MM 17: Nanomaterials

Sessions: Nanomaterials I and II

Time: Tuesday 10:15–13:00 Location: H46

MM 17.1 Tue 10:15 H46

Vacancy-controlled design of MoN/TaN superlattices — Nikola Koutná[1,2], Rainer Hahn[1], Jakub Záležák[3], Martin Friák[2], Matthias Bartosik[1], Jozef Keckes[3], Mojmír Šob[2], Paul Mayrhofer[1], and •David Holec[3] — [1]Institute of Materials Science and Technology, TU Wien, Vienna, Austria — [2]Institute of Physics of Materials, Academy of Sciences of the Czech Republic, Brno, Czech Republic — [3]Department of Materials Science, Montanuniversität Leoben, Leoben, Austria

Superlattices are effective though experimentally simply-enough accessible microstructural design which allows tuning phase stability and mechanical properties beyond limits of their parent phases. In this contribution we report on our first principles calculations focusing on MoN and TaN, both of which prefer vacancies in their cubic-structured bulk forms. Interestingly, the vacancies strongly segregate to the MoN phase when combined with TaN into superlattices with bi-layer periods in a nm range. This trend based on energetics is further confirmed by evaluating mechanical stability based on elastic constants as well as dynamical stability from lattice vibrations. As a results, we could predict that the most stable configuration for typical conditions during magnetron sputtering, should be MoN_x/TaN system with N vacancies in the MoN phase. This theoretical prediction was experimentally confirmed by X-ray diffraction and an elemental analysis in transmission electron microscope for our reactively-sputtered superlattices.

MM 17.2 Tue 10:30 H46

Impact of the initial alloy composition on the mechanical properties of nanoporous gold — •Birthe Zandersons[1], Lukas Lührs[1], and Jörg Weissmüller[1,2] — [1]Institute of Materials Physics and Technology, Hamburg University of Technology — [2]Institute of Materials Research, Materials Mechanics, Helmholtz-Zentrum Geesthacht

Nanoporous gold (NPG) is an attractive model system for small scale material behavior. The feature size of the chemical stabile, network like structure is tunable from a few to several hundred nanometers. Remarkable are clear distinctions in stiffness and strength, occurring by variations of the solid fraction, ϕ. Yet, due to different processing approaches, the published data are restricted in comparability. A comparative study of the initial composition of precursor alloys, which controls ϕ, and the processing steps is indispensable.
We systematically varied the alloy composition of Au_xAg_{100-x}, with $x = 20, 25, 30, 35$ and we also varied the dealloying procedure with electrochemical corrosion in 1M $HClO_4$ and free corrosion in concentrated HNO_3. Using compression tests with continuous loading and load/unload protocols, we explored the stress-strain behavior, Young's modulus and Poisson's ratio, emphasizing comparability. We confirm significant dependences on the master alloy compositions and show a database of the variation of the mechanical response with ϕ for a given ligament size and push the current approaches to stiffness and strength of nanoscale metal networks forward.

MM 17.3 Tue 10:45 H46

Nanoporous Copper-Nickel - Macroscopic bodies of a strong and deformable nanoporous base metal by dealloying — •Lukas Lührs[1] and Jörg Weissmüller[1,2] — [1]Institute of Materials Physics and Technology, Hamburg University of Technology — [2]Institute of Materials Research, Materials Mechanics, Helmholtz-Zentrum Geesthacht

In the field of nanostructured materials, nanoporous metals offer significant functionalization potential due to their high surface area to volume ratio. Profiting from high structural definition, potential applications arise as actuators, sensors and structural materials with tunable mechanical properties. Following material characteristics have to be met in these fields: Affordability is an obvious requirement as well as resistance against corrosion, most importantly when potential cycles in electrolyte provide the functionalization. Lastly, deformability is required for avoiding premature failure upon exposure to stress concentrations. So far, macroscopic samples of nanoporous metals with a high surface area and deformability have been limited to precious, and thereby costly, metals such as Au, Pd and Pt.

Here we present nanoporous Copper-Nickel (npCN), a nanoporous base metal that can be made in macroscopic dimensions. Fabricated through dealloying in aqueous media, npCN exhibits a uniform, bicontinous network structure with feature sizes that can be controlled from 13 to 40 nm by thermal annealing. Compression tests find ductile deformation behavior accompanied with a high strength compared to other nanoporous base metals as well as macroporous Cu- and Ni-foams.

MM 17.4 Tue 11:00 H46

Electrosorption in Polypyrrole-Silicon Hybrid Nanopores: Insights from Cyclic Voltammetry and Dilatometry — •Manuel Brinker[1], Guido Dittrich[1], Pirmin Lakner[2], Thomas Keller[2], and Patrick Huber[1] — [1]Technische Universität Hamburg — [2]Deutsches Elektronen-Synchrotron DESY

Porous silicon provides a scaffold structure to study confinement effects of soft matter, since the pore diameter, pore length and pore shape can be tuned in a wide range. We investigate the electrosorption of electrolyte anions and the electrochemical behaviour of nanoporous silicon in acidic electrolytes. The silicon-electrolyte interface acts as a capacitor which allows the accumulation of electrolyte anions in a chemical double layer by an applied voltage. The sorption characteristics can be measured by cyclic voltammetry. The surface stresses that emerge in a monolithic porous silicon membrane by electrosorption lead to a macroscopic strain which can be measured in-situ with a dilatometer. Furthermore, we investigate the properties of a functional filling of the electrically conductive polymer polypyrrole (PPy) into nanoporus silicon. We successfully demonstrate the filling of PPy into pores of substantial depth of up to 100 μm. In particular, PPy allows for sensoric and actoric applications for the hybrid system. PPy swells when it is exposed to a voltage in an electrolyte, since ions from the electrolyte are intercalated into the polymer structure and expelled subsequently. The confinement effect of the pores on the swelling can be studied with dilatometry measurements as well and is compared to the nanoporous silicon itself.

MM 17.5 Tue 11:15 H46

Sorbitol capping of gadolinium oxide nanoparticles for contrast enhancement in magnetic resonance imaging — •Natalia Abrikosova[1,2], Caroline Brommesson[2], Peter Eriksson[2], Zhangjun Hu[2], and Kajsa Uvdal[2] — [1]Materials Modeling and Development Laboratory, National University of Science and Technology "MISIS", 119049 Moscow, Russia — [2]Department of Physics, Chemistry, and Biology (IFM), Linköping University, SE-58183 Linköping, Sweden,

Diagnostic with magnetic resonance imaging (MRI) is the method of choice to detect diseases accompanied by an inflammation within the body. MRI contrast agents based on magnetic nanoparticles represent an efficient tool to improve image quality by enhancing the contrast between normal and diseased tissue, thereby increasing the utility of MRI. In this work, we report an investigation of the effect of sorbitol on the performance of Gd-oxide nanoparticles (GdNPs) as MRI contrast agents. Two sets of experiments were performed, where GdNPs were either capped to or immersed in sorbitol. The longitudinal relaxation rates for hematopoietic cell samples, were measured. The results show that the presence of sorbitol as capping layer on GdNPs clearly improves the nanoparticle performance. Moreover, measurements on human neutrophil granulocytes and the production of reactive oxygen species (ROS), evidently demonstrate improved biocompatibility of the GdNPs capped with sorbitol. We hereby conclude that the strategy to cap nanoparticles with sorbitol is a promising pathway in search for the next generation of MRI contrast agents.

MM 17.6 Tue 11:30 H46

Atom probe analysis of nanoparticles: development of new sample preparation methods — •Jan Paul Josten and Peter Felfer — Department Materials Science and Engineering, Friedrich-Alexander-Universität Erlangen-Nürnberg, Institute I, Martensstraße 5, 91058 Erlangen, Germany

Atom probe tomography (APT) of nanoparticles (NPs) has shown

great potential with its atomic resolution for chemical and structural characterization. [1] Two novel methods are used to produce NP APT samples. First, the so called 'stamping transfer' (ST) [2] is used that was originally developed to produce free standing micro- and NPs on top of tip substrates for electron tomography by an in-situ SEM procedure. Second, based on an approach where single NPs have been attached to field emitters inside the analysis chamber [3] we developed a field ion microscope set-up (ES-FIM) where NPs can be introduced into ultra-high vacuum (UHV) as an electrospray aerosol through a transfer system. In order to understand the NP-APT sample set-up, field evaporation simulation using models developed at Group des Materiaux (GPM) by Vurpillot et al. [4,5] are used and results presented along with first experimental results and a comparison of the two methods to already existing methods.

[1] Tedsree, K. et al.; Nat. Nanotechnol. **2011** 6, 302-307
[2] Przybilla, T. et al.; Small Methods **2018** 2, 1700276
[3] Castro, T. et al.; J. Vac. Sci. Technol. **1989** 7, 2845-2849
[4] Vurpillot F., et al.; Ultramicroscopy **2000** 84, 213-224
[5] Rolland N., et al.; Microsc. Microanal. **2015** 6, 1649-1656

15 min. break

MM 17.7 Tue 12:00 H46

Spin, angle and time-resolved photoemission studies of WTe_2 and WSe_2 — •Jakub Schusser[1,2], Jan Minar[2], Maria Christine Richter[1], Mauro Fanculli[1], Olivier Heckmann[1], Laurent Nicolai[2], Waly Ndiaye[1], Zakariae El Youbi[1], Thierry Ruchon[3], David Bresteau[3], and Karol Hricovini[1] — [1]LPMS, University of Cergy-Pontoise, Neuville-sur-Oise, France — [2]University of West-Bohemia, New Technologies Centre, Pilsen, Czech Republic — [3]ATTOLab, CEA, Saint-Aubin, France

Molybdenum dichalcogenides are probably the most studied single layer TMDCs by virtue of being appealing for sundry possible applications suchlike transistors, diodes, solar cells or more fundamental studies of spin or valley pseudospin and their interactions. Tungsten-based counterparts are on the other hand evincing much stronger spin-orbit coupling due to which all the spin-related effects are more stable at room temperature and thus more feasible for application. We have conducted several experiments following the evolution of the spin texture near the X, Y, K and M points of the Brillouin zone (WTe_2 and WSe_2 respectively) which is substantial for understanding the fundamental properties of the structure-property relation of the system. Ab-initio set of photoemission calculations was also performed using SPR-KKR package. Furthermore, TR-SARPES studies will be carried out by the group on such materials to determine the ultrafast dynamics of the carrier density and to disentangle the subsequent relaxation processes using pump-probe experiments.

MM 17.8 Tue 12:15 H46

Towards plasmonic tunnel gaps for nanoscale photoemission currents by on-chip laser ablation — Philipp Zimmermann[1,2], •Alexander Hötger[1], Noelia Fernandez[1], Reinhard Kienberger[3,4], and Alexander Holleitner[1,2] — [1]Walter Schottky Institute and Physics Department, Technical University of Munich, Am Coulombwall 4a, 85748 Garching, Germany — [2]Nanoinitiative Munich (NIM), Schellingstr. 4, 80799 München, Germany — [3]Physics Department E11, Technical University of Munich, James-Franck-Str. 1, 85748 Garching, Germany — [4]Max-Planck-Institute für Quantenoptik, Hans Kopfermann-Straße 1, 85748 Garching, Germany

We demonstrate that prestructured metal nanogaps can be shaped on-chip to below 10 nm by femtosecond laser ablation. We explore the plasmonic properties and the non-linear photocurrent characteristics of the formed tunnel junctions. The photocurrent can be tuned from multi-photon absorption towards the strong-field tunneling regime in the nanogaps. We demonstrate that a unipolar ballistic electron current is achieved by designing the plasmonic junctions to be asymmetric, which allows ultrafast electronics on the nanometer scale.

MM 17.9 Tue 12:30 H46

The Effect of Molecular Orientation on the Plasmon Resonance of Metal Nanostructures — •Thomas Purcell[1], Shira Yochelis[2], Yossi Paltiel[2], and Tamar Seideman[1] — [1]Chemistry Department, Northwestern University, Evanston, IL, USA — [2]Applied Physics Department and the Center for Nanoscience and Nanothechnology, Hebrew University of Jerusalem, Jerusalem, Israel

Plasmon-based nanophotonics is becoming increasingly popular, in part because of its ability to improve the efficiency of optical devices by enhancing electromagnetic fields near plasmonic hot-spots˜[1]. To fully describe the plasmonic enhancement in these devices, contributions from both the sensitizers and the nanostructures need to be accounted for. Modeling the coupling between those two contributions, including the often decisive alignment between the sensitizers' and plasmon's dipole moments, remains an open challenge. By modifying the finite-difference time-domain method we develop a continuous model for a layer of molecular dipoles with an arbitrary orientation relative to a nanoparticle's surface, and study the coupled system's optical˜[2] and chiroptical˜[3] response. We demonstrate how the molecules alter the plasmon resonance of nanostructures and change the coupling between the plasmon and a colloidal quantum dot monolayer. Finally we include chiroptical effects to get a better understanding how the molecular dipole orientation affects chiral imprinting inside nanoparticles.

[1] T. Purcell, et al., J. Phys. Chem., 120, 21837 (2016)
[2] T. Purcell, et al., J. Phys. Chem., 122, 16901 (2018)
[3] T. Purcell and T. Seideman, ACS Photonics, Accepted

MM 17.10 Tue 12:45 H46

static friction vs young's modulus: the essential factors in reusable anodic aluminum oxide (AAO) template as a master mold — •Huanming Zhang, Min Zhou, Yang Xu, Rui Xu, Zhiqiang Zeng, and Yong Lei — Institute für Physics & IMN MacroNano (ZIK), Technische Universität Ilmenau, 98693 Ilmenau

To construct ordered nanostructure over a large area, Anodic Aluminum Oxide (AAO) template-directed fabrication is a promising technology. Herein, we propose a facial method to fabricate highly ordered metal film with AAO template as a master mold. After metal deposition in the AAO pores, the ordered metal films can be easily obtained by mechanical stripping from AAO template. To obtain a complete metal film, control experiments were conducted, and the aspect of the pore in AAO template and the Young's modulus of the metal deposited in the AAO pores was supposed to be the essential factors. The aspect-dependent static friction interacts with Young's modulus of the metal deposited in the AAO pores closely.