DS 36: Postersession I

Time: Wednesday 17:00–19:00 Location: P2-EG

DS 36.1 Wed 17:00 P2-EG

Interaction of oxygen with plasma-deposited Si:N:H primer coatings — •Lisa Wurlitzer[1], Sebastian Dahle[2], and Wolfgang Maus-Friedrichs[1,2] — [1]Clausthal Centre of Material Technology, 38678 Clausthal-Zellerfeld, Germany — [2]Insitute for Energy Research and Physical Technology

The coatings are applied in a two-step process which is carried out through dielectric barrier discharge (DBD) plasma treatments. The DBD plasma is used in the first processing step along with a gaseous mixture of silane and nitrogen to deposit the primer film. In the second processing step, the primer film is converted into a silicon oxide coating. Previous measurements show that this conversion yields stoichiometric silicon dioxide when employing a DBD plasma treatment in air or pure oxygen, while an exposure to air at atmospheric pressures without DBD plasma leads to a partial conversion of the film. This high reactivity against oxygen is now investigated by exposure to small vapor pressures of oxygen in an ultra-high vacuum chamber, again without a DBD plasma treatment. Photoelectron spectroscopy is employed to study the interaction of oxygen with the Si:N:H primer coating.

DS 36.2 Wed 17:00 P2-EG

Flexible, robust and conformal SERS active substrates for rapid trace detection of pesticides — •Samir Kumar and J P Singh — Department of Physics, Indian Institute of Technology Delhi

Silicon wafers and glass slides are two of the most common substrates used for the growth of SERS active layers. However, these substrates are rigid and brittle and hence, these static substrates severely limit the application of plasmonic nanostructures. The metal nanostructures deposited by using conventional techniques such as physical vapor deposition suffers from a low adhesion strength of Ag or Au on to silicon or glass substrates. Here, we demonstrate a simple and facile method for fabricating highly adhesive large area AgNRs arrays embedded in the PDMS film SERS-active, flexible and robust substrate for conformal and rapid extraction and detection of trace molecules. The AgNRs arrays were grown over Si(100) substrates by thermal evaporation of silver powder using glancing angle deposition (GLAD) technique. The AgNRs arrays were embedded in low index PDMS to achieve enhanced portability and mechanical stability. The embedded AgNRs layers show good adhesion onto the PDMS surface. The in situ SERS measurements on these flexible substrates under mechanical tensile strain conditions showed that flexible SERS substrates can withstand a tensile strain (ϵ) value as high as 30% without losing SERS performance. Through strongly enhanced Raman signals on the AgNRs embedded SERS substrate, pesticide thiram was effectively detected on apple peels at concentrations as low as 2.4×10^{-9} g/cm^2.

DS 36.3 Wed 17:00 P2-EG

Zig-zag silver nanorods with high density hotspots for surface enhanced Raman scattering — •Samir Kumar and J P Singh — Department of Physics, Indian Institute of Technology Delhi

In recent years, silver nanorod (AgNR) arrays fabricated by GLAD have attracted significant attention due to their high surface enhanced Raman spectroscopy (SERS) performance. For SERS, the major enhancement mechanism is due to the enhancement of localized electric field generated by metallic nanostructures. The SERS performance significantly depends upon the number of hotspots. On folding a nanorod into zig-zag structure can generate corners or bends and hence it enhances the SERS performance. Among the different types of hotspots nanogaps can tremendously enhance the SERS intensity. In this work, we investigated that the SERS intensity increases with number of hotspots. For this, different arms silver zig-zag nanostructures have been fabricated. Their SERS spectra revealed that the SERS performance can be improved on increasing the number of arms. Further, the role of nanogaps in silver zig-zag nanostructures has been studied. It is observed that the SERS intensity from nanogap zig-zag silver nanorods array is higher than from silver zig-zag nanostructures i.e. nanogaps contributed more in SERS enhancement. The SERS signals was investigated by using Raman probe molecule trans-1,2-bis(4-pyridyl)ethane (BPE). Our observations showed that the Ag zig-zag plasmonic structures with nanogaps between their arms produced extremely high SERS signal. This can be explained due to the plasmon coupling interaction between the Ag nanorods.

DS 36.4 Wed 17:00 P2-EG

Influence of 5-Ammoniumvaleric Acide Iodide on the Stability of Methylammonium Lead Halide Perovskite Films Grown on Zinc Oxide — •Georg Dewald[1,2], Martina Stumpp[1,2], Raffael Ruess[1,2], and Derck Schlettwein[1,2] — [1]Justus-Liebig-University Giessen, Institute of Applied Physics — [2]Justus-Liebig-University Giessen, Laboratory for Materials Science

As an alternative to TiO_2 in perovskite photovoltaics ZnO deserves closer attention as it possesses a higher conductivity. Further, ZnO can be prepared at low temperatures via electrochemical deposition. However, preparing $CH_3NH_3PbI_3$ directly on top of ZnO, leads to rapid degradation. Such stability problems could be addressed by adding 5-ammoniumvaleric acide iodide (AVAI) to $CH_3NH_3PbI_3$. AVA ions can form hydrogen bonds between the PbI_6 octahedrons of the perovskite and, therefore, influence the resulting morphology and electrical properties. Bond formation across the perovskite/ZnO interface is expected to stabilize it by hindering the deprotonation by the basic zinc oxide surface. In this study, $CH_3NH_3PbI_3$ and $(AVA)_x(CH_3NH_3)_{1-x}PbI_3$ films were prepared via spin-coating on ZnO, which was electrodeposited on micro-structured gold electrode arrays on SiO_2/Si wafers. The current-voltage curves of Au/ZnO/perovskite/ZnO/Au were measured during the annealing process at 100 °C by sweeping the voltage from -2 to +2 V in nitrogen atmosphere. SEM imaging was used to examine the influence of AVAI on the morphology of the perovskite films. The SEM images and I-V characteristics of films with and without 5-AVAI will be discussed.

DS 36.5 Wed 17:00 P2-EG

Electrochemical Deposition of Porous Nickel Oxide Films as Electrodes in Electrochromic Devices and Solar Cells — •Simon P. Schneider[1,2], Christian Lupo[1,2], and Derck Schlettwein[1,2] — [1]Justus-Liebig-University Giessen, Institute of Applied Physics — [2]Justus-Liebig-University Giessen, Laboratory for Materials Science

Nickel oxyhydroxide films were deposited onto transparent conductive oxide substrates via electrochemical deposition in an aqueous bath containing nickel sulfate and ammonia. The deposition was carried out using cyclic voltammetry in a three-electrode setup, where a Ag/AgCl-electrode was used as reference and a platinum sheet as counter electrode. After deposition, the films were treated at different temperatures to obtain porous nickel oxide. Furthermore, the concentrations and ratios of nickel sulfate and ammonia in the solution were adjusted to optimize the deposition. The film morphology was investigated using scanning electron microscopy revealing homogenously porous film surfaces and a high reproducibility. Different annealing temperatures and bath concentrations did not affect size and shape of the pores. However, the annealing temperature seems to have an influence on the oxidation state of nickel and thus on the optical properties of the films.

DS 36.6 Wed 17:00 P2-EG

Proof of the existence of Sn_3O_4 through Raman spectroscopy: a combined theoretical and experimental study — •Christian Heiliger[1], Bianca Eifert[1], Marcel Giar[1], Martin Becker[2], Christian T. Reindl[2], Lilan Zheng[3], Angelika Polity[2], Yunbin He[3], and Peter J. Klar[2] — [1]Institute of Theoretical Physics, Justus-Liebig-University, Heinrich-Buff-Ring 16, 35392 Giessen, Germany — [2]I. Institute of Physics, Justus-Liebig-University, Heinrich-Buff-Ring 16, 35392 Giessen, Germany — [3]Faculty of Materials Science and Engineering, Hubei University, Wuhan 430062, China

The existence of an intermediate phase within the tin oxide system was first reported in 1882. However, its stoichiometry and its crystal structure have been dubious and heavily debated ever since, despite a multitude of structural investigations. Here we show that a combined Raman spectroscopic investigation based on *ab initio* methods and experiments offers an alternative to diffraction studies, which are not conclusive for this material system. It allows us to unambigiuously identify the intermediate phase as Sn_3O_4 and to rule out the other likely candidate, Sn_2O_3. We assign the one-phonon Raman signals of Sn_3O_4 to the mode symmetries of the corresponding point group C_{2h} and confirm the space group as $P2_1/c$ with 14 atoms per unit cell.

DS 36.7 Wed 17:00 P2-EG

BFO based memristor as artificial synapse in machine learning circuits — •Mahdi Kiani[1], Nan Nu[1], Christian Mayr[2], Danio Bürger[1], Iluna Skrupa[1,3], Stefan Shultz[4], Oliver Schmidt[1,5], and Heidemarie Schmidt[1,4] — [1]Materials systems for nanoelectronics, chemnitz university of technology, chemnitz, germany — [2]Highly-parallel vlsi systems and neuro-microelectronics, technische universität dresden, dresden, germany — [3]Helmholtz-zentrum dresden-rossendorf, institute of ion beam Physics and materials research,dresden, germany — [4]Fraunhofer-Institut für Elektronische Nanosysteme, Abteilung Back-End of Line, Technologie, Chemnitz, Germany — [5]Institute for Integrative Nanosciences, IFW Dresden, Dresden, Germany

Neuromorphic engineering takes advantage of artificial neurons and artificial synapses to mimic the most complicated human attribute, learning. BiFeO3 memristor as artificial synapse and newly designed electronic circuit as artificial neuron are used to implement associative, supervised, unsupervised, and deep learning. Spike-timing dependent plasticity (STDP) with a single pairing of one presynaptic voltage spike and one postsynaptic voltage spike with different time delays for Long-term potentiation (LTP) which determine learning status and Long-term depression (LTD) where forgetting occurs and also number cycle dependent plasticity (NCDP) for both student and teacher artificial synapses are demonstrated

DS 36.8 Wed 17:00 P2-EG

An element specific investigation of the disorder induced phase transition in $Fe_{60}Al_{40}$ thin films driven by ion irradiation — •Benedikt Eggert[1], Enrico La Torre[1], Alevtina Smekhova[1,2], Thomas Szyjka[1], Rantej Bali[3], Katharina Ollefs[1,4], Soma Salamon[1], Fabrice Wilhelm[4], Rudra Banerjee[6], Andrei Rogalev[4], Eugen Weschke[5], Jürgen Lindner[3], Biplab Sanyal[6], Carolin Schmitz-Antoniak[2], and Heiko Wende[1] — [1]University of Duisburg-Essen and CENIDE, Duisburg — [2]FZ Jülich (PGI-6), Berlin — [3]HZDR, Dresden — [4]ESRF, ID12, Grenoble — [5]HZB (BESSY II), Berlin — [6]Uppsala University, Uppsala

Chemically ordered $Fe_{60}Al_{40}$ in the B2 structure shows weak ferromagnetism, while the disordered phase with the A2 structure exhibits a ferromagnetic state. Correspondingly the transition leads to an increase of the effective number of Fe-Fe nearest neighbors and of the lattice constant [1]. This phase transition can be driven by ion irradiation. In this work we investigate $Fe_{60}Al_{40}$ thin films before and after 10 and 20 keV Ne^+ irradiation by means of X-ray magnetic circular dichroism (XMCD) at the Fe $L_{2,3}$- and K-edge to analyze the microscopic magnetic structure. For a comparison magnetometry was used concerning the depth-profile of the induced magnetism [2,3]. These results are correlated to the modified structural properties.

[1] J. Fassbender et al. Phys. Rev. B 2008, 77, 174430
[2] R. Bali et al. Nano Lett. 2014, 14 (2), pp 435-441
[3] N. Tahir et al. Phys. Rev. B 2015, 92, 144429

DS 36.9 Wed 17:00 P2-EG

Spectroscopic Ellipsometry as a Method for Structural Investigation of Spinel Ferrite Thin Films — •Vitaly Zviagin[1], Yogesh Kumar[1], Paula Huth[2], Israel Lorite[1], Annette Setzer[1], Daniel Spemann[3], Karsten Fleischer[4], Jan Meijer[1], Reinhard Denecke[2], Pablo Esquinazi[1], Marius Grundmann[1], and Rüdiger Schmidt-Grund[1] — [1]Universtät Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, Germany — [2]Universtät Leipzig, Wilhelm-Ostwald-Institut für Physikalische und Theoretische Chemie, Linnéstr. 2, Germany — [3]Leibniz-Institut für Oberflächenmodifizierung e. V., Permoserstr. 15, Germany — [4]School of Physics, Trinity College Dublin, Dublin 2, Ireland

$ZnFe_2O_4$ and composite $Zn_xFe_{3-x}O_4$ thin films were deposited at different conditions on $SrTiO_3$ (100) and MgO (100) substrates by pulsed laser deposition. Features in the diagonal elements of the dielectric tensor, obtained by spectroscopic ellipsometry, hint to the presence of Fe^{2+} and Fe^{3+} cations located within the lattice by assignment of electronic transitions. While the increase of Fe^{2+} cation concentration on octahedral lattice sites corresponds to the increase in conductivity, measured by Hall effect, the increase of Fe^{3+} cation concentration on tetrahedral lattice sites corresponds to the increase in ferrimagnetic response of the spinel thin films, measured by SQUID.[1] In agreement with complimentary methods such as XPS and XAS, the presence of the mentioned cations corresponds to disorder and inversion of the lattice structure, also induced by annealing or irradiation with Si ions.

[1] V. Zviagin et al., Appl. Phys. Lett. **108**, 13 (2016)

DS 36.10 Wed 17:00 P2-EG

Bipolar heterodiodes comprising β-gallium oxide — •Peter Schlupp, Daniel Splith, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Institut für experimentelle Physik II, Germany

The large bandgap of 4.9 eV makes β-gallium oxide interesting for many applications e. g. for power electronics or if alloyed with indium oxide for visible- and solar-blind UV photodetectors [1]. In order to fabricate thin film transistors a gate contact is needed. A reasonable option are highly rectifying contacts which can also be used to perform space charge region based spectroscopy. Beside using Schottky diodes [2] these contacts can be realized by using bipolar heterodiodes.

We present β-gallium oxide bipolar heterodiodes grown on sapphire substrates by pulsed laser deposition (PLD). The p-type layers are realized by nickel oxide and amorphous zinc cobalt oxide fabricated by PLD at room-temperature. Best diodes exhibit rectification ratios of more than eight orders of magnitude and ideality factors of about 1.5. Temperature dependent current voltage measurements from 90 K to 300 K will be dicussed as well as space charge region based spectroscopy.

References

[1] Zhang et al., Appl. Phys. Lett. **108**, 123503 (2016)
[2] Splith et al., Phys. Status Solidi A **211**, 40 (2014)

DS 36.11 Wed 17:00 P2-EG

Temperature dependent investigation on Pt Schottky contacts on PLD grown In_2O_3 thin films — •Steffen Lanzinger, Daniel Splith, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Germany

Indium oxide is a material which, in its highly tin doped form, is already widely used for applications as a transparent conducting oxide. However, in recent years also interest in the semiconducting properties of In_2O_3 arose. First rectifying contacts on In_2O_3 thin films were realized by von Wenckstern et al. [1,2], utilizing reactively sputtered platinum or the p-type semiconductors zinc cobalt oxide or nickel oxide. Utilizing these rectifying contacts, the investigation of electronic defect states using space charge region based measurements was possible [3].

In this contribution we investigated the electrical properties of reactively sputtered platinum Schottky diodes on PLD grown undoped and Mg-doped In_2O_3 on c-plane sapphire by means of current voltage measurements and temperature dependent current voltage measurements between $T = 85$K and $T = 330$K. Additionally, the Schottky contacts were used to investigate the electronic defect states of the In_2O_3 thin films using thermal admittance spectroscopy.

[1] H. von Wenckstern *et al.*, APL Mat., 2, 4: 046104 (2014)
[2] H. von Wenckstern *et al.*, Adv. Electron. Mater., 1, 4 (2015)
[3] F. Schmidt *et al.*, Phys. Status Solidi B, 252, 10: 2304-2308 (2015)

DS 36.12 Wed 17:00 P2-EG

Synthesis of Carbon Nanowalls from a single source metalorganic precursor — •Nicolas Wöhrl, André Giese, and Volker Buck — Faculty of Physics and CENIDE, University of Duisburg-Essen, Lotharstr. 1, 47057 Duisburg, Germany

In this work the deposition of carbon nanowalls (CNWs) by an inductively-coupled-plasma-assisted chemical vapor deposition process (ICP-PECVD) is investigated. The CNWs are electrically conducting and show a large specific surface area, which is a key characteristic to make them applicable for sensors, catalysts or energy storage systems. Here, CNWs are deposited from the single source metalorganic precursor aluminum-acetylacetonate. This precursor in combination with the ICP-PECVD is relatively unknown in literature. Silicon, stainless steel, nickel and copper can be used as substrate materials without any pretreatment. The deposited CNWs are characterized by SEM, Raman spectroscopy and AES. The combination of Bias-voltage, substrate temperature, and substrate material revealed a strong influence on the morphology of the nano-graphitic CNWs, strongly influencing the surface area. With regard to these results, a first growth model for the deposition of CNWs by ICP-PECVD using aluminum-acetylacetonate is proposed that takes the surface diffusion into account.

DS 36.13 Wed 17:00 P2-EG

Epitaxial growth of GeTe Phase Change Alloy on Si(111)

Substrate by Pulsed Laser Deposition — •Isom Hilmi[1], Andriy Lotnyk[1], Jürgen W. Gerlach[1], Philipp Schumacher[1], and Bernd Rauschenbach[1,2] — [1]Leibniz-Institut für Oberflächenmodifizierung e.V., 04318, Leipzig, Germany — [2]Universität Leipzig, Institut für Experimentelle Physik II, 04103, Leipzig, Germany

GeTe phase change thin films have been grown on highly lattice-mismatched Si(111) substrates by means of pulsed laser deposition technique. Depending on the substrate temperature, the films grew in amorphous, oriented polycrystalline and single crystalline structures, consecutively, between RT and 300°C, as revealed by reflection high-energy electron diffraction (RHEED), x-ray diffraction and transmission electron microscopy (TEM). The narrow epitaxial window of GeTe on Si(111) is observed around 230°C. The crystalline thin films grow mainly in a distorted rock-salt structure, with the out-of-plane and in-plane epitaxial relationships were determined to be GeTe[111]//Si[111] and GeTe[11-2]//Si[11-2], respectively. The RHEED and atomic force microscopy measurements revealed that the film grew according to Stranski-Krastanov mode. The TEM measurements showed the presence of overlapping twins and the out of plane rotated grains in the thin films.

DS 36.14 Wed 17:00 P2-EG

Pulsed laser deposition of epitaxial Sb2Te3 thin films on Si(111) — •Isom Hilmi[1], Andriy Lotnyk[1], Jürgen W. Gerlach[1], Philipp Schumacher[1], and Bernd Rauschenbach[1,2] — [1]Leibniz-Institut für Oberflächenmodifizierung e.V., 04318, Leipzig, Germany — [2]Universität Leipzig, Institut für Experimentelle Physik II, 04103, Leipzig, Germany

An attempt to deposit a single crystalline chalcogenide phase change materials is of interests to improve the material performance for an application in non-volatile memory. In this report, the fabrication of high-quality Sb2Te3 by pulsed laser deposition is presented. The thin films were epitaxially grown on Si(111) substartes. The epitaxial growth was achieved at elevated substrate temperature ranging from 130° to 260°C. The films were grown in layer-by-layer mode. X-ray diffraction and transmission electron microscopy reveal that the films possess trigonal Sb2Te3 structure containing twin domains. The thin film growth starts with Sb/Te passivation layer. This results open up the feasibility to fabricate thin multilayer structure of chalcogenide phase change materials.

DS 36.15 Wed 17:00 P2-EG

Ruddlesden-Popper interface in correlated manganite heterostructures induces magnetic decoupling and dead layer reduction — Alexandr Belenchuk[1], Oleg Shapoval[1], Vladimir Roddatis[2], •Vitaly Bruchmann-Bamberg[3], Konrad Samwer[3], and Vasily Moshnyaga[3] — [1]IIEN, Academy of Sciences of Moldova, str. Academiei 3/3, MD-2028 Kishinev, Republic of Moldova — [2]Institut für Materialphysik, Georg-August-Universität-Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen — [3]I. Physikalisches Institut, Georg-August-Universität-Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

We report on the interface engineering in correlated manganite heterostructures using embedded stacks of atomic layers that form the Ruddlesden-Popper structure. A room temperature magnetic decoupling was achieved through insertion of $(SrO)_2$–TiO_2–$(SrO)_2$ sequence of atomic layers at the interface between ferromagnetic metallic $La_{0.7}Sr_{0.3}MnO_3$ and $(La_{0.7}Sr_{0.3})(Mn_{0.9}Ru_{0.1})O_3$ films. Moreover, the narrowing of interfacial dead layer in ultrathin $La_{0.7}Sr_{0.3}MnO_3$ films was demonstrated by deposition of a single $(SrO)_2$ rock-salt layer at the interface with $SrTiO_3$ (100) substrate.

The obtained results are discussed basing on the symmetry breaking and disconnection of the MnO_6 octahedra network at the interface that may lead to the improved performance of all-oxide magnetic tunnel junctions. We suggest that octahedral decoupling realized by formation of Ruddlesden-Popper interfaces is an effective structural mechanism to control functionalities of correlated perovskite heterostructures.

DS 36.16 Wed 17:00 P2-EG

Electrical properties of CVD molybdenum disulfide — •wajid awan[1], tommy schönherr[1], antony george[2], andrey turchanin[2], stefan facsko[1], and artur erbe[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Fredrich-Schiller-Universität Jena, Germany

Two dimensional materials are attractive for the use in next-generation nanoelectronic devices as compared to one dimensional material because it is relatively easy to fabricate complex structures from them. Recently the layered 2D semiconducting Transition metal dichalcogenides came into the picture and got a place in a wide range of novel applications as well as in basic research. Strikingly, MoS_2 receives significant attention since it undergoes transition from indirect bandgap (bulk form) to a direct bandgap (1.8eV) semiconductor due to the 2D confinement. The bandgap is an essential property for tunable 2-D nanodevices. We performed electrical transport measurements at room temperature for CVD grown MoS_2 on SiO_2/Si substrate. Standard Electron beam lithography (EBL) was used to pattern Gold (Au) metal contacts on MoS_2 flakes. For the purpose of sample characterization, we performed the Atomic Force Microscopy (AFM) and Raman Spectroscopy techniques, respectively, which confirm that the thickness of the CVD grown MoS_2 triangular flakes corresponds to single layers. Low temperature characterization of the electrical properties of the layers elucidates the exact mechanisms of charge transport in the 2d-layers. This knowledge will be used to modify the electrical properties in a controlled way, for example by ion irradiation.

DS 36.17 Wed 17:00 P2-EG

Direct observation of the M2 phase with its Mott transition in a VO_2 film — Hoon Kim[1,2], Tetiana Slusar[3], •Dirk Wulferding[1,4], Ilkyu Yang[1], Jin-Cheol Cho[3], Minkyung Lee[1,5], Hee Cheul Choi[1,5], Yoon Hee Jeong[2], Hyun-Tak Kim[3], and Jeehoon Kim[1,2] — [1]CALDES, Institute for Basic Science, Pohang, Korea — [2]Dept. of Phys., POSTECH, Pohang, Korea — [3]ETRI, Daejeon, Korea — [4]IPKM und LENA, TU-BS, Braunschweig, Germany — [5]Dept. of Chem., POSTECH, Pohang, Korea

In VO_2, the explicit origin of the insulator-to-metal transition is still disputable between Peierls and Mott insulators. Along with the controversy, its second monoclinic (M2) phase has received considerable attention due to the presence of electron correlation in undimerized vanadium ions. However, the origin of the M2 phase is still obscure. We study a granular VO_2 film using conductive atomic force microscopy and Raman scattering. Upon the structural transition from monoclinic to rutile, we observe directly an intermediate state showing the coexistence of monoclinic M1 and M2 phases. The conductivity near the grain boundary in this regime is six times larger than that of the grain core, producing a donut-like landscape. Our results reveal an intragrain percolation process, indicating that VO_2 with the M2 phase is a Mott insulator. [H. Kim, et al., arXiv:1611.09508 (2016).]

DS 36.18 Wed 17:00 P2-EG

Performance characterization of a custom quadrupole setup for creation of an energy and mass selective hyperthermal ion beam — •Michael Mensing[1], Philipp Schumacher[1], Jürgen W. Gerlach[1], Stephan Rauschenbach[2], and Bernd Rauschenbach[1,3] — [1]Leibniz Institute of Surface Modification, Leipzig, Germany — [2]Max Planck Institute for Solid State Research, Stuttgart, Germany — [3]Faculty of Physics and Earth Sciences, Leipzig University, Leipzig, Germany

To explore the influence of the ion kinetic energy and ion species, i.e. molecular or atomic nitrogen ions, on the growth and the resulting properties of ultrathin nitride films an existing ion-beam assisted molecular beam epitaxy (IBA-MBE) setup is equipped with a radio-frequency quadrupole ion optical setup. Prerequisite to such investigations is a thorough characterization of the properties of the generated ion beam. In this contribution (i) the performance of the mass separation is quantified. (ii) The distribution of the ion energy and its scaling within the hyperthermal energy range (20 eV - 200 eV) is discussed. As the present setup utilizes a constricted glow-discharge plasma source, the controlled extraction of the ions from the plasma determines the ion kinetic energy of the resulting ion beam. (iii) The ion beam shape is determined and (iv) achievable ion beam currents are presented. Furthermore, the influence of space charge effects in individual segments of the setup is evaluated and clarified by ion trajectory simulations using the SIMION computer code. In conclusion, the mass and energy selected ion beam fulfills the requirements for nanofilm growth studies.

DS 36.19 Wed 17:00 P2-EG

Influence of processing conditions on the properties of kesterite thin films from solution-deposition — •Vincent Steininger, Mohamed Sayed, and Levent Gütay — Laboratory for Chalcogenide Photovoltaics, Department of Energy and Semiconductor Research, Institute of Physics, University of Oldenburg, D-26111 Oldenburg, Germany

Kesterite semiconductor compounds are being considered as attractive alternative absorbers for thin film solar cells. Various chemical solution deposition techniques have been widely employed for the fabrication of kesterite thin films including spin coating and doctor blading. Doctor blading technique offers a lot of advantages for the processing of thin films due to its simplicity, cost effectiveness and its application for large area deposition.

The precursor processing conditions such as blading parameters and selenization parameters play a critical role and have significant impact on the properties of the kesterite thin films and hence the device performance. In this study we have deposited Cu_2ZnSnS_4 (CZTS) precursors by doctor blading technique under ambient air followed by an annealing step in selenium atmosphere to obtain $Cu_2ZnSn(S,Se)_4$ (CZTSSe) thin films.

The influence of different processing conditions on the properties of the prepared thin films was investigated using SEM, XRD and Raman spectroscopy.

CZTSSe thin film solar cells were fabricated and the resulting efficiencies are discussed in context of the varied parameters.

DS 36.20 Wed 17:00 P2-EG

Modeling of current voltage characteristics of Schottky contacts on Ga_2O_3 and In_2O_3 — •Daniel Splith, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Leipzig, Germany

We present a model for the calculation of current voltage characteristics of Schottky contacts (SCs) taking into account barrier height inhomogeneities and variations of the net doping density in growth direction determining the spatial dependence of band bending. For each barrier height the band diagram was calculated using the finite element method. Subsequently, thermionic and thermionic field emission (TE and TFE) currents were calculated using the transfer matrix method. Additionally, charging currents were taken into account.

The model was used to calculate the IV characteristics of SCs on β-Ga_2O_3 and In_2O_3, utilizing the barrier parameters determined from temperature dependent IV measurements. Using a homogeneous doping profile for the β-Ga_2O_3, the modeled and measured temperature dependent characteristics are in good agreement. The modeled data shows that in the reverse direction, charging and TFE currents are dominant. For SCs on In_2O_3 the influence of the thickness of a Mg-doped layer on top of a nominally undoped thin film was investigated. Assuming a step-like doping profile and using the barrier parameters of the contact with the thickest Mg-doped layer, the modeled characteristics show a good agreement to the measured data for different layer thicknesses. The TFE current, while dominant for thin Mg-doped layers, is reduced with increasing layer thickness.

DS 36.21 Wed 17:00 P2-EG

Pulsed Radiofrequency sputtering of gallium oxide — •Philipp Schurig[1], Angelika Polity[1], Peter Klar[1], and Martin Eickhoff[2] — [1]1. Physikalisches Institut, AG Funktionelle Dünnschichten, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 16, 35392 Giessen — [2]Universität Bremen, Institut für Festkörperphysik, Festkörpermaterialien, Otto-Hahn Allee 1, 28359 Bremen

The interest in transparent semiconductor materials is still at a high level due to possible applications in the field of (opto-)electronics, for example as photoresistors/-diodes and solar cells. One transparent oxide with a band gap of around 4.9 eV is the oxide of gallium, with its thermodynamically most stable phase β-gallium oxide. One critical parameter during deposition is the growth temperature which is relatively high with 650°C for β-gallium oxide. For industrial applications it is desirable to lower this value. Recent studies [Nak14] have shown that pulsed sputter deposition allows an increase of the coupled rf power and at the same time a decrease of the growth temperature without severe structural degradation of the material. This approach was adopted to the deposition of gallium oxide and the influence of parameters like pulse frequency or duty cycle time on the layer characteristics was examined. Nevertheless, post growth annealing was still necessary and performed at temperatures of 1000 °C in oxidizing atmosphere. UV-Vis-NIR, XRD, EDX and SEM measurements were performed after deposition. [Nak14] E. Nakamura et al.: Dramatic reduction in process temperature of InGaN-based light-emitting diodes by pulsed sputtering growth technique; (2014) Doi: 10.1063/1.4864283

DS 36.22 Wed 17:00 P2-EG

Synthesis of 2D lead-free hybrid perovskites (CnH2n+1NH3BX4; B = Mn, Cu; X = Cl, Br, I) and characterization — •Irina Anusca, Adela Bronja, Martina Pantaler, Christian Fettkenhauer, and Doru C. Lupascu — Institute for Materials Science and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, Universitätsstraße 15, 45141 Essen, Germany

Organic-inorganic lead halide perovskites have a high content of toxic lead which may eventually hamper their commercialization [1]. 2D perovskites (CnH2n+1NH3BX4; B = Mn, Cu; X = Cl, Br, I) can be alternative classes of lead free perovskite for optoelectronic application. We prepare different series of Cu and Mn perovskites by mixing of different CnH2n+1 organic ammonium cation (alkyl and aromatic) and X halide ion and we studied the optical properties in such systems. Properties were analyzed using x-ray diffraction und UV-VIS spectroscopy.

[1] Daniele Cortecchia, Herlina Arianita Dewi et al., Inorganic Chemistry, 2016, 55(3) pp. 1044-1052.

DS 36.23 Wed 17:00 P2-EG

Investigation of the structural and electrical properties of PLD grown gallium oxide thin films on quartz glass — •Laurenz Thyen, Daniel Splith, Stefan Müller, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Germany

For high power electronics, β-gallium oxide (Ga_2O_3) is of great interest due to its bandgap of 4.5 to 4.9 eV[1] at room temperature. As an alternative to homoepitaxy, being still costly nowadays, and heteroepitaxy on crystalline substrates, we investigated the structural, optical and electrical properties of SiO_2-doped β-gallium oxide thin films on quartz glass substrates. In that process, Ga_2O_3 thin films were fabricated by pulsed laser deposition at different temperatures and oxygen pressures. Additionally, the influence of an undoped Ga_2O_3 buffer layer was investigated in order to optimize the properties of the thin films on quartz glas. X-ray diffraction measurements yield that the thin films are amorphous up to a growth temperature of 400°C. At higher temperatures polycrystaline growth was observed. The roughness of the thin films which were directly grown on glass substrate is comparable to that of thin films grown on c-plane sapphire substrate. For the investigation of the electrical properties, PtO_x-Schottky contacts were fabricated on the Ga_2O_3 thin films by sputtering. From current-voltage characteristics, ideality factors of 1.2, effective barrier heights up to 1.35 eV and rectification ratios of 10^7 were determined.

[1] T. Matsumoto *et al.*, Jpn. J. Appl. Phys. 13, 1578 (1974).

DS 36.24 Wed 17:00 P2-EG

Bismuth and antimony-based lead free double perovskites — •Martina Pantaler, Irina Anusca, Christian Fettkenhauer, and Doru C. Lupascu — Institute for Materials Science and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg Essen, Universitätsstraße 15 45141 Essen

Bismuth- or antimony-based lead-free double perovskites as Cs2AgBiBr6 have been considered as alternatives to the emerging lead-based perovskites for solar cell applications. Until now, the class of compounds, Cs2AgBiBr6 and Cs2AgBiCl6 have been synthesized, which crystallize in 3D crystal structure, where the rock-salt arrangement of B and C cations is energetically favored, primarily because of the large charge difference between monovalent and trivalent C cations. These Pb-free double perovskites have been reported to have promising PV properties, including long carrier recombination lifetime,good stability against air and moisture, and low carrier effective masses. In our work, we report the different synthesis paths (solid state synthesis, solution state synthesis and hydrothermal synthesis) including single crystals synthesis of a halide double perovskite, A2BCX6 (A=Cs+, Rb+, MA+, B=Ag+, Cu+, C=Sb3+, Bi3+, X=Cl-, Br-, I-). We explore different properties and possibility to be used in PV. Film deposition was performed using spin coating and vapor deposition. References [1] Zewen Xiao et al., ChemSusChem 2016, 9, 2628-2633

DS 36.25 Wed 17:00 P2-EG

Surface-enhanced Raman spectroscopy (SERS) on $La_{0.7}Ca_{0.3}MnO_3$: Indication for a Jahn-Teller dominated surface structure — •Sebastian Merten, Bernd Damschke, Konrad Samwer, and Vasily Moshnyaga — I. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, D-37077 Göttingen, Germany

Raman spectroscopy is a powerful tool to study different degrees of freedom at the same time. However, for thin films its use is limited

by the normally strong background of the substrate. SERS allows one to overcome this limitation and opens new insights into the structural properties of ultrathin films and surfaces due to the small penetration depths of less than 5 nm. Here we report SERS measurements on thin TiO_2 and $La_{0.7}Ca_{0.7}MnO_3$ films grown by metalorganic aerosol deposition (MAD). As model system we used 20nm thick TiO_2 on a Si(100) substrate and a gold nano-layer on top of it, both grown by MAD. Only Si background is seen in the Raman spectrum of bare TiO_2. After deposition of the Au-layer, a strongly enhanced E_g-mode at 143 cm^{-1} of the anatase TiO_2 phase was observed. LCMO/MgO(100) and LCMO/$LaAlO_3$(001) films show a strong enhancement of the Jahn-Teller modes compared with normal Raman spectroscopy. This suggests the presence of cooperative Jahn-Teller effect at the film surface due to symmetry-breaking-induced electron-lattice reconstruction. Financial support from DFG via SFB 1073 (TP B01 and B04) is acknowledged.

DS 36.26 Wed 17:00 P2-EG

Effect of Bi-content and Gd-doping on the multiferroic properties of $BaTiO_3$-$BiFeO_3$ superlattices — •Stefan Hohenberger[1], Michael Lorenz[1], Vera Lazenka[2], and Marius Grundmann[1] — [1]Institut für Experimentelle Physik II, Universität Leipzig, D-04103 Leipzig, Germany — [2]Instituut voor Kern- en Stralingsfysica, KU Leuven, B-3001 Leuven, Belgium

Epitaxial superlattices consisting of $BaTiO_3$-$BiFeO_3$ double layers show vastly improved magnetoelectric (ME) voltage coefficients α_{ME} of up to 49 V cm^{-1} Oe^{-1} [1], compared with single-phase $BiFeO_3$ films. The microscopic origins of this enhanced ME coupling, however, are currently not fully understood. A series of films were prepared by pulsed laser deposition on $SrTiO_3$ substrates using $BiFeO_3$ targets with overstochiometric Bi-content ($Bi_{1.1}FeO_3$), as well as targets doped with Gd ($Bi_{1-x}Gd_xFeO_3$). These modifications have shown to increase the ferromagnetic and ferroelectric properties in single phase $BiFeO_3$ films.

The samples were studied with a vibrating sample magnetometer in a magnetocryostat at 10 K and 300 K. Ferroelectric polarization hysteresis measurements were carried out with a thin film analyzer. Furthermore, piezo-force microscopy was carried out. The results show the impact of chemical composition and rare earth doping on the multiferroic performance of oxide superlattices.

[1] M. Lorenz, V. Lazenka, P. Schwinkendorf, M. J. Van Bael, A. Vantomme, K. Temst, M. Grundmann, T. Höche, Adv. Mater. Interfaces **3**, 11 (2016).

DS 36.27 Wed 17:00 P2-EG

Epitaxial growth of NiO on GaN(0001) by molecular beam epitaxy and its photocatalytic application — •Melanie Budde, Carsten Tschammer, Jumpei Kamimura, and Oliver Bierwagen — Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin, Germany

Nickel oxide is a transparent and semiconducting p-type oxide, which is interesting for various applications. For example, it works as a co-catalyst which allows for higher stability and efficiency of GaN photocatalysts for hydrogen generation. Furthermore, it can be used in normally off GaN-based heterojunction field-effect transistors as a gate dielectric to reduce the distance between source and drain. Therefore, well-defined and smooth NiO layers on GaN are required. Here NiO was grown by plasma-assisted molecular beam epitaxy on GaN templates. The topography and layer quality for different growth parameters was investigated using in-situ reflecticion high-energy electron diffraction as well as ex-situ x-ray diffraction and atomic force microscopy. The epitaxial relationship between substrate and layer was defined and rationalized by the concept of domain matching epitaxy. The impact of NiO layers on the stability of the photocatalytic application was tested.

DS 36.28 Wed 17:00 P2-EG

Thermal Conductivity of Thin Films Determined via IR thermography — •Natalie Galfe[1], Anton Greppmair[1], Benedikt Stoib[1], Nitin Saxena[2], Caroline Gerstberger[1], Peter Müller-Buschbaum[2], Martin Stutzmann[1], and Martin S. Brandt[1] — [1]Walter Schottky Institut and Physik-Department, Technische Universität München, Am Coulombwall 4, 85748 Garching — [2]Lehrstuhl für Funktionelle Materialien, Physik-Department, Technische Universität München, James-Franck-Strasse 1, 85748 Garching

In fields such as microelectronics and thermoelectrics, heat management becomes increasingly important. However, with the continuous miniaturization of the corresponding devices, established methods for the determination of the thermal conductance face severe challenges. Here, we demonstrate a simple and quick method for the measurement of the in-plane thermal conductance of thin films via steady-state infrared thermography. The films are suspended above a hole in an opaque substrate and homogeneously heated by a visible light source. The temperature distribution of the thin films is captured via IR microscopy and fitted to the analytical expression obtained for the specific hole geometry used in order to obtain the in-plane thermal conductivity. For thin films of PEDOT:PSS post-treated with ethylene glycol and of polyimide we find conductivities of 1.0 W/mK and 0.4 W/mK at room temperature, respectively. Furthermore, we are able to demonstrate the influence of varying the electrical conductance of the PEDOT:PSS films on the resulting thermal conductance. All results are in very good agreement with literature values.

DS 36.29 Wed 17:00 P2-EG

Thermoelectric Characterization of Organic Thin Films — •Kiana Baumgaertner[1], Alexander Steeger[1], Florian Huewe[1], and Jens Pflaum[1,2] — [1]Experimental Physics VI, Julius Maximilian University of Würzburg, 97074 Würzburg — [2]Bavarian Center for Applied Energy Research (ZAE Bayern), 97074 Würzburg

Conducting organic thin films have recently been proposed as innovative thermoelectric materials to recover waste heat at low cost[1]. To characterize their thermoelectric figure of merit zT it is necessary to determine the materials' electrical and thermal conductivity as well as their Seebeck coefficient. In this study, we developed an experimental setup to consistently measure this set of parameters on a single thin film sample for temperatures ranging from 4 K to 300 K. The thermal conductivity is characterized based on the 3ω-method by periodic Joule heating of a metal strip deposited atop the film. This metal strip acts as a heater creating a temperature gradient across the sample for measurement of the Seebeck voltage between two separate contacts. Optimizing the measurement geometry by performing finite-element simulations on thin films of thicknesses below $d = 1\,\mu$m and thermal conductivities of $\kappa \leq 1\,\mathrm{W/(mK)}$, the functionality of this setup has been verified on oxide as well as polymeric thin film samples. First results on the thermoelectric performance of functionalized organic layers will be presented that highlight the potential of this material class. [1] O. Bubnova et al., Nat. Mater. 2011, 10, 429.

DS 36.30 Wed 17:00 P2-EG

Resistive switching dynamics in BiFeO3 — •Nan Du[1], Niveditha Manjunath[1], Yuan Li[1], Tiangui You[1], Danilo Buerger[1], Ilona Skorupa[1,2], Damian Walczyk[3], Christian Walczyk[3], Thomas Schroeder[3], Stephan Menzel[4], Eike Linn[5], Rainer Waser[4,5], Oliver G. Schmidt[1,6], and Heidemarie Schmidt[1] — [1]Faculty of Electrical and Information Engineering, TU Chemnitz — [2]Institute of Ion Beam Physics and Materials Research, HZDR — [3]Leibniz-Institut für innovative Mikroelektronik, IHP — [4]Peter Grünberg Institut, Forschungszentrum Jülich — [5]Institut für Werkstoffe der Elektrotechnik, RWTH Aachen — [6]Institute for Integrative Nanosciences, IFW Dresden

Experimental and model impedance and dynamic switching experiments for the study of hopping transport of electron charges and positively charged oxygen vacancies in memristive BiFeO3 switches with substitutional Ti donors close to the bottom electrode are reported. The drift velocity of oxygen vacancies in the electric field of the writing pulse determines the dynamics of resistive switching. The modelled activation energy for trapping and release of oxygen vacancies at the bottom electrode reflects the local enhancement of the electrostatic potential profile at the bottom electrode due to the Ti donors. The data analysis of the experimental electrostatic potential profile will be useful for a quantitative comparison between experimental and future principles computational design of memristive oxide switches with substitutional dopants for trapping and releasing oxygen vacancies.

DS 36.31 Wed 17:00 P2-EG

Morphological and structural studies of perovskite layers deposited on various substrates — Mohammad I. Hossain, Mohammed I. Helal, and •Abdelhak Belaidi — Qatar Environment & Energy Research Institute (QEERI), Hamad Bin Khalifa University (HBKU), Qatar Foundation, P.O. Box 5825 Doha, Qatar

Perovskite, (CH3NH3PbI3), is an organic-inorganic material that has showed vast potential as an absorber in the photovoltaic (PV) research due to its suitable electronic, optical, and structural properties. Morphological studies of such layers are beneficial for PV applications due

to the variation in grain size which affects directly the charge transport. In this work, we have prepared perovskite (CH3NH3PbI3) layers using one step solution process in air on various substrates, like FTO and TiO2, with various concentration ratios of PbI2/ CH3NH3I from 0.3 to 1.1. The deposited layers were then characterized after post-annealing treatment in air at 100oC using XRD, SEM, and UV-Vis. The crystallographic structure of the layers deposited using such solution process depends on the ratio of PbI2/CH3NH3I. XRD results confirm that for the ratio 1.1 both perovskite and PbI2 phases exist, however for ratios 0.8, 0.7, and 0.6 only the perovskite phase exists. Interestingly, SEM images show that the morphology of the deposited films with ratios 1.1 and 0.8 are fibrous shape, whereas, for the other ratios the shape disappears. UV-Vis results confirm the bandgap of perovskite layers laying around 1.63 eV. Hence, the study of the variation of PbI2/CH3NH3I ratio is promising to design perovskite solar cells with the optimum morphological properties.

DS 36.32 Wed 17:00 P2-EG

Effect of a moderating etching front in reactive ion beam figuring of optical aluminium surfaces — •Jens Bauer, Frank Frost, and Thomas Arnold — Leibniz-Institut für Oberflächenmodifizierung, Permoserstraße 15, D-04318 Leipzig, Germany

Shape-adapted mirror optics are highly interesting for short-wavelength applications. Ion beam figuring is an established method in high-end optical surface manufacturing. But the direct machining of optical Al surfaces failed up to now, since the surface roughness increases drastically as a result of structural, crystallographic and chemical matrix irregularities. Our contribution focuses RIBE figuring of RSA Al6061 and Al905 with O_2 and N_2 containing process gas. In contrast to the classical RIBE scheme, no volatile process products are generated, but the machined surface is determinately chemically modified. A very stable and non-hazardous etch mechanism is obtained. The etch behaviour is analysed by WLI, AFM, and TOF-SIMS. Supplemented by Monte Carlo simulations a phenomenological model is presented. In particular, due to the impact of the energetic reactive ions a homogeneous and temporally stable surface oxide or nidride layer is formed. This layer results from a quasi-stationary equilibrium between ion implantation and sputter erosion. The surface layer acts as an etching front moderating the inhomogeneous structural conditions of the aluminium bulk material. Thus, the surface roughness is preserved almost in its initial state. Deterministic narrow ion beam operation via a dwell-time approach is now qualified for ultra-precision figure error correction of high-quality Al mirror optics.

DS 36.33 Wed 17:00 P2-EG

Microstructure of pulsed-laser deposited Ge-Sb-Te phase-change thin films on surface-reconstructed silicon substrates — •Ulrich Ross, Andriy Lotnyk, Isom Hilmi, and Bernd Rauschenbach — Leibniz Institut für Oberflächenmodifizierung e.V. Permoserstr. 15 D-04318 Leipzig

The stable layered phases of Ge-Sb-Te based phase-change thin films are of technological interest for a number of novel properties, most prominently the crystalline resistance switching behaviour in stacked superlayers. In order to provide such thin films for structure and property investigations, precise control and understanding of the crystalline thin film growth behaviour is required.

Thin films of the prototypical phase-change material Ge_2-Sb_2-Te_5 were grown by pulsed laser deposition onto (111) oriented silicon substrates. The Si(111) 7x7 surface reconstruction was achieved by thermal treatment before natural cooldown to the final deposition temperature. The growth process was observed by in-situ RHEED measurements, and the resulting crystalline quality evaluated by SEM and XRD. Cross-sectional specimens were investigated by aberration-corrected STEM using analytic techniques as well as atomic-resolution imaging and image simulation. The results reveal a highly characteristic surface-passivated Van-der-Waals interface structure for the epitaxial growth regime, while the crystalline lattice structure is dominated by stoichiometric stacking disorder. At intermediate deposition temperatures, the domain-epitaxy growth results in stressed in-plane rotation domains and twin formation.

DS 36.34 Wed 17:00 P2-EG

Noble gas ion-induced pattern formation on indium oxide thin films — •Hans Hofsäss, Omar Bobes, and Ronja Langendorf — Fakultät für Physik, Universität Göttingen, Göttingen, Germany

Formation of self-organized surface patterns by noble gas ion irradiation has been studied in the past. Ripple pattern formation on oxides was mainly investigated for fused silica [1], sapphire [2] and also Indium-Tin-oxide (ITO) [3]. Whereas silica and sapphire exhibits the expected behavior regarding ripple formation, ripple formation on ITO was investigated only for grazing incidence, where parallel ripple were observed. It was conclude that crystallinity plays a crucial role for pattern formation on ITO [3]. We studied the pattern formation on ITO for 1 keV Ar and Xe ion irradiation and a broad range on ion incidence angles. We find flat surfaces except for grazing ion incidence where perpendicular ripples similar to [2] are observed. Results for ion irradiation at lower ion energy will be presented. We compare the existing data for silica, sapphire and ITO with predictions from linear theories, where we use curvature coefficients determined from Monte Carlo simulations. The simulation results are in good quantitative agreement with the experiments done with silica and sapphire but not for ITO.

[1] A. Keller et al., J. Phys.: Condens Matter 21 (2009) 495305
[2] H. Zhou et al., Phys. Rev. B 78 (2008) 165404
[3] T. Škereň et al., Thin Solid Films 589 (2015) 315

DS 36.35 Wed 17:00 P2-EG

Comparison of pattern formation of Si and Si_3N_4 by N^+ and $N_2{}^+$ ion irradiation — •Hans Hofsäss, Omar Bobes, and Lukas Janos Richter — Fakultät für Physik, Universität Göttingen, Göttingen, Germany

Recently Bradley and Hofsäss introduced ion implantation as an additional effect contributing to pattern formation. Ion implantation should contribute to surface instability an pattern formation at larger ion incidence angles, typically above 45-50°. To demonstrate the the effect of ion implantation, we compare N^+ and $N_2{}^+$ ion irradiation of Si and silicon nitride substrates. Silicon itride cannot accommodate N beyond the given stoichiometry and implanted N must diffuse out. The stoichiometry of the films remains unchanged irradiation with N and additional N incorporation can be neglected. On the other hand, N will be incorporated into Si and an amorphous SiN_x layer will form. Here, implanted N should contribute to pattern formation. We irradiated Si and silicon nitride samples with ions in the energy regime few keV up to 10 keV and ion incidence angles between 60° and 75°. We find no pattern formation on Si_3N_4 for all investigated irradiation parameters. In contrast, N irradiation of Si leads to pronounced ripple patterns. The behavior can be understood from a comparison with simulation results based on the crater function formalism and Monte Carlo simulations of the ion solid interaction. We find strong support that pattern formation on N ion irradiated Si is mainly determined by N ion implantation.

DS 36.36 Wed 17:00 P2-EG

An explanation for the unusual pattern formation behavior on Ge — •Hans Hofsäss, Omar Bobes, and Kun Zhang — Fakultät für Physik, Universität Göttingen, Göttingen, Germany

Pattern formation on Germanium surfaces due to ion irradiation has been extensively studied experimentally [1,2,3]. Common to these experiments is that the onset of parallel ripple patterns occurs at an unusual large critical angle of incidence of about 60° and only for heavier ions such as Kr and Xe. For Ar and Ne no pattern formation was found for all angles of incidence [1]. This behavior cannot be understood on the basis of the Bradley-Harper and the Carter-Vishnyakov model.

We have carried out experiments, which confirm the above mentioned experimental results. Monte Carlo simulations using the SDTrimSP program were performed to calculate the curvature coefficients using the crater function formalism. We take into account incorporation of noble gas ions and density reduction due to swelling and void formation. We find that pattern formation on Ge surfaces should indeed be absent for keV Ne and Ar ion irradiation and is suppressed for keV Kr and even Xe ions, except for large angles of incidence.

[1] M. Teichmann, J. Lorbeer, B. Ziberi, F. Frost, and B. Rauschenbach, New. J. Phys. 15 (2013) 103029.
[2] J. C. Perkinson, C. S. Madi, and M. J. Aziz, J. Vac. Sci. Technol. A 31 (2013) 021405.
[3] E. Anzenberg, J. C. Perkinson, C. S. Madi, M. J. Aziz, and K. F. Ludwig, Phys. Rev. B 86 (2012) 245412.

DS 36.37 Wed 17:00 P2-EG

Neon ion beam induced surface pattern formation on Si — •Hans Hofsäss, Kun Zhang, and Omar Bobes — Fakultät für Physik, Universität Göttingen, Göttingen, Germany

The development of self-organized surface patterns on Si due to noble

gas ion irradiation has been studied extensively in the past. However, in nearly all experiments to date, no pattern formation on Si was observed for ion irradiation with Ne ions [1]. One exception is an experiment carried out by Carter et al. in 1995 where parallel ripple patterns with about 1.1 μm wave length are observed for 20 keV Ne ions incident on Si at an angle of 45° [2].

We present experimental data on pattern formation for Ne ion irradiation of Si with different ion energies and incidence angles larger than 45°. Using the crater function formalism and Monte Carlo simulations we calculate curvature coefficients of linear continuum models of pattern formation. Our simulations show that pattern formation is strongly suppressed for most ion energies. However, at very low energies $<$ 500 eV and also for energies above 20 keV parallel ripples can be expected. The role of incorporation of noble gas ions and a reduced density due to possible void formation is discussed.

[1] F. Frost, B. Ziberi, A. Schindler, B. Rauschenbach, Appl. Phys. A 91 (2008) 551.

[2] G. Carter, V. Vishnyakov, Yu. V. Martynenko, and M. J. Nobes, J. Appl. Phys. 78 (1995) 3559.

DS 36.38 Wed 17:00 P2-EG

Carbon ion beam induced surface pattern formation on amorphous carbon — •Hans Hofsäss, Omar Bobes, and Kun Zhang — Fakultät für Physik, Universität Göttingen, Göttingen, Germany

Using a mass selected carbon ion beam provided by our ion beam deposition system, we are able to perform irradiations of substrates with carbon ions at defined energies between about 100 eV and 60 keV and for variable ion incidence angle. We investigate the formation of ripple patterns on a-C films on Si. The hydrogen-free a-C films with thickness of 270 nm were grown on Si wafers by vacuum arc deposition and had a sp^3 bond fraction of about 60 percent. The special interest in carbon ion irradiation has several reasons:

(i) Unlike noble gas ion irradiation, carbon ions are incorporated into the a-C film as self atoms. Therefore we can study the effect of ion implantation on pattern formation without the complication of compound formation.

(ii) The sputter yield of carbon is rather low, in particular for the case of carbon ion irradiation. We therefore have a system where mass redistribution should be the dominant mechanism for pattern formation.

(iii) Carbon is even lighter than Ne and the comparison between C and Ne ion irradiation should provide further insight into the pattern formation mechanisms.

In this contribution we compare recent experimental results with Monte Carlo simulations using the SDTrimSP program.

DS 36.39 Wed 17:00 P2-EG

Combinatorial approach to structural and electrical properties of $(In,Ga)_2O_3$ thin films grown by pulsed laser deposition — •R. Hölldobler, H. von Wenckstern, D. Splith, J. Lenzner, H. Hochmuth, M. Lorenz, and M. Grundmann — Universität Leipzig, Fakultät für Physikund Geowissenschaften, Institut für Experimentelle Physik II,Linnéstr. 5, 04103, Leipzig, Germany

Combinatorial approaches in solid state science have been used more and more in recent years for an efficient exploration of novel materials. One approach is the growth of thin films with lateral composition gradient(s) and their spatially resolved characterization. We present the growth of $(In,Ga)_2O_3$ thin films by pulsed laser deposition (PLD) using a single but segmented PLD target [1]. The samples are deposited at various growth temperatures and oxygen pressures. Spatially resolved investigations of the chemical composition, structural and electrical properties are presented show an interplay between growth temperature, oxygen pressure and desorption of gallium sub-oxides as previously reported for molecular beam epitaxy [2]. Our results allow growth of alloyed thin film with tailored properties for specific application such as rectifiers or photodetectors.

[1] H. von Wenckstern, Z. Zhang, F. Schmidt, J. Lenzner, H. Hochmuth, and M. Grundmann, CrystEngComm **15**, 10020 (2013). [2] P. Vogt and O. Bierwagen, Appl. Phys. Lett. **109**, 062103 (2016).

DS 36.40 Wed 17:00 P2-EG

Investigation of oxygen-degraded organometallic halide perovskite via photoluminescence and photothermal deflection spectroscopies — •Alexandra Bausch[1,2], Paul Fassl[1,2], Qing Sun[1,2], David Becker-Koch[1,2], Paul E. Hopkinson[1,2], and Yana Vaynzof[1,2] — [1]Kirchhoff-Institute for Physics, Heidelberg University, Germany — [2]Centre for Advanced Materials, Heidelberg University, Germany

In recent years organo-metallic perovskite solar cells have been enthusiastically investigated due to their high power conversion efficiencies, low production costs and simple device fabrication. While the performance and electronic properties of perovskite photovoltaic devices are extensively researched, their environmental stability remains a major challenge to their potential integration into industrial application and is far less investigated. In order to develop a deeper understanding of the degradation processes taking place in perovskite solar cells when exposed to oxygen and light, we study the optical properties of degraded methylammonium lead iodide using photoluminescence and photothermal deflection spectroscopies. For this purpose, perovskite films fabricated using different methods are exposed to simulated sunlight under precisely controlled levels of oxygen in a dry environment. Longtime photoluminescence measurements reveal the effect of oxygen induced degradation on the efficiency of emission from the perovskite layers. Furthermore, photothermal deflection spectroscopy allows careful evaluation of the absorption edge of the perovskite layers, which enables the calculation of the Urbach energy.

DS 36.41 Wed 17:00 P2-EG

In Situ Stress Analysis In Ion-Implanted GaAs — •Paul Kutza, Emanuel Schmidt, Sascha Creutzburg, and Elke Wendler — Institut für Festkörperphysik, Friedrich-Schiller-Universität, Jena, Germany

Stress and damage formation in GaAs ion-implanted at room temperature are investigated. 1 MeV Si-ions are implanted with fluences up to 5E15 cm^{-2}. Various ion fluxes between 3E10 $cm^{-2}s^{-1}$ and 5E11 $cm^{-2}s^{-1}$ were applied. The stress evolution during the implantation is investigated in situ by measuring the radius of curvature of a GaAs cantilever via the position of a HeNe laser beam reflected by the bent surface of the GaAs sample. A strong dependence of damage formation on the chosen ion flux is observed. While ion fluxes up to 2.3E11 $cm^{-2}s^{-1}$ feature a steady increase of stress up to saturation, rates above 3E11 $cm^{-2}s^{-1}$ exhibit a stress maximum at a certain fluence followed by a significant stress decrease until a lower saturation value is reached. Ex Situ Rutherford Backscattering Spectroscopy in channeling mode (RBS/C) measurements reveal that only samples showing the latter stress evolution have developed an amorphous layer. When only point defects or extended defects are formed, stress relaxation does not occur. The fluence dependences are modeled, combining the damage concentration determined by RBS/C and the stress evolution. Additionally, effects of a low temperature implantation and a sudden shutdown of the Si-ion beam are investigated.

DS 36.42 Wed 17:00 P2-EG

Thermal Conductivity in Kesterite Crystals — •Martin Handwerg[1,2], Rüdiger Mitdank[1], Laura-Elisa Valle-Rios[2,3], Susan Schorr[2,3], and Saskia F. Fischer[1] — [1]Novel Materials, Humboldt-Universität zu Berlin, 12489 Berlin, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, 14109 Berlin, Germany — [3]Free University Berlin, Institute of Geological Sciences, 14195 Berlin, Germany

The kesterite materials Copper-Zinc-Tin-Sulfide and -Selenide are of huge interest for future solar cell applications due to the ideal band gap and high absorption rate. Insight in the thermal conductivity of a solar absorption material is important for the thermal management of the cell and therefore for the temperature-dependent efficiency. However, thermal conductivity investigations are rare actually.

Here we used the 3ω-method[1] to investigate the thermal conductivity of CZTSe macro-crystals with different compositions. The crystal thicknesses were in the range of several hundred micrometers. The metal heater lines with a width of 10 μm were deposited on the polished crystal surface. The measured thermal conductivity values are about 3 $Wm^{-1}K^{-1}$. The measured temperature-dependence of the thermal conductivity allows conclusions concerning the transport process. Phonon-phonon-Umklapp-scattering dominates the thermal conductivity for $T > 180$ K and point-defect-scattering occurs for $T < 180$ K.

[1] Handwerg *et al.*, Semicond. Sci. Technol. **30**, 024006 (2015).

DS 36.43 Wed 17:00 P2-EG

Production of fully Au-embedded ^{163}Ho for Neutrino Mass Measurements — •Tom Kieck[1,2], Christoph Düllmann[1], Lisa Gamer[3], Leonard Winkelmann[2], and Klaus Wendt[2] — [1]Institut für Kernchemie, Johannes Gutenberg-Universität Mainz, Germany — [2]Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany — [3]Kirchhoff-Institut für Physik, Universität Heidelberg, Germany

The ECHo collaboration aims at measuring the electron neutrino mass by recording the spectrum following electron capture of ^{163}Ho using metallic magnetic calorimeters (MMC). The radioisotope ^{163}Ho has been produced from enriched ^{162}Er in a high flux nuclear reactor and has to be fully embedded into the 250 x 250 μm^2 MMC-absorbers with minimum losses [1].

The application of resonant laser ionization at the RISIKO mass separator guarantees optimum elemental and isotopic selectivity for ultra-pure ^{163}Ho ion implantation with a sub millimeter beam spot [2]. An in-situ deposition of gold using the technique of pulsed laser deposition (PLD) ensures a homogeneous ^{163}Ho/Au layer production as absorber of the MMC. In this way a saturation of the implantation-dose by sputtering effects is prevented and the targeted activity of 10 Bq per detector is achieved.

[1] Hassel et al., J. Low Temp. Phys. 184, 910-921 (2016)
[2] Schneider et al., NIM B 376, 388-392 (2016)

DS 36.44 Wed 17:00 P2-EG

Protective ceramic layers deposited by chemical vapor deposition on complex 3D tools — Gregor Fornalczyk[1], •Sebastian Schipporeit[2,3,4], Frank Mumme[1], Friederike Deuerler[2], and Volker Buck[3,4] — [1]Gemeinnützige KIMW Forschungs-GmbH, Luedenscheid — [2]University of Wuppertal, School of Mechanical Engineering and Safety Engineering, Material Technology, Wuppertal — [3]University Duisburg-Essen, Thin Film Technology Group, Faculty of Physics, Duisburg — [4]CENIDE, Duisburg

Yttrium-doped ZrO_2 coatings are well-known to protect metallic tools and injection molds from wear and corrosion. This material is a highly anti-corrosive and wear resistant ceramic. It is particularly suitable for coating steel substrates, because their thermal expansion coefficient and mechanical properties are similar. We used a mixture of metal acetylacetonates in a 3D conformal aerosol-assisted chemical vapor deposition process. These precursors decompose at low temperatures (<500°C) and, thus, allow the deposition of layers into narrow cracks and holes without corroding or mechanically harming the steel substrates. We deposited films with excellent adhesion and wear properties at a nearly constant coating rate in aspect ratios up to 1:50 in 0.1 mm thin columns.

DS 36.45 Wed 17:00 P2-EG

Neon ion beam induced pattern formation on amorphous carbon surfaces — •Omar Bobes, Hans Hofsäss, and Kun Zhang — II. Physikalisches Institut, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

We investigate the ripple pattern formation on amorphous carbon surfaces at room temperature during low energy Ne ion irradiation as a function of ion incidence angle. Monte Carlo simulations of the curvature coefficients applied to the Bradley-Harper and Cater-Vishnyakov models, including the recent extensions by Harrison-Bradley and Hofsäss and taking into account the incorporation of the ions into the film predict that pattern formation on amorphous carbon should be possible for low energy Ne ions from 250 eV up to 5 keV. Moreover, simulations are able to explain the absence of pattern formation in certain cases. Our experimental results are compared with prediction using current linear theoretical models and applying the crater function formalism as well as Monte Carlo simulations to calculate curvature coefficients using SDTrimSP program.

DS 36.46 Wed 17:00 P2-EG

Low temperature transport measurements of metallic nanostructures prepared by area-selective atomic layer deposition on ultrathin platinum templates fabricated with focused electron beam induced deposition — •Peter Gruszka, Giorgia Di Prima, Roland Sachser, and Michael Huth — Goethe Universität, Max-von-Laue-Str. 1, 60438 Frankfurt am Main

Focused electron beam induced deposition (FEBID) is a serial, bottom-up and direct write approach with superior lateral resolution (< 10 nm) but results in samples with poor material purity. Much effort is put into the investigation of optimal deposition parameters to increase the material yield which in most cases is an impossible task. In contrast, atomic layer deposition(ALD) allows for depositing high purity thin films with sub-monolayer accuracy but lacks lateral control. Mackus, et al.[1] developed a combined technique which uses FEBID to predefine templates for the subsequent area selective ALD process.

We performed the combined FEBID-ALD process using purified platinum FEBID nanostructures as templates utilizing a purification technique developed by Sachser, et al.[2]. Afterwards the purified platinum templates were processed with ALD in our scanning electron microscope while monitoring in-situ the conductance over time. Additionally, our transport measurements in a Helium-3 cryostat showed that with this approach one can achieve high purity thin film nanostructures which behave nearly like platinum bulk samples.

[1] Mackus, et al., J. Appl. Phys 107 (2010), 116102
[2] Sachser, et al., ACS Appl. Mater. Interfaces 6 (2014), 15868 - 15874

DS 36.47 Wed 17:00 P2-EG

On-chip lateral anodic oxidation of titanium — •Daniela Welk, Svenja Herbertz, Thomas Heinzel, Paulus Aleksa, and Mara Zielinski — Solid State Physics Laboratory, Heinrich-Heine-Universität Düsseldorf

We demonstrate that it is possible to generate and increase the width of a TiO_x line in a Ti film by application of a DC voltage. The process has the character of an on-chip anodic oxidation and can be used to generate as well as tune electronic circuit elements on-chip. During oxidation, the TiO_x line changes its width, height, roughness and resistance. This growth of the oxide is studied under different ambient conditions.

DS 36.48 Wed 17:00 P2-EG

Solution-processed bottom-contact metal-oxide thin-film transistors with transparent monolayer graphene electrodes — •Ersoy Subasi[1], Sebastian Meyer[2], Duy-Vu Pham[2], Claudia Bock[1], and Ulrich Kunze[1] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, Bochum, Germany — [2]Evonik Resource Efficiency GmbH, Electronic Solutions, Marl, Germany

In this study we demonstrate the suitability of monolayer graphene (MLG) electrodes for solution-processed metal-oxide thin-film transistors (MOTFTs), which are capable of being used in the field of flexible and transparent low-cost electronics.

Solution-processed metal-oxide films are promising candidates to replace amorphous silicon as the active layer used in TFTs, e.g. in display applications, because of there simplicity, low-cost and high performance. Since conventional metal electrodes are not suitable for transparent electronics graphene is a promising material for next-generation transparent electrodes. We successfully prepared solution-processed bottom-contact MOTFTs with MLG electrodes and mobilities comparable to those of amorphous silicon $\mu_{\mathrm{FE,sat}} \approx 1.4\ \mathrm{cm^2V^{-1}s^{-1}}$. Using ultraviolet photoelectron spectroscopy under ambient conditions we determined the work function of the MLG electrodes to 5.0 eV. Since the electron affinity of the metal-oxide amounts approximately 3.7 eV [1] the work function of the MLG electrodes should be reduced (e.g. by doping). We achieved a reduction of the work function via a thin Al-film on top of the MLG electrodes ($\Delta\Phi_{\mathrm{M}} \approx -1.0$ eV).

[1] O. Lang *et al.*, J. Appl. Phys. 86, 5687 (1999).

DS 36.49 Wed 17:00 P2-EG

Temperature dependent absorption measurement at oxide semiconductors — •Jonathan Prexl[1], Karim Imani[3], Matthias Kleine-Boymann[3], Matthias Elm[2], and Sangam Chatterjee[2] — [1]Faculty of Physics and Materials Sciences Center, Philipps-Universität Marburg, Germany — [2]Institute of Experimental Physics I, Justus-Liebig-University Giessen, Germany — [3]Institue of Physical Chemistry, Justus-Liebig-University Giessen, Germany

Thermochromic oxide-semiconductors are highly interesting for a wide range of applications due to their intriguing optical properties. Quantitative measurements of their thermo-optical properties require stable thermal conditions for the sample in combination with a well-defined ambient gas atmosphere. The heating unit should, furthermore, enable a large number of experimental possibilities like spectrally and spatially resolved transmission or reflections measurements, multiple beam setups etc.

Here, we present an in-house developed, low cost heating unit for stable temperatures up to 800°C. We discuss the technical approach and constructing details to create stable environments and present some exemplary temperature dependent absorption data on CeO2 and (Ce,Zr)O2 samples prepared by pulsed laser deposition.

DS 36.50 Wed 17:00 P2-EG

Raman study of orthorombic Ga_2O_3 — •Daniel Zink, Marcel Weinhold, Max Kracht, Martin Eickhoff, and Peter J. Klar — Justus-Liebig-Universität Gießen, I. Physikalisches Institut, Heinrich-Buff-Ring 16, 35392 Gießen

In the fifties *Roy et al* reported five polymorphs of Ga_2O_3 obtained from solvothermal synthesis. Subsequently many studies of their catalytic properties werer performed. The availability of epitaxial synthesis routes recently gave rise to a new interest in this material system, also in the context of optoelectronic devices. Therefore a comprehensive structural analysis is required. The more so as the different synthesis ways with nanocrystalline mixed phases led to a confused naming of the Ga_2O_3-polymorphs. We will give a brief review of all known Ga_2O_3-structures and present Raman measurements of Sn-doped Ga_2O_3 prepared by plasma assisted MBE.

DS 36.51 Wed 17:00 P2-EG

Sputter Deposition of Nitrogen doped ZnMgO Thin Films — •Hannes Giese, Philipp Schurig, and Angelika Polity — I. Physikalisches Institut, Justus-Liebig-Universität, Giessen, Deutschland

ZnO is an intrinsic n-type semiconductor, which is favourable for the use as a transparent conductive thin film produced by sputter deposition. The addition of MgO results in a ternary system that has a tuneable band gap in dependence on the amount of Mg inside the system. The Mg content also has an influence on the crystal structure of the material. For many years theoretical calculations have shown the possibility of p-type doped ZnMgO for usage as optoelectronic devices made of ZnMgO homojunctions for example. The most promising way is doping the material with nitrogen to create the necessary defect levels above the valence band. The thin films are produced by RF sputter deposition from a self-made ceramic target with a composition of Zn(0,8)Mg(0,2)O with argon and oxygen as sputtering gases. Furthermore, an addition of nitrogen-gas as a reactive gas should lead to defects that provide a p-type doping. The nitrogen gas flow is varied in a wide range to investigate this influence. The changes in crystal quality, optical properties and electric behaviour are characterized by XRD, UV/Vis spectroscopy and Hall-effect measurements.

DS 36.52 Wed 17:00 P2-EG

Structural and optical investigations of Sn-doped $(Ga,Al)_2O_3$ thin films — •Anna Werner, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Semiconductor Physics Group, Institut für Experimentelle Physik II, Leipzig, Germany

Deep ultraviolet photodiodes find wide use in applications such as flame and oil spill detection or water desinfection. Ga_2O_3 is a suitable detector material and has a large bandgap of 4.5–4.9 eV[1], which band gap can be increased by alloying with Al_2O_3.

We present structural and optical investigations of $(Ga,Al)_2O_3$-thin films grown by pulsed laser deposition on c-plane sapphire using different oxygen pressure p_{O_2} and temperature T_g. Furthermore the thin films were doped with 1% SnO_2 to improve the electric conductivity. We investigated the $(Ga,Al)_2O_3$-thin films with X-ray diffraction (XRD), which shows that the crystal grew along the (-201) direction. Also optical transmission measurements were performed. We find that the cation composition ratio strongly depends on the deposition parameters. For lower (higher) p_{O_2} (T_g) the incorporation of Al is favored due to desorption of gallium sub-oxides during growth[2]. This leads to a change of lattice constant and absorption edge.

[1] T. Matsumoto, M. Aoki, A. Kinoshita, and T. Aono, Jpn. J. Appl. Phys. 13, 1578 (1974)
[2] P. Vogt and O. Bierwagen, APL Mater. 4, 086112 (2016)

DS 36.53 Wed 17:00 P2-EG

Influence of strain on the binding energies of Rydberg excitons in Cu_2O — •Sjard Ole Krüger, Peter Grünwald, Florian Schöne, and Stefan Scheel — Institut für Physik, Universität Rostock, D-18059 Rostock, Germany

In recent years, excitons in Cu_2O have emerged as a promising platform for the study of Rydberg physics [1], showing a strong Rydberg blockade. Experiments examining the collective behaviour of multi-exciton systems often employ effective trapping potentials which can be induced by nonuniform straining of the crystal. One experimental advantage of Rydberg excitons over Rydberg atoms is the feasibility of almost arbitrary trap geometries. Here, we will examine the influence of a uniform strain on the Rydberg exciton resonances in Cu_2O as a preliminary step to the description of Rydberg excitons in such traps. This will be achieved by the inclusion of the strain-induced deformation of the Γ_7^+ valence band [2] in numerical calculations, which include the full valence band nonparabolicity [3].

[1] T. Kazimierczuk *et al.*, Nature **514**, 7522 (2014)
[2] K. Suzuki and J.C. Hensel, Phys. Rev. B **9**, 10 (1974)
[3] F. Schöne *et al.*, Phys. Rev. B. **93**, 075203 (2016)

DS 36.54 Wed 17:00 P2-EG

Synthesis and crystal structure characterization of W5O14 and W18O49 nanowires — •Muhammad Saqib, Maja Remskar, and Janez Jalenc — Institut Jozef Stefan, Condensed matter Physics department, Ljubljana, Slovenia

Compared with other transition metal oxides, tungsten oxides have attracted great attention and have been investigated extensively due to their outstanding electrochromic, optochromic, and gas chromic properties. The individual W5O14 nanowires (NWs) made good ohmic contacts with W and Pt at room temperature and had excellent field-emission properties. Photoelectron spectroscopy revealed the metallic conductivity of the W5O14 NWs, which was confirmed by direct-transport measurements on a double stranded NWs. Here we report on achieving of reduction of tungsten three oxides to different sub- oxides nanowires by adding of elemental tungsten into the growth process. W5O14 and W18O49 nanowires are synthesized by the transport reaction in the presence of nickel as growth promoter and iodine as transport agent. The scanning electron microscope revealed rigid W5O14 and W18O49 NWs. Morphology and current-voltage characteristics of individual W5O14 NWs put on graphite were measured by scanning tunneling microscope operating in ultra-high vacuum. Surface structure of the W5O14 NWs was found affected by tunneling current, particularly on the NWs with weak interaction with the substrate. The work function of the NWs has been determined by Kelvin microscopy in non-contact atomic force microscopy operating in ultra-high vacuum.