O 53: Surface Nanopatterns

Time: Wednesday 15:15–18:30 Location: MA 043

O 53.1 Wed 15:15 MA 043

Investigation of surface modifications induced by swift heavy ions in the MeV regime. Part I: Experiment — •Sevilay Akcöltekin and Marika Schleberger — Universität Duisburg-Essen, Fachbereich Physik, Lotharstrasse 1, 47048 Duisburg

Over the past few years, ion-induced track formation on various crystal surfaces have been observed in many studies. Depending on the energy and charge state of the projectile-ions as well as the target properties, track production can turn out differently. Experimental investigation of track creation on different sample surfaces with energetic heavy $^{131}Xe^{23+}$ (0.71 MeV/u) and $^{207}Pb^{28+}$ (0.51 MeV/u) projectiles in the electronic stopping regime are discussed in the present work. Focusing on two classes of target materials such as oxides ($SrTiO_3$, TiO_2, Al_2O_3) and highly oriented pyrolytic graphit (HOPG), we present 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.

O 53.2 Wed 15:30 MA 043

Investigation of surface modifications induced by swift heavy ions in the MeV regime. Part II : Theory — •Orkhan Osmani[1,2] and Marika Schleberger[1] — [1]Universität Duisburg-Essen, Fachbereich Physik, Lotharstrasse 1, 47048 Duisburg — [2]TU Kaiserslautern, Fachbereich Physik, Gottlieb-Daimler-Straße, 67653 Kaiserslautern

In the last few years various experiments on ion-solid interactions have been performed. In a recent experiment structural chain like surface modifications with chain length up to some micrometers have been observed. These modifications are strongly dependent on the angle of incidence and believed to be created by local melting of the solid due to the energy transfer of the ion to the solid. An new model will be presented which is capable to describe the energy loss of a swift heavy ion penetrating an insulator like $SrTi0_3$ and the creation of the so called nanodots. At ion energies of several 10 MeV to 100 MeV the energy loss is due to electronic stopping only. To describe the electronic excitation induced bye the ion–electron interaction we use an approach taking the electronic density into account. Time and spatially resolved energy losses are calculated and used as sourceterms for the electrons within a Two–Temperature–Modell. Finally, the relaxation of the electrons by simultaneous phononic excitation leads to a phononic temperature distribution. In this way, it can be checked if the phononic temperature is above the melting temperature, thus leading to a thermal melting.

O 53.3 Wed 15:45 MA 043

X-ray scattering and diffraction from Xe-induced ripples in crystalline silicon — •Andreas Biermanns[1], Ullrich Pietsch[1], Souren Grigorian[1], Jörg Grenzer[2], Stefan Facsko[2], Antje Hanisch[2], Dina Carbone[3], and Hartmut Metzger[3] — [1]Universität Siegen, Germany — [2]Foschungszentrum Dresden-Rossendorf, Germany — [3]ID01 beamline, ESRF, France

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 those nanostructures are wave-like patterns (ripples) produced by an interplay between a roughening process 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 after irradiation with Xe^{+}-ions using ion-energies up to 40keV. During the sputtering, an amorphous surface-layer is formed followed by a rather sharp interface towards crystalline material, showing the same morphology as the surface. The structures of the amorphous layer and the amorphous-crystalline interface were studied by means of grazing-incidence - small angle scattering (GISAXS) and diffraction (GID) using synchrotron-radiation. We found that the crystal structure at the interface is expanded along the ripples, caused by the creation of defects inside the surface region, whereas this expansion is strongly reduced across the ripples. This different relaxation may play a driving role in pattern formation at the interface.

O 53.4 Wed 16:00 MA 043

High energy Xe^{+} ion beam induced ripple structures on silicon — •Antje Hanisch[1], Joerg Grenzer[1], Stefan Facsko[1], Ingolf Winkler[1], Andreas Biermanns[2], Souren Grigorian[2], and Ullrich Pietsch[2] — [1]Forschungszentrum Dresden-Rossendorf, Institute for Ion Beam Physics and Materials Research, Bautzner Landstrasse 128, 01328 Dresden, Germany — [2]University of Siegen, Institute of Physics, Walter-Flex-Strasse 3, 57078 Siegen, Germany

Ion beam bombardment on semiconductor surfaces leads to well-defined morphological structures in the nanoscale range. Due to the impact of ions a self-organized wave-like surface structure develops. Ion bombardment causes an amorphization of a surface-adjacent layer of several nanometers and creates a periodical structure on the surface as well as at the amorphous-crystalline interface. We investigate the dependence of the periodicity on the crystallography of (100) silicon bombarded with Xe^{+} ions, the ion beam incidence and the azimutal angle of the sample surface. So far we found that the ripple wavelength scales with the ion energy in a range of 5 to 70 keV. In order to understand 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.

O 53.5 Wed 16:15 MA 043

Continuum model for pattern formation on ion-beam eroded surfaces under target rotation — •Karsten Dreimann and Stefan Jakob Linz — Institut für Theoretische Physik, Universität Münster, Wilhelm-Klemm-Straße 9, 48149 Münster, Germany

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 occurence of flat surfaces. Comparison with recent experimental results will also be given.

[1] S. Vogel, S.J. Linz, Europhys.Lett. **76**, 884-890 (2006)
[2] K. Dreimann, S.J. Linz, unpublished

O 53.6 Wed 16:30 MA 043

Bifurcation behavior of the anisotropic damped Kuramoto-Sivashinsky equation — Christian Rehwald, Karsten Dreimann, Sebastian Vogel, and •Stefan Jakob Linz — Institut für Theoretische Physik, Universität Münster, Wilhelm-Klemm-Straße 9, 48149 Münster, Germany

A recently proposed continuum model [1] for the formation of surface patterns on semiconductor surfaces generated by low-energy ion-beam erosion under normal and oblique ion incidence is studied in analytical and numerical details. After transformation, this model takes on the form of a damped anisotropic Kuramoto-Sivashinsky equation. Primary focus of our investigation [2] is the theoretical analysis of the competition of flat, rhombic and ripple-like surface structures and their stability and bifurcation behavior as function of the entering parameters. Comparison with recent experimental results will also be given.

[1] S. Vogel, S.J. Linz, Europhys.Lett. **76**, 884-890 (2006)
[2] C. Rehwald, K. Dreimann, S. Vogel, S.J. Linz, unpublished

O 53.7 Wed 16:45 MA 043

Electron beam stimulated thermal desorption of oxygen: a lithographic method — •Jan Rönspies, Tammo Block, Svend Vagt, and Herbert Pfnür — Leibniz Universität Hannover, Institut

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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 contigous metallic nanowires with thickness of a few monolayers.

These uncovered structures with lateral dimensions down to $10nm$ were analyzed futher 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 simultanous 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 $5.7nm$ 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 Schilp, and Michael Zharnikov — Angewandte Physikalische Chemie, Universität Heidelberg, 69120 Heidelberg, Germany

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 tuning the extent of the exchange-reaction between a SAM covering the substrate and a potential molecular substituent 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 pattern 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 Lukasczyk, 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). Hereby, the beam of a high resolution UHV scanning electron microscope (SEM, spot size < 3 nm) is exploited to locally crack certain precursor molecules resulting in a deposit of the non volatile fragments. Two pathways to generate oxidic nanostructures are explored: (a) the selective oxidation of clean metallic EBID nanostructures (FeO_x on Rh(110)); (b) the direct EBID deposition of oxide structures (TiO_x on Si(001)) using a metal- and oxygen-containing precursor molecule. The latter approach leads to deposits, which contain large amounts of carbon from the precursor molecule titanium (IV) isopropoxide. Postannealing while dosing oxygen leads to the formation of clean TiO_x nanocrystallites as verified by local Auger spectroscopy. The growth of the crystallites can be observed in situ by means of SEM. Latest results and the perspective of this method will be discussed. This work was supported by the Deutsche Forschungsgemeinschaft under grant MA 4246/1-1.

O 53.10 Wed 17:30 MA 043

Fabrication of Clean Iron Nanostructures with Arbitrary Shape via an Electron-Beam Induced Process — •Thomas Lukasczyk, Michael Schirmer, Hans-Peter Steinrück, and Hubertus Marbach — Lehrstuhl für Physikalische Chemie II, Universität Erlangen-Nürnberg, Egerlandstr. 3, D-91058 Erlangen

The generation of pure metallic nanostructures with arbitrary shape is still a fundamental challenge in the fast growing field of nano science. Our approach is the technique of 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 metallic 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 Wilde — Institut für Materialphysik, Universität Münster

Ordered arrays of surface nanostructures (nanodots and nanoholes) and free-standing one-dimensional nanostructures (nanotubes and nanowires) were fabricated on flat substrates using an UTAM (ultra-thin alumina mask) surface nano-patterning technique. The nanodot and nanohole arrays were prepared using vacuum evaporation processes and focused-ion-beam etching, respectively, while the nanowire and nanotube arrays were prepared using electrochemical processes and CVD processes. The structural parameters (size, spacing, and shape) of the UTAM-fabricated surface nanostructures can be adjusted by controlling the pore size of the UTAMs. The advantages of the UTAM surface nano-patterning, such as the achievement of tunable structural parameters and properties, large pattern area, high throughput and low equipment costs, make the technique suitable for fabricating ordered surface nanostructures with a broad range of applications ranging from optical, sensing, and electronics devices.

References: 1. Y. Lei, W.P. Cai, G. Wilde, Prog. Mater. Sci., 52 (2007) 465-539. 2. Y. Lei, Z. Jiao, M.H. Wu, G. Wilde, Adv. Eng. Mater., 9 (2007) 343-348. 3. Y. Lei, et al., Chem. Mater., 17 (2005) 580-585. 4. Y. Lei, W.K. Chim, H.P. Sun, G. Wilde, Appl. Phy. Lett., 86 (2005) 103106. 5. Y. Lei, W.K. Chim, J. Weissmuller, G. Wilde, et al., Nanotechnology, 16 (2005) 1892-1898. 6. Z. Chen, Y. Lei, et al., J. Cryst. Growth, 268 (2004) 560-563.

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 Plettl, Marc Saitner, Fabian Enderle, Achim Manzke, Christian Pfahler, and Paul Ziemann — Institut für Festkörperphysik, Universität Ulm, D-89069 Ulm, Germany

Periodically ordered nanomasks are generated by a micellar 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-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.

[1] G. Kästle et al., Adv. Funct.Mat. 13, 853 (2003).
[2] A. Manzke et al., Adv. Mater. 19, 1337 (2007).
[3] S. Brieger et al., Nanotechnology 17, 4991 (2006).

O 53.13 Wed 18:15 MA 043

Self-organized nano-patterning of solid surface: dependence on the target material — •Olga Varlamova[1,2], Guobin Jia[2], and Juergen Reif[1,2] — [1]LS Experimentalphysik II, BTU Cottbus, Konrad-Wachsmann-Allee 1, 03046 Cottbus — [2]IHP/BTU Joint-Lab, Konrad-Wachsmann-Allee 1, 03046 Cottbus

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.