O 10: [DS] Focused electron beam induced processing for the fabrication of nanostructures I (focused session, jointly with O – Organizers: Huth, Marbach)

Time: Monday 15:00–17:00 Location: H 0111

Invited Talk O 10.1 Mon 15:00 H 0111

Focused electron beam lithography in the 1-10 nanometer range. — •Cornelis Wouter Hagen — Delft University of Technology, Charged particle Optics Group, Lorentzweg 1, 2628CJ Delft, The Netherlands

What if one would like to make something really small, for instance something consisting of only a few thousand atoms, then how would one do it? And what if one would also like to have control over its final shape and its composition? How could that be achieved? The answer is: with focused electron beam induced processing (FEBIP), because an electron beam can be focused down to a tiny sub-nanometer spot. When such a beam is scanned over a substrate with an adsorbed monolayer of precursor molecules, the molecules are dissociated. Only at the positions where the electron beam has been, solid fragments are left behind at the surface, forming a high-resolution pattern. I will review what we have learned about this process, focusing on the superb resolution, and the fundamentals of the dissociation process. To turn FEBIP into a user-friendly lithography technique, dedicated instruments will have to be developed. I will sketch the route that we envision towards such instrumentation.

Topical Talk O 10.2 Mon 15:30 H 0111

Fabrication of 1 nm thick Carbon Nanomembranes using FEBIP — •Armin Gölzhäuser — Universität Bielefeld, Bielefeld, Germany

We employ a combination of molecular self-assembly and focused electron beam induced processing (FEBIP) to fabricate only 1 nm thick, but mechanically stable carbon nanomembranes (CNM). Self-Assembled Monolayers (SAMs) of amphiphilic biphenylthiols are formed on gold surfaces and then exposed to electron beams that lead to a C-H cleavage. The dehydrogenation is followed by a lateral cross-linking between neighboring molecules [1]. The resulting two-dimensional film can be released from the surface, forming a mechanically stable CNM with the thickness of the original monolayer, i.e. 1 nm [2]. We have developed procedures for the handling of CNMs, i.e. to transfer them onto arbitrary surfaces and to prepare them as free-standing films. It will be shown that free-standing CNMs can be used as supports for transmission electrons microscopy [3]. Free-standing CNMs also can act as substrates for a FEBIP fabrication of very small metal clusters [4].

[1] A. Turchanin et al. Langmuir 25, 7342 (2009).
[2] A. Turchanin et al. Adv. Mater. 21, 1233 (2009).
[3] C.T. Nottbohm et al. Ultramicroscopy 108, 885 (2008).
[4] W.F. van Dorp et al. Nanotechnology 22, 115303 (2011).

Topical Talk O 10.3 Mon 16:00 H 0111

Towards a microscopic understanding of the electron beam induced deposition of tungsten — •Harald Jeschke, Kaliappan Muthukumar, Ingo Opahle, Juan Shen, and Roser Valentí — Institut für Theoretische Physik, Goethe-Universität Frankfurt, 60438 Frankfurt am Main, Germany

We present two density functional theory investigations into the electron beam induced deposition with tungsten hexacarbonyl $W(CO)_6$ as precursors. For the initial adsorption of the precursor on SiO_2 substrates, we consider two different surface models, a fully hydroxylated and a partially hydroxylated SiO_2 surface, corresponding to substrates under different experimental conditions and leading to physisorption and chemisorption, respectively. On the partially hydroxylated surface, we find a spontaneous dissociation of the precursor molecule with chemisorption of $W(CO)_5$ and removal of one of the CO ligands [1]. Other precursors like $MeCpPtMe_3$ and $Co_2(CO)_8$ are discussed. We also investigate the nature of the granular deposits with varying compositions of tungsten, carbon and oxygen that are produced in the EBID process. We employ an evolutionary algorithm to predict the crystal structures starting from a series of chemical compositions known from experiment. We approximate the amorphous structures by reasonably large unit cells that can accommodate local structural environments that resemble the true amorphous structure. Our predicted structures show an insulator to metal transition close to the experimental composition at which this transition is actually observed.

[1] K. Muthukumar *et al.*, Phys. Rev. B **84**, 205442 (2011).

O 10.4 Mon 16:30 H 0111

Proximity Effects in Focused Electron Beam- Induced Processing on Ultra-thin Membranes — Marie-Madeleine Walz, Florian Vollnhals, Florian Rietzler, Michael Schirmer, Hans-Peter Steinrück, and •Hubertus Marbach — Lehrstuhl für Physikalische Chemie II and Interdisciplinary Center for Molecular Materials (ICMM), Friedrich-Alexander-University, Erlangen-Nuremberg, Egerlandstr. 3, 91058 Erlangen

A fundamental challenge in lithographic and microscopic techniques employing focused electron beams are so-called proximity effects due to backscattering in the sample or forward scattering in an already formed deposit. In this work, we apply a method which allows for visualizing processes on the substrate surface triggered by an electron beam. The resulting defects are decorated by iron deposits formed by decomposition of, e.g., $Fe(CO)_5$ and the corresponding technique is denoted as electron beam induced surface activation (EBISA). Applying this technique for the deposition of nanostructures has the advantage that no forward scattering in an already formed deposit occurs [1,2]. Conventional wisdom holds that by using thin membranes proximity effects can be effectively reduced. We demonstrate that, contrary to the expectation, proximity effects on a 200 nm SiN-membrane are even larger than on the respective bulk substrate. A peculiar charging effect is suggested to play a key role in this unexpected phenomenon.

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[1] Walz et al., Angew.Chem.Int.Ed.49 (2010) 4669, [2] Walz et al., PCCP, 13 (2011) 17333.

O 10.5 Mon 16:45 H 0111

Binary Pt-Si Nanostructures Prepared by Focused Electron-Beam-Induced Deposition — •Marcel Winhold[1], Christian Schwalb[1], Fabrizio Porrati[1], Roland Sachser[1], Achilleas S. Frangakis[2], Britta Kämpken[3], Andreas Terfort[3], Norbert Auner[3], and Michael Huth[1] — [1]Physikalisches Institut, Goethe-Universität, Max-von-Laue-Str.1, 60438 Frankfurt am Main — [2]Institut für Biophysik, Goethe-Universität, Max-von-Laue Str. 1, 60438 Frankfurt am Main — [3]Institut für Anorganische und Analytische Chemie, Goethe-Universität, Max-von-Laue Str. 7, 60438 Frankfurt am Main

Binary systems of Pt-Si were prepared by focused electron-beam-induced deposition (FEBID) using the two precursors trimethyl(methylcyclopentadienyl)platinum(IV) ($MeCpPt(Me)_3$) and neopentasilane ($Si(SiH_3)_4$) simultaneously. By this new approach for the preparation of binary systems with FEBID, we can vary the relative flux of the two precursors during deposition. We analyzed the binary composites of platinum and silicon by means of energy dispersive X-ray spectroscopy, atomic force microscopy, electrical transport measurements, and transmission electron microscopy. The results show strong evidence for the formation of an amorphous, metastable Pt_2Si_3 phase, leading to a maximum in the conductivity for a Si:Pt ratio of 3:2.[1] Furthermore the influence of post-treatment by electron irradiation as well as annealing on samples with Si:Pt ratios of 3:2 and 1:1 will be presented.