MI 5: Session on Nanostructuring Beyond Conventional Lithography

Chair: Hartmut S. Leipner (Martin-Luther-Universität Halle-Wittenberg)

Time: Wednesday 11:30–13:15 Location: MER 02

MI 5.1 Wed 11:30 MER 02

X-ray waveguide optics — •Sarah Hoffmann-Urlaub, Mike Kanbach, Hsin-Yi Chen, and Tim Salditt — Institut für Röntgenphysik,Georg-August Universität, Friedrich-Hund Platz 1, 37077 Göttingen

Virtual x-ray sources as provided by channel waveguides exhibit nanoscale sizing [1] as well as a high degree of coherence. We report on imaging experiments and the fabrication process of these hard x-ray waveguides deployed at the synchrotron sources at DESY and ESRF. Among nother techniques e-beam lithography, reactive ion etching and Silicon wafer bonding are involved within the fabrication of two-dimensional, sub-100 nm sized waveguide channels. Both waveguide geometry [2] and material [3] can be adapted to meet the requirements of a specific experiment, such as the photon energy (7.9-17.5 keV), the desired source size, or the application of a reference beam in a holography setup [4].

[1] H. Neubauer et al., J. Appl. Phys. 115, 214305 (2014)
[2] H.-Y. Chen, et al. Appl. Phys. Lett. 106(19), 194105 (2015)
[3] S. Hoffmann-Urlaub, et al. Microelec. Eng. 164: 135-138. (2016)
[4] S. Hoffmann-Urlaub, et al. Acta Cryst. A, 72.5 (2016)

MI 5.2 Wed 11:45 MER 02

Additive Fabrication of Nanostructures with Focused Soft X-Rays — •Andreas Späth[1], Fan Tu[1], Florian Vollnhals[2], Hubertus Marbach[1], and Rainer H. Fink[1] — [1]FAU Erlangen-Nürnberg, Physical Chemistry II, Erlangen, Germany — [2]Luxembourg Institute of Science and Technology (LIST), Materials Research and Technology, Belvaux, Luxembourg

We have developed a novel technique for the deposition of metallic nanostructures by illuminating gas phase precursors with focused soft X-rays in a zone plate based scanning transmission X-ray microscopy (STXM) setup. With this technique we have been able to produce localized Co and Mn nanostructures with growth rates and purity competitive with electron beam induced deposition (EBID) [1]. We demonstrate that our approach exhibits significant selectivity with respect to incident photon energy leading to enhanced growth for resonant absorption energy of the precursor molecule. This finding opens a new field of photon energy selective deposition from precursor mixtures and deposition from various precursors within one production cycle. The impact of several deposition parameters on the growth rate, such as illumination time, precursor pressure and multi-sweep experiments are discussed with respect to a deeper understanding of deposition processes and optimization of the procedure. Furthermore, we discuss routes to the formation of magnetic deposits.

[1] A. Späth et al., RSC Advances, 2016, 6, 98344.

Invited Talk MI 5.3 Wed 12:00 MER 02

NanoFrazor Lithography - Revolutionizing nanofabrication — •Zhengming Wu[1], Colin Rawlings[2], Simon Bonanni[1], Tero Kulmala[1], Heiko Wolf[2], Urs Duerig[2], Armin W. Knoll[2], Martin Spieser[1], Philip Paul[1], and Felix Holzner[1] — [1]SwissLitho AG, Zurich, Switzerland — [2]IBM Research - Zurich, Rueschlikon, Switzerland

Thermal Scanning Probe Lithography (t-SPL) is an alternative maskless lithography technique which is also commercially available since 2014 under the name NanoFrazor Lithography. It provides similar speed (up to 20 mm/s) and resolution (10 nm half-pitch) as EBL, but without charged particles involved. In addition 3D topographical structures can be written in just one step at better than 2 nm vertical resolution. Here, we present the technology involved and the examples of high resolution and high density nano-structures made by the NanoFrazor for applications like photonics, plasmonics etc. Furthermore, the remaining topography from structures buried under the spincoated resist is detectable and extremely accurate overlay alignment to these structures (e.g. nanowires & 2D material flakes) is achieved. The capability to write large area pattern is explored. The alternative applications of the heated tip are discussed.

MI 5.4 Wed 12:30 MER 02

Nanopillar with self-assembled Si nanodot for single electron transistor — •Thomas Prüfer, Karl-Heinz Heinig, Wolfhard Möller, and Johannes von Borany — Helmholtz-Zentrum Dresden-Rossendorf, Dresden-Rossendorf, Deutschland

Conventional Lithography allows the fabrication of structures down to ~10 nm, being still too large for single electron transistors (SET) operating at room temperature (RT), which requires a tiny quantum dot (<5nm) embedded in SiO2, with tunnel distances to the source and drain <2nm. Here, we predict a fully CMOS-compatible method of self-assembly of a single Si quantum dot. We assume that 10*20nm thin nanopillars of a layer stack c-Si/6nm SiO2/30nm a-Si are made by conventional lithography. We predict that such a single dot is self-organized and self-assembled between the top and bottom silicon layer by phase separation of metastable SiOx. The SiOx is made by collisional mixing in the layer stack, which is simulated by TRI3DYN [1]. The phase separation of SiOx is described by 3D kinetic lattice Monte Carlo simulations [2]. Our results predict that a single Si nanodot forms if the volume of SiOx is smaller than (10nm)^3. This work has been funded by the European Union's Horizon 2020 research and innovation program under grant agreement No 688072. [1] W. Möller; NIM B, 322, 23*33; [2] M. Strobel, K.H. Heinig, W. Möller, PRB 64, 245422

MI 5.5 Wed 12:45 MER 02

Site-controlled formation of Si nanodots in a buried SiO2 layer via ion-beam implantation and phase separation — •Xiaomo Xu[1], Daniel Wolf[1], Gregor Hlawacek[1], René Hübner[1], Ahmed Gharbi[2], Thomas Prüfer[1], Lothar Bischof[1], Karl-Heinz Heinig[1], Stefan Facsko[1], and Johannes von Borany[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]CEA-LETI, Grenoble, France

The single electron transistor (SET) is a promising candidate for low energy-dissipation computing units. However, so far its success is hindered by low-temperature requirements and the lack of CMOS-compatible fabrication route. By combining standard top-down lithography with bottom-up self-assembly of Si nanodots we will overcome this barrier.

In this work, Si nanodots, sufficiently small for RT operation of SETs, are formed in a CMOS-compatible way inside a buried SiO2 layer. This is achieved via ion beam mixing in a geometrical restricted volume and subsequent thermally activated phase separation via RTA. Guided by 3DkMC and TRI3DYN simulations, we perform focused Ne+ beam irradiation with Helium Ion Microscopy (HIM) on planar layers, and Si+ broad-beam irradiation of nano-pillars with embedded SiO2. Both approaches lead to a constrained size of the collision cascade and hence the mixed volume. The as-formed Si nanodots are studied with TEM, SIMS and electrical characterization techniques.

This work has been funded by the European Union Horizon 2020 Research and Innovation Program under grant agreement No. 688072.

MI 5.6 Wed 13:00 MER 02

Transmission Helium Ion Microscopy — Christoph Herrmann and •Karen L. Kavanagh — Dept. Physics, Simon Fraser University, Burnaby, BC V5A 1S6 Canada

The application of a Si p-i-n detector array (Modupix) for the imaging of a coherent helium ion beam (25 keV, Zeiss nanofab) is described. The beam intensity as a function of ion current, aperture size, spot size, focus condition, and gas pressure have been investigated. The transmission through thin films (Si, Al, C and polymers) have been imaged with a lateral resolution of 5 microns, limited by the detector pixel size (55 microns) and distance below the sample (15 cm). The potential for the detection of ion milling rates, diffraction and channeling is discussed.