HL 40: ZnO: preparation and characterization III

Time: Thursday 9:30–12:45 Location: BEY 118

HL 40.1 Thu 9:30 BEY 118

Experimental and numerical analysis of the waveguiding properties of ZnO nanowires — •Dongchao Hou, Jan-Peter Richters, and Tobias Voss — Institute of Solid State Physics, University of Bremen, P.O. Box 330440, D-28334 Bremen

Tapered silica fibers can be used as convenient and robust tools to couple external laser light into the waveguide modes of semiconductor nanowires. This coupling technique allows for a systematic study of the low- and high-order mode profile supported by the nanowire as well as of coupling processes between different nanowires. Using a simple flame-heated fiber-pulling method, we fabricated tapered silica fibers from standard multi-mode silica optical fibers with diameters down to below 1 micron. Optical microscopy showed that the fabricated fibers possess a high diameter uniformity and surface smoothness. With such tapered fibers, we coupled light into single ZnO nanowires and observed their waveguiding losses for different alignments between the silica fiber and the ZnO nanowires. We numerically simulated the experimentally observed waveguide properties of the nanowires using the finite-difference time-domain (FDTD) method. The dependence of the coupling efficiency on the diameters, the overlap length and separation was investigated. We found a maximum coupling efficiency of up to 0.8 for silica and ZnO nanowires with typical diameters used in experiment. The results show that silica tapered fibers are well suited to study the waveguiding properties of semiconductor nanowires which are of importance for the design and optimization of nanowires lasers, sub-wavelength waveguides and sensors.

HL 40.2 Thu 9:45 BEY 118

Investigations of ZnO/$Zn_{1-x}Cd_xO$ double heterostructures grown by pulsed laser deposition — •Martin Lange, Jan Zippel, Gabriele Benndorf, Christian Czekalla, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, D-04103 Leipzig, Germany

ZnO/$Zn_{1-x}Cd_xO$ double heterostructures have been grown on a-plane sapphire substrates by pulsed laser deposition. The oxygen partial pressure and the substrate temperature was varied to fabricate samples with high cadmium content and hence smaller bandgap energy than ZnO but though high luminescence yield.

The samples have been studied with temperature dependent photoluminescence in the temperature range from 2 to 295 K. A S-shape behaviour for the peak energy of the $Zn_{1-x}Cd_xO$-luminescence was observed and the standard derivation of the potential σ was estimated with a fit of this S-shape. A large number of phonon replicas indicate localization of excitons. With the help of the Huang-Rhys factor and the fraction of strongly localized excitons the depth of the localization potentials was estimated in good agreement with σ. Using the intensity of the $Zn_{1-x}Cd_xO$-luminescence as function of the temperature the thermal activation energy of non-radiative processes has been determined.

HL 40.3 Thu 10:00 BEY 118

Investigation of ZnO electronic properties by optical deep level transient spectroscopy — •Martin Ellguth, Matthias Schmidt, Rainer Pickenhain, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, 04103 Leipzig, Germany

Since ZnO is a promising material for future transparent electronic and opto - electronic devices, a classification of defects according to their optical absorption is necessary. We investigated electronic properties of impurities typically present in ZnO with special regard to the photo cross - section as a fundamental property of a defect. The prominent defects E1, E3, E4 and a presently not reported trap E200 with binding energy of approx. 200 meV were detected by deep level transient spectroscopy (DLTS) measurements. Optical DLTS measurements (ODLTS) were conducted and a measurable signal was achieved for E4 and E200. The photo cross - section of these traps was then calculated from the wavelength dependent optical emission rate obtained from the ODLTS signal. Furthermore, the presence of defect states far from the conduction band edge and therefore undetectable by any thermal capacitance spectroscopic methods has been inferred from the detection of the optically excited emission which some of these defects exhibit.

HL 40.4 Thu 10:15 BEY 118

The 3.367eV band in ZnO — •Martin Feneberg, Anton Reiser, Christian M. Krauss, Rolf Sauer, and Klaus Thonke — Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm

Low temperature photoluminescence experiments in ZnO show frequently a band at 3.367eV, which is broad and overlaps with the sharp bound exciton lines. This feature has been explained as being due to so-called surface excitons, e.g. excitons bound to defects that are located close to the surface of the semiconductor. Here, we show that an excitonic origin of the 3.367eV band is unlikely and instead give an explanation in terms of donor-to-surface acceptor transitions consistent with data reported in the literature.

15 min. break

HL 40.5 Thu 10:45 BEY 118

Strukturelle Charakterisierung der Donator-Akzeptor-Kodotierung von ZnO — •Muhammed Türker, Peter Reichert, Manfred Deicher, Herbert Wolf und Thomas Wichert — Technische Physik, Universität des Saarlandes, 66123 Saarbrücken

Auf Grund seiner optischen Eigenschaften ist ZnO ideal für optoelektronische Anwendungen im blauen und UV-Bereich. Allerdings bereitet im Gegensatz zur n-Dotierung die p-Dotierung nach wie vor große Schwierigkeiten. Als Möglichkeit für eine verbesserte p-Dotierung werden die Donator-Akzeptor-Kodotierung [1] oder die Cluster-Dotierung [2] vorgeschlagen. Dabei führt die Bildung von Donator-Akzeptor-Komplexen zur Verbesserung der Akzeptorlöslichkeit und somit zu einer Steigerung der p-Leitfähigkeit. Experimentell wurde dieser Ansatz für die In-N-Kodotierung durch elektrische Messungen bestätigt [3]. Auf atomarer Ebene sind solche Defektkomplexe durch einen elektrischen Feldgradienten (EFG) am Ort des Donators Indium charakterisiert, der mit Hilfe der gestörten $\gamma\gamma$-Winkelkorrelation (PAC) und des radioaktiven Donators ^{111}In gemessen werden kann. Für verschiedene Verfahren der In-N-Kodotierung (Implantation und/oder Diffusion) wurde neben dem EFG des ungestörten ZnO-Gitters ($\nu_{QGitter}$ = 31 MHz) ein durch ν_Q = 151(1) MHz charakterisierter Defekt beobachtet, der auf eine Bildung von In-N-Komplexen hinweisen kann.
Gefördert durch das BMBF, Projekt 05KK7TS1.
[1] T. Yamamoto *et al.*, Physica B **302-303** (2001) 155
[2] L.G. Wang *et al.*, Phys. Rev. Lett. **90** (2003) 256401
[3] L.L. Chen *et al.*, Appl. Phys. Lett **87** (2005) 252106

HL 40.6 Thu 11:00 BEY 118

Photocurrent measurements on magnesium zinc oxide in the infrared spectral range — •Dieter Stender, Heiko Frenzel, Kerstin Brachwitz, Holger von Wenckstern, Gisela Biehne, Holger Hochmuth, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig

We report on deep defects in $Mg_xZn_{1-x}O$ thin films with different magnesium content x up to 40%, investigated by Fourier-transform infrared photocurrent (FTIR-PC) spectroscopy in the mid and far infrared spectral range. The samples were grown on a-plane sapphire substrates by pulsed-laser deposition at a growth temperature of 700°C and oxygen partial pressure of 0.016 mbar. Analogue studies on pure ZnO were performed in [1], in which the deep defects E1 at ∼110 meV, E3 at ∼320 meV and L2 at ∼260 meV have been observed. In MgZnO, peaks at similar energies have been found indicating the presence of common ZnO point defects. The results are discussed and compared with electrical measurements like deep level transient spectroscopy (DLTS) and temperature dependent admittance spectroscopy (TAS). Based on these results, ZnO/MgZnO single heterostructures as well as quantum wells were investigated in order to observe intersubband transitions.
[1] H. Frenzel *et al.*, Phys. Rev. B **76**, 035214 (2007)

HL 40.7 Thu 11:15 BEY 118

A comparative study of DFT corrections to charge transition levels of transition metals in ZnO — •Marc A. Gluba and N. H. Nickel — Helmholtz-Zentrum Berlin für Materialien und Energie GmbH (formerly Hahn-Meitner-Institut Berlin), Kekuléstraße 5,

D-12489 Berlin, Germany

Transition metals (TM) doped into zinc oxide (ZnO) have attracted considerable interest because of their potential application for spintronic devices. Since the experimental realization of dilute ferromagnetic ZnO is still challenging a detailed knowledge of the atomic structure and the energetics of TM ions in ZnO is essential. Density functional theory (DFT) is a feasible tool for the prediction of both, the local structure and stable charge states of single TM ions in a ZnO host matrix. However, since DFT is a ground state theory it shows significant deficiencies in describing the fundamental band gap especially of wide gap semiconductors like ZnO. Therefore, charge transition levels of dopands calculated by DFT have to be carefully interpreted. In this study we compare two different approaches for the correction of the fundamental band gap of ZnO – the *a posteriori* correction by Janotti and Van de Walle [Phys. Rev. B **76**, 165202 (2007)] with an *a priori* approach by Paudel and Lambrecht [Phys. Rev. B **77**, 205202 (2008)]. Hence we determine the corrected charge transition levels of common transition metals in ZnO.

HL 40.8 Thu 11:30 BEY 118

Defect spectroscopy of homoepitaxial ZnO thin films — •Holger von Wenckstern, Alexander Lajn, Matthias Brandt, Christof Dietrich, Gabriele Benndorf, Michael Lorenz, Gisela Biehne, Holger Hochmuth, and Marius Grundmann — Universität Leipzig, Abteilung Halbleiterphysik, Institut für ExperimentellePhysik II

Homoepitaxially grown ZnO thin films exhibit compared to heteroepitaxial thin films a superior structural quality and a lower defect density [1]. In this work nominally undoped ZnO thin films, grown at various oxygen partial pressures by pulsed laser deposition on thermally pretreated hydrothermally grown ZnO single crystal substrates are investigated. Atomic force microscopy and high resolution X-ray diffraction were carried out to determine the morphological and structural properties of the ZnO thin films. Schottky contacts have been fabricated on the thin films by reactive sputtering of Pt. The barrier heights are ≥ 0.6 eV, yielding, despite the low substrate conductivity, rectification ratios of up to 10^2. This permits the application of space charge layer based defect spectroscopy. We correlate electronic properties measured by photoluminescence at 2 K with thermal admittance spectroscopy results and the growth parameters.

[1] H. v. Wenckstern et al.: phys. stat. sol. (RRL) 1,129 (2007).

15 min. break

HL 40.9 Thu 12:00 BEY 118

Influence of uniaxial strain onto the optical and vibrational properties of high quality ZnO substrates — •Gordon Callsen, Markus R. Wagner, Ronny Kirste, Jan Schulze, and Axel Hoffmann — Technische Universität Berlin, Department of solid state physics, Hardenbergstr. 36, 10623 Berlin, Germany

Homoepitaxial growth of ZnO films requires high quality ZnO substrates with minimal strain and a low impurity concentration. Justified by these requirements we evaluate ZnO substrates of several main suppliers. Therefore, we apply Micro-Raman, XRD and uniaxial strain depended PL measurements. XRD measurements clearly show that the c/a ratio is not a constant throughout the selection of our samples. This is mainly due to a varying compressive strain and defects in the samples as revealed by Micro-Raman measurements. In order to gain further insight into these results we investigate the influence of uniaxial strain onto the free and bound excitonic emission lines of the ZnO substrates (PRB 56, 13087). The uniaxial strain induced change of the crystal field causes a shift of the free excitonic lines. This allows the determination of the deformation potentials of the ZnO substrates (JJAP 40, L1089). The results of those measurements give further insight into the symmetry and ordering of the ZnO valence band. The controlled change of the piezo-electric field of the ZnO crystal also provides conclusions concerning the pressure induced shift of the bound excitons with their different localization energies. Based on our evaluation of the ZnO samples we map out necessary requirements for ZnO substrates in order to achieve homoepitaxial growth of ZnO.

HL 40.10 Thu 12:15 BEY 118

Electron Spin Resonance measurements on ZnMgO thin films grown by plasma assisted molecular beam epitaxy — •Thomas A. Wassner[1], Bernhard Laumer[1], Jochen Bruckbauer[1], Martin S. Brandt[1], Martin Stutzmann[1], and Martin Eickhoff[2] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [2]I. Physikalisches Institut, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

ZnO and $Zn_{1-x}Mg_xO$ thin films were grown epitaxially on (0001)-plane sapphire by plasma assisted molecular beam epitaxy (PAMBE). The obtained thin films were investigated by electron spin resonance (ESR) at a temperature of 4K. In ZnO, an ESR signal with a g-value of about 1.955 was observed. By comparison with the literature, the observed g-value may point to a shallow donor, e.g. In or Al. The intensity of this resonance can be significantly increased by above bandgap illumination and remains almost constant for more than 30 min after stopping the illumination. In $Zn_{1-x}Mg_xO$ the g-value of this resonance systematically shifts to higher values with increasing Mg content, accompanied by an attenuated angular dependence of the line position.

HL 40.11 Thu 12:30 BEY 118

Space charge spectroscopy applied to epitaxial ZnO — •Florian Schmidt[1], Holger von Wenckstern[1], Matthias Schmidt[1], Christian Borschel[2], Carsten Ronning[2], and Marius Grundmann[1] — [1]Universität Leipzig, Institut für Experimentelle Physik II — [2]Friedrich Schiller Universität Jena, Institut für Festkörperphysik

One advantageous material property of the wide band-gap II-VI semiconductor ZnO is it's higher radiation hardness compared to the most commonly used semiconductor materials Si and GaAs, respectively. Nevertheless, certain defects are introduced by radiation, implantation or even contact metal deposition. For systematic investigations we used pieces of a single 2 inch ZnO thin film grown by pulsed-laser deposition. To study the influence of the contact metal the thin films were used in their as-grown state. The introduction rate of intrinsic defects is determined for argon-ion implanted thin films. All samples were investigated by depth-resolved cathodoluminescence and space charge spectroscopic methods.