HL 45: HL Posters III

Time: Thursday 18:30–21:00 Location: Poster E

HL 45.1 Thu 18:30 Poster E

Deep Level Transient Spectroscopy on Perovskite Solar Cells — •Florian Schwarz[1], Mathias Fischer[1], Andreas Baumann[2], and Vladimir Dyakonov[1] — [1]Experimental Physics VI, Julius Maximilian University of Würzburg, 97074 Würzburg — [2]Bavarian Center for Applied Energy Research (ZAE Bayern), 97074 Würzburg

In thin-film perovskite solar cells (PSC) charge carriers can be captured by trap states located in the active layer or at the interface towards the transport layers, which often results in a reduced performance of the device. Therefore different techniques were established for the characterization of charge carrier trapping. One popular method is the so-called '-deep level transient spectroscopy-' (DLTS), which allows to determine the emission rate, capture cross-section and activation energy of such deep states close to the middle of the band gap. We use DLTS to investigate the defect formation in PSC with respect to the incorporation of different additives, which may play a role of dopants, to the methylamonium lead iodide (MAPI) layer. The knowledge about the impact of such additives on the defect formation in the PSC is an essential step towards a controlled doping of the perovskite absorber itself.

HL 45.2 Thu 18:30 Poster E

Investigation of organic/inorganic lead tribromide perovskite single crystals — •Julian Höcker[1], Melina Armer[1], Volker Drach[1], Vladimir Dyakonov[1], and Andreas Baumann[2] — [1]Experimental Physics VI, Julius Maximilian University of Würzburg, 97074 Würzburg — [2]Bavarian Center for Applied Energy Research (ZAE Bayern), 97074 Würzburg

Lead halide perovskites (HaPs) are a hot topic in the field of optoelectronic materials due to their unprecedented performance as solution-processed layer, e.g. in photovoltaics and light emitting diodes. Nevertheless, further optimization of HaP solar cell devices is needed, but this requires a deeper understanding of the physical phenomena especially charge carrier transport processes. Here we investigate the fundamental transport mechanism in 3D HaP crystals. The so-called inverse temperature crystallization (ITC) growth technique was used, which is based on the substantial decrease of perovskite solubility, in certain solvents, at elevated temperatures. We focused on three different types of HaP, i.e. organo lead tribromide perovskite single crystals methylammonium lead tribromide ($MAPbBr_3$) and formamidinium lead tribromide ($FAPbBr_3$) comparing to a completely inorganic perovskite crystal caesium lead tribromide ($CsPbBr_3$). The grown crystals are studied by means of powder X-ray diffraction, atomic force microscopy (AFM) and scanning electron microscopy (SEM). The optical properties of the different crystals are characterized by steady-state and transient photoluminescence (PL) and the charge carrier dynamics by Time-of-flight measurements.

HL 45.3 Thu 18:30 Poster E

Influence of excitonic effects on charge carrier extraction in organic-inorganic perovskite solar cells — •Philip Lange[1], Fabian Ruf[1], Ihteaz M. Hossain[2,3], Ulrich W. Paetzold[2,3], Moritz Schultes[4], Erik Ahlswede[4], Heinz Kalt[1], and Michael Hetterich[1,2] — [1]Institute of Applied Physics, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany — [2]Light Technology Institute, KIT, 76131 Karlsruhe, Germany — [3]Institute of Microstructure Technology, KIT, 76344 Eggenstein-Leopoldshafen, Germany — [4]Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW), 70563 Stuttgart, Germany

Organic-inorganic perovskites are among the most promising absorber materials for thin-film solar cells with reported conversion efficiencies above 23 %. However, it is still not sufficiently clear, to which degree the relatively strong excitonic effects in this material system hamper the separation of optically generated electron-hole pairs and the subsequent collection of the charge carriers. In order to elaborate this, semi-transparent solar cells employing $(MA)PbI_3$ and $Cs_{0.1}(MA_{0.17}FA_{0.83})_{0.9}Pb(I_{0.83}Br_{0.17})_3$ as absorbers are investigated utilizing a combination of absorption and photocurrent measurements as a function of temperature. First results will be discussed in this contribution.

HL 45.4 Thu 18:30 Poster E

Identifying recombination mechanisms in perovskite solar cells — •Seth Niklas Schumann, Fabian Meier, Clemens Göhler, and Carsten Deibel — Institut für Physik, Technische Universität Chemnitz, 09126 Chemnitz, Germany

Organic-inorganic perovskite solar cells yield high power conversion efficiencies above 20 % at low manufacturing cost. The recombination of charge carriers influences the performance. We studied recombination in $(FAPbI_3)_x(MAPbBr_3)_{1-x}$, processed with a one step approach. To identify the dominant loss mechanism we measured the open circuit voltage and time-resolved photoluminescence as a function of the incident light intensity. We compare the resulting ideality factor and recombination lifetime of the samples with different $FAPbI_3$ to $MAPbBr_3$ ratios and discuss them with respect to the solar cell parameters.

HL 45.5 Thu 18:30 Poster E

Reversible changes of the bandgap energy in multiple-cation mixed-halide perovskite solar cells under illumination and bias investigated by optical spectroscopy — •Eva Wirth[1], Fabian Ruf[1], Meltem F. Aygüler[2], Jonas Hanisch[3], Pablo Docampo[4], Erik Ahlswede[3], Heinz Kalt[1] und Michael Hetterich[1,5] — [1]Institute of Applied Physics, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]Dept. of Chemistry and CeNS, LMU Munich, München, Germany — [3]Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW), Stuttgart, Germany — [4]Physics Dept., School of Electrical and Electronic Engineering, Newcastle University, Newcastle upon Tyne, United Kingdom — [5]Light Technology Institute, KIT, Karlsruhe, Germany

One advantage of perovskite solar cells, with power conversion efficiencies of more than 23 %, is the wide tunability of the bandgap (by intermixing of different ions) which enables the fabrication of tandem cells. However, the stability of mixed perovskites is still problematic. We investigate compositional instabilities and resulting shifts of the bandgap energy of these compounds non-destructively using electroreflectance spectroscopy whereby the relative change of the reflectivity $\Delta R/R$ is analyzed. Under illumination with a solar simulator while varying relative humidity and applied voltage, shifts of the bandgap are observed. The latter are caused by segregation effects in the Br*I system, which are partly reversible. We compare perovskite solar cells with different absorber materials in order to reveal the influence of different architectures.

HL 45.6 Thu 18:30 Poster E

Reversible changes of the bandgap energy in multiple-cation mixed-halide perovskite solar cells under illumination and bias investigated by optical spectroscopy — •Eva Wirth[1], Fabian Ruf[1], Meltem F. Aygüler[2], Jonas Hanisch[3], Pablo Docampo[4], Erik Ahlswede[3], Heinz Kalt[1] und Michael Hetterich[1,5] — [1]Institute of Applied Physics, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]Dept. of Chemistry and CeNS, LMU Munich, München, Germany — [3]Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW), Stuttgart, Germany — [4]Physics Dept., School of Electrical and Electronic Engineering, Newcastle University, Newcastle upon Tyne, United Kingdom — [5]Light Technology Institute, KIT, Karlsruhe, Germany

Perovskite solar cells (PSC) provide a wide-range bandgap tunability (by intermixing of different ions) enabling the fabrication of tandem cells. But the stability of mixed PSC is still problematic. We investigate compositional instabilities and resulting shifts of the bandgap energy of these compounds non-destructively using electroreflectance spectroscopy. Thereby the relative change of the reflectance $\Delta R/R$ is analyzed. Under illumination as well as varying relative humidity and applied voltage, shifts of the bandgap are observed. The latter are caused by segregation effects in the Br–I system, which are partly reversible. We compare PSC with different absorber materials in order to reveal the influence of different architectures. To study the halide segregation in more detail, we apply TOF-SIMS measurements.

HL 45.7 Thu 18:30 Poster E

π-extended phosphoniumfluorenes: a new type of hole blocking layer in p-i-n perovskite solar cells — •Qingzhi An[1,2], Qing Sun[1,2], Andreas Weu[1,2], Sebastian Amdt[3],

A.Stephen K Hashmi[3,4], and Yana Vaynzof[1,2] — [1]Kirchhoff-Institut für Physik, Heidelberg, Germany — [2]Centre for Advanced Materials,Heidelberg,Germany — [3]Organisch-Chemisches Institut,Heidelberg,Germany — [4]Chemistry Department,Jeddah,Saudi Arabia

Hole blocking layer (HBL) is applied to p-i-n perovskite solar cells for avoiding charges recombination by blocking the holes transfer to the anode, leading to achieve a higher fill factor (FF) and power conversion efficiency (PCE). In this work, 7 different π-extended phosphoniumfluorene molecules were synthesized and applied as HBL to p-i-n planar heterojunction perovskite solar cells. A combination of characterization techniques was utilized to investigate HBL molecular crystallization and charge recombination kinetics in the solar cells. Our study shows that the HBL can also modify the open circuit voltage (Voc). A better coverage and faster extraction HBL leads to an increase of Voc and PCE to 1.05V and 18%, respectively. Though the in-depth mechanism between Voc and HBL is unclear so far, this work provides new guidelines for designing efficient HBL materials and demonstrates that open circuit voltage can be further improved by HBL.

HL 45.8 Thu 18:30 Poster E

Impact of precursor stoichiometry on the energetic trap landscape in methylammonium lead iodide perovskite solar cells — •Philipp Rieder[1], Andreas Baumann[2], and Vladimir Dyakonov[1] — [1]Experimental Physics VI, Julius Maximilian University of Würzburg, 97074 Würzburg — [2]Bavarian Center for Applied Energy Research (ZAE Bayern), 97074 Würzburg

Hybrid organic inorganic perovskite has turned out to be the most promising candidate for highly efficient next generation thin film photovoltaics, amongst others due to its solution processability. Interestingly, the use of slightly non-stoichiometric precursors, typically with a slight excess of lead halide salt, has proven to be essential to achieve the highest efficiencies reported so far. On the contrary, lead halide is known to be the most prominent by-product of film decomposition. In fact, any initial presence of excess lead halide has been linked to an accelerated degradation of the photoactive layer. Here, we study the impact non-stoichiometry of the perovskite layer on the trap landscape of perovskite solar cells in p-i-n layout by means of Thermally Stimulated Current (TSC). We incorporated an increasing amount of lead halide salt in the phenotype of perovskite solar cell absorbers, methylammonium lead iodide. We found that unreacted lead iodide leads to an increase in the density of energetically shallow trap states with an activation energy of around 100 meV. Moreover, we found that the commonly known low temperature phase transition between the orthorhombic and tetragonal crystal phase shifts to even lower temperatures when excess lead iodide is incorporated in the film.

HL 45.9 Thu 18:30 Poster E

Stable hybrid organic-inorganic halide perovskites for photovoltaics from ab-initio high-throughput calculations — •Sabine Körbel[1], Miguel A. L. Marques[2], and Silvana Botti[1] — [1]Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Germany — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Germany

Hybrid perovskites, such as methylammonium lead iodide, have revolutionized research on solar cells in the past years. Well known instability and toxicity issues restrain however the large-scale application of these perovskites in commercial photovoltaic technology. It is therefore crucial to find chemical substitutions which stabilize these and other lead-free perovskites, preserving at the same time their excellent absorption and charge-transport properties. Using density-functional theory, we screened the periodic table of the elements for perovskites with the composition $A^+B^{2+}X_3^-$, where A is a molecular organic cation, B is a divalent element, and X is a halogen. For the molecular cation, we vary the molecule size from sulfonium (H_3S, very small) to tert-butylammonium (C_4NH_{12}, very large). All thermodynamically stable hybrid perovskites were then further characterized by calculating their band gaps and effective masses, to identify the most promising candidates for further experimental and theoretical characterization. We find that the substitution of the organic molecule is the most promising way to enhance thermodynamic stability, while there is no optimal replacement for lead or Sn, unless one considers partial substitution or alloying.

HL 45.10 Thu 18:30 Poster E

Perovskite-on-Quantum Dot solar cells — •Miguel Albaladejo-Siguan[1,2], David Backer-Koch[1,2], and Yana Vaynzof[1,2] — [1]Kirchhoff-Institut für Physik, Heidelberg — [2]Centre for Advanced Materials, Heidelberg

Nanometer-sized quantum dots offer the possibility to build flexible, low-cost, thin film photovoltaic devices. In recent years, device engineering and optimized architectures have contributed to a fast rise in performance, reaching a record power conversion efficiency of 13.4 %. At the same time, pervoskite based solar cells are showing promising results in device performance with open circuit voltage values surpassing 1.2 V, which motivates the option of combining both materials in one solar cell. In this study we focus on the growth of perovskite crystals on the surface of colloidal lead sulfide quantum dots by performing a ligand exchange in a solution containing the perovskite precursor, followed by thin film deposition and annealing. A succesful incorporation of the perovskite shell could be measured as well as an improved passivation and higher interdot coupling, which translates into an enhanced open circuit voltage.

HL 45.11 Thu 18:30 Poster E

Raman spectroscopy of hybrid perovskites and perovskite-like structures — •Sebastian Lotter[1], Felix Kampmann[1,2], Daniel Niesner[1], Mykhailo Sytnyk[3], Ievgen Levchuk[3], Wolfgang Heiss[3], Christoph J. Brabec[3], and Janina Maultzsch[1] — [1]Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin — [3]Department of Materials Science and Engineering, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

In recent years organic-inorganic hybrid perovskites have been subject to intense research efforts in physics and materials science, due to their promising efficiency in solar cell applications [1]. Providing an organic cation and an inorganic frame, these materials have a rich vibrational spectrum. Understanding the phonon modes of these hybrid crystals and their effect on the electronic properties is key to future design of perovskites materials for applications.

In this work we present Raman scattering and photoluminescence (PL) spectra of different organic-inorganic perovskites, such as MAPbBr3 and of perovskite-like ferroelectrics. The experiments are performed at different temperature regimes between 5K and 300K and at different excitation wavelengths. Furthermore, we compare Raman spectra and PL between bulk crystals and thin-film samples.

[1] Y. Hou et al., A generic interface to reduce the efficiency-stability-cost gap of perovskite solar cells, Science 358, 1192 (2017).

HL 45.12 Thu 18:30 Poster E

Investigating the damaging effect of GCIB etching during XPS/UPS depth profiling on perovskite considering temperature dependence — •Joshua Kress and Yana Vaynzof — Universität Heidelberg

In order to properly evaluate gas cluster ion beam (GCIB) etching studies it is important to understand the physical processes taking place in the layer. Our studies focus on the effect of argon cluster beams on various perovskite layers, especially taking into account substrate temperature dependence, in order to identify the ideal cluster etching conditions. The composition and energetics of the layers can be measured in situ, directly after etching via x-ray (ultraviolet) photoelectron spectroscopy (XPS/UPS). Additional studies of morphology (SEM), optical properties (UV-VIS, PDS) or vibronic properties (FTIR) have been performed.

HL 45.13 Thu 18:30 Poster E

Surface potential distribution studies on Cu(In,Ga)Se_2 solar cell cross sections with Kelvin Probe Force Microscopy — •Jonas Schundelmeier[1], Jasmin Seeger[1], Wolfram Witte[2], Dimitrios Hariskos[2], Oliver Kiowski[2], Heinz Kalt[1], and Michael Hetterich[1,3] — [1]Institute of Applied Physics, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany — [2]Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW), 70563 Stuttgart, Germany — [3]Light Technology Institute, KIT, 76131 Karlsruhe, Germany

The efficiency of Cu(In,Ga)Se_2 (CIGS) thin-film solar cells might be further improved by the use of alternatives compared to the CdS buffer layer as well as by changing the gallium concentration within the CIGS absorber. In order to investigate the influence of these modifications on the potential distribution through all the layers of the devices, Kelvin Probe Force Microscopy (KPFM) on CIGS cross sections is employed. Potential distributions for three different Ga concentrations of the absorber and for different solution-grown buffer layer materials (CdS,

Zn(O,S) and In_xS_y) are compared, enabling conclusions about the influence of the mentioned parameters on the diffusion voltage and the Fermi energy within the absorber.

HL 45.14 Thu 18:30 Poster E

A mathematical model for an InGaAs/GaAs based waveguide solar cell showing 36% efficiency — •Bhaskar Singh[1] and Daniel Schaadt[2] — [1]Institute of Energy Research and Physical Technologies, TU Clausthal, Leibnizstr. 4, 38678 Clausthal-Zellerfeld — [2]Institute of Energy Research and Physical Technologies, TU Clausthal, Leibnizstr. 4, 38678 Clausthal-Zellerfeld

The use of a waveguide structure in solar cell device to achieve full trapping of photons is of interest in the field photovoltaics. We designed an In0.2Ga0.8As/GaAs based quantum well solar cell structure, where the In0.2Ga0.8As layer is behaving as a quantum well in the confinement direction while acting as a waveguide in planer direction of the device and calculated the photovoltaic characteristics. The results show that the short-circuit current density of our device increases by 19% leading to an enhancement in the conversion efficiency by 13% with respect to a GaAs p-i-n solar cell without inserted quantum well. For the proposed waveguide solar cell, a total efficiency of 36% under AM1.5G solar illumination is achieved.

HL 45.15 Thu 18:30 Poster E

Simulation of electroreflectance spectra of CIGS solar cells — •Ellen Förstner[1], Alice Magin[1], Fabian Ruf[1], Christian Huber[1], Wolfram Witte[2], Dimitrios Hariskos[2], Oliver Kiowski[2], Heinz Kalt[1], and Michael Hetterich[1,3] — [1]Institute of Applied Physics, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany — [2]Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW), 70563 Stuttgart, Germany — [3]Light Technology Institute, KIT, 76131 Karlsruhe, Germany

Thin-film solar cells such as $Cu(In,Ga)Se_2$ (CIGS) offer an alternative to the widely spread silicon technology. Electroreflectance (ER) spectroscopy is a non-destructive tool enabling the investigation of their electronic properties. For instance, both the bandgap energy of absorber and buffer layer can be determined.

In this contribution, we present a numerical procedure developed to calculate ER spectra based on the model described in [1]. Electronic effects are modelled by SCAPS [2] and subsequently the modulated reflection signal is calculated using a transfer-matrix method. We further improve the simulation to achieve quantitative agreement with measured ER spectra and show applications of the procedure. Comparison of simulations with measured ER spectra allow for a conclusive interpretation of the experimental results.

[1] C. Huber *et al.*, Phys. Rev. B **92**, 075201 (2015).

[2] M. Burgelman *et al.*, Thin Solid Films **361-362**, 527-532 (2000).

HL 45.16 Thu 18:30 Poster E

Electroreflectance studies of CdS buffers in CIGS solar cells: Influence of Ga content and thermal annealing on the CdS bandgap — •Nico Weber[1], Jasmin Seeger[1], Jonas Grutke[1], Wolfram Witte[2], Dimitrios Hariskos[2], Oliver Kiowski[2], Heinz Kalt[1], and Michael Hetterich[1,3] — [1]Institute of Applied Physics, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany — [2]Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW), 70563 Stuttgart, Germany — [3]Light Technology Institute, KIT, 76131 Karlsruhe, Germany

$Cu(In,Ga)Se_2$ (CIGS) has proven to be ideally suited as absorber material for high efficiency thin-film solar cells due to its excellent optical and electrical properties. In order to further improve the CIGS solar cells, a detailed understanding of the absorber–buffer interface is required. For this purpose, CIGS solar cells with the commonly used CdS buffer layer are investigated utilizing angle-resolved electroreflectance (ARER) spectroscopy. This new approach enables an accurate and destruction-free bandgap energy determination of the buffer layer despite the occurring interference effects caused by the layer stack. Therefore, ARER can provide information about possible interdiffusion processes between buffer and absorber layers. In this contribution, we employ ARER to study the impact of different gallium contents of the absorber on the bandgap energy of the buffer layer. In addition, the influence of thermal annealing on the bandgap energy of the buffer layer is investigated.

HL 45.17 Thu 18:30 Poster E

Efficiency of an absorber with hot carrier harvesting — •Magdulin Dwedari, Björn Sothmann, and Dietrich E. Wolf — University of Duisburg-Essen, Lotharstr. 1, 47057 Duisburg, Germany

A hot carrier solar cell consists of an absorber and energy filters that facilitate the separation of electrons and holes before they relax to the edges of the conduction or valence band, respectively, after having been created by optical excitation with an energy much larger than the band gap. In this way the efficiency of a solar cell might be enhanced beyond the Shockley-Queisser limit. In this work we present an absorber-load system, where the absorber is modulated by the time evolution of non-equilibrium distribution functions in the valence and the conduction band due to photo excitations as well as electron-electron and electron-phonon interactions. The photo-excited hot carriers separate via energy filters and flow to a load that extracts a certain power P out of the system. A detailed examination of the efficiency with respect to the excitation strength and extracted power is presented.

HL 45.18 Thu 18:30 Poster E

Properties of In_2S_3:V-Based Intermediate Band Solar Cells — •Tanja Jawinski[1,2], Rainer Pickenhain[1], Leonard Wägele[2], Michael Lorenz[1], Roland Scheer[2], Marius Grundmann[1], and Holger von Wenckstern[1] — [1]Universität Leipzig, Halbleiterphysik, Germany — [2]Universität Halle, Photovoltaik, Germany

To overcome the Shockley Queisser limit of single junction solar cells an intermediate band (IB) can be introduced in wide band gap materials in order to reduce thermalization [1]. Absorption of photon energies smaller than the band gap can generate transitions from the valence band to the IB and from the IB to the conduction band. Theoretical calculations suggest that In_2S_3 hyper-doped with vanadium is a suitable candidate for realization of such an IB solar cell.

Intrinsic V-doped and undoped In_2S_3 layers are grown by physical co-evaporation of the elements. Heterostructure *pin* solar cells are formed using *n*-ZnO:Al and *p*-ZnCo2O4 grown by radio-frequency sputtering and pulsed laser deposition, respectively [2]. Furthermore, we grew In_2S_3 and In_2S_3:V epitaxially on p-Si wafers to improve structural properties of the samples. The samples are investigated using a combination of tuneable IR and VIS lasers allowing simultaneous excitation with multiple photons of well defined sub-band gap energies for photocurrent measurements. We compare undoped and V-doped samples with varying doping concentrations and find a small increase in sub-band gap photocurrent for samples with highest doping concentrations of 1.1 at%. [1] Luque and Martí, Phys. Rev. Let., 78(26),1997 [2] Jawinski et al., Phys. Stat. Sol. A, 215(11), 2018

HL 45.19 Thu 18:30 Poster E

Intermediate band solar cells - Two photon excitation of transition metal doped indium sulfide — •R. Hildebrandt[1], T. Jawinski[1], L. Wägele[2], H. von Wenckstern[1], R. Scheer[2], and M. Grundmann[1] — [1]Universität Leipzig, Felix Bloch Institute for Solid State Physics, Linnéstraße 5, 04103 Leipzig, Germany — [2]Martin-Luther-Universität Halle-Wittenberg, Institute of Physics, Von-Dankelmann-Platz 3, 06120 Halle, Germany

The Shockley-Queisser limit for solar cell efficiency of 33.7% is based on a trade-off between generated photocurrent and photovoltage [1]. Intermediate band (IB) solar cells are proposed to overcome this trade-off by an additional two step photon absorption via states within the band gap [2]. Those states may be realized by quantum dots, band anti-crossing in highly mismatched alloys or deep level impurities.

In this work we pursue a deep level impurity approach for IB solar cells. The heterostructure consists of *p*-$ZnCo_2O_4$/*i*-In_2S_3/*n*-ZnO:Al [3]. The transition metal (V, Nb or Ti) doped In_2S_3 absorber material is deposited by thermal co-evaporation. $ZnCo_2O_4$ is deposited by pulsed laser deposition and ZnO:Al by HF-sputtering.

The devices were characterized with photocurrent measurements and with a two photon excitation setup provided by two UV/VIS and IR supercontinuum laser sources. Thermal admittance spectroscopy measurements revealed a sulfur vacancy at 400 meV depth.

[1] W. Shockley, H. J. Queisser: J. Appl. Phys., 32(3):510-519, 1961.

[2] A. Luque, A. Martí: Phys. Rev. Lett., 78(26):5014-5017, 1997.

[3] T. Jawinski et al.: pss (a), 215(1700827):1-6, 2018.

HL 45.20 Thu 18:30 Poster E

Organic nano-triode arrays based on self-assembled porous Al and PMMA — •Erjuan Guo, Shen Xing, Felix Dollinger, Hans Kleemann, and Karl Leo — Dresden Integrated Center for Applied Physics and Photonic Materials (IAPP) and Institute for Applied Physics, Technische Universität Dresden, 01062 Dresden, Germany

We utilize the colloidal lithography method for solution processable electronics and demonstrate massively parallel organization of connected three terminal vertical organic transistors. The vertical transistor devices consist of connected organic nano-triode arrays obtained using nanoporous aluminum and PMMA as templates with pore density of about 10^9 pores/cm^2. In this structure, a collector-emitter diode gives rise to a space charge limited current, which can be controlled by a third intermediate porous base electrode to give transistor like characteristics. The transistors achieve a high on/off ratio greater than 10^5 at low operation voltage of -1.5 V. The output current density is 115 mA/cm^2 with current gain greater than 1000, thereby facilitating the development of cost-efficient organic power devices. This study provides a potential foundation for achieving cost-efficient colloidal lithography in real production environment.

HL 45.21 Thu 18:30 Poster E

Monte-Carlo-Simulation organischer Halbleiter für verschiedene Phthalocyanine — •Inga Fischer[1], Sreetama Banerjee[1], Tobias Rüffer[2], Georgeta Salvan[1] und Angela Thränhardt[1] — [1]Institut für Physik, Technische Universität Chemnitz — [2]Institut für Chemie, Technische Universität Chemnitz

Organische Materialien wie Phthalocyanine stehen seit etlichen Jahren im Fokus der Entwicklung neuer Halbleiteranwendungen. Wir berichten über die Simulation des Stromflusses mittels Hüpfleitungsprozess durch makroskopische Proben aus verschiedenen Phthalocyaninen, die sich hinsichtlich des Zentralatoms sowie der Substitution von Wasserstoffatomen durch Halogene unterscheiden. Die Ladungsträgerlaufzeiten und die hieraus ermittelten Stromstärken werden in Abhängigkeit von Spannung, Temperatur, räumlicher und energetischer Unordnung sowie dem Einfluss der Kontaktierungen unter Berücksichtigung verschiedener Kristallstrukturen untersucht. Die Simulationsergebnisse für bis zu 5 Mio. Moleküle bzw. 300 Mio. Atome werden experimentellen Befunden gleichgroßer Proben gegenübergestellt.

HL 45.22 Thu 18:30 Poster E

Tunable Polymer Photodetectors: Towards Low Dark Current and High Detectivity — •Shen Xing, Erjuan Guo, Hans Kleemann, and Karl Leo — Dresden Integrated Center for Applied Physics and Photonic Materials (IAPP) and Institute for Applied Physics, Technische Universität Dresden, 01062 Dresden, Germany

Photodetectors with a high detectivity as well as a high spectral selectivity are essential for high-resolution image sensor arrays. Here, we introduce a method for tuning the polymer photodetector (PPD) spectra without an optical filter. The devices have a simple planar junction architecture with the photoactive layer being a sequentially solution-processed film of PC71BM onto the pre-deposited bottom layer of doped P3HT. We demonstrate a redshift of response peak of around 100 nm in the red light range (645-745 nm) by tuning the PTB7 doping ratio in P3HT layer. In addition, for optimized doping ratio in P3HT, the external quantum efficiency of the response peak is doubled and the dark current density is simultaneously reduced by two orders of magnitude, leading to a maximum detectivity over 10^{12} Jones. This design concept allows for response tuning and is generic for other spectral windows.

HL 45.23 Thu 18:30 Poster E

Investigating Oxygen Degradation in PCE-11 Solar Cells — •Andreas Weu and Joshua Kress — Centre for Advanced Materials, Heidelberg

Recently, the efficiency of organic solar cells was improved to over 13%, bringing organic photovoltaics one step closer to serious commercialisation. However, the environmental stability of such devices, which is an essential step towards further development, remains rather insufficiently understood. Here, we address the effect of oxygen on the operation of the high-efficiency material system PCE-11:PC71BM. By using ultra-fast transient absorption (TA) and ultra-sensitive photo-thermal deflection (PDS) techniques in combination with field-effect transistors, we show that oxygen-induced doping of the active layer is mainly responsible for the observed device degradation. We find that exposure to light is accelerating this effect without causing photo-oxidation of the materials.

HL 45.24 Thu 18:30 Poster E

Investigation of New Organic Acceptor Materials for Bulk-Heterojunction Solar Cells — •Julian Butscher[1,2], Sebastian Hahn[3], Uwe Bunz[3], and Yana Vaynzof[1,2] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Heidelberg, Germany — [2]Center for Advanced Materials (CAM), Heidelberg, Germany — [3]Organisch-Chemisches Institut, Universität Heidelberg, Heidelberg, Germany

Promising cost reductions and advantages in fabrication, organic photovoltaics attracted much research effort over the last years. In this context, the choice of new non-fullerene acceptor materials for the active layer plays a key role in increasing efficiency and stability of bulk-heterojunction (BHJ) solar cells.

We investigate bent phenanthrene-analogous N-heteroacenes as non-fullerene acceptor materials in organic solar cells. By means of different spectroscopic and microscopic techniques, we examine their photovoltaic properties. First experiments show promising power conversion efficiencies. In order to improve the solar cells' performance, we study different preparation parameters as for example annealing time, acceptor-donor stochiometry and additive concentration.

HL 45.25 Thu 18:30 Poster E

Growth of Na-doped SnSe single crystals — •Ali Scherzad, Yannik Bartlock, Kristin Kliemt, Marius Peters, Sebastian Witt, and Cornelius Krellner — Physikalisches Institut, Goethe Universität Frankfurt, 60438 Frankfurt am Main, Germany

Single crystalline tin-selenid has proven to be an excellent thermoelectric material, since new studies have shown that the figure of merit of hole doped SnSe is above 1 [1]. The large figure of merit arises mainly from a huge increase of the power factor, e.g. an increase of the electrical resistivity and the thermopower. This work presents the single crystal growth of tin-selenid and various Na-doped tin-selenid compounds via vertical Bridgman method. The samples were analyzed with x-ray diffraction and probed by van de Pauw measurements to investigate the influence of the Na-doping on the density and the mobility of the charge carriers. Furthermore a new setup is developed for future thermopower measurements.

[1] L.-D. Zhao et al., Science **351**, 141 (2016)

HL 45.26 Thu 18:30 Poster E

Mesoporous silicon filled with functionalized molecules as novel thermoelectric hybrids — •Natalia Gostkowska, Klaus Habicht, and Tommy Hofmann — Helmholtz-Zentrum Berlin für Materialien und Energie Hahn-Meitner-Platz 1 14109 Berlin

This contribution presents objectives and first results of the DFG project 'Hybrid thermoelectric materials based on porous silicon: Linking macroscopic transport phenomena to microscopic structure and elementary excitations'. The approach to associate mesoporous semiconductors and functionalized molecules in novel thermoelectric materials is thoroughly motivated. We discuss in detail the synthesis of the mesoporous silicon by means of electrochemical etching in a newly designed etching cell. Nitrogen sorption isotherms and scanning electron microscopy studies reveal comprehensively the morphology of the synthesized porous membranes. To complete the thermoelectric characterization the Hall effect, Seebeck coefficient, thermal conductivity and electrical conductivity measurements are performed to elucidate the interplay of morphology and thermoelectric transport. The presentation finally discusses the P3HT, PEDOT:PSS, polypyrrole and other functionalized molecules as potential candidates for the envisioned hybrids and provides an outlook on synthesis routes.

HL 45.27 Thu 18:30 Poster E

Influence of defect and impurities in tin telluride nanowires: a theoretical study — Tainá Matendal de Souza, Maicon Luan Stefan, Fellipe de Souza Reis, and •Ernesto Osvaldo Wrasse — Universidade Tecnológica Federal do Paraná, Toledo, Brazil

A crescent demand of energy, and the necessity of renawable sources of energy, has increased the interess of materials that present a high thermoelectric efficiency, defined by the figure of merit ZT. Tin telluride (SnTe) is one of the most promissing materials for apllications in thermoelectricity. Recent works suggest that SnTe nanowires have a greather thermoelectric efficiency when compared to the bulk, and n-type doping can improve significantly the value of ZT. In this contribution, quantum mechanical calculations in the framework of the Density Functional Theory (DFT)as implemented in the VASP code, were employed to describe SnTe nanowires. The influence of intrinsic defects (vacancies and antisites) and group III impurities (Al, Ga, In, and Tl) in the structural and electronic properties were analised. Similar as obtained in SnTe bulk phase, Sn vacancie has the lowest formation energy among all the defects in SnTe nanowires. Due defect levels, the system became a p-type semiconductor. For the impurities, Ga and Tl substitutional to Sn atoms have the lowest formation en-

ergy, and give rise to a n-type semiconductor character in the SnTe nanowires. As a resume, by combining quantum confinement and doping, our results show that SnTe nanowires are good candidates for applications in efficient thermoelectric devices.

HL 45.28 Thu 18:30 Poster E

Construction and Application of an Apparatus to Measure the Seebeck-Effect in Modulation Doped Semiconductors — •Timo Kruck, Arne Ludwig, and Andreas D. Wieck — Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstraße 150, D-44780 Bochum

Most processes (for instance information processing, power generation and power conversion) don't perform at maximum possible efficiency. The resulting waste heat can be converted into electric energy using thermoelectric generators even from a very small temperature gradient. This is called Seebeck-Effect. Today they only offer a small efficiency, that is represented by the "Figure of Merit", $ZT = S^2\sigma T/\kappa$, but offer a wide range of other benefits, like reliability and scalability. S is the Seebeck-coefficient, σ is the electrical conductivity and κ the thermal conductivity. For this work an apparatus to measure the Seebeck-Effect in semiconductors was constructed and with that the influence of a few parameters (for instance the type of doping, the charge-carrier mobility and density, and the specific heterostructure) on the Seebeck-Coefficient S will be analyzed. Experimentally we use a single thermocouple to locally heat the sample, measure the local temperature and the resulting thermovoltage in the sample.

HL 45.29 Thu 18:30 Poster E

Enhancing potassium-ion battery performance by defect and interlayer engineering — •Yuhan Wu[1], Yang Xu[1], Farzaneh Bahmani[2], Chenglin Zhang[1], and Yong Lei[1] — [1]Institut für Physik & IMN MacroNano (ZIK), Technische Universität Ilmenau — [2]Department of Chemistry, Institute for Advanced Studies in Basic Sciences

Defect and interlayer engineering is applied to exploit the large van der Waals gaps of transition metal dichalcogenides for potassium ion batteries. As a demonstrator, MoS2 nanoflowers with expanded interlayer spacing and defects in the basal planes are used as KIB anodes in the voltage range of 0.5 to 2.5 V, where an intercalation reaction rather than a conversion reaction takes place to store K-ions in the van der Waals gaps. The nanoflowers show enhanced K-storage performance compared to the defect-free counterpart that has a pristine interlayer spacing. Kinetic analysis verifies that the K-ion diffusion coefficient and surface charge storage are both enhanced in the applied voltage range of the intercalation reaction. The collective effects of expanded interlayer spacing and additionally exposed edges induced by the in-plane defects enable facile K-ion intercalation, rapid K-ion transport and promoted surface K-ion adsorption simultaneously.

HL 45.30 Thu 18:30 Poster E

Photoinduced transient spin polarization in the semiconducting lead halide perovskite $(CH_3NH_3)PbI_3$ above the orthorhombic-tetragonal phase transition — •Oskar Schuster[1], Daniel Niesner[1], Thomas Fauster[1], Shreetu Shrestha[2], Ievgen Levchuk[2], Miroslaw Batentschuk[2], and Christoph Brabec[2] — [1]Lehrstuhl für Festkörperphysik, Univ. of Erlangen–Nürnberg, Staudtstr. 7, D-91058 Erlangen — [2]I-MEET, Univ. of Erlangen–Nürnberg, Martensstr. 7, D-91058 Erlangen

$(CH_3NH_3)PbI_3$ belongs to a class of semiconducting lead halide perovskites with singly degenerate valence and conduction band, playing an important role in current solar cell research. At 160 K the material undergoes a transition from a centrosymmetric orthorhombic phase to a tetragonal phase which is centrosymmetric on average, exhibiting local disorder. The concept of a "dynamical Rashba effect" induced by the local electric fields in the disordered structure has been proposed by theoretical models and by measurements of optically induced spin currents [1]. For the disordered, high–temperature phase a transient magneto–optical Kerr effect (MOKE) is induced by pumping the fundamental optical transition with circularly polarized light. A clear MOKE signal is absent in the ordered, low-temperature phase. This further supports the idea of a "dynamical Rashba effect". We discuss the picosecond spin dynamics and the possible spin scattering mechanisms in this new class of Rashba semiconductors.

[1] D. Niesner et al., Proc. Natl. Acad. Sci. **115**, 9505 (2018)

HL 45.31 Thu 18:30 Poster E

Optical amplification of spin noise spectroscopy via homodyne detection — •Pavel Sterin, Julia Wiegand, Jens Hübner, and Michael Oestreich — Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, D-30167 Hannover, Germany

Spin noise (SN) spectroscopy measurements on delicate semiconductor spin systems, like single InGaAs quantum dots, are currently limited by electrical noise of the detection system rather than by optical shot noise[1]. Here, we report a realization of homodyne SN spectroscopy enabling shot noise limited SN measurements. The proof-of-principle measurements on impurities in an isotopically enriched rubidium atom vapor show that homodyne SN spectroscopy can be utilized even in the low frequency spectrum which facilitates advanced semiconductor spin research like higher order SN measurements on spin qubits.

HL 45.32 Thu 18:30 Poster E

Electron spin polarization in singly charged (In,Ga)As/GaAs quantum dots: Spin inertia and extended pump-probe — •Eiko Evers[1], Vasilii V. Belykh[1,2], Alex Greilich[1], Dmitri R. Yakovlev[1,3], Dirk Reuter[4], Andreas D. Wieck[5], and Manfred Bayer[1,3] — [1]Experimentelle Physik 2, TU Dortmund University, 44221 Dortmund, Germany — [2]P.N. Lebedev Physical Institute of the Russian Academy of Sciences, 119991 Moscow, Russia — [3]Ioffe Institute, Russian Academy of Sciences, 194021 Saint Petersburg, Russia — [4]Optoelectronic Materials and Devices, Paderborn University, 33098 Paderborn, Germany — [5]Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany

The electron spin in n-type, singly charged (In,Ga)As/GaAs quantum dots offers μs long transversal and longitudinal relaxation times, a timescale too long for optical pump-probe measurements using a mechanical delay. We determine characteristic timescales of the longitudinal electron spin relaxation using the spin inertia [1],[2] and the extended pump-probe technique [3]. While the spin-inertia technique is based on the inability of the electron spin polarization to follow excitation with high frequency, the extended pump-probe technique adds an electronically controlled delay between pump and probe pulses. We compare the extracted time scales and show differences between the techniques.

[1] F. Heisterkamp et al., Phys. Rev. B **91**, 235432 (2015)
[2] E. A. Zhokuv et al., Phys. Rev. B **98**, 121304 (2018)
[3] V. V. Belykh et al., Phys. Rev. B **94**, 241202 (2016)

HL 45.33 Thu 18:30 Poster E

NV-centers, embedded in a diamond transistor structure — •Dennis Oing[1], Martin Geller[1], Stefan Borgsdorf[2], Ulrich Köhler[2], Nicolas Wöhrl[1], and Axel Lorke[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Lotharstr. 1, 47057 Duisburg, Germany — [2]Institut für Experimentalphysik IV - AG Oberflächen, Ruhr-Universität Bochum, 44780 Bochum

Nitrogen-vacancy-centers (NV-centers) in diamond are promising candidates for applications in quantum information technology.
So far, mostly optical spectroscopy and read-out of NV-centers in diamond have been performed and three different charge states were observed. However, electrical control and read-out of the charge states has been proven to be difficult.
In this contribution, we present a transistor-like structure in diamond that allows us to electrically control the charge state of the NV-centers and which could have the potential for electrical read-out and manipulation.
The sample consists of bulk diamond with NV-centers, where a hydrogen termination on the surface induces a two-dimensional hole gas as a conductive surface layer. Reactive ion etching was used to define a mesa and two different ion implantation steps to form a graphite electrode 95 nm and the NV-centers 10 nm below the surface. After implantation the sample is coated with a thin aluminium oxide layer and annealed in high vacuum. We show device characterization like IV-characteristics, Raman spectroscopy and gate dependent photoluminescence.

HL 45.34 Thu 18:30 Poster E

Laser writing of scalable single spin in SiC — •Yu-Chen Chen[1], Patrick Salter[2], Matthias Niethammer[1], Matthias Widmann[1], Klorian Kaiser[1], Roland Nagy[1], Naoya Morioka[1], Charles Bbin[1], Patrick Berwian[3], Jürgen Erlekampf[2], Martin Booth[3], and Jörg Wrachtrup[1,4] — [1]3.Physikalisches Institut, Universitaet Stuttgart, Germany — [2]Department of Engineering Science, University of Oxford, Oxford, UK — [3]Fraunhofer IISB, D-91058 Erlangen, Germany — [4]Max-Planck Institute for Solid State Research, Stuttgart, Germany

Single photon emitters in silicon carbide (SiC) have attracted widespread attention as photonic systems, applied on quantum applications [1-2]. However, to achieve scalable devices it is essential to generate the single photon emitters at desired location on demand. Here we report the controlled creation of single silicon vacancy (V_{Si}) centres in 4H SiC using laser writing and without annealing. Due to the aberration correction in the writing apparatus and the non-annealing process, the generation of single V_{Si} centres with yield up to 30%, located within about 80 nm of the desired position in the transverse plane. We also investigated the mechanism of the laser writing V_{Si} centres and there are 15.5 photons involved in the laser writing V_{Si} centres process. The results demonstrate a new tool to fabricate single V_{Si} centres in SiC for quantum technologies and provide some insight into the laser writing defects in dielectric materials.

1. A. Lohrmann et al, Rep. Prog. Phys. 80 (2017) 2. S. Castelletto et al, Adv. Optical Mater. 1 (2013)

HL 45.35 Thu 18:30 Poster E

Taking OLEDs for a Spin — •Nikolai Bunzmann[1], Sebastian Weissenseel[1], Jeannine Grüne[1], Christoph Boehme[2], Vladimir Dyakonov[1], and Andreas Sperlich[1] — [1]Experimental Physics VI, Julius Maximilian University of Würzburg — [2]University of Utah, Salt Lake City, USA

Organic light emitting diodes (OLEDs) based on thermally activated delayed fluorescence (TADF) exhibit a high upconversion rate from non-emissive triplet to emissive singlet states due to a a small energy splitting ΔE_{ST} between the respective states. Electroluminescence and electrically detected magnetic resonance (ELDMR, EDMR) are suitable methods to investigate such devices as they connect spin-dependent processes with optical and electrical properties. Both techniques were previously used by us to reveal excitation pathways of intermediate excited states in donor:acceptor based TADF OLEDs. However continous wave (cw) experiments do not always allow to fully explain the origin of the observed magnetic resonance effects since different spin- and time-dependent processes may result in indistinguishable spectra. Therefore, we apply pulsed EDMR (pEDMR) to donor:acceptor based TADF OLEDs and by varying the parameters of these experiments such as pulse intensity and length we explore the genesis of TADF emission with respect to interspin coupling and spin relaxation time (T1).

HL 45.36 Thu 18:30 Poster E

Multifrequency Spin-Resonance Experiments on organic LEDs based on Triplet-Singlet Conversion — •Rebecca Bönnighausen, Sebastian Weissenseel, Sebastian Lulei, Vladimir Dyakonov, and Andreas Sperlich — Experimental Physics VI, Julius Maximilian University of Würzburg

In organic light emitting diodes (OLEDs), which are based on thermally activated delayed fluorescence (TADF), the small energy splitting ΔE_{ST} between singlet and triplet states is utilized to achieve an increased light output. The so called exciplexes (weakly bound e-h pairs) in the triplet state can upconvert from the triplet state to the singlet state via reverse intersystem crossing (RISC). This process can be investigated by spin sensitive techniques such as electroluminescence detected magnetic resonance (ELDMR). The triplet states split in an external magnetic field and transitions between those states can be induced by resonant microwaves, which results in a detectable change in the luminescence. We investigate the change to this ELDMR spectrum if an additional microwave frequency is applied to the sample. It saturates the spin transition, which is seen as a spectral hole burning. We discuss the mechanism responsible for such "hole burning" and its practical use to enhance the sensitivity of ELDMR due to the inhomogeneous linewidth to probe the interspin coupling in OLEDs for TADF and the involved mechanisms of RISC and interspin coupling.

HL 45.37 Thu 18:30 Poster E

Engineering and Resonant Excitation of Highly Coherent Spin Defects in Silicon Carbide — •C. Kasper[1], A. Sperlich[1], T. Ohshima[2], V. Soltamov[1], G. V. Astakhov[1,3], and V. Dyakonov[1] — [1]Experimental Physics VI, Julius Maximilian University of Würzburg — [2]National Institutes for Quantum and Radiological Science and Technology, Takasaki — [3]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf

Quantum centers in silicon carbide (SiC) have been demonstrated to be more than just the hampering defects for device performance. With their long spin coherence times [1] and the possibility of downscaling to single-photon source level [2], they have proven themselves to be promising candidates for a multitude of quantum information applications. By using the pulsed-ODMR technique we compare the two main spin-coherence parameters (T1 and T2) of silicon vacancies in SiC created with neutron, electron and proton irradiation in a broad range of silicon vacancy densities. Additionally we examine the influence of sample annealing and tuning of the laser excitation-wavelength on the ODMR contrast and the coherence properties in several potentially interesting SiC polytypes, 4H, 6H and 15R. Our results give an insight into the effects of irradiation method, sample annealing and excitation wavelength on the spin-coherence properties of silicon vacancies in SiC and hence allow their optimization for a concrete task.

[1] Simin et al., Phys. Rev. B 95, 161201(R) (2017)
[2] F. Fuchs et al., Nature Commun. 6, 7578 (2015)

HL 45.38 Thu 18:30 Poster E

Sensing Weak Microwave Signals by Quantum Control — •Timo Joas, Andreas M. Waeber, Georg Braunbeck, and Friedemann Reinhard — Walter Schottky Institut und Physik-Department, Technische Universität München

Solid state qubits, such as the Nitrogen-Vacancy (NV) center in diamond, are attractive sensors for nanoscale magnetic and electric fields, owing to their atomically small size. A major key to their success have been dynamical decoupling protocols (DD), which enhance sensitivity to weak AC signals such as the field of nuclear spins from a single protein. However, those methods are currently limited to signal frequencies up to several MHz.

Here we harness a quantum-optical effect, the Mollow triplet splitting of a strongly driven two-level system, to overcome this limitation. We microscopically understand this effect as a pulsed DD protocol and find that it enables sensitive detection of fields close to the driven transition. To this end, we create a pair of photon-dressed qubit states which support a new transition with narrow linewidth. Generally, our scheme is applicable to any qubit but we consider sensitive detection of signals close to the NV's transition frequency (≈ 2 GHz). As a result, we demonstrate slow Rabi oscillations with a period up to $\Omega_{Rabi}^{-1} \sim T_2$ driven by a weak signal field. The corresponding sensitivity could enable various applications. Specifically, we consider single microwave photon detection, as well as fundamental research on spin-phonon coupling.

HL 45.39 Thu 18:30 Poster E

An Optical Interface to Spin Qubits in GaAs — •Zheng Zeng[1], Arne Ludwig[2], Eva Gross[1], Detlev Grützmacher[1], Hendrik Bluhm[3], and Beata Kardynał[1] — [1]Peter Grünberg Institute (PGI-9), Forschungszentrum Jülich, D-52425 Jülich, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [3]JARA-Institute for Quantum Information, RWTH Aachen University, D-52074 Aachen, Germany

Connecting quantum information processors over long distances using photons as qubits would enable more complex quantum computing architectures and quantum networks. Spin qubits in GaAs/AlGaAs gate-defined quantum dots (GDQDs) have been demonstrated to be promising scalable qubits. Since GaAs is a direct band gap material, a coherent transfer of information between a spin qubit and a photon qubit is in principle possible but cannot be achieved directly using GDQDs. Here we investigate a possibility of using InAs self-assembled quantum dots (SAQDs) to facilitate a coherent transfer of an energy encoded photon qubit into a spin qubit. We discuss the protocol of the spin qubit transfer between the two quantum dots of the device and show the results of fabrication and characterization of a hybrid device with a gate-defined double quantum dot (GDDD) tunnel coupled to a SAQD. We show an optical method that enables alignment of the two component quantum dots with an accuracy of 20 nm and analyze the proximity effect of the two components of the device on each other.

HL 45.40 Thu 18:30 Poster E

Defect-affected Current in Silicon Carbide: Towards Photoelectric Spin Readout — •M. Hollenbach[1,2,3], C. Kasper[3], A. Sperlich[3], M. Takahiro[4], T. Ohshima[4], V. Dyakonov[3], and G.V. Astakhov[1,3] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam and Materials Research, Dresden — [2]Technische Universität Dresden, Dresden — [3]Experimental Physics VI, Julius-Maximilians-Universität Würzburg, Würzburg — [4]National Institutes for Quantum and Radiological Science and Technology (QST, formerly Japan Atomic Energy Agency), Takasaki, Japan

Silicon carbide (SiC) is a technologically advanced wide bandgap semi-

conductor for high-power and high-temperature electronics and is envisioned to be a viable candidate for solid-state quantum information applications. At present, laser excitation as well as optical readout of the atomic-scale defects, localized within the bandgap, are typically based on confocal microscopy. In this study, we implemented a hybrid detection method, allowing the direct light induced photoelectric readout of the silicon defects (V_{Si}) in SiC. Here, we characterize particularly 4H-SiC diodes with varying spatial distribution introduced by electron irradiation with regard to their optical and electrical properties. By analyzing I-V-characteristics, photoluminescence spectra as well as optically and electrically detected magnetic resonance (ODMR, EDMR) of active V_{Si} centers, we identify an irradiation threshold to boost diodes with sufficient quantity of V_{Si} for nanotesla magnetic field sensing applications.

HL 45.41 Thu 18:30 Poster E

Electrical readout of NV^- centres — •Manuel Schiefer, Julius Röwe, David Vogl, and Martin S. Brandt — Walter Schottky Institut and Physik-Department, Technische Universität München, Garching, Germany

Recently, the readout of the spin state of NV^- centres in diamond has been demonstrated monitoring conductivity rather than luminescence. This approach carries the potential to significantly simplify the realisation of integrated devices for, e.g., quantum information processing or metrology. In this contribution, we study the elementary processes leading to the photoionisation of the NV^- centre to further understand and improve the electrical spin readout.

HL 45.42 Thu 18:30 Poster E

Calculation of Emitter-Photon Waveguide Dynamics Using Binary Tensor Networks — •Oliver Kästle, Sandra Kuhn, and Marten Richter — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik von Halbleitern, Technische Universität Berlin, 10623 Berlin, Germany

We investigate the radiation dynamics of semiconductor quantum dots within a one-dimensional waveguide, where spontaneous radiative decay is caused by electron-photon interactions. Typically the coupling elements are approximated by a constant coupling rate to avoid the numerical demand for non-Markovian calculations. We utilize tensor networks to act as a data compression scheme for high dimensional tensors, yielding the possibility to calculate the dynamics of even large quantum many-body systems [1]. The proposed method allows for the use of millions of grid points for photonic wave numbers and their corresponding coupling elements, enabling investigations of non-Markovian dynamics of several quantum dots and multiple photons inside the waveguide. The density matrix elements are decomposed into matrix product states (MPS) using a bit decomposition scheme. System operators are constructed from binary logic gates, imposing the system dynamics on the bit-encoded MPS.

[1] S. Kuhn and M. Richter, arXiv:1807.09036v1 (2018).

HL 45.43 Thu 18:30 Poster E

Hybrid Assembly of Elements for Quantum Networks — •Andreas W. Schell — Quantum Optical Technology Group, CEITEC, Brno, Czech Republic

Bringing quantum technology from the laboratory to real world applications is a complex, but very rewarding, task. It will enable society to exploit the new opportunities the laws of quantum mechanics offer compared to purely classical physics. However, before the new quantum technology can be deployed, platforms to implement such a technology need to be discovered and developed. Here, we will show our ongoing efforts to implement such a platform using the so called hybrid approach for the assembly of quantum photonic elements. In the hybrid assembly approach, structures and emitters from different materials are combined in order to exploit the specific strength of the individual material while avoiding possible disadvantages by use of complementary other materials. This approach is highly flexible and can be adapted to many different material systems and structures. In particular, we will introduce techniques based on scanning probe microscopy and three-dimensional laser writing. Assembled systems include emitter coupled to on-chip resonators and waveguides, different kinds of fiber integrated cavities, and incorporate a variety of emitter such as NV centers, quantum dots, and defects in two-dimensional materials, such as hexagonal boron nitride. From these examples it can be seen that photonics elements assembled using hybrid techniques might help to facilitate the transition of quantum photonic networks out of lab to real-world applications.

HL 45.44 Thu 18:30 Poster E

Optical properties of implanted transition-metal impurities in SiC — •Zhen Shang[1,2], Yonder Berencén[1], Shengqiang Zhou[1], and Georgy Astakhov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany

Atomic-scale defects in silicon carbide, such as silicon vacancy (Vsi), are attracting worldwide attention because of their potential application in quantum technology. These defects can be used as optically addressable single photon emitters at room temperature. They are also considered as stable solid-state spin qubits because its spin state can be easily manipulated. Generally, these defects can be divided into two categories, the intrinsic defects such as Vsi and the transition-metal impurities-related defects such as titanium or vanadium related defects. For the intrinsic defects, the optical and spin properties as well as the fabrication method have been well investigated. However, the investigation of the transition-metal impurities in silicon carbide still remains elusive. Here we introduce transition-metal impurities into SiC by ion implantation and subsequent annealing. We use irradiation fluence of vanadium and titanium up to 1e17 and thermal annealing up to 1700°C. We investigate the optical properties of the created defects, and compare the relative intensities of the zero-phonon lines to those in reference samples, where titanium- and vanadium-related defects are incorporated during growth. This work is the first step for the realization of single photon emission and spin manipulation from vanadium- and titanium-related defects in SiC.

HL 45.45 Thu 18:30 Poster E

Line shapes in Raman spectroscopy of amorphous semiconductors — •priyanka Yogi[1], priyanka yogi[1], and Rajesh Kumar[2] — [1]Institut für Festkörperphysik, ATMOS, Leibniz Universität Hannover Appelstr. 2, D-30167 Hannover, Germany — [2]Material Research Laboratory, Discipline of Physics & MEMS, Indian Institute of Technology Indore, Simrol-453552, India

The theoretical analysis of line shapes of Raman scattering data from amorphous semiconductors like silicon, germanium etc. turned out to contain important information about short range order correlations and size distributions of local nanocrystals formed. For that purpose, an existing modified phonon confinement model (MPCM) is used to analyze the Raman scattering data of amorphous semiconducting materials. A MPCM includes two main conventions namely phonon momentum conservation and shift in zone centre phonon frequency. These two factors were amalgamated to generate the theoretical Raman lineshape that was fitted to experimentally observed Raman spectra of amorphous materials. Experimentally observed Raman scattering data of amorphous materials which are prepared by different techniques are well fitted, and has been used to quantify the distance of short-range order. It can be established that the Raman line-shape obtained within the framework of MPCM is a close representative Raman line-shape of amorphous semiconducting materials. The quantification of the degree of order may prove to be scientifically and technologically important to enhance the efficiency of solar cells of amorphous materials such as amorphous silicon solar cells etc.

HL 45.46 Thu 18:30 Poster E

Nonequilibrium Resonance in Quantum Dots without Electronic Wetting Layer States — •Ibrahim A. Engin, Ismail Bölükbasi, Sven Scholz, Andreas D. Wieck, and Arne Ludwig — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

Self assambled InAs quantum dots (SAQD) proved promising semiconductor structures as single photon sources.

We investigate electronic resonances in illuminated InAs SAQDs by using C(V)-spectroscopy. With constant illumination of SAQDs metastable hole states can be created [1]. Furthermore, non-equilibrium states have been observed by increased illumination or tunnel barrier length [2].

SAQDs are grown inevitably with a wetting layer (WL), which interferes with the SAQD observation by affecting the photon emission spectrum of quantum dots. Here we modify the growth of SAQDs by adding a monolayer of AlAs on the quantum dots to suppress electronic WL-states [3] by more than 30dB and study non-equilibrium electron resonances.

[1] Labud, P. et al., "Direct Quantitative Electrical Measurement of Many-Body Interactions in Exciton Complexes in InAs Quantum Dots", Phys. Rev. Lett. 112 (2014), 046803

[2] Valentin, S. et al., "Illumination-induced nonequilibrium charge states in self-assembled quantum dots", Phys. Rev. B 97 (2018), 045416

[3] Löbl, M. et al., "Excitons in InGaAs Quantum Dots without Electron Wetting Layer States", eprint arXiv:1810.00891 (2018)

HL 45.47 Thu 18:30 Poster E

Pseudomorphic strain in corundum-phase Al-rich $(Al,Ga)_2O_3$ thin films grown on R-plane sapphire — •Marius Grundmann, Michael Lorenz, Stefan Hohenberger, and Eduard Rose — Universität Leipzig, Felix-Bloch-Institut für Festkörperphysik, Linnéstr. 5, 04103 Leipzig

We present the theory of pseudomorphic elastic continuum strain for heterostructures for rhombohedral/trigonal materials for arbitrary orientation of the epitaxial plane [1]. For $C_{14} = 0$ it degenerates to the theory for hexagonal (wurtzite) materials. We test the theory for atomically smooth, pseudomorphic α-$(Al_{1-x}Ga_x)_2O_3$ ($0 \leq x < 0.08$) thin films grown on R-plane sapphire (01.2) by pulsed laser deposition at growth temperatures up to 1,000°C. A careful analysis of lattice constants and tilt from 13 symmetric, skew-symmetric and asymmetric X-ray peaks agrees quite well with the strain theory [2]. The Ga-contents x and weak deviations from the expected ratio of rhombohedral/hexagonal c/a lattice constants are obtained from best fits of the spacing of the (02.4), (04.8), and (00.6), (00.12) film and substrate reflections, in reasonable agreement with chemical EDX analyses.

[1] M. Grundmann, J. Appl. Phys. 124(18), 185302:1-10 (2018).
[2] M. Lorenz, S. Hohenberger, E. Rose, M. Grundmann, Appl. Phys. Lett., accepted (2018).

HL 45.48 Thu 18:30 Poster E

Optical phonon modes and dielectric function of orthorhombic κ-Ga_2O_3 thin films — •Andreas Müller, Chris Sturm, Max Kneiss, Vitaly Zviagin, and Marius Grundmann — Felix-Bloch-Institut für Festkörperphysik, Universität Leipzig, Linnéstraße 5, 04103 Leipzig

The large band gap energy of about 4.8 eV [1] makes Ga_2O_3 interesting as transparent conductive oxide. Of special interest is the orthorhombic κ-phase, due to its large predicted spontaneous electric polarization, which can be utilized for polarization doping to create high carrier densities at heterointerfaces [2]. However, the optical and phonon properties have not been explored in detail yet.

We determined the dielectric function of κ-Ga_2O_3 thin films, deposited by pulsed laser deposition on Al_2O_3, MgO and STO substrates [3], by means of spectroscopic ellipsometry from the infrared up to the ultraviolet spectral range (0.04 eV − 8.50 eV). By means of a parametric model dielectric function approximation, the nature and the properties of the electronic band-to-band transitions as well as of the phonon modes were examined. Complementary to the investigations done by spectroscopic ellipsometry, we investigated the phonon modes by Raman spectroscopy and 8 phonon modes were identified.

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HL 45.49 Thu 18:30 Poster E

Growth of MoO_3 Microfakes by Thermal Evaporation — •Sophie Müller, Daniel Splith, Holger von Wenckstern, and Marius Grundmann — Felix-Bloch-Institut, Universität Leipzig

The discovery of graphene as a 2-dimensional material had great impact on current research. Nevertheless, a 2-dimensional material with semiconducting properties, especially a band gap, would be desirable for the realization of 2-dimensional electronic devices. Molybdenum oxide is a semiconductive metal oxide with numerous interesting properties, like its wide band gap of more than 2.7 eV [1]. Balendhran *et al.* investigated 2-dimensional molybdenum oxide and reported a high room temperature electron mobility of 1160 $cm^2\ V^{-1}\ s^{-1}$ [2].
In order to realize electronic devices like field-effect transistors based on 2-dimensional MoO_3, a reproducible fabrication of thin molybdenum oxide nano- or microflakes is necessary. In this contribution, we investigated the growth of preferably thin molybdenum oxide microflakes via thermal evaporation. The influence of the major growth parameters temperature and argon gas flow were determined. Furthermore, the separation and thinning of the microflakes into nanoflakes was investigated. With this, nanoflakes with lateral dimensions of several 10 μm and thicknesses between 20 and 30 monolayers were realized.

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[2] Balendhran *et al.*, Advanced Materials, 25.1, 109-114 (2013)

HL 45.50 Thu 18:30 Poster E

Structural, electrical and optical properties of $W_xMo_{1-x}O_3$ thin films fabricated by pulsed laser deposition — •Peter Schlupp, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Felix-Bloch-Institut für Festkörperphysik, Leipzig, Germany

To reduce the energy consumption of buildings, controlled reduction of the energy flow through the glazing is a promising option. Electrochromic coatings on the windows can be used to switch the light flow within minutes blocking light from outside (summer) or repelling light from inside the building (winter). Today, oxide based materials, especially tungsten oxide thin films, are often used [1]. Alloying WO_3 with MoO_3 can enhance the electrochromic properties [2]. Using pulsed laser deposition (PLD), it is possible to fabricate material libraries using a segmented target [3].

We present $W_xMo_{1-x}O_3$ thin films with a continuous composition spread grown by PLD. Crystalline structure investigated by X-ray diffraction, electrical properties determined by Hall-effect measurements and optical properties from transmission and reflection measurements in dependence on the cation ratio will be presented. The properties of an electrochromic cell, with $W_xMo_{1-x}O_3$ as cathodic and NiO as anodic material will be discussed.

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HL 45.51 Thu 18:30 Poster E

Tuning of material properties of ZnMgON by cationic substitution — •Antonia Welk[1], Anna Reinhardt[1], Holger von Wenckstern[1], Marius Grundmann[1], Thorsten Schultz[2], and Norbert Koch[2] — [1]Felix-Bloch-Institut für Festkörperphysik, Universität Leipzig, Linnéstraße 5, 04103 Leipzig, Germany — [2]Institut für Physik, Humboldt-Universität zu Berlin, Brook-Taylor-Straße 6, 12489 Berlin, Germany

Amorphous zinc oxynitride (a-ZnON) with Hall mobilities up to 100 $cm^2V^{-1}s^{-1}$ [1][2] is a promising low-temperature deposition channel material for thin film transistors (TFTs). In order to fabricate transparent devices we suggested to add magnesium as an additional cation to a-ZnON to increase the mobility gap of 1.3 eV and to reduce the charge carrier concentration to 10^{17} cm^{-3} or below.
We deposited ZnMgON thin films by reactive magnetron co-sputtering. In general, an increased magnesium content leads to a profound decrease in charge carrier concentration, an absorption edge shift to higher energies and a decrease in Hall mobility. However, some films do not show a systematic decrease of the charge carrier concentration. XPS and temperature dependent Hall measurements were applied to correlate differences in chemical bonding configuration with different electrical transport properties.

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HL 45.52 Thu 18:30 Poster E

Growth and functionalisation of ZnO nanowires for H_2S detection in the low ppb region for medical purpose — •Angelika Kaiser[1], Yujia Liu[1], Florian Huber[1], Klaus Thonke[1], and Ulrich Herr[2] — [1]Institute of Quantum Matter / Semiconductor Physics Group, Ulm University — [2]Institue of Functional Nanosystems, Ulm University

Over the past few years, the medical role of hydrogen sulfide (H_2S) in the human body was extensively investigated. Revealing numerous medical applications, e.g. H_2S acting as a biomarker for asthma or as a moderator in the glucose metabolism, a reliable H_2S detection mechanism for target gas concentrations in the parts per billion range (ppb range) is needed. In our research we focus on resistive gas detection using nanostructured metal oxide grown by chemical-vapor-deposition (CVD). Different types of ZnO nanowires (ZnO NW) were grown either by the vapor-liquid-solid (VLS) method with gold catalyst on silicon, or by the vapor-solid (VS) method without catalyst on sapphire. To overcome the poor stability or selectivity of metal oxides towards gases, we investigate the impact of various post growth treatments on the H_2S detection by ZnO. Possible treatments are the annealing in O_2 rich and O_2 poor atmosphere, or ZnO NW surface functionalistation with gold (Au) and copper (Cu) nanoparticles. Because the planar sensor design used is effectively a ChemFET formed by the ZnO NWs with gas sensitive open gate, the suitability of these

is tested by electrical measurements. Here, H_2S sensing is performed at room temperature and in synthetic air to mimic the characteristic of the human breath.

HL 45.53 Thu 18:30 Poster E

Structural and magnetic properties of MBE-grown NiO thin films studied by Raman spectroscopy — •Johannes Feldl, Melanie Budde, Carsten Tschammer, Oliver Bierwagen, and Manfred Ramsteiner — Paul-Drude-Institut für Festkörperelektronik, Leibniz-Institute of the Forschungsverbund Berlin e. V., Hausvogteiplatz 5–7, 10117 Berlin, Germany

NiO is an antiferromagnetic oxide and a transparent p-type semiconductor making this material interesting for applications in the fields of spintronics and transparent electronics. The physical properties of NiO thin films often depend on the strain state and existence of grain boundaries. Using Raman spectroscopy, the structural and magnetic properties of NiO films grown on MgO(100) by plasma-assisted molecular beam epitaxy at different substrate temperatures were investigated. The structural properties of the NiO films are studied by the analysis of second-order phonon scattering. The respective frequencies reflect the strain state in the NiO films. In addition, the phonon confinement due to the formation of grains and the diffusion of Mg into the NiO films possibly affect the actual values of the phonon frequencies. The magnetic characteristics of the NiO films is investigated by temperature-dependent second-order Raman scattering originating from magnons. As a result, a clear dependence of the Néel temperature on the growth conditions is found. The analysis of our results allows for the identification of structural effects on the antiferromagnetic superexchange interaction in the NiO films.

HL 45.54 Thu 18:30 Poster E

Herstellung und Charakterisierung von LuftfeuchteMikrosensoren auf TiO_2-Basis — •Felix Gross, Beate Horn-Cosfeld und Thomas Heinzel — Lehrstuhl für Festkörperphysik, HHU Düsseldorf,

Es wurden Titandioxidstrukturen mit verschiedenen Herrstellungsverfahren auf ihre Funktion als Luftfeuchtesensor getestet. Das physikalische Grundprinzip der Luftfeuchtedetektion basiert auf der Änderung der Permittivität ϵ_r durch die Adsorption von H_2O auf der TiO_2 Oberfläche, sodass $\epsilon_r = \epsilon_r(c_{H_20})$.

Der Imaginärteil der Impedanz weist eine qualitative Abhängigkeit von der relativen Luftfeuchte im Bereich 5-100% r.H. auf. Wir konnten durch die Änderung des Realteils der Impedanz zudem die Bildung der ersten chemisorbierten Monolage H_2O an TiO_2 nach dem Prinzip der Grothusskette identifizieren.

HL 45.55 Thu 18:30 Poster E

Structural, Optical and Electrical Properties of Si- and Zr-Doped κ-$(In_xGa_{1-x})_2O_3$ Thin Films — •Catharina Krömmelbein, Anna Hassa, Daniel Splith, Max Kneiss, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Felix-Bloch-Institut für Festkörperphysik, Linnéstraße 5, 04103 Leipzig, Germany

The orthorhombic polymorph of the wide band-gap semiconductor Ga_2O_3 has a predicted large spontaneous polarization of $23\,\mu C/cm^2$ [1]. At the interface of κ-Ga_2O_3-based, ternary heterostructures occurs a discontinuous change of the polarization leading to a charge accumulation that can potentially be exploited in high-electron mobility transistors. Therefore, it is crucial to determine deposition conditions allowing growth of ternary layers with tailored material properties.

In this study, we present κ-$(In_xGa_{1-x})_2O_3$ thin films prepared on c-sapphire substrates by pulsed laser deposition doped with Si or Zr to improve electrical conductivity. We added tin to induce the growth of the orthorhombic phase [2]. Resulting thin films were investigated by means of energy-dispersive X-ray spectroscopy, X-ray diffraction, atomic force microscopy, transmission, and Hall effect measurements. Further, Schottky barrier diodes were studied at room temperature by current-voltage measurements.

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HL 45.56 Thu 18:30 Poster E

Finite element simulation and experimental characterization of field-effect transistors based on amorphous zinc tin oxide — •Michael Bar, Daniel Splith, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Felix-Bloch-Institut für Festkörperphysik, Leipzig, Germany

Within the quest for field-effect transistors (FETs) with high frequency switching capability various designs have been proposed, including vertical layouts [1,2]. Cost effective production of transparent, flexible FETs also requires a naturally abundant material such as zinc tin oxide (ZTO), a transparent amorphous oxide semiconductor which can be deposited at room temperature [3].

Simple lateral device designs, however, are not optimal for achieving high frequency switching for which vertical layouts are well suited due to the strongly reduced channel length, avoiding the need for submicrometer lithography.

In this contribution, a finite element approach was used to simulate lateral and vertical thin-film field-effect transistors in order to determine the influence of device geometry on static and dynamic properties such as transfer characteristics, cut-off frequency and on-resistance. The obtained data is then compared with experimental results obtained from transistors fabricated on sputtered ZTO thin films [4].

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HL 45.57 Thu 18:30 Poster E

Characterization of κ-$(Al,Ga)_2O_3$ Thin Films grown by VCCS PLD — •P. Storm, M. Kneiss, D. Splith, H. von Wenckstern, M. Lorenz, and M. Grundmann — Universität Leipzig, Felix-Bloch Institut für Festkörperphysik

Ga_2O_3 is a wide band gap semiconductor with $E_g = 4.4 - 5.3$ eV depending on the respective polymorph [1]. Compared to the monoclinic β-phase, the orthorhombic κ-phase exhibits promising features like ferroelectic properties with high spontaneous polarization, possibly leading to the formation of 2DEGs with high electron densities at heterointerfaces. Alloying with Al allows band gap engineering, which is substantial for optoelectronic devices utilizing heterostructures, such as quantum well infrared photodetectors or modulation doped FETs and has therefore been investigated in this study. To achieve this, VCCS-PLD, a novel PLD method allowing the realization of vertical continuous composition spread (VCCS), has been utilized [2]. It enables direct control of the particle flux composition in the PLD plasma and the corresponding thin film compositions using a single radially-segmented target. Employing this technique, we have grown $(Al,Ga)_2O_3$ thin films (on c-sapphire substrates and MgO(111) buffer layers) with varying flux of tin in the PLD plasma to determine the critical content of this catalyst for κ-phase growth. Using the same technique, we varied the Al-content to investigate the structural and morphological impacts of Al in κ-phase Ga_2O_3.

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HL 45.58 Thu 18:30 Poster E

PLD-growth of epitaxial κ-$(In_x,Ga_{1-x})_2O_3$/κ-Ga_2O_3 heterostructures — •Max Kneiss, Anna Hassa, Daniel Splith, Holger von Wenckstern, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Felix-Bloch-Institut für Festkörperphysik, Leipzig, Germany

Ga_2O_3 in the metastable κ-phase has recently gained remarkable interest. Like the monoclinic β-modification, it features a high E_g of ≈5 eV [1] and the possibility of alloying with Al_2O_3 or In_2O_3 for bandgap engineering. However, κ-Ga_2O_3 is additionally expected to possess a high spontaneous electric polarization along its c-direction [2]. Polarization differences at heterointerfaces can be utilized to achieve high electron densities in a 2DEG located at the interface. For high quality heterostructures, epitaxial growth of e.g. κ-$(In_x,Ga_{1-x})_2O_3$ on κ-Ga_2O_3 templates and vice versa is necessary. We demonstrate epitaxial growth of (001)-oriented κ-$(In_x,Ga_{1-x})_2O_3$ layers with various In-concentrations x on κ-Ga_2O_3 thin film templates fabricated by pulsed laser deposition (PLD) employing elliptically-segmented and Sn-doped $(In_x,Ga_{1-x})_2O_3/Ga_2O_3$ targets (VCCS-PLD [3]). Additionally, a κ-Ga_2O_3/κ-$(In_x,Ga_{1-x})_2O_3$/κ-Ga_2O_3 double heterostructure was investigated. Epitaxial growth on the κ-Ga_2O_3 template and its epitaxial relationship with various substrates were determined by XRD; AFM measurements reveal smooth surfaces.

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HL 45.59 Thu 18:30 Poster E

Gasadsorbtion of epitaxial thin β-Ga_2O_3 layers — •Martin Handwerg[1], Robin Ahrling[1], Rüdiger Mitdank[1], Günter Wagner[2], Zbigniew Galazka[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

The transparent conductive oxide β-Ga_2O_3 is of huge interest for high power electronics and optoelectronics because of its high band gap ($E_G \approx 4.8eV$) and breakthrough voltage. Due to the surface electron accumulation layer β-Ga_2O_3 has possible gas sensing application as well. To date only gas sensing mechanics at high temperatures several hundred degree above room temperature could be found.
Here, we investigate the dependence of the conductivity from the atmospheric conditions at room temperature. We used thin homoepitaxially MOCVD grown films of β-Ga_2O_3 which are silicon doped. We show, that pressure and atmospheric composition have influence on the conductivity of very thin films with a thickness $t < 30$ nm. Vander-Pauw and Hall-measurements in relation to nitrogen and oxygen content and pressure of the atmosphere were used. Additionally, the time dependence and the recovery rate of the conductivity change is investigated and discussed.

HL 45.60 Thu 18:30 Poster E

Optimizing the sputter deposition process of amorphous zinc oxynitride thin films — Anna Reinhardt[1], •Antonia Welk[1], Holger von Wenckstern[1], Marius Grundmann[1], Thorsten Schultz[2], and Norbert Koch[2] — [1]Universität Leipzig, Felix-Bloch-Institut für Festkörperphysik, Semiconductor Physics Group — [2]Humboldt-Universität zu Berlin, Institut für Physik

Amorphous zinc oxynitride (a-ZnON) was demonstrated to be a promising high-mobility semiconductor for low-temperature fabricated, high-performance thin-film transistors, whereby reactive sputtering with two reactive gases (O_2 and N_2) either in RF or DC mode is the method of choice for thin film deposition [1–3]. However, the reported electron mobility values for a-ZnON span a wide range of $20-120$ $cm^2V^{-1}s^{-1}$. Due to the complexity of the reactive sputtering process a profound knowledge of the relations between sputter parameters and film properties is nescessary to optimize the latter. We investigated in detail the influence of the sputtering mode and parameters on the electrical properties of a-ZnON thin films. We found that the achievable electron mobility is directly linked to the discharge voltage which can be tuned by applying an additional negative substrate bias. Furthermore, the effect of N_2-plasma-assistence during sputtering process was analyzed regarding the chemical bonding states by means of depth-profiling XPS measurements.

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HL 45.61 Thu 18:30 Poster E

X-ray Photoelectron Spectroscopy of Gallium-Sesquioxide — •Sebastian L. Benz[1], Martin Becker[1], Philipp Schurig[1], Max Kracht[1], Fabian Michel[1], Alexander Karg[2], Martin Eickhoff[2], and Angelika Polity[1] — [1]Institute for Exp. Physics I and Center for Materials Research (LaMa), Justus Liebig University Giessen, Germany — [2]Institute of Solid State Physics - Semiconductor Epitaxy - University of Bremen, Germany

X-ray Photoelectron Spectroscopy is used to characterize Ga_2O_3 thin films (β- and ϵ-phase) grown by different synthesis methods. Particularly, the provided thin films were prepared by plasma-assisted molecular beam epitaxy, an adapted pulsed sputtering method and ion-beam sputter deposition. All thin films share a gallium excess independent of the specific growth method. However, for a stoichiometric template, grown by edge-defined film-fed growth, it is found that the characterization with X-ray Photoelectron Spectroscopy leads to an overestimation of the Ga concentration of about 6 at%. It is believed that this result can be explained by the effect of preferential sputtering. A correction factor is determined to adjust the data of Ga_2O_3 thin films. As a consequence, all mentioned growth methods are capable to produce stoichiometric Ga_2O_3.

HL 45.62 Thu 18:30 Poster E

Modifying GaAs-Heterostructures with laser-annealing — •Hans-Georg Babin, Julian Ritzmann, Marcel Schmidt, Arne Ludwig, and Andreas D. Wieck — Ruhr-Universität Bochum, D-44780 Bochum, Germany

Ex-situ modification of semiconductors is crucial for sample preparation and further experiments. For example the fabrication of ohmic contacts to the relevant structure can be decisive for the success of the conducted transport experiment.

Our goal is to use laser radiation to locally thermal anneal our samples. Due to the high power density and low spot size, it is possible to confine the thermal effects to a small area. Another benefit is the fast heating and cooling ramp when processing the sample, especially when compared to other methods like Rapid-Thermal-Annealing (RTA).

The main focus is to provide low resistance ohmic contacts to two-dimensional-electron gases (2DEG). This can be achieved by combining laser-annealing with focused-ion-beam (FIB) implantation. It is possible to produce stronger and more homogenous doping profiles compared to thermally diffused alloy contacts. Another benefit is a much lower use of thermal budget, which can be achieved by only locally heating the samples for a shorter time. This minimizes unwanted diffusion processes in the functional semiconductor structure.

HL 45.63 Thu 18:30 Poster E

Optimization of the Contact Resistance for Conductance Spectroscopy — •Mario Werner Farny, Carsten Ebler, Andreas Dirk Wieck, and Arne Ludwig — Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstraße 150, D-44780 Bochum

The development of time resolved conductance spectroscopy enhanced the possibilities to investigate two-dimensional electron gases (2DEG) coupled to Quantum Dots [1]. It allows time resolved observation of Quantum Dot charging dynamics. For this, modulation doped field effect transistor structures are made and measured at cryogenic temperatures. The success of the measurements depends on the highest possible response current of the 2DEG and a good signal to noise ratio. To ensure this, the source and drain contact resistance should be low.

We present results of the influence of various device processing steps. In particular, the influence of wet-chemical etching to reduce the distance to the 2DEG, as well as the necessity of wet-chemical surface passivation will be presented.

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HL 45.64 Thu 18:30 Poster E

Investigation of the effect of FIB processing on the surface recombination velocity of semiconductor TEM lamellas — •Christopher Wendeln, Arne Ahrens, and Michael Seibt — IV. Physical Institute of Georg-August University, Göttingen, Germany

'Dead layers' are electrically damaged regions occurring at the surfaces of processed samples and are considered as recombination centers for electrons and holes. The effect of a dead layer on the properties of a material increases with decreasing size since surface-near regions make up a significant proportion of the sample. Thus, electrical measurements on the nanoscale are affected due to the position of the dead layers at the surfaces. Examples are electron beam induced current (EBIC) measurements [1] and electron holography [2] in transmission electron microscopes (TEM). The preparation of TEM lamellas with a focused ion beam (FIB) can cause dead layers to emerge and to disturb the EBIC measurements on that system. Unfortunately, the influence of sample preparation on the formation and thickness of dead layers is not well understood. In this work EBIC investigations of differently FIB-prepared cross sections of an Au/n-Si Schottky contact were conducted to provide insights about the existence and formation of dead layers.

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HL 45.65 Thu 18:30 Poster E

Contactless Measurement of the Sheet Resistance of two-dimensional Electron Gases — •Timo A. Kurschat 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. Such a method could be used to measure whole wafers in order to evaluate quality and homogeneity of the samples before further processing.

Therefore two electrodes (small metal plates) are placed close to the wafer so that they form capacitances C with the conducting layer. If an alternating voltage is applied, the transmitted signal can be measured,

from which the sheet resistance can be calculated. The reactance of the capacitance is proportional to $\frac{1}{\omega C}$. To minimize the influence of the capacitance, either the frequency can be set high, or the capacitance can be determined from the phase or from the signal amplitude at multiple frequencies.

The lateral resolution depends on the size of the electrodes, which in turn determines the capacitance and frequency. In this work, circular electrodes with 3 mm diameter, 3 mm distance (6 mm distance center-to-center) and frequencies of some 100 MHz up to about 10 GHz are used. We expect an effective sensitivity footprint of about 5 mm diameter which is then the lateral resolution of this technique.

HL 45.66 Thu 18:30 Poster E

Triangular nanoperforation and band engineering of InGaAs quantum wells: a lithographic route towards Dirac cones in III-V semiconductors — •Christiaan Post[1], Tao Xu[2,3], Nathali Franchina Vergel[2], Yannick Lambert[2], Francois Vaurette[2], Ludovic Desplanque[2], Xavier Wallart[2], Didier Stiévenard[2], Bruno Grandidier[2], Christophe Delerue[2], and Daniel Vanmaekelbergh[1] — [1]Debye Institute for Nanomaterials Science, Utrecht, The Netherlands — [2]Institute of Electronics, Microelectronics and Nanotechnology (IEMN), Lille, France — [3]Key Laboratory of Advanced Display and System Applications, Shanghai, China

The design of two-dimensional periodic structures at the nanoscale has renewed attention for band structure engineering. In case of a nano scale honeycomb geometry, and entirely new band structure emerges in which the highest valence and lowest conduction bands become Dirac cones at the K-points, while the semiconductor quantum well band gap remains nearly unaltered.

In this research we report on the fabrication of a 10 nm thick InGaAs quantum well (QW) on a p-type InP substrate with a honeycomb symmetry structure by creating a triangular anti-lattice inside the QW using high-resolution electron beam lithography. The morphology of the samples is intensively studied, and the quality of the lattice is characterized, which is used for an extensive statistical analysis to determine the disorder inside the lattices. The results are supported by theoretical simulations on the band structure and density of states (DOS).

HL 45.67 Thu 18:30 Poster E

Reduction reflection for silicon wafer with maskless plasma etching by CHF3 and H2 — •Alena Okhorzina[1,2], Jens Hirsch[1,2], and Norbert Bernhard[1] — [1]Hochschule Anhalt, 06366, Köthen, Deutschland — [2]Fraunhofer Center for Silicon Photovoltaics CSP, Otto-Eißfeldt-Straße 12, 06120 Halle (Saale)

The main goal is the development of a basic fluorocarbon plasma etching process for the structuring of silicon surfaces and its compounds. Plasma texturing of glass surface allows getting a moth-eye surface which has a light trapping effect. This will increase the efficiency of solar modules The main problem with the use of CHF3 and H2 gases is the determination of the parameters of the etching process for the predominance of the etching over the deposition. In this work, prescanning experiments were obtained for a maskless plasma texturing of silicon by CHF3/H2 within a design of experiments. Results of this investigation were the main impact parameters of the plasma etching according to the wafer reflection. The main impact parameters are (I) the CHF3/H2 fraction, (II) the value of capacitive and inductive coupled power, and (III) the pressure in the plasma chamber. The reflection of silicon samples after CHF3/H2 plasma texturing was investigated in this work. Sample one shows a reflection of 3-5 % in the short wavelength region ($<$ 500 nm) and a reflection of 10-20 % in the long wavelength region ($>$ 500 nm). The second investigated sample shows similar results but has a reflection of approx. 20 % in the short wavelength region.