HL 92: Poster Session: II-VI Semiconductors & ZnO and related Materials

Time: Thursday 16:00–19:00 Location: Poster D

HL 92.1 Thu 16:00 Poster D

Optical spectroscopy of MBE grown $ZnSe_xTe_{1-x}$ and ZnS_xTe_{1-x} layers — •Tobias Bertram[1], Christian Karcher[1], Carsten Kruska[1], Henning Klaer[2], Sebastian Klembt[2], Carsten Kruse[2], Detlef Hommel[2], and Wolfram Heimbrodt[1] — [1]Department of Physics and Material Sciences Centre, Philipps University of Marburg, Germany — [2]Institute of Solid State Physics, University of Bremen, Germany

This study aims to produce a comprehensive understanding of the band formation processes in $ZnSe_xTe_{1-x}$ and ZnS_xTe_{1-x} semiconductor alloys. These solid solutions are known to feature large bowing parameters which cannot be explained solely by disorder as demonstrated in other II-VI systems, e.g. $ZnSe_xS_{1-x}$. This behaviour has previously been observed in II(N, VI) alloys, where it stemmed from the high differences in electronegativity and size between the substitutional N and the replaced ion. Such conditions create a strong interaction between the localized electronic states and the band structure of the host. This can be described by the band anticrossing (BAC) model, which results in a respective formation of two subbands E_- and E_+. To evaluate the applicability of this model to mixed II-VI semiconductors, e.g. the case of Se or S impurities in the ZnTe host, high quality layers grown by molecular beam epitaxy were studied using photoluminescence, photo- and electromodulated reflectance and absorption spectroscopy. These measurements reveal the emission and absorption characteristics of the systems between room temperature and 10 K.

The relevance of the BAC model will be discussed in detail.

HL 92.2 Thu 16:00 Poster D

Raman- and photoluminescence-spectroscopy studies of $CdSe_xS_{1-x}$ under hydrostatic pressure — •Markus S. Rinn, Thomas Sander, and Peter J. Klar — I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen

$CdSe_xS_{1-x}$ samples (x: 0.0 to 0.6) were studied by Raman spectroscopy at room temperature under the application of hydrostatic pressure. The spectra were recorded in backscattering geometry using a 633 nm excitation laser. The hydrostatic pressure was applied by a diamond anvil cell using the pressure induced shift of the ruby fluorescence as a pressure gauge. Furthermore, photoluminescence (PL) measurements were performed in the temperature range between 80 and 300 K. The influence of pressure and Se concentration on the Raman and PL spectra will be discussed.

HL 92.3 Thu 16:00 Poster D

Optische Beobachtung der Au-Diffusion in CdTe — •Robert Gerten, Florian Strauss, Herbert Wolf, Manfred Deicher und Thomas Wichert — Technische Physik, Universität des Saarlandes, 66123 Saarbrücken

Ortsaufgelöste Photolumineszenzmessungen (μPL) erlauben die gleichzeitige Beobachtung der Diffusion aller optisch aktiven Defekte in einem Halbleiter. In CdTe wurde mit Radiotracer-Experimenten gezeigt, dass ^{193}Au nach Implantation und Tempern unter Cd-Atmosphäre bei 800 K ein zur Probenmitte symmetrisches Uphill-Diffusionsprofil ausbildet [1]. Zur Untersuchung des zugrundeliegenden Mechanismus wurden μPL-Messungen an Te-reichen, einseitig mit Au implantierten CdTe-Kristallen durchgeführt. Nach Tempern unter den obigen Bedingungen stimmt die Form des Intensitätsprofils des mit Au-korrellierten PL-Signals sehr gut mit den Konzentrationsprofilen aus Radiotracer-Experimenten überein [1]. Die Intensitätsprofile der gleichzeitig beobachteten anderen Akzeptor- oder Donator-korrelierten Defekte stimmen mit den Beobachtungen von Horodyský et al. [2] an nominell undotiertem CdTe überein und liefern Informationen über das Diffusionsverhalten von Verunreinigungen und intrinsischen Defekten in CdTe. Diese mit der Radiotracer-Methode nicht zugänglichen Informationen bestätigen das Modell über die Entstehung solcher Konzentrationsprofile [1] und zeigen, dass diese Verunreinigungen ebenfalls entgegen ihres Konzentrationsgradienten diffundieren.

[1] H. Wolf *et al.*, Phys. Status Solidi B **247** (2010) 1405
[2] P. Horodyský *et al.*, Phys. Status Solidi C **2** (2005) 1189

HL 92.4 Thu 16:00 Poster D

Ground state properties, excitation spectra and formation energies for the mercury chalcolgenide HgS, mercury chloride Hg2Cl2 and sulfochloride mineral Hg3S2Cl2 — •Fabiana Da Pieve[1], Dirk Lamoen[1], Johan Verbeeck[1], Koen Janssens[2], and Gustav Van Tendeloo[1] — [1]EMAT, Physics, Department, University of Antwerp, Groenenborgerlaan 171, B-2020 Antwerp, Belgium — [2]XMBA, Chemistry Department, University of Antwerp, Campus Drie Eiken, Universiteitsplein 1, B-2610 Wilrijk, Belgium

We perform a study of stuctural, electronic properties and EELS response in the core loss region for several Hg compounds, with the aim of understanding the evolution of the red cinnabar (alpha-HgS) observed in several historical paintings. Calculations are performed within DFT-GGA and give results for the structural and electronic properties of alpha-HgS,beta-HgS,Hg2Cl2, and Hg3S2Cl2 polymorphs which are in good agreement with previous experimental and computational results. The electron energy loss spectra at the Cl and S K edge of the different compounds and an analysis based on energies of formation gives new insights into the darkening process.

HL 92.5 Thu 16:00 Poster D

Connecting ZnO nanowires for light emitting devices. — •Yaser Haj Hmeidi, Rapheal Niepelt, Martin Gnauck, Frank Schmidl, and Carsten Ronning — Institut für Festkörperphysik, Universität Jena, Max-Wien-Platz 1, 07743 Jena

ZnO nanowires can be easily grown via vapor-liquid-solid (VLS) mechanism and are suitable for optoelectronic applications. Furthermore, they have an emission wavelength in the UV region. We developed a simple and powerful approach on basis of spin-on-glass SiO2 [1]. This approach is intrinsically scalable since every step involved can be carried out in parallel over an entire wafer. The challenge in this particular geometry is the fabrication of top metallic contacts to the nanowires in a way that the contact dose not short. In this presentation, we will demonstrate how this approach can be utilized for assembling ZnO nanowires devices. These light emitting devices are based on p-n heterostructure between ZnO nanowires and highly doped substrate. The obtaining devices show rectifying properties and under certain conditions, also light emission.

HL 92.6 Thu 16:00 Poster D

Persistent Ion Beam Induced Conduction in Zinc Oxide Nanowires — •Andreas Johannes, Raphael Niepelt, Martin Gnauck, and Carsten Ronning — FSU Jena, Max-Wien-Platz 1, Jena, Deutschland

Ion implantation gives access to adjustable doping of semiconductor nanowires. However, in several cases not all of the implanted doping species are in fact contributing to the doping level, even after annealing. Additionally, ion implantation is also known to induce radiation damage that can also affect the electrical properties of the nanowires. As a predictable and reliable doping method is of huge necessity for a further integration of nanowires into technology, interest is directed to a closer investigation of implantation induced effects inside nanostructures. In this work, we report persistently increased conduction in ZnO nanowires irradiated by ion beam with various ion energies and species. This effect is shown to be related to the already known Persistent Photo Conduction (PPC) in ZnO and dubbed Persistent Ion beam induced Conduction (PIC). Both effects show similar excitation efficiency, decay rates and chemical sensitivity. PIC will potentially allow countable (i.e. single dopant) implantation in ZnO nanostructures and other materials showing PPC.

HL 92.7 Thu 16:00 Poster D

Microstructures and photoluminescence properties of one-dimensional ZnO nanostructures — •Peter Hess[1], Yong Lei[1,2], Martin Peterlechner[1], and Gerhard Wilde[1] — [1]Inst. f. Materialphysik, WWU Münster — [2]Inst. f. Physik & IMN (ZIK) MacroNano, TU Ilmenau

One-dimensional (1-D) ZnO nanostructures were systematically investigated concerning their microstructures and their photoluminescence properties. The main focus of this work is on the assembly of nanowires of different shapes and sizes by a CVD process to investigate their properties. For the Chemical Vapour Deposition (CVD) system ZnO/C mixtures was used as sources, Au-coated silicon or sapphire as substrates, and an argon and oxygen gas flow as a distributor and oxi-

dation source. Depending on the growth conditions during the CVD process, different kinds of 1D and 2D ZnO nanostructures were obtained. The morphology of the ZnO nanostructures was checked by SEM and the photoluminescence properties were investigated using a spectrometer. Additionally, the crystalline structures, the growth direction, and the lattice spacing of ZnO nanostructures were characterized using TEM. Also the effects of different annealing temperatures and durations on the green band photoluminescence were investigated.

HL 92.8 Thu 16:00 Poster D

Micro-patterned, hydrothermally grown ZnO nanowire arrays for light-emitting devices — •Jonas Conradt[1,2], Marco Braun[1,2], Mario Hauser[1,2], Julian Fischer[3], Torsten Beck[1,2], Janos Sartor[1,2], and Heinz Kalt[1,2] — [1]Karlsruhe Institute of Technology (KIT), Institute for Applied Physics (AP), Karlsruhe, Germany — [2]Karlsruhe Institute of Technology (KIT), Center for Functional Nanostructures (CFN), Karlsruhe, Germany — [3]Karlsruhe Institute of Technology (KIT), Institut für Angewandte Materialien, Karlsruhe, Germany

Hydrothermal, aqueous synthesis represents a simple and low-cost method easily adaptable to industrial scale for the synthesis of ZnO nanostructures on various substrates, including flexible polymer foils, inorganic semiconductors and organic layers. We report on a micropatterning technique for hydrothermally grown ZnO nanowire arrays using a femtoliter droplet spotter. By selectively depositing ZnO nanocrystals, which act as nuclei during the latter growth of the wires, almost arbitrary patterns can be plotted using the nanowires, with a dot size of less than $20\,\mu m$. Blue light-emitting diodes, based on micro-patterned ZnO nanowire arrays grown on p-doped GaN, are built, characterized and discussed.

HL 92.9 Thu 16:00 Poster D

Ab initio study of ZnO dual doping with Ag and N acceptors in the presence of H — Oksana Volnianska and •Piotr Boguslawski — Institute of Physics PAS, al. Lotnikow 32/46, 02-668 Warsaw, Poland

In spite of considerable recent effort in the last years, stable and efficient p-doping of ZnO is not satisfactorily solved yet. Recently, good results were obtained by using Ag [1] and N [2], or the dual doping with both species [3]. Here, we investigate theoretically efficiency of ZnO doping with Ag and N shallow acceptors, which substitute respectively cations and anions. First principles calculations indicate a strong tendency towards formation of nearest neighbor Ag-N pairs and N-Ag-N triangles. Binding of acceptors in driven by the formation of quasi-molecular bonds between dopants, and has a universal character in semiconductors. In the considered case, the Ag-N binding energy is higher than that of both Ag-Ag and N-N pairs, which are more distant. The pairing increases energy levels of impurities in the band gap, and thus lowers doping efficiency. In the presence of donors, pairing is weaker or even forbidden. However, hydrogen has a tendency to form clusters with Ag and N, which favors the Ag-N aggregation and lowers the acceptor levels of such complexes.

[1]. H.S. Kang et al., App. Phys. Lett. 88, 202108 (2006); E. Kaminska et al., in Proc. ICPS 2008, p.120. American Institute of Physics.

[2] J. M. Bian et al., Appl. Phys. Lett. 85, 4070 (2004); Z. P. Wei et al., Appl. Phys. Lett . 89, 102104 (2006).

[3]. A. Krtschil et al., Appl. Phys. Lett. 87, 262105 (2005).

HL 92.10 Thu 16:00 Poster D

TLM measurements of sheet and contact resistance of different ZnO layers produced by wet chemical or sputtering methods — •Julia Waltermann[1], Kay-Michael Günther[2], Stefan Kontermann[1], and Wolfgang Schade[1,2] — [1]Fraunhofer Heinrich-Hertz-Institute, Am Stollen 19B, 38640 Goslar, Germany — [2]Clausthal University of Technology, EFZN, EnergieCampus, Am Stollen 19B, 38640 Goslar, Germany

Within the last few decades zinc oxide emerged as a new material for wide band gap optoelectronic devices. In photovoltaics, ZnO is tested as a transparent electrode or as part of the heterojunction to improve the open circuit voltage. In any case the understanding and control of the electric contacts to ZnO are imperative to realize high performance devices. Considerable studies about metal contacts on crystalline ZnO were published during the last decade. Nevertheless, from an economic point of view low-quality ZnO layers, made by wet chemical or sputtering methods, are still interesting and their contacting has not been investigated in detail. In this work we compare different sputtered or sol gel produced ZnO-layers regarding their sheet and contact resistances to different metals using the transmission line method (TLM). First results show that wet chemical ZnO layers possess a very high sheet resistance due to the large number of grain boundaries. Moreover, even metal contacts like Ti/Au, which were reported to form an ohmic contact to ZnO, show a Schottky like behavior in the IV-characteristics.

HL 92.11 Thu 16:00 Poster D

Nonlinear magneto-optical study of excitons in ZnO — •Marco Lafrentz[1], David Brunne[1], Benjamin Kaminski[1], Victor V. Pavlov[2], Roman V. Pisarev[2], Dmitri R. Yakovlev[1,2], Dietmer Fröhlich[1], and Manfred Bayer[1] — [1]Experimentelle Physik 2, Technische Universitaet Dortmund, D-44221 Dortmund, Germany — [2]Ioffe Physico-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia

We show that application of magnetic field causes in bulk wurtzite ZnO the optical second-harmonic generation (SHG) at energies of $2s/2p(A/B)$-excitons in the Voigt geometry for $\mathbf{B} \perp \mathbf{k} \parallel [0001]$, where SHG should be forbidden in the electric-dipole (ED) approximation. Investigations of magnetic- and electric field, temperature and azimuthal dependencies of SHG intensity allow us to deduce that this phenomenon arises from the higher order magnetic field perturbation known as magneto-Stark effect for excitons. This pertubation transforms like an effective electric field and leads to admixture of exciton wave functions of different parity and thus to resonant SHG enhancement.

HL 92.12 Thu 16:00 Poster D

Designing a dense blocking layer of electrochemically grown zinc oxide for hybrid solar cell applications — •Thilo Richter, Miriam Schwarz, and Veit Wagner — School of Engineering and Science, Jacobs University Bremen, Campus Ring 1, 28759 Bremen, Germany

Electrochemical deposition of zinc oxide (ZnO) provides a low temperature, cost effective approach to designing crystalline, inorganic scaffolds in hybrid photovoltaics. In this context, a blocking layer between the p-type semiconductor and the anode is generally desired to prevent shunting in photovoltaic devices. We show that generating such a dense blocking layer during electrochemical growth of ZnO is not simply achievable by adjusting the main deposition parameters such as temperature, electrolyte concentration or voltage. Though, we demonstrate that the application of voltage variation during electrocrystallization is a possible way of controlling the ZnO growth. Dense blocking layers are possible if proper voltage variations are applied. Theoretical modeling of the results is presented based on solving the field diffusion equation of the relevant ions.

HL 92.13 Thu 16:00 Poster D

Anisotropic dielectric properties of MgZnO in the energy range from 2 to 25 eV — •Maciej D. Neumann[1], Christoph Cobet[1], Norbert Esser[1], and Rüdiger Goldhahn[2] — [1]Leibniz-Institut für Analytische Wissenschaften – ISAS – e.V., 12489 Berlin, Germany — [2]Otto-von-Guericke-Universität Magdeburg, 39106 Magdeburg, Germany

An accurate determination of the complex dielectric function (DF) of MgZnO is of great interest for the fundamental understanding of its electronic properties and is a key to optimize optoelectronic devices. Especially in the band gap region the DF is strongly affected by coulomb interaction and the polar character of the material. Even at room temperature this leads to characteristic features connected to free excitons and exciton-phonon complexes (EPC).

Using a home-made VUV ellipsometer at the Berlin synchrotron radiation facility BESSY II, nonpolar MgZnO samples were investigated with very high spectral resolution at temperatures between 10 and 300 K and photon energies ranging from 2 to 25 eV. We present the ordinary and extra ordinary DFs of the dielectric tensor obtained by employing an anisotropic model. The results are in remarkable agreement to novel *ab-initio* calculations and confirm the importance of excitonic effects in the entire VUV DF of MgZnO. The high resolution of around 0.5 meV allows us to extract all free band gap excitons ($n = 1$ and $n = 2$) and to elucidate the fine structure of the accompanying EPC.

HL 92.14 Thu 16:00 Poster D

Polarisation dependence of UV Raman scattering in ZnO — •Christian Kranert, Rüdiger Schmidt-Grund, and Mar-

ius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Semiconductor Physics Group, Leipzig, Germany

The usage of UV lasers for the excitation of Raman scattering in wide-bandgap semiconductors has become popular in recent times. This is mainly due to the fact that their light is strongly absorbed in the material allowing for a higher depth (and lateral) resolution which is particularly attractive for micro- and nanosized samples. However, there is a lack of basic research in this field which we show to be essential for a correct interpretation of the acquired spectra.

We present polarisation dependent Raman scattering spectra of bulk ZnO excited by the 325 nm line of a HeCd laser. These are dominated by peaks attributed to "forbidden" (=Fröhlich interaction induced, exciton mediated) scattering from longitudinal optical (LO) phonons. In contradiction to commonly made assumptions, the spectral position as well as lineshape and relative intensity of these peaks show a clear dependence on the applied polarisation configuration, i.e. polarisation of the scattered light relative to the incident light and polarisation of the incident light relative to the *c*-axis, respectively. A discussion on the observed effects will be given.

HL 92.15 Thu 16:00 Poster D

ZnO-based planar and nanowire heterostructures emitting in the visible spectral range — •Martin Lange, Christof P. Dietrich, Michael Lorenz und Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, D-04103 Leipzig, Germany

The rising complexity and efficiency of optoelectronic devices is based on heterostructures and therefore band gap engineering is essential. A reduction of the ZnO bandgap is possible when Cd is incorporated [1] whereas a larger bandgap is obtained for MgZnO. By applying a low substrate temperature of $\approx 300°$C the ZnCdO related luminescence can be tuned down to energies of 2.5 eV for samples grown by puled-laser deposition [2].

By combining ZnCdO with ZnO or MgZnO the fabrication of quantum well (QW) heterostructures is possible. In such structures the QW-related emission energy can be tuned between the ZnCdO and the ZnO or MgZnO emission energy, by changing the QW-thickness only. For ZnCdO/MgZnO heterostructures the accessible spectral range is larger due to the larger bandgap in comparison to ZnO. An additional advantage is a reduced lattice mismatch for this combination due to an increasing *a*-lattice constant with increasing Cd/Mg-content for both alloys. In this regard, ZnCdO/ZnO and ZnCdO/MgZnO planar and nanowire heterostructures were fabricated. We report on the study of their luminescence properties.

[1] S. Sadofev *et al.*, Appl. Phys. Lett. **89**, 201907 (2010)
[2] M. Lange *et al.*, Phys. Status Solidi RRL, 10.1002/pssr.201105489

HL 92.16 Thu 16:00 Poster D

Tungsten trioxide as high-κ gate dielectric for highly transparent and temperature-stable zinc-oxide-based thin-film transistors — •Michael Lorenz, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig

We demonstrate metal-insulator-semiconductor field-effect transistors with high-κ, room-temperature deposited, highly transparent tungsten trioxide (WO_3) as gate dielectric [1]. The channel material consists of a zinc oxide (ZnO) thin-film. The transmittance and resistivity of WO_3 films was tuned in order to obtain a highly transparent and insulating WO_3 dielectric. The devices were processed by standard photolithography using lift-off technique. On top of the WO_3 dielectric a highly transparent and conductive oxide consisting of ZnO: Al 3% wt. was deposited. The gate structure of the devices exhibits an average transmittance in the visible spectral range of 86%. The on/off-current ratio is larger than 10^8 with off- and gate leakage-currents below 3×10^{-8} A/cm^2. Due to the high relative permittivity of $\varepsilon_r \approx 70$, a gate voltage sweep of only 2 V is necessary to turn the transistor on and off with a minimum subthreshold swing of 80 mV/decade. The channel mobility of the transistors equals the Hall-effect mobility with a value of 5 cm^2/Vs. It is furthermore shown, that the devices are stable up to operating temperatures of at least 150°C.

[1] M. Lorenz, H. von Wenckstern, M. Grundman, Adv. Mater. 2011, doi: 10.1002/adma.201103087

HL 92.17 Thu 16:00 Poster D

Microscopic identification of hot spots in multi-barrier Schottky contacts on pulsed laser deposition grown zinc oxide thin films — •Stefan Müller[1], Holger von Wenckstern[1], Otwin Breitenstein[2], Jörg Lenzner[1], and Marius Grundmann[1] — [1]Universität Leipzig, Semiconductor Physics Group, Institut für Experimentelle Physik II, Leipzig, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik Weinberg 2, 06120 Halle, Germany

We report on investigations of Schottky contacts (SC) on ZnO thin films that exhibit spatially discrete variations of the barrier height. For this study we used nominally undoped ZnO thin films grown on a ZnO:Al buffer on a-plane sapphire substrates by pulsed-laser deposition. On the nominally undoped layer circular Pd(Au)O_y/ZnO-SC were fabricated by reactive dc-sputtering. The areas of the SCs are in the range from $1.8 - 44 \times 10^{-4}$ cm^2. About 50% of the prepared SCs exhibit one or more kinks in the room temperature IV-characteristic being a clear indication for the existence of at least two different barrier heights. The characteristics were modelled by assuming a parallel connection of a respective number of individual diodes individual diodes. Using dark lock-in thermography low-barrier patches were visualized for small forward currents. Current transport at low forward voltages for low temperatures is primarily through these patches. The origin of the local decrease of barrier height was traced by energy dispersive X-ray spectroscopy on a cross section prepared by focused ion beam and is due to aluminium oxide particles in the buffer layer[1].

[1] S.Müller *et al.*, IEEE Transaction on Electron Devices, in press.

HL 92.18 Thu 16:00 Poster D

Wavelength selective photodetectors based on (Mg,Zn)O-heterostructures — •Zhipeng Zhang, Holger von Wenckstern, Matthias Schmidt, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstraße 5, 04103, Leipzig

We report on ultraviolet metal-semiconductor-metal (MSM) photodetectors based on $Mg_yZn_{1-y}O/Mg_xZn_{1-x}O$ heterostructures ($0 < y < x \leq 0.5$, wurtzite modification) allowing to design wavelength selective detectors with narrow bandwidth [1]. The $Mg_xZn_{1-x}O$ thin film acts as optical edge filter and the $Mg_yZn_{1-y}O$ layer is the active layer of the devices. Therefore, ideally only light in a defined photon energy range of $E_g^y < E_{ph} < E_g^x$ contributes to the photoresponse. The spectral bandwidth is given by the bandgap difference ΔE_g of the two (Mg,Zn)O layers. The interdigital MSM-electrodes were fabricated by photolithography and reactive dc-sputtering of palladium (Pd) with an additional metallic Pd-capping layer [2]. A FWHM of only 7 nm was achieved for a photodetector operating around 3.4 eV and the center of band was shifted by using different $y : x$-combinations between 370 and 325 nm. A maximum spectral photoresponse of about 1.8 A/W was achieved. An internal gain mechanism in the device was observed and is attributed to trapping of minority carriers at PdO_z/(Mg,Zn)O-interface [3].

[1]: Z. Zhang et al., Appl. Phys. Lett. **99**, 083502 (2011)
[2]: A. Lajn et al., J. Vac. Sci. Technol. B, **27**, 1769 (2009)
[3]: O. Katz et al., Appl. Phys. Lett. **84**, 4092 (2004)

HL 92.19 Thu 16:00 Poster D

ZnO-$ZnCo_2O_4$-diodes — •Markus Winter, Friedrich Schein, Holger von Wenckstern und Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany

The wide band gap semiconductor ZnO is a promising material for UV optoelectronic applications, photodetectors, front contacts of solar cells or transparent electronics. However, the growth of high quality *p*-type ZnO remains challenging. Therefore we investigated $ZnCo_2O_4$ as a suitable *p*-conducting oxide and fabricated semitransparent *pn*-diodes with *n*-ZnO.

The samples were grown by pulsed-laser deposition on *a*-plane sapphire substrates. We deposited ZnO:Al and ZnO at 680 °C and then amorphous $ZnCo_2O_4$ at room temperature, followed by dc-sputtered Au as ohmic contact. Transmittance of the ZnO/$ZnCo_2O_4$ layer structure is about 60%. The *pn*-diodes exhibit current on/off ratios (± 2 V) up to 10^{10} and typically in the range of 10^7. Temperature-dependent current voltage measurements will be discussed. The spectral dependence of the photocurrent was determined and it was found that photocurrent is generated primarily in the ZnO-layer.

HL 92.20 Thu 16:00 Poster D

The 3.06 eV-Donor-Acceptor-Pair Recombination in homoepitaxial grown ammonia doped ZnO — •Melanie Pinnisch[1], Sebastian Eisermann[1], Markus R. Wagner[2], Christian Nenstiel[2], Matthew Phillips[2], Detlev M. Hofmann[1], and

Bruno K. Meyer[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 16, D-35392 Giessen — [2]UT Sidney, Institute for Nanoscale Technology, PO Box 123, Broadway NSW 2007, Australia

In ammonia doped ZnO films grown, between sample temperatures of 350 °C and 400 °C, by chemical vapour deposition (CVD), two donor-acceptor-pair recombinations (DAP) were observed in steady state photoluminescence (PL) experiments. One is the well known DAP-band with its zero-phonon-line (ZPL) at 3.24 eV [1], and additionally a second DAP-band with the ZPL-position at 3.03 eV. This DAP-band shows a similar LO-phonon coupling (Huang-Rhys factor) as the 3.24 eV DAP-band, but its intensity decreases much faster with increasing measurement-temperature. A deep PL-band at 3.03 eV was only detected in films grown on non-polar substrates, and is absence in samples grown on c-plane ZnO-substrates. Cathodoluminescence (CL) and Raman experiments were performed to get more insight in the complex recombination behaviour of the samples.

[1] S. Lautenschlaeger et al., PSS B, 1-5 (2011)

HL 92.21 Thu 16:00 Poster D

Characterization and fabrication of ZnO/GaN heterostructures — •Julian Benz, Achim Kronenberger, Sebastian Eisermann, Stefan Lautenschläger, Torsten Henning, Bruno K. Meyer, and Peter J. Klar — I. Physikalisches Institut, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, 35392 Gießen

Zinc oxide (ZnO) is a n-type semiconductor with a wide direct band gap of 3.37 eV. The abundance of the resources zinc and oxygen make it a promising candidate for the development of sustainable optoelectronic devices in the UV spectral range. A reproducible way of p-type doping ZnO has not been reported yet. A possible approach is to replace the p-ZnO by p-GaN. We report on the fabrication of ZnO/GaN heterostructures. Thin films of ZnO can be prepared by several methods, such as sputter deposition and chemical vapor deposition. Electrical and optical characteristics of samples prepared by those methods are compared.

HL 92.22 Thu 16:00 Poster D

Structural parameters of ZnMgO from first principles and experiment — •Marcel Giar[1], Thomas Wassner[2], Bernhard Laumer[1,2], Martin Eickhoff[1], and Christian Heiliger[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität, D-35392 Giessen — [2]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, D-85748 Garching

Recent experimental research on the evolution of the lattice parameters of wurtzite ZnMgO alloys with Mg content x show that due to relaxation processes the lattice parameter a strongly depends on the film thickness. For layers with a thickness of about 300 nm grown by molecular beam epitaxy a is found to be independent of x [1] whereas for a thickness of 1 μm we find an increase in a with increasing x. We conduct cell relaxation calculations keeping the lattice parameter a fixed in the basal plane as well as complete cell relaxations and we determine the resulting a lattice parameters from an a-plane-growth modeling. All calculations are based on the LDA and a supercell approach in combination with alloy statistics to consider different alloy configurations inside the supercell.

[1] T. A. Wassner, B. Laumer, S. Maier, A. Laufer, B. K. Meyer, M. Stutzmann, M. Eickhoff, J. Appl. Phys. 105, 023505 (2009)

[2] M. Heinemann, M. Giar, C. Heiliger, Mater. Res. Soc. Symp. Proc. 1201, H05-33 (2010)

HL 92.23 Thu 16:00 Poster D

two unique photoluminescence emissions in vapor phase grown ZnO single crystals — •xi zhang, frank herklotz, and jörg weber — Institut für Angewandte Physik, Technische Universität Dresden, 01062, Dresden, Germany

Defects play a crucial role in the optical and electrical properties of wide bandgap semiconductor ZnO. We detect two unidentified defects with low temperature photoluminescence lines at 3.3643 eV (P1) and 3.3462 eV (P2) in vapor phase grown ZnO single crystals [1]. The P1 line is observed in the as-grown samples. From the position of the associated two-electron-satellite, P1 is attributed to the recombination of an exciton bound to a shallow donor with a donor binding energy of 42.2 meV. Hydrogenation of the sample by annealing in hydrogen atmosphere at 700 oC leads to the appearance of the P2 line and a reduction of the P1 line. The results of isochronal annealing series suggest a correlation between P2 and the interstitial hydrogen donor HBC, which exhibits an excitonic recombination at 3.3601 eV. The possible microscopic origins of the P1 line and P2 line will be discussed. This work was supported by the European Regional Development Fund and the Free State of Saxony. SAB project 14253/2423

[1] X. Zhang, F. Herklotz, E. Hieckmann, J. Weber, P. Schmidt, J. Vac. Sci. Technol. A 29, 03A107 (2011)

HL 92.24 Thu 16:00 Poster D

Temperaturabhängigkeit des elektrischen Feldgradienten von In in ZnO bei verschiedener Dotierung — •Philipp Krumbholz und Reiner Vianden — Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn, Bonn, Deutschland

Es wird die Temperaturabhängigkeit des elektrischen Feldgradienten (EFG) von implantiertem ^{111}In als Sonde in ZnO bei unterschiedlicher Dotierung mit der Methode der gestörten Winkelkorrelation (PAC) untersucht.

Dazu wurde einkristallines ZnO mit den Dotierungen ^{27}Al, ^{115}In (Donator), ^{87}Rb (wahrscheinlicher Akzeptor) und ^{51}V, ^{52}Cr (Ferromagnetismus) implantiert und mit ^{111}In als Sonde nachimplantiert, um durch die Ladungsträgerkonzentration den EFG zu beeinflussen. Anschließend wurde das Ausheil- und Temperaturverhalten des EFG beobachtet.

Ergebnisse werden präsentiert und mit den Ergebnissen von Sato et al. [1] verglichen.

[1] W. Sato, et al., Phys. Rev. B 78, 045319 (2008)

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Dependence of impurity incorporation on the surface termination of ZnO — •Alba Seibert[1], Andreas Laufer[1], Niklas Volbers[1], Sebastian Eisermann[1], Kay Potzger[2], Sebastian Geburt[3], Carsten Ronning[3], and Bruno K. Meyer[1] — [1]1. Physikalisches Institut, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — [3]Institut für Festkörperphysik, Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Zinc oxide (ZnO) is regarded as a promising material for optoelectronic devices, due to its electronic properties. The severe difficulties in obtaining p-type ZnO have been partially attributed to intrinsic defects and impurities that act as compensating donors. To avoid these effects, the identification and quantification of impurities is a major demand. For quantitative information using secondary ion mass spectrometry (SIMS), so-called relative sensitivity factors (RSF) are essential. We present the determined RSF values for ZnO using primary (ion implanted) as well as secondary (bulk doped) standards. These RSFs have been applied to commercially available ZnO substrates of different surface termination (a-plane, Zn-face, and O-face) to quantify the contained impurities. Although these ZnO substrates originate from the same single-crystal, we observe discrepancies in the impurity concentrations. These results cannot be attributed to surface termination dependent RSF values for ZnO.

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Spectroscopic and Morphological Studies of Zinc Oxide Sprayed Films — •Iulia G. Korodi, Falko Seidel, Daniel Bülz, Ovidiu D. Gordan, and Dietrich R. T. Zahn — Semiconductor Physics, Chemnitz University of Technology, D-09107 Chemnitz, Germany

Nowadays, one way of producing "green" energy can be achieved via photovoltaic cells. For such devices, ZnO can be used as a transparent window, or if doped as a transparent electrode material. Moreover, its transparency and wide bandgap makes it suitable for future transparent electronics. In this work, highly pure (99.995 %) zinc acetylacetonate hydrate ($Zn(acac)_2$) was used as a precursor for obtaining ZnO layers. The $Zn(acac)_2$ powder was solved in ethanol and the saturated solution was sprayed on heated silicon substrates (T = 150°C) in a glove box under nitrogen (N_2) atmosphere. Three different treatments were applied to these samples with the purpose of achieving ZnO films: flashing with a Xenon lamp (in N_2 environment immediately after spraying), illumination with a UV lamp (in ambient atmosphere) and annealing on a heating plate (in ambient atmosphere). The observed changes in the films obtained after employing the three different post-spraying treatments were investigated using Spectroscopic Ellipsometry, UV-Raman Spectroscopy, Fourier Transform Infrared Spectroscopy and Atomic Force Microscopy techniques. The investigation was performed varying the number of the applied flashes, the time during illumination, and the annealing. The results of this study will

be presented and discussed.

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Analysis of nitrogen doped ZnO via SIMS — •André Portz, Andreas Laufer, Michael Hofmann, Stefan Lautenschläger, Sebastian Eisermann, and Bruno K. Meyer — 1. Physikalisches Institut, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

During the last years the II-VI compound semiconductor zinc oxide (ZnO) has experienced a renaissance due to its interesting characteristics such as resistivity against high energy radiation, its transparency for visible light or also the possibility to achieve high crystal quality in epitaxial growth. But even more interesting seems the effort to accomplish reproducable p-conductivity by appropriate doping with group V-elements replacing oxygen in the crystal and creating the requested acceptor-level. This would form the foundation for numerous new applications in semiconductor-technology like efficient LEDs in the blue and ultraviolet spectral range. In the presented work nitrogen-doped zinc oxide (ZnO:N) was analysed using secondary ion mass spectrometry. Two series of samples were investigated. Both were homoepitaxially grown using CVD. In the first case the influx of NH_3, acting as nitrogen source, was varied. In the second case the substrate temperature was changed. The resulting nitrogen concentrations were determined and consequences are discussed.