HL 65: GaN-based Devices

Time: Friday 10:15–12:45 Location: H15

HL 65.1 Fri 10:15 H15

Calculation of optical eigenmodes and gain in semipolar and nonpolar InGaN/GaN laser diodes — •Wolfgang Scheibenzuber and Ulrich Schwarz — Fraunhofer IAF, Freiburg, Deutschland

Growth on semipolar and nonpolar crystal planes poses a possibility to reduce polarization fields and thereby enhance stimulated emission in (Al,In)GaN laser diodes. In this case the anisotropic optical properties of wurtzite (Al,In)GaN influence the optical eigenmodes of the laser waveguide and the optical gain .

This contribution reports the calculation of the optical eigenmodes in semipolar and nonpolar laser diodes taking into account the birefringence of GaN. Furthermore it shows calculations of the optical gain in such devices based on self-consistent 6x6 k*p valence band calculations.

Depending on the orientation of the laser diode's ridge waveguide relative to the c-axis, the eigenmodes of the laser diode are TE-/TM-modes or extraordinary/ordinary modes polarized along the crystal directions. The polarization of the eigenmodes then enters the calculation of the optical gain. Resulting spectra for c-plane, semipolar and nonpolar structures are compared at different charge carrier densities. It is found that for high indium concentrations the gain can be significantly increased by going from the c-plane to a semipolar or nonpolar crystal orientation. However, due to birefringence and composition of the topmost valence band wavefunction, the ridge has to be oriented along the projection of the c-axis on the growth plane.

HL 65.2 Fri 10:30 H15

Anisotropy in semipolar InGaN laser diodes: Consequences for resonator design and facet formation — •Jens Rass[1], Tim Wernicke[2], Wilfred John[2], Sven Einfeldt[2], Patrick Vogt[1], Markus Weyers[2], and Michael Kneissl[1,2] — [1]Technische Universitaet Berlin, Institute of Solid State Physics, Hardenbergstrasse 36, 10623 Berlin — [2]Ferdinand-Braun-Institut fuer Hoechstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin

For InAlGaN-based light emitting devices on nonpolar and semipolar substrate orientations the polarization fields can be reduced. Birefringence and gain anisotropy influence the optical modes of semipolar separate confinement hetero structures. We have investigated the threshold for amplified spontaneous emission and the optical polarization state of the eigenmodes for laser resonators with different orientations on various semipolar and nonpolar substrates. We found that semipolar resonators along the projection of the c-axis onto the surface have a lower threshold and the light is TE-polarized. Nonpolar resonators perpendicular to the c-axis on the other hand have elevated thresholds and hence a lower gain as well as a tilted linear optical polarization with the electric field nearly parallel to the c-axis of the crystal.

In order to obtain devices with low threshold and maximum performance, laser resonators on semipolar substrates have to be oriented along the semipolar orientation, posing a challenge for the fabrication of laser facets. Technologies such as laser assisted cleaving, chemical dry etching and wet chemical post processing are presented and their suitability for the generation of smooth vertical facets is discussed.

HL 65.3 Fri 10:45 H15

GaN-based laser structure with semipolar InGaN QWs realized by selective area epitaxy — •Thomas Wunderer[1], Johannes Biskupek[2], Andrey Chuvilin[2], Ute Kaiser[2], Yakiv Men[3], Junjun Wang[1], Frank Lipski[1], Stephan Schwaiger[1], Kamran Forghani[1], and Ferdinand Scholz[1] — [1]Institute of Optoelectronics, Ulm University, Germany — [2]Central Electron Microscopy Facility, Ulm University, Germany — [3]Institute of Electron Devices and Circuits, Ulm University, Germany

It was shown that by the use of selective area epitaxy three dimensional (3D) GaN structures can be realized providing semipolar surfaces. Using this technique a high material quality can be achieved on low-cost full 2 inch c-oriented sapphire wafers. It was shown that InGaN/GaN MQWs or even complete light emitting diode (LED) structures can be realized by growing the respective layers on these facets.

Now, we successively reduced the size of the 3D GaN structures in order to implement the semipolar QWs in a conventionally grown, well working laser structure. Therefore, the mask period of the structures were reduced to a lateral dimension of just 240nm using electron beam lithography and sputter coating of SiO2 mask deposited on the lower AlGaN cladding layer. Then, the active area consisting of an InGaN QW is grown on the 3D GaN structures and planarized by GaN grown under 2D conditions. The GaN layers, representing a waveguide layer, and the zigzag grown semipolar QW are embedded in planar AlGaN cladding layers as known from standard devices. Detailed structural analyses including TEM as well as optical properties will be presented.

HL 65.4 Fri 11:00 H15

Heterostructure design optimisation of (In)AlGaN deep ultraviolet light emitting diodes — •T. Kolbe[1], T. Sembdner[1], A. Knauer[2], V. Küller[2], H. Rodriguez[2], S. Einfeldt[2], P. Vogt[1], M. Weyers[2], and M. Kneissl[1,2] — [1]TU Berlin, Institute of Solid State Physics, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany

Ultraviolet (UV) light emitting diodes (LEDs) based on III-nitride semiconductors have attracted great interest in recent years. However, due to weak carrier confinement, strong piezoelectric fields and high defect densities the external quantum efficiency of UV LEDs is still only a few percent.

We have investigated 316 nm (In)AlGaN LEDs with one, three, five and seven quantum wells (QWs). The carrier injection in the devices is simulated and compared to electroluminescence measurements. The emission power of all devices is nearly the same due to a strongly inhomogeneous carrier distribution between the wells. In the secound series (In)AlGaN multi-quantum-well UV LEDs with a varying QW thickness of 1.5 nm, 2.2 nm and 3.2 nm have been investigated. We could show that the light output power depends strongly on the QW thickness. The highest output power was obtained for the LEDs with a QW thickness of 2.2 nm. This effect is attributed to the interplay between electron and hole wave function overlap and carrier concentration in the active region.

HL 65.5 Fri 11:15 H15

GaN-based LEDs on 200 mm diameter substrates — Adam Boyd[1], Hannes Behmenburg[1,2], Olaf Rockenfeller[1], Bernd Schineller[1], and •Michael Heuken[1,2] — [1]AIXTRON AG, Herzogenrath, Germany — [2]Inst. f. Theoretische Elektrotechnik, RWTH-Aachen, Aachen, Germany

We report on the growth of GaN-based structures on 200 mm sapphire and silicon by MOCVD using a CRIUS® Close Coupled Showerhead® reactor. The temperature profile was monitored in real time using an ARGUS pyrometer scanner and continuously adapted by adjusting the power to the three radial heater zones. A deflectometer was used to monitor the wafer curvature in the radial direction. To gauge the uniformity of a GaN nucleation layer on sapphire a thick layer was grown under nucleation layer growth conditions (530°C growth temperature, 900 mbar total pressure, 1 h duration). Ex-situ white-light interference measurements yielded a standard deviation of the thickness uniformity of 0.25% (6 mm edge exclusion). Under these conditions the uniformity approaches that of the gas phase delivery. Similar mapping of an LED structure gave 5.34 μm total thickness with a standard deviation over the wafer of 2.1%. The InGaN / GaN multiple quantum well peak wavelength uniformity was assessed by photoluminescence and indicated an average of 502 nm peak wavelength with a standard deviation of 10.7 nm. Results from an iteration of the edge design of the wafer recess as well as additional in-situ data and post growth material assessment will also be presented.

15 Min. Coffee Break

HL 65.6 Fri 11:45 H15

Electrical and Optical Characteristics of GaN based MSM Photodetectors — •Martin Martens[1], Jessica Schlegel[1], Patrick Vogt[1], Frank Brunner[2], Richard Lossy[2], Joachim Würfl[2], Markus Weyers[2], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, EW 6-1, 10623 Berlin — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin

GaN metal-semiconductor-metal (MSM) structures are attractive candidates for ultraviolet (UV) photodetectors because of their fabrication

simplicity and their potentially high quantum efficiency, high UV/VIS contrast and high speed. We have characterized MSM UV photodetectors fabricated on semi-insulating GaN by photocurrent spectroscopy and current-voltage (I-V) measurements. The responsivity spectra show a sharp cut-off at 365 nm according to the GaN band gap and high response at shorter wavelengths. Under UV-VIS illumination we measured photocurrents up to 1 mA depending on the applied bias. These high currents indicate an internal gain mechanism which was investigated by photocurrent measurements for different bias and light intensities. After switching off the light the photocurrent decays slowly indicating a persistent photoconductivity (PPC) effect. Therefore the dark I-V characteristics were measured after the samples had been kept in the dark for several hours. Under these conditions the dark current is in the range of 10 nA at 50 V. Subsequent I-V measurements show a degradation in the I-V characteristics suggesting a trap-related effect to cause this behaviour.

HL 65.7 Fri 12:00 H15

Quantum corrections to the Drude conductivity in $Al_xGa_{1-x}N$/GaN two-dimensional electron gas — •Stepan Shvarkov, Andreas Jupe, Dirk Reuter, and Andreas D. Wieck — Ruhr-Universität Bochum, Deutschland

The magnitotransport properties of Gd-implanted $Al_xGa_{1-x}N$/GaN heterostructures are studied. We observe an increase of the longitudinal resistance with decreasng temperature < 80 K. This is atributed to both electron-electron interactions and weak localization. The presence of Gd atoms in the sample makes Kondo effect also possible, but due to the fact that the behavior of the Kondo effect and weak localization with temperature and magnetic field change are very similar, further studies of these effects in $Al_xGa_{1-x}N$/GaN are necessary and currently under way.

HL 65.8 Fri 12:15 H15

Long term investigations of neuronal cell cultures with AlGaN/GaN-based HEMTs — •H. Witte[1], C. Warnke[1], T. Voigt[2], A. de Lima[2], and A. Krost[1] — [1]Inst. of Experimental Physics, University of Magdeburg, Magdeburg — [2]Inst. of Physiology, University of Magdeburg, Magdeburg

Planar devices based on metal layers or Si-devices are widely used for the detection of electrical activity of neuron cells. As an alternative more and more AlGaN/GaN- based devices are applied for analysis of biological molecules and single cells. Otherwise, the use of AlGaN/GaN based high electron transistors (HEMTs) as sensors for biological networks are seldom up to now. We have applied AlGaN/GaN HEMTs for monitoring the growth behavior of neurons from embryonic rat cerebral cortex form active networks after one week in vitro. Both, the source-drain current at 0.1 V bias as well as the frequency dependent impedance at zero voltage were measured within the time regime of culturing during some days. From these investigations we can distinguish the culture medium and the changes due to the growing neuron cell network. Results from long term investigations will be compared with phenomena of long term stimulation using a gold electrode / neuron network interface with respect to damaging processes by electrical fields. This knowledge is the basic for the detection of mechanism, e.g. of the energy metabolism.

HL 65.9 Fri 12:30 H15

Recording glycolytic oscillations in yeast cells using AlGaN/GaN high electron mobility transistor (HEMT) — •Christian Warnke[1], Hartmut Witte[1], Thomas Mair[2], Marcus J. B. Hauser[2], and Alois Krost[1] — [1]Otto-von-Guericke-Universität Magdeburg, Inst. Exp. Phys., Abt. Halbleiterepitaxie — [2]Otto-von-Guericke-Universität Magdeburg, Inst. Exp. Phys., Abt. Biophysik

Glycolytic oscillations in yeast cells are a well documented example of a macroscopic oscillator in biology. Methods for recording the glycolytic oscillations are the measurement of the NADH-fluorescence and impedance of a planar yeast cell/blank metal electrode interface [1]. As a new approach we used the source-drain-current and the impedance of a gateless AlGaN/GaN High Electron Mobility Transistor (HEMT) with different insulating surface layers. We show that these HEMTs exhibit a strong dependence of their resistance and capacitance when electrolytic solutions with different conductance and pH-values are placed on these HEMTs. We have measured the dielectric behavior of living yeast cells with these HEMTs. The measured period agrees well with results from control measurements via optical methods. We detected that the fluorescence of the yeast cells strongly enhances the signal output of the HEMTs. It was found that this signal enhancement results from photosensitivity of the insulating Durimide layer.

[1] Reiher, A. et al.: Electrical stimulation of the energy metabolism in yeast cells using planar Ti-Au-Electrode interface, J. Bioenerg. Biomembr. 38 (2006), 143-148.