HL 28: ZnO: preparation and characterization I

Time: Wednesday 9:30–13:00 Location: BEY 118

HL 28.1 Wed 9:30 BEY 118

Growth and optical properties of ZnO nanostructures grown on ZnO seed layers — •yong xie, martin feneberg, anton reiser, ingo tischer, michael wiedenmann, reinhard frey, uwe Roeder, rolf sauer, and klaus thonke — Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm

Using a ZnO seed layer, we grow well-aligned ZnO nanopillars on different substrates including a-plane sapphire, c-plane GaN, and (100) silicon. We use Atomic Force Microscopy (AFM) and Scanning Electron Microscopy (SEM) to characterize the morphology of the ZnO seed layers and of the ZnO nanopillars. Layers and nanopillars were also investigated by optical spectroscopy. For all kinds of substrates used, we find well-faceted nanopillars which are uniform along the whole length. The data indicate that they grow via the vapour-solid (VS) mechanism under well-controlled growth conditions. The photoluminescence of the ZnO nanopillars shows sharp near-band-edge luminescence and nearly no green or yellow band luminescence, indicating very low contamination.

HL 28.2 Wed 9:45 BEY 118

Growth and Characterization of ZnO/ZnMgO Quantum Wells — •Bernhard Laumer[1], Thomas A. Wassner[1], Jochen Bruckbauer[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

$ZnO/Zn_{1-x}Mg_xO$ quantum wells (QWs) were grown on c-plane sapphire substrates by plasma assisted molecular beam epitaxy (PAMBE). In order to obtain smooth interfaces, growth was initiated by deposition of a thin MgO/ZnO double buffer and a thick ZnO intermediate layer. This was followed by the actual $Zn_{1-x}Mg_xO/ZnO/Zn_{1-x}Mg_xO$ QWs with Mg contents x up to 0.18. The ZnMgO barriers were found to grow pseudomorphically. The photoluminescence (PL) spectra taken at 4.2 K are dominated by an emission line that is blue-shifted with respect to the ZnO emission and that is attributed to localized excitons in the QWs. Increasing the Mg content x in the barrier results in a blue-shift of the QW emission, as expected from quantum confinement. Temperature-dependent PL measurements show that at higher temperatures the emission of free excitons prevails. Furthermore, an emission line (D) below that of ZnO with pronounced phonon replica appears, which red-shifts with increasing x.

HL 28.3 Wed 10:00 BEY 118

Growth of ZnO heterostructures in an ultra compact MBE system — •Marcel Ruth[1,2] and Cedrik Meier[2] — [1]University of Duisburg-Essen, Institute of Experimental Physics, Lotharstr. 1, 47048 Duisburg — [2]University of Paderborn, Group Nanophotonics and Nanomaterials, Warburger Str. 100, 33098 Paderborn

Due to its unique properties such as the large direct bandgap of 3.37eV and its high exciton binding energy, zinc oxide (ZnO) is a very promising semiconductor for optoelectronic and photonic applications even at room temperature. By adding cadmium (Cd) or magnesium (Mg) the bandgap can be tuned between 3.0eV and 4.0eV.

It has already been shown that plasma assisted molecular beam epitaxy (PA-MBE) is a very suitable technique for growing high-quality epilayers of ZnO. Especially for research issues small samples are often sufficient. By using ultra compact MBE-systems the running costs can be kept down. However, the special system geometry and the very compact design lead to high requirements on the system. It is not trivial that in such a system stoicometric and homogeneous growth conditions be achieved anyway. Furthermore, very high growth-rates can be obtained. By working in the zinc- (Zn) or oxygen-rich (O) regime completely different surface morphologies free of any metallic clusters are created.

We present a systematic study on the growth conditions in such a compact system. Especially, the determinaton of the flux will be discussed and the grown heterostructures will be characterised for their usability for nanophotonic devices.

HL 28.4 Wed 10:15 BEY 118

Growth of ZnO on Si by pulsed laser deposition under different oxygen partial pressures and temperatures — •Andreas Kraus, Helena Hilmer, Philipp Kühne, Stefan Schöche, Gerald Wagner, Christof Dietrich, Holger von Wenckstern, Matthias Brandt, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

ZnO thin films were grown on Si (111) substrates by pulsed-laser deposition at different oxygen partial pressures and temperatures, respectively. They were characterized by X-ray diffraction (XRD), I-V measurements, spectroscopic ellipsometry and for selected samples by transmission electron microscopy (TEM). XRD measurements show that by increasing the oxygen partial pressure, the crystalline quality first increases and then decreases. Further, the crystalline quality improves with increasing substrate temperature. Ellipsometry measurements show that the growth rate first increases with increasing the oxygen partial pressure and then decreases similar to the structural quality. The resistivity obtained by I-V characteristics indicates that the higher the temperature the lower is the resistivity. TEM images show a presence of a large number of grain boundaries which are due to the amorphous SiO_x layer on top of the Si substrate. These grain boundaries determine the electrical properties and consequently the I-V characteristics of the deposited ZnO layers.

15 min. break

HL 28.5 Wed 10:45 BEY 118

Growth of ZnO thin films on lattice matched GaN buffered sapphire substrates using pulsed laser interval deposition with in-situ RHEED — •Alexander Hirsch[1], Christian Wille[1], Frank Ludwig[1], Meinhard Schilling[1], Uwe Rossow[2], and Andreas Hangleiter[2] — [1]TU Braunschweig, Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik, Hans-Sommer-Straße 66, D-38106 Braunschweig, Germany — [2]TU Braunschweig, Institut für Angewandte Physik, Mendelssohnstraße 2, D-38106 Braunschweig

Due to its wide and direct band gap ZnO is an interesting oxide semiconducting material. Nevertheless, p-type doping with long time stability remains difficult. One way to overcome the doping problem is to use n-type doped ZnO in combination with p-type doped GaN. Therefore, we have studied the pulsed laser deposition (PLD) growth of ZnO thin films on lattice matched GaN buffered Al_2O_3 substrates.

The target was prepared by standard ceramics synthesis. To achieve lattice matching to ZnO GaN was grown on top of the Al_2O_3-substrates using MOVPE. The ZnO thin films were grown using a PLD setup equipped with a high-pressure reflection high energy electron diffraction (RHEED) for in-situ investigation of the thin film quality. The structural investigation was supplemented by XRD and AFM.

The influence of the growth temperature and the effect of interval deposition on the thin film quality was analyzed. RHEED intensity oscillations have been observed. Best results are achieved using high temperatures and the technique of interval deposition. These conditions lead to high quality crystalline films with roughnesses < 1 nm.

HL 28.6 Wed 11:00 BEY 118

Design and characterization of ZnO-based MESFETs on glass substrates — •Michael Lorenz, Heiko Frenzel, Holger Hochmuth, Gisela Biehne und Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig

Metal-semiconductor field-effect transistors (MESFETs) were fabricated by reactive dc-sputtering of Ag as Schottky-gate contact on ZnO thin films grown by pulsed-laser deposition (PLD) on glass substrates. For applications in transparent electronics, the use of cheap glass substrates is more beneficial than sapphire or other crystalline substrates. However, the non-epitaxial growth leads to more structural defects like dislocations, twist and tilt of grain boundaries, and higher surface roughness of the ZnO films. An insulating MgZnO buffer layer was introduced to decrease the influence of such defects on the Al-doped ZnO channel layer. X-ray diffraction, atomic force microscopy as well as Hall-measurements were performed on samples grown at different substrate temperatures between 440°C and 630°C and oxygen partial

pressures ranging from 0.1 to 3×10^{-4} mbar. The channel mobilties are at about 1 cm^2/Vs and the on/off-ratio is 10^5. Normally-on and normally-off MESFETs were achieved by adjusting the Al-doping concentration between 0.01% and 0.001%.

HL 28.7 Wed 11:15 BEY 118

Direct Synthesis of Zinc Oxide Nanoseaurchins and Nanocups from Zn-Powder — •Yogendra Kumar Mishra[1], Seid Jebril[1], Rahul Singhal[2], Devesh Kumar Avasthi[2], and Rainer Adelung[1] — [1]Functional Nanomaterials, Institute of Materials Science, Faculty of Engineering, CAU Kiel — [2]Inter University Accelerator Centre, P. O. Box 10502, New Delhi-110067, India

ZnO, a II-VI semiconductor and a member of wurtzite structure family, has attracted enormous research interest due to it fascinating properties like high exciton binding energy, hydrophobic nature and biocompatibility [1]. In present work, we report the synthesis of ZnO nanourchins and nanocups by a vapour-liquid-solid (VLS) approach from Zn-powder in a tube furnace. The synthesis conditions like temperature and fractions were varied to investigate the fundamental phenomenon of growth. In some cases, formation of ZnO nanocups was observed however in most of the cases growth of long crystalline ZnO nanowhiskers were obtained, suggesting a growth kinetics that will be explained here. Au-ZnO nanocomposite was synthesized by atom beam co-sputtering and formation of ZnO nanorods with Au nanoparticles on the top after annealing at 600C was observed[2]. Scanning/transmission electron microscopies were used to observe the grown nanostructures. Experiments to utilize the structures as sensors as well as in biomedical engineering are in progress, first results are presented here.

[1] Z. L. Wang, Materials Today 26 (June 2004). [2] Y. K. Mishra et al., Appl. Phys. Lett. 92 (2008)43107.

HL 28.8 Wed 11:30 BEY 118

Homo- and heteroepitaxial growth of non-polar ZnO — Stefan Lautenschlaeger, •Sebastian Eisermann, Joachim Sann, Melanie Pinnisch, Andreas Laufer, and Bruno K. Meyer — 1st physics institute, JLU Gießen, Heinrich Buff Ring 16, 35392 Gießen

Polarization fields, parallel to the c-axis, strongly reduce the quantum efficiency in wurzite semiconductors. To eliminate these polarization fields epitaxial ZnO thin films have been grown on a-plane ZnO, r-plane sapphire and a-plane GaN templates. The grown epilayers have been investigated using low temperature Photoluminescence (PL), Atomic Force Microscopy (AFM), Secondary Ion Mass Spectrometry (SIMS), Scanning Electron Microscopy (SEM), X-Ray Diffraction (XRD) and Raman spectroscopy. We compare the hetero- and the homoepitaxially grown samples with respect to their morphological and optical quality.

15 min. break

HL 28.9 Wed 12:00 BEY 118

Identification of excitonic transitions in $Mg_xZn_{1-x}O$ thin films grown by pulsed laser deposition — •Christof Dietrich, Gabriele Benndorf, Jörg Lenzner, and Marius Grundmann — Universität Leipzig, Semiconductor Physics Group, Institut für Experimentelle Physik II, Leipzig, Germany

The incorporation of Mg-atoms into ZnO leads to an increase of the band-gap allowing a tuning between 3,4 eV and about 8 eV. Nevertheless the recombination mechanisms in MgZnO are not yet well understood because alloy broadening superimposes spectral information.

In order to obtain more information about the recombination mechanisms, MgZnO thin films with a low Mg-content (1 - 7 %) were grown on a-plane sapphire substrates by pulsed-laser deposition. Buffer layers containing about 40 % Mg were deposited prior to the thin films. The Mg-contents were determined by energy dispersive x-ray diffraction spectroscopy.

Photoluminescence measurements at 2 K showed two peaks with a separation of 15 meV in the excitonic regime which we attribute to the transitions of the free and the Al-donor bound excitons. Temperature dependent photoluminescence measurements from 5 K up to room temperature confirmed this and revealed a S-shape behaviour for the donor bound exciton only.

HL 28.10 Wed 12:15 BEY 118

Magneto-optical studies of bound exciton complexes in homoepitaxially grown polar ZnO Epilayers — •J.-H. Schulze[1], M. R. Wagner[1], C. Rauch[1], A. Hoffmann[1], J. Sann[2], S. Lautenschläger[2], B. K. Meyer[2], and A. Rodina[3] — [1]Technische Universität Berlin, Institut für Feskörperphysik, Herdenbergstraße 36, 10623 Berlin, Germany — [2]Justus Liebig Universität Giessen, I. Physics Insitute, Heinrich-Buff-Ring 16, 35592 Giessen, Germany — [3]A. F. Ioffe Physico-Technical Institute, 194021 St.-Petersburg, Russia

The optical properties of homoepitaxially grown ZnO are strongly influenced by the surface polarity of the substrate. This dependency is e.g. shown at the luminescence of complex bound excitons. Our investigations revealed excitonic recombination lines that could exclusively be observed from a sample grown on O-polar ZnO (PRB 77, 144108). In order to determine the complex properties of this excitons magneto-optical investigations are performed. The electron- and hole effective g-values of the involved complex are calculated from these measurements. To obtain information about the symmetry of the excitonic valence states angular resolved magneto-optical data is acquired. Temperature and power dependent PL measurements are done to get further insight into the explicit recombination behavior with respect to the fine structure splitting. In addition pico-second time resolved measurements reveal the recombination dynamics. These results are compared with the temperature and magnetic field dependent thermalization behavior. Possible defect models and energy level splittings are discussed and compared to theoretical models.

HL 28.11 Wed 12:30 BEY 118

Electrical properties of ZnMgO thin films grown by pulsed-laser deposition — •Kerstin Brachwitz, Holger von Wenckstern, Holger Hochmuth, Gisela Biehne, Christof Dietrich, Matthias Brandt, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Abteilung Halbleiterphysik

We present electrical investigations of $Mg_xZn_{1-x}O$-semiconductor alloys, grown by pulsed-laser deposition (PLD). The Mg-content in the samples ranged from 4% to 50%. We grew nominally undoped and intensionally Al-doped (0.5%) MgZnO thin films and investigated their structural and electrical properties in dependence on the Mg-content. Furthermore we monitored changes of the samples properties after annealing for 30 minutes at different temperatures (500°C, 700°C and 900°C) in 700 mbar oxygen. High quality Schottky contacts were realized by reactive dc-sputtering of Pd. We investigated their properties by current-voltage- (IV) and capacitance-voltage-measurements (CV). Further on, we used these Schottky diodes to investigate defect states using depletion layer spectroscopy. Additionally we characterized the samples by X-ray-diffraction (XRD), atomic force microscopy (AFM) and photoluminescence (PL). In conclusion we will show correlations between the structural and electronic properties for the as-grown and the annealed samples.

HL 28.12 Wed 12:45 BEY 118

Nitrogen incorporation in ZnO thin films grown by radio frequency (RF) sputtering — •Sebastian Eisermann, Stefan Lautenschlaeger, Andreas Laufer, Angelika Polity, and Bruno K. Meyer — 1. Physikalisches Institut, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen

Bipolar conduction of electron and holes is mandatory for many electronic and opto-electronic applications of ZnO. Among the impurity atoms suited for acceptor formation nitrogen is the prime candidate. Controlling the incorporation without the formation of deep donors and acceptors and avoiding the deterioration of the materials quality is a main goal for homo- and heteroepitaxially grown ZnO films. We report on the sputter deposition of N-doped ZnO layers and will show by SIMS and Raman spectroscopy how the substrate type and substrate temperature influence the nitrogen incorporation.