O 88: Metallic Nanostructures II (on Semiconductors)

Time: Friday 9:30–12:30 Location: MA 005

O 88.1 Fri 9:30 MA 005

Interactions Between Ag Nanoclusters on Carburized W(110) — •Magdalena Bachmann, Martin Gabl, Norbert Memmel, and Erminald Bertel — Institute of Physical Chemistry, University of Innbruck, A-6020 Innsbruck, Austria

Silver nanoclusters arranged in quasi-one dimensional chains were prepared on the R(15x12)-C/W(110) surface. Evidence is presented that these silver cluster chains form thermodynamic equilibrium structures. We address the question of possible interactions between neighbouring clusters by studying the length distributions of silver cluster chains with scanning tunnelling microscopy. Data are compared with theoretical expectations for various cluster-cluster interaction strengths. Best agreement between theory and experiment is obtained for a non-vanishing, slightly repulsive interaction energy of 14 +- 10 meV, despite the rather large cluster distance of 1.4 nm.

O 88.2 Fri 9:45 MA 005

Faceted silver clusters on HOPG and their stability — •Niklas Grönhagen, Farhad Ghaleh, and Heinz Hövel — Technische Universität Dortmund, Experimentelle Physik I, 44221 Dortmund

Silver clusters are interesting objects due to their optical and electronic properties. Close to the Fermi level silver is a nearly free electron metal where the electron delocalization leads to strongly cluster size dependent states [1]. However, the influence of the d-electrons is not negligible, e.g. for the optical properties of the clusters [2]. This interesting electronic structure is combined with a moderate chemical reactivity, which may be the reason why silver is used in many of the experiments for clusters on surfaces.

In the present study we produce faceted silver clusters by depositing silver atoms on HOPG samples, prestructured with nanometer sized pits [3,4]. Subsequently the clusters are investigated with STM. In these experiments we observe different shapes of the cluster facets as well as discrete cluster heights. Furthermore we investigate the clusters in terms of stability in different environments, e.g. air, bad vacuum or after STM-tip interaction.

[1] H. Hövel, B.Grimm, M. Bödecker, K. Fieger, B. Reihl: Surf. Sci. 463, L603 (2000)

[2] U. Kreibig, M. Vollmer, Optical properties of Metal Clusters: Springer Tracts in Materials Science 25 (Springer-Verlag, 1995)

[3] H. Hövel, Appl. Phys. A 72, 295 (2001)

[4] F. Ghaleh, R. Köster, H. Hövel, L. Bruchhaus, S. Bauerdick, J. Thiel, R. Jede: J. Appl. Phys. 101, 044301 (2007)

O 88.3 Fri 10:00 MA 005

Anisotropic Photoemission from Faceted Au Clusters on Graphite — •Ingo Barke[1], Heinz Hövel[2], Farhad Ghaleh[2], Richard C. Hatch[3], and Hartmut Höchst[3] — [1]Universität Rostock, Universitätsplatz 3, D-18051 Rostock — [2]Technische Universität Dortmund, Otto-Hahn-Str. 4, D-44221 Dortmund — [3]Synchrotron Radiation Center, 3731 Schneider Dr., Stoughton, WI 53589, USA

Quantized Shockley surface states have been observed on hexagonal facets of large Au clusters by means of scanning tunneling spectroscopy [1] and photoelectron spectroscopy [2]. Here we report on recent results obtained by angle resolved photoelectron spectroscopy (ARPES) with synchrotron radiation at the Synchrotron Radiation Center in Stoughton, WI (USA). Optimized preparation parameters resulted in narrow size distributions which allow for the direct observation of the size-dependent peak distance of quantized states. Angle resolved spectra reveal another striking difference between cluster facets and the bulk surface: we observe an unexpected asymmetry of emission intensity with respect to the emission angle which is very sensitive to the photon energy. With a suppression of almost 100% for one of the two branches of the parabolic dispersion this effect is much stronger and of opposite sign compared to the bulk Au(111) surface state.

[1] I. Barke, H. Hövel, Phys. Rev. Lett. 90, 166801 (2003).

[2] H. Hövel, I. Barke, Prog. Surf. Sci. 81, 53 (2006).

O 88.4 Fri 10:15 MA 005

Enhanced Bonding of Gold Nanoparticles on Oxidized TiO2(110) — •Stefan Wendt, Daniel Matthey, Jianguo Wang, Jesper Matthiesen, Renald Schaub, Erik Laegsgaard, Bjørk Hammer, and Flemming Besenbacher — Interdisciplinary Nanoscience Center (iNANO), and Department of Physics and Astronomy, University of Aarhus, DK-8000 Aarhus C, Denmark

We studied the nucleation of gold clusters on TiO2(110) surfaces in three different oxidation states by high-resolution scanning tunneling microscopy (STM). The three TiO2(110) supports chosen were (i) reduced having bridging oxygen vacancies, (ii) hydrated having bridging hydroxyl groups, and (iii) oxidized having oxygen ad-atoms. At room temperature gold clusters nucleate homogeneously on the terraces of the reduced and oxidized supports, whereas on the hydrated TiO2(110) surface clusters form preferentially at the step edges [1]. From interplay with density functional theory (DFT) calculations, we identified two different gold-TiO2(110) adhesion mechanisms for the reduced and oxidized supports. The adhesion of gold clusters is strongest on the oxidized support, and the implications of this finding for catalytic applications are discussed.

[1] Matthey, D.; Wang, J. G.; Wendt, S.; Matthiesen, J.; Schaub, R.; Laegsgaard, E.; Hammer, B.; Besenbacher, F., Science, 315, 1692 (2007).

O 88.5 Fri 10:30 MA 005

Aluminum oxide on $Ni_3Al(111)$. A Template for Ordered Fe and Co Cluster Growth — •Andreas Buchsbaum[1], Micheal Schmid[1], Georg Kresse[2], and Peter Varga[1] — [1]Inst. f. Allg. Physik, TU Wien, Austria — [2]Faculty of Physics, CMS, University of Vienna, Austria

The structure of the aluminum oxide on $Ni_3Al(111)$, which has been solved recently, exhibits holes at the corner of the $(\sqrt{67} \times \sqrt{67})$ R12.2° unit cell, reaching down to the metal substrate [1]. These holes are large enough to trap atoms of any kind of metal. Therefore, the ultrathin oxide film, forming a nanomesh, should be a perfect template for growing highly regular arranged metal clusters. Several metals have been deposited on the aluminum oxide and the clusters grown have been studied by scanning tunneling microscopy. The unmodified oxide, however, is not a good template for most metals. While Pd atoms nucleate in the corner holes and, hence, show a perfect hexagonal arrangement, Fe and Co clusters grow on other local defects, indicating a barrier to jump into the hole. By predeposition of a Pd seed layer, however, we can create a metallic nucleation site on each corner hole and Fe as well as Co clusters form a well-ordered hexagonal arrangement, making the oxide to a versatile template for growing highly regular arranged metal clusters [1]. We have also studied the morphology of the clusters and applied different methods to determine the orientation of the clusters. We have found different types of clusters, where only few of them show flat close-packed facets on top.

[1] M.Schmid et al., Phys. Rev. Lett. 99, 196104 (2007).

O 88.6 Fri 10:45 MA 005

Boron nitride nanomesh: an ultrathin insulating template — •Ivan Brihuega, Christian H Michaelis, Jiang Zhang, Sangita Bose, Violetta Sessi, Jan Honolka, Alexander M Schneider, Axel Enders, and Klaus Kern — Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, D-70569 Stuttgart, Germany

A key challenge in nanotechnology is the search of new materials suitable to act as nanoscale templates and also the growth of ultrathin insulating layers on metal surfaces which can be used to electronically decouple adsorbates from the substrate. Great success has been obtained in the formation of materials with templating or insulating capabilities, however, the combination of both abilities in the same system has not been yet achieved. In this work we show that the recently discovered BN nanomesh [1] combines both properties: templating at the nanoscale and electronic decoupling from the substrate. By covering the Rh(111) surface only partially with the Boron Nitride (BN) nanomesh, we have been able to directly compare the electronic properties of the BN nanomesh with the ones of the bare metal. Our low temperature scanning tunneling microscopy and spectroscopy experiments show that the BN nanomesh acts both as a nanotemplate, laterally ordering Co clusters deposited on it with a nearest neighbor distance of 3.2 nm, and as an insulator, electronically decoupling the clusters from the metal substrate.

[1] Corso, M. et al. Science 303, 217 (2004).

O 88.7 Fri 11:00 MA 005

Optical properties of single Mg particles on MgO thin films — •Philipp Myrach, Hadj Mohamed Benia, Niklas Nilius, and Hans-Joachim Freund — Fritz-Haber-Institut, Berlin, Germany

Light emission spectroscopy with an STM is employed to study the optical properties of single Mg particles grown on 5-10 ML thick MgO films on Mo(001). The particles exhibit distinct rectangular shapes with edges that align with the close-packed O rows of the oxide support. Luminescence spectra taken in the field emission regime (U>40 V) reveal a photon peak at 550 nm in addition to the well-known exciton emission of bare MgO at 400 nm. A similar emission peak is detected in the tunneling mode (U<10 V) for individual particles. The emission is assigned to a plasmon excitation in the Mg deposits. The high spatial resolution of the method allows also mapping of the emission intensity within one particle, thus providing information on the symmetry of the underlying optical mode.

O 88.8 Fri 11:15 MA 005

Two metal nano-particle enhanced Raman spectroscopy and microscopy — •Phillip Olk[1], Jan Renger[2], Marc Tobias Wenzel[1], Thomas Härtling[1], and Lukas M. Eng[1] — [1]Institut für angewandte Photophysik, TU Dresden — [2]ICFO-Institut de Ciencies Fotoniques, Barcelona

The distance and polarization dependent near-field enhancement of two coupling metal nanoparticles (MNPs) is analyzed by means of the novel Scanning Particle-enhanced Raman Spectroscopy (SPRM) technique [1]. In contrast to single MNP Raman experiments, the near-field coupling between two dissimilar MNPs leads to a Raman hot spot yielding an extra enhancement factor, as proven here both in experiment and theory.

The Au80 MNP is attached to the apex of an optical fiber manipulator and exposed to the exctitation light. A monolayer of 1-octanethiol molecules covering the Au80 MNP serves as the electric field prober when scanning the substrate carrying the Au30 MNP through the optical focus.

This constellation allows recording the Raman signatures from a very low number of well confined molecules. Moreover, also the spectral and spatial dependence could be explored with a superb sensitivity and very low integration time.

[1] P. Olk, J. Renger, T. Härtling, M. T. Wenzel, and L. M. Eng. *Nano Lett.* 6(7), 1736–1740, 2007.

O 88.9 Fri 11:30 MA 005

Evaluation of near field enhanced Raman spectroscopy on industrial Silicon structures — •Benjamin Uhlig[1], Jens-Hendrik Zollondz[2,3], Marc Tobias Wenzel[4], Martin Haberjahn[2,3], Peter Kücher[3], and Lukas M. Eng[4] — [1]Fraunhofer -Institut für Keramische Technologien und Systeme, Winterbergstrasse 28, 01277 Dresden, Germany — [2]Qimonda Dresden GmbH & Co. OHG, Königsbrücker Strasse 180, D-01099 Dresden, Germany — [3]Center of Competence CoC Metrology/Analytic, Fraunhofer-Center Nanoelektronische Technologien CNT, Königsbrücker Straße 180, D-01099 Dresden, Germany — [4]Institut für Angewandte Photophysik, TU Dresden, George-Bähr-Straße 1, D-01069 Dresden, Germany

Following Moores Law, semiconductor structures become smaller and smaller. The understanding of stress intentionally implemented in devices or stress in multi layer components due to thermal mismatch is a major challenge for metrology. A promising technique to obtain highly localized stress information is Tip Enhanced Raman Spectroscopy (TERS). This paper discusses under which conditions TERS can be applied to industrial semiconductor structures and which effects can be expected. In order to obtain an idea of the enhancement effects on Silicon, we show several Surface Enhanced Raman Spectroscopy (SERS) experiments using Au nanoparticles. By varying particle diameter, incident laser wavelength, aperture angle, aswell as incoming and scattered polarization orientation we achieve up to 100% enhancement on bulk Silicon (100 nm Au nanoparticles, 633 nm laser excitation).

O 88.10 Fri 11:45 MA 005

Design of SERS-active metallo-dielectric nanostructures — •André Siegel, Manuel Rodrigues Gonçalves, and Othmar Marti — Institute of Experimental Physics, Ulm University, Albert-Einstein-Allee 11, D-89069 Ulm, Germany

Since its discovery in the 1970's surface enhanced Raman scattering (SERS) has been an active field of research. Its attraction stems from the possibility to detect very tiny concentrations of certain molecules. These high sensitivities are correlated to strong local electric fields, which are usually generated by exploiting the plasmonic properties of metallic nanostructures at optical frequencies. However, many approaches ranging from irregularly shaped nanoparticles, dimers and clusters of nanoparticles to nanoporous metallic films can show very strong SERS spectra, though their reproducibility is mostly not satisfactory.

Therefore we have concentrated on the design and fabrication of periodic metallo-dielectric nanostructures using colloidal crystals as templates, as well as on FEM calculations to predict the associated local field enhancements. The used techniques and our results will be presented.

O 88.11 Fri 12:00 MA 005

Fabrication of metallic cones for optical near-field investigations — •Monika Fleischer[1], Florian Stade[1], Kai Braun[2], Johannes Stadler[2], Andreas Heeren[1], Michael Häffner[1], Marcus Sackrow[2], Catrinel Stanciu[2], Alfred J. Meixner[2], and Dieter P. Kern[1] — [1]Institute of Applied Physics, Auf der Morgenstelle 10, 72076 Tübingen, Germany — [2]Institute of Physical and Theoretical Chemistry, Auf der Morgenstelle 8, 72076 Tübingen, Germany

Metallic cones with dimensions of the order of 100 nm are highly favourable objects for optical near-field investigations using visible light. Upon illumination, strong electric field enhancement can be observed up to a few nanometers above the cone tip. However, fabricating well-defined metallic cones with a sharp tip on the nanoscale is nontrivial. We present a process flow in which arrays of cones are shaped from a continuous metal sandwich layer on silicon by subtractive ion milling. In the process, patterned hydrogen silsesquioxane resist (HSQ) is used as an etch mask. The resulting cones have tunable base diameters around 150 nm and tip radii down to less than 10 nm. Their optical characteristics are investigated by means of apertureless optical near-field microscopy. Field enhancement at the cone tip has been demonstrated both by simulation and by experiment. In combination, the metallic scanning probe of the microscope and the cone form a vertical antenna configuration. This antenna features a small tunable gap and strong variable field enhancement within the gap region.

O 88.12 Fri 12:15 MA 005

Analysis of damascene-fabricated Cu lines by electron backscatter diffraction and X-ray diffraction — •Anastasia Moskvinova, Steffen Schulze, Michael Hietschold, Ramona Ecke, Ina Schubert, and Stefan E. Schulz — Solid Surface Analysis Group and Center for Microtechnologies, Chemnitz University of Technology, 09107 Chemnitz, Germany

Electroplated copper has become the method of choice for filling narrow interconnect features for microelectronics applications in one processing step. However, as the trench width decreases, the influence of the physical-vapour deposited (PVD) seed layer becomes more important. Due to changes in the growth dynamics the volume fraction of the PVD copper rises significantly compared with the ECD copper. Therefore we focused our interest on understanding the grain growth mechanism in thin PVD copper films and its differences from the growth dynamics in ECD copper structures and films. For that reason we analyzed the grain size and crystallographic orientation by electron backscatter diffraction (EBSD) and X-ray diffraction. Both techniques indicate a strong (111) texture. The grain structure of the Cu line in the trenches may differ considerably from that of blanket films. Grain size of copper within the trenches is affected by size constraints Cu. In narrow lines we find more small grains than in wider lines, suggesting that the grain structure depends on the line geometry.