HL 49: ZnO: Optical properties

Time: Thursday 10:45–13:00 Location: ER 164

HL 49.1 Thu 10:45 ER 164

Lasing modes in ZnO microwires — •Christian Czekalla, Jörg Lenzner, Rüdiger Schmidt-Grund, Bingqjang Cao, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103, Leipzig, Germany

We report lasing from single hexagonally shaped ZnO microwires detected using spatially resolved photoluminescence spectroscopy (PL) under high excitation conditions. The structures were synthesized by a carbothermal evaporation process at ambient pressure and show a efficient excitonic radiative recombination at low excitation intensities. The wires were either dispersed on silicon or sapphire substrates or on carbon gluepads. Under high excitation conditions at low temperature, additional peaks due to inelastic exciton collisions and the formation of an electron hole plasma can be seen. Furthermore, sharp peaks are observed in the spectra growing superlinearly with the excitation intensity, indicating stimulated emission and lasing from Fabry-Perot-modes between the side facets of the microwires with a resonator length between 3 μm and 20 μm. The peaks exhibit a FWHM of only 2 meV and a lasing threshold intensity of about 150 kW/cm^2. Spectra as a function of temperature, wire diameter and polarization will be presented.

HL 49.2 Thu 11:00 ER 164

Influence of dielectric capping on the phololuminescence spectrum of ZnO nanowires nanowires — •Jan Richters, Tobias Voss, Ilja Rückmann, and Jürgen Gutowski — Institute of Solid State Physics, University of Bremen, P.O. Box 330440, D-28334 Bremen

Due to the large surface-to-volume ratio and the photon confinement, ZnO nanowires are expected to be good candidates for applications in nanoscale optoelectronics in the blue spectral region and for sensors. For many devices, the nanowires need to be embedded in organic or inorganic materials or functionalized with surfactants. It is important to understand the influence of these treatments on the optical and electronic properties of ZnO nanowires to optimize their use in such devices. We report on room-temperature and low-temperature photoluminescence studies of ZnO nanowires embedded in organic and inorganic dielectrics. For this, we investigate ZnO nanowires embedded in various polymers as well as aluminum/ZnO nanowire core-shell structures. The capping in general results in a more pronounced surface exciton band. Additionally, a decreased relative intensity of the green deep-level emission with respect to the near band-edge emission can be observed. These effects scale with the dielectric constants of the amorphous dielectrics. Capping with a dielectric influences the surface states as well as the band bending at the semiconductor surface. We present a model to explain the changes of the relative intensities of the photoluminescence bands.

HL 49.3 Thu 11:15 ER 164

Optical and electrical characterization of acceptors implanted into ZnO — •Joachim Dürr[1], Daniel Stichtenoth[1], Sven Müller[1], Carsten Ronning[1], Amilcar Bedoya Pinto[2], Jörg Malindretos[2], Lars Wischmeier[3], and Tobias Voss[3] — [1]II. Institute of Physics, University of Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]IV. Institute of Physics, University of Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [3]Institute for Solid State Physics, University of Bremen, Bibliothekstraße 1, 28359 Bremen, Germany

Group I- and V-elements are the most promising candidates for p-type doping of ZnO. We doped ZnO bulk crystals with several of them using ion implantation, because this technique offers several advantages compared to doping during growth, e.g. precise control of the lateral and vertical dopant concentration even beyond solubility limits. After implantation and annealing of the introduced defects, we performed photoluminescence measurements in order to monitor the optical activation of the dopants. We investigated the dependence of acceptor-related features of the spectra on dopant concentration and annealing conditions as well as the temperature dependence. First Hall measurements of acceptor-implanted ZnO will also be presented.

HL 49.4 Thu 11:30 ER 164

Random lasing in ZnO nanopowders — •Roman J.B. Dietz, Johannes Fallert, Felix Stelzl, Huijuan Zhou, Janos Sartor, Claus Klingshirn, and Heinz Kalt — Institut für Angewandte Physik, Universität Karlsruhe (TH), Germany

We investigate the optical properties and random lasing effects of nanocrystalline ZnO powders under high optical excitation. The powders are excited by a pulsed Nd:YAG laser at 355 nm with a pulse duration of 5 ns. The different powders have different average particle sizes which vary from 50 nm to several μm. This gives us the opportunity to measure the threshold of lasing in dependence, among others, on particle size. Furthermore by investigating single pulse spectra we are also able to make statistical evaluations of the lasing probability. We also evaluate the dependence on temperature and size of excited area.

HL 49.5 Thu 11:45 ER 164

DBR und RC-LED Strukturen im ZnSe-basierten Materialsystem — •Kai Otte, Carsten Kruse, Jens Dennemarck, Arne Gust und Detlef Hommel — Institut für Festkörperphysik, Universität Bremen, Otto-Hahn-Allee 1, 28359 Bremen

Hochreflektive Bragg-Spiegel (DBRs) sind ein Schlüsselbaustein für Bauelemente wie oberflächenemittierende Laserdioden mit Vertikalresonator (VCSEL) und resonanter Kavitäts-LEDs (RC-LED). Auf Basis eines, in seinen optischen und elektrischen Eigenschaften optimierten, DBRs wurde erstmals eine RC-LED mit Quantenpunkten als aktivem Gebiet für den grünen Spektralbereich realisiert. Dies ist ein wichtiger Schritt in Richtung elektrisch betriebener VCSEL.

Die Bragg-Spiegel, bestehend aus einer ZnSSe Schicht als Hochindexmaterial und einem MgS/ZnSe Übergitter(SL) als Niedrigindexmaterial wurden mittels Molekularstrahlepitaxie auf GaAs Substraten abgeschieden. Mit diesen Bragg-Spiegeln können Reflektivitäten von über 99% erreicht werden. Das ZnSe Materialsystem ermöglicht das Wachstum von DBRs im Wellenlängenbereich von 470 nm bis über 600 nm.

Durch Optimierung des Schichtdickenverhältnisses im MgS/ZnSe SL kann die Leitfähigkeit von n-dotierten DBRs signifikant verbessert werden. Die besten Werte lagen bei 90 $\frac{A}{cm^2}$ bei 3 V für einen 12fach DBR.

HL 49.6 Thu 12:00 ER 164

Gain and dynamics in ZnO nanorod lasers — •Johannes Fallert[1], Roman J. B. Dietz[1], Felix Stelzl[1], Huijuan Zhou[1], Janos Sartor[1], Anton Reiser[2], Klaus Thonke[2], Rolf Sauer[2], Claus Klingshirn[1], and Heinz Kalt[1] — [1]Institut für Angewandte Physik, Universität Karlsruhe (TH), Germany — [2]Institut für Halbleiterphysik, Universität Ulm, Germany

Recent progress in reliable p-doping of ZnO and the realization of ZnO based LEDs foster the hope to achieve ZnO-based short-wavelength laser diodes. In particular, ZnO nanorods which can be grown in ordered, extended arrays offer the possibility to realize nano-scaled lasers. There, ZnO is not only the gain medium, but also acts as a laser resonator. Under lasing conditions the emission wavelength is defined by the guided modes in the nanorod. Here we study the lasing dynamics of individual nanorods by time-resolved μ-photoluminescence. We demonstrate that these modes show gain competition and pronounced shifts with varied pump intensity as well as within their temporal evolution. We find that even at low temperature the gain is exclusively due to an electron-hole plasma. Furthermore the influence of temperature on the available gain is examined and room-temperature lasing is achieved under ns-excitation.

HL 49.7 Thu 12:15 ER 164

Dynamics of charge carrier relaxation and recombination in high quality homoepitaxial-grown and single crystal ZnO — •Markus R. Wagner[1], Ute Haboeck[1], Axel Hoffmann[1], Stefan Lautenschläger[2], Joachim Sann[2], and Bruno K. Meyer[2] — [1]Institut für Festkörperphysik, Technische Universität Berlin — [2]I. Physikalisches Institut, Justus-Liebig-Universität Gießen

The improvement of growth procedures enables the fabrication of high quality homoepitaxial-grown ZnO layers with negligible amounts of strain near the interface. The optical, electronical and vibrational properties of homoepitaxial grown layers are compared to those of high quality ZnO single crystals. In particular, we report experimental re-

sults of time resolved PL and Raman spectroscopy, which provide information on the recombination and relaxation dynamics of charge carriers. The decay times of the observable exciton complexes were studied for different laser energies, resulting in resonant and non-resonant excitation. The dynamics and energy transfer processes were analyzed by probing the free and bound exciton states and phonon replicas, while varying the laser energy. The phonon and carrier dynamics are investigated by time resolved pump and probe spectroscopy. High energy excitation produces hot carriers by two-photon absorption. Their relaxation is accompanied by the emission of phonons, which are studied by time-resolved Raman spectroscopy. The results including resonant and non-resonant Raman measurements are discussed considering electron-phonon and phonon-phonon interactions.

HL 49.8 Thu 12:30 ER 164

Asymmetry in the excitonic recombinations and impurity incorporation of the two polar faces of homoepitaxially grown ZnO films — •Joachim Sann[1], Stefan Lautenschläger[1], Niklas Volbers[1], Bruno K. Meyer[1], Markus R. Wagner[2], Ute Haboeck[2], and Axel Hoffmann[2] — [1]1st Physics Institute, Justus-Liebig University Giessen, Heinrich Buff Ring 16, 35392 Giessen, Germany — [2]Institute of Solid State Physics, TU Berlin, Hardenbergstr. 38, 10623 Berlin, Germany

Homoepitaxial ZnO layers were grown on O-polar and Zn-polar surfaces of ZnO single crystal substrates by chemical vapour deposition. While the structural properties (surface roughness, rocking curve half width) were within experimental error identical, the optical properties as monitored by photoluminescence (PL) were strikingly different. Four excitonic recombination lines are exclusively found on the O-polar surface. In order to understand the defects involved secondary ion mass spectrometry was employed which clearly demonstrated that the impurity incorporation is substantially higher on the O-polar surface. Temperature and power dependent PL measurements provide further insight into the initial-final state recombinations. The newly observed recombinations are caused by excitons bound to a neutral defect complex. In order to account for the thermalisation behaviour found in the temperature dependent measurements splittings in the excited as well as in the ground state must be present. A neutral, isoelectronic Zn vacancy-donor pair is consistent with the experimental data.

HL 49.9 Thu 12:45 ER 164

Stacking fault-related 3.31eV luminescence in zinc oxide — •M. Schirra[1], R. Schneider[1], A. Reiser[1], G.M. Prinz[1], M. Feneberg[1], J. Biskupek[2], U. Kaiser[2], C.E. Krill[3], R. Sauer[1], and K. Thonke[1] — [1]Institut für Halbleiterphysik, Universität Ulm, D-89069 Ulm — [2]Materialwissenschaftliche Elektronenmikrokopie, Universität Ulm, D-89069 Ulm — [3]Institut für Mikro- und Nanomaterialien, Universität Ulm, D-89069 Ulm

Epitaxial layers, bulk material, and nanostructures of ZnO often exhibit a characteristic luminescence band at ≈3.31eV. The nature and origin of this band has been the subject of some debate, frequently being interpreted in terms of acceptor-related recombination taken as confirmation of successful p-type doping. Our epitaxial ZnO layers, grown nominally undoped on a-plane sapphire substrates, also show the 3.31eV band together with dominant near-band edge emission. A combination of spatially resolved cathodoluminescence (CL) and transmission electron microscopy (TEM) studies performed on the same samples finds that the 3.31eV band appears along distinct lines, which we identify as being related to basal plane stacking faults. Temperature-dependent CL measurements reveal that the 3.31eV band is a free-to-bound $\left(e, A^0\right)$ transition, involving an acceptor state localized at the stacking fault. The acceptor ionization energy is 130meV. Some samples show an additional line ≈13meV below the 3.31eV band. Its properties are consistent with a donor-acceptor-pair transition. The average pair distance is only 4nm. Possible implications of these new results with regard to p-type doping of ZnO are discussed.