HL 5: Nitrides: mostly transport properties and recombination processes

Time: Monday 9:30–11:00 Location: POT 251

HL 5.1 Mon 9:30 POT 251

Non-radiative recombination mechanisms in GaN by first-principles total energy calculations — •Ying Cui, Christoph Freysoldt, and Jörg Neugebauer — Max-Planck-Institut für Eisenforschung, Max-Planck-Str. 1, 40627 Düsseldorf

Non-radiative recombination limits the efficiency of GaN based LEDs. However, the chemical nature and atomic geometry of the recombination centers and their recombination cross-sections are generally not known. Employing a Shockley-Read-Hall model, we propose a one-dimensional (1-D) model to locate the transition state in the capture process using the defect level occupation as a natural reaction coordinate. The calculations are based on density functional theory with hybrid functional (HSE). Employing this approach, we obtain the electron (hole) capture cross-sections, which can be directly compared with experimental results, such as deep-level transient spectroscopy(DLTS). Among all the defects in our study, nitrogen vacancies show the largest potential to be effective non-radiative recombination centers. Their calculated activation energy and electron capture cross-sections agree well with experimental data reported in literature.

HL 5.2 Mon 9:45 POT 251

Recombination rates in GaInN/GaN quantum wells: Beyond the ABC model — •Torsten Langer[1], Alexey Chernikov[2], Dimitri Kalincev[2], Marina Gerhard[2], Heiko Bremers[1], Uwe Rossow[1], Martin Koch[2], and Andreas Hangleiter[1] — [1]Institute of Applied Physics, Technische Universität Braunschweig — [2]Faculty of Physics and Materials Science Center, Philipps-Universität Marburg

We report on an excitonic enhancement of recombination processes in GaInN/GaN single quantum wells being evident from temperature and density dependent time-resolved photoluminescence spectroscopy over a wide range of excitation densities. The proposed method allows for a determination of the radiative and nonradiative recombination times as a function of the excess carrier density (rather than a function of the generation rate) free of any a priori assumptions on the dynamics of the recombination processes. Excitonic radiative recombination is evidenced by density independent radiative lifetimes in the high injection regime, i.e. excess densities are larger than the background density. The transition from low to high injection is calibrated via the observed increase of Shockley-Read-Hall lifetimes in the intermediate regime. At high densities, a weak temperature dependence of non-radiative lifetimes that are proportional to the inverse of the density imply an excitonic, threshold-less Auger process. The density dependence of both radiative and nonradiative lifetimes thus differs strongly from the predictions of simple free-carrier ABC models.

HL 5.3 Mon 10:00 POT 251

Reduced electron accumulation at InN(0001) surfaces via saturation of surface states by donor- or acceptor-type adsorbates — •Stephanie Reiss, Anja Eisenhardt, Stefan Krischok, and Marcel Himmerlich — Institut für Physik and Institut für Mikro- und Nanotechnologien, Technische Universität Ilmenau, PF 100565, 98684 Ilmenau, Germany

We investigate the impact of selected donor- and acceptor-type adsorbates (potassium and oxygen) on the electronic properties of InN(0001) surfaces implementing in-situ photoelectron spectroscopy. Potassium adsorption leads to a strong decrease in the work function Φ from initially 4.4 to 1.6 eV indicating electron transfer from K adatoms towards the InN surface. In parallel, a reduction of the surface downward band bending V_{bb} by 0.2 eV and the formation of potassium induced electron states close to the valence band maximum are observed. The interaction of oxygen induces an increase of Φ up to 5.2 eV due to an opposite charge transfer towards the adsorbate and a reduction of V_{bb} by 0.4 eV. The depletion of the surface electron accumulation layer in both cases can be explained by adsorbate-induced saturation of free dangling bonds at the InN surface resulting in the disappearance of surface states, which initially pin the Fermi level and induce downward band bending. The results prove that the electronic structure can be modified by adlayers resulting in a possible pathway for compensation of the surface electron accumulation.

HL 5.4 Mon 10:15 POT 251

Formation of Schottky contacts on n-type GaN bulk crystals grown by hydride vapor phase epitaxy (HVPE) — •Ronald Stübner[1], Vladimir Kolkovsky[1], Jörg Weber[1], Gunnar Leibiger[2], and Frank Habel[2] — [1]Technische Universität Dresden, 01062 Dresden, Germany — [2]Freiberger Compound Materials GmbH, 09599 Freiberg, Germany

In the present study we investigate the formation of Schottky contacts on GaN grown by hydride vapor phase epitaxy (HVPE). Evaporated silver exhibits good rectifying contacts with leakage currents of about 10^{-5} A cm^{-2} and a rectification ratio of about 2000 on as-grown n-type GaN for small growth ratios between N and Ga. Contacts have no rectifying behavior in samples grown at a higher ratio of N/Ga. We correlate these observations with the presence of negatively charged gallium vacancies in our samples. They compensate the positively charged donors and lead to a significant increase in series resistance. Deep level transient spectroscopy studies reveal two deep level defects E250 and E610 in our samples. The results are consistent with the previous assignment of E250 to a defect containing a gallium-vacancy [1] and E610, which was attributed to the nitrogen antisite [2]. [1] Z.-Q. Fang *et al.* Appl. Phys. Lett. **78**, 332 (2001). [2] P. Hacke *et al.*, J. Appl. Phys. **76**, 304 (1994).

HL 5.5 Mon 10:30 POT 251

Electrical properties of Si-doped AlGaN layers with high aluminum mole fraction — •Harald Pingel[1], Frank Mehnke[1], Eberhard Richter[2], Frank Brunner[2], Tim Wernicke[1], Christian Kuhn[1], Viola Kueller[2], Arne Knauer[2], Michael Lapeyrade[2], Markus Weyers[2], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Germany — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin, Germany

The electrical properties of Si-doped $Al_xGa_{1-x}N$ layers with $x > 0.8$ were studied by temperature-dependent resistance and Hall measurements. $Al_xGa_{1-x}N$:Si layers with a thickness of 1.2 μm – 1.6 μm were grown by metal organic vapor phase epitaxy using TMAl, TMGa, NH_3 as precursors and SiH_4 and H_2 as dopant source and carrier gas, respectively. A set of samples with different aluminum content and SiH_4/III-ratios was investigated. At room temperature the resistivity strongly depends on the aluminum content as well as the SiH_4/III-ratio. With increasing aluminium content the resistivity increases from 0.07 Ωcm ($x = 0.82$) to 4.3 Ωcm ($x = 0.95$) at a constant SiH_4/III-ratio of 2×10^{-5}. A distinct minimum in the resitivity was found for a series of SiH_4/III-ratios. In order to investigate the cause of this behavior, the charge carrier density, the resistivity and the mobility were measured between 300 K and 720 K. From this, the donor densities and the activation energies were determined. The increase in resistivity for increasing aluminum content could be attributed to an increase in the donor activation energy.

HL 5.6 Mon 10:45 POT 251

Field-dependent photoluminescence of InAlN/GaN based HEMT structures — •Christoph Koch[1], Martin Feneberg[1], Rüdiger Goldhahn[1], María Fátima Romero[2], Fernando Calle[2], Zhan Gao[2], María Ángeles Pampillón[3], Enrique San Andrés[3], Pedro C. Feijoo[3], and Pavel Y. Bokov[4] — [1]Otto-von-Guericke Universität, Magdeburg, Germany — [2]Universidad Politécnica de Madrid, Madrid, Spain. — [3]Universidad Complutense de Madrid, Madrid, Spain — [4]Moscow State University, Moscow, Russia

The optical properties of InAlN/GaN based HEMT structures were examined by field-dependent photoluminescence spectroscopy as a function of temperature.

Samples grown on Si subtrate were investigated. On top of a thick GaN buffer layer, an InAlN barrier of 10 nm causes a two-dimensional electron gas (2DEG), which dominates PL spectra at low temperatures at energies slightly below the donor-bound exciton. Semi-transparent metal contacts were processed either directly on top of the structures or seperated by an additional high-k dielectric, serving as Schottky or MIS diodes, respectively. Free exciton recombinations of the GaN buffer were observed for higher temperatures and allow determination of the strain in the GaN layer. Due to sample structure PL measurements exhibit mostly GaN related features.

PL spectra with varying voltages and thus modified band diagrams were systematically studied. Consequently, a voltage-dependent shift of 2DEG related luminescence is observed, corroborating the assignment of this band to a 2DEG to free-hole transition.