HL 50: ZnO: Tansport

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HL 50.1 Thu 14:00 ER 164

Conductivity of single ZnO Nanorods after Ga-Implantation in a Focused-Ion-Beam System — •Daniel Weissenberger[1], Michael Dürrschnabel[1], Dagmar Gerthsen[1], Fabián Pérez Willard[1,2], Anton Reiser[3], Günther Prinz[3], Martin Feneberg[3], Klaus Thonke[3], and Rolf Sauer[3] — [1]Laboratorium für Elektronenmikroskopie, Universität Karlsruhe, D-76128 Karlsruhe, Germany — [2]Center for Functional Nanostructures (CFN), Universität Karlsruhe, D-76128 Karlsruhe, Germany — [3]Institut für Halbleiterphysik, Universität Ulm, D-89081 Ulm, Germany

Electrical transport measurements on single Ga^+-implanted ZnO nanorods are presented in this contribution. The nanorods were grown by the vapor solid liquid technique and electrically contacted using a procedure based on electron-beam lithography. The implantations were carried out in a combined scanning electron microscope/focused-ion-beam system with doses between 10^{11} and 10^{17} cm^{-2}. At implantation doses of about 10^{14} cm^{-2}, a maximum of the resistance is observed, which we attribute to the decrease of carrier mobility due to lattice defects. High-resolution transmission electron microscopy shows that a high density of stacking faults is generated which consist of inserted (0002) planes perpendicular to the current flow. At high implantation doses, a significant reduction of the resistance is observed. Low specific resistivities of about 3x10^{-3} Ωcm are reached without additional annealing treatment after high-dose implantation [1].

[1] D. Weissenberger et al., Appl. Phys. Lett. 91, 132110 (2007).

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Magnetotransport and Transport Properties of Compacted ZnO Nanoparticles — •Sonja Hartner[1,2], Moazzam Ali[3], Hartmut Wiggers[2], Axel Lorke[1], and Markus Winterer[3] — [1]Experimental Physics and CeNIDE, Universität of Duisburg-Essen, Duisburg, Germany — [2]Institute for Combustion and Gas Dynamics, Universität of Duisburg-Essen, Duisburg, Germany — [3]Nanoparticle Process Technology, Universität of Duisburg-Essen, Duisburg, Germany

The present study investigates the magnetotransport properties of compacted pellets of nanosized ZnO powders using Hall measurements and impedance spectroscopy (IS). Measurements performed at room temperature show a clear Hall voltage and an ohmic transport behavior. The doped ZnO particles exhibit n-type semiconducting behavior. A charge carrier concentration which is far below the value of bulk material and a mobility of 5 cm^2/Vs, which is half of the value for bulk material are determined. The compacted ZnO nanoparticles show a decreasing mobility with increasing carrier concentration. The IS was performed in air and in hydrogen atmosphere at temperatures ranging from 323K to 673K. By doping the ZnO with 7% aluminum, the conductivity increases by two orders of magnitude in comparison to undoped ZnO. At 523K in hydrogen atmosphere, the conductivity is up to seven orders of magnitude higher than for room temperature and exhibits a positive temperature coefficient as it is known from metallic conductors. The differing properties are attributed to a change in the oxygen vacancy concentration of the sample material.

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ZnO-based MIS diodes — •Heiko Frenzel, Holger von Wenckstern, Holger Hochmuth, Gisela Biehne, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany

Metal-Insulator-Semiconductor(MIS)-diodes with ZnO as the semiconductor and high-k-dielectric oxides as insulator were fabricated using pulsed laser deposition (PLD). Metal contacts were deposited either by thermal evaporation or dc sputtering. Back contacts were realized by a thin degenerated Al-doped ZnO layer [1]. The MIS-diodes were investigated by I-V, quasi-static and dynamic C-V measurements, respectively. For polycrystalline 100 nm thick Al_2O_3 films and Pt-contacts on ZnO, dielectric constants between 9 and 16 have been found. The leakage current for such samples lies in the range of picoamperes for electric fields up to 1.5 MV/cm. C-V measurements reveal a negative shift of the flatband voltage due to positive oxide charges. Annealing experiments have been carried out to improve the dielectric properties of the gate oxide and to reduce parasitic charges. The non-intentionally doped ZnO-MIS-diodes show typical n-type behavior with accumulation and depletion regime and net doping concentrations between 10^{14} and 10^{17} cm^{-3}. Inversion regime should be achieved generating minority charge carriers by irradiating with ultraviolet ($hf > E_g$) light.

[1] H. von Wenckstern *et al.*, Appl. Phys. Lett. **88**, 092102 (2006)

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Modelling of the frequency and temperature dependence of ZnO Schottky diode capacitance — •Martin Ellguth[1], Matthias Schmidt[2], Alexander Lajn[1], Holger von Wenckstern[1], Rainer Pickenhain[1], and Marius Grundmann[1] — [1]Universität Leipzig, Leipzig, Germany — [2]Forschungszentrum Dresden–Rossendorf e.V., Dresden, Germany

Understanding conduction in semiconductors requires knowledge about incorporated electrically active defects. Commonly, capacitance–spectroscopical methods like capacitance–voltage, deep level transient– and thermal admittance spectroscopy (TAS) are used to characterize these defects. We analyze such measurements by modelling the current–free Schottky diode capacitance. We solve numerically Poisson's equation as well as the donor occupancy time–evolution.

Our model gives exact solutions for the temperature, voltage and probing frequency dependence of the capacitance. In contradiction to classical TAS analysis, our simulation models entire capacitance–temperature/frequency spectra instead of obtaining the defect parameters (energetical depth, concentration, and electron capture cross section) only from the turning points in measured spectra. Additionally, line shape analysis allows the determination of the concentrations of two energetically close–lying levels which cannot be obtained from classical TAS analysis. We applied our simulations on TAS data obtained from ZnO single crystals and thin films and were able to improve the accuracy of the values for the electron capture cross section and to determine the respective concentrations for each defect.

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Electrical characterisation of oxygen implanted ZnO thin films. — •Matthias Schmidt[1], Gerhard Brauer[1], Wolfgang Skorupa[1], Manfred Helm[1], Holger v. Wenckstern[2], Rainer Pickenhain[2], and Marius Grundmann[2] — [1]Forschungszentrum Dresden – Rossendorf e.V., Dresden, Germany — [2]Universität Leipzig, Leipzig, Germany

Since the achievement of reproducible p–type conduction is a premise for ZnO devices, it is necessary to minimize the donor–like defects causing n–type conduction. Up to now it is under discussion whether intrinsic defects like vacancies or unintentionally incorporated dopants like hydrogen or group three elements are the main source of donors.

In this work we set out to detect donor–like defects which have their origin in oxygen excess or deficiency. In order to generate only intrinsic defects and to minimize oxygen vacancies we implanted oxygen ions into ZnO thin films grown by pulsed laser deposition. After thermal annealing, rectifying palladium contacts were deposited. The rectifying behaviour of the samples has been characterized by current–voltage, and capacitance – voltage measurements. Trap concentrations and energetical depths were obtained from deep level transient–, and thermal – admittance – spectroscopy. In the oxygen implanted samples we found a trap with an energetical depth between 500 meV and 600 meV which was not detectable in virgin samples.

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Magnetoresistance in n-type conducting Co-doped ZnO — •Qingyu Xu[1], Lars Hartmann[1], Heidemarie Schmidt[1], Holger Hochmuth[2], Michael Lorenz[2], Daniel Spemann[2], and Marius Grundmann[2] — [1]Forschungszentrum Dresden-Rossendorf, Institut für Ionenstrahlphysik und Materialforschung, Bautzner Landstraße 128, 01328 Dresden, Germany — [2]Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstrasse 5, D-04103 Leipzig, Germany

Series of Co-doped Al-codoped ZnO films with electron concentration at 5 K ranging from 8.3×10^{17} cm^{-3} to 9.9×10^{19} cm^{-3} were prepared by pulsed laser deposition under different O_2 pressure and substrate temperature. The magnetoresistance (MR) effect was studied between

5 K and 290 K with fields up to 6 T, showing large electron concentration and temperature dependence. A large positive MR of 124 % has been observed in the film with the lowest electron concentration , while only negative MR of -1.9 % was observed in the film with highest electron concentration at 5 K. The positive MR is attributed to the quantum correction on the conductivity due to the s-d exchange interaction induced spin-splitting of the conduction band [1]. The negative MR is attributed to the magnetic field suppressed weak localization [1]. The modelled superimposed positive and negative MR agrees well with the experimentally observed MR and hints towards the physical origin of MR in Co-doped ZnO [2]. [1] P. A. Lee et al. Rev. Mod. Phys. 57, 287 (1985) [2] Q. Xu et al. Phys. Rev. B 76, 134417 (2007)

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Determination of the free charge carrier profile in ZnO films
— •Chris Sturm[1], Holger von Wenckstern[1], Rüdiger Schmidt-Grund[1], Matthias Brandt[1], Tsvetan Chavdarov[1], Bernd Rheinländer[1], Carsten Bundesmann[2], Holger Hochmuth[1], Michael Lorenz[1], Mathias Schubert[3], and Marius Grundmann[1] — [1]Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig — [2]Leibniz-Institut für Oberflächenmodifizierung e.V., 04318 Leipzig — [3]Department of Electrical Engineering, University of Nebraska-Lincoln, 68588-0511 Lincoln, Nebraska, USA

Non-polar ZnO is a promising material for optoelectronic applications since internal electric fields are avoided. For ZnO based devices such as LEDs, FETS and microcavities ZnO-Al_2O_3 heterostructures are of interest, e.g. as electrical barrier. However it was found that a thin layer in ZnO near to the ZnO-Al_2O_3 interface shows a high free charge carrier concentration. We present investigations of the thickness and the free charge carrier concentration of this layer using two complementary methods: infrared spectroscopic ellipsometry and Hall measurements.

The nominally undoped non-polar ZnO films were grown by pulsed laser deposition *r*-plane sapphire substrates with different film thicknesses (30 nm − 600 nm). For all ZnO films we have found a remarkably higher free charge carrier concentration at the ZnO-sapphire interface compared to the remaining layer. We obtain an increasing charge sheet density with increasing film thickness. Attempts will be presented to clear up the origin of the experimentally found high concentration.