DS 18: Micro- and Nanopatterning (jointly with O)

Time: Wednesday 9:30–11:30 Location: H8

DS 18.1 Wed 9:30 H8

Evolution of Ge surface topography during low energy ion beam erosion — •Marc Teichmann, Jan Lorbeer, Frank Frost, and Bernd Rauschenbach — Leibniz-Institut für Oberflächenmodifizierung e.V., Permoserstraße 15, 04318 Leipzig, Germany

The self-organized pattern formation on Ge(100) by low-energy ion beam sputtering with noble gases is studied. We investigated the surface topography in dependency on the angle of incidence. Furthermore the evolving structures are investigated as a function of ion beam energy in the range from 400 eV up to 2000 eV and in a fluence range form $1.1 \times 10^{18}\,\text{cm}^2$ until $1.3 \times 10^{19}\,\text{cm}^2$.

The surface remains flat up to an angle of incidence of about 60 deg before a ripple pattern evolves at higher angles with wave vector parallel to the projection of the ion beam. This pattern also vanishes at 75 deg when a saw tooth profile evolves on the surface. At grazing incidence a pattern emerges with wave vector perpendicular to the ion beam. Furthermore we observe an energy dependency on the transition between smoothening and patterning and a temporal coarsening of the structures. The observations suggest that the projectile mass is an important parameter for pattern formation and gradient dependent sputtering is a main mechanism of surface destabilization which is also supported by TRIM.SP [1] calculations that also reveal that reflected ions can contribute to surface stabilization and surface smoothing.

Support by Deutsche Forschungsgemeinschaft through FOR 845 is gratefully achknowledged.

[1] J. P. Biersack, W. Eckstein, Appl. Phys. A, **34**, 73-94 (1984).

DS 18.2 Wed 9:45 H8

Pattern formation on sapphire by low energy ion beam erosion — •Jan Lorbeer, Marc Teichmann, Frank Frost, and Bernd Rauschenbach — Leibniz Institut für Oberflächenmodifizierung e.V, Leipzig, Deutschland

The pattern formation on sapphire by low-energy ion beam erosion is investigated. In detail the influence of the ion incidence angle ($\theta = 0 - 85$ deg), ion energy ($E_{ion} = 400 - 2000$ eV), ion species (Ne, Ar, Kr, Xe) and fluence ($\Phi \approx 2 \times 10^{18} - 1.5 \times 10^{19}$ cm^{-2}) were evaluated.

In general there are four regimes of surface evolution. At low incidence angles the surface is smoothened with an minimal RMS value of about 90 pm. At angles of around 50 deg a ripple pattern develops. The wavelengths can be tuned in the range from 10 to 50 nm. Following the surface becomes faceted, connectet with a maximum in the surface roughness at about 75 degrees. At even higher incidence angles the surface is smoothened again.

It has been shown, that the regualarity of the formed ripples strongly depends on the ion mass, whereby heavier ions form a more regular surface pattern.

For higher ion energies the onset of ripple formation shifts to higher incidece angles.

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DS 18.3 Wed 10:00 H8

Modelling the etching behavior of GaAs irradiated with protons in a proton beam writing process — •Ulrich Vetter, Tristan Koppe, Charlotte Rothfuchs, and Hans Hofsäss — 2. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

Creating three dimensional structures in semiconductors such as GaAs is a very promising application of proton beam writing [1] which has been realized recently without changing the beam energy or the ion species, but simply by varying the fluence during MeV proton irradiation [2]. In order to predict the evolving structures in the subsequent electrochemical etching process it is desirable predict the 3D damage concentration distribution as input for finite element simulations of the etching process. This distribution is determined from SRIM simulations [3] and the damage dependent transition behavior known from work on proton implantation isolation frequently applied in semiconductor manufacturing processes [4].

[1] J.A. van Kan et al., Appl. Phys. Lett. 83 (2003) 1629.
[2] M. Schulte-Borchers , U. Vetter, T. Koppe, H. Hofsäss, J. Micromech. Microeng. 22 (2012) 025011.
[3] J.F. Ziegler, J.P. Biersack, and M.D. Ziegler. SRIM - The Stopping and Range of Ions in Matter. SRIM Co. 2008.
[4] S.J. Pearton, Mater. Sci. Rep. 4 (1990) 313

DS 18.4 Wed 10:15 H8

Selective deposition of nanospheres in trenches on silicon surfaces by self-organisation — •Katharina Brassat and Jörg K. N. Lindner — University of Paderborn, Paderborn, Germany

The self-organisation of nanospheres on surfaces has been extensively studied in the last decades, as it allows for the simple and cost-effective creation of regular arrays of nano-objects such as metallic nanodots. These can be achieved by nanosphere lithography (NSL), i.e. deposition of a metal through a monolayer of nanospheres acting as a mask. Various techniques have been invented to create nanosphere monolayers as a first step of NSL. In the present work, we use the spreading knife technique as a fast and well controllable large area convective self-assembly technique in order to form chains of nanospheres sitting in a linear trench on a pre-patterned silicon surface. The goal is to use these templates as a deposition mask, by which linear chains of opposing metallic nanotips can be formed. Optical lithography and reactive ion etching (RIE) are used to form trenches on Si(100) wafers whose shape, depth and width are subsequently investigated by confocal laser scanning microscopy (CLSM). Using the spreading knife technique, polystyrene (PS) spheres with a diameter of 2.1 *m are assembled exclusively inside the trenches. This is achieved by optimisation of process parameters and functionalisation of the silicon surface with amphiphilic agent octadecyltrichlorsilane (OTS) which forms a self-assembled molecular monolayer (SAM). By this, linear chains of tangent PS-spheres with a length of up to 0.5 mm are obtained and can be used as a deposition mask.

DS 18.5 Wed 10:30 H8

Nickel Nanodot Arrays on Silicon formed by Nanosphere Lithography: A TEM Study — •Johannes Pauly and Jörg K. N. Lindner — Department of Physics, University of Paderborn, 33098 Paderborn, Germany

Nanosphere lithography (NSL) is a cost-effective bottom-up technique to form equally sized nanodots on surfaces, which can be easily scaled up to large areas. It is based on the self-organized arrangement of colloidal nanospheres in a hexagonally close packed monolayer which serves as a shadow mask for a subsequent thin film deposition process. The lateral size of nanodots and their density depend on the diameter of spheres, while the exact shape of dots depends on the deposition method and the dot/substrate combination used. This is due to the fact that the deposition technique defines the angular distribution of atoms arriving at the sample and the dot/substrate materials combination determines the crystallization and wetting properties of the dots. In addition the clogging of masks strongly affects the growth of dots. While in previous studies mostly scanning electron and atomic force microscopy were used to image dots, in the present study transmission electron microscopy is used to characterize the shape and structure of dots. To this end nanosphere masks of several square centimetre size were prepared on silicon using a doctor blade technique and an aqueous suspension of polystyrene spheres. Nickel thin films were deposited by thermal evaporation at room temperature. It is shown that nanocrystalline triangular Ni dots with extremely sharp tips are formed, the radius of tip curvature being given by the size of Ni grains.

DS 18.6 Wed 10:45 H8

Fabrication and electrical transport properties of binary Co-Si nanostructures prepared by focused electron beam-induced deposition — •Fabrizio Porrati and Michael Huth — Physikalisches Institut, Goethe Universität, Frankfurt am Main

CoSi-C binary alloys have been fabricated by focused electron beam-induced deposition (FEBID) by the simultaneous use of dicobaltoctacarbonyl, $Co_2(CO)_8$, and neopentasilane, Si_5H_{12}, as precursor gases. The alloys are made of Co-Si nanoparticles embedded in a carbonaceous matrix. By varying the relative precursors fluxes, alloys with variable Si:Co ratio are obtained. The electrical transport properties are governed by the electron tunneling between neighboring Co nanoparticles. According with the metal content of the alloy, the electrical conductivity can be tuned from the insulating regime into the

quasi-metallic tunneling coupling regime.

DS 18.7 Wed 11:00 H8

Realizing three-dimensional nanostructures using nano-templates: concept, properties and high performance devices — •Fabian Grote, Liaoyong Wen, Zhibing Zhan, Ahmed Al-Haddad, Yan Mi, Samar Tarish, Chengliang Wang, Ranjith Vellacheri, Huaping Zhao, and Yong Lei — Fachgebiet 3D-Nanostrukturierung, Institut für Physik & IMN MacroNano (ZIK), Technische Universität Ilmenau, Prof. Schmidt Str. 26, 98693 Ilmenau, Germany

Here we introduce a templates-based three-dimensional (3D) nanostructuring technique,[1,2] which has been utilized to fabricate diverse functional 3D nanostructures in our group, including highly ordered arrays of nanowires, nanotubes, core-shell and heterojunction nanowire and tubes. Due to the well-defined structures of nano-porous templates, the structural parameters of the prepared 3D nanostructures can be precisely controlled, such as size, length, spacing and tube thickness. The fabrication processes of the proposed 3D nano-structuring technique is highly cost-effective for preparing large-area of nanostructure arrays, which is desirable for device applications. So far different devices have been constructed based on these 3D nanostructures including supercapacitors, sensors, catalysts and solar cells. The high performance of these devices confirms that this innovative 3D nanostructuring technique is the key to realize the next generation of functional nano-devices. Reference: [1] Y. Lei, S. Yang, M. Wu, G. Wilde, Chem. Soc. Rev. 2011, 40, 1247. [2] Y. Lei, W. Cai, G. Wilde, Progress in Materials Science 2007, 52, 465.

DS 18.8 Wed 11:15 H8

Characterization of high-end photomasks by spectroscopic ellipsometry — •Anett Heinrich[1], Ingo Dirnstorfer[1], Thomas Mikolajick[1], Jörg Bischoff[2], and Uwe Richter[3] — [1]NaMLab gGmbH, 01187 Dresden, Germany — [2]Osires, 98693 Ilmenau, Germany — [3]Sentech Instruments GmbH, 12489 Berlin, Germany

We evaluated spectroscopic ellipsometry as an optical metrology method to determine critical parameters on nanostructured photomasks in high resolution and short process time. An industrial opaque MoSi on glass (OMOG) photomask with line/space gratings consisting of pitches between 280 and 640 nm and different duty cycles was analyzed. The polarization-dependent diffraction effects in Psi and Delta were measured in a wavelength range of 320 to 800 nm. The mask parameters were determined by modeling the ellipsometric response with the rigorous coupled wave analysis (RCWA) method. It was found that the pitch could be determined within sub-nm accuracy down to 130 nm, where the rayleigh singularities move out of the spectral range. The simulated critical dimension (CD) values are systematically smaller than the nominal mask CD. This CD offset was between 10 to 25 nm depending on the absolute CD. A through pitch sensitivity analysis showed that the evaluated metrology is sensitive to CD variations even for sub-50 nm features.