

HL 36: ZnO: preparation and characterization II

Time: Wednesday 14:00–16:15

Location: POT 51

HL 36.1 Wed 14:00 POT 51

Ultrafast exciton dynamics of highly excited ZnO — ●JAN-PETER RICHTERS¹, TINA SHIH², JÜRGEN GUTOWSKI¹, and TOBIAS VOSS¹ — ¹Institute of Solid State Physics, University of Bremen, P.O. Box 330440, D-28334 Bremen — ²School of Engineering and Applied Sciences and Department of Physics, Harvard University, Cambridge, MA, USA

Large band-gap semiconductors like ZnO are currently of great interest as light emitting material and lasing media in the blue-UV spectral range. In order to make use of these materials it is mandatory to understand the charge carrier dynamics and excitonic effects at high excitation densities.

We present results of pump-probe reflectance spectroscopy of c-plane and m-plane ZnO bulk material with a temporal resolution of $\Delta t < 200$ fs. The sample is excited using a frequency tripled (266 nm) Ti:Sapphire laser. The white light probe pulse ($300 \text{ nm} < \lambda_{\text{probe}} < 600 \text{ nm}$) is generated by converting the Ti:Sapphire pulse with a CaF₂ crystal. We analyze the results of the reflectivity measurements by use of an exciton polariton model, from which we can obtain damping, shift, and broadening of the exciton resonances. For excitation densities near to the damage threshold of ZnO, the resonance is completely bleached on a time scale of several tens of ps. Our results indicate that lasing in ZnO observed under high excitation densities using fs-lasers is most probably not an excitonic process, but needs to be described in the frame of a strongly Coulomb correlated electron-hole plasma.

HL 36.2 Wed 14:15 POT 51

Properties of reactively sputtered Ag, Au, Pd, and Pt Schottky contacts on n-type ZnO — ●ALEXANDER LAJN¹, HOLGER VON WENCKSTERN¹, GISELA BIEHNE¹, HOLGER HOCHMUTH¹, MICHAEL LORENZ¹, MARIUS GRUNDMANN¹, SANDRA KÜNZEL², CHRISTIAN VOGT², and REINHARD DENECKE² — ¹Universität Leipzig, Abteilung Halbleiterphysik, Institut für Experimentelle Physik II — ²Universität Leipzig, Physikalische Chemie der Oberflächen, Wilhelm-Ostwald-Institut für Physikalische und Theoretische Chemie

The contact properties of reactively sputtered Ag, Au, Pd, and Pt Schottky contacts on nominally undoped n-ZnO thin films prepared by pulsed-laser deposition on a-plane sapphire substrates are compared. Without any surface preparation rectifying contacts were reproducibly realized by dc sputtering in an Ar/O₂ atmosphere. The degree of oxidation of the contact metals was investigated by X-ray photoelectron spectroscopy (XPS). Furthermore current-voltage (*IV*), capacitance-voltage (*CV*) and capacitance-frequency (*Cf*) measurements were employed. Ideality factors and barrier heights determined from *IV* measurements between 20 K and 300 K depend strongly on temperature indicating lateral fluctuations of the barrier potential. Considering a Gaussian distribution of barrier heights permits to describe the temperature dependence of the ideality factor and the barrier for $T > 200$ K. Assuming thermionic emission being the only current transport process and taking the Gaussian distribution of barrier heights into account we were able to model the entire *IV* characteristic (forward and reverse current for $U = \pm 2$ V) at 300 K.

HL 36.3 Wed 14:30 POT 51

Properties of hydrogen doped ZnO thin films prepared by RF magnetron sputtering — ●ACHIM KRONENBERGER, MARC K. DIETRICH, STEVE PETZNICK, ANDREAS LAUFER, ANGELIKA POLITY, and BRUNO K. MEYER — I. Physikalisches Institut, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

In the 1950s E. Mollwo [1] observed the effect that hydrogen diffused into ZnO single crystals strongly decreases their resistivity. About 50 years later the forming of shallow donor levels due to hydrogen incorporation in ZnO was described theoretically by C. G. Van de Walle [2] and experimentally proved by several groups [3,4]. In our work hydrogen doped thin films have been prepared by radio frequency magnetron sputtering at different substrate temperatures using hydrogen and oxygen as reactive gases. The incorporation of hydrogen was quantified by secondary ion mass spectrometry and its influences on the structural, electrical and optical film properties have been investigated. By varying the deposition parameters we were able to adjust the electrical properties between semiconductor like and degenerated (highly conductive) behaviour for films deposited at room temperature.

[1]E. Mollwo, Z. Phys. 138 (1954) 478. [2]C. G. Van de Walle, Phys. Rev. Lett. 85 (2000) 1012. [3]D. M. Hofmann, A. Hofstaetter, F. Leiter, H. J. Zhou, F. Henecker, B. K. Meyer, S. B. Orlinskii, J. Schmidt, P. G. Baranov, Phys. Rev. Lett. 88 (2002) 045504. [4]S. F. J. Cox, E. A. Davis, S. P. Cottrell, P. J. C. King, J. S. Lord, J. M. Gil, H. V. Alberto, R. C. Vila*o, J. Piroto Duarte, N. Ayres de Campos, A. Weidinger, R. L. Lichti, and S. J. C. Irvine, Phys. Rev. Lett. 86 (2000) 2601.

HL 36.4 Wed 14:45 POT 51

Excitonic Recombination in MgZnO thin films — ●ALEXANDER MÜLLER, MARKO STÖLZEL, GABRIELE BENNDORF, HOLGER HOCHMUTH, MICHAEL LORENZ, and MARIUS GRUNDMANN — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany

We present time-resolved photoluminescence (TRPL) measurements on MgZnO thin films. The samples have been grown by pulsed laser deposition on a-plane sapphire. We used time-correlated single photon counting to investigate the luminescence decay. The measured transients have been fitted using the convolution of a model decay function with the device function.

Due to random fluctuations of the local potential, the photoluminescence (PL) emission of MgZnO shows a large mixed crystal broadening. In contrast to pure ZnO, for Mg contents of more than 3 % in the thin films it is not possible to spectrally resolve the luminescence bands using standard PL. Therefore, the origin of the luminescence is not well known.

In this contribution, we present the spectral and temperature dependence of the TRPL transients. For low temperatures, we observe a blue shift of the spectral luminescence maximum over time. This can be explained by a slow process at higher emission energies.

The transients could be fitted using a sum of two model decay functions. The time-integrated intensities of the model decays show different spectral maxima. We attribute these to the emission of donor-bound and free excitons.

15 min. break

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Strukturuntersuchungen an polykristallinem In₂O₃(ZnO)_m und InGaO₃(ZnO)_m — ●PATRICK KESSLER¹, REINER VIANDEN¹, WENTAO YU² und WERNER MADER² — ¹HISKP, Universität Bonn — ²Institut für anorganische Chemie, Universität Bonn

Transparente und leitende Oxid-Filme (TCO) sind Gegenstand aktueller Forschung, da sie als transparente Elektroden in optoelektronischen Anwendungen wie zum Beispiel Flachbildschirmen genutzt werden können. Weit verbreitet sind In₂O₃:Sn-Filme, die wegen der geringen Verfügbarkeit von In, sehr teuer geworden sind. Als Alternative werden In₂O₃-ZnO Systeme mit hoher ZnO Konzentration diskutiert, welche die gleichen optischen und elektrischen Eigenschaften aufweisen. Die genaue atomare Struktur dieser Filme ist noch nicht abschließend geklärt.

Untersucht wird deshalb In₂O₃(ZnO)_m und InGaO₃(ZnO)_m mit der Methode der gestörten γ - γ Winkelkorrelation (PAC). Dazu wird ¹¹¹In als Sondenatomen durch Diffusion in gepresstes Pulver eingebracht und bei 1300°C gesintert. Mit der PAC kann nun die direkte Sondenumgebung studiert werden.

Indium in In₂O₃(ZnO)_m befindet sich ab einer bestimmten Konzentration ($m > 6$) auf basalen Ebenen und sich dazwischen bildenden Zick-Zack Strukturen (ZZ), wie Messungen und theoretische Rechnungen zeigen. Bei InGaO₃(ZnO)_m wird das Gallium bevorzugt auf diesen ZZ Plätzen eingebaut und verdrängt dort das Indium. Dies kann nun mit der PAC durch Vergleich der Sondenumgebungen in In₂O₃(ZnO)_m und InGaO₃(ZnO)_m überprüft werden.

HL 36.6 Wed 15:30 POT 51

Deep levels in nitrogen implanted ZnO — ●MATTHIAS SCHMIDT¹, MARTIN ELLGUTH¹, FLORIAN SCHMIDT¹, THOMAS LÜDER¹, RAINER PICKENHAIN¹, MARIUS GRUNDMANN¹, GERHARD BRAUER², and WOLFGANG SKORUPA² — ¹Universität Leipzig, Institut für Experimentelle Physik II, 04103 Leipzig, Germany — ²Forschungszentrum Dresden – Rossendorf e.V., Dresden, Germany

We investigated deep levels in a nitrogen implanted, PLD grown ZnO thin film. Subsequent to the ion implantation the sample has been thermally annealed. In preparation of capacitance spectroscopy measurements a Schottky contact made from evaporated palladium was deposited on the sample. From capacitance – voltage measurements the spacial dependence of the net doping concentration was obtained. Deep level transient spectroscopy was employed for the characterisation of deep levels with binding energies $E_c - E_d < 700$ meV below the conduction band edge. The prominent deep level E3 and a deeper one with $E_c - E_d \approx 590$ meV were detected. The presence of further defects was proven by photo – capacitance and photo – current measurements. A strong increase of the capacitance as well as on the current was observed for excitation with energies approx. 200 meV below the bandgap. This behaviour hints to the existence of a trap close to the valence band edge.

HL 36.7 Wed 15:45 POT 51

Nitrogen doping of ZnO — •MICHAEL HOFMANN¹, MELANIE PINNISCH¹, ANDREAS LAUFER¹, SEBASTIAN ZÖLLER¹, SEBASTIAN EISERMANN¹, STEFAN LAUTENSCHLÄGER¹, BRUNO K. MEYER¹, GORDON CALLISON², MARKUS R. WAGNER², and AXEL HOFFMANN² — ¹Ist physics insitute, Justus Liebig University Gießen — ²institute for semiconductor physics, Hardenbergstraße, Berlin

The controlled incorporation of acceptors into the ZnO matrix is still

a not well understood obstacle for the fabrication of bipolar ZnO devices. We investigated the incorporation of nitrogen using low growth temperatures, different nitrogen precursors and polar or non polar ZnO surfaces. To characterize our thin films we used Raman spectroscopy, low temperature photoluminescence and secondary ion mass spectrometry measurements. It turned out that certain conditions, especially substrate polarity and temperature, favour the nitrogen incorporation.

HL 36.8 Wed 16:00 POT 51

On Cu diffusion in ZnO — •F. HERKLOTZ, E.V. LAVROV, and J. WEBER — Technische Universität Dresden, 01062 Dresden, Germany

Copper in ZnO is of special interest since recent theoretical and experimental studies found ferromagnetic behavior of ZnO:Cu at room temperature. In addition, Cu is a deep acceptor in ZnO and one of the causes of the green emission band.

Experimental studies of Cu diffusion in bulk ZnO single crystals were carried out in the temperature range 1030 to 1180 °C. Concentration profiles of substitutional Cu were determined via IR absorption at 5817 cm⁻¹. Our findings reveal that the diffusion coefficient of Cu is $7.6 \times 10^7 \exp(-4.56 \text{ eV}/k_B T) \text{ cm}^2 \text{ s}^{-1}$. This is about a factor of 25 higher than reported in the earlier studies, which probed the total Cu concentration. The discrepancy is explained by the formation of Cu complexes, which occurs at high concentrations. Diffusion mechanisms are discussed.