# HL 37: ZnO: devices

Time: Wednesday 16:15–18:00 Location: POT 51

HL 37.1 Wed 16:15 POT 51

**Optical characterization of zinc oxide microwire lasers** — •Christian Czekalla, Chris Sturm, Rüdiger Schmidt-Grund, Jesus Zuniga Perez, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103, Leipzig, Germany

We report the optical characterization including photoluminescence (PL) spectroscopy and optical pumping of hexagonally shaped zinc oxide (ZnO) microwires. The structures were grown by a simple carbothermal evaporation process. Under high excitation conditions, whispering gallery mode lasing can be observed [1]. The observed lasing peaks can be calculated very precisely from a simple plane wave model [2]. The lasing modes exhibit a full width at half maximum (FWHM) of down to 0.6 meV, limited solely by radiation loss in good agreement with the theory of hexagonal cavities [3]. This leads to quality factors of about 4000.

In order to tune the emitted photon energy of the microwire lasers, MgZnO/ZnO core shell heterostructures have been grown around the microwires by pulsed laser deposition. The PL results clearly indicate the growth of MgZnO barriers and ZnO quantum wells. Additionally, high excitation spectroscopy results will be shown.

[1] C. Czekalla et al., *Appl. Phys. Lett.* **92**, 241102 (2008)
[2] T. Nobis et al., *Phys. Rev. Lett.* **93**, 103903 (2004)
[3] J. Wiersig, *Phys. Rev. A* **67**, 023807 (2003)

HL 37.2 Wed 16:30 POT 51

**Localized modes in ZnO random lasers** — •Johannes Fallert, Janos Sartor, Roman J. B. Dietz, Daniel Schneider, Viktor Zalamai, Claus Klingshirn, and Heinz Kalt — Institut für Angewandte Physik, Universität Karlsruhe (TH), Germany

Zinc oxide nanoparticles can act as gain and scattering medium in a random laser where light emission can be significantly amplified. In this work we focus on the degree of spatial localization for random lasing modes. By investigating the laser emission of defined microstructured fields, filled with nanocrystalline ZnO powder, we can easily allocate the position of the differently localized modes in SEM images of the sample. The observed emission lines can be attributed to modes provided by random alignment of ZnO nanoparticles at a certain position within the field while emission from single, large grains can be excluded. Recent theoretical papers predict that strongly localized and even extended modes lead to random lasing [1]. In agreement with these predictions we observe the coexistence of laser modes with strong as well as weak localization.

[1] D.S. Wiersma, Nature Physics 4, 359 (2008)

HL 37.3 Wed 16:45 POT 51

**Transport investigations on ZnO-based MESFETs** — •Heiko Frenzel, Alexander Lajn, Holger von Wenckstern, Matthias Brandt, Gisela Biehne, Holger Hochmuth, and 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 either Ag, Pt, Pd, and Au as Schottky-gate contacts on ZnO thin films grown by pulsed-laser deposition on *a*-plane sapphire substrates. In contrast to ZnO-based metal-insulator field-effect transistors (MISFETs), MESFETs show high dynamics switching within a gate-voltage range of only ±1 V with an on/off-ratio of up to $10^8$ [1]. The channel mobilities are not limited by scattering at the insulator/semiconductor-interface and therefore equal the Hall mobilities of the thin films achieving values up to 27 $cm^2/Vs$. MESFETs comprised of the four most common Schottky metals on ZnO were electrically investigated in a temperature range between 25°C and 150°C. For Ag, Pt, and Au, the device performance was at least stable until 100°C even showing an improvement due to the annealing [2]. Studies of the dependencies on different gate-geometries as well as reliability tests under the influence of light will be presented.

[1] H. Frenzel *et al.*, Appl. Phys. Lett. **92**, 192108 (2008)
[2] H. Frenzel *et al.*, Proc. of the 2nd Internat. Symp. on Transparent Conductive Oxides, Thin Solid Films, *submitted*

**15 min. break**

HL 37.4 Wed 17:15 POT 51

**Lasing emission in ZnO nanorods** — •Victor Zalamai[1], Johannes Fallert[1], Janos Sartor[1], Daniel Schneider[1], Heinz Kalt[1], Claus Klingshirn[1], Veaceslav Ursaki[2], and Ion Tiginyanu[2] — [1]Institut für Angewandte Physik, Universität Karlsruhe (TH), Germany — [2]Technical University of Moldova, Moldova

In this work we investigate lasing effects in zinc oxide nanorods. Vertically aligned hexagonal ZnO nanorods have been prepared by low pressure chemical vapour deposition (CVD). The photoluminescence (PL) spectroscopy demonstrates the high crystal quality of the produced nanorods which is comparable with the quality of bulk ZnO single crystals. The transition from spontaneous to stimulated emission is observed in arrays of hexagonal nanorods with an almost uniform diameter of 200 nm and length of 1.5 $\mu$m under excitation by 5 ns laser pulses above a certain threshold of excitation power density which depends from nanorod sizes. Multiple sharp peaks representing different lasing modes emerge in the emission spectrum above the lasing threshold. The lasing modes are better resolved when the emission from a single nanorod is analyzed. A broad emission band is characteristic for randomly oriented ZnO nanostructures with a variety of geometrical parameters. This band represents a superposition of lasing modes coming from ZnO nanorods with different diameters and lengths.

HL 37.5 Wed 17:30 POT 51

**Inverter Structures based on Zinc Oxide** — •Friedrich Schein, Heiko Frenzel, Alexander Lajn, Gisela Biehne, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig

The increased interest in wide bandgap semiconductors in the last years is partially due to lots of potential applications in transparent electronics. Zinc oxide is a promising candidate for the fabrication of such transparent devices, e. g. for diodes and transistors. Recent investigations of ZnO-based transistors mostly considered metal-insulator-semiconductor field-effect transistors (MISFETs), suffering from low field-effect mobility and high switching voltages. In this study metal-semiconductor FETs (MESFETs) are used [1]. They possess a higher channel mobility and with that faster switching speeds. Furthermore typical MESFET switching voltages of ±1 V are about one order of magnitude smaller than for MISFETs, yielding less power consumption. The transistor's switching performance can be determined using ring oscillator structures, consisting of inverters. In this work, we use Schottky diodes and MESFETs, both based on ZnO thin films grown by pulsed-laser deposition, to fabricate inverter structures. These are known from GaAs technology as Schottky-diode FET logic. The electrical properties including on-off ratio, steepness and transfer characteristic are investigated. Further the integration, necessary for the fabrication of ring oscillators, is discussed.

[1] Frenzel *et al.*, Appl. Phys. Lett., **92**, 192108 (2008)

HL 37.6 Wed 17:45 POT 51

**Ferroelectric thin film transistors based on ZnO/$BaTiO_3$ heterojunctions** — •Brandt Matthias, Heiko Frenzel, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für ExperimentellePhysik II, Leipzig, Germany

ZnO and $BaTiO_3$ (BTO) are transparent oxide materials. ZnO is a semiconductor showing a spontaneous electric polarization and is very easily doped n–type. BTO is an insulating ferroelectric at room temperature. The ability to control the free carrier concentration in the ZnO by the polarization of the BTO can be used to develop ZnO/BTO based ferroelectric field effect transistors, thus demonstrating fully transparent non–volatile memory elements.

We have grown epitaxial BTO/ZnO heterostructures by pulsed laser deposition on lattice matched $SrTiO_3$ and $SrTiO_3$:Nb substrates. The electrical properties of ZnO/BTO heterostructures have been investigated by current-voltage measurements, showing that the BTO layer is highly insulating ($I_l < 10^{-9}$ A/cm$^2$ at 5V). Field effect transistors were fabricated with an on–current of up to $6 \times 10^{-5}$ A and an on/off ratio of $10^6$. The FETs are normally on. The structures could be programmed by a positive gate voltage pulse and erased by a negative gate voltage. The ratio in the source–drain currents in both states could be as high as 1000, depending on the gate voltage at read–out. The effect was reproducible in repeated switching cycles, showing the suitability of the structure as a memory device.