# O 95: Micro- and Nanopatterning (DS jointly with O)

Time: Friday 9:30–11:15 Location: CHE 89

O 95.1 Fri 9:30 CHE 89

**Effect of periodic pre-patterned structures on ripple wavelength and propagation velocity on ion-irradiated surfaces** — •Detlef Kramczynski[1], Bernhard Reuscher[2], and Hubert Gnaser[1,2] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Institute for Surface and Thin-Film Analysis (IFOS), 67663 Kaiserslautern, Germany

Glass surfaces were patterned by milling periodic trench structures with wavelengths from 150 to 750 nm in a focused ion beam (FIB) system. Upon exposure to 30 keV $Ga^+$ ion irradiation under an incidence angle of 52° with respect to the surface normal, these patterns were found to transform into "ripple"-like nanostructures. Their evolution was monitored in situ for ion fluences up to $2.5 \times 10^{18}$ $Ga^+$ ions/$cm^2$ using the scanning electron microscope incorporated in the FIB. With increasing fluence, the wavelengths of the ripples were found to stay constant (and equal to their original feature size) while they propagate across the surface, in a direction which coincides with the projection of the ion beam's incident direction onto the surface. The propagation velocity was determined to scale inversely proportional to the wavelength, being in the range (60-100) nm/($10^{17}$ ions/$cm^2$). On pristine surface areas (which had not been pre-patterned) ripples were also formed by ion bombardment. However, their wavelength was found to increase with ion fluence from initially ∼250 nm to ∼420 nm.

O 95.2 Fri 9:45 CHE 89

**structural evolution upon thermal annealing for Fe ion irradiated Si(100)** — •behnam khanbabaee[1], jörg grenzer[2], stefan facsko facsko[2], and ullrich pietsch[1] — [1]Universität Siegen, Festkörperphysik,Siegen, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, 01314 Dresden, Germany

Off-normal irradiation of Si(100) by Fe ions leads to the surface patterning. In order to understand the mechanism of pattern formation, chemical reactions between Fe and Si atoms have to be considered to influence the surface instability required for pattern formation. Since the as-irradiated surface area is amorphous, we examined the recrystallization process of the Fe-Si layer formed by off-normal 20 keV irradiation using a Si(100) substrate comparing the effect of low (1*10ˆ16 ions/cmˆ2) and high (5*10ˆ17 ions/cmˆ2) fluencies, where only the higher fluence leads to patterned surface. The samples were annealed up to a temperature of 800°C and characterized by in-situ grazing incidence X-ray diffraction (GI-XRD). Depth profiling by GI-XRD confirmed that $\epsilon$-FeSi was formed close to the surface changing to a $\beta$-FeSi2 phase with lower Fe content at larger depths. While the polycrystalline $\beta$-FeSi2 phase dominates for higher ion fluencies, a nearly equal ratio between $\epsilon$-FeSi and $\beta$-FeSi2 is found for lower ones. Our results suggest that phase distribution is related to the Fe concentration profile and can be considered as the relevant factor in the process of pattern formation.

O 95.3 Fri 10:00 CHE 89

**Nano-structured surfaces produced by low energy ion beam sputtering of amorphous $Fe_xSi_{1-x}$ films** — •Kun Zhang, Christoph Brüsewitz, and Hans Hofsäss — II. Physikalisches Institut, Universität Göttingen, Göttingen, Germany

It is well known that metallic surfactants induce pronounced dot and ripple patterns on Si substrate surfaces during normal ion incidence sputter erosion. These surfactant atoms are co-deposited on the substrate surface either from intentional co-deposition or inadvertently contaminations from sputtering of the vacuum chamber walls. In the present contribution we investigate the pattern formation on amorphous $Fe_xSi_{1-x}$ thin films with different Fe atomic fraction x, irradiated with Xe ions of 5 keV and 10 keV energies and normal incidence. In this situation the Fe atoms work as surfactants, but are supplied from the bulk of the substrate. The resulting surface morphologies were examined ex-situ by AFM, while the Fe concentration and its depth profile were determined with RBS and high resolution RBS. Nanopattern forms on the substrates with x = 0.02 - 0.08. In this case Fe atoms accumulate in the surface near region ( 13 nm in depth) after ion irradiation, revealing a phase separation towards a FeSi2 phase. For the samples with x >0.09, the average Fe concentration near the surface exceeds x=0.33 and the surface remains flat. For x <0.02 no pattern formation occurs. The results give further evidence of phase separation as a major drive force for surfactant induced the pattern formation.

O 95.4 Fri 10:15 CHE 89

**Redeposition during ion-beam erosion can stabilize well-ordered nanostructures** — •Christian Diddens and Stefan J. Linz — Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster

We investigate the redeposition effect, i.e. the reattachment of eroded particles on the surface, in the context of self-organized pattern formation on semiconductor targets during ion-beam erosion. Within the framework of a continuum model for this non-local, inherently complicated process, we present (i) the distribution of redepositing particles on the surface, (ii) an approximation of the redeposition effect in terms of the surface height and (iii) the spatio-temporal evolution of one- [1] two-dimensional [2,3] surface morphologies subject to combined erosion and redeposition. We are able to conclude that an interplay of erosion, diffusion and redeposition can reproduce the hexagonally arranged nanodots found in experiments in extended regions of the parameter space.

[1] C. Diddens and S. J. Linz, Eur. Phys. J. B, 86 (2013) 397
[2] C. Diddens and S. J. Linz, EPL, 104 (2013) 17010
[3] C. Diddens and S. J. Linz, (in preparation)

O 95.5 Fri 10:30 CHE 89

**Nanoscale low energy electron induced graphitization in tetrahedral amorphous carbon thin films** — •Frederik Klein and Thomas Mühl — Leibniz Institute for Solid State and Materials Research Dresden, PF 270116, D-01171 Dresden, Germany

Under ambient or vacuum conditions diamond and related materials like tetrahedral amorphous carbon (ta-C) are in a metastable state. By application of energy the material is able to undergo a phase change to a graphitic or $sp^2$-hybridised state. We induce local phase changes in ta-C thin films by eV and low keV electron beams in ultrahigh vacuum provided by a scanning tunneling microscope (STM) and a scanning electron microscope (SEM), respectively. These are accompanied by huge changes in many physical properties such as electrical conductivity.

The graphitization is analyzed by STM-based current-distance spectroscopy and conductive atomic force microscopy (c-AFM). The total tip-sample circuit contains the tunneling gap resistance in series with the resistance of the carbon thin film $R_{\mathrm{carbon}}$. An analysis of the STM spectra provides the tunneling barrier height $\Phi$ and $R_{\mathrm{carbon}}$.

We observe a decrease of $R_{\mathrm{carbon}}$ as well as an increase of $\Phi$ in the graphitized areas. However, an expected surface elevation due to a reduction of the material's mass density cannot be seen.

O 95.6 Fri 10:45 CHE 89

**Surface nanostructuring of fused silica assisted by laser-induced self-assembling of thin metal layers: Theory and experiment** — •Pierre Lorenz[1], Michael Klöppel[2,3], Tomi Smausz[4], Tamas Csizmadia[4], Frank Frost[1], Martin Ehrhardt[1], Klaus Zimmer[1], Bela Hopp[1], and Pu Li[2] — [1]Leibniz-Institut für Oberflächenmodifizierung e. V., Permoserstraße 15, 04318 Leipzig, Germany — [2]Simulation and Optimal Processes Group, Institute of Automation & Systems Engineering, Ilmenau University of Technology, POB 10 05 65, 98684 Ilmenau, Germany — [3]Institute of Scientific Computation, Department of Mathematics, TU Dresden, 01062 Dresden — [4]Department of Optics and Quantum Electronics, University of Szeged, H-6720 Szeged, Dóm tér 9, Hungary

The introduced laser method demonstrates a novel concept of complex nanostructuring of dielectric surfaces assisted by a laser-induced molten metal layer deformation process. This method allows the fast, large-scale, and cost-effective production of randomly distributed surface nanostructures with a lateral dimension down to 10 nm. However, for an optimizing of this process a profound physical understanding is necessary. For this, the process was simulated under the assumption of the heat equation and the Navier-Stokes equations. Furthermore, the resultant structures were investigated dependent on the metal layer thickness and the laser parameter by AFM and SEM. Additionally, the dynamics of the deformation process were analysed by time-dependent

reflection and transmission as well as time-dependent optical microscopic measurement.

O 95.7 Fri 11:00 CHE 89

**Interference Lithography Combined with Hard Anodization Leading to Highly Ordered Nanoporous Alumina** — Josep M. Montero Moreno[1], •Robert Zierold[1], Martin Waleczek[1], Stephan Martens[1], Victor Vega Martinez[2], Victor M. Prida[2], and Kornelius Nielsch[1] — [1]Institut für Angewandte Physik, Universität Hamburg — [2]Department of Physics, University of Oviedo

A perfect order of the pores in nanoporous alumina is desired for application in the fields magneto-optical and opto-electronic devices, photonic crystals, solar cells, fuel cells, and chemical and biochemical sensing systems, to name a few.

We present the fabrication of thick nanoporous $Al_2O_3$ membranes with mono-oriented, perfect hexagonal packing of pores, and precise control of all structural parameters over large areas by matching the conditions of three-beam laser interference lithography and subsequent hard anodization. The periodic concavities after the patterning step in the aluminum surface guide the pore nucleation during the anodization, and the self-ordering phenomenon guarantees the maintenance of the predefined arrangement throughout the entire layer.

The cylindrical pores—diameters adjustable between 20 and 450 nm with advanced post-processing techniques such as atomic layer deposition or selective-chemical etching—are uniform in shape and widely tunable in their dimensions with aspect ratios as high as 500. With that technique, the interpore distance can be easily and accurately tuned in the range of 200 to 500 nm without time-consuming prefabrication of hard-masking stamps.