DS 2: Focus Session: Innovative GaN-based High-power Devices: Growth, Characterization, Simulation, Application 1

Organizers:
Bernd Witzigmann, University Erlangen-Nürnberg
Frank Bertram, Magdeburg University

The transition to globally sustainable energy generation requires a further significant rise of sharing electrical energy. Power electronics is a key technology enabling efficient distribution, conversion, and use of these large amounts of electrical energy. Thanks to the advances in semiconductor materials with solid-state properties, power electronics research remains a focal point. The remarkable progress in wide-bandgap semiconductor materials such as Gallium Nitride (GaN) allows for power devices reaching switching speeds an order of magnitude above the state of the art, with significantly reduced ohmic and dynamic losses, and improved thermal properties. GaN-based devices and circuits therefore enable the design of highly compact power-electronic systems with highest efficiencies. Considerable energy savings are possible, e.g. with energy and vehicle technology alone, a previously unused potential of up to 35% can be exploited. This not only offers economic advantages, but also significantly reduces the CO_2 equivalents associated with the applications.

Time: Monday 9:30–11:15 Location: H17

Invited Talk DS 2.1 Mon 9:30 H17

GaN-based power converters enabling talktive power — •Marco Liserre — Kiel University, Kiel, Germany

GaN power semiconductors with their extremely fast switching characteristics enable not only electrical energy conversion which is almost free from switching losses but also to bridge for the first time two fields which have been developing separately for more than 70 years: energy and information transfer. This contribution will start from the physical characteristics of GaN power semiconductors to show what they allow in power conversion and how they can lead to realize power exchange which carries also information.

Invited Talk DS 2.2 Mon 10:00 H17

Energy-efficient power electronics based on Gallium Nitride — •Oliver Ambacher — Sustainable Systems Engineering (INATECH), Albert-Ludwigs-Universität, Freiburg

Around 40% of the energy converted worldwide by technical systems is already provided in the form of electricity. This share is expected to increase to around 60% in 2040. These enormous amounts of energy not only have to be generated in a way that conserves resources and the environment, but also distributed and used efficiently. The power electronics required for this is an *emerging field* of electrical engineering, which makes it possible to provide electrical energy optimally adapted for a wide variety of applications. These applications include the integration of renewable energy sources into the electrical supply network, drive technology for electromobility, the power supply for data centers or the high-frequency network for mobile communications. Using the example of the development and use of particularly energy-efficient gallium nitride-based power electronic circuits, the presentation will illustrate the high potential for saving energy that further optimization of semiconductor materials and microelectronic components offers and how sustainable electronic systems can be realized from them. Based on a basic understanding of the *atomic building blocks*, functional material properties are derived and presented for the design of novel power electronic devices and components. These GaN-based components are demonstrated for high performance amplifiers and voltage converters that are characterized by particularly energy-efficient operation.

DS 2.3 Mon 10:30 H17

Influence of space-charge region on luminescence in a lateral GaN superjunction — •Gordon Schmidt[1], Peter Veit[1], Frank Bertram[1], Jürgen Christen[1], Arne Debald[2], Michael Heuken[2,3], Thorsten Zweipfennig[2], Holger Kalisch[2], and Andrei Vescan[2] — [1]Otto-von-Guericke-University Magdeburg, Magdeburg, Germany — [2]RWTH Aachen University, Aachen, Germany — [3]AIXTRON SE, Herzogenrath, Germany

The superjunction concept, based on charge compensation in the drift region by fully balanced n- and p-regions, is intended to break the tradeoff between breakdown voltage and on-resistance in GaN-based power devices.

In this study, a lateral GaN p-n^+ superjunction was investigated by scanning transmission electron microscope cathodoluminescence microscopy. The structure was grown on top of a GaN/sapphire template. After the growth of an AlGaN marker layer, the superjunction was epitaxially deposited composed of alternating 91 nm thick p-GaN with $5 \cdot 10^{18}$ cm^{-3} Mg doping and 23 nm thick n^+GaN with $1 \cdot 10^{19}$ Si doping. Finally, the structure was capped by a n^+GaN layer. To probe the space charge region of the superjunction, the luminescence evolution across the pn^+p junctions was investigated at T = 16 K. Donor-acceptor-pair recombination (DAP) is dominating the spectrum in the n-doped layers. In the near-band-edge region, bound exciton luminescence is observed in GaN:Mg. Both, excitons bound to an acceptor as well as to a donor exhibit reduced intensity in the space-charge region indicating exciton dissociation by the built-in electric field.

Invited Talk DS 2.4 Mon 10:45 H17

Potential of Aluminum Nitride for Vertical Power Electronics — •Andreas Waag[1,2], Klaas Strempel[1,2], Lukas Peters[1,2], Christoph Margenfeld[1,2], Samuel Faber[3], Friedhard Römer[3], and Bernd Witzigmann[3] — [1]Institute of Semiconductor Technology, Technische Universität Braunschweig, Hans-Sommer-Straße 66, 38106 Braunschweig, Germany — [2]Laboratory for Emerging Nanometrology (LENA), Technische Universität Braunschweig, Langer Kamp 6, 38106 Braunschweig, Germany — [3]Institute for Optoelectronics, Friedrich-Alexander Universität Erlangen-Nürnberg, Konrad-Zuse Str. 3/5, 91052 Erlangen, Germany

Owing to its excellent material properties, AlN is considered to be highly promising for power electronics. One of the main obstacles for AlN, however, is the poor availability of single crystal substrates. A particularly promising technique is the high temperature annealing (HTA) of sputtered AlN thin films on sapphire. AlN is one of the few compound semiconductors, which is curing its crystal lattice during HTA without thermal decomposition or evaporation if processed in a face-to-face configuration.

In addition to the material aspects, we discuss the design of AlN devices, supported by TCAD simulations, combining microscopic drift-diffusion currents with electron/hole continuity equations and the Poisson equation.