HL 10: Focus: High-resolution Lithography and 3D Patterning (Part I) (joint session KFM/HL/CPP)

Chair: Robert Kirchner (TU Dresden)

Time: Monday 9:30–12:50 Location: TOE 317

Invited Talk HL 10.1 Mon 9:30 TOE 317

Novel device integration - combining bottom-up and top-down approaches — •Artur Erbe — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Scaling electronic devices to smallest structure sizes well below 10nm will require novel developments for the fabrication of single components. Smallest functional devices can be assembled using chemical methods leading to, e.g., single molecules with electronic functionalities. Reliable contacting of single molecules using metallic contacts is, however, an extremely challenging task which has not been solved so far. We have therefore developed techniques which use self-assembly for the creation of conducting nanostructures in order to create small, self-assembled circuits which then can be contacted reliably using standard lithographic methods. In this talk, we demonstrate how single organic molecules can be contacted using mechanically controllable break junctions. In addition, we show how DNA Origamis can be used for the self-assembly of metallic nanowires, which are contacted using electron beam lithography and electrically characterized. Further integration of such nanostructures into standard silicon electronics may be achieved by connecting them with 1d- or 2d-semiconductors. We have therefore developed transistors based on 2d-materials and silicon nanowires using electron beam lithography and dry etching (i.e. using a classical top-down approach), which are reconfigurable. With the combination of these devices with self-assembled nanostructures, a large variety of electronic nanocircuits can be constructed in future applications.

HL 10.2 Mon 10:00 TOE 317

Fabrication of NbC Josephson-junction arrays by focused-ion-beam-induced deposition — •Fabrizio Porrati, Felix Jungwirth, Sven Barth, and Michael Huth — Goethe-University, Institute of Physics, Frankfurt a. M.

In this work, a Ga focused-ion-beam is used in combination with the precursor Nb(NMe2)3(N-t-Bu) to fabricate 2D Josephson-junction arrays made of NbC nanodots with typical diameter of 40 nm. Square-arrays with lattice constant between 70 nm and 100 nm are characterized by transport measurements. The ratio Ej/Ec between Josephson coupling energy and the charging energy can be varied by tuning either the dot thickness or the inter-dot distance. As a consequence, a superconductor to insulator transition takes place, as shown by temperature-dependent resistivity measurements. In the Josephson regime, the arrays show magnetic frustration. The resistance as function of the magnetic field exhibits an oscillating behavior with a period of 380 mT for the square-array with lattice constant of 70 nm.

HL 10.3 Mon 10:20 TOE 317

Avoiding amorphization during semiconductor nanostructure ion beam irradiation — •G. Hlawacek[1], X. Xu[1], W. Möller[1], H.-J. Engelmann[1], N. Klingner[1], A. Gharbi[2], K.-H. Heinig[1], S. Facsko[1], and J. von Borany[1] — [1]Ion Beam Physics and Materials Research, Helmholtz—Zentrum Dresden – Rossendorf, Dresden, Germany — [2]CEA-Leti, Grenoble, France

Ion beam induced amorphization of semiconductor nanostructures limits the applicability of ion beam processing to semiconductor nanostructures. Here, we present an approach that not only avoids this amorphization but in addition allows to tailor the lateral device dimensions of pillars and fins used in modern GAA and Fin-FET designs. Si nanopillars (diameter: 25–50 nm) have been irradiated by either 50 keV broad beam Si^+ or 25 keV focused Ne^+beam from a helium ion microscope (HIM) at various temperatures using fluences of 2×10^{16} cm^{-2} and higher. While at room temperature strong deformation of the nanopillars has been observed, the pillar shape is preserved above 325°C. This is attributed to ion beam induced amorphization of Si at low temperatures allowing plastic flow due to the ion hammering effect and surface capillary forces. Plastic deformation is suppressed for irradiation at elevated temperatures. Above 325°C, as confirmed by diffraction contrast in BF-TEM, the nanopillars remain crystalline, and are continuously thinned radially with increasing fluence down to 10 nm. This is due enhanced forward sputtering through the sidewalls of the pillar, and agrees well with 3D ballistic computer simulations.

Supported by the H-2020 under Grant Agreement No. 688072.

HL 10.4 Mon 10:40 TOE 317

Grayscale Lithography: Creating complex 2.5D structures in thick photoresist by direct laser writing — •Dominique Collé — Heidelberg Instruments, Heidelberg, Germany

Heidelberg Instruments's lithography systems make it possible to expose any pattern directly without fabricating a mask, which results in a significantly shorter prototyping cycle. The use of a digital mask also allows some quick modification of the design when necessary. The possibility to modulate the energy of each pixel exposed brings the control over the 3rd dimension. This localized dose modulation can be represented as gray tones in a design between black (no dose / no depth in the resist) and white (highest dose / maximum depth in the resist) with up to 1024 different gray tones. Grayscale lithography opens a new world of application from texturing to micro-optic. Micro lenses array, light diffusers, Fresnel lenses, blazed gratings and diffractive optic elements are some typical micro-structures made with grayscale lithography.

20 min. break

Invited Talk HL 10.5 Mon 11:20 TOE 317

Shapeable materials technologies for high resolution patterning of 3D microelectronic devices — •Daniil Karnauschenko — Institute for Integrative Nanosciences, Leibniz IFW, Helmholtz str. 20, 01069 Dresden, Germany

Electronic devices are continually evolving to offer improved performance, smaller sizes, lower weight, and reduced costs, often requiring state of the art manufacturing and materials to do so. An emerging class of materials and fabrication techniques, inspired by self-assembling biological systems shows promise as an alternative to the more traditional methods that are currently used in the microelectronics industry. Mimicking unique features of natural systems, namely flexibility and shapeability, the geometry of initially planar microelectronic structures can be tailored. Heavily relying on cylindrical geometry, fabrication of microwave helical antennas, coils, resonators and magnetic sensors is challenging, when conventional fabrication techniques are applied. Involving high resolution lithographic patterning and self-assembly strategies realization of these spatially non-trivial devices in a compact form and with a reduced number of fabrication steps become feasible. This spatial self-assembly process, triggered by an external stimulus, offers a possibility of an improved performance while reducing overall manufacturing complexity of devices and components by harnessing the relative ease in which it can produce microscopic 3D geometries such as a *Swiss-roll* architecture. These benefits can lead to tighter a system integration of electronic components including active electronics with reduced costs fabricated from a single wafer.

HL 10.6 Mon 11:50 TOE 317

Coupling Single Mode Fibers to Single Quantum Emitters using Femtosecond 3D Printing Technology — •Ksenia Weber[1], Simon Thiele[2], Simon Ristok[1], Sarah Fischbach[3], Jan Hausen[3], Lucas Bremer[3], Mark Saritson[4], Simone Protalupi[4], Alois Herkommer[2], Stefan Reitzenstein[3], Peter Michler[4], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, Stuttgart — [2]Institute for Applied Optics and Research Center SCoPE, University of Stuttgart, Stuttgart — [3]Institute of Solid State Physics, Technische Universität Berlin — [4]Institut für Halbleiteroptik und Funktionelle Grenzflächen and Research Center SCoPE, University of Stuttgart

We propose a method to efficiently couple single photon quantum emitters to optical single mode fibers. Due to the undirected emission of single photon sources, such as quantum dots or defect centers in crystals, coupling into optical fibers which is essential for long range quantum communication is typically associated with high losses. To overcome this limitation, femtosecond two-photon lithography can be used to directly fabricate a combination of a microlens and an optical fiber holder onto a quantum emitter. A single mode optical fiber is then integrated into the fiber holder. Due to the high precision of the femtosecond 3D printing process, the position of the fiber core can be adjusted with sub-micrometer accuracy to match the focal point of the microlens. Light from the emitter which is focused by the microlens can therefore efficiently be coupled into the fiber. We present a number of different optical layouts and discuss their pros and cons.

HL 10.7 Mon 12:10 TOE 317

Optical properties of photoresists for femtosecond 3D printing: Refractive index, extinction, luminescence - dose dependence, aging, heat treatment and comparison between 1-photon and 2-photon exposure — •Michael Schmid, Dominik Ludescher, and Harald Giessen — 4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Femtosecond 3D printing has emerged as an important technology for manufacturing nano- and microscopic optical devices and elements. Detailed knowledge of the dispersion in the visible and near-infrared spectral range is crucial for the design of these optical elements. Here we provide refractive index measurements for different UV-doses, aging times, heat treatment and 2-photon exposed structures for the photoresists IP-S, IP-Dip, IP-L, OrmoComp, IP-Visio, and PO4. We use a modified and automized Pulfrich refractometer setup, utilizing critical angles of total internal reflection with an accuracy of $5{\cdot}10^{-4}$ in the visible and near-infrared spectral range. We compare Cauchy and Sellmeier fits to the dispersion curves. We also give Abbe numbers and Schott Catalog numbers of the almost entirely polymerized resists. Additionally, we provide quantitative extinction and luminescence measurements for all photoresists.

HL 10.8 Mon 12:30 TOE 317

Acoustic Impedance Matching on Ultrasonic Devices using Additive Manufacturing — •Severin Schweiger, Sandro Koch, Marcel Krenkel, and Marco Kircher — Fraunhofer Institute for Photonic Microsystems, Dresden, Germany

Acoustic impedance matching layers are attached to ultrasonic transducers to increase acoustic energy transmission into the load medium. A capacitive micromachined ultrasonic transducer (CMUT) emits sound via electrostatic deflection of a flexible electrode. Especially air-coupled CMUTs with protective or focusing layers exhibit a notable impedance mismatch. We propose a new approach to fabricate impedance matching metamaterials with low load-side specific acoustic impedance values, by employing a photolithographic additive manufacturing technology using two photon absorption. It will enable improved impedance matching, which has a beneficiary effect on acoustic bandwidth, efficiency and sensitivity of the CMUT. The center operating frequency of the CMUT can be influenced via this process as well. The technology also allows for direct fabrication of microstructures on the chip, foregoing any adhesion layers that disturb the impedance matching and enabling the protective and/or focusing aspects of the layer. This contribution will show analytic and FEM simulations of CMUTs with matching layers. Fabricated impedance matching layer samples and on chip fabrication will be presented as well. Electric impedance and acoustic measurements are in progress and will be featured accordingly.