

## O 9: Nanostructures at Surfaces I

Time: Monday 10:30–12:45

Location: H6

## O 9.1 Mon 10:30 H6

**Fabrication of nanostructures on thin organic layers by Focused Electron Beam Induced Processing** — ●MARTIN DROST<sup>1</sup>, FAN TU<sup>1</sup>, FLORIAN VOLLNHALS<sup>1</sup>, IMRE SZENTI<sup>2</sup>, JANOS KISS<sup>2</sup>, HANS-PETER STEINRÜCK<sup>1</sup>, and HUBERTUS MARBACH<sup>1</sup> — <sup>1</sup>Physik. Chemie II, FAU Erlangen-Nürnberg, GER — <sup>2</sup>MTA-SZTE Reaction Kin. and Surf. Chem. Research Group, Un. of Szeged, HUN

Focused Electron Beam Induced Processing (FEBIP) comprises several nanofabrication techniques in which a focused electron beam of an electron microscope is used to modify the properties of adsorbed precursor molecules or the substrate itself. We demonstrate that it is possible to fabricate nanostructures using FEBIP with the precursors Co(CO)<sub>3</sub>NO and Fe(CO)<sub>5</sub>, on Si(111) and TiO<sub>2</sub>(110), both pre-covered with several layers of 2H-Tetraphenylporphyrin (2HTPP). At room temperature, both pristine surfaces are catalytically active towards the decomposition of Co(CO)<sub>3</sub>NO, leading to growth of a granular film, whereas EBID with Fe(CO)<sub>5</sub> is selective. The catalytic activity of the pristine surfaces towards decomposition of Co(CO)<sub>3</sub>NO can be inhibited by a thin 2HTPP layer. On the corresponding organic interfaces it is possible to selectively fabricate nanostructures using FEBIP, with both precursors. The deposits are characterized by Scanning Electron Microscopy (SEM) and local Auger Electron Spectroscopy (AES). Supported by the DFG through grant MA 4246/1-2, research unit FOR 1878/funCOS; COST Action CM1301; Excellence Cluster EAM of the FAU Erlangen-Nürnberg.

## O 9.2 Mon 10:45 H6

**Nanostructures fabricated via Focused X-ray Beam Induced Deposition (FXBID)** — ●FAN TU, MARTIN DROST, FLORIAN VOLLNHALS, ANDREAS SPÄTH, KRICK CALDERON SANDRA, RAINER H. FINK, HANS-PETER STEINRÜCK, and HUBERTUS MARBACH — Lehrstuhl für Physikalische Chemie II, Friedrich-Alexander Universität Erlangen-Nürnberg, Egerlandstr.3, D-91058, Erlangen, Germany

We will report the usage of a focused monochromatic X-ray beam for the fabrication of nanostructures by the local dissociation of adsorbed precursor molecules. A particular appealing aspect of monochromatic X-rays is thereby the potential to selectively address certain atoms and/or bonds within the precursor molecule and thus tuning the decomposition process. It has been proposed that especially the Auger decay process following the creation of a core hole by photoabsorption causes the selective dissociation of different bonds [1]. The local X-ray irradiation and the successive characterization were conducted at the PolLux beamline at the Swiss light source with a scanning transmission X-ray microscope (STXM). X-ray energy dependent deposition of Cobalt and Manganese carbonyl precursors will be investigated. The Chemical composition and the deposition yield were characterized by in-situ X-ray adsorption spectroscopy (XAS) in the STXM instrument.

Supported by the DFG via grant MA 4246/1-2, MA 4246/2-1, the cluster of excellence Engineering of Advanced Materials at the FAU Erlangen-Nürnberg and two granted beamtimes at the PolLux STXM of Swiss Light Source.

[1] Cazaux, J. *Microsc.* 188(1997), 106

## O 9.3 Mon 11:00 H6

**Vertically aligned MWCNTs on glassy carbon: A nanostructured all carbon electrode** — ●ESER METIN AKINOGLU<sup>1,2</sup>, ÖMER AKAY<sup>1</sup>, and MICHAEL GIERSIG<sup>1,3</sup> — <sup>1</sup>Freie Universität Berlin, Department of Physics, 14195 Berlin, Germany — <sup>2</sup>Max-Planck-Institut für Kolloid- und Grenzflächenforschung, Potsdam-Golm Science Park, 14476 Potsdam, Germany — <sup>3</sup>Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Institut Nanoarchitekturen für die Energiewandlung, 14109 Berlin, Germany

Multi-walled carbon nanotubes (MWCNTs) are known for their unique mechanical and electronic properties and find applications in many aspects of science. MWCNTs as a powder have been shown to be extraordinary supports for catalytically active materials where they are beneficial for surface area enhancement effects as well as for charge separation and transport. Another carbon material, namely glassy carbon, is widely used in electrochemistry as an electrode material due to its high conductivity, high corrosion resistance and abundance of carbon. In this contribution we present a nanostructured all carbon electrode that is based on vertically aligned MWCNTs directly grown

on glassy carbon via plasma enhanced chemical vapor deposition. Besides structural and electronic characterization of our materials we show first applications of our concept towards highly conductive, inexpensive nanostructured high surface area electrodes.

## O 9.4 Mon 11:15 H6

**Correlation of scanning x-ray microscopy and HRTEM measurements of carbon nanomaterials** — ●FABIAN FRITZ<sup>1,2</sup>, RASMUS WESTERSTRÖM<sup>3</sup>, LOTHAR HOUBEN<sup>4</sup>, MARTINA LUYSBERG<sup>4</sup>, ALEXEY A. POPOV<sup>5</sup>, CLAUS M. SCHNEIDER<sup>2</sup>, and CAROLA MEYER<sup>1</sup> — <sup>1</sup>Fachbereich Physik, Universität Osnabrück, Germany — <sup>2</sup>Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich GmbH, Germany — <sup>3</sup>Physik-Institut, Universität Zürich, Switzerland — <sup>4</sup>Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons, Forschungszentrum Jülich GmbH, Germany — <sup>5</sup>Leibniz Institute for Solid State and Materials Research (IFW), Dresden, Germany

High resolution transmission electron microscopy (HRTEM) is often used to study the structure of nanomaterials. Scanning transmission x-ray microscopy (STXM) is a synchrotron based nano-spectroscopy technique for recording nano-scaled images with chemical and magnetic contrast.

Here we present a combined HRTEM and STXM study of carbon nanotube (CNT) bundles filled with Er<sub>3</sub>N@C<sub>80</sub> fullerenes. The measurements demonstrate that unique CNT bundles can be located and studied with the two techniques. We also obtained erbium M5 edge x-ray absorption spectra from a single bundle. Images recorded on and off resonance provide an erbium map of the sample.

We correlate HRTEM and STXM images of the same nanometer scaled object and discuss the combination of the two techniques.

## O 9.5 Mon 11:30 H6

**Covalent or organometallic networks? A comparative study of a dibromo-diiodo-pyrene derivate on Ag(111) vs. Au (111) by XPS, NEXAFS, and STM** — ●MATTHIAS LISCHKA<sup>1,2</sup>, JOHANNA EICHHORN<sup>1,2</sup>, MASSIMO FRITTON<sup>1,2</sup>, THOMAS STRUNSKUS<sup>3</sup>, VIJAY VYAS<sup>4</sup>, WOLFGANG M. HECKL<sup>1,2,5</sup>, and MARKUS LACKINGER<sup>1,2,5</sup> — <sup>1</sup>Department of Physics, TU München, James-Frank-Str. 1, 85748 Garching — <sup>2</sup>Center for NanoScience, Schellingstr. 4, 80799 Munich — <sup>3</sup>Institute for Materials Science - Multicomponent Materials, Christian-Albrechts- Universität zu Kiel, Kaiserstr. 2, 24143 Kiel — <sup>4</sup>MPI für Festkörperforschung, Heisenbergstraße 1, 70569 Stuttgart — <sup>5</sup>Deutsches Museum, Museumsinsel 1, 80538 Munich

The thermally activated surface chemistry of a dibromo-diiodo-pyrene is comparatively studied on Ag(111) and Au (111) under ultrahigh vacuum conditions. X-ray photoelectron spectroscopy of C 1s, Br 3d, and I 3d was used to identify chemical changes that indicated the occurrence of two distinct phases for both surfaces. Upon progressive heating on Ag (111), an initially formed partly organometallic phase becomes fully organometallic. On Au (111) at room temperature, however the precursor is already deionated and partially forms covalent bonds. Further heating drives debromination and results in conversion to a fully covalent network. The structural characterization of each phase is carried out by a combination of high resolution scanning tunneling microscopy and C 1s near edge x-ray absorption fine structure. Special emphasis is put on buckling in the networks as a consequence of covalent bond formation due to steric hindrance.

## O 9.6 Mon 11:45 H6

**Probing reactive metal atoms on functionalized surfaces by porphyrin metalation** — ●JAN NOWAKOWSKI<sup>1</sup>, SYLWIA NOWAKOWSKA<sup>2</sup>, GITIKA SRIVASTAVA<sup>1</sup>, MILOS BALJOZOVIC<sup>1</sup>, JAN GIROVSKY<sup>1</sup>, NIRMALYA BALLAV<sup>3</sup>, and THOMAS A. JUNG<sup>1</sup> — <sup>1</sup>Paul Scherrer Institute, Villigen, Switzerland — <sup>2</sup>University of Basel, Switzerland — <sup>3</sup>IISER Pune, India

On-surface metalation of porphyrins has been established on a wide range of surfaces including atomically clean metallic substrates [1] as well as metal-oxides [2] and metallic surfaces modified by oxygen [3]. In this contribution [4], we use the well-studied metalation reaction to present evidence that Cl- and N-induced modifications of the top-most surface layer (i.e. adsorbate-induced surface superstructures) on Cu(001) have decisive and contrasting impact on the reac-

tivity of the surface, as well as on molecular self-assembly. The N superstructure facilitates the metalation reaction and self-assembled domains of CuTPP are formed at room temperature. On the contrary, the Cl superstructure fully inhibits the reaction and causes 2HTPP to assemble into small 'magic' clusters. A spectro-microscopy correlation approach combining X-ray Photoelectron Spectroscopy, Ultraviolet Photoelectron Spectroscopy, Low Energy Electron Diffraction and Scanning Tunnelling Microscopy has been used in this study.

[1] Auwärter, W. et al., *ChemPhysChem* 8, 250 (2007); [2] Wang, C. et al., *Chem Commun* 50, 8291 (2014); [3] Nowakowski J. et al., *Chem. Commun.*, 49, 2347 (2013); [4] Nowakowski J. et al., submitted.

O 9.7 Mon 12:00 H6

**Controlled creation and imaging of quantum states of dangling bond structures on H-terminated Si(001)** — •ASIF M SULEMAN, KIAN A RAHNEJAT, CYRUS F HIRJIBEHEDIN, NEIL J CURSON, GABRIEL AEPPLI, DAVID R BOWLER, and STEVEN R SCHOFIELD — University College London, London, UK

An understanding of how semiconductor point defects interact is needed if they are to fulfil their potential as the basis of future nanoelectronic and quantum devices. Scanning tunnelling microscopy (STM) has been used to investigate point defects on semiconductor surfaces. Here we present an investigation of interacting dangling bond (DB) orbitals on H-terminated Si(001). The STM tip is used to selectively desorb individual H atoms to create a DB [1]. Pairs, or dimers, of DBs interact as their individual excited states overlap, signalled by the appearance of a bright protrusion between them in a molecular-like state [2]. Tip-induced band bending calculations show this excited molecular state of the dimer come into tunnelling range at high biases and low currents. The energy alignment with the tip Fermi level is also affected by additional DBs in the vicinity of the dimer. 2D structures of DBs, including trimers and tetramers, were produced that exhibit 2D extended excited molecular states that we present here for the first time. By modelling each DB with a 2D Pöschl-Teller potential well holding two bound states, we could simulate the bound states for the DB structure and find good agreement with experiment. [1] J. W. Lyding *et al. Appl. Phys. Lett.* **64**, 2010 (1994). [2] S. R. Schofield *et al. Nat. Commun.* **4**, 1649 (2013). [3] A. M. Suleman *et al. In prep.* (2015).

O 9.8 Mon 12:15 H6

**Interaction of dangling bond bound states on boron passi-**

**vated Si(111)** — •MANUEL SIEGL — London Centre for Nanotechnology University College London 17-19 Gordon St London WC1H 0AH United Kingdom

Scanning tunnelling microscopy (STM) was used in the creation of quantum structures such as quantum corrals showing bound electron states across multiple lattice sites on a Fermi-level pinned metal surface [1]. Taking degenerately boron doped Si(111), we extend STM-imaging to spatially resolved scanning tunnelling spectroscopy maps (CITS) [2] in order to examine the electronic structure of point defect induced bound states on a semiconductor Fermi-level pinned surface [3]. We investigate the site dependent interaction of these atomic size quantum dots in varying arrangements, with changing dangling bond separation and crystallographic direction. The experimental results are then compared to first principle density function theory (DFT) calculations and we confirm a non-linear constructive interference between the excited states of positively charged dangling bonds [4].

References [1] M. F. Crommie et al., *Science* 262, 218 (1998). [2] R. J. Hamers et al., *PRL* 56, 18 (1986). [3] M. Berthe et al., *PRL* 97, 206801 (2006) [4] H. Hedgeland, M. Siegl et al. In preparation (2016).

O 9.9 Mon 12:30 H6

**Morphology and Environment dependent Luminescence of Dye Aggregates** — •MOHAMMADREZA BAHRAMI<sup>1</sup>, SVEN KRAFT<sup>1</sup>, TAMAM BOHAMUD<sup>1</sup>, KAI WARDELMANN<sup>1</sup>, BJÖRN VOGLER<sup>1</sup>, JOHANNES A.A.W. ELEMANS<sup>2</sup>, INGO BARKE<sup>1</sup>, and SYLVIA SPELLER<sup>1</sup> — <sup>1</sup>University of Rostock, Institute of Physics, 18059 Rostock, Germany — <sup>2</sup>Radboud University Nijmegen, Institute for Molecules and Materials, 6525 AJ Nijmegen, The Netherlands

We study the spatially resolved photoluminescence, as one of the relaxation pathways of excitons, from Copper-based porphyrin [1] aggregates which form on surfaces via self-organization. Among the different observed morphological motifs of the aggregates we focus on isotropic aggregates as well as branched strands with typical heights between 30 and 150 nm. Fluorescence and phosphorescence microscopy images show different intensity from these two morphologies. Utilizing atomic force microscopy we correlate photoluminescence and structural properties to elaborate on possible reasons of such morphology-dependent luminescence. We further present our results on the effect of metallic nanostructures in the vicinity of the aggregates and address the role of these metal systems as local sources of enhanced excitation fields.

[1] M.J.J. Coenen, et al., *Phys. Chem. Chem. Phys.* **15**, 12451 (2013)