) as the function of the electrode potential. The possibilities for further improvements of structural and functional properties in such hybrid nanomaterials will be also discussed.

MM 44.2 Wed 12:00 IFW B

Nanostructure Formation during Dealloying: Theory and Experiment — •Anastasia V. Strasser and Jörg Weissmüller — Hamburg University of Technology

From an empirical point of view, the corrosion conditions for making high quality nanoporous gold samples by dealloying silver-gold solid solutions are well established. The ligament size and the composition of the nanoporous material can be tuned in a reproducible way. Yet, the mechanisms and driving forces of the nanostructure formation are only partly understood. Our understanding of the process relies on the model by Erlebacher and co., that considers a balance between dissolution of the less noble element and surface diffusion of the more noble element, along with nucleation of corrosion on deeper terraces. From an experimental point of view, alloy corrosion has seen STM (scanning tunneling microscope) studies under conditions of passivation. Since bulk dealloying is achieved in the regime where the dissolution outruns the passivation, additional studies of that regime are of high interest. Here we present a direct atomic scale observation of the nanostructure formation during electro- chemical dealloying using in-situ EC-STM (electrochemical scanning tunneling microscope) in the bulk dealloying regime and the results from the corresponding kinetic Monte-Carlo simulation. Series of pictures showing subsequent steps of the structure formation can be correlated to the corrosion rate. Our results from in-situ STM observations and KMC simulation confirm essential suppositions of the current understanding.

MM 44.3 Wed 12:15 IFW B

Topological changes in coarsening networks — •Dana Zöllner[1] and Paulo R. Rios[2] — [1]Institute of Structural Physics, Technical University Dresden, Dresden, Germany — [2]Escola de Engenharia Industrial Metalúrgica, Universidade Federal Fluminense, Volta Redonda, Brasil

The topology of polygonal networks in materials like grain and foam microstructures has been a topic of scientific interest for decades - not only for mathematicians but also for materials scientists due to their imfortance for materials properties. Such networks consist in two dimensions of edges and vertices. As a result, a certain number of edges and likewise vertices surround a polygonal area, which forms a cell or grain.

In the present work, we show what kind of topological changes occur in such two-dimensional networks. To that aim, computer simulations of ideal coarsening have been carried out for different initial networks and at different coarsening stages. We will follow the temporal development of topological changes as well as the trajectories of individual cells.

MM 44.4 Wed 12:30 IFW B

Hierarchically structured nanomaterials — •Benedikt Roschning[1] and Jörg Weissmüller[1,2] — [1]Institute of Materials Physics and Technology, Hamburg University of Technology, Hamburg, Germany — [2]Institute of Materials Research, Materials Mechanics, Helmholtz-Zentrum Geesthacht, Geesthacht, Germany

Porous microstructures used as functional materials often demand contradictory requirements on the pore size, which may be tackled by hierarchical structures consisting of porosity on different length scales. The aim of our project is the development of manufacturing routines for hierarchically structured nanomaterials combining different electrochemical approaches. Previous work focused on the preparation of nanoporous gold via corrosion of a dilute Au-Ag solid solution yielding a nanoporous Au-Ag alloy as intermediate product [1]. Coarsening creates the upper hierarchy level which can be corroded a second time to create the lower hierarchy level. However, corrosion induced shrinkage leads to intense crack formation making the material unsuitable for mechanical applications. Addition of Pt to the master alloy favors a high Au retention in the first dealloying step, reduces the shrinkage, prevents crack formation and allows the production of mm sized samples [2]. Yet, complete corrosion of the specimen and functionalization need to be shown.

[1] Qi, Weissmüller, ACS Nano 7 (2013) 5948-5954.

[2] Qi, Vainio, Kornowski, et al., Adv. Funct. Mater. 25 (2015) 2530-2536.

MM 44.5 Wed 12:45 IFW B

Bulk density measurements of small solids using Laser Confocal Microscopy — •Askar Kilmametov[1], Stefan Walheim[1], and Horst Hahn[1,2] — [1]Karlsruhe Institute of Technology (KIT), Institute of Nanotechnology, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany — [2]Technische Universität Darmstadt (TUD), Joint Research Laboratory Nanomaterials (KIT and TUD), Jovanka-Bontschits-Straße 2, Darmstadt 64287, Germany

A novel approach for precise density measurement of a small weight samples in the range of 1-3 mg is presented. A new kind of displacement method has been developed, by which a solid object is dropped into a semi-confined cylindrical cavity, which is filled with a nonvolatile liquid, to determine the volume of the sample. Due to surface tension, the upper level of the liquid forms a spherical meniscus pinned at the circular contact line, which is limited by a printed hydrophobic self-assembled monolayer. Monitoring of the liquid level is performed by confocal laser microscopy with a micrometer resolution. A straightforward procedure is developed to build-up a mass/volume linear dependence. This enables to determine the density of small solids with an accuracy of <0.5%. The method appears to be very sensitive to open and closed porosity. Applying a vacuum of 20 mbar to the already immersed samples allows to perform quantitative porosimetry on a rather limited amount of material of only 0.25 microliter. This corresponds to about 2-5 mg for most metals, 1-2 mg for most ceramics, or even only 0.25-1 mg for organic materials.

MM 44.6 Wed 13:00 IFW B

Hierarchical Nanoporous Nickel as Bulk Electrochemical Actuators — •Chuan Cheng[1], Lukas Lührs[1], Tobias Krekeler[2], and Jörg Weissmüller[1] — [1]Institute of Materials Physics and Technology, Hamburg University of Technology, 21073 Hamburg, Germany — [2]Central Division of Electron Microscopy, Hamburg University of Technology, 21073 Hamburg, Germany

Materials which can mimic the properties of mammal muscles upon outside electrical/chemical triggering are called artificial muscles. Commercialized actuation materials such as piezoceramics, electroactive polymers and shape memory alloys are restricted by ultra-high actuation voltages, or small strain amplitude, or rather low energy efficiency. In the last decade, increasing attention has been paid to nanostructured materials, including nanoporous metals, carbon nanotubes, conducting polymers, nanographene, and so on, to transform electrochemical energy into mechanical energy for potential applications as artificial muscles. Nanoporous metals for artificial muscle applications have unique combination of low operating voltage, relatively high strain amplitude, high strength and stiffness compared with high voltage operated piezoceramics and soft polymer based actuators. We present a 3-D macroscopic actuator composed of nanoporous structured nickel with dual-scaled pores, in which the large sized pores facilitate fast ion transfer kinetics and small sized pores contributed to the large surface area for surface charge storage and strain generation. Advanced actuation performances with both high strain amplitude and strain rate were obtained.