DS 25: Trends in Ion Beam Technology: From the Fundamentals to the Application

Time: Thursday 11:15–13:00 Location: H 2013

DS 25.1 Thu 11:15 H 2013

Nano-Structures made by Swift Heavy Ions — •Wolfgang Bolse[1], Hartmut Paulus[1], Thunu Bolse[2], and Lothar Bischof[3] — [1]Institut für Halbleiteroptik und funktionelle Grenzflächen, Universität Stuttgart — [2]Institut für physikalische Chemie, Universität Stuttgart — [3]Institut für Ionenstrahlphysik und Materialforschung, Forschungszentrum Rossendorf

Recently we have discovered that the irradiation of thin oxide films with swift heavy ions (SHI) at small incident angles results in an instability of the film against periodic cracking and subsequent reorganisation on a sub-micron level due to ion hammering. Varying the conditions during irradiation (ion species, rotating the target) we were able to generate a wide range of nano-structures and patterns, the most interesting of which was an array of NiO-nanopillars with a diameter of the order of 100 nm and a height of about 2000 nm. Unfortunately, the arrangement of these nanotowers was not regular. [1] To overcome this problem, we have prestructured the films by means of a focused ion beam with an array of perpendicular cuts of about 100 nm width and 1000 nm distance. In fact, the subsequent irradiation with SHI under grazing incidence and permanent target rotation results in an ordered array of the NiO nanotowers. To our surprise, the same treatment of TiO-films lead to an ordered pattern of holes.

[1] W. Bolse, T. Bolse, C. Dais, D. Etissa-Debissa, A. Elsanousi, A. Feyh, M. Kalafat, H. Paulus, Surf. Coat. Technol. 200 (2005) 1430

DS 25.2 Thu 11:30 H 2013

Experimental demonstration of a determinstic single ion source with an expected implantation resolution of a few nm — •Kilian Singer, W. Schnitzler, N. M. Linke, J. Eble, and F. Schmidt-Kaler — Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, D-89069 Ulm

We have realized a universal deterministic single ion source on the basis of an ion trap applicable to a wide range of elements and molecules[1]. Initially, cold $^{40}Ca^{+}$ ion crystals are trapped within a segmented linear trap. Those ions are then deterministically extracted and shot into a detector at a distance of 25 cm from the trap. With single ions, more than 90% of these extractions were successful. The kinetic energy distribution of the ions amounts to less than 0.1%. We have also demonstrated the extraction of mixed crystals containing other dopant ions. For the implantation with nm precision, we plan to utilize an electrostatic Einzel-lens to further improve the spatial resolution of the extracted ions. These can then be used to generate color centers in diamond for optical detection or to implant P into Si. Both systems provide the foundation for the realization of a solid state quantum computer [2,3]. In addition, the electrical properties of semiconductor devices can be greatly enhanced by the deterministic implantation of single ions [4].

[1] J. Meijer et. al., Appl. Phys. **A 83**, 321 (2006).
[2] F. Jelezko et. al., Phys. Rev. Lett. **93**, 130501 (2004).
[3] B. E. Kane, Nature **393**, 133 (1998).
[4] T. Shinada et. al., Nature **437**, 1128 (2005).

DS 25.3 Thu 11:45 H 2013

Fabrication of novel pinholes for digital in-line X-ray holography by FIB and their application — •Ruth Barth[1], Todd Simpson[2], Silvia Mittler[2], Michael Grunze[1], and Axel Rosenhahn[1] — [1]Angewandte Physikalische Chemie, Universität Heidelberg — [2]Department of Physics and Astronomy, The University of Western Ontario, Canada

One way of adapting the classical Gabor geometry for in-line holography to photons instead of electrons includes a pinhole which provides a diverging photon beam and a detector to record the hologram. As the resolution is determined by the wavelength of the photons and the numerical aperture of the detection system, it is straightforward to increase the photon energy in order to enhance the performance of the technique. Vacuum-ultraviolet (VUV) synchrotron radiation has been successfully utilized for this purpose, and the implementation of digital Gabor microscopy with 14 nm radiation was proven. As the effective numerical aperture is limited by the size of the central Airy maximum, which is in turn inversely depending on the diameter of the pinhole, small apertures with sizes of the order of the wavelength are desired. We show the application of new pinholes produced by Focused Ion Beam milling through thin gold membranes. Due to the high aspect ratio of about 1:5 to 1:10 it is possible to obtain homogeneous illumination of the CCD chip by the central Airy maximum without direct beam contribution. With these new point sources for soft X-ray holography reconstructions with resolution of presently 400 nm are possible.

DS 25.4 Thu 12:00 H 2013

Optical anisotropy induced by oblique incidence ion bombardment of Ag(001) — •Herbert Wormeester, Frank Everts, and Bene Poelsema — Solid State Physics, MESA+ Institute for Nanotechnology,

Oblique incidence ion sputtering has become a widely used method for the creation of highly regular patterns of lines and dots. On a Ag(001) surface oblique incidence sputtering creates a ripple pattern that exhibits plasmonic features. The photon energy of the plasmonic feature depends on the ripple periodicity. The development of these anisotropic features was measured in-situ with the optical technique Reflection Anisotropy Spectroscopy (RAS) for 2 keV Ar ions with a flux of a few $\mu A/cm^2$ in a temperature range of 300 - 420K. With RAS, a periodicity of ripples above 200 nm is measured by a shift in photon energy of the plasmon resonance. Features with a smaller periodicity show a plasmon resonance around 3.65 eV. The Rayleigh-Rice description for scattering from a slightly rough surface enables to relate the measured plasmonic feature quantitatively to the ripple's rms, wavelength and wavelength distribution. Ripple patterns created with ions at 70° and 80° polar angles of incidence are compared. High resolution LEED measurements after sputtering are used to determine the facet angles of the created ripples.

DS 25.5 Thu 12:15 H 2013

Chemical epitaxy of quartz after alkali-ion implantation: luminescence and surface structure — Stanislawa Gasiorek[1], Juhani Keinonen[1,2], •Klaus-Peter Lieb[1], Pratap Sahoo[1], and Timo Savajaara[2] — [1]II. Physikalisches Institut, Universität Göttingen, D-37077 Göttingen — [2]Accelerator Laboratory, FI-00014 University of Helsinki

Doping of alpha-quartz by ion implantation leads to amorphization even at low fluences, but subsequent annealing in air or oxygen can restore the crystalline order (chemical epitaxy [1,2]). Here we report on measurements of Rutherford backscattering channeling (RBS-C) and cathodoluminescence (CL) spectra during chemical epitaxy of quartz irradiated with Na and Rb ions and annealed in 18O-gas. In particular, the variation of the damage profile and CL spectra (the latter taken at 10 K and 300 K) as functions of the Na-ion fluence will be discussed. The CL spectra at 10 K are dominated by a 2.90-eV band and differ greatly from the ones taken at 300 K. Conclusions concerning the underlying photoactive defect structures will be drawn. A spider-net type surface structure developing after Rb-ion irradiation was measured by means of atomic force microscopy.

[1] K. P. Lieb, in Encyclopedia of Nanoscience and Nanotechnology, vol. 3, H. S. Nalwa, Ed., Am. Scient. Publ. (2004) pp. 233-251.
[2] K. P. Lieb and J. Keinonen, Cont. Phys. 47 (2006) 305.

DS 25.6 Thu 12:30 H 2013

Ion beam induced effects at 15 K in z-cut$LiNbO_3$ — •Thomas Gischkat, Frank Schrempel, and Werner Wesch — Institut für Festkörperphysik,Friedrich-Schiller-Universität Jena

The primary effects of the damage formation in z-cut $LiNbO_3$ due to ion irradiation was investigated. Therefor the samples were irradiated stepwise and subsequently measured by means of Rutherford Backscattering Spectrometry (RBS) at 15 K without changing the temperature of the sample. The irradiation was done with 30 keV H-, 50 keV Li-, 160 keV O- and 350 keV Ar-ions at ion fluences between $5\times10^{11}\ cm^{-2}$ and $2\times10^{17}\ cm^{-2}$. The RBS measurements were performed with 1.4 MeV He-ions in steps of equal charges providing a series of subspectra. It was observed that the backscattering yield of the damaged region decreases with increasing number of subspectra indicating an annealing of defects as a consequence of the RBS measurement. The energy deposited into electronic processes by the analyzing He beam is mostly responsible for the observed defect annealing. The amount of annealing depends on the defect concentration and the ion species. The undisturbed defect accumulation which will be observed without any effect of measurement was calculated for the different ion species by an analytical formula taking into account the He-beam induced annealing.

DS 25.7 Thu 12:45 H 2013

Channeling irradiation of $LiNbO_3$ — •Tobias Steinbach, Frank Schrempel, Thomas Gischkat, and Werner Wesch — Institut für Festkörperphysik,Friedrich-Schiller-Universität Jena

The influence of the crystal orientation on the damage formation of x- and z-cut $LiNbO_3$ single crystals irradiated with 550 and 750 keV Si-ions was investigated. The irradiation was carried out along the corresponding axial channel as well as at different tilt angles. The damage accumulation was investigated by means of Rutherford Backscattering Spectrometry (RBS/C). Because the channelled ions are prevented from close collisions with the target atoms, the projected range of the ions is increased and the number of defects created by channelled ions at a certain ion fluence is less compared to a random irradiation. As a consequence the damage distribution is shifted to larger depths if the irradiation is performed along low index crystallographic directions. Selected samples were etched at 40°C in a HF-solution of 3.7% and 40%, respectively. Compared to the random irradiation with 550 keV Si-ions, the etched depth increases by a factor of 1.4 and 1.2 if the irradiation is carried out along the x- and the z-axis, respectively. From the dependence of the shift of the damage peak on the tilt angle a critical angle to avoid channeling of about 1.35° was determined for 750 keV Si-ions.