HL 30: Poster I

This poster session includes contributions from the following topics:

- Nitrides: Devices - Nitrides: Preparation and characterization - Focus Session: Functional Metal Oxides for Novel Applications and Devices - Oxide semiconductors - THz and MIR physics in semiconductors - Heterostructures, interfaces and surfaces - Quantum transport and quantum Hall effects - Transport properties

Please put up your poster at the beginning of the session and remove the poster immediately after the session. The person peresenting the poster should attend it for at least half of the session duration and indicate the time when to find him/her at the poster.

Time: Tuesday 13:30–15:45 Location: P3

HL 30.1 Tue 13:30 P3

Towards Sustainable, Flexible Electronics from Abundant Elements: Integrated Circuits Comprising TFTs Based on Amorphous Room-Temperature-Fabricated Zinc-Tin-Oxide — •Oliver Lahr, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Felix-Bloch-Institut für Festkörperphysik, Linnéstraße 5, 04103 Leipzig, Germany

During the last decade, amorphous oxide semiconductors have advanced into a thriving research area for transparent and flexible electronics and since then, the field has grown rapidly towards, for instance, next-generation flat-panel displays. The widely commercially deployed and by far most mature representative indium-gallium-zinc-oxide, however, consists of rare elements such as indium and gallium that innovative research is attempting to substitute by materials containing abundant cations only.
Amorphous zinc-tin-oxide (ZTO) turns out to be a suitable candidate for sustainable, flexible and transparent electronics since it consists of abundant, non-toxic elements and exhibits promising performance even in case of room temperature fabricated circuits comprising MESFETs and JFETs [1,2]. Since previously reported TFTs relied on high-temperature processed ZTO channels, we report the first ZTO-based TFTs that neither require deposition at elevated temperature nor additional annealing in order to maintain compatibility with flexible substrates, while still representing current state-of-the-art devices.
[1] Lahr, IEEE Trans. Electron Devices, **66**, 8, 2019.
[2] Lahr, Adv. Electron. Mater., 1900548, 2019.

HL 30.2 Tue 13:30 P3

Effect of plasma treatment on electronic devices based on In_2O_3 — •Fabian Schöppach, Daniel Splith, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Felix Bloch Institute for Solid State Physics, Linnéstraße 5, 04103 Leipzig, Germany

Indium oxide (In_2O_3) has promising physical properties such as high conductivity and transparency in the visible. However, In_2O_3 is not used in active devices such as diodes or transistors yet. This is due to its tendency to form an electron accumulation layer on its surface which is reported to be caused by surface near oxygen vacancies [1]. Compensating Mg doping and plasma treatment are reported to reduce this effect and enable the resulting device operation [2,3].

In this work, the performance of first prototype metal-semiconductor field-effect transistors (MESFETs) based on In_2O_3 thin films was improved by an initial plasma treatment of the channel material. The thin films were grown via pulsed laser deposition and were treated afterwards with a pure oxygen plasma. For source and drain contacts gold was deposited via inert ambient sputtering. Schottky gate diodes were fabricated in a reactive sputter process, which is a requirement for obtaining rectifying contacts to In_2O_3 [5,6].

[1] King, et al. Physical Review B 80.8, 081201 (2009)
[2] Schmidt, et al. physica status solidi (b) 252.10, 2304-2308 (2015)
[3] Michel, et al. ACS Appl. Mater. Interf. 11, 27073-27087 (2019)
[4] von Wenckstern, et al. APL Materials 2.4, 046104 (2014)
[5] Schultz, et al. Phys. Rev. Appl. 9, 064001 (2018)

HL 30.3 Tue 13:30 P3

Investigation of charge carrier transport mechanism in amorphous ZnON and ZnSnO thin films by temperature dependent Hall effect measurements — Antonia Welk, Holger von Wenckstern, and •Marius Grundmann — Felix-Bloch-Institut für Festkörperphysik, Universität Leipzig, Linnéstraße 5, 04103 Leipzig, Germany

Amorphous semiconductors as zinc oxynitride (a-ZnON) or zinc tin oxide (a-ZTO) with Hall mobilities up to $100\,cm^2V^{-1}s^{-1}$ [1,2] or $13\,cm^2V^{-1}s^{-1}$ [3] are promising low-temperature deposition channel materials for thin film transistors (TFTs). For the enhancement of device performance it is necessary to gain a profound understanding of the charge carrier transport mechanism.
In this work we performed temperature dependent Hall effect measurements on magnetron sputtered ZnON and PLD grown ZnSnO thin films. We compared our experimental results to the theoretical description of percolation transport in the random band edge model [4,5]. That way we were able to validate the theoretical description for two further amorphous oxides aside of InGaZnO [5] and determined the band edge disorder parameter δ and the conduction mobility μ_0.

[1] A. Reinhardt *et al.*, Phys. Status Solidi A 213 (7), 1767 (2016)
[2] H. Kim *et al.*: *Sci. Rep.* **3**, 1459 (2013)
[3] P. Schlupp *et al.*, MRS Proceedings 1633, 101-104 (2014)
[4] I.I. Fishchuk *et al.*, Phys. Rev. B 93 (19), 195204 (2016)
[5] A.V. Nenashev *et al.*, Phys. Rev. B 100 (12), 125202 (2019)

HL 30.4 Tue 13:30 P3

Growth of transparent, p-conductive γ-CuI by PLD — •Philipp Storm, Michael Bar, Chang Yang, Daniel Splith, Holger von Wenckstern, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Felix-Bloch Institut für Festkörperphysik

Transparent semi-conductive materials (TSM) are typically unipolar such that heterostructures are required for pn-diodes. So far, n-type TSMs like ZnO or Ga_2O_3 typically have high electron mobility while p-TSMs suffer very low hole mobilities. CuI is currently one of the most promising p-type TSM due its wide band gap, high hole mobility and density as well as high exciton binding energy [1]. However, the physical vapor deposition (for example sputtering or thermal evaporation) of CuI turned out to be difficult to obtain smooth thin films [2,3] and therefore impeding progress towards uniform multilayered device structures. In this work, the growth of CuI by pulsed laser deposition (PLD) is presented. The morphological, structural and optical properties of the obtained thin films suggest a high potential of PLD-grown CuI for thin-film device applications.
[1] M. Grundmann *et al.* : Phys. Status Solidi A 210, 9, 1671 (2013)
[2] C. Yang *et al.* : Sci. Rep. 6, 21937 (2016)
[3] C. Moditswe *et al.* : Ceramics International 43, 6, 5121 (2017)

HL 30.5 Tue 13:30 P3

Electrical properties of all amorphous ZnMgON/$ZnCo_2O_4$ bipolar heterojunction diodes — •Arne Jörns, Antonia Welk, Anna Reinhardt, Holger von Wenckstern, and Marius Grundmann — Felix-Bloch-Institut für Festkörperphysik, Universität Leipzig, Linnéstraße 5, 04103 Leipzig, Germany

Amorphous zinc magnesium oxynitride (a-ZnMgON) is a promising low-temperature deposition material for flexible electronics. The incorporation of magnesium into amorphous ZnON, typically having free electron concentrations above $10^{18}\,cm^{-3}$ [1], leads to a reduction of the free carrier concentration and an absorption edge shift towards higher energies. By means of co-sputtering we were able to fabricate a-ZnMgON thin films with magnesium concentrations up to 5 at. %, free carrier concentrations in the range of 10^{16}-$10^{17}\,cm^{-3}$ and an absorption edge of 1.3 eV or higher.

In this study, we investigated all amorphous n-ZnMgON/p-$ZnCo_2O_4$ bipolar heterojunction diodes deposited on glass with rectification ratios in the range of 10^3-10^4. Modeling of the IV-characteristics yields a series resistance of 130-140 Ω, a parallel resistance in the range of 10^{10}-10^{11} Ω and an ideality factor of 2.8. In order

to suppress leakage currents in the reverse bias regime, a thin insulating, highly resistive ZnMgON layer was introduced between ZnMgON and $ZnCo_2O_4$. Furthermore, the diodes were investigated by means of temperature dependent IV-measurements and capacitance voltage measurements.

[1] A. Reinhardt *et al.*, Phys. Status Solidi A 213 (7), 1767 (2016)

HL 30.6 Tue 13:30 P3

HyGlas - a novel approach for smart windows as energetically efficient hybrid double-skin facades using electrochromic WO_3 thin films. — •Florian Kuhl, Angelika Polity, and Peter J. Klar — Institute of Experimental Physics I and Center for Materials Research (ZfM/LaMa), Justus Liebig University Giessen, Heinrich-Buff-Ring 16, DE-35392 Giessen, Germany

Since about 40 % of the global energy demand and one third of CO_2 equivalent is consumed by buildings and for example their climate control, smart windows that are commercially available can be used to reduce this energy demand in the following years. However, as of 2050 the existing political concepts of the BRD and EU claim a completely climate-neutral building stock. In general there is a focus on minimizing the cooling load in summer and the heating demand in winter which can be put into practice by using the solar energy stored between the glazings of a facade. We introduce the idea of integrating differently switchable electrochromic smart windows combined with venting systems for the whole facade system in the Framework of the HyGlas project. A commercially available electrochromic smart window, whose transmittance can be switched in the visible range of the solar spectrum, will be extended by a second electrochromic multilayer system that can be modulated in the infrared region. For this purpose we investigate rf-sputtered WO_3 thin films in terms of their structural, stoichiometrical and compositional properties as well as in their electrochemical and optical behaviour, i.e. the modulation of the transmittance in the intended range of the solar spectrum.

HL 30.7 Tue 13:30 P3

Vertical field-effect transistors based on amorphous zinc-tin oxide - simulation and fabrication — •Michael Bar, Daniel Splith, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Germany

Zinc-tin oxide (ZTO) is a wide gap semiconductor consisting of abundant, non-toxic elements. It unites transparency in the visible spectral range with high electron mobility in the amorphous state. Its deposition at room temperature has been proven successful for numerous device applications [1-3]. However, a greatly reduced channel length is needed for the fabrication of TFTs with high-frequency switching capabilities.

In this work a vertical device structure approach was used to fabricate vertical field-effect transistors (VFETs) with channel lengths of several hundred nanometers and without the use of submicrometer lithography equipment. Additionally, a finite element method has been used to simulate said devices. The static and dynamic properties obtained by transfer characteristics and drain-current modulation measurements were evaluated and compared to conventional lateral field-effect transistors. In this comparison the simulation of VFETs showed an increase in cut-off frequency of up to three orders of magnitude.

[1] S. Vogt *et al.*, Appl. Phys. Lett., **113**(13), 133501, (2018).
[2] O. Lahr *et al.*, IEEE Trans. Electron Devices, **66**(8), 3376, (2019).
[3] O. Lahr *et al.*, Adv. Electron. Mater., 1900548, (2019).

HL 30.8 Tue 13:30 P3

Electrical characterization of p-conductive transparent copper iodide thin films deposited by PLD — •Michael Bar, Philipp Storm, Holger von Wenckstern, Chang Yang, Michael Lorenz, and Marius Grundmann — Universtät Leipzig, Germany

Copper iodide (CuI) is a p-type, wide-bandgap semiconductor which unites transparency in the visible spectral range with exceptional hole conductivity. This makes CuI a viable candidate for various transparent electronic devices such as diodes and field-effect transistors. In recent years, sputtered CuI heterojunctions have been presented [1]. However, practical challenges regarding the growth of epitaxial films remain before CuI can be employed into TFTs.

In this contribution we present electrical properties of CuI thin films which were prepared by pulsed laser deposition. The electrical characterization of these films was performed using current-voltage and Hall measurements. Remarkable properties of these films are for example hole carrier densities in the order of $10^{17}\,cm^{-3}$ and a hole mobility of $10\,cm^2/Vs$.

[1] C. Yang *et al.*, Sci. Rep., **6**(1), 21937, (2016).

HL 30.9 Tue 13:30 P3

Towards Thermal Conductivity measurements in β-Ga_2O_3 Thin Films — •Robin Ahrling[1], Martin Handwerg[1], Olivio Chiatti[1], Rüdiger Mitdank[1], Zbigniew Galazka[2], Günter Wagner[2], Andreas Popp[2], and Saskia F. Fischer[1] — [1]Novel Materials Group, Humboldt-Universität zu Berlin, 10099 Berlin, Germany — [2]Leibniz Institute for Crystal Growth, 12489 Berlin Germany

As a wide-band gap semiconductor with a high breakthrough field, gallium oxide (Ga_2O_3) has shown to be a promising material for applications in high power electronics. However, due to the materials low thermal conductivity [1,2] heat dissipation may pose a threat for future device applications. Therefore, the thermal transport in Ga_2O_3 films needs to be explored. Electrical measurements have shown, that in very thin films the scattering processes change drastically with decreasing film thickness. [3] In this work, we investigate the thermal conductivity in these thin films, using the 3-ω method.

A variation of the 3-ω method with sub μm heater widths, causing the heaters to be thinner than the thickness of the examined films, is used. The heaters are produced by electron beam lithography.

We investigate the thermal conductivity in dependence of temperature and the thickness of the Ga_2O_3 films with a special interest in changes in the the phonon transport machanisms in very thin films.

[1] M. Handwerg *et al.*, Semicond. Sci. Technol. **30** (2015) 024006
[2] M. Handwerg *et al.*, Semicond. Sci. Technol. **31** (2016) 125006
[3] R. Ahrling *et al.*, Sci. Rep. **9**, 13149 (2019).

HL 30.10 Tue 13:30 P3

Stabilization of single phase α-$(Al_xGa_{1-x})_2O_3$ by pulsed laser deposition — •Max Kneiss, Anna Hassa, Daniel Splith, Chris Sturm, Holger von Wenckstern, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Felix-Bloch-Institut für Festkörperphysik

The α-phase of Ga_2O_3 exhibits a bandgap of 5.3 eV, which is slightly larger than that of the thermodynamically stable β-phase, and crystallizes in the same rhombohedral crystal structure as α-Al_2O_3 (sapphire). The availability of cost-effective low-mismatch sapphire single crystal substrates and the possibility of heteroepitaxy without rotation domains as well as n-type doping [1] renders this phase highly promising for device applications. Bandgap engineering as well as heterostructure devices are possible by alloying with Al. However, reports on α-$(Al_xGa_{1-x})_2O_3$ are rather scarce. We present the expitaxial stabilization of α-$(Al_xGa_{1-x})_2O_3$ on sapphire substrates by PLD. Utilizing radially-segmented $(Al_xGa_{1-x})_2O_3/Ga_2O_3$ targets (VCCS-PLD [2]) we were able to grow thin films in the α-phase on a- and m-plane sapphire covering the complete composition range between α-Ga_2O_3 and α-Al_2O_3. In-plane as well as out-of-plane lattice constants were determined by reciprocal space map measurements and a linear dependence on x was found. Above a critical Al-content, pseudomorphic growth was confirmed on the a-sapphire substrates. Further, the composition-dependent bandgaps as well as surface morphologies will be presented. [1] Ahmadi *et al.*, J. Appl. Phys. **126**, 160901 (2019) [2] Kneiß *et al.*, ACS Comb. Sc. **20**, 643 (2018)

HL 30.11 Tue 13:30 P3

Rectifying contacts to κ-Ga_2O_3 — •Max Kneiss, Anna Hassa, Peter Schlupp, Daniel Splith, Holger von Wenckstern, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Felix-Bloch-Institut für Festkörperphysik

The orthorhombic κ-phase of Ga_2O_3 possesses a similarly high bandgap of 5 eV as the thermodynamically stable β-phase. Further, it is expected to exhibit a high spontaneous electrical polarization of $23\,\mu C/cm^2$ [1] that can be utilized for polarization doping in heterostructures to localize a 2DEG by polarization differences at interfaces which then can serve as active layer in device applications. To employ κ-Ga_2O_3 in devices such as UV- or quantum-well infrared photodetectors, the realization of rectifying contacts is a prerequisite. However, reports on such contacts to κ-Ga_2O_3 are rare. In this talk, we present sputtered PtO_x/Pt and PdO_x/Pd Schottky contacts to κ-Ga_2O_3 as well as PLD grown NiO/κ-Ga_2O_3 and $ZnCo_2O_4$/κ-Ga_2O_3 pn-heterojunctions. The κ-Ga_2O_3 thin films were grown epitaxially by PLD from tin-containing targets [2] on ZnO/ZnO:Al growth templates on a-sapphire. The Al-doped ZnO layer is needed as highly con-

ductive current-spreading backcontact since lateral transport is suppressed in our κ-Ga_3O_3 thin films due to the presence of rotation domains. A Ti/Al/Au layer stack was employed as ohmic contact. By IV-measurements, we found rectifying behavior for all investigated types of contacts with rectification ratios of up to 8 orders of magnitude. [1] Maccioni *et al.*, Appl. Phys. Expr. **9**, 041102 (2016) [2] Kneiß *et al.*, APL Materials **7**, 022516 (2019)

HL 30.12 Tue 13:30 P3

Material Investigations of Corundum-Structured Group-III-Sesquioxides by PLD on (00.1) Al_2O_3 — •C. Petersen, A. Hassa, M. Kneiss, H. Wenckstern, D. Splith, C. Sturm, and M. Grundmann — Universität Leipzig, Felix-Bloch-Institut für Festkörperphysik, Linnéstraße 5, 04103 Leipzig, Germany

Due to its outstanding material properties, recently much attention was drawn to the wide bandgap semiconductor gallium oxide for possible applications e.g. in high-power devices. Apart from the well-studied β-phase of Ga_2O_3, the corundum α-polymorph is in particular well suited for heterostructures, because it is isostructural to α-In_2O_3 and α-Al_2O_3. This, in principle, enables alloying the material system across the entire phase diagram and bandgap engineering over a considerable energy range ($E_{g,Ga_2O_3} = 5.3\,\text{eV}$, $E_{g,In_2O_3} = 3.7\,\text{eV}$ and $E_{g,Al_2O_3} = 8.75\,\text{eV}$ [1].
In this contribution we present material properties of binary α-Ga_2O_3 thin films as well as it's ternary alloys with In or Al. The thin films were grown by pulsed laser deposition with continuous composition spread [2] on (00.1) Al_2O_3. Resulting samples were investigated by means of X-ray diffraction, transmission, energy-dispersive X-ray spectroscopy, atomic force microscopy, and electrical transport measurements.
[1] S. Fujita *et al.*, Jpn. J. Appl. Phys., 1202A3 (2016).
[2] H. v. Wenckstern *et al.*, CrystEngComm 15, 10020 (2013).

HL 30.13 Tue 13:30 P3

The influence on defect states in Aluminium oxide on conductivity of a hydrogen-terminated diamond surface — •Dennis Oing, Jens Kerski, Nicolas Wöhrl, Martin Geller, and Axel Lorke — Faculty of Physics and CENIDE, University of Duisburg-Essen, Lotharstr. 1, 47057 Duisburg, Germany

Hydrogen-terminated diamond shows a surface conductivity induced by transfer doping by acceptor states in adsorbate layers. Hence, the thermal and longtime stability of such devices is usually low. When covered with metal oxides, e.g. Al_2O_3 or MoO_3 a functionalized diamond surface show a higher thermal stability of reduced to $500°C$ due to not desorption of mentioned acceptor states.
In this study, defects in Al_2O_3-layers are used as acceptors on hydrogen-terminated diamond. These states are characterized using time-resolved charging and discharging of the defects by optical illumination using an UV-LED.
Temperature dependent Hall measurements show that the carrier density of the 2DHG induced by adsorbates from air is $1.3 \times 10^{-13}\,\text{cm}^{-2}$, while it is $6.7 \times 10^{-12}\,\text{cm}^{-2}$ with Al_2O_3 coverage. Carrier density is temperature independent in both cases. After illumination with an UV-LED, the conductivity of the 2DHG increases by 11 % at room temperature and 2.6 % at 200 K. The excitation shows 3 distinct time constants between 41 s and 40 min at room temperature. It is suggested that the transfer of electrons to the defect states is a three step process.

HL 30.14 Tue 13:30 P3

Modification of GaAs based Heterostructures by Laser Annealing — •Hans-Georg Babin, Julian Ritzmann, Marcel Schmidt, Arne Ludwig, and Andreas D. Wieck — Ruhr-Universität Bochum, D-44780 Bochum, Germany

Ex-situ thermal processing is a crucial step in semiconductor preparation. The applications range from the healing of crystal Damage[1], over the production of functional structures[2] up to the subsequent manipulation of material properties[3].

In addition to the obvious possibility of heating the sample in a furnace, high-intensity laser radiation can also be used for local heating of the semiconductor. This is called laser annealing.

This contribution deals with the realization of a Laser-Annealing-Setup for ex-situ modification of semiconductors. The construction and characterization will be discussed. In addition, the possibilities of laser annealing for the processing of GaAs heterostructures are estimated. The investigations include annealing of crystal damage, processing of insulating lines and alloying of ohmic contacts at GaAs/AlGaAs HEMTs. Finally, the change of the emission of quantum dots after Laser-Annealing is investigated.

1 S. D. Ferris et al.: AIP Conference Proceedings 50, 647, 1979
2 D. Bouwmeester et al.: Applied Physics Letters 95, 251104, 2009
3 L. Wang et al.: Applied Physics Letters 90, 073120, 2007

HL 30.15 Tue 13:30 P3

Molecular Beam Epitaxy growth and epitaxial lift off of (111)B-AlAs/GaAs heterostructures — •Tobias Henksmeier, Martin Eppinger, and Dirk Reuter — Department of Physics, Paderborn University, Warburgerstr. 100, 33098 Paderborn, Germany

In the recent years second harmonic generation (SHG) in nanoparticles has gained much interest as a platform for nonlinear optics. Thin (111)-GaAs films transferred to transparent substrates exhibit efficient forward directionality emission while for (100)-GaAs there is a strong pump pulse polarization dependence hindering efficient SHG emission perpendicular to the surface. We present the molecular beam epitaxy growth of $Al_xGa_{1-x}As$ heterostructures ($0<x<1$) on (111)B-GaAs substrates with a 1° miscut towards (211) and the fabrication of thin (111)B-GaAs films on arbitrary substrates via epitaxial lift off. We obtained similar growth rates on the (111)B surface as on the standard (100) surface. First, (111)B-$Al_xGa_{1-x}As$ ($x>0.7$) sacrificial layers were grown; then these layers were overgrown by a thin (111)B-GaAs layer. Surface roughness was investigated by atomic force microscopy (AFM). With optimized growth parameters a roughness <1 nm was obtained. 4×4 mm samples cleaved from the wafer were submerged in hydrofluoric acid to perform the epitaxial lift off of the GaAs layer. The etch rate of approximately 100μm/h is similar to those of (100)-$Al_xGa_{1-x}As$ ($0<x<1$) and will be discussed in detail. The released GaAs layer is bonded to a glass substrate. The film roughness <1 nm of the bonded GaAs was measured by AFM and the optical quality was checked by photoluminescence measurements.

HL 30.16 Tue 13:30 P3

Charge transport in graphene, encapsulated by hexagonal boron nitride, as a field effect transistor device — •Leo Schnitzspan[1], Alexander Tries[1,2,3], Marie-Luise Braatz[1,2], and Mathias Kläui[1,2] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz — [2]Graduate School of Excellence Materials Science in Mainz — [3]Max Planck Institute for Polymer Research

Two dimensional van der Waals-materials with conducting, insulating or ferromagnetic properties attract attention due to their extraordinary charge- and spin-transport characteristics and their simple realization by stamping 2D layers one above the other. This can be accomplished by means of a dry transfer method [1]. This method was further developed in order to transfer hexagonal boron nitride (hBN) and graphene, to achieve a hBN/graphene/hBN heterostructure device. With electron beam-lithography (EBL), electrodes were patterned such that the temperature dependent charge transport and magnetoresistance could be measured. The data analysis showed a high charge carrier mobility and a non-negligible impact of the interface between electrode leads and graphene. In addition, Shubnikov-de Haas oscillations were observed at temperatures of 2 K, which allow the extraction of the carrier concentration in graphene.

[1] Zomer, P. J., et al., *Appl. Phys. Lett.* **105**, 013101 (2014).

HL 30.17 Tue 13:30 P3

Ab Initio investigations on the accuracy of the band offset in GaAs/AlGaAs heterojunction — •Felix Scholler[1], Jonas F. Schäfer-Richarz[1,2], Philipp Risius[1,2], and Christian Heiliger[1,2] — [1]Institut für theoretische Physik, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen — [2]Zentrum für Materialforschung (LaMa), Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen

The prediction of materials properties for optimized material development requires an exact calculation of the band structure. A characteristic feature of the band structure of heterojunctions is the band offset. We want to assess the accuracy with which the Korringa Kohn Rostoker (KKR) method, which is a Green's functions based Density Functional Theory method, can predict the band offset of GaAs/AlGaAs heterojunctions. This system has been extensively studied experimentally, but theoretical treatment is challenging since a correct description of the alloy AlGaAs must be provided. Here, we treat AlGaAs with the Coherent Potential Approximation (CPA). Our results showcase the power of the KKR and the CPA for a simple materials system.

Comparing the calculated values with experimental results allows us to assess the accuracy with which band offsets can be calculated not only for AlGaAs/GaAs heterojunctions, but also for other semiconductor junctions.

HL 30.18 Tue 13:30 P3

Do equidistant energy levels necessitate a harmonic potential? — •Fabian Teichert, Eduard Kuhn, and Angela Thränhardt — Institute of Physics, Technische Universität Chemnitz, 09107 Chemnitz, Germany

Experimental results from literature show energetically equidistant quantum well states in thin Bi films on surfaces, suggesting a harmonic oscillator description [1,2]. Yet is this conclusion imperative, especially considering that any measurement only yields energy levels in a finite range and with a nonzero uncertainty? Within this study we investigate whether equidistant energy levels actually necessitate a harmonic potential or whether alternative potential shapes with equidistant levels exist. First, we describe experimental results from literature by a harmonic oscillator model, obtaining a realistic size and depth of the resulting quantum well. Second, we use the shift-operator approach to calculate anharmonic non-polynomial potentials producing (partly) equidistant spectra. We discuss different potential types and interpret the possible modeling applications [3]. Finally, by applying nth order perturbation theory we show that exactly equidistant eigenenergies cannot be achieved by polynomial potentials, except by the harmonic oscillator potential.

[1] P. Kröger et al.: Physical Review B 97 (2018), 045403
[2] T. Hirahara et al.: Physical Review B 75 (2007), 035422
[3] F. Teichert et al.: arXiv:1910.12522 [quant-ph]

HL 30.19 Tue 13:30 P3

Focused ion beam implantation of rare-earth ions in semiconductor nanostructures — •Christian Düputell[1], Arne Ludwig[1], Jörg Debus[2], Manfred Bayer[2], and Andreas D. Wieck[1] — [1]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum — [2]Experimentelle Physik 2, Technische Universität Dortmund

We report on focused ion beam (FIB) implantation of rare-earth ions in semiconductor nanostructures. Semiconductor nanostructures have attracted a lot of attention due to their unique optical, electrical and mechanical properties. There is a huge potential for applications in many fields. To use nanostructures for a certain purpose, often very specific properties have to be achieved. An elegant method to tune the electrical and optical properties of semiconductor nanostructures is focused ion beam implantation. Using ion beams offers high-resolution lateral engineering, local band gap modulation due to ion-induced intermixing as well as local doping applications. To carry out implantation of rare-earth ions in semiconductor nanostructures we especially focus on the incorporation of Erbium ions into GaAs. Erbium and rare-earth ions, in general, are known for their huge magnetic moments, which exceed the Bohr magneton of at least a factor of 7. The dominant part of this magnetism originates from the $4f$ magnetic moments. Not only the f- but also d-states can participate in spin interactions so that we are going to obtain a rich spectrum of possible spin coupling processes in our studies. Therefore, we also examine the influence of annealing processes and the dependence on the ion fluence.

HL 30.20 Tue 13:30 P3

Correlation of optical properties and interface morphology in type-II semiconductor heterostructures — •Luise Rost, Milan Maradiya, Jannick Lehr, Wolfgang Stolz, and Wolfram Heimbrodt — Department of Physics and Materials Sciences Center, Philipps-Universität Marburg, Germany

The (Ga,In)As/GaAs/Ga(As,Sb) material system is used for lasers operating over a wide spectral range in the infrared. To further optimize the design of such heterostructures, it is important to have deep understanding of the influence of the interface morphology and the charge carrier dynamic through the interface. Here (Ga,In)As/GaAs/Ga(As,Sb) type-II double quantum well heterostructures and the inverted structure have been grown by metall-organic vapor phase epitaxy. A growth interruption procedure was used to intentionally modify the morphology of the internal interfaces. Here we show a furrow investigation of the influence of interface morphology and optical properties, for this 0s, 10s and 120s growth interruptions were introduced on different places of the heterostructure. With photoluminescence spectroscopy and atomic force microscopy we will illustrate this correlation and its importance for laser performance.

HL 30.21 Tue 13:30 P3

Atomic structure of $GaAs_xP_{1-x}$ surfaces during MOCVD-preparation — •Agnieszka Paszuk, Oliver Supplie, Jan Philipp Stöckmann, Harita Gordhanbhai Rupapara, Peter Kleinschmidt, and Thomas Hannappel — Institute of Physics, University of Technology Ilmenau, Germany

Low defect $GaAs_xP_{1-x}$ graded buffers grown on Si enable highly efficient III-V-on-Si multi-junction solar cells. The As/P content of individual GaAsP graded buffer layers can be quantified *in situ* during metalorganic chemical vapor phase deposition with reflection anisotropy spectroscopy (RAS) due to a characteristic spectral fingerprint of the GaAsP surfaces [1]: With increasing As supply, a peak close to the GaP E_1 critical point energy shifts towards GaAs E_1 at lower energy. Here, these RAS fingerprints are correlated with the surface reconstructions and chemical composition identified in UHV by LEED and XPS, respectively. We show that the surface structure of GaAsP buffers depends on the GaAsP stoichiometry and post-growth process route. GaAsP surfaces with low As content exhibit P-rich, (2x1) reconstructed surfaces. LEED patterns of GaAsP buffers with 50% of As in the bulk exhibit a mix of (2x1) reconstruction with additional spots present at third order. We find both P-P and As-As dimers present at this surface. The same buffers annealed additionally at 500°C exhibit As-rich (2x4) reconstructed surfaces, whereas annealing at 700°C leads to Ga-rich surfaces. Future studies are aimed to resolve the actual atomic structure of the complex surface unit cell. [1] O. Supplie et al., Proceedings 45th IEEE PVSC Conf. (2018) 3923.

HL 30.22 Tue 13:30 P3

Back-gated FET operation in 4H SiC for controlling transport in epitaxial graphene nanojunctions — •Maria T. Schlecht, Christian Ott, Stefan Malzer, and Heiko B. Weber — Lehrstuhl für Angewandte Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen, Germany

For many experiments with epitaxial graphene on Silicon carbide (SiC) it is essential to leave graphene accessible, therefore charge carrier control must be achieved by a backgate buried in the substrate. This can be realized by placing an implanted conductive layer in the substrate without losing its semi-insulating behaviour. This has been successfully established on 6H SiC due to the vanadium compensation of the semi-insulating material [1]. Implanting a working back-gate within the technologically more relevant polytype 4H SiC is more challenging as it is "intrinsically" semi-insulating. Here, we present a study on implanted bottom gates for quasi-freestanding bilayer graphene (QF-BLG) on 4H SiC using nitrogen as a dopant. Investigating various implantation profiles we found an optimum at an implantation concentration of $5{\cdot}10^{17}$ cm^{-3} and a depth of 1 μm. A reduction of the charge carrier concentration by $5{\cdot}10^{12}$ cm^{-2} at a gate voltage of 90 V was achieved. The back gate was proven to be working in the temperature range of interest from 30 K to 300 K and was only limited by leakage current. A local maximum of the leakage current at 120 K will be discussed taking into account defect levels within the SiC.[1] Waldmann et al, DOI: 10.1038/nmat2988 (2011)

HL 30.23 Tue 13:30 P3

Electronic properties of the GaP/Si(001) heterointerface studied by HAXPES — Oleksandr Romanyuk[1], •Jan P. Stöckmann[2], Agnieszka Paszuk[2], Oliver Supplie[2], Regan G. Wilks[3], Jakob Bombsch[3], Claudia Hartmann[3], Raül Garcia-Diez[3], Shigenori Ueda[4], Igor Bartoš[1], Ivan Gordeev[1], Jana Houdkova[1], Peter Kleinschmidt[2], Marcus Bär[3], Petr Jiříček[1], and Thomas Hannappel[2] — [1]Institute for Physics, Fundamentals of energy materials, University of Technology, Ilmenau, Germany — [2]Institute of Physics, Prague, Czech Republic — [3]Department Interface Design, Helmholtz-Zentrum Berlin, Germany — [4]SPring-8, National Institute for Materials Science (NIMS), Japan

For highly efficient III-V-on-Si optoelectronic devices it is crucial to prepare defect-free III-V/Si heterointerfaces with defined electronic properties. Defects known as antiphase boundaries in the III-V layer can be avoided by preparing the Si(100) surface with double-atomic steps. Here, GaP/Si(001) heterointerfaces prepared by MOCVD were investigated by hard X-ray photoelectron spectroscopy. Thin (4 - 50 nm) GaP films were grown on H- or As-terminated Si(001) surfaces. Preparation of double-atomic steps on Si surface was controlled by optical in situ spectroscopy. We observed core-level broadening and shifts of peak maxima positions depending on GaP thickness, Si wafer doping type and Si surface preparation. We were able to identify interface-

related core level components and to deduce the valence band offsets at the heterostructures. These results are related to charge displacements at the interface.

HL 30.24 Tue 13:30 P3

Investigation of Poole-Frenkel-ionization in magnesium-doped AlGaN short period superlattices — •Emil Mickein[1], Anton Muhin[1], Norman Susilo[1], Luca Sulmoni[1], Martin Guttmann[1], Christian Kuhn[1], Tim Wernicke[1], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institute of Solid State Physics, Berlin, Germany — [2]Ferdinand-Braun-Institut, Leibnitz-Institut für Höchstfrequenztechnik, Berlin, Germany

UVC-transparent $Al_xGa_{1-x}N$:Mg/$Al_yGa_{1-y}N$:Mg short period superlattices (SPSL) with $x, y \geq 0.6$ are required for efficient light emitting diodes with emission wavelength below 280 nm. However, AlGaN:Mg layers with high aluminum mole fractions exhibit high acceptor ionization energies and consequently a poor electrical conductivity. Moreover, the electric properties of AlGaN:Mg-SPSL are not well established, especially for high Al mole fraction. In this paper the vertical conductivity (σ_V) of $Al_{0.71}Ga_{0.29}N$:Mg/$Al_{0.65}Ga_{0.35}N$:Mg-SPSLs will be investigated. By comparing LEDs with varing SPSL-thickness σ_V was extracted. The value of σ_V was found to be strongly field- and temperature-dependent and fits well to predictions made by 3D-Poole-Frenkel-effect (3D-PFE). An activation energy of 530 meV and an intertrap distance of 6 nm were extracted for the SPSL. When comparing a SPSL with an Al-content of 78 % and a SPSL with an Al-content of 65 % σ_V is increased by more than one order of magnitude, respectively.

HL 30.25 Tue 13:30 P3

Effect of Mg doping in the electron blocking layer on UVC-LED efficiency characterized by temperature–dependent electroluminescence spectroscopy — •Katharina Müller[1], Priti Gupta[1], Norman Susilo[1], Martin Guttmann[1], Tim Wernicke[1], Markus Weyers[2], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institute of Solid State Physics, Berlin, Germany — [2]FBH, Berlin, Germany

The external quantum efficiency (EQE) of UVC emitters crucially depends on the Mg doping profile in the LED heterostructure. In this study, a series of flip-chip mounted AlGaN-based UVC-LEDs with different Mg doping in the electron blocking layer (EBL) is investigated using temperature–dependent (100 K - 330 K) electroluminescence spectroscopy. During the growth, the Cp_2Mg/group-III precursor ratio (x) in the EBL layer was varied with x = 0.155%, 1.0% and 1.5%. At 330 K and 10 mA, LEDs with x = 1.0% show higher EQE (up to 0.28%) compared to LEDs with x = 0.155% (EQE: 0.11%) and x = 1.5% (EQE: 0.15%). This difference between different doping levels becomes more pronounced with decreasing temperature. While the EQE increases with decreasing temperature for x = 1.0% with a maximum at around 210 K, the EQE for x = 0.155% and 1.5% continuously decreases or remains very low with lowering temperature. This indicates a higher injection efficiency in LEDs with x = 1%, in comparison to x = 0.155% and x = 1.5%. The optimal doping profile in the EBL was found to be at around x = 1.0%, leading to an improved carrier injection and thus higher EQE.

HL 30.26 Tue 13:30 P3

Simulation of Magnetoelectric Microbeams — Simeon Katzer[1], Bernd Hähnlein[1], •Maximilian Krey[2], Katja Tonisch[1], Stefan Krischok[1], and Hannes Toepfer[2] — [1]Technical Physics 1 Group, Technische Universität Ilmenau, Germany — [2]Advanced Electromagnetics Group, Technische Universität Ilmenau, Germany

Magnetic field sensors cover a wide field of applications, for example in bio-medicine, non-destructive testing or geo-exploration. In terms of sensitivity, super conductive quantum interference devices (SQUIDs) are state of the art, but with the disadvantage of the necessary liquid helium cooling in order to reach a super conductive state. Thus, our research efforts focus on the development of magnetic field sensors based on magnetoelectric resonant MEMS for room temperature operation. In beam-like structures a combination of piezoelectric and magnetostrictive materials is used to convert the magnetic field input in an electrically measurable output. The sensor principle is based on an eigenfrequency shift of the structure under the influence of a magnetic field. Simulations of this behavior require the consideration of aspects such as material science, mechanical vibrations, magnetism, electricity as well as mutual effects like piezoelectricity, magnetostriction and the Delta-E- effect. Due to the multi-physics problem many degrees of freedom arise, which can be used to optimize the structure for maximum output signal amplitude and frequency shift. We present an investigation targeting a simulative description of a magnetoelectric sensor based on scandium aluminum nitride with Comsol Multiphysics.

HL 30.27 Tue 13:30 P3

Highly reflective and conductive AlInN/GaN distributed Bragg reflectors realized by Ge-doping — •Cleophace Seneza, Christoph Berger, Hartmut Witte, Jürgen Bläsing, Anja Dempewolf, Armin Dadgar, Jürgen Christen, and André Strittmatter — Otto-von-Guericke-University Magdeburg, 39106 Magdeburg, Germany

Lattice-matched AlInN has been proven as well-suited material to realize highly reflective AlInN/GaN distributed Bragg reflectors (DBRs), which are mandatory for the fabrication of vertical-cavity surface-emitting lasers (VCSELs) using GaN-based material. In contrast to GaAs-VCSELs with highly conductive arsenide-based DBRs, AlInN/GaN-based DBRs usually exhibit high electrical resistance due to large polarization fields and a significant conduction band offset between GaN and AlInN. Therefore, intracavity contacts are employed for VCSELs to inject current into the active region. We demonstrate that Ge can be used as n-type donor to realize low-resistive lattice-matched AlInN/GaN DBRs. Various Ge-doping levels were utilized to study the vertical electrical conductivity and reflectance properties of lattice-matched AlInN/GaN DBRs grown by MOVPE. We will present the effect of Ge-doping on structural properties, electrical and optical properties of DBRs. With Ge-doping, lattice-matched AlInN/GaN DBRs exhibit ohmic behavior and high reflectivity. Such DBRs structures have a huge potential to improve the current-injection, lower the threshold-current density and will also help to simplify the fabrication processes for VCSELs.

HL 30.28 Tue 13:30 P3

A study of ultrathin c-plane GaInN/GaN quantum wells and discs grown by MBE — •André Schendel, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Institut für Angewandte Physik, Technische Universität Braunschweig

In this contribution we present our study of ultrathin c-plane GaInN/GaN quantum wells (QWs) and incomplete quantum wells (discs) grown by molecular beam epitaxy (MBE) in terms of morphology and composition homogeneity. The ternary semiconductor GaInN offers many opportunities for applications as optoelectronic devices with its direct band gap tunable between 0.65 eV for InN and 3.42 eV for GaN. Nowadays, especially green emitting LED's are in the focus of research, because there is no high efficient green emitting LED available yet for any kind of material. Theoretically, GaInN should be able to close this gap, but in practice the In-content can hardly be increased above 30% if it is grown on GaN. Additionally, the emissivity in the green spectral range is very low due to increased defect formation which is caused by the increased lattice mismatch between the two material systems with increasing In-content. In this study, the growth process of GaInN with low and high In-content is investigated in terms of morphology and composition homogeneity by varying the growth parameters material fluxes and growth temperature to get a better understanding of the impact of the single parameters.

HL 30.29 Tue 13:30 P3

Structure and dielectric function tensor of (Al,Sc)N thin films — •Sascha Kürth, Rüdiger Schmidt-Grund, Stefan Krischok, and Katja Tonisch — Institut für Physik, Technische Universität Ilmenau, Weimarer Straße 32, 98693 Ilmenau, Germany

We present the dielectric function tensor of (Al,Sc)N thin films for the full composition range and derive material properties such as band-gap energies and refractive index dispersion. The thin films have been grown on silicon with conductive interlayers such as platinum and titanium nitride and on sapphire by reactive sputter deposition. Both, the structural as well as optical properties vary with Sc content and with the actualy used substrate. While excitonic enhancement is observed mainly for pristine aluminium nitride, the transition between the hexagonal and cubic crystal structure of ScAlN is observed by the transition between optic uniaxiality and isotropy. For increasing Sc content, we further observe a redshift of the optical absorption edge as well as an increase of the refractive index.

(Al,Sc)N is a very promising material system for piezoelectric applications as the piezoelectric coefficient gains values as big as d_{33} = 28 pm/V [1]. But only recently films of sufficient quality have been

achieved, thus a comprehensive understanding of optical and electronic properties is still missing.

[1] T. Yanagitani, M. Suzuki, Appl. Phys. Lett. **105**, 122907 (2014).

HL 30.30 Tue 13:30 P3

Nonempirical dielectric-dependent hybrid functional for semiconductors and insulators — •Wei Chen[1], Giacomo Miceli[2], Gian-Marco Rignanese[1], and Alfredo Pasquarello[2] — [1]Institute of Condensed Matter and Nanoscicence (IMCN), Université catholique de Louvain, Louvain-la-Neuve 1348, Belgium — [2]Chaire de Simulation à l'Echelle Atomique (CSEA), Ecole Polytechnique Fédérale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland

We present a general scheme of range-separated hybrid functionals in which the mixing parameters of Fock exchange are determined solely from the dielectric function and hence fully nonempirical. We show that the full dielectric dependence leads to an unscreened Fock exchange in the short range, while the Fock exchange is correctly screened by the macroscopic dielectric constant in the long range. The range separation is obtained by fitting to the calculated static dielectric function in the long-wavelength limit. The resulting dielectric-dependent hybrid functional (DD-CAM) accurately accounts for the band gaps of various semiconductors and insulators with a mean absolute error of 0.2 eV.

HL 30.31 Tue 13:30 P3

Theoretical investigation of the monoclinic and orthrombic phase of WO_3 — •Felix Bernhardt and Simone Sanna — Institut für Theoretische Physik and Center for Materials Research, Justus-Liebig-Universität Gießen, 35392 Gießen, Germany

Tungsten trioxide (WO_3) is a semiconductor which proved suitable for a wide variety of applications, due to its many temperature driven phase transitions, and an electronic band gap within the optical spectrum [1]. It is employed in a multitude of devices, ranging from smart windows [3] to gas sensors [5]. In this work, we concentrate on the equilibrium structures of the at room temperature stable monoclinic phase, as well as the orthrombic phase of WO_3. Within density functional theory the lattice parameters, electronic band structure and phononic band structure are calculated. The phonon spectra are then used to describe the thermodynamic properties and the transition temperature. Our results are in excellent agreement to other theoretical investigations [1,4] as well as experiments [2]. [1] M. Mansouri, T. Mahmoodi, Turkish Journal of Physics 41, 238 (2017) [2] B. O. Loopstra, H. M. Rietveld, Acta Cryst., 25(1420) (1968) [3] L. Liang et al, Sci. Rep. 3, 1936 (2013) [4] F. Wang et al, Journal Of Physical Chemistry, 115(8345) (2011) [5] N. Yamazoe et al, Catalysis Surveys from Asia 7, 63-75 (2003)

HL 30.32 Tue 13:30 P3

Gating technologies for bilayer 2D carrier systems — •Jana Marie Meyer[1], Jan Scharnetzky[2], Simon Parolo[2], Christian Reichl[2], Werner Dietsche[2], Werner Wegscheider[2], Lars Tiemann[1], and Robert Blick[1] — [1]Center for Hybrid Nanostructures, University of Hamburg, 22761, Germany — [2]ETH Zürich, 8092 Zürich, Switzerland

Electrostatic gating is a versatile and crucial tool in nanotechnology and allows to change the intrinsic electron density of two-dimensional carrier systems, that is given by doping in the growth process. Bilayer systems like gallium arsenide double quantum wells can be electrically separated and the electron density of each layer can be tuned independently with a sophisticated system of patterned back gates and metallic top gates. To achieve a higher sample quality, the back gates are patterned via ion implantation before the overgrowth of the double layer system allowing also a low charge carrier concentration. This versatile technology is can be applied to generate confinement potentials, tune the carrier concentration and study a variety of quantum phenomena.

HL 30.33 Tue 13:30 P3

Quantum Hall Effect in Bulk-insulating Sn-doped $Bi_{1.1}Sb_{0.9}Te_2S$ Topological Insulators — •Dingxun Fan, Yongjian Wang, and Yoichi Ando — II. Physikalisches Institut, Universität zu Köln, Zülpicher Str. 77, D-50937 Köln, Deutschland

Realization of bulk-insulating materials is among the central tasks of the research efforts in the past decade in the field of topological insulators (TIs). To better address the intriguing properties of the topological surface states, it is desired to have a TI platform with a single Dirac cone well isolated from the bulk bands.

We have grown Sn-doped $Bi_{1.1}Sb_{0.9}Te_2S$ topological insulator single crystals by a modified Bridgman method. Transport characterization on these crystals shows large low temperature bulk resistivity, low bulk carrier density, and clear Shubnikov-de Haas oscillations from the surface state. We also observed the integer quantum Hall effect in dual-gated Hall bar devices fabricated from exfoliated thin flakes. Efforts of proximitizing the surface state by superconducting contacts will also be shown.

HL 30.34 Tue 13:30 P3

Anomalous and topological hall effect in magnetically-doped topological insulator thin films grown by molecular beam epitaxy — •Anjana Uday[1], Gertjan Lippertz[1,2], Andrea Bliesner[1], Alexey Taskin[1], and Yoichi Ando[1] — [1]Physics Institute II, University of Cologne, Germany — [2]Quantum Solid State Physics, KU Leuven, Belgium

There is an increasing demand for magnetic topological quantum materials in recent years as such materials offer a productive platform for the development of next-generation spintronic devices. When a topological insulator (TI) is magnetically doped, the breaking of time reversal symmetry (TRS) opens up an energy gap at the Dirac point of the surface states. Furthermore, a remarkable quantum phenomenon known as the quantum anomalous Hall effect (QAHE) is observed in such materials when their fermi level is tuned into this exchange gap. When the QAHE is realized, the spontaneous magnetization leads to a dissipationless spin-polarised edge channel, giving rise to a quantized Hall resistance of h/e^2. An additional topological Hall component has recently been observed in such samples, possibly originating from the formation of Skyrmions. Our observation of the anomalous and topological Hall effect in V- and Cr-doped $(Bi_xSb_(1-x))_2Te_3$ films grown by MBE show how a gradient in the Bi/Sb ratio along the growth direction leads to a broken inversion symmetry and the appearance of an additional topological Hall component near the coercive field while homogeneous samples exhibit the usual anomalous Hall effect close to the quantized Hall resistance of h/e^2.

HL 30.35 Tue 13:30 P3

Topological insulator nanowires grown selectively by molecular beam epitaxy — •Gertjan Lippertz[1,2], Andrea Bliesener[1], Anjana Uday[1], Gian-Luca Ansermetti[1], Oliver Breunig[1], Alexey Taskin[1], Lino Pereira[2], and Yoichi Ando[1] — [1]Physics Institute II, University of Cologne, Germany — [2]Quantum Solid State Physics, KU Leuven, Belgium

Inducing superconductivity into a topological insulator (TI) nanowire by proximitizing it with an s-wave superconductor is predicted to give rise to Majorana bound states. However, TI nanowires grown by the Vapor-Liquid-Solid (VLS) technique are difficult to integrate into scalable device structures. Therefore, we are pursuing an alternative route towards nanowire structures, selective-area growth (SAG) by molecular beam epitaxy (MBE). A Si_3N_4 layer is deposited on a sapphire substrate and patterned into nanowire devices using electron-beam lithography and reactive ion etching. Within a small parameter range, $(Bi_{1-x}Sb_x)_2Te_3$ can be selectively grown by MBE inside the trenches of the pre-patterned substrate. Control over the chemical potential of the nanowires is achieved by a side-gate fabricated in the same process, alleviating the need for additional fabrication steps after growth.

In this presentation, we show our first results towards growing bulk-insulating TI nanowires with a width below 100 nm. Such SAG-TI nanowires are expected to show non-equidistant resistance peaks as a function of the gate voltage, which was recently shown to be the unique signature of quantum-confined Dirac surface states.

HL 30.36 Tue 13:30 P3

Optical-pump/THz-probe spectrometer using mode-matching via field-enhancement — •Julia Lang, Michael Seidel, and Georg Herink — Experimental Physics VIII, University of Bayreuth, Germany

Optical-pump/THz-probe spectroscopy presents a powerful scheme for characterizing the transient carrier dynamics in electronic materials and devices. In order to improve the sample excitation and the probe signal strength, we introduce mode-matching between optical-pump and THz-probe. Specifically, this approach employs sub-diffraction Terahertz confinement in metallic microstructures to reduce the large mismatch between optical and THz foci. The setup, based on a compact high repetition rate mode-locked fiber laser, efficient frequency conversion and photoconductive detection, is demonstrated for transient spectroscopy of photo-induced charge carriers in semiconductors.

HL 30.37 Tue 13:30 P3

Switchable THz wavefront modulators made of thermocromic $V_xW_{1-x}O_2$ thin films — •Janine Lorenz[1], Florian Kuhl[1], Angelika Polity[1], Yan Zhang[2], and Peter J. Klar[1] — [1]Institute of Experimental Physics I and Center for Materials Research (ZfM/LaMa), Justus Liebig University Giessen, Heinrich-Buff-Ring 16, DE-35392 Giessen, Germany — [2]Beijing Key Lab for Metamaterials and Devices, Capital Normal University, Beijing, China

Due to the rapid progress in the reasearch field of terahertz generation and detection over the last years, terahertz applications have recently gained a lot of interest. Similar to VO_2 the insulator to metal transition (IMT) in thermochromic $V_xW_{1-x}O_2$ allows us to design thermally switchable THz optics.
Here we present microfabricated resonator structures in rf-sputtered $V_xW_{1-x}O_2$ thin films. The fabrication of the resonators is realised by photolithography and ion beam etching. Modulation properties of the resonators can be improved by depositing TiO_2 buffer layers onto the c-sapphire substrates used. In comparison to VO_2, the switching temperature of $V_xW_{1-x}O_2$ can be reduced and tuned by varying the concentration x of tungsten. Measurements on unstructured thin films show typical switching temperatures for VO_2 of about 55 °C and 35 °C for $V_xW_{1-x}O_2$ with x between 1 and 2 %. The modulating behavior of the resonator structures in the insulating and metallic phase was investigated by terahertz time-domain spectroscopy. Switchable devices are obtained since THz modulation only occurs in the metallic phase.

HL 30.38 Tue 13:30 P3

Creation of a shallow graphitic layer in diamond for field effect applications — •Dennis Oing, Martin Geller, Axel Lorke, and Nicolas Wöhrl — Faculty of Physics and CENIDE, University of Duisburg-Essen, Lotharstr. 1, 47057 Duisburg, Germany

Diamond is a promising wide band gap semiconductor with high hole and electron mobilities, high electric breakdown field and the highest thermal conductivity.
However, a field effect transistors based on the surface conductivity of the two-dimensional hole gas need a dielectric material, e.g. Al_2O_3, between the diamond surface and the gate. However, these materials have a lower electric breakdown field and lower thermal conductivity. Hence, transistors using these materials lack the potential that transistors solely made from diamond possess.
In this contribution, graphitic layers as bottom-gate below the two-dimensional hole gas were produced 100 nm below the diamond surface by ion implantation. Implantation was done on CVD-grown single crystal layers using ^{12}C-ions with a kinetic energy of 95 keV. The samples were subsequently annealed from 210° up to 650° to form the graphitic layers. The produced layers were characterized using Raman spectroscopy and measuring IV-characteristics.
Raman spectroscopy reveals that after implantation a small G-peak appears. Additionally, a D-peak can be observed after annealing. These peaks correspond to the formation of amorphous carbon layers. Our results suggest that the created structures can be used for field effect applications.

HL 30.39 Tue 13:30 P3

Deep level transient spectroscopy on thin rutile films — •Lukas Berg[1], Laurin Schnorr[1], Thomas Heinzel[1], Carlos Cesar Bof Bufon[2] und Leandro Merces[2] — [1]Heinrich Heine - Universität Düsseldorf — [2]Brazilian Center for Research, Campinas

Time resolved electro-optical admittance measurements were performed on mono-crystalline Rutile thin films through an optically transparent rolled-up gold gate. Excitation pulses of different wavelengths in the infrared band were applied to the structure as a function of the temperature and the electric field and the admittance transients were recorded. The analysis of the time evolution reveals a binding energy of 0.6 eV for a single prominent defect level. Furthermore, a temperature and light intensity dependent delayed trap response was observed and investigated under various conditions.

HL 30.40 Tue 13:30 P3

Thermoelectric properties of Bi-based core/shell nanowires — •Maximilian Kockert[1], Jeongmin Kim[2], Hongjae Moon[2], Danny Kojda[1], Mahni Müller[1], Rüdiger Mitdank[1], Anna Mogilatenko[3], S. Hoda Moosavi[4], Michael Kroener[4], Peter Woias[4], Wooyoung Lee[2], and Saskia F. Fischer[1] — [1]Novel Materials Group, Humboldt-Universität zu Berlin, 10099 Berlin, Germany — [2]Departement of Materials Science and Engineering, Yonsei University, 03722 Seoul, Republic of Korea — [3]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, 12489 Berlin, Germany — [4]Laboratory for Design of Microsystems (IMTEK), University of Freiburg, 79110 Freiburg, Germany

Bi-based core/shell nanowires are promising thermoelectric materials in order to improve the dimensionless figure of merit $ZT = \frac{\sigma S^2}{\lambda} T$, with the electrical conductivity σ, the Seebeck coefficient S, the thermal conductivity λ and the bath temperature T. The mismatch of the different lattice constants between the core (Bi) and the shell (Te or TiO_2) lead to a strain-induced reduction of the band overlap in the Bi-core [1].

However, the determination of σ, S, λ and structural properties of the same individual [2] core/shell nanowire remains an open issue. Here, we present a complete temperature-dependent thermoelectric and structural characterization of an individual Bi/Te and Bi/TiO_2 core/shell nanowire.

[1] J. Kim *et al.*, *Acta Materialia* **144**, 145 (2018).
[2] D. Kojda *et al.*, *Physical Review B* **91**, 024302 (2015).

HL 30.41 Tue 13:30 P3

Electroluminescence emission in a GaAsSb resonant tunneling diode with emitter prewell — •Edgar David Guarin Castro[1], Edson Cardozo de Oliveira[1], Andreas Pfenning[2], Fabian Hartmann[2], Lukas Worschech[2], Sven Höfling[2,3], Gilmar Marques[1], Marcio Daldin Teodoro[1], and Victor Lopez-Richard[1] — [1]Departamento de Física, Universidade Federal de São Carlos, 13565-905 São Carlos, SP, Brazil — [2]Technische Physik and Wilhelm Conrad Röntgen Research Center for Complex Material Systems, Physikalisches Institut, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [3]SUPA, School of Physics and Astronomy, University of St Andrews, St Andrews, KY16 9SS, United Kingdom

We study the electroluminescence (EL) emission of an n-type GaSb resonant tunneling diode with pseudomorphically grown ternary $GaAs_0.05Sb_0.95$ emitter prewell and quantum well. Emission peaks are observed along to the spectral range of 1.1 μm to 1.6 μm. We attribute the radiative recombination to the generation of holes via impact ionization processes. Comparing EL and photoluminescence (PL) emissions, we observe a high EL on-off-ratio which is one order of magnitude greater than the PL on-off-ratio. The larger EL on-off ratio correlates with the coherent current channel. To understand the carrier dynamics inside the quantum well, we characterize the carrier lifetimes using Time-resolved Photoluminescence spectroscopy. We demonstrate the existence of different carrier relaxation processes, unveiled under different current conditions.

HL 30.42 Tue 13:30 P3

Contactless Measurement of the Sheet Resistance of two-dimensional Electron Gases — •Timo A. Kurschat, Arne Ludwig, and Andreas D. Wieck — Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstraße 150, D-44780 Bochum

The aim of this work is to measure the sheet resistance of two-dimensional electron gases in GaAs without the need for built-in contacts. Thus a characterization is possible without destroying the wafer. With this method quality and homogeneity can be evaluated before further processing.

The sheet resistance is measured by placing two electrodes (round metal plates) close to the sample. These electrodes form capacitances C with the conductive layer. With a high-frequency alternating voltage applied to one electrode, the transmitted power can be measured at the other one. The measured amplitude depends on the sample resistance and the impedance of the capacitance, which is proportional to $1/\omega C$.

The electrodes have a diameter of 3 mm and 6 mm center-to-center distance. For low surface resistances from 100 to over 1000 Ω/sq the amplitude was evaluated at a frequency of 10 GHz. At higher resistances up to some 10 kΩ/sq, a frequency sweep from 1 MHz to 400 MHz was performed, and the resistance was determined with a fit.

It is possible to create maps of complete wafers. The lateral resolution depends on the size of the electrodes, so we expect an effective footprint of around 5 mm diameter.

HL 30.43 Tue 13:30 P3

Schottky junctions on GeSn bottom-up grown nanowires by Nickel-stanogermanidation via flash-lamp annealing — •Shima Jazavandy Ghamsari, Artur Erbe, and Yordan M. Georgiev

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Direct bandgap was achieved in Ge by introducing high contents of Sn (>6%) [1]. GeSn was also predicted to exhibit high carriers* mobilities, making it an ideal material for co-integration of optoelectronic and high-speed electronic devices. Moreover, GeSn nanowires can add the gate-all-around benefit in efficient electrostatic control of FET device channels. Beside the large body of data on GeSn thin films growth, the number of reports on growth of GeSn nanowires with significant Sn incorporation is very limited. Silicon and germanium metal alloys were widely studied for low-resistance contacts. For GeSn thin films, however, there are only few studies on Ni and NiPt stanogermanides (NiGeSn and NiPtGeSn). In this work, the benefits of flash-lamp annealing were used for producing Schottky junctions on GeSn bottom-up grown nanowires [2], to overcome the thermal budget limitations because of the low Sn melting point. [1] S. Gupta et al., J. Appl. Phys. 113, 073707 (2013). [2] S. Biswas et al. Nat Commun. 7, 11405 (2016).