

MM 1: Topical Session Nanoporous Functional Materials I

Time: Monday 10:15–11:45

Location: IFW A

Invited Talk MM 1.1 Mon 10:15 IFW A
Fabrication and Properties of Nanoporous Metals by Electrochemical Dealloying — ●JONAH ERLEBACHER — Johns Hopkins University, Baltimore, MD

Dealloying, the electrochemical selective dissolution of a multi-component alloy, is an intrinsically nanoscale phenomena that under the right conditions leads to the formation of highly porous metals due to an atomic-scale competition between electrochemical dissolution and crystalline surface diffusion of the remaining components. Recent attention in this area is focused toward practical application of dealloying to form "nanoporous" metals with pore sizes less than 10 nm possessing ultra-high surface areas. Nanoporous metals formed by dealloying are microstructurally contiguous porous single crystal networks, and not fragile sintered agglomerations of nanoparticles. For this reason, they are finding many new applications in sensing and catalysis.

In this presentation, we will describe the evolution of the beautiful nanoporous microstructure of dealloyed metals and their applications in a variety of contexts. We will also discuss the use of a minority ternary component in the alloy precursors that stymie surface mobility along step edges, stabilizing the nanoporous morphology during dealloying, and the use of electrochemical tricks to control the surface composition of the nanoporous metal. Finally, we will discuss the development of new nanoporous metals that exhibit remarkable catalytic activity, particularly toward chemical reactions important to energy technologies, such as oxygen reduction in fuel cells

Topical Talk MM 1.2 Mon 10:45 IFW A
The role of surface chemistry on the properties of nanoporous gold — ●JUERGEN BIENER¹, ARNE WITTSTOCK^{1,2}, LUIS A. ZEPEDA-RUIZ¹, MONIKA M. BIENER¹, VOLKER ZIELASEK², DOMINK KRAMER³, RAGHAVAN N. VISWANATH³, JOERG WEISSMÜLLER³, MARCUS BAEUMER², and ALEX V. HAMZA¹ — ¹Nanoscale Synthesis and Characterization Laboratory, Lawrence Livermore National Laboratory, USA — ²Institut für Angewandte und Physikalische Chemie, Universität Bremen, Germany — ³Institut für Nanotechnologie, Forschungszentrum Karlsruhe, Germany

Although surfaces or, more precisely, surface atoms determine the way how materials interact with their environment, the influence of surface chemistry on the bulk of the material is generally considered to be small. However, in the case of high surface area materials such as nanoporous gold the influence of surface properties can no longer be neglected. Therefore, actively controlling surface properties such as diffusion barriers and surface stress by surface chemistry should provide an opportunity to manipulate and fine-tune material properties. Specifically, we will show that surface chemistry is an important factor in determining the stability of nanostructured gold surfaces, and that macroscopic strain can be generated by surface-chemistry induced changes of the surface stress. The latter effect can be used to directly convert chemical energy into a mechanical response without generating heat or electricity first and thus opens the door to surface-chemistry driven actuator and sensor technologies. Prepared by LLNL under Contract DE-AC52-07NA27344.

MM 1.3 Mon 11:15 IFW A
Electrochemical actuation using nanoporous metals — ●VISWANATH RAGHAVAN NADAR¹, DOMINIK KRAMER¹, and JÖRG WEISSMÜLLER^{1,2} — ¹Forschungszentrum Karlsruhe, Institut für Nanotechnologie, Karlsruhe, Germany — ²Technische Physik, Universität des Saarlandes, Saarbrücken, Germany

Actuating in response to an electric stimulus is well known for solid insulators, for instance piezo-ferroelectrics and conducting polymers, where an electric field penetrating the sample creates bulk distortion. The more recent observation of reversible dimension changes in nanoporous metal electrodes exploits different physics: Varying the electrode potential results in the formation of double layer, with a local electric field that is screened in the surface region. Changes in the mean surface atom bonding, due to the excess charge, modify the capillary forces at the surface, and bulk strain is required to set up a compensating stress throughout the lattice. Owing to their large specific surface area and large capacity, nanoporous Pt, Au, Pd wetted by electrolytes will thus exhibit reversible volume changes when their potential is varied. In a suitable setup, the action can be seen with the naked eye. In-situ dilatometry studies on these metals demonstrate that the variation of reversible strain is a linear function with charge. This highlights the distinction of the underlying capillary parameter, the surface stress, from the surface tension. Outside of the double layer regime, the stress-charge response reflects, among other factors. Thus, experiments on actuation of nanoporous metals provide insights into the microscopic processes at the electrochemical interface.

MM 1.4 Mon 11:30 IFW A
A light-weight, large strain nanoporous actuator material that can be used in compression — ●LIHUA SHAO¹, JÜRGEN BIENER², DOMINIK KRAMER¹, VISWANATH RAGHAVAN NADAR¹, THEODORE F. BAUMANN², and JÖRG WEISSMÜLLER¹ — ¹Forschungszentrum Karlsruhe, Institut für Nanotechnologie, Karlsruhe, Germany — ²Lawrence Livermore National Laboratory, Livermore, California, USA

Considerable progress has been made about the charge induced strain of nanoporous materials. Possible actuator applications have been suggested for noble metals and carbon nanotubes. The high costs of such materials are an impediment to application, as the fact that carbon nanotube arrays cannot be loaded in compression. It is therefore of interest to search for alternative materials which combine mechanical and chemical stability with low cost. We will report first results on the mechanical and electrochemical properties of a light-weight, bulk material with extremely large surface area that can be used in compression, and that achieves a reversible strain of 0.45%. Besides actuation applications, nanoporous solids impregnated by electrolyte are also of interest with regards to the measurement of a fundamental parameter, namely the potential of zero charge (pzc). For liquid metals the pzc coincides with the maximum of the surface tension, from which it can be measured. However, the strain of solids is governed by the surface stress, which is not a maximum at the pzc. We measured the pzc and the charge-dependent strain in various electrolytes and excluded an agreement between pzc and the potential of length minimum.