HL 11: Focused Session: Semi- and nonpolar group III nitrides I

Time: Tuesday 9:30–12:45 Location: HSZ 01

Topical Talk HL 11.1 Tue 9:30 HSZ 01

Characterization and Control of Recombination Dynamics in Low-dimensional InGaN-based Semiconductors — •Yoichi Kawakami, Akio Kaneta, Masaya Ueda, and Mitsuru Funato — Department of Electronic Science and Engineering, Kyoto University, Kyoto 615-8510, Japan

We have recently proposed the re-growth technique, where c-oriented (0001) GaN is used as a seed, where the growth on GaN templates patterned with a striped geometry along the [1-100] direction form (0001), <11-22>, and <11-20> facets. We found that the InGaN/GaN QWs on the <11-22> semipolar facets show higher photoluminescence (PL) efficiency, compared with conventional (0001) QWs. Consequently, nanoscopic optical characterization was performed on <11-22> microfacet QWs using scanning near field optical microscopy (SNOM). Unlike the phenomena observed in (0001) QWs, there is not a difference between the PL spectra acquired under the illumination-collection and illumination modes, which indicates that the carrier diffusion length in the <11-22> QW is less than the probing fiber aperture of 160 nm due to a much faster radiative recombination processes as a result of a well-reduction of internal electric field. The correlation between IQE and emission wavelength shows that the highest internal quantum efficiency (IQE) is approximately 50% at 520 nm, which is about 50 nm longer than in (0001) QWs, suggesting that the <11-22> QW is a suitable green emitter with a controllability of polarization direction. Moreover, tailored emission color synthesis has been achieved using the combination of microfacet QWs without phosphors.

Topical Talk HL 11.2 Tue 10:00 HSZ 01

Optical polarization properties of nonpolar-oriented GaN films for polarization-sensitive and narrow-band photodetectors — •Holger T. Grahn — Paul-Drude-Institut, Berlin

The optical polarization properties of unstrained and strained GaN films with a nonpolar orientation are reviewed. In unstrained *A*-plane GaN films, the *A* exciton becomes completely linearly polarized perpendicular to the *c* axis, while the *B* and *C* excitons are only partially polarized. In *M*-plane or *A*-plane GaN films under anisotropic in-plane compressive strain, all three interband transitions between the three uppermost valence bands and the conduction band can become completely linearly polarized for sufficiently large strain values. The complete linear polarization can be directly observed in reflection, transmission or photo-reflectance by a polarization-dependent energy gap. This complete linear polarization can be used to realize polarization-sensitive photo-detectors in the ultraviolet spectral range, which do not need a polarization filter in front of the photo-detector. By combining a polarization filter and photo-detector or two photo-detectors from the same material with their *c* axes oriented perpendicular to each other, a narrow-band photo-detection configuration can be achieved in the ultraviolet spectral range with a band width below 8 nm. Since both realizations are also polarization sensitive, a configuration with four photo-detectors is necessary to achieve narrow-band sensitivity regardless of the polarization state of the incident light. At the same time, the configuration with four photo-detectors allows for the determination of the absolute angle of polarization.

15 min. break

Topical Talk HL 11.3 Tue 10:45 HSZ 01

Growth and characterisation of planar (11-20) and (11-22) GaN-based multiple quantum well structures — •Menno Kappers — Department of Materials Science and Metallurgy, Pembroke Street, University of Cambridge, Cambridge, CB2 3QZ, UK

The effects of polarisation charges observed in polar (0001) GaN-based heterostructures can be eliminated or reduced by growing on the nonpolar (11-20) and semi-polar (11-22) planes, respectively. This may result in improvements to the recombination efficiency in QW structures where the reduced overlap between the electron and hole wavefunctions caused by electric fields leads to long radiative lifetimes. However, planar non- and semi-polar GaN-based structures grown on sapphire substrates are burdened by a high defect density, which are possible sources of non-radiative recombination that compromises the predicted high IQE of QW structures. Indeed, great advances in device efficiencies have been made by a few groups around the world using non- and semi-polar GaN bulk substrates with very low dislocation densities. The challenge for the rest of us is to improve the quality of hetero-epitaxial GaN-based structures. Some have chosen to study heterostructures on non- and semi-polar facets grown on basal-plane substrates, others prefer the growth of planar epilayers on R- and M-plane sapphire. Part of the combined research efforts at the Universities of Cambridge and Manchester is to find methods of defect reduction in planar (11-20) and (11-22) GaN and the structural and optical characterization of GaN/AlGaN and InGaN/GaN MQW structures. An up-to-date overview of our research progress will be given.

Topical Talk HL 11.4 Tue 11:15 HSZ 01

Materials issues towards green laser diodes — •Andreas Hangleiter — PolarCoN Research Group & Institute of Applied Physics, TU Braunschweig

For the past 15 years, group-III nitrides have shown an unprecedented development. Driven by applications in lighting and optical data storage quantum well heterostructures with high efficiency in the violet-blue spectral region have been realized. For green wavelengths, however, the efficiency of light-emitting diodes encounters the “green gap”, laser diodes are still limited to a greenish blue. Among the problems responsible for that are the huge piezoelectric fields as well as the large strain arising from the large Indium mole fraction required to reach the green region. The diminishing refractive index contrast between GaN and AlGaN represents an additional challenge for laser waveguide structures.

In order to reduce the internal fields we are studying semipolar and nonpolar growth planes instead of the polar c-plane. Careful low-temperature growth of GaInN turns out to be the key to achieve homogeneous high In incorporation. Additional care needs to be applied to the growth of cladding layers in order to avoid thermal damage to those high-In layers. We use high-resolution XRD to control relaxation as well as transmission electron microscopy to study defects in those layers. Important information regarding homogeneity comes from micro-photoluminescence as well as from cathodoluminescence studies. Optical gain measurements reveal key laser properties such as peak gain, carrier losses, and optical losses.

15 min. break

HL 11.5 Tue 12:00 HSZ 01

Thermal trap emissions associated with stacking faults in undoped non c-plane GaN — •Kay-Michael Günther, Hartmut Witte, Matthias Wieneke, Jürgen Bläsing, Armin Dadgar, and Alois Krost — Otto-von-Guericke-Universität Magdeburg

Recently, GaN-based materials are used in optoelectronic and microelectronic devices like LEDs, vertical cavity surface emitting laser or high electron mobility transistors. In some applications strong piezoelectric fields in c-plane GaN are undesired evoking for instance the quantum confined stark effect (QCSE). In this case the reduced polarization of non c-plane GaN layers is useful for better radiative efficiency. Unfortunately, due to its anisotropic nature the growth of semipolar GaN produces much more stacking faults than in c-axis oriented GaN. The basal and prismatic plane stacking faults act as deep defects which are well known from photoluminescence measurements. However, little is known on their thermal emission and trapping behavior. Therefore, we have characterized deep defects of a series of high resistance and undoped semipolar GaN samples grown by MOVPE on sapphire substrates by comparison of defect-related transitions in photoluminescence, thermal emissions in photocurrent spectroscopy and in thermally stimulated currents (TSC). These results are compared to measurements on polar c-plane GaN samples and the correlation between the stacking faults and thermal trap emissions is discussed.

HL 11.6 Tue 12:15 HSZ 01

Facet formation and ohmic contacts for laser diodes on non- and semipolar GaN — •Jens Rass[1], Simon Ploch[1], Tim Wernicke[2], Luca Redaelli[2], Patrick Vogt[1], Sven Einfeldt[2], and Michael Kneissl[1,2] — [1]Technische Universitaet Berlin, Institute of Solid State Physics, Secretariat EW6- 1, Hardenbergstrasse 36, 10623 Berlin, Germany — [2]Ferdinand- Braun-Institut fuer Hoechstfrequen-

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Group-III-Nitride heterostructures grown on nonpolar and semipolar planes allow the realization of highly efficient devices such as laser diodes and LEDs due to the reduction or elimination of the quantum confined stark effect. However, the realization of these devices poses a number of challenges, in particular the formation of smooth laser facets and the fabrication of ohmic contacts.

In this talk optimized schemes for facet formation and contact resistance reduction for nitride based devices on non- and semipolar planes will be presented and various concepts will be discussed. We will discuss a laser scribing process that allows the cleaving of facets along the c- and a-plane for devices grown on nonpolar substrates. For semipolar planes there is no low-index cleavage plane in order to form resonators along the projection of the c-axis. Therefore we have investigated etching techniques in order to produce flat facets perpendicular to the plane of growth. For the challenging formation of p-type contacts to GaN we will discuss different methods such as chemical treatments, different metallization schemes and capping layers to reduce the contact resistivity.

HL 11.7 Tue 12:30 HSZ 01

Growth of nonpolar a-plane GaN on r-plane Sapphire via HVPE — •Stephan Schwaiger, Thomas Wunderer, Frank Lipski, and Ferdinand Scholz — Institut für Optoelektronik, Universität Ulm

We report on the growth of a-plane GaN on r-plane sapphire via hydride vapor phase epitaxy (HVPE). Prior to the HVPE growth the substrates were loaded into a MOVPE reactor to deposit a template GaN layer on an AlN nucleation layer. The MOVPE growth parameters have been optimized and SiN interlayers for defect reduction have been investigated and successfully introduced. By varying typical growth parameters like the V/III ratio, the temperature, and the pressure during the HVPE growth just small influences on the crystal quality could be observed. The improvement of the MOVPE grown templates seems to have more impact on the resulting nonpolar layers. These layers have been characterized by x-ray rocking curve as well as photoluminescence (PL) measurements. Our optimized layers showed a comparably strong near-band-edge excitonic line as compared to the commonly observed lower energy defect signals caused by stacking faults.