DS 17: Ion and Electron Beam Induced Processes

Time: Tuesday 14:00–16:15 Location: CHE 91

DS 17.1 Tue 14:00 CHE 91

Reverse Epitaxy — •Xin Ou, Adrian Keller, Manfred Helm, Jürgen Fassbender, and Stefan Facsko — Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf (HZDR) e.V., P.O. Box 510119, 01314 Dresden, Germany.

Based on a self-organized ion beam erosion process, periodic ripple, hole, or dot arrays can be produced on various semiconductor surfaces. However, the main drawback of this method is that the irradiated semiconductor surfaces are amorphized. For device fabrication, a crystalline surface of high quality is indispensable. In this work we report the recent discovery of single crystal Ge nanopattern surface formation based on a *reverse epitaxy* process at elevated temperature.[1] The vacancies created during ion beam irradiation distribute according to the crystallographic anisotropy, which results in an orientation-dependent pattern formation on single crystal Ge surface. This process shows nicely the equivalence of epitaxy with deposited adatoms and *reverse epitaxy* with ion induced surface vacancies on semiconductors, and the formation of these patterns is interpreted as the result of a surface instability due to an Ehrlich-Schwoebel barrier for ion induced surface vacancies. The simulation of the pattern formation is performed by a continuum equation accounting for the effective surface currents. [1] Xin Ou et al., Phys. Rev. Lett. 111, 016101 (2013).

DS 17.2 Tue 14:15 CHE 91

Gallium Nitride Films by Ion-Beam Assisted MBE - Effects of Long-Term Ion Irradiation — •Annemarie Finzel, Jürgen Gerlach, Frank Frost, Jan Lorbeer, and Bernd Rauschenbach — Leibniz-Institut für Oberflächenmodifizierung e.V. (IOM Leipzig), Permoserstraße 15, D-04318 Leipzig, Germany

One technique to grow GaN thin films of high quality and purity is ion-beam assisted molecular-beam epitaxy (IBA-MBE). Ga is evaporated in an effusion cell and adsorbs at the heated substrate (superpolished 6H-SiC(0001) at 700 °C) surface, while it is bombarded by hyperthermal N ions ($E_{kin} \leq 25$ eV) generated by a hollow-anode plasma source. The aim of the present study is to examine whether a long-term irradiation with hyperthermal N ions has an effect on an already deposited GaN film. For this purpose, heated (700 °C , 600 °C) and non-heated (RT) GaN films were irradiated up to 6 h with N ions. To test that there is no thermal GaN decomposition one film was heated for several hours at the typical deposition temperature (700 °C) without ion irradiation. The investigations using RHEED, UHV-STM and AFM have shown that a long (2 h) irradiation with hyperthermal N ions after the film deposition has an effect on the surface of the GaN films. The roughness of the irradiated samples was increased and a large amount of holes and canyons was formed which could be due to sputtering or due to a rearrangement of atoms at the GaN film surface. It could be proven that a long heating of the GaN film at 700 °C and a long irradiation at RT has no visible influence on the surface structure and topography. The effects of the ion irradiation will be discussed.

DS 17.3 Tue 14:30 CHE 91

Systematic investigations of low energy ion beam sputtering of Ge — •Rene Feder, Horst Neumann, Carsten Bundesmann, and Bernd Rauschenbach — Leibniz-Institut für Oberflächenmodifizierung e.V, Leipzig, Germany

The ion beam sputter deposition (IBD) technique provides intrinsic features which influence the properties of the growing films. Ion properties and geometrical process conditions generate different kinetic energy and spatial distributions of both the sputtered and the scattered particles and consequently influence the properties of the growing films.

A vacuum deposition chamber has been set up which allows ion beam sputtering of different targets under variation of geometrical parameters (incidence and emission angles) and of ion beam parameters (species, energy) to make a systematic analysis of the correlation between the properties of the ion beam, the properties of the sputtered and scattered particles, and the properties of the deposited films. Several sets of samples were prepared and characterized with respect to selected film properties, such as thickness, optical properties, composition and surface topography. The experiments indicate a systematic influence of the deposition parameters on the film properties. For a better understanding of these correlations, the energy distribution of secondary particles was measured using an ESMS. Among others, experiments revealed high-energetic maxima for backscattered primary ions, which shift with increasing emission angle to higher energies. Experimental data are compared with MC simulations.

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DS 17.4 Tue 14:45 CHE 91

Enhanced Sputtering Effects of Ion Irradiated Silicon Nanowires — •Stefan Noack[1], Andreas Johannes[1], Henry Holland-Moritz[1], Markus Glaser[2], Alois Lugstein[2], and Carsten Ronning[1] — [1]Institiut für Festkörperphysik, Friedrich-Schiller-Universität Jena — [2]Institut für Festkörperelektronik, Technische Universität Wien

While being easy to fabricate through both physical and chemical approaches, nanostructure customization often finds its limits due to thermal equilibrium. Ion implantation has become an important tool to circumvent this restriction, especially when doping semi-conductive materials. For the prediction of the behaviour of ion beam irradiated nanostructures, different approaches in theoretical calculation and computer simulation have been implemented, such as the Monte Carlo simulation program *iradina* [1]. The description of effects like sputtering, however, which differs greatly for nanostructures compared to bulk material, still has to be verified experimentally. With focus on this matter, etched silicon nanowires with a wide array of diameters were irradiated by argon ions of different energies, meeting conditions in order to preserve crystallinity and prevent bombardment induced bending. Subsequently, SEM investigations were made to quantify the sputter yield in comparison with the results from *iradina* simulations, all to be discussed in this presentation.

[1] C. Borschel, C. Ronning; Nucl. Instrum. Meth. Phys. Res. B 269, 2133 (2011)

DS 17.5 Tue 15:00 CHE 91

Investigation of dopant profiles, losses and heating using an energy filter for ion implantation — •Florian Krippendorf[1], Constantin Csato[1], Michael Rüb[1], Carsten Ronning[2], and Johannes von Borany[3] — [1]Ernst-Abbe-Fachhochschule Jena, Carl-Zeiss-Promenade 2, 07745 Jena — [2]Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena — [3]Helmholtz-Zentrum Dresden-Rossendorf e.V., Bautzner Landstraße 400, 01328 Dresden

Creating doped areas with depth distributions of several μm is difficult for some materials. A combination of a monoenergetic ion implantation (narrow depth distribution) and a subsequent diffusion step is not a suitable process, if diffusion coefficients are small. To overcome this problem a so called energy filter [1] has been developed. It consists of a micro patterned silicon membrane which modifies the ion beam in such a way, that the irradiated substrate is doped in a larger depth distribution. In the talk we show our results from the work on the energy filter. We demonstrate doping of a 7x7mm^2 Si substrate with 7MeV B ions in a depth distribution of 4 μm with only one implantation. SIMS and SRP measurements show the shape of the implanted profile and loss of ions due to scattering. To support these data the energy spectra of the ion beam after passing different microstructures and the resulting implantation profiles are simulated. The properties of the filter regarding heating, channelling, degradation etc. are discussed.

[1] F. Krippendorf et al., Proceedings MikroSystemTechnik Kongress 2013, 14.-16. Oktober 2013, Aachen: VDE Verlag, 2013, 8.12, 662-665

DS 17.6 Tue 15:15 CHE 91

Novel porous liquid metal ion source for surface modification with heavy polyatomic ions — •Daniel Bock[1], Wolfgang Pilz[1], Martin Tajmar[1], and Lothar Bischoff[2] — [1]Technische Universität Dresden, 01062 Dresden — [2]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstrasse 400, 01328 Dresden

The most common Liquid Metal Ion Source emitters for focused ion beam (FIB) applications are from the tungsten needle type. Wetted with different elementary or alloy materials, a broad spectrum of mono- and polyatomic ions can be extracted and applied for surface modification purposes by using ion optics containing an ExB mass filter which is not restricted to FIB but to single ended ion accelerators as well. It was recently shown, that the impact of heavy polyatomic ions leads to quite different interactions on material surfaces as it is known up to now due to the enormous local energy deposition [1].

A new Micro-Powder Injection Molding technique allows the fabrication of porous tungsten emitters in nearly any shape, which is not accessible by mechanical machining [2]. Such porous tungsten emitters combine the advantages of needle and capillary type emitters. Due to their improved wettability and material flux, such an emitter can deliver ion currents of tens of μA concentrated in one beam focused by a special ion optics design. This new type of LMIS as well as its fabrication procedure and operational conditions will be discussed using a GaBi alloy liquid metal ion source.

[1] L. Bischoff, et al., Nucl. Instr. and Meth. B 272 (2012) 198.
[2] M. Tajmar, et al., Ultramicroscopy 111(2010)1.

DS 17.7 Tue 15:30 CHE 91

Charge exchange and energy loss of slow highly charged ions in 1nm thick carbon nanomembrane — •Richard A. Wilhelm[1], Elisabeth Gruber[2], Robert Ritter[2], René Heller[1], Stefan Facsko[1], and Friedrich Aumayr[2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Technische Universität Wien, Wien, Österreich

It has been demonstrated in recent years that slow highly charged ions can be used as an efficient tool for nano-structure formation on insulating solid surfaces mainly by deposition of their potential energy. By reducing the solid thickness into the nano-meter range a limit is reached where on the one hand the ion may not be completely neutralized in the solid membrane and on the other hand dissipation of the deposited energy may be limited to two spacial dimensions. To investigate the energy deposition and neutralization processes in 2D-materials by slow highly charged ions we performed charge exchange and energy loss measurements of slow highly charged Xe ions transmitted through ultra thin polymeric carbon membranes. Surprisingly, two distinct exit charge state distributions accompanied by charge exchange dependent kinetic energy losses are observed. The energy loss for ions exhibiting large charge loss shows a quadratic dependency on the incident charge state, indicating that equilibrium stopping force values do not apply in this case. The combination of charge transfer and kinetic energy loss measurements allows us to link the two different exit charge state distributions to ion trajectories through distinct local electron densities distributions in the membrane.

DS 17.8 Tue 15:45 CHE 91

Comparison of proton and electron induced electronic excitations in thin metal films — •Lars Breuer[1], Andreas Wucher[1], and Detlef Diesing[2] — [1]Fakultät für Physik, Universität Duisburg-Essen, Duisburg, Germany — [2]Fakultät für Chemie, Universität Duisburg-Essen, Essen, Germany

The electronic excitation in thin metal films by low energy protons and electrons ($60\,\mathrm{eV} < E < 1000\,\mathrm{eV}$) is detected as a current flowing from the ion or electron irradiated metal film through a thin oxide layer to an aluminium back electrode. Thus, the thin film metal–insulator–metal device couples the electronically excited metal (silver in the present work) to a metal (aluminium in the present work) in its electronic ground state. By the application of a bias voltage to the device in the course of ion irradiation a spectroscopy of the irradiation induced electronic excitation becomes possible. The device allows a characterisation of the excited electrons and of the excited holes as well in contrast to a conventional spectrometer with a retarding field. Proton induced excitations are found to store a significant amount of the energy in excited holes. Electron induced excitations on the other hand show only a negligible fraction of energy stored in holes, the main fraction of energy consists of secondary electrons in this type of excitations.

DS 17.9 Tue 16:00 CHE 91

Formation of PbTe nano particle by low energy ion beam mixing of Te/Pb bilayer — •Srashti Gupta[1,2], Dinesh Agarwal[3], Saif Khan[3], Sonathi Neeleshwar[2], Sunil Ohja[3], Ambuj Tripathi[3], S Amirthapandian[4], Binaya Panigrahi[4], and Devesh Avasthi[3] — [1]II. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]University School of Basic and Applied Sciences, G.G.S. Indraprastha University, Delhi- 110075, India — [3]Inter University Accelerator Centre, New Delhi-110067, India — [4]Materials Physics Division, Indira Gandhi Centre for Atomic Research, Kalpakkam-603102, India

The present work reports the formation of PbTe by low energy ion beam mixing of Te/Pb bilayer. Te/Pb bilayer samples are deposited using thermal evaporation technique with thicknesses (20 nm each) where Te is the top layer. These bilayer samples are irradiated at room temperature by 90 keV Ar and 140 keV Kr ion irradiation at different fluences ranging from $3*10^{15}$ ions/cm2 to $3*10^{16}$ ions/cm^2. The samples are characterized by resonant Rutherford backscattering spectrometry (RRBS) and reveal that PbTe starts forming at initial fluence of $3*10^{15}$ ions/cm2, and at fluence of $5*10^{15}$ ions/cm2 complete mixing takes place. RRBS also indicates the desorption of oxygen during irradiation. High-resolution transmission electron microscopy (HRTEM) and X-ray diffraction (XRD) are used to confirm the PbTe phase formation. HRTEM also confirms the formation of PbTe nanocrystals of 3-5 nm by Kr ion irradiation at fluence of $7*10^{15}$ ions/cm2.