# DS 20 Ion beam induced nanostructures

Time: Thursday 14:00–16:15 Room: GER 37

## Invited Talk DS 20.1 Thu 14:00 GER 37

**Nanostructures by grazing incidence ions: ripple patterns, athermal coarsening and subsurface channeling** — •Thomas Michely — I. Physikalisches Institut, RWTH Aachen, 52056 Aachen

The recent years showed significant progress in our ability to use ion beams for the controlled patterning of surfaces. New applications of such patterned substrates as functional surfaces or templates for subsequent growth of thin films emerge. Nevertheless, our present understanding of the atomic scale mechanisms governing pattern formation is still poor.

With the help of scanning tunneling microscopy investigations and molecular dynamics simulations a few steps towards a better understanding of metal surface patterning in the grazing incidence ion beam geometry could be made. Most surprising, pattern formation depends crucially on the angle of incidence of the ions. As soon as this angle allows subsurface channeling of the ions, pattern regularity and alignment with respect to the ion beam greatly improves. These effects rare traced back to the positionally aligned formation of vacancy islands through the damage created by the ions at dechanneling locations. The long term pattern evolution is characterized by a temperature independent increase of the ripple pattern wavelength. This coarsening is shown to be due to pattern defects, which travel in the ion beam direction and perform defect reactions.

The contributions of Henri Hansen, Alex Redinger, Sebastian Meßlinger, Yudi Rosandi and Herbert Urbassek to this work are acknowledged.

DS 20.2 Thu 14:45 GER 37

**Self-organized pattern formation on Si and Ge surfaces during low-energy ion beam erosion** — •Frank Frost, Bashkim Ziberi, and Bernd Rauschenbach — Leibniz-Institut für Oberflächenmodifizierung e. V., Permoserstrasse 15, D-04318 Leipzig

Self-organization during low-energy ion bombardment or erosion of solid surfaces is a promising approach for the generation of large-area nanostructured surfaces. In addition to superficial materials removal upon sputtering, caused by energy and momentum transfer from the incoming ions to target atoms, the interplay between sputter-induced roughening and various surface relaxation mechanisms can lead to a wide range of surface topographies and patterns. In this contribution recent findings on topography evolution on Si and Ge surfaces caused by low energy noble gas ion beam erosion ($Ar^+$, $Kr^+$, $Xe^+$; $E_{ion} \leq 2000$ eV)at normal and oblique ion incidence at room temperature are summarized. In particular, it is demonstrated that various surface topographies do arise during erosion of surfaces depending on ion species, ion energy and ion incidence angle. Examples for highly ordered dot as well as ripple pattern are shown where the size of the individual structure elements (ripples or dots) is well below 50 nm.

DS 20.3 Thu 15:00 GER 37

**Formation of nanopatterns induced by low-energy ion sputtering of Si surfaces** — •Frank Rotter[1], Kun Zhang[1], Carsten Ronning[1], Hans Hofsäss[1], Michael Uhrmacher[1], and Johann Krauser[2] — [1]II. Physikalisches Institut and SFB 602, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]Fachbereich Automatisierung und Informatik, Hochschule Harz, Friedrichstraße 57-59, D-38855 Wernigerode

Sputter erosion of Si generates nanoscale ripple patterns which are stable at ambient conditions and which may serve as experimental test of ripple formation theories. This ion-beam induced surface morphology evolution is the result of a balance between ion beam erosion roughening and soothing surface diffusion processes. The evolution of Si surfaces has been investigated using atomic force microscopy after low-energy ($\leq$ 50 keV) $Xe^+$ ion irradiation at room temperature with ion-fluences up to $1 \cdot 10^{17}$ ions/cm$^2$. Different effects have been observed as a function of the incidence angle of the ion beam: mount-like roughening occurs near normal direction ($\theta \leq 45°$); whereas, ripple formation takes place for $\theta \geq 60°$ with the wave-vector parallel or perpendicular to ion-beam direction, depending on the incidence angle and the ion-fluences. Furthermore it is found that the orientation of the induced ripple pattern switches from perpendicular to parallel with increasing the ion-fluence at glance incidence angle ($\theta \geq 80°$).

DS 20.4 Thu 15:15 GER 37

**In-situ X-Ray Diffraction of GaSb Nanopatterned by Normal Incidence Sputter Erosion** — •Adrian Keller[1], Stefan Facsko[1], Olivier Plantevin[2,3], Dina Carbone[2], Hartmut Metzger[2], and Raul Gago[4] — [1]IIM, Forschungszentrum Rossendorf, Dresden, Germany — [2]ID01, ESRF, Grenoble, France — [3]CSNSM, Orsay, France — [4]CMAM, Universidad Autónoma de Madrid, Spain

Low energy ion erosion of surfaces can lead to the formation of self-organized structures in the range from 10 to 100 nm [1]. Periodic ripple patterns and hexagonally ordered dot arrays can be achieved for oblique and normal incidence, respectively. The evolution of ripple structures on different materials has been studied extensively during the last decades whereas the formation of dots has been discovered only recently [2] and is not fully understood yet. In the presented work, the evolution of GaSb(001) surface morphology under normal incidence sputtering has been studied *in-situ* by Grazing Incidence Small Angle X-ray Scattering (GISAXS) and Grazing Incidence Diffraction (GID) measurements which have been performed at the beam line ID01 at the ESRF. These techniques were used to study the evolution of the dots for ion energies from 100 to 1000 eV. With GISAXS the morphology and the correlation of the dots is analysed, while in GID information about the crystalline structure (i.e. strain) is added. This way, three regimes are observed and identified as smoothing, pattern formation and increase of lateral order.

[1] M. Navez, D. Chaperot and C. Sella, C. R. Acad. Sci. 254 (1962), 240
[2] S. Facsko et al., Science 285 (1999), 1551

DS 20.5 Thu 15:30 GER 37

**Ripple to dot transition on Si and Ge surfaces by ion beam erosion** — •Bashkim Ziberi[1], Frank Frost[1], Dina Carbone[2], Hartmut Metzger[2], and Bernd Rauschenbach[1] — [1]Leibniz-Institut für Oberflächenmodifizierung e. V., Permoserstr. 15, D-04318 Leipzig, Germany — [2]ID01, ESRF, Grenoble, France

In the last years, pattern formation during low-energy ion beam erosion becomes a promising tool for large-area and cost-efficient nanostructuring of surfaces. Due to self-organization processes caused by low-energy ion beam erosion, well arranged nanostructures can evolve on different materials. In this contribution results for noble gas ion beam erosion (ion energy $\leq$ 2000 eV) of silicon and germanium semiconductor surfaces under oblique ion incidence without sample rotation are presented. It will be shown that in both materials there is a continuous transition from ripple to dot patterns by varying the ion incidence angle from 5 deg up to 35 deg. The evolving dots, with a mean size of $\approx$ 45 nm, show a large area ordering given by the previous existence of ripples. For Si square arrays of almost perfectly ordered dots evolve on the surface, while for Ge the dots show a hexagonal ordering. The formation of the dot nanostructures is influenced by different parameters of the ion beam. Additionally, a appropriate adjustment of the ion optical parameters of the broad beam ion source offers the possibility to influence the large-area ordering of dots. The surface topography and structure ordering are analyzed using high resolution scanning force microscopy (AFM) and grazing incidence small angle x-ray scattering and diffraction (GISAXS/GID).

DS 20.6 Thu 15:45 GER 37

**Ion sputtering induced surface nanostructuring of ferromagnetic thin films** — •Kun Zhang[1], Frank Rotter[1], Carsten Ronning[1], Hans Hofsäss[1], Michael Uhrmacher[1], and Johann Krauser[2] — [1]II. Physikalisches Institut and SFB 602, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]Fachbereich Automatisierung und Informatik, Hochschule Harz, Friedrichstraße 57-59, 38855 Wernigerode, Germany

We have investigated the possibility of nanoscale ripple formation on polycrystalline iron and nickel thin films (typically of 100 nm in thickness) and the correlation between surface morphology and magnetic textures of these films. Sputter erosions were performed by using Xe ions at room temperatures with energies between 4 keV and 10 keV, ion fluences up to $1{\times}10^{17}$ ions/cm$^2$, and incidence angle up to 85° respective to the surface normal. Atomic force microscopy, magneto optical Kerr effect, and Rutherford backscattering have been used to characterize the evolution of surface morphology, magnetic properties and sputter yield, respectively. The as-deposited films have a rms roughness of 1 nm and magnetically isotropic properties. The sputter erosion increased the surface roughness and decreased the coercive field of the films. Ripple formation was observed at incidence angles of $\theta \geq 80°$ for an ion-energy of 5 keV and an ion-fluence of $1\times10^{16}$ ions/cm$^2$. A small uniaxial magnetic anisotropy was detected being parallel to the ripple orientation and the direction of the incident ion beam.

DS 20.7 Thu 16:00 GER 37

**Self-organized nanoscale multilayer growth during the deposition of hyperthermal species** — •Hayo Zutz[1], Inga Hannstein[1], Carsten Ronning[1], Michael Seibt[1], Hans Hofsäss[1], Wan-Yu Wu[2], and Jyh-Ming Ting[2] — [1]2. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen — [2]Department of Materials Science and Engineering, National Cheng Kung University, Tainan, Taiwan, ROC

The quasi-simultaneous deposition of low energy mass selected $C^+$ and either $Au^+$ or $Fe^+$ ions resulted in the formation of alternately metal-rich and metal-deficient layers with periods in the nm range. Transmission electron microscopy reveals that the metal-rich layers consist of rather densely distributed crystalline particles while the metal deficient layers are amorphous or contain only smaller numbers of crystalline clusters. The concentration variation is confirmed by Rutherford backscattering spectroscopy and Auger electron spectroscopy depth profiling. A similar structure was found in films grown by dc-magnetron sputtering of Cu, Pt, and Ni targets in an Ar/$CH_4$ plasma. The processes during mass selected ion beam deposition and magnetron sputtering deposition are far from thermodynamical equilibrium. Therefore, the formation of such periodic concetration variations cannot be attributed to mechanisms like Liesegang pattern formation. The multilayer formation can be decribed by an interplay of sputtering, surface segregation, ion induced diffusion, and the stability of small clusters against ion bombardment.