
Investigation of surface modifications induced by swift heavy ions in the MeV regime. Part II : Theory — O. Osmani, M. Schleberger, Universität Duisburg-Essen, Fachbereich Physik, Lotharstrasse 1, 47048 Duisburg — Université de Lorraine, Institut de Physique Nucléaire, F-54000 Nancy, France — Université des Sciences et Technologies de Lille, Institut de Physique Nucléaire de Lille, F-59000 Lille, France

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Experimental data on (AFM, STM) track formation after irradiation at varying angle of incidence from 90° down to 0.3°. Especially at grazing angle of incidence, elongated chains of nanohillocks with lengths of about several hundred nanometers can be created. A statistical analysis of the track length and distance between the neighboring hillocks shows a strong dependence on the angle of incidence. Based on these experimental results a new approach describing the track formation could be developed.

The formation of surface-nanostructures with a characteristic size ranging from several nanometer up to microns has attracted significant interest in the last decades in the context of fabrication of novel opto-electronic and storage devices. One kind of these nanostructures are wave-like patterns (ripples) produced by an interplay between a roughening effect caused by ion beam erosion (sputtering) of the surface and smoothening processes caused by surface diffusion. In this contribution we report on investigations of patterned Si (001) surfaces under target rotation. After transformation, this model stands the initiation of the ripple formation we also ask the question which role the initial surface structure plays. Therefore we investigate the formation of ripples on pre-structured and rough surfaces such as wafers with an intentional miscut. Therefore, we not only introduce a certain initial roughness but also vary the orientation of the (100) lattice plane in respect to the surface. We try to distinguish between ion beam induced surface effects (sputter erosion) and the influence of the crystalline Si lattice (strain) on the ripple formation.


A recently proposed continuum model [1] for the formation of nanostructures on semiconductor surfaces generated by low-energy ion-beam erosion under normal and oblique ion incidence is generalized to the case of additional target rotation. After transformation, this model takes on the form of a driven damped isotropic Kuramoto-Sivashinsky equation. Primary focus of our investigation [2] is the theoretical analysis of the competition of flat, hexagonal and square-like surface structures as function of the external rotation rate and the sputtering time. As a major result, we find that target rotation stabilizes the occurrence of flat surfaces. Comparison with recent experimental results will also be given.

Electron beam stimulated thermal desorption of oxygen: a lithographic method — J. Ronspies, T. Block, S. Vagt, and H. Penner — Universität Hannover, Institut
We explored the structural limits of unconventional electron beam lithography by directly writing with an electron beam into ultra-thin SiO$_2$ films. These bare silicon windows structures are suitable for growing contiguous metallic nanowires with thickness of a few monolayers.

These uncovered structures with lateral dimensions down to 10nm were analyzed further by tunneling microscopy. The Auger excitation process (Knotek-Feibelman mechanism) necessary for electron-beam stimulated thermal desorption of oxygen (EBSTD) allows generation of ultra-small structures. The subsequent processing step combines thermal desorption of the remaining monoxide and simultaneous etching promoted by thermally activated silicon atoms, which turns out to be a strongly anisotropic process close to step edges. Applying this combination of processes to a regularly stepped Si (557) sample which consists of a periodic array of small (111) and (112) oriented mini-facets with an average periodicity of 5.7 nm normal to the steps, line widths close to the resolution of the electron microscope of 5nm were obtained. Thus exploitation of the quantized nature of ultrasmall structures far above liquid He temperatures becomes feasible as well as contacting of single molecules.

**O 53.8**  Wed 17:00  MA 043

**A new approach to Electron Beam Chemical Lithography** — **Nirmalya Ballav, Sören Schidl**, and **Michael Zahnke**

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We present a new lithographic technique - electron beam chemical lithography (EBCL) with aliphatic self-assembled monolayers (SAMs) as resist materials. The technique is based on irradiation-promoted exchange reaction (IPER). The key idea of the IPER approach is to use an ICP exchange-reaction between a SAM covering the substrate and a potential molecular substrate by electron irradiation, which allows to get binary mixed SAMs of variable composition depending on the dose. Since the irradiation can be performed by a focused electron beam, IPER can be directly implemented into the lithographic framework and used for the fabrication of different chemical patterns on micro- and nanometer length scales. We demonstrated a feasibility of such approach by the preparation of chemical templates for the surface-induced polymerization (SIP) of the test polymer poly-N-isopropylacrylamide. Using these templates, we fabricated polymer micro- and nanobrushes in a broad height range. The advantages of EBCL-IPER are (i) the use of commercially available aliphatic compounds; (ii) a broad variety of different chemical patterns; and (iii) much lower patterning dose as compared to aromatic resists used before for EBCL. The approach is not limited by SIP, but can be used for different applications, relying on chemical patterning, e.g. biomedical studies and sensor fabrication.

**O 53.9**  Wed 17:15  MA 043

**Lithographic Fabrication of Clean Oxidic Nanostructures by Means of Electron-Beam Induced Deposition (EBID)** — **Michael Schirmer, Thomas Lukaszyck, Florian Vollnhals, Miriam Schwarz, Hans-Peter Steinrück**, and **Hubertus Marbach**

— Universität Erlangen-Nürnberg, Lehrstuhl für Physikalische Chemie II, Egerlandstraße 3, D-91058 Erlangen, Germany

In this contribution we present a route to generate iron oxide and titanium oxide nanostructures on different surfaces. The method we use is electron-beam induced deposition (EBID) in ultra high vacuum (UHV), in which a highly focused spot of electrons is utilized to locally crack adsorbed precursor molecules, resulting in the deposition of non-volatile fragments. An electron-column, integrated in an UHV-Chamber, in combination with a lithographic package enables the controlled fabrication of nanostructures, which can be characterized via scanning electron microscopy, scanning tunneling microscopy and Auger electron spectroscopy. The precursor iron pentacarbonyl (Fe(CO)$_5$) proved to be very effective for the generation of pure iron structures on silicon and rhodium single crystal surfaces. For both substrates the deposits are composed almost completely of iron. Interestingly, on Si(100), the deposited nanostructures are discontinuous in shape, consisting of pure iron dots smaller than 10 nm. The deposit purity and appearance is greatly influenced by the substrate temperature and the surface condition. Furthermore, it will be discussed that UHV is mandatory to achieve pure metal deposits. This work was supported by the Deutsche Forschungsgemeinschaft under grant MA 4246/1-1.

**O 53.11**  Wed 17:45  MA 043

**Surface nano-patterns with high structural regularity, tunable properties, and diverse applications** — **Yong Lei and Gerhard Wild**

Institut für Materialphysik, Universität Münster

Ordered arrays of surface nanostructures (nanodots and nanoholes) and free-standing one-dimensional nanostructures (nanotubes and nanowires) were fabricated using vacuum evaporation processes and an ICP-RIE plasma etcher is used subsequently. CF$_4$/O$_2$-gas mixtures were applied for manipulation of Si$_3$ and SiO$_2$ surfaces. The order of the masks is transferred into arrays of pillars or holes from the sub10 nm scale to standard subµm scale with aspect ratios of about 10. The mask fabrication offers the possibility for nonperiodic arrangements. Some examples of application will be given.


**O 53.12**  Wed 18:00  MA 043

**Ordered nanomasks on Si and SiO$_2$ surfaces for the preparation of templates on the nanoscale** — **Alfred Plett, Mathias Sattner, Fabian Enderle, Achim Manzke, Christian Pfeiffer, and Paul Ziemann**

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Periodically ordered nanomasks are generated by a micelle technique [1], a miniemulsion technique [2] and an extension of a well known colloidal patterning method (Fischer pattern) to the sub100 nm regime by a new isotropic plasma etching procedure. For template preparation an ICP-RIE plasma etcher is used subsequently. CF$_4$/CHF$_3$/O$_2$-gas mixtures were applied for manipulation of Si$_3$ and SiO$_2$ surfaces. The order of the masks is transferred into arrays of pillars or holes from the sub10 nm scale to standard subµm scale with aspect ratios of about 10 for the smallest structures. Combining these unconventional lithography techniques with the conventional electron beam lithography offers the possibility for nonperiodic arrangements. Some examples of application will be given.

Self-organized surface patterns (ripples) were induced on different materials (dielectrics, semiconductors, metals and amorphous silica) by femtosecond laser irradiation with intensity below the single-shot damage threshold. In all cases, the dependence on characteristic features like irradiation dose and laser polarization was studied in our experiments. It is shown, that general features of the surface patterns do not depend on the type of material, nor was any correlation to the atomic structure of the irradiated surface detected. Instead, in all materials a similarly strong correlation between polarization direction of the laser beam and the orientation of the ripples is observed. The main difference between the different targets, however, is the intensity dependence of typical feature sizes and a specific window of irradiation dose for each material to produce surface nano-pattering.