KFM 26: Lithography IV: Lithography and Structuring (joint session KFM/DS)

This second lithography session focuses mainly on the application of advanced methods for quantum applications and the fabrication of lower dimensional systems. With the mass production of transistors devices at the 10 nm level with transmissive optical masks and with extreme UV reflective masks being at the horizon for mass fabrication, the industrial photomask fabrication is currently facing a significant technology transition and new technology requirements needed to keep pace with. The session also looks into those industrial challenges. Finally, the session focuses on important characterization methods required for the above mentioned state-of-the art lithography methods and their characterization.

Organizer: Robert Kirchner - Technische Universität Dresden

Time: Thursday 15:00–18:10 Location: EMH 025

Invited Talk KFM 26.1 Thu 15:00 EMH 025

Electron Beam Lithography and Ion Beam Patterning for Applications in Quantum Technology — •Jörg Stodolka, Michael Kahl, Axel Rudzinski, and Sven Bauerdick — Raith GmbH, Dortmund, Germany

Electron Beam Lithography and Ion Beam Patterning allow to fabricate structures with nm resolution and accuracy, which is required for many devices based on quantum technology. After a general overview we present two specific applications.

First, we show an approach for a deterministic realization of photonic devices with very high process yield utilizing cathodoluminescence spectroscopy (CL) in combination with electron beam lithography: An electron beam is used to write nanopatterns in resist at positions that are preselected by local generation of light detected by CL.

Second, we present a method for scalable and maskless fabrication of silicon vacancy (VSi) defect arrays in silicon carbide using focused ion beam. The photoluminescence spectrum and optically detected magnetic resonance of the generated defect spin ensemble are used to analyze the synthesized centers and their desired defect state. The reliable production of VSi defects with a dedicated focused ion beam system allowing single ion implantation could pave the way for applications in quantum photonics and quantum information processing.

KFM 26.2 Thu 15:30 EMH 025

Technology for fabrication of suspended sub-5 nm silicon nanowires and applications thereafter — Nikolay Petkov[1] and •Yordan M. Georgiev[2] — [1]Tyndall National Institute, University College Cork, Lee Maltings, Dyke Parade, Cork, T12R5CP, Ireland — [2]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Bautzner Landstrasse 400, 01328 Dresden, Germany

Si nanowires (Si NWs) are very promising as channels for field effect transistors (FETs) and also as sensing devices. When the NW diameter is in the sub-10 nm range, quantum confinement of carriers is observed at room temperature, which is very appealing from scientific and application point of view.

This paper will present a technology for fabrication of sub-5 nm suspended Si NWs on silicon-on-insulator wafers. News of 20 nm width are first defined in the top Si layer by electron beam lithography and reactive ion etching. Then the NWs are subjected to three consecutive cycles of rapid thermal oxidation in oxygen atmosphere and wet etching in hydrofluoric acid. The resulting suspended Si NWs have high-quality crystalline structure and sub-5 nm size.

The possible applications of such NWs will be discussed, including FET-based Si NW chemo-/biosensors as well as gate all around (GAA) FETs. Additionally, the development of self-aligned nickel silicide NW contacts will be presented. The formation mechanism was examined by in-situ electron microscopy as a function of NW diameter and surface oxide.

KFM 26.3 Thu 15:50 EMH 025

Photomask Manufacturing Technology - An Overview — •Christian Buergel, Torben Heins, and Martin Sczyrba — AMTC Dresden, Raehnitzer Allee, 0199 Dresden, Germany

Semiconductor devices are designed as vertical stacks of electrical components (e.g. transistors, capacities, wiring and connections), which are manufactured layer by layer during wafer processing.

Pattern formation on the wafer is done by using projection lithography and photomasks are key elements for the lithography. At least one photomask is required for each layer, where the mask contains the design information and is used as master for the desired geometries. The design, as represented on the photomasks, is replicated as a 4x demagnified image onto the wafer in the desired amount, hence enabling rapid and cost effective semiconductor production.

This presentation will give a broad overview of the manufacturing chain of a photomask. It will introduce into required processes like data preparation and manipulation for mask writing, resist and absorber material processing, metrology and inspection as well as mask repair and its qualification.

KFM 26.4 Thu 16:10 EMH 025

Simulation of Ion Beam induced Surface Dynamics — •Alrik Stegmaier and Hans Hofsäss — 2. Physikalisches Institut, Georg-August Universität Goettingen

Structuring of surfaces through ion beam irradiation can be used to create self organizing dune-like waves, dimples, flat surfaces or chaotic patterns. The final structures are a result of the interplay of sputtering, redeposition, projectile implantation, transport and viscous flow, void/bubble formation and the initial surface conditions.

Accurate simulations of structuring are possible through molecular dynamics simulations, but these simulations are computationally too expensive to allow for a prediction of up to micrometer scale structure. A much faster approach is available through the use of continuum models. For this the net effect of the irradiation is expressed as the local change in surface height as a function of and up to forth order spacial derivatives of the local surface height. Typically the resulting equations of motion are taylor-expanded up to second order. Such an approach can be accurate when the surface is relatively flat and shadowing is not important, but the parameters often need to be empirically readjusted for experiments at different impact angles, ion energies or materials.

Here we present a new software package that allows for the rapid simulation of surface dynamics for arbitrary, nonlinear equations of motion that can also include nonlocal effects. With this software we explore nonlinear expansions to some of the common models, the effects of shadowing at flat impact angles and parameter determination through binary collision approximation simulation.

20 min. break

KFM 26.5 Thu 16:50 EMH 025

NFFA-Europe: enhancing European competitiveness in nanoscience research and innovation — •Dimitrios Kazazis — Paul Scherrer Institut, 5232 Villigen, Switzerland

NFFA-Europe is a European open-access resource for experimental and theoretical nanoscience. It brings together advanced infrastructures throughout Europe, specialized on growth, nanolithography, nanocharacterization, theory, simulation and fine-analysis with Synchrotron, FEL and Neutron radiation sources to create a multi-site research platform that enables European and international researchers to carry out advanced project proposals impacting science and innovation. NFFA-Europe coordinates access to infrastructures on different aspects of nanoscience research that are not currently available at single specialized sites. Technique and tool selection, proposal construction and submission are all done through a single and intuitive web portal. The access to the combined infrastructures through NFFA-Europe is centrally coordinated and free of charge for all technologically feasible and internationally peer-reviewed and approved user projects. Not only do the approved projects have access to the combined infrastructures, but they also benefit from the competences and the technical support of the NFFA sites as well as a contribution towards travel and subsistence costs. NFFA-Europe's internal joint research activities address key bottlenecks of nanoscience and nanotechnology i.e. nonostracture traceability, protocol reproducibility, in-operando nanomanipulation and analysis, open data etc. (www.nffa.edu)

KFM 26.6 Thu 17:10 EMH 025

Fresnel-Mirror-Setup for Interference Lithography — •Arrigo Facchini[1], Bodo Fuhrmann[2], Hartmut S. Leipner[2], Georg Schmidt[1,2], and Roland Scheer[1] — [1]Martin Luther University Halle-Wittenberg Institute of Physics, D-06099 Halle (Saale), Germany — [2]Martin Luther University Halle-Wittenberg Interdisciplinary Center of Materials Sciences, D-06099 Halle (Saale), Germany

Interference lithography is one of many alternative lithography techniques for the fast fabrication of large area regular nano- and micro-scale patterns. A variety of more or less complex setups using Lloyd*s interferometers or beam splitters are described in literature.

In particular, rigid Lloyd*s interferometer setups allow the fast change of the periodicity by simply changing the angle of incidence. They have, however, the drawback that for smaller angles of incidence (larger periodicity) the illuminated area decreases and as a consequence also the possible sample size.

Here a robust Fresnel mirror setup is presented, which overcomes this problem and allows the fast fabrication of regular patterns in the *m-range with freely selectable periodicity. The maximum sample size is only determined by the setup chosen.

KFM 26.7 Thu 17:30 EMH 025

Analysis of rough nanostructured surfaces by EUV-scatterometry — •Analía Fernández Herrero, Frank Scholze, and Victor Soltwisch — Physikalisch-Technische Bundesanstalt, Abbestr. 2-12, 10587 Berlin, Germany

Lamellar-gratings are commonly-used as diffractive optical elements or in state-of-the-art integrated electronic circuits. For the control of the lithographic manufacturing process in semiconductor manufacturing a rapid in-line characterization of the nanostructures is indispensable. With shrinking structure sizes, roughness gains influence on the device performance. Therefore the analysis of nanostructured surfaces demands the development of new metrology tools capable of destruction-free measurements, which, at the same time, deliver statistical information, relevant for the study of the imperfections. Small angle X-ray scattering under grazing incidence has already been investigated for the determination of the geometry parameters of such structures. Several reports stress the importance of the identification of the roughness contributions. Using EUV or soft X-ray radiation, with longer wavelengths, larger incidence angles can be used reducing the beam footprint on the samples without compromising the surface sensitivity. We present a new experimental tool to be developed at the PTB soft X-ray beamline at the electron storage ring BESSY II for the measurement of small structures and roughness contributions based on soft X-ray and EUV scatterometry.

KFM 26.8 Thu 17:50 EMH 025

GISAXS reconstruction of profiles of gratings produced by quadruple patterning — •Mika Pflüger[1], Victor Soltwisch[1], R. Joseph Kline[2], Frank Scholze[1], and Michael Krumrey[1] — [1]Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany — [2]National Institute of Standards and Technology (NIST), Gaithersburg, United States

New approaches are needed for the fast, non-destructive dimensional measurement of complex nanostructures produced in the semiconductor industry. One technique being considered is Small-Angle X-ray Scattering (SAXS), which has already been used to reconstruct the line profile of gratings with low uncertainties. Grazing-Incidence SAXS (GISAXS) additionally provides surface sensitivity, but the interpretation of the scattering is complicated by multiple scattering effects.

To produce structures beyond the diffraction limit of a single lithographic exposure, self-aligned double patterning (SADP) can be used. In SADP, sidewalls are deposited on the original line and the original line is removed, such that the sidewalls form lines with a doubled structure density. If the sidewall width and the original linewidth do not match, an alternating pitch error is introduced, impacting the performance of the resulting structures.

We present GISAXS measurements of a sample series produced by self-aligned quadruple patterning with varying pitch errors. From the intensities of the grating diffraction orders, we quantify the pitch errors and compare our results to previous SAXS measurements of the same samples.