HL 14 II-VI semiconductors I

Time: Tuesday 11:00–13:15 Room: POT 151

HL 14.1 Tue 11:00 POT 151

Magnetic field studies of bound exciton complexes in Lithium doped ZnO — •Rob McKenna[1,2], Markus R. Wagner[1], Axel Hoffmann[1], Joachim Sann[3], Stefan Lautenschläger[3], and Bruno K. Meyer[3] — [1]Intitute for Solid State Physics, Technical University Berlin — [2]University of Technology Sydney — [3]I. Physics Institute, Justus Liebig University Giessen

Lithium located at the Zn site in the ZnO matrix could be a valid acceptor for p-conduction. Our magneto-PL and -PT investigation of a Lithium doped ZnO film on a ZnO substrate found I_6 to I_8, as well as I_0 and I_1 bound exciton complexes, with the smallest FWHM of 80 μm. Zeeman-splitting of peaks up to 580 μeV at 5 T, produced electron g-values in good agreement with previous publications. An additional splitting of peaks in magnetic fields stronger than 3 T, was also clearly apparent. A non-zero an-isotropic hole effective g-value for $B \perp c$ is discussed as the possible origin of the observed splitting. The neutral or ionised nature of the I_0 and I_1 bound exciton complexes in the magnetic field was also further clarified and the appearance of a new peak on the lower energy side of the I_1 peak, indicating zero-field-splitting, was also investigated. In addition to this, the forbidden exciton could be observed. Temperature dependent measurements were employed to investigate the donor or acceptor character of the bound exciton complexes and angular and polarisation dependent measurements clarify whether the involved holes originate from a valence band with Γ_7 or Γ_9 symmetry.

HL 14.2 Tue 11:15 POT 151

Photoluminescence properties of $Mg_xZn_{1-x}O$ thin films grown by pulsed laser deposition — •Susanne Heitsch, Gregor Zimmermann, Holger Hochmuth, Daniel Spemann, Gabriele Benndorf, Heidemarie Schmidt, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, D-04103 Leipzig, Germany

$Mg_xZn_{1-x}O$ thin films ($0 \leq x \leq 0.18$) have been grown on a-plane sapphire substrates with or without ZnO buffer layers by pulsed laser deposition. The Mg content in the films was controlled by using different MgZnO targets and by applying different oxygen partial pressures $p(O_2)$ during the deposition, respectively. Higher oxygen partial pressures caused a lower Mg content in the thin films. The surface roughness measured by AFM shows no dependence on x, but on $p(O_2)$. A minimum could be found for samples grown at $p(O_2) \sim 1 \times 10^{-3}$ mbar. Samples with equal x grown at lower oxygen partial pressures show a broader photoluminescence (PL) emission than samples grown at higher pressures. With increasing x the PL maximum shifts approximately linearly to higher energies and the emission exhibits a broadening not only due to alloy broadening. The blueshift of the PL peak position on x is found to be larger at room temperature than at 2 K. Deposition of the $Mg_xZn_{1-x}O$ thin films on ZnO buffer layers improves the surface quality as well as the half width of the emission.

HL 14.3 Tue 11:30 POT 151

Excitonic-recombination dynamics of individual ZnO nanowires — •Lars Wischmeier, Tobias Voss, Ilja Rückmann, and Jürgen Gutowski — Institute of Solid State Physics, University of Bremen, P.O. Box 330440, D-28334 Bremen

Zincoxide (ZnO) nanowires show near band-edge photoluminescence (PL) in the UV spectral region ($E_{gap} = 3.37\ eV$ at room temperature) and have therefore recently attracted many research activities because they are considered to be promising building blocks for nanometer-scale optoelectronic devices. Here the optical properties of individual nanowires with diameters $< 200\ nm$ prepared from an as-grown ensemble are analyzed.
The PL of ZnO is composed of various near band-edge emissions which are accompanied by phonon-assisted recombinations. These different emissions of an individual nanowire are measured time-resolved by a combination of a micro-photoluminescence setup and the time-correlated single-photon counting technique. The temporal development of the PL is studied as a function of intensity, temperature, and size of the wires. From the experimental results the decay times are determined. The results are analyzed by use of rate equations to model the excitonic recombination processes.
Additionally the results performed on an individual nanowire are compared to the results performed on the as-grown nanowire ensemble.

HL 14.4 Tue 11:45 POT 151

Optical and microelectrical characterization of ZnO single crystals implanted with group V elements — •Matthias Brandt[1], Holger von Wenckstern[1], Gabriele Benndorf[1], Jörg Lenzner[1], Heidemarie Schmidt[1], Michael Lorenz[1], Marius Grundmann[1], Gabriel Braunstein[2], and Gerhard Brauer[3] — [1]Universität Leipzig, Institut für Experimentelle Physik II, Leipzig, Germany — [2]University of Central Florida, Department of Physics, Orlando, Florida, USA — [3]Institut für Ionenstrahlphysik und Materialforschung, FZ Rossendorf, Dresden, Germany

We have implanted ZnO single crystals produced by pressurized melt growth with nitrogen, phosphorous and arsenic ions, as well as with argon. The samples have been annealed at temperatures ranging from 300 to 1000°C in an oxygen atmosphere for 45 minutes or in air for 60 minutes. They were characterized optically by cathodoluminescence and photoluminescence measurements and electrically by scanning capacitance microscopy and scanning surface potential microscopy. Results have been compared to the properties of as-grown samples. We find a strong dependence on a) the implanted species and b) the annealing temperature. An intense donor-acceptor pair transition was observed in luminescence of N-implanted crystals annealed at 700°C only. Strong indication for a p-type conductivity surface layer was found for P-implanted ZnO annealed at 700°C.

HL 14.5 Tue 12:00 POT 151

Deep defects generated in n-conducting ZnO:TM thin films — •Heidemarie Schmidt, Mariana Diaconu, Holger Hochmuth, Michael Lorenz, Holgerr von Wenckstern, Gisela Biehne, Daniel Spemann, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstrasse 5, D-04103 Leipzig, Germany

The ferromagnetism in highly transparent and intrinsically n-type conducting zinc oxide doped with 3d transition metals (TM), is predicted to be defect mediated. We investigate the generation of deep defects in n-conducting 1 μm thick ZnO:TM films (TM=Co, Mn, Ti) with a nominal TM content of 0.02, 0.20 and 2.00 at% grown by pulsed laser deposition on a-plane sapphire substrates using deep level transient spectroscopy. We find that a defect level is generated, independent of the TM content, located 0.31 eV and 0.27 eV below the conduction band minimum of ZnO:Mn and ZnO:Ti, respectively. Different defect levels are generated in dependence on the Co content in ZnO:Co. The undoped ZnO reference sample reveals the well-known E1, E3 and Eα1 [1] defect level. This work shows that an optimization of defect-related ferromagnetism in n-conducting ZnO:TM thin films will only be possible if the preparation sensitive formation of deep defects is controlled in the same time.
[1] F. D. Auret et al., Appl. Phys. Lett. 80 (2002) 1340 and F. D. Auret et al., phys. stat. sol. (c) 1 (2004) 674.

HL 14.6 Tue 12:15 POT 151

Resonantly and Non-Resonantly Excited Bound Excitons in ZnO Epilayers — •Frank Bertram, Sören Giemsch, Jürgen Christen, Armin Dadgar, and Alois Krost — Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany

The photoluminescence (PL) spectrum of ZnO exhibits a rich excitonic structure in the near bandgap region at 4K. A 8 μm thick ZnO epi-layer MOVPE grown on a GaN / sapphire template was investigated. The non-resonant PL spectrum is dominated by the impurity bound exciton I_8 and exhibits further individual BE lines (I_1, I_2, I_6, I_9), the TES-lines of I_8 and I_9 as well as the LO phonon replica exclusively from I_8. Under resonant excitation, i.e. $E_{excitation} = E(I_8)$ the TES-I8 line and the I_8-LO line are much more intense and reveal a smaller line width. Under excitation at the spectral position of I_9 the optical features associated with I_8 completely disappear, while TES-I_9 increases and I_9-LO shows up. Resonantly excited time-resolved PL yields a mono-exponential decay with lifetimes $\tau(I_8)$=270 ps and $\tau(I_9)$=280ps, respectively, - distinctively different from the lifetimes obtained for non-resonant excitation. Measuring the decay lifetime as a function of tuned laser photon energy, both, I_8 and I_9 reveals a clear resonance, i.e. drop in time constant (< 200 ps), for E_{laser}-E_{BE}=5 meV. This corresponds to the A-B-valence band splitting and indicates strong scattering into the B-valence band.

HL 14.7 Tue 12:30 POT 151

Mid-infrared photocurrent spectroscopy of thin ZnO films — •H. Frenzel, A. Weber, H. v. Wenckstern, G. Biehne, H. Hochmuth, M. Lorenz, and M. Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany

We investigate mid-infrared photocurrent properties of thin ZnO films in a temperature range from 4 K to 300 K. The films were grown by pulsed laser deposition on *a*-plane sapphire substrates with substrate temperatures varying from 550°C to 800°C and oxygen partial pressures between 10^{-3} to 0.1 mbar [1]. High-quality Pd/ZnO Schottky diodes were realized by thermal evaporation of Pd on the Zn-face of the *c*-oriented thin films. The ideality factors of the diodes were characterized with Current–Voltage (*I–U*) measurements.

The optical absorption by shallow impurity traps in the ZnO space charge region of the diodes is studied with Fourier transform infrared photocurrent spectroscopy. The results are compared to non-optical techniques like deep level transient spectroscopy [2].

[1] E. M. Kaidashev, et al., Appl. Phys. Lett. **82**, 3901 (2003).
[2] M. Grundmann, et al.: in *Zinc Oxide – A Material for Micro- and Optoelectronic Applications* (eds.: N. H. Nickel and E. Terukov), 47–57, Springer (2005).

HL 14.8 Tue 12:45 POT 151

ZnO nanorods as laser emitters — •Robert Hauschild[1], Holger Lange[1], Alexander Urban[1], Hongjin Fan[2], Margit Zacharias[2], Claus Klingshirn[1], and Heinz Kalt[1] — [1]Universität Karlsruhe, Karlsruhe, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany

By means of time resolved spectroscopy and numerical calculations we evaluate different ZnO nanorods samples with respect to their suitability as stimulated emitters. The influence of diameter and length on the field enhancement inside the nanorods is studied numerically by solving the scalar Helmholtz equation in 3D. According to our simulations the interface nanorod/substrate is mainly responsible for the low Q value of the nanorod resonators. In one sample a variation in VLS growth results in gold nanoparticles being present at the bottom of nanorods. This layer enhances the resonator properties of the nanorods due to the larger reflectivity. The better mode confinement in these nanorods is also confirmed by the finite element analysis. Consequently, laser emission from single rods of this sample is evidenced up to 150 K.

HL 14.9 Tue 13:00 POT 151

Thickness dependent magnetoresistance of ZnCoO:Al thin films — •Qingyu Xu, Lars Hartmann, Heidemarie Schmidt, Holger Hochmuth, Michael Lorenz, Rüdiger Schmidt-Grund, Daniel Spemann, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstrasse 5, D-04103 Leipzig, Germany

$Zn_{0.90}Co_{0.10}O$ films doped with 0.5 at% Al of different thickness (689 nm, 408 nm, 355 nm) were prepared by pulsed laser deposition (PLD) on a-plane sapphire substrates. The room temperature electron concentration and mobility increase from $2 \times 10^{18} cm^{-3}$ and 12 $cm^2V^{-1}s^{-1}$ to $2 \times 10^{19} cm^{-3}$ and 36 $cm^2V^{-1}s^{-1}$ with increasing film thickness, respectively. Magnetoresistance (MR) effects were measured in the temperature range from 5 K to 290 K. At low temperature, the positive MR increases with decreasing film thickness. With increasing temperature, the MR of the thicker film will change to negative, while positive MR was still observed for the 355 nm thick film at room temperature. Anomalous Hall effect (AHE) provides information about the Co-generated internal field experienced by itinerant carriers. AHE was observed in the 355 nm thick film at 20 K, indicating possible intrinsic ferromagnetism in $Zn_{0.90}Co_{0.10}O$. The observed thickness dependence of the MR suggests that structural defects may play an important role in the ferromagnetism of ZnCoO:Al thin films.