HL 10: Nitrides: Devices

Time: Monday 15:00–17:30 Location: EW 203

HL 10.1 Mon 15:00 EW 203

Mechanism and Reduction of temperature-dependent RF loss of GaN-HEMTs on Silicon substrate — •Tien Tung Luong, Yi Heng Chen, Chung Han Chiang, Yen Teng Ho, Shane Chang, and Edward Yi Chang — National Chiao Tung University, Hsinchu, Republic of China (R.O.C)

Regarding the unique characteristics (high breakdown field, high power density, high efficiency, and broadband); GaN-based HEMTs are able to operate at high power, high frequencies, and high temperatures; exhibiting various excellent characteristics superior to those of conventional Si-based semiconductors. GaN-HEMTs on Si technology is expected to drastically reduce the fabrication cost. Nevertheless, one of the main issues is the parasitic loss that can adversely impact the RF device performances. In order to reduce the loss of RF operation of devices on Si, a high-resistivity (HR) Si substrate is commonly used; however, the RF loss drastically increases at high-junction temperature. A free-electron inversion channel, which is caused by the positive piezoelectric charge at the AlN/Si interface induced by the piezoelectric field in the tensile AlN grown on Si, plays a critical role in the RF losses. Understanding the loss mechanisms of GaN-HEMT on Si will undoubtedly help to design epitaxial growth structure for further improving the overall device RF performance. An adoption of a low-temperature AlN near Si interface induces an unintentionally carbon-doped layer acting as a negatively fixed charge layer that is able to compensate for positive piezoelectric charge resulting in the improvements of both the RF losses and thermal degradation.

HL 10.2 Mon 15:15 EW 203

Implementation of a GaN:Mg/GaN:Ge tunnel junction in blue vertical-cavity surface-emitting laser structures — •Christoph Berger, Silvio Neugebauer, Gordon Schmidt, Cleophace Seneza, Jürgen Bläsing, Jürgen Christen, Armin Dadgar, and André Strittmatter — Otto-von-Guericke-Universität Magdeburg, Universitätsplatz 2, 39106 Magdeburg

Due to their unique properties GaN-based vertical-cavity surface-emitting lasers (VCSELs) are desirable for various applications. Besides the demanding realization of nitride-based microcavities with highly reflective distributed Bragg-reflectors, major challenges are the homogeneous current injection into the cavity region and the realization of a current aperture to achieve a sufficient current density in the gain region. Most commonly, current apertures are formed by selective passivation of the cavity p-side with SiO2 or SiNx and lateral current injection is accomplished by covering the aperture with an ITO-layer. In our approach the p-doped GaN is overgrown with highly doped GaN:Ge by metalorganic chemical vapor phase epitaxy. This transparent conductive nitride ensures excellent lateral current spreading, while carrier injection is enabled via tunneling at the GaN:Mg/GaN:Ge interface. Such VCSEL structures give reason to expect a significant reduction of internal losses in the cavity that are otherwise induced by the relatively high absorption coefficient of the ITO-layer. For current confinement we will address different approaches, like selective passivation of the p-GaN or selective oxidation of a buried, lattice-matched AlInN layer.

HL 10.3 Mon 15:30 EW 203

$Al_xGa_{1-x}N$:Mg short period superlattice cladding layers with $x \geq 0.6$ for UVC laser diodes — •C. Kuhn[1], M. Guttmann[1], N. Susilo[1], M. Martens[1], F. Mehnke[1], L. Sulmoni[1], T. Wernicke[1], and M. Kneissl[1,2] — [1]Technische Universität Berlin, Institute of Solid State Physics, Berlin, Germany — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin, Germany

Key challenges for the realization of UVC laser diodes with emission wavelength below 270 nm are carrier injection, light absorption and waveguiding. The waveguiding requires low loss $Al_xGa_{1-x}N$ cladding layers with high aluminum content $x > 0.7$. However, this limits efficient carrier injection due to the typically high resistance of Mg-doped AlGaN layers. To increase the conductivity short period superlattices (SPSL) can be implemented. Nevertheless, a high conductivity and its accurate determination still remains particularly demanding, especially for high Al contents.

This paper investigates the optical and electrical properties of AlGaN:Mg SPSLs up to $x = 0.8$. Such high Al contents shift the absorption edge far away from the lasing wavelength resulting in low absorption $< 50\,cm^{-1}$ in the layers due to Mg-related transitions. AlGaN:Mg SPSLs with average $x = 0.22$ exhibit a relatively low lateral resistivity of $0.6\,\Omega$cm which strongly increases to $70\,\Omega$cm for transparent AlGaN:Mg with $x = 0.6$. Vertical resistivity measurements hint to an additional field-induced ionization of the Mg acceptors leading to an increase of the turn-on voltage, but allowing for relatively low series resistances and high pulsed current densities up to $5\,kA/cm^2$.

HL 10.4 Mon 15:45 EW 203

AlGaN-based deep UV LEDs grown on sputtered and high temperature annealed AlN/sapphire — •Norman Susilo[1], Sylvia Hagedorn[2], Dominik Jaeger[3], Hideto Miyake[4], Ute Zeimer[2], Christoph Reich[1], Bettina Neuschulz[1], Luca Sulmoni[1], Martin Guttmann[1], Frank Mehnke[1], Christian Kuhn[1], Tim Wernicke[1], Markus Weyers[2], and Michael Kneissl[1,2] — [1]Institute of Solid State Physics, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Straße 4, 12489 Berlin, Germany — [3]Evatec AG, Hauptstraße 1a, 9477 Trübbach, Switzerland — [4]Department of Electrical and Electronic Engineering, Mie University, Mie 514-8507, Japan

The structural and electro-optical properties of AlGaN-based deep ultraviolet light emitting diodes (UV-LEDs) grown by metalorganic vapor phase epitaxy on sputtered and high temperature annealed (HTA) AlN/sapphire templates are investigated and compared to LEDs grown on epitaxially laterally overgrown (ELO) AlN/sapphire. Both templates show similar threading dislocation densities in the range of $1\times10^9\,cm^{-2}$. The output powers are also comparable and in the range of 0.4 mW at 20 mA for the emission wavelength of 268 nm. This opens a new way for the fabrication of efficient UVC-LEDs with reduced complexity and thus reduced costs.

HL 10.5 Mon 16:00 EW 203

Structural and optical properties of $In_xAl_yGa_{1-x-y}N$ layers for UVB-LEDs — •Tolga Teke[1], Johannes Enslin[1], Gunnar Kusch[2], Lucia Spasevski[2], Christoph Reich[1], Bettina Neuschulz[1], Tim Wernicke[1], Robert Martin[2], and Michael Kneissl[1] — [1]Technische Universität Berlin, Institute of Solid State Physics — [2]University of Strathclyde, Department of Physics, SUPA

There are numerous applications for UVB-light emitting diodes (LED) emitting in the range from 280 nm to 315 nm such as UV-curing, phototherapy, and plant growth lighting. However, currently the external quantum efficiency (EQE) of these devices is just in the low percentage range. Several reports have indicated a strong increase of the internal quantum efficiency (IQE) for LEDs with quaternary $In_xAl_yGa_{1-x-y}N$ quantum wells (QWs). However, detailed studies on how the indium-content influences the IQE, polarizaion fields and carrier localization in the QWs are still missing. In this work, we investigate bulk $In_xAl_yGa_{1-x-y}N$ layers in order to realize UVB-LEDs with $In_xAl_yGa_{1-x-y}N$ QWs with different In-content and emission wavelengths near 310 nm. A series of bulk $In_xAl_yGa_{1-x-y}N$ layers with thickness of 150 nm was grown by MOVPE where the In-content was varied by changing the growth temperature and the In precursor supply. We will present the dependence of the quaternary composition of these layers on the growth conditions determined by wavelength dispersive x-ray spectroscopy (WDX) and its influence on the optical properties by photoluminescence, transmission and cathodoluminescence spectroscopy.

15 min. break.

HL 10.6 Mon 16:30 EW 203

Evidence of nanoscale Anderson localization induced by intrinsic compositional disorder in InGaN/GaN quantum wells by scanning tunneling luminescence spectroscopy — •Wiebke Hahn[1], Jean-Marie Lentali[1], Petr Polovodov[1], Nathan Young[2], Shuji Nakamura[2], James S. Speck[2], Claude Weisbuch[1,2], Marcel Filoche[1], Fouad Maroun[1], Lucio Martinelli[1], Yves Lassailly[1], and Jacques Peretti[1] — [1]Laboratoire de Physique de la Matière Condensée, Ecole polytechnique, CNRS, Université Paris Saclay, Palaiseau Cedex, France —

[2]Materials Department, University of California, Santa Barbara, USA

In nitride ternary alloys, intrinsic compositional disorder, resulting from the random distribution of atoms on the crystal lattice, induces strong electronic localization effects. We will present direct experimental evidences of Anderson localization induced at a scale of a few nanometers by the intrinsic alloy compositional disorder in an InGaN/GaN quantum well (QW). The experiment consists in locally injecting electrons from a scanning tunneling microscope (STM) tip into a p-type heterostructure incorporating an InGaN/GaN QW nearby the surface. The luminescence spectrum from the electrons captured in the QW is detected as a function of the injecting tip position. Spatial fluctuations of the luminescence peak energy and linewidth are observed on the scale of a few nanometers, characteristic of disorder-induced carrier localization. A model based on the so-called localization landscape theory accounts well for the observed nanometer scale carrier localization and the fluctuations in the luminescence peak energy.

HL 10.7 Mon 16:45 EW 203

Transport of localized charge carriers in disordered media — Jean-Marie Lentali[1], Marcel Filoche[1], and •Svitlana Mayboroda[2] — [1]Physique de la Matière Condensée, Ecole Polytechnique, CNRS, 91128 Palaiseau, France — [2]School of Mathematics, University of Minnesota, Minneapolis, Minnesota 55455, USA

Our work is based on the theory of the localization landscape, which purpose is to study the effects of disorder on the localization of wave functions without actually solving the Schrödinger equation. Bypassing the Schrödinger equation notably allows 3D computations, self-consistent with the Poisson equation and the drift-diffusion transport equations. This new approach has been successfully applied to nitride based structures such as InGaN quantum wells, where the disorder stems from the random distribution of Indium atoms during growth process [1]. However, the transport between localized states in the plane of the well could only be described by an effective mobility, until recently. We now propose a dynamic transport model which integrates the coupling between neighboring localized states by an external potential such as the electric field and/or the phonon-electron interaction. Evaluating this coupling requires the use of the Agmon distance, which describes the exponential decay of localized wave functions in any dimension, and we report its first utilization in quantum physics.

[1] Localization landscape theory of disorder in semiconductors. III. Application to carrier transport and recombination in light emitting diodes Chi-Kang Li, et al. - Phys. Rev. B 95, 144206 - Published 18 April 2017

HL 10.8 Mon 17:00 EW 203

Electronic processes in nitride compounds and devices — Wiebke Hahn[1], Jean-Marie Lentali[1], James S. Speck[2], Claude Weisbuch[1,2], Marcel Filoche[1], Lucio Martinelli[1], and •Jacques Peretti[1] — [1]Laboratoire de Physique de la Matière Condensée, Ecole polytechnique, CNRS, Université Paris-Saclay, 91128 Palaiseau, France — [2]Materials Department, University of California, Santa Barbara, CA, USA

Despite the fast development of nitride semiconductor technology, a deep understanding of the fundamental properties of nitride compounds and heterostructures is still lacking in order to understand the microscopic mechanisms which govern electronic processes in nitride devices. Here, we present unconventional approaches which allow to address challenging issues like multivalley transport [1,2], non-radiative recombination processes [1], disorder-induced localization effects [3-5]. Direct spectroscopic signatures of critical electronic processes are obtained which provide novel inputs both for the theoretical description of nitride compounds and heterostructures and for the modeling and design of devices [6]. [1] Iveland et al., Phys. Rev. lett. 110, 177406 (2013) [2] Piccardo et al., Phys. Rev. B 89, 235124 (2014) [3] Filoche et al., Phys. Rev. B 95, 144204 (2017) [4] Piccardo et al., Phys. Rev. B 95, 144205 (2017 [5] Li et al., Phys. Rev. B 95, 144206 (2017) [6] Hahn et al., Submitted.

HL 10.9 Mon 17:15 EW 203

Q factor limitation in the UVA in III-nitride-on-silicon photonic crystal cavities — •Farsane Tabataba-Vakili[1,2,3], Iannis Roland[1], Thi-Mo Tran[1], Xavier Checoury[1], Moustafa El Kurdi[1], Sébastien Sauvage[1], Christelle Brimont[4], Thierry Guillet[4], Stéphanie Rennesson[5], Jean-Yves Duboz[5], Fabrice Semond[5], Bruno Gayral[2,3], and Philippe Boucaud[1] — [1]C2N, CNRS, Univ. Paris-Sud, Université Paris-Saclay, F-91405 Orsay, France. — [2]CEA, INAC-PHELIQS, F-38000 Grenoble, France. — [3]Univ. Grenoble Alpes, F-38000 Grenoble, France. — [4]Laboratoire C. Coulomb (L2C), CNRS-Univ. Montpellier, F-34095 Montpellier, France. — [5]Université Côte d'Azur, CRHEA-CNRS, F-06560 Valbonne, France.

In this work, we investigated L3 photonic crystal (PhC) cavities that were fabricated in a 75 nm AlN layer, containing five 1.2 nm GaN QWs. The III-N PhC membranes were released by selective underetching of the Si substrate. The devices were probed by room temperature micro-photoluminescence to measure the Q factor of the cavities. We demonstrate resonances down to 315nm and Q factors up to 1085 at 337nm. Using spectroscopic ellipsometry, we determine residual absorption in thin AlN layers grown on Si by molecular beam epitaxy. This residual absorption is expected to be the main cause of substantially decreased Q factors at shorter wavelengths when no active layers with a large absorption, such as quantum wells or quantum dots are present. Ultimately, the residual absorption should thus limit the Q factor to 2000 at 300 nm when no active layers are present.