HL 32: Poster: ZnO and its relatives

Time: Monday 17:00–20:00 Location: P2

HL 32.1 Mon 17:00 P2

Method of choice for the fabrication of high-quality ZnO thin film based Schottky diodes — •Stefan Müller[1], Holger von Wenckstern[1], Florian Schmidt[1], Robert Heinhold[2], Martin Allen[2], and Marius Grundmann[1] — [1]Universität Leipzig, Semiconductor Physics Group, Institut für Experimentelle Physik II, Leipzig, Germany — [2]The MacDiarmid Institute for Advanced Materials and Nanotechnology, University of Canterbury, Christchurch 8043, New Zealand

In this contribution we present a comprehensive comparison of electrical properties of differently fabricated high quality Schottky contacts on ZnO thin films grown by pulsed laser deposition. Thermally evaporated Pd/ZnO Schottky contacts exhibit ideality factors as low as 1.06 due to their high lateral homogeneity. The effective Richardson constant of such Schottky contacts is with $7.7 \pm 4.8\,\mathrm{A\,cm^{-2}\,K^{-2}}$ close to the theoretical value of $32\,\mathrm{A\,cm^{-2}\,K^{-2}}$. At the same time the on/off ratio of such Schottky contacts is at most five orders of magnitude due to their comparably small effective barrier height ($\approx 0.7\,\mathrm{eV}$). The largest effective barrier heights up to 1.11 eV and on/off ratios up to 7×10^{10} were obtained for reactively sputtered PdO_x/ZnO Schottky contacts. However, the ideality factors are increased to 1.3. Eclipse pulsed laser deposited IrO_x/ZnO Schottky contacts combine the very good homogeneity ($n \approx 1.1$), the large barrier height (0.96 eV) and large on/off ratio (≈ 9 orders of magnitude) of evaporated and sputtered contacts.

HL 32.2 Mon 17:00 P2

Low frequency noise in ZnO-based MESFETs — •Fabian J. Klüpfel, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Linnéstr. 5, 04103 Leipzig

We examined the sources of noise in metal-semiconductor field-effect transistors (MESFETs) based on n-type ZnO channels on a-plane sapphire substrates for frequencies up to 100 kHz. Measurements have been performed in dependence on the channel geometry prior and after gate deposition. The noise has also been characterized depending on the applied source-drain voltage. In addition to thermal noise a contribution with a 1/f power density spectrum can be observed at ZnO channels without gate, which is best described by a generation-recombination process in the semiconductor with a broad range of attributed time constants. To realize MESFETs we used reactively sputtered platinum Schottky contacts. The noise measured at ungated channels and at Schottky contacts was compared with the drain current noise of the transistors, in order to identify the dominating source of noise and its dependence on geometrical parameters. The results can be used to improve the signal-to-noise ratio in ZnO-based sensor applications.

HL 32.3 Mon 17:00 P2

Electrical and optical properties of (Mg,Zn)O:Al thin films for solar cell application — •A. Mavlonov, H. von Wenckstern, S. Richter, R. Schmidt-Grund, and M. Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany

We investigated electrical, and optical properties of $Mg_xZn_{1-x}O$:Al thin films in dependence on the aluminum concentration. For that we used a thin film with two perpendicular, lateral composition gradients (of Al and Mg, respectively). The sample was grown by pulsed-laser deposition (PLD) using a single but threefold segmented PLD target [1]. The spatial variation of chemical composition was investigated by energy dispersive X-ray (EDX) spectroscopy. The free carrier density and the mobility were determined by Hall-effect measurement. For a fixed Al concentration the bandgap increases systematically with increasing Mg content, and the plasma frequency, determined from IR spectroscopic ellipsometry decreases due to an increase of the effective electron mass. As expected, increasing the Al dopant concentration led to an increase of the free carrier density (varying between $2-9\times10^{20}\mathrm{cm}^{-3}$) and conductivity, and a minor decrease of the mobility. The absorption edge increases also with increasing Al concentration due to the Burstein-Moss effect. The reduced electron mass was calculated for different Mg content x, being $0.62\mathrm{m}_e$, $0.71\mathrm{m}_e$ and $0.78\mathrm{m}_e$ for x=0.01, 0.03 and 0.05, respectively.

[1] H. von Wenckstern *et al.*: CrystEngComm 15, 10020-10027 (2013).

HL 32.4 Mon 17:00 P2

Terahertz spectroscopy on electron transport in disordered zinc oxide — •Stefan Gerhard Engelbrecht, Ludovica De Angelis, Marc Tönnies, and Roland Kersting — Photonics and Optoelectronic Group, Physics Department and Center for NanoScience (CeNS), Ludwig-Maximilians-Universität München, Germany

The characterization of disordered semiconductors by conventional electronic techniques is challenging since slow processes such as hopping transport or scattering at grain boundaries mask the fast transport within the crystallites. Terahertz (THz) time-domain spectroscopy offers an alternative approach for characterizing charge transport in disordered semiconductors. We report on THz spectroscopy of electron transport in nanocrystalline zinc oxide deposited by spray pyrolysis. In our experiments, the electromodulation of charge carriers in the ZnO films leads to a differential THz signal, which provides the AC conductivity. The experiments reveal an unexpected deviation from Drude transport that exhibits a negative imaginary conductivity over the accessible frequency range. Both, the Drude-Smith model as well as the Bruggeman model reproduce the experimental data well. The analysis delivers the fundamental scattering times and reveals the percolated nature of high frequency conductivity in disordered films.

HL 32.5 Mon 17:00 P2

IR absorption study of cobalt doped ZnO — •Preeti Pandey[1,2], Edward V. Lavrov[1], and Jörg Weber[1] — [1]Technische Universität, 01062 Dresden, Germany — [2]Indian Institute of Technology Roorkee, Roorkee, India

Ferromagnetic Diluted Magnetic Semiconductors (DMSs) are expected to be a potential candidate for spin dependent electronics known as spintronics. Prediction of room temperature ferromagnetism in transition metal doped ZnO has initiated extensive research in this area [1]. Although much of research has been done regarding the electrical and magnetic properties of the material, it is equally important to analyze the optical properties. Vapor phase grown ZnO crystals doped with cobalt have been investigated by means of FTIR spectroscopy. Along with the temperature dependent spectra, polarized spectra of $Co^{2+}(d^7)$ ions occupying substitutional Zn sites have been studied. Absorption lines due to $^4A_2(F) \rightarrow {}^4T_2(F)$ transitions positioned at 3609.4, 3614.9, 3628.5 and 3634.1 cm^{-1} are observed. Effect of hydrogen treatment on the cobalt-related complexes has also been probed. [1]. T. Dietl et al., Science, Vol. 287, 1019, 2000

HL 32.6 Mon 17:00 P2

Low-temperature ZnO buffer for high-quality ZnO epitaxy on Si(111) substrate grown by molecular beam epitaxy — •Manuel H. W. Bader and Cedrik Meier — University of Paderborn, Experimental Physics & CeOPP, 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 of 60meV, zinc oxide (ZnO) is a very promising semiconductor for optoelectronic and photonic applications even at room temperature. Especially quantum wells and multi-quantum wells can function as light emitting sources inside photonic devices. Therefore, thin ZnO films have been grown in a plasma-assisted molecular beam epitaxy system using Silicon (111) substrates. Growth conditions were systematically studied using ex-situ atomic force microscopy (AFM), x-ray diffraction (XRD) and photoluminescence (PL). Due to the large mismatch between the in-plane lattice constants of ZnO(0001) and Si(111), usually granular films are obtained. A solution capable of overcoming the effects of the undesired mismatch is achieved by inducing a low-temperature ZnO buffer layer between the substrate and the ZnO film. The effects of the additional buffer layer are studied and optimized in order to obtain a high-temperature ZnO film on top of the buffer layer with high-quality.

HL 32.7 Mon 17:00 P2

Persistent Photoconductivity of ZnO nanowires — •Martin Dickel, Manfred Madel, Florian Huber, Bruno Amann, and Klaus Thonke — Institute of Quantum Matter / Semiconductor

Physics Group, University of Ulm

A very striking characteristic of ZnO is the persistent photoconductivity (PPC). During illumination with light in the UV region, the conductivity increases, and after switching off the light, the photocurrent persists with decay times of hours. This effect is related to oxygen vacancies acting as shallow donors, which can undergo a large lattice relaxation. Also the ambient plays a important role in the PPC behaviour, especially the adsorption and desorption of oxygen from the surface. Overall this effect is still not completly understood.

In this contribution we investigate the role of temperature and different gases on the decay of the PPC. By this method, the oxygen concentration can be detected down to the lower ppm range.

HL 32.8 Mon 17:00 P2

Patterned growth of ZnO nanowires on the 10 μm to 200 nm scale — •Florian Huber[1], Manfred Madel[1], Julian Jakob[1], Dominik Heinz[2], Manuel Hartmann[3], Alfred Plettl[3], Ferdinand Scholz[2], and Klaus Thonke[1] — [1]Institute of Quantum Matter / Semiconductor Physics Group, Ulm University — [2]Institute of Optoelectronics, Ulm University — [3]Institute of Solid State Physics, Ulm University

Two different approaches for the structured growth of ZnO nanowires via chemical vapour deposition (CVD) were realized. On the one hand GaN pyramids grown via metalorganic vapour phase epitaxy (MOVPE) were used to control the alignment of the nanowires. On the other hand several types of substrates were patterned using PS-lithography. Both methods show a very good alignment over wide ranges. The diameter of the nanowires could be controlled from 400 nm down to less than 100 nm. Furthermore different filling factors could be realized. An additional method for a controlled positioning of single nanowires via dielectrophoresis was established. This enables the investigation of the gas sensing behaviour of single nanowires with varying diameters via an optical readout in micro-photoluminescence measurements under different gas atmospheres.

HL 32.9 Mon 17:00 P2

Linear and nonlinear optical deformation potentials in bent ZnO microwires — •Sherzod Khujanov, Christof P. Dietrich, Jörg Lenzner, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnestr. 5, 04103 Leipzig, Germany

The wide-band gap semiconductor ZnO has outstanding optical and piezoelectrical properties that can be modified under tensile and compressive strain [1]. The piezoelectric coefficient of ZnO is at least twice as high as for other II-IV compounds with wurtzite crystal structure. Hexagonal zink oxide microwires were fabricated by using a vapor-phase transport process [2] at temperature of 1150 °C . The grown wires have diameters in the range of $0.5 - 50\ \mu m$ and lengths between 0.1 and 20 mm. For low temperature cathodoluminescence measurements, the microwires were transferred onto silicon substrates, mechanically bent and fixed with silver paste. Linescans (in steps of 100 nm) from the tensile to the compressivly strained part of the wires revealed different strain regimes. We observe a linear energy shift for uniaxial strain up to ±1.5% and deduce a deformation potential which is in very good agreement to previous studies [1]. For higher strain values (up to ±3%), we are observed the onset of nonlinear effects.

[1] C. P. Dietrich, *et al*: Appl. Phys. Lett. 98, 031105 (2011).
[2] M. Lorenz *et al*: Phys. Stat. Sol.(b) 247, 1265 (2010).

HL 32.10 Mon 17:00 P2

Effect of external magnetic field on the photoresistance of ZnO based wires — •Israel Lorite[1], Carlos Ivan Zalandazini[2], Silvia Perez[2], and Pablo Esquinazi[1] — [1]Division of Superconductivity and Magnetism, Institute for experimental Physics II, Fakultät für Physik und Geowissenschaften, Linnéstrasse 5, 04103 Leipzig, Germany — [2]Laboratorio de Física del Sólido, Dpto. de Física, FCEyT, Universidad Nacional de Tucumán, 4000 Tucumán, Argentina

An exhaustive study of the effect of the external magnetic field on the transient photoresitance of Hydrogen implanted Li doped ZnO was carried out. The wire was illuminated with light at different wavelength; 549 nm, 500 nm and 370 nm, respectively. A variation of the relaxation time is observed when external magnetic field is applied. This variation changes as a function of the used light to illuminate the wire and the intensity of the magnetic field. This variation is interpreted by means of the electronic state variation of the point defects of ZnO, such as oxygen vacancies, Vo, after illumination. The Vo can be single ionized, Vo+. Since the Vo+ presents net magnetic moment, the external magnetic field could change its spin state. This change would increase the probability of the photo generated electron-hole recombination to reduce the transient photo resistance time.

HL 32.11 Mon 17:00 P2

Comparative study of deep defects in ZnO microwires, thin films and bulk single crystals — •Florian Schmidt[1], Thorsten Schultz[1], Stefan Müller[1], Holger von Wenckstern[1], Christof Peter Dietrich[1], Robert Heinhold[2], Hyung-Suk Kim[2], Martin Ward Allen[2], and Marius Grundmann[1] — [1]Universität Leipzig, Institut für Experimentelle Physik II, Abteilung Halbleiterphysik, Linnéstraße 5, 04103 Leipzig — [2]The MacDiarmid Institute for Advanced Materials and Nanotechnology, University of Canterbury, Christchurch 8043, New Zealand

In this study we report on the electrical properties and deep-level defects of a ZnO microwire grown by carbo-thermal evaporation, a pulsed laser deposited ZnO thin film and a hydrothermally grown ZnO bulk crystal. Deep defects were investigated by means of deep-level transient spectroscopy. The origin of a defect labelled T2 is assumed to be a donor-acceptor complex, with its concentration being limited by the acceptor involved [1]. Our investigations suggest the zinc vacancy V_{Zn} as a possible candidate for the acceptor. From first-principles studies it is known that V_{Zn} has a smaller formation energy for a higher Fermi level which is proportional to the net-doping density in our samples. That would suggest that the formation of such an acceptor is most likely in the PLD thin film, followed by the bulk sample and the microwire which is supported by the experiment [2].

[1] M. Schmidt *et al.*, phys. stat. sol. **249**, 588 (2012).
[2] F. Schmidt *et al.*, Appl. Phys. Lett. **103**, 062102 (2013).