GANEXT

Newsletter No. 01

February 2020

GaN Technology for Optoelectronics & Electronics

Coordinated by **CRHEA-CNRS** research laboratory, this monthly newsletter is produced by **Knowmade** in collaboration with the managers of **GANEXT** groups. The newsletter presents a selection of newest scientific publications, patent applications and press releases related to **Optoelectronics** (LED, micro-LED, laser, photonics, etc.) and **Electronics** (Power, RF, advanced electronics, etc.) based on **III-Nitride semiconductors** (GaN, AlN, InN and alloys).

All issues on www.ganex.fr in *Veille* section.
Free subscription http://www.knowmade.com/ganex

GANEXT

Cluster of Excellence (Labex, 2020-2024)

GANEXT is a cluster gathering French research teams involved in GaN technology. The objective of GANEXT is to strengthen the position of French academic players in terms of knowledge and visibility, and reinforce the French industrial players in terms of know-how and market share. **GANEXT** replaces and succeed **GANEX** Cluster of Excellence (Labex 2012-2019).
www.ganex.fr

KnowMade

Knowmade is a Technology Intelligence and IP Strategy consulting company specialized in analysis of patents and scientific information. The company helps innovative companies and R&D organizations to understand their competitive landscape, follow technology trends, and find out opportunities and threats in terms of technology and patents. **Knowmade**'s analysts combine their strong technology expertise and in-depth knowledge of patents with powerful analytics tools and methodologies to turn patents and scientific information into business-oriented report for decision makers working in R&D, Innovation Strategy, Intellectual Property, and Marketing. Our experts provide prior art search, patent landscape analysis, scientific literature analysis, patent valuation, IP due diligence and freedom-to-operate analysis. In parallel the company proposes litigation/licensing support, technology scouting and IP/technology watch service. **Knowmade** has a solid expertise in Compound Semiconductors, Power Electronics, Batteries, RF Technologies & Wireless Communications, Solid-State Lighting & Display, Photonics, Memories, MEMS & Solid-State Sensors/Actuators, Semiconductor Manufacturing, Packaging & Assembly, Medical Devices, Medical Imaging, Microfluidics, Biotechnology, Pharmaceutics, and Agri-Food.
www.knowmade.com

IMPORTANT NOTE:

The end of **GaNeX** Cluster of Excellence program (Labex 2012-2019) was scheduled on December 2019. However, the French government decided **to expand the labex program for five additional years**, in order to further strengthen the synergy between French academic research organizations and industrial players in the field of GaN optoelectronics and electronics. Therefore, **GANEXT** Cluster of Excellence program **will replace and succeed GaNeX** for the next five years (2020-2024).

Accordingly, the **GANEXT newsletter** will follow and adapt to the new program, **focusing on scientific publications, patent applications and press releases related to optoelectronics** (LED, µ-LED, laser, photonics, etc.) **and electronics** (power, RF, advanced electronics, etc.), ruling out publications which are not related to one of these two families of applications. For instance, publications dealing with MEMS, sensors, photovoltaics, nanostructures, semi-polar and non-polar materials, fundamental physics, etc. that do not obviously relate to optoelectronic or electronic applications will not be included in the **GANEXT newsletter**.

Besides, a panel of **GANEXT** experts will continue to interact with Knowmade team in order to select the most relevant publications of the month, consistently with **GANEXT**'s ongoing projects.

TABLE OF CONTENTS

METHODOLOGY 3

SCIENTIFIC PUBLICATIONS 4

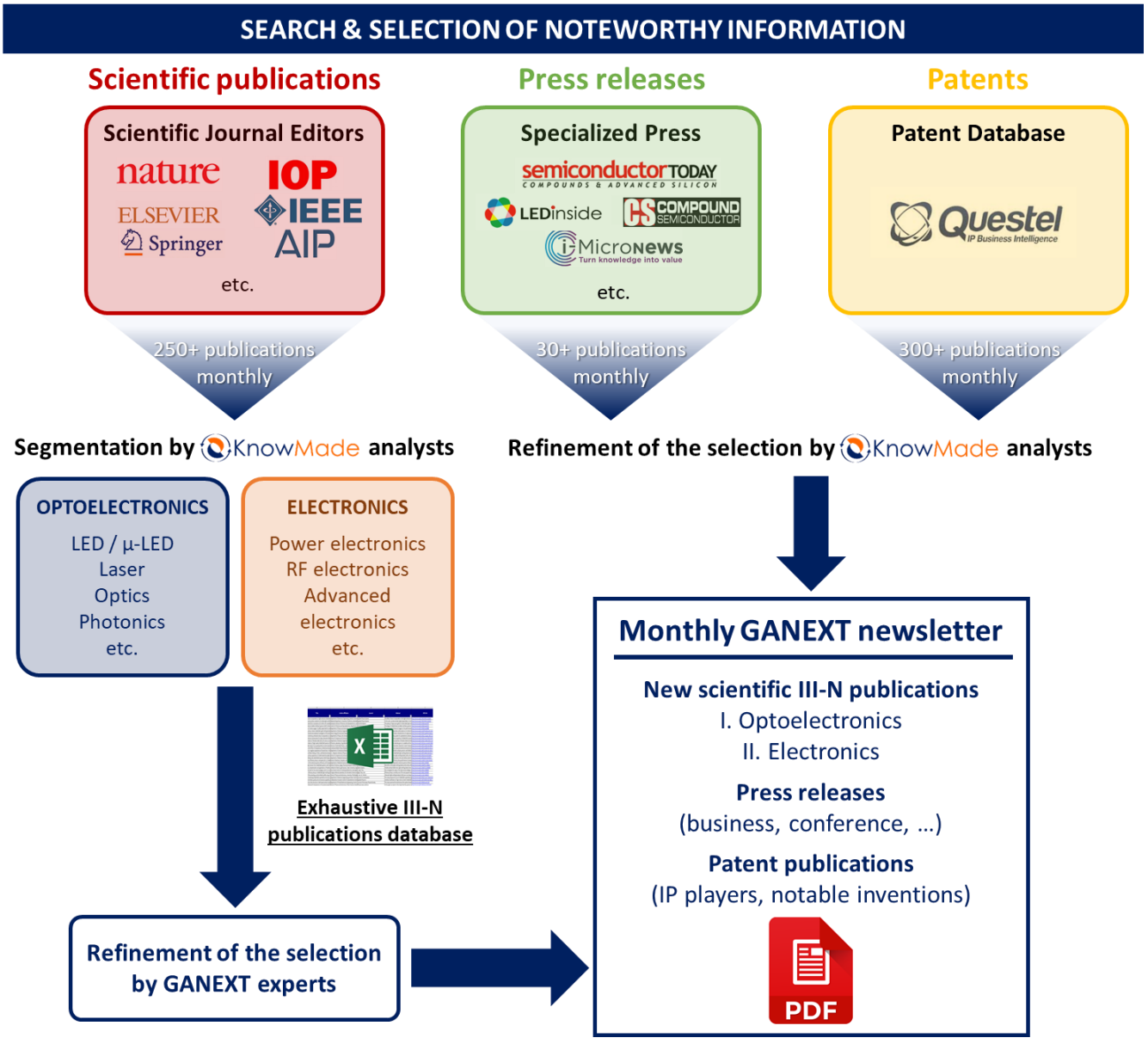
OPTOELECTRONICS 4

ELECTRONICS 11

PRESS RELEASE 29

PATENT APPLICATIONS 56

METHODOLOGY



Powered by KnowMade

SCIENTIFIC PUBLICATIONS

Selection of new scientific articles

OPTOELECTRONICS

Group leader: Bruno Gayral (CEA)

Information selected by Julien Brault (CNRS-CRHEA) and Maria Tchernycheva (CNRS-C2N)

Light-induced capacitance enhancement and successive carrier escape in InGaN/GaN multiple quantum wells

Department of Physics, Yonsei University, Seoul 120-749, South Korea
Department of Physics, Kongju National University, Kongju, Chungnam 314-701, South Korea

Journal of Applied Physics
https://doi.org/10.1063/1.5108915

We observed large enhancement of capacitance with strong voltage sensitivity in InGaN/GaN multiple quantum wells with additional laser illuminations. We have found that the observed negative differential capacitance and its related capacitance peaks in the capacitance-voltage profile are due to the photogenerated charge separation and accumulation at the well/barrier interfaces and its subsequent carrier escape by the applied forward bias. By analyzing temperature dependent photocurrent spectra simultaneously, it is shown that photocarrier separation and strong carrier escape simultaneously occur in an individual quantum well. We can analyze the contribution of a single individual quantum well to the total capacitance of the device, resulting from the nanometer scale carrier separation and accumulation, and clarify the detailed process of accumulation and escape of carriers in the respective quantum wells.

A direct epitaxial approach to achieving ultra-small and ultra-bright InGaN micro light emitting diodes (µLEDs)

Department of Electronic and Electrical Engineering, University of Sheffield, Mappin Street, Sheffield, S1 3JD, United Kingdom

ACS Photonics
https://doi.org/10.1021/acsphotonics.9b01351

A direct epitaxial approach to achieving ultra-small and ultra-bright InGaN micro light emitting diodes (µLEDs) has been developed, leading to the demonstration of ultra-small, ultra-efficient and ultra-compact green µLEDs with a dimension of 3.6 µm and an inter-pitch of 2 µm. The approach does not involve any dry-etching processes which are exclusively used by any current µLED fabrication approaches. As a result, our approach has entirely eliminated any damage induced during the dry-etching processes. Our green µLED array chips exhibit a record external quantum efficiency (EQE) of 6% at ~515 nm in the green spectral region, although our measurements have been performed on bare chips which do not have any coating, passivation, epoxy or reflector which is generally used for standard LED packaging in order to enhance extraction efficiency. High luminance of >10^7 cd/m^2 has been obtained on the µLED array bare chips. Temperature dependent measurements show that our µLED array structure exhibits an internal quantum efficiency (IQE) of 28%. It is worth highlighting that our epitaxial approach is fully compatible with any existing micro-display fabrication techniques.

Deep-UV Porous AlGaN Distributed Bragg Reflectors for Deep Ultraviolet Light-Emitting Diodes and Laser Diodes

Department of Materials Science and Engineering, National Chung Hsing University, 145 Xingda Rd., South Dist., Taichung City 402, Taiwan‡Electronics and Optoelectronics Research Laboratory, Industrial Technology Research Institute, Hsinchu 31040, Taiwan.Department of Electrical Engineering, Yale University, 15 Prospect St, New Haven, CT, 06511, United States

ACS Appl. Nano Mater.
https://doi.org/10.1021/acsanm.9b02034

A porous-Al0.47GaN/n-Al0.47GaN stack structure with a large refractive index contrast has been fabricated through a homoepitaxial growth process on a Si-doped n+-Al0.47GaN/n-Al0.47GaN stack structure with a simple electrochemical wet etching process. A 20-pairs porous-Al0.47GaN distributed Bragg reflector structure (DBR) with a high aluminum content was

Powered by KnowMade

fabricated at the deep-ultraviolet wavelength region of light emitting diodes. Low compressive strain and high reflectance has been observed in a porous-AlGaN/n-AlGaN DBR structure with 93% reflectivity at 276 nm. The high reflectance spectrum was measured at the 265 to 287 nm wavelength region in the porous AlGaN DBR structure. The absorption wavelength of the AlGaN layer was observed at about 250 nm, which is shorter than the high reflectance wavelength region of the porous DBR. Light extraction efficiency of the deep-UV optoelectronic devices can be improved by integrating the embedded porous AlGaN reflectors during the epitaxial growth process.

Beyond 53% internal quantum efficiency in a AlGaN quantum well at 326 nm UVA emission and single-peak operation of UVA LED

RIKEN Cluster for Pioneering Research, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan
RIKEN Center for Advanced Photonics (RAP), 2-1 Hirosawa, Wako, Saitama 351-0198, Japan
Yamaguchi University, 2-16-1 Tokiwadai, Ube Yamaguchi 755-8611, Japan

Optics Letters
https://doi.org/10.1364/OL.376894

AlGaN-based ultraviolet-A (UVA) light-emitting-diodes (LEDs) at emission under 330 nm are of great importance for numerous applications, including medicine and photochemical technologies. In this Letter, a highly relaxed n-AlGaN electron injection layer (EIL) underneath the multi-quantum wells (MQWs) for the suppression of both threading dislocation densities and piezoelectric effect was attempted. When the Ga-rich n-AlGaN EIL in the UVA LED was relaxed up to 75%, the full width at half-maximum values of the X-ray rocking curves for the (10–12) planes were reduced from our previous value of approximately 793 to 564 arcsec. Subsequently, a maximum light power of 3.1 mW was achieved in the 326 nm band UVA LED. However, carrier confinement and transport issues in the MQWs were observed. To resolve these issues of carrier confinement and transport, we provide a short roadmap for experimental efforts to realize an internal quantum efficiency (IQE) beyond 53% in AlGaN UVA-MQWs.

Compact optical neural probes with up to 20 integrated thin-film µLEDs applied in acute optogenetic studies

University of Freiburg, Department of Microsystems Engineering (IMTEK), Freiburg, Germany
University Lyon 1, Lyon, France,
Team Waking, Lyon Neuroscience Research Center, INSERM U1028-UMR 5292

IEEE Transactions on Biomedical Engineering
https://doi.org/10.1109/TBME.2020.2966293

This paper reports on the development, characterization and in vivo validation of compact optical neural probes. These novel intracerebral devices comprise micro light-emitting diodes (µLEDs) integrated along their slender probe shanks with up to 20 µLEDs per device. Blue light with a peak wavelength of 455nm is emitted from circular apertures 100µm in diameter. The µLEDs are structured on GaN-on-sapphire wafers and subsequently transferred onto silicon (Si) carrier wafers. The wafer-scale transfer process provides the opportunity to process the functional GaN layer stack from both sides and hence enables maximizing the efficiency of the µLEDs. Combined with standard MEMS fabrication processes for Si, linear µLED arrays with small inter-µLED distances are achieved on thin probe shanks with cross-sections measuring 150µm × 65 µm. Devices are interconnected using highly flexible polyimide cables in order to mechanically decouple them from the peripheral electronics during in vivo experiments. Assembled probes emit a peak optical radiant flux of 440µW (emittance 56mWmm−2) at 5mA driving current. Thermal characterization of test probes reveals a temperature increase of 1.5K measured using an integrated thermistor. Electrical functionality stress tests have been carried out to evaluate the device passivation against the physiological environment. It is estimated to endure at least 48 h during continuously pulsed µLED operation. A compact driving circuitry enables low-noise µLED operation in in vivo optogenetic experiments. The radiant flux necessary to elicit an acceptable neuronal response is determined between 1.36µW and 17.5 µW. Probe validation successfully demonstrates the layer-specific stimulation in the cortex in multiple in vivo trials.

Powered by KnowMade

Whispering-Gallery Mode Lasing in a Floating GaN Microdisk with a Vertical Slit

Peter Grünberg Research Centre, College of Telecommunications and Information Engineering, Nanjing University of Posts and Telecommunications, Nanjing, 210003, China
State Key Laboratory of Bioelectronics, Southeast University, Nanjing, 210096, China
State Key Laboratory on Tunable Laser Technology, Harbin Institute of Technology, Shenzhen, 518055, China
College of Science, Jiangsu University of Science and Technology, Zhenjiang City, 212003, China

Scientific Reports
https://doi.org/10.1038/s41598-019-57118-y

Controlling the lasing mode, emission direction, threshold, and quality factor of whispering-gallery mode lasing is important for practical applications such as optical interconnections, on-chip communications, trace detection, high-density storage, etc. In order to simultaneously control the mode and emission direction and to achieve a high-quality factor in a low-threshold whisper-gallery mode laser, such as a GaN floating microdisk, a novel fabrication design of a microdisk with a vertical slit is proposed. To demonstrate proof of concept, we experimentally measure whispering-gallery mode lasing spectra of microdisks with and without a slit. Our findings suggest that the disks can indeed operate in whispering-gallery mode, and the slit is able to change the optical path in the microcavity without breaking lasing resonance. The slit in the microdisk can also influence the lasing mode, quality factor, and directional emission. Therefore, our study provides a feasible way to control whispering-gallery mode lasing properties.

Spectral-temporal dynamics of (Al,In)GaN laser diodes

Institute of Physics, Chemnitz University of Technology, Chemnitz 09126, Germany

Optics Express
https://doi.org/10.1364/OE.382257

(Al,In)GaN laser diodes have various relevant applications, especially in projection systems for virtual and augmented reality devices and in optical communication, all requiring fast modulation. This corresponds to pulses in the nanosecond to microsecond range, where a rich longitudinal mode dynamics occurs. We investigate this spectral-temporal dynamics experimentally with a streak camera system and simulate it using a longitudinal multi-mode rate equation model. We observe an interplay of effects, which have been observed selectively, such as relaxation oscillations, mode competition and inhomogeneous pumping of multiple quantum wells. A mechanism is included in the simulations to model the red-shift of the gain spectrum due to the carrier density in the quantum wells exceeding threshold density, which is amplified by inhomogeneous pumping. Mode competition leads to spectral cycles of the active mode with a noticeable jitter, which is observed in single pulse measurements in comparison to multi pulse averaged measurements where blurring occurs. Here, some statistical behavior as well as repeating patterns are investigated at the same effect. Also thermal effects as laser diode self-heating are discussed and have been measured over six orders of magnitude in time.

High-Performance Ultraviolet Light-Emitting Diodes Using n-ZnO/p-hBN/p-GaN Contact Heterojunctions

State Key Laboratory of Integrated Optoelectronics, College of Electronic Science and Engineering, Jilin University, Qianjin Street 2699, Changchun 130012, China
Department of Physics and Engineering, Zhengzhou University, Daxue Road 75, Zhengzhou 450052, China
State Key Laboratory of Optoelectronic Materials and Technologies, Sun Yat-Sen University, Xin-Gang-Xi Rd. 135, Guangzhou 510275, China

ACS Appl. Mater. Interfaces
https://doi.org/10.1021/acsami.9b21894

Effective ultraviolet light-emitting diodes (LEDs) were fabricated by clamping the n-ZnO films on the top of p-hBN/p-GaN/sapphire substrates. An ultraviolet emission originating from ZnO was measured from the diode under forward bias, the electroluminescence (EL) spectra of which show a peak wavelength of ~376 nm with a narrow full-width at half maximum of ~12 nm. Compared with the reference diode fabricated by directly growing n-ZnO on the p-hBN substrates using metal-organic chemical vapor deposition, the proposed diode showed a dramatic increment of the EL intensity, meanwhile its emission onset lowered

Powered by KnowMade

down considerably. The improved optical property of the proposed LED is mainly ascribed to suppressing the formation of the BNO-related layer at the n-ZnO/p-hBN interface. The present work provides a simple and feasible approach for developing advanced ZnO-based optoelectronic devices.

Interplay between various active regions and the interband transition for AlGaN-based deep-ultraviolet light-emitting diodes to enable a reduced TM-polarized emission

Institute of Micro-Nano Photoelectron and Electromagnetic Technology Innovation, School of Electronics and Information Engineering, Hebei University of Technology, 5340 Xiping Road, Beichen District, Tianjin 300401, People's Republic of China
Key Laboratory of Electronic Materials and Devices of Tianjin, 5340 Xiping Road, Beichen District, Tianjin 300401, People's Republic of China
National Key Laboratory of ASIC, Hebei Semiconductor Research Institute, Shijiazhuang 050051, People's Republic of China
State Key Laboratory of Solid-State Lighting, Institute of Semiconductors, Chinese Academy of Sciences, Beijing 100083, China

Journal of Applied Physics
https://doi.org/10.1063/1.5127916

Al-rich AlGaN-based deep-ultraviolet light-emitting diodes (DUV LEDs) have a low light extraction efficiency, especially when the emission wavelength is shorter than 280 nm, and this is partially because of the dominant transverse-magnetic polarized light. Our results show that the transverse-electric (TE) polarized light can be obtained even if the emission wavelength becomes even shorter by reducing the quantum well thickness. The ultrathin quantum well enables the enhanced TE-polarized emission that arises from the redistributed subbands for holes. On the contrary to the common belief, we observe a blueshift for the emission wavelength when the AlN composition in the quantum barrier increases. The internal quantum efficiency (IQE) for DUV LEDs with ultrathin quantum wells is no longer determined by the quantum-confined Stark effect, while quantum barrier with high AlN composition is vitally important to improve the electron injection efficiency and thus enhance the IQE.

Monolayer GaN excitonic deep ultraviolet light emitting diodes

Department of Electrical Engineering and Computer Science, University of Michigan, Ann Arbor, Michigan 48109, USA
Department of Materials Science and Engineering, University of Michigan, Ann Arbor, Michigan 48109, USA

Applied Physics Letters
https://doi.org/10.1063/1.5124828

We report on the molecular beam epitaxy and characterization of monolayer GaN embedded in N-polar AlN nanowire structures. Deep ultraviolet emission from 4.85 to 5.25 eV is measured by varying the AlN barrier thickness. Detailed optical measurements and direct correlation with first-principles calculations based on density functional and many-body perturbation theory suggest that charge carrier recombination occurs predominantly via excitons in the extremely confined monolayer GaN/AlN heterostructures, with exciton binding energy exceeding 200 meV. We have further demonstrated deep ultraviolet light-emitting diodes (LEDs) with the incorporation of single and double monolayer GaN, which operate at 238 and 270 nm, respectively. These unique deep ultraviolet LEDs exhibit highly stable emission and a small turn-on voltage around 5 V.

Using a Multi-Layer Stacked AlGaN/GaN Structure to Improve the Current Spreading Performance of Ultraviolet Light-Emitting Diodes

Wide Bandgap Semiconductor Technology Disciplines State Key Laboratory, School of Advanced Materials and Nanotechnology, Xidian University, Xi'an 710071, China
Wide Bandgap Semiconductor Technology Disciplines State Key Laboratory, School of Microelectronics, Xidian University, Xi'an 710071, China

Materials
https://doi.org/10.3390/ma13020454

To obtain excellent current spreading performance of ultraviolet light-emitting diodes (UVLEDs), a 60-period stacked Si modulation-doped n-AlGaN/u-GaN structure is proposed to replace the traditional n-AlGaN structure. The high-resolution X-ray diffraction ω-scan rocking curves show that the periodic growth of AlGaN and GaN layers plays a positive role in

Powered by KnowMade

reducing dislocation density. Compared with the conventional UV light-emitting diodes (LEDs), light emission micrographs of devices with a multi-layer stacked n-AlGaN/u-GaN structure reveal higher brightness and a more uniform distribution. In addition, the output power and external quantum efficiency under a 20-mA injection current are increased by 22% and 26.5%, respectively. Experimental and simulation results indicate that a multi-layer stacking structure can alleviate the current crowding effect in four ways: 1) a reduction in dislocation density; 2) replacement of quasi-two-dimensional electron transport with electronic bulk transport to enhance electron mobility; 3) an increase in electron concentration without improving the impurity concentration; and 4) a weakening of the electron scattering effect by reducing the impurity concentration.

Process Integration and Interconnection Design of Passive-Matrix LED Micro-Displays with 256 Pixel-Per-Inch Resolution

Department of Materials Science and Engineering, National Chung Hsing University, Taichung 402, Taiwan
Graduate Institute of Precision Engineering, National Chung Hsing University, Taichung 402, Taiwan
Institute of Electronics, National Chiao Tung University, Hsinchu 30010, Taiwan
Innovation and Development Center of Sustainable Agriculture, National Chung Hsing University, Taichung 40227, Taiwan
Research Center for Sustainable Energy and Nanotechnology, National Chung Hsing University, Taichung 40227, Taiwan

IEEE Journal of the Electron Devices Society
https://doi.org/10.1109/JEDS.2020.2967476

A 0.28-inch InGaN-based blue micro-LED display with 256 pixel-per-inch resolution and a pitch of 100 µm was successfully fabricated in this study. A thick Ti/Al/Ti/Au interconnection metal was deposited on the n-type gallium nitride (n-GaN) region to reduce the interconnection resistance. The micro-LED array with interconnection metal exhibits better electrical property consistency as compared with that of the traditional one. The output power, forward voltage, and external quantum efficiency of micro-LED, which measured under 1-mA current injection with the full lighting mode, are 0.8 mW, 3.0 V, and 10%, respectively. This technique has the potential to integrate InGaN-based LEDs with quantum dots for full-color applications.

GaN/InGaN Blue Light-Emitting Diodes on Polycrystalline Molybdenum Metal Foils by Ion Beam-Assisted Deposition

Center for High-Technology MaterialsThe University of New MexicoAlbuquerque, NM 87106, USA
Advanced Materials SciencesSandia National LaboratoriesAlbuquerque, NM 87123, USA
iBeam MaterialsSanta Fe, NM 87507, USA

physica status solidi a
https://doi.org/10.1002/pssa.201900800

Light-emitting diode (LED) arrays fabricated on a polycrystalline metal substrate are demonstrated using a novel technique that enables the growth of epitaxial metal-organic chemical vapor deposition (MOCVD) GaN layers on non-single-crystal substrates. Epitaxial GaN is deposited directly on metal foil using an intermediate ion beam-assisted deposition (IBAD) aligned layer. For a single 170 µm-diameter LED on the metal foil, electroluminescence (EL) spectrum shows a peak wavelength of ≈452 nm and a full width at half maximum (FWHM) of ≈24 nm. The current–voltage (I–V) characteristics show a turn-on voltage of 3.7 V, a series resistance of 10 Ω. LEDs on metal show a relative external quantum efficiency (EQE) that is roughly 3× lower than that of similar LEDs fabricated on a sapphire substrate. InGaN LEDs on large-area non-single-crystal substrates such as metal foils enable large-area manufacturing, reducing production cost, and opening the door for new applications in lighting and displays.

480-nm distributed-feedback InGaN laser diode for 10.5-Gbit/s visible-light communication

Photonics Laboratory, King Abdullah University of Science and Technology (KAUST), Thuwal 23955-6900, Saudi Arabia

Optics Letters
https://doi.org/10.1364/OL.385954

In this Letter, we demonstrate a novel distributed-feedback (DFB) InGaN-based laser diode with narrow-linewidth emission at ~480nm (sky blue) and its

Powered by KnowMade

application to high-speed visible-light communication (VLC). A significant side-mode suppression ratio (SMSR) of 42.4 dB, an optical power of ∼14mW, and a resolution-limited linewidth of ∼34pm were obtained under continuous-wave operation. A 5-Gbit/s VLC link was realized using non-return-to-zero on–off keying modulation, whereas a high-speed 10.5-Gbit/s VLC data rate was achieved by using a spectral-efficient 16-quadrature-amplitude-modulation orthogonal frequency-division multiplexing scheme. The reported high-performance sky-blue DFB laser is promising in enabling unexplored dense wavelength-division multiplexing schemes in VLC, narrow-line filtered systems, and other applications where single-frequency lasers are essential such as atomic clocks, high-resolution sensors, and spectroscopy. Single-frequency emitters at the sky-blue wavelength range will further benefit applications in the low-path-loss window of underwater media as well as those operating at the H-beta Fraunhofer line at ∼486nm.

Nanopatterned sapphire substrates in deep-UV LEDs: is there an optical benefit?

Helmholtz Zentrum Berlin für Materialien und Energie, Berlin, Germany
Ferdinand-Braun-Institute, Leibniz-Institut für Höchstfrequenztechnik, Berlin, Germany
Zuse Institute Berlin, Berlin, Germany
JCMwave, Berlin, Germany

Optics Express
https://doi.org/10.1364/OE.379438

Light emitting diodes (LEDs) in the deep ultra-violet (DUV) offer new perspectives for multiple applications ranging from 3D printing to sterilization. However, insufficient light extraction severely limits their efficiency. Nanostructured sapphire substrates in aluminum nitride-based LED devices have recently shown to improve crystal growth properties, while their impact on light extraction has not been fully verified. We present a model for understanding the impact of nanostructures on the light extraction capability of DUV-LEDs. The model assumes an isotropic light source in the semiconductor layer stack and combines rigorously computed scattering matrices with a multilayer solver. We find that the optical benefit of using a nanopatterned as opposed to a planar sapphire substrate to be negligible, if parasitic absorption in the p-side of the LED is dominant. If losses in the p-side are reduced to 20%, then for a wavelength of 265 nm an increase of light extraction efficiency from 7.8% to 25.0% is possible due to nanostructuring. We introduce a concept using a diffuse (’Lambertian’) reflector as p-contact, further increasing the light extraction efficiency to 34.2%. The results underline that transparent p-sides and reflective p-contacts in DUV-LEDs are indispensable for enhanced light extraction regardless of the interface texture between semiconductor and sapphire substrate. The optical design guidelines presented in this study will accelerate the development of high-efficiency DUV-LEDs. The model can be extended to other multilayer opto-electronic nanostructured devices such as photovoltaics or photodetectors.

AlGaN Nanowires for Ultraviolet Light-Emitting: Recent Progress, Challenges, and Prospects

Department of Electrical and Computer Engineering, McGill University, 3480 University Street, Montreal, QC H3A 0E9, Canada

Micromachines
https://doi.org/10.3390/mi11020125

In this paper, we discuss the recent progress made in aluminum gallium nitride (AlGaN) nanowire ultraviolet (UV) light-emitting diodes (LEDs). The AlGaN nanowires used for such LED devices are mainly grown by molecular beam epitaxy (MBE) and metalorganic chemical vapor deposition (MOCVD); and various foreign substrates/templates have been investigated. Devices on Si so far exhibit the best performance, whereas devices on metal and graphene have also been investigated to mitigate various limitations of Si substrate, e.g., the UV light absorption. Moreover, patterned growth techniques have also been developed to grow AlGaN nanowire UV LED structures, in order to address issues with the spontaneously formed nanowires. Furthermore, to reduce the quantum confined Stark effect (QCSE), nonpolar AlGaN nanowire UV LEDs exploiting the nonpolar nanowire sidewalls have been demonstrated. With these recent developments, the prospects, together with the general challenges of AlGaN nanowire UV LEDs, are discussed in the end.

Powered by KnowMade

A high performance self-powered ultraviolet photodetector based on a p-GaN/n-ZnMgO heterojunction

State Key Laboratory of Luminescence and Applications, Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences, Changchun 130033, China
Center of Materials Science and Optoelectronics Engineering, University of Chinese Academy of Sciences, Beijing 100049, China

Journal of Materials Chemistry C
https://doi.org/10.1039/C9TC06416H

A high performance p-GaN/n-ZnMgO heterojunction photodiode was demonstrated and investigated. A high quality p-GaN film was grown on GaN/sapphire templates by plasma-assisted molecular beam epitaxy and subsequently an n-ZnMgO layer was deposited on p-GaN by a metal organic chemical vapor deposition technique. The p-GaN/n-ZnMgO heterojunction photodetector shows a clear rectifying I–V characteristic with a turn-on voltage of 2.5 V. At zero-bias voltage, the device shows a high peak responsivity of 196 mA W−1 at 362 nm. The 10–90% rise time and 90–10% decay time of the device can be as short as 1.7 ms and 3.3 ms, respectively. The excellent crystal quality and electrical properties of p-GaN play an important role in the high performance of the photodiode. This work provides a feasible way for the development of high-performance heterojunction self-powered UV detectors.

AlGaN deep-ultraviolet light-emitting diodes grown on SiC substrates

Materials Department, University of California, Santa Barbara, CA 93106, USA
Department of Electrical and Computer Engineering, University of California, Santa Barbara, CA 93106, USA

ACS Photonics
https://doi.org/10.1021/acsphotonics.9b00600

The disinfection industry would greatly benefit from efficient, robust, high-power deep-ultraviolet light-emitting diodes (UV-C LEDs). However, the performance of UV-C AlGaN LEDs is limited by poor light-extraction efficiency (LEE) and the presence of a large density of threading dislocations. We demonstrate high power AlGaN LEDs grown on SiC with high LEE and low threading dislocation density. We employ a crack-free AlN buffer layer with low threading dislocation density and a technique to fabricate thin-film UV LEDs by removing the SiC substrate, with a highly selective SF6 etch. The LEDs (278 nm) have a turn-on voltage of 4.3 V and a CW power of 8 mW (82 mW/mm2) and external quantum efficiency (EQE) of 1.8% at 95 mA. KOH submicron roughening of AlN surface (nitrogen-polar) and improved p-contact reflectivity are found to be effective in improving the LEE of UV light. We estimate the improved LEE by semi-empirical calculations to be 33% (without encapsulation). This work establishes UV LEDs grown on SiC substrates as a viable architecture to large-area, high-brightness, and high power UV LEDs.

Influence of Silicon-Doping in n-AlGaN Layer on the Optical and Electrical Performance of Deep Ultraviolet Light-Emitting Diodes

School of Electronic Information and Electrical Engineering, Shanghai Jiao Tong University, 200240, Shanghai, China
School of Physics and Optoelectronic Engineering, Guangdong University of Technology, 510006, Guangzhou, China
Research and Development Center for Solid State Lighting, Institute of Semiconductors, Chinese Academy of Sciences, 100083, Beijing, China

Russian Journal of Physical Chemistry A volume
https://doi.org/10.1134/S003602441913034X

The influence of two different methods of silicon doping in AlGaN layer, that is, modulation-doping (MD) and delta-doping (DD), on the optical and electrical performance of deep ultraviolet light-emitting diodes (DUV-LEDs) has been investigated. Both the photoluminescence and electroluminescence intensities in the Si-DD structure are stronger than those obtained by the Si-MD method, while the forward voltage and reverse leakage current are slightly smaller in the DD structure than that in the MD structure. Compared with the MD structure, the DD structure shows higher capacitance-voltage characteristics. This study suggests that the DD method can improve the optical and electrical performance of DUV-LEDs.

Powered by KnowMade

ELECTRONICS

Group leader: Farid Medjoub (CNRS-IEMN)

Information selected by Farid Medjoub (CNRS-IEMN) and Yvon Cordier (CNRS-CRHEA)

An SEB Hardened AlGaN/GaN HEMT with Barrier Interlayer

Key Laboratory of RF Circuits and Systems, Ministry of Education, Hangzhou Dianzi University, Hangzhou 310018, China

IEEE Access
https://doi.org/10.1109/ACCESS.2020.2964948

A new single event burnout (SEB) hardened AlGaN/GaN structure with a thin barrier interlayer (IL) is presented in this work. The proposed hardened structure is compared with the simulation results of the conventional structure. The comparative analysis demonstrates that the IL lifts the conduction band energy in buffer layer and a new quantum well is formed. The quantum well limits the electrons induced by heavy ion below the second channel into the first channel. Thus, better SEB performance is achieved compared with the conventional structure. Moreover, the breakdown characteristic of the new structure is significantly improved, while the output characteristic is slightly reduced. Under the condition that the two structures are irradiated vertically by heavy ion having the linear energy transfer (LET) value of 0.6 pC/μm, the SEB threshold voltage of the conventional structure is 280 V, while the hardened structure can achieve 375 V.

Edge Termination for III-Nitride Vertical Power Devices Using Polarization Engineering

Department of Electrical and Computer Engineering, Lehigh University, Bethlehem, PA 18015 USA
Center for Photonics and Nanoelectronics, Lehigh University, Bethlehem, PA 18015 USA

IEEE Transactions on Electron Devices
https://doi.org/10.1109/TED.2019.2958485

A method for edge termination utilizing polarization-induced charge for GaN vertical power devices is presented. The polarization edge termination is simulated on a GaN power diode and consists of a 5-nm-thick n-type AlGaN layer on top of a p-type GaN layer that is located at the periphery of the main p-n junction. The spontaneous and piezoelectric polarization present in III-nitrides result in fixed charges at the AlGaN/GaN heterointerface, and the p-GaN layer becomes depleted at this interface under reverse bias. Numerical simulations show that this AlGaN/GaN heterointerface can be engineered to control the depletion region under reverse bias to prevent localization of electric fields and premature avalanche breakdown. Nearly parallel-plate reverse breakdown performance can be achieved. In addition, a simple analytical model based on charge balancing predicts the performance of this edge termination method.

Dynamic Temperature Measurements of a GaN DC/DC Boost Converter at MHz Frequencies

Faculty of Engineering and Physical Sciences, University of Surrey, 3660 Guildford, Surrey United Kingdom of Great Britain and Northern Ireland GU2 7XH
Microsanj, San Clara, California United States
Colorado School of Mines, 3557 Golden, Colorado United States

IEEE Transactions on Power Electronics
https://doi.org/10.1109/TPEL.2020.2964996

For reliability estimations, gallium nitride transistors require accurate estimations of the peak operating temperatures within the device. This paper presents a new application of thermoreflectance-based temperature measurements performed on a gallium nitride high electron mobility transistor. The submicron spatial and nanosecond temporal resolutions of the measurement system enables for the first time, the dynamic temperature measurement of a transistor operating up to 5 MHz. The GaN transistor is first biased in class-A and excited with a 1 MHz AC signal to demonstrate the dynamic temperature measurement. The transistor is then incorporated in a 20-40 V DC/DC boost converter to measure the dynamic temperature distributions across the semiconductor die operating under real loading conditions at 1 and 5 MHz switching frequencies. This technique captures the temperature variations that occur during the switching of the transistor and the recorded peak temperatures

Powered by KnowMade

indicate an increase of up to 7.4 C compared with conventional measurement and simulation methodologies.

Demonstration of a GaN/AlGaN superlattice based p-channel FinFET with high on-current

Department of Electrical and Computer Engineering, University of California Santa Barbara, Santa Barbara, CA 93106 USA

IEEE Electron Device Letters
https://doi.org/10.1109/LED.2019.2963428

In this letter, we report on the demonstration of a Mg-doped GaN/Al0.2Ga0.8N superlattice (SL) based depletion mode p-channel FinFET to improve the on current (Ion). A two-step approach involving a dry etch followed by a Tetramethylammonium hydroxide (TMAH) wet etch was employed to obtain fins with minimum width of 50 nm using optical lithography. Normalizing current with fin height, an Ion of 52 mA/mm and 110 mA/mm were achieved for 80 and 105 nm wide fins respectively.

Degradation Behavior and Mechanisms of E-Mode GaN HEMTs With p-GaN Gate Under Reverse Electrostatic Discharge Stress

Science and Technology on Reliability Physics and Application of Electronic Component Laboratory, The No.5 Electronics Research Institute of the Ministry of Industry and Information Technology, Guangzhou 510610, China
South China University of Technology, Guangzhou 510610, China

IEEE Transactions on Electron Devices
https://doi.org/10.1109/TED.2019.2959299

The degradation behavior and its mechanisms of E-mode GaN high electron mobility transistors (HEMTs) with p-GaN gate under electrostatic discharge (ESD) stress were investigated. Reverse short-pulse stress was generated by a transmission line pulse (TLP) tester in order to simulate the static electricity. The experiment results show that the reverse short-pulse stress leads to the characteristic degradation of the E-mode GaN HEMTs with p-GaN gate. The values of the threshold voltage and on-resistance increase, and the gate capacitance curve shifts positively. The low-frequency noises (LFNs) were obtained for the E-mode GaN HEMTs with p-GaN gate before and after the reverse short-pulse stress. The concentration of traps was extracted, and it has doubled after 700 cycles. The degradation mechanism could be attributed to the generation of traps at p-GaN/AlGaN heterointerface, AlGaN barrier, and GaN/AlGaN interface. Such an investigation can be a significant reference in the design and application of E-mode GaN power devices.

Reverse Leakage Analysis for As-grown and Regrown Vertical GaN-on-GaN Schottky Barrier Diodes

School of Electrical, Computer and Energy Engineering, Arizona State University, Tempe, AZ 85287 USA
School for Engineering of Matter, Transport and Energy, Arizona State University, Tempe, AZ 85287 USA
Key Laboratory of Nanodevices and Applications, Suzhou Institute of Nano-tech and Nano-bionics, CAS, Suzhou 215123, China
Department of Physics, Arizona State University, Tempe, AZ 85287 USA

IEEE Journal of the Electron Devices Society
https://doi.org/10.1109/JEDS.2020.2963902

Vertical GaN-on-GaN Schottky barrier diodes based on as-grown and regrown samples were fabricated to investigate the effects of the etch-then-regrow process on device performance. The surface roughness increased slightly after dry etching and decreased after regrowth. According to X-ray diffraction results, the etch-then-regrow process caused a slight increase of defect density due to increased edge dislocations. Schottky parameters extracted from forward current-voltage curves, such as turn-on voltages of 0.74 V and 0.72 V, ideality factors of 1.07 and 1.10, and barrier heights of 1.07 eV and 1.05 eV, were obtained for diodes based on the regrown and as-grown samples, respectively. The breakdown voltage of the regrown sample was much lower than the as-grown sample. The regrowth interface can be regarded as a n-doping GaN layer due to the high interface charge density after the etch-then-regrown process. This equivalent n-doping GaN layer reduced the effective thickness of the UID-GaN under the Schottky contact thus causing lower breakdown voltage for the regrown sample. Poole-Frenkel emission and trap-assisted tunneling processes were responsible for the leakage of both as-grown and regrown samples according to the temperature dependence of the reverse currents.

Powered by KnowMade

Design and Validation of 100 nm GaN-On-Si Ka-Band LNA Based on Custom Noise and Small Signal Models

Electronic Engineering Department, Università di Roma Tor Vergata, 00131 Roma, Italy
OMMIC SAS, 2 rue du Moulin, 94453 Limeil Brèvannes, France
Thales Alenia Space, via Saccomuro 19-21, 00131 Rome, Italy
European Commission—Research Executive Agency (REA), place Rogier 16, 1049 Bruxelles, Belgium

Electronics
https://doi.org/10.3390/electronics9010150

In this paper a GaN-on-Si MMIC Low-Noise Amplifier (LNA) working in the Ka-band is shown. The chosen technology for the design is a 100 nm gate length HEMT provided by OMMIC foundry. Both small-signal and noise models had been previously extracted by the means of an extensive measurement campaign, and were then employed in the design of the presented LNA. The amplifier presents an average noise figure of 2.4 dB, a 30 dB average gain value, and input/output matching higher than 10 dB in the whole 34–37.5 Ghz design band, while non-linear measurements testify a minimum output 1 dB compression point of 23 dBm in the specific 35–36.5 GHz target band. This shows the suitability of the chosen technology for low-noise applications.

Vertical breakdown of GaN on Si due to V-pits

Fraunhofer Institute for Integrated Systems and Device Technology IISB, Schottkystr. 10, 91058 Erlangen, Germany
Chair of Electron Devices, University of Erlangen-Nürnberg, Cauerstr. 6, 91058 Erlangen, Germany
Department of Information Engineering, University of Padova, via Gradenigo 6/B, 35131 Padova, Italy
Naval Research Laboratory, 4555 Overlook Avenue, Washington, DC 20375, USA
EpiGaN, Kempische Steenweg 293, 3500 Hasselt, Belgium
CNRS-IEMN, Institute of Electronics, Microelectronics and Nanotechnology, Avenue Poincaré, 59650 Villeneuve d'Ascq, France

Journal of Applied Physics
https://doi.org/10.1063/1.5129248

Gallium nitride on silicon (GaN/Si) is an important technological approach for power electronic devices exhibiting superior performance compared to devices based on a pure silicon technology. However, the material defect density in GaN/Si is high, and identification of critical defects limiting device reliability is still only partially accomplished because of experimental difficulties. In this work, atomic force microscopy, scanning electron microscopy, secondary ion mass spectrometry, and cathodoluminescence were employed to investigate commonly occurring epitaxial overgrown V-pits and inhomogeneous incorporation of oxygen and carbon across layer stacking in the vertical direction. These experiments identified V-pits as regions with higher n-type carrier concentrations and paths for vertical leakage through the buffer, as directly probed by conductive atomic force microscopy. The deleterious effect of V-pits on device performance is demonstrated by evaluating test devices fabricated on two wafers with significantly diverse density of buried V-pits induced by varying growth conditions of the aluminum nitride nucleation layer. A clear correlation between observed vertical breakdown and density of V-pits within the C-doped GaN layer below the device structures is obtained. Back-gating transient measurements also show that the dynamic device behavior is affected by the V-pit density in terms of the detrapping time constants.

Transient Simulation for the Thermal Design Optimization of Pulse Operated AlGaN/GaN HEMTs

Science and Technology on Monolithic Integrated Circuits and Modules Laboratory, Nanjing Electronic Devices Institute, Nanjing 210016, China

Micromachines
https://doi.org/10.3390/mi11010076

The thermal management and channel temperature evaluation of GaN power amplifiers are indispensable issues in engineering field. The transient thermal characteristics of pulse operated AlGaN/GaN high electron mobility transistors (HEMT) used in high power amplifiers are systematically investigated by using three-dimensional simulation with the finite element method. To improve the calculation accuracy, the nonlinear thermal conductivities and near-junction region of GaN chip are considered and treated appropriately in our numerical analysis. The periodic transient pulses temperature and temperature distribution are analyzed to estimate

Powered by KnowMade

thermal response when GaN amplifiers are operating in pulsed mode with kilowatt-level power, and the relationships between channel temperatures and pulse width, gate structures, and power density of GaN device are analyzed. Results indicate that the maximal channel temperature and thermal impedance of device are considerably influenced by pulse width and power density effects, but the changes of gate fingers and gate width have no effect on channel temperature when the total gate width and active area are kept constant. Finally, the transient thermal response of GaN amplifier is measured using IR thermal photogrammetry, and the correctness and validation of the simulation model is verified. The study of transient simulation is demonstrated necessary for optimal designs of pulse-operated AlGaN/GaN HEMTs.

Single Pulse Charge Pumping Measurements on GaN MOS-HEMTs: Fast and Reliable Extraction of Interface Traps Density

School of Electrical and Computer Engineering, Purdue University, West Lafayette, IN 47907 USA
Birck Nanotechnology Center, Purdue University, West Lafayette, IN 47907 USA
Department of Electrical and Computer Engineering, King Abdulaziz University, Jeddah 21589, Saudi Arabia

IEEE Transactions on Electron Devices
https://doi.org/10.1109/TED.2019.2961090

In this article, we report on the single pulse charge pumping (SPCP) measurements as a method to extract the interface trap density (Nit) on the GaN metal-oxide-semiconductor high-electron-mobility transistors (MOS-HEMTs). The electron capture and emission processes are monitored in the time domain and studied during the rising and falling edges of a gate voltage pulse. Two different gate stacks are studied by SPCP including epitaxial Mg0.25 Ca0.75O (MgCaO) and amorphous Al_2O_3. The signature charge pumping (CP) current peaks are observed enabling a direct extraction of Nit as low as 1.4 x 10^{11} cm^{-2} with gate voltage sweeping from OFF-state to ON-state in the GaN MOS-HEMT with epitaxial MgCaO gate stack. A significant reduction of Nit by the MgCaO gate stack compared to Al_2O_3 only gate stack is also confirmed by the SPCP method. SPCP realizes a direct Nit measurement on GaN transistors and confirms the high quality interface between the single crystalline epitaxial MgCaO and GaN. It is verified as a fast and reliable interface characterization method on III-V HEMTs, gate-all-around nanowire transistors, and 2-D transistors, which do not exhibit body contacts as the conventional Si transistors needed for conventional CP measurements.

Hf0.5Zr0.5O2 Based Ferroelectric Gate HEMTs (FeHEMTs) with Large Threshold Voltage Tuning Range

Department of Electrical Engineering, University of Notre Dame, Notre Dame, IN 46556 USA

IEEE Electron Device Letters
https://doi.org/10.1109/LED.2020.2965330

AlGaN/GaN high-electron-mobility transistors (HEMTs) with Hr0.5Zr0.5O2 ferroelectric gate stacks exhibiting significant ferroelectric switching for threshold voltage control are experimentally demonstrated. Ferroelectric gate HEMTs (FeHEMTs) with large threshold voltage tuning range of 2.8 V were obtained, with an on/off ratio of ~10 5 based on a GaN-channel HEMT structure suitable for RF applications. Improved subthreshold performance has also been achieved compared to conventional MIS-HEMTs, with reduction in average sub-threshold swing (SSavg) by a factor of 2. As a consequence of the significant ferroelectric polarization achieved on AlGaN/GaN heterostructures, Hr0.5Zr0.5O2 based ferroelectric gate AlGaN/GaN HEMTs appear promising for nonvolatile and reconfigurable RF and microwave applications.

Design of GaN Based Multilevel Switched Capacitor Converters - Benefits and Challenges

Renesas Electronics Corporation, 133783 California United States
Efficient Power Conversion Corp, Blacksburg, Virginia United States 24060

IEEE Transactions on Industry Applications
https://doi.org/10.1109/TIA.2020.2965902

With the significant reduction in board space occupied by the smaller GaN transistors, topologies that require a greater number of active devices as a tradeoff for reduced passive size, the main barrier to higher power

Powered by KnowMade

density, have become attractive. Switched capacitor multilevel converters are good examples of topologies that can effectively reduce or eliminate passive components. Two GaN based proof-of-concept designs, based on the three-level buck converter, one for a low voltage (LV) 48 V server application and the other as a candidate for a higher voltage (HV) 400 V power factor correction (PFC) circuit application are discussed in this paper. As a result of using lower figure-of-merit (FOM) devices, significant efficiency gains are observed for the LV and HV converters developed in this paper compared to a two-level topology. Smaller passive size (mainly inductors) also provides a significant increase in power density for the LV converter. A startup scheme is discussed which eliminates the need for extraneous control loops or high voltage rated devices for the top switch. Finally, the thermal benefit of the three-level converter is demonstrated when compared to a two-level system for the 48 V server application.

Effect of Uniaxial Tensile Strains at Different Orientations on the Characteristics of AlGaN/GaN High-Electron-Mobility Transistors

Faculty of Information Technology, School of Microelectronics, Beijing University of Technology, Beijing 100124, China
Electric Engineering Division, University of Cambridge, Cambridge CB3 0FA, U.K.
State Key Laboratory of New Ceramics and Fine Processing, School of Materials Science and Engineering, Tsinghua University, Beijing 100084, China

IEEE Transactions on Electron Devices
https://doi.org/10.1109/TED.2019.2961956

The influence of uniaxial tensile strains with different orientations to the conduction channel on the electrical and physical properties of AlGaN/GaN high-electron-mobility transistors (HEMTs) was investigated. The output current decreases with the increase of the tensile strain as the orientation of strain changes from 0° to 90° with respect to the conduction channel. The results of the measured C-V curves show that for the same strain level the two-dimensional electron gas (2DEG) density decreases monotonically to different extents depending on the strain orientation. A conversion of the strain at different orientations to an equivalent strain parallel to the conduction channel shows that the theoretical resultant changes of the 2DEG density are consistent with the experimental results. The corresponding electron mobility is also calculated, which shows a decreasing trend under the tensile strain. Furthermore, using the transient current method, it is established that the detrapping time constant increases as a result of the tensile strain, which is ascribed to the movement of the trap level away from the conduction band.

Transient Analysis When Applying GaN+Si Hybrid Switching Modules to A Zero-voltage-switching EV On-board Charger

Hella Electronics Corporation
Center for Ultrawide-Area Resilient Electric Energy Transmission Networks (CURENT), The University of Tennessee, Knoxville, TN, USA
EECS, University of Tennessee, Knoxville, USA

IEEE Transactions on Transportation Electrification
https://doi.org/10.1109/TTE.2020.2966915

Wide-bandgap (WBG) devices are considered to be a better alternative to silicon switches to realize high-efficiency and high-power-density power electronics converters, such as electric vehicle on-board chargers. The two major challenges of GaN devices remain are their relatively high cost (5 times as compared to Si) and much smaller footprint than Si, which though is preferred in the high-power density application is preferred but brings thermal challenges. Much like SiC is paralleled with Si, GaN could be paralleled with Si to resolve these challenges. In this paper, GaN HEMTs are paralleled to various Si MOSFETs. Two different triggering approaches are considered, one adds a time delay between gate signals and the other uses a pulse triggering technique. Both methods ensure the GaN endure the switching loss while the Si switches conduct the majority of the current thereby maximizing the advantages of both types of switches. To follow is a comprehensive study of the critical transient processes, such as the gate cross talking between Si and GaN, current commutation in the dead band, voltage spikes during the turn-off caused by parasitics, the thermal performance and the cost analysis. Demonstrated success testing this approach at 400V/80A provides evidence that this is a possible approach in the on-board EV (electric vehicle) battery

Powered by KnowMade

charger applications. The success of testing under 400V/80A makes it possible to an on-board EV battery charger.

Al-rich AlGaN based transistors

Sandia National Laboratories, PO Box 5800, Albuquerque, New Mexico 87185-1085

Journal of Vacuum Science & Technology A
https://doi.org/10.1116/1.5129803

Research results for AlGaN-channel transistors are reviewed as they have progressed from low Al-content and long-channel devices to Al-rich and short-channel RF devices. Figure of merit (FOM) analysis shows encouraging comparisons relative to today's state-of-the-art GaN devices for high Al-content and elevated temperatures. Critical electric field (EC), which fuels the AlGaN transistor FOM for high Al-composition, is not measured directly, but average gate-drain electric field at breakdown is substantially better in multiple reported AlGaN-channel devices compared to GaN. Challenges for AlGaN include the constraints arising from relatively low room temperature mobility dominated by ternary alloy scattering and the difficulty of making low-resistivity Ohmic contacts to high Al-content materials. Nevertheless, considerable progress has been made recently in the formation of low-resistivity Ohmic contacts to Al-rich AlGaN by using reverse compositional grading in the semiconductor, whereby a contact to a lower-Al alloy (or even to GaN) is made. Specific contact resistivity (ρc) approaching $\rho c \sim 2 \times 10{-}6\ \Omega\ cm2$ to AlGaN devices with 70% Al-content in the channel has been reported. Along with scaling of the channel length and tailoring of the threshold voltage, this has enabled a dramatic increase in the current density, which has now reached 0.6 A/mm. Excellent ION/IOFF current ratios have been reported for Schottky-gated structures, in some cases exceeding 109. Encouraging RF performance in Al-rich transistors has been reported as well, with fT and fmax demonstrated in the tens of gigahertz range for devices with less than 150 nm gates. Al-rich transistors have also shown lesser current degradation over temperature than GaN in extreme high-temperature environments up to 500 °C, while maintaining ION/IOFF ratios of ∼106 at 500 °C. Finally, enhancement-mode devices along with initial reliability and radiation results have been reported for Al-rich AlGaN transistors. The Al-rich transistors promise to be a very broad and exciting field with much more progress expected in the coming years as this technology matures.

A highly efficient method to fabricate normally-off AlGaN/GaN HEMTs with low gate leakage via Mg diffusion

State Key Laboratory of Luminescent Materials and Devices, South China University of Technology, Guangzhou 510641, People's Republic of China

Applied Physics Letters
https://doi.org/10.1063/1.5134918

A method to achieve p-type doping gate by Mg diffusion is proposed to fabricate normally-off AlGaN/GaN high electron mobility transistors (HEMTs). The fabrication is completed via first slight etching to introduce defects into the gate region and then rapid annealing to diffuse Mg ions into the AlGaN barrier, thereby forming a p-type doping layer and positively shifted threshold voltage. In addition, the MgO layer formed by thermal oxidation could effectively passivate the surface traps that were caused in the previous etching procedure. The as-fabricated HEMTs demonstrate a low gate leakage of 2 × 10−7 mA/mm and a VTH of 1.4 V. This technique offers a simplified and highly effective method to fabricate high performance GaN power devices.

A Family of Ultra-High Efficiency Fractional DC-DC Topologies for High Power Energy Storage Device

FREEDM Systems Center, North Carolina State University, Raleigh, North Carolina, USA
Electrical and Computer Engineering and University of Texas at Austin, Austin, Texas, USA

IEEE Journal of Emerging and Selected Topics in Power Electronics
https://doi.org/10.1109/JESTPE.2020.2966177

The application of a non-isolated bidirectional fractional DC-DC topology is proposed for high power energy storage device in this paper. The proposed topology has the benefits of ultra-high efficiency, simple structure and low cost, because it processes only a fractional of the total power. With the existence of an extra low voltage power source, the converter

Powered by KnowMade

voltage stress is only the difference between the DC bus and high voltage power source, therefore low cost low voltage transistors can be used in high voltage high power applications. Since a majority of the power is transferred directly between the energy storage device and DC bus, ultra-high system efficiency can be achieved. Converter operating principle and design considerations such as battery capacity calculation methodologies and over voltage protection are presented. A GaN transistor based prototype is fabricated. Experimental results of a 1.2kW battery energy storage prototype are presented to validate the analysis. The system efficiency is higher than 99% in a wide input/output voltage range are achieved. The fractional converter is convincing in achieving high efficiency and high conversion power with reduced cost for energy storage devices.

Low Gate Lag Normally-Off p-GaN/AlGaN/GaN High Electron Mobility Transistor with Zirconium Gate Metal

Department of Electronics Engineering, Chang Gung University, Taoyuan 333, Taiwan
Department of Radiation Oncology, Chang Gung Memorial Hospital, Taoyuan 333, Taiwan
The College of Engineering, Ming Chi University of Technology, Taishan 243, Taiwan
Materials & Electro-Optics Research Division, National Chung-Shan institute of Science & Technology, Longtan 325, Taiwan
Department of Digital Multimedia Technology, Vanung University, Chungli 32061, Taiwan

Crystals
https://doi.org/10.3390/cryst10010025

The impact of gate metal on the leakage current and breakdown voltage of normally-off p-GaN gate high-electron-mobility-transistor (HEMT) with nickel (Ni) and zirconium (Zr) metals were studied and investigated. In this study, a Zr metal as a gate contact to p-GaN/AlGaN/GaN high mobility transistor (HEMT) was first applied to improve the hole accumulation at the high gate voltage region. In addition, the ZrN interface is also beneficial for improving the Schottky barrier with low nitrogen vacancy induced traps. The features of Zr are low work function (4.05 eV) and high melting point, which are two key parameters with p-GaN Schottky contact at reversed voltage. Therefore, Zr/p-GaN interface exhibits highly potential for GaN-based switching power device applications

Extreme Temperature Modeling of AlGaN/GaN HEMTs

Fraunhofer Institute for Applied Solid State Physics (IAF), 79108 Freiburg, Germany
Department of Engineering, Macquarie University, Sydney, NSW 2109, Australia
Department of Aeronautics and Astronautics, Stanford University, Stanford, CA~94305~USA
AdMOS GmbH, 72636~Frickenhausen, Germany

IEEE Transactions on Electron Devices
https://doi.org/10.1109/TED.2019.2960573

The industry standard advanced SPICE model (ASM)-GaN compact model has been enhanced to model the GaN high electron mobility transistors (HEMTs) at extreme temperature conditions. In particular, the temperature dependence of the trapping behavior has been considered and a simplifying approximation in the temperature modeling of the saturation voltage in the ASM-GaN model has been relaxed. The enhanced model has been validated by comparing the simulation results of the model with the dc I-V measurement results of a GaN HEMT measured with chuck temperatures ranging from 22 °C to 500 °C. A detailed description of the modeling approach is presented. The new formulation of the ASM-GaN compact model can be used to simulate the circuits designed for extreme temperature environments.

Modeling dislocation-related leakage currents in GaN p-n diodes

Materials Department, University of California, Santa Barbara, California 93106, USA
Department of Electrical Engineering, National Taiwan University, Taipei City 10617, Taiwan

Journal of Applied Physics
https://doi.org/10.1063/1.5123394

Finite element analysis software was used to model and visualize two p-n junction models: one with a single threading dislocation (TD) and a control model without a dislocation. TDs are modeled as a Gaussian distribution of trap states with an FWHM of 5 nm localized around the r=0 line in a cylindrical coordination such that the linear trap state density

Powered by KnowMade

was 1 trap/c-translation; this model allows the cylindrical symmetry of the c-plane GaN crystal orientation to be utilized to avoid more computationally intensive 3D models. It was discovered that the interaction of the charged dislocation region with the p-n junction had many notable effects. At zero bias, it was observed that the depletion region width (using the Depletion Approximation) and the maximum electric field were markedly reduced near the dislocation line. More significantly, an asymmetric reduction in the diffusion barrier for electrons (Veffbi=3.03eV) and holes (Veffbi=0.81eV) was observed due to the asymmetric nature of the dislocation band bending related to the doping. The asymmetric reductions in diffusion barriers persisted into VA=2.4V leakage case where asymmetric current profiles for electrons and holes were also observed. Lastly, the diffusion barrier reduction resulted in an additional Shockley-Read-Hall nonradiative recombination leakage caused by a high np-product and trap state density near the intersection of the dislocation with the junction.

Vertical Leakage in GaN-on-Si Stacks Investigated by a Buffer Decomposition Experiment

Department of Information Engineering, University of Padova, 35151 Padova, Italy
Fraunhofer Institute for Integrated Systems and Device Technology IISB, 91058 Erlangen, Germany
EpiGaN, 3500 Hasselt, Belgium
IEMN-CNRS, 59652 Villeneuve d'Ascq, France

Micromachines
https://doi.org/10.3390/mi11010101

We investigated the origin of vertical leakage and breakdown in GaN-on-Si epitaxial structures. In order to understand the role of the nucleation layer, AlGaN buffer, and C-doped GaN, we designed a sequential growth experiment. Specifically, we analyzed three different structures grown on silicon substrates: AlN/Si, AlGaN/AlN/Si, C:GaN/AlGaN/AlN/Si. The results demonstrate that: (i) the AlN layer grown on silicon has a breakdown field of 3.25 MV/cm, which further decreases with temperature. This value is much lower than that of highly-crystalline AlN, and the difference can be ascribed to the high density of vertical leakage paths like V-pits or threading dislocations. (ii) the AlN/Si structures show negative charge trapping, due to the injection of electrons from silicon to deep traps in AlN. (iii) adding AlGaN on top of AlN significantly reduces the defect density, thus resulting in a more uniform sample-to-sample leakage. (iv) a substantial increase in breakdown voltage is obtained only in the C:GaN/AlGaN/AlN/Si structure, that allows it to reach VBD > 800 V. (v) remarkably, during a vertical I–V sweep, the C:GaN/AlGaN/AlN/Si stack shows evidence for positive charge trapping. Holes from C:GaN are trapped at the GaN/AlGaN interface, thus bringing a positive charge storage in the buffer. For the first time, the results summarized in this paper clarify the contribution of each buffer layer to vertical leakage and breakdown.

Strain-controlled power devices as inspired by human reflex

CAS Center for Excellence in Nanoscience, Beijing Key Laboratory of Micro-nano Energy and Sensor, Beijing Institute of Nanoenergy and Nanosystems, Chinese Academy of Sciences, Beijing, 100083, China
School of Nanoscience and Technology, University of Chinese Academy of Sciences, Beijing, 100049, P. R. China
Graduate School of Electrical and Electronic Engineering, Chiba University, Chiba, 263-8522, Japan
Estuarine and Coastal Environment Research Center, Chinese Research Academy of Environmental Sciences, Beijing, 100012, P. R. China

Nature Communications volume
https://doi.org/10.1038/s41467-019-14234-7

Bioinspired electronics are rapidly promoting advances in artificial intelligence. Emerging AI applications, e.g., autopilot and robotics, increasingly spur the development of power devices with new forms. Here, we present a strain-controlled power device that can directly modulate the output power responses to external strain at a rapid speed, as inspired by human reflex. By using the cantilever-structured AlGaN/AlN/GaN-based high electron mobility transistor, the device can control significant output power modulation (2.30–2.72 × 103 W cm−2) with weak mechanical stimuli (0–16 mN) at a gate bias of 1 V. We further demonstrate the acceleration-feedback-controlled power application, and prove that the output power can be effectively adjusted at real-time in response to acceleration changes, i.e., ▵P

Powered by KnowMade

of 72.78–132.89 W cm−2 at an acceleration of 1–5 G at a supply voltage of 15 V. Looking forward, the device will have great significance in a wide range of AI applications, including autopilot, robotics, and human-machine interfaces.

Reliability Assessment of AlGaN/GaN Schottky Barrier Diodes under ON-state stress

Departamento de Física, Escuela Politécnica Nacional (EPN), Quito-Ecuador
ISEP, Paris-France
DIMES, Università della Calabria, Rende-Italy
IMNE, Universidad San Francisco de Quito, Quito-Ecuador
imec, Leuven-Belgium

IEEE Transactions on Device and Materials Reliability
https://doi.org/10.1109/TDMR.2020.2969638

This article aims to study the degradation of Schottky Barrier Diodes (SBDs) with a Gated Edge Termination (GET) under ON-state stress conditions. After all the stress experiments a recoverable behavior is observed, which indicates charge trapping in pre-existing defects and no creation of new traps. A broad statistical analysis demonstrates better reliability and a longer lifetime compared to previous works in a 200-V technology. Some systematic differences in parameter degradation are observed depending on wafer location, likely caused by process-related variations. By using matched pairs (MPs) technique, we have demonstrated that probability distributions characterized by single Weibull slopes can be obtained over the wafer that could allow better characterization of the intrinsic reliability of these devices.

Resonance Suppression and EMI Reduction of GaN-Based Motor Drive with Sine Wave Filter

Electrical Engineering, Harbin Institute of Technology, Harbin, Heilongjiang China 150001

IEEE Transactions on Industry Applications
https://doi.org/10.1109/TIA.2020.2969873

Applying high-frequency power devices, such as gallium nitride (GaN) semiconductor devices, to the motor drive can significantly reduce system volume, losses, audible noise and increase system power density. In this paper, an LC filter designed as a sine wave filter is introduced into the servo drive system based on the GaN power device. An undamped method with variable delay time is proposed to solve the electrical resonance issue caused by LC filter and stator inductor. Detailed stability analysis is conducted, and rules on parameter tuning are provided. With additional proper time delay, the system can be stable without any extra sensors or power losses. Besides, this method is suitable for resonance suppression at variable switching frequency. Moreover, a wait-free and phase-continuous spread spectrum frequency modulation is applied to solve the issue of electromagnetic interference (EMI). The field-programmable gate array (FPGA) is used to achieve high control bandwidth when implementing the control algorithm. Finally, the ideal sinusoidal drive and low conducted EMI of permanent magnet synchronous motor (PMSM) is realized. Experiments on a 100 kHz GaN inverter with LC filter verify the validity of the proposed design and method.

Interdependence of Electronic and Thermal Transport in AlxGa1-xN Channel HEMTs

Department of Mechanical Engineering and Pennsylvania State University, University Park, Pennsylvania, 16802, USA
Sandia National Laboratories, Albuquerque, New Mexico, 87185, USA
School of Mechanical Engineering, Purdue University, West Lafayette, IN 47907, USA
Materials and Manufacturing Directorate, Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio, 45433, USA
Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139

IEEE Electron Device Letters
https://doi.org/10.1109/LED.2020.2969515

Aluminum gallium nitride (AlGaN) high electron mobility transistors (HEMTs) are candidates for next-generation power conversion and radio frequency (RF) applications. AlxGa1-xN channel HEMT devices (x = 0.3, x = 0.7) were investigated using multiple in-situ thermal characterization methods and electro-thermal simulation. The thermal conductivity, contact resistivity, and channel mobility were characterized as a function of temperature to understand and compare the heat generation profile and electro-thermal transport within these devices. In contrast to GaN-

Powered by KnowMade

based HEMTs, the electrical output characteristics of Al0.70Ga0.30N channel HEMTs exhibit remarkably lower sensitivity to the ambient temperature rise. Also, during 10kHz pulsed operation, the difference in peak temperature between the AlGaN channel HEMTs and GaN HEMTs reduced significantly.

A Reliable Ultra-Fast Short Circuit Protection Method for E-mode GaN HEMT

Department of Electrical and Computer Engineering, The Ohio State University, Columbus, Ohio United States
USCRC, Power electronics department, ABB INC., Raleigh, North Carolina United States 27606

IEEE Transactions on Power Electronics
https://doi.org/10.1109/TPEL.2020.2968865

A unique three-step short circuit protection method is proposed for the 650 V Enhancement Mode (E-mode) Gallium Nitride High Electron Mobility Transistor (GaN HEMT). This method can quickly detect the short circuit event, reduce gate voltage to enhance the device short circuit capability, and turn off the device under fault after confirmation. Experimental results prove that with this method, the short circuit fault detection time for E-mode GaN HEMT is shortened from 2 µs to several tens of nanoseconds, and the device can be successfully protected from fatal failure under high dc bus voltage without mis-triggering.

Modeling of the Vertical Leakage Current in AlN/Si Heterojunctions for GaN Power Applications

Department of Information Engineering, University of Padova, Padova, Italy
Center for Microsystems Technology (CMST), imec, Leuven, Belgium

IEEE Transactions on Electron Devices
https://doi.org/10.1109/TED.2020.2964060

We present a model for the vertical conduction through an AlN/p–Si junction, which is used as a base for the growth of GaN power devices. First, we recall that for resistive silicon substrates, the I – V curves of the AlN/p–Si show a monotonic increase, interrupted by a plateau region. Then, to quantitatively explain this behavior, we propose a novel two-diode model. More specifically, we demonstrate that the AlN/p-Si structure can be split into the series connection of two substructures: 1) an equivalent AlN/n + -Si junction and 2) an equivalent n + -Si/p-Si diode. The n + layer models the electron inversion layer in the silicon at the interface with the AlN layer. Technology Computer-Aided Design (TCAD) simulations were used to validate these two diode models. By comparing the leakage current of the AlN/p-Si structure with the current through the diodes, we demonstrate that within the plateau region, all the applied voltage drops on the equivalent n + -Si/p-Si junction, and the current through the diodes is limited by the reverse leakage current of the n + -Si/p-Si diode. The plateau ends as soon as impact ionization occurs in the Si substrate, due to the high electric field in the depletion region. After the plateau, the current through the diodes is again limited by charge injection from the inversion layer into the AlN, which occurs through a phonon-assisted tunneling mechanism (possibly trap-assisted).

High-Efficiency Hybrid LLC Resonant Converter for On-board Chargers of Plug-in Electric Vehicles

Electrical Engineering, Yeungnam University, 35032 Gyeongsan, Gyeongsangbuk-do Korea

IEEE Transactions on Power Electronics
https://doi.org/10.1109/TPEL.2020.2968084

This paper proposes a hybrid LLC resonant converter with three modes of operation for on-board chargers of electric vehicles (EVs). The converter can operate as a full-bridge converter, dual-phase half-bridge LLC converter or single-phase half-bridge LLC converter to improve efficiency at low voltage and light load conditions. Without using additional switches, the operation mode of the proposed converter is switched by different modulation schemes. Moreover, the resonant inductance for LLC operation can be reduced so as to be integrated into the transformers, resulting in an increase in the power density. During the operation of three modes, all the primary switches achieve zero-voltage switching (ZVS), thus minimizing the switching losses. A 3.2 kW-rated prototype using GaN devices with a power density of 65.5 W/in3 has been designed and tested to verify the effectiveness of the converter. Experimental results have shown smooth and stable transitions among three modes. A flat efficiency curve with a peak efficiency of 98.5% at full load condition has been achieved.

Powered by KnowMade

Observation of ID-VD Kink in N-polar GaN MIS-HEMTs at Cryogenic Temperatures

Transphorm, Inc., Goleta (CA), USA
University of California, Santa Barbara, Department of Electrical and Computer Engineering
University of Padova, Department of Information Engineering

IEEE Electron Device Letters
https://doi.org/10.1109/LED.2020.2968875

This paper reports on the hot-carrier effects and semi-on-state behavior of nitrogen-polar GaN MIS-HEMTs at cryogenic temperatures (from 300 K down to 100 K). In the semi-on-state (VG ≈-2 V), holes are generated by impact ionization in the high field region at the drain-side of the gate-edge. At room temperature, holes overcome the SiN/AlGaN stack and are collected at the gate-terminal, resulting in measurable hole gate-current (~11 nA/mm). Conversely, at cryogenic temperatures, the top SiN/AlGaN stack confines the holes within the GaN channel, thus inducing a negative threshold voltage shift (-0.4 V) and a sharp increase in drain current (0.18 A/mm). This behavior, referred to as "kink," is readily observable on the ID-VD characteristics. We demonstrated that the kink is related to impact ionization and follows a non-monotonic behavior maximized in the semi-on-state. Our interpretation is supported by a quantitative analysis based on the latest experimental impact-ionization coefficients available in the literature.

p-GaN Gate Power Transistor with Distributed Built-in Schottky Barrier Diode for Low-loss Reverse Conduction

Department of Electronic and Computer Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong

IEEE Electron Device Letters
https://doi.org/10.1109/LED.2020.2968735

A 700-V normally-off p-GaN gate power transistor with distributed built-in Schottky barrier diode (SBD) is demonstrated in this work. The transistor cell and diode cell are alternately arrayed along the device width and are locally isolated using ion implantations. The built-in SBD provides a low reverse turn-on voltage which is independent of the threshold voltage and gate bias of the transistor. Compared to the two-device scheme consisting of an anti-parallel p-GaN gate HEMT/SBD pair, the proposed transistor exploits the common access region in both forward conduction and reverse conduction, thus a significant reduction in chip area is obtained.

Desynchronizing Paralleled GaN HEMTs to Reduce Light-Load Switching Loss

Department of Engineering, University of Cambridge, 2152 Cambridge United Kingdom of Great Britain and Northern Ireland CB3 0FA

IEEE Transactions on Power Electronics
https://doi.org/10.1109/TPEL.2020.2970240

Parallel connection of GaN high-electron-mobility transistors (HEMTs) is commonly used to achieve higher current ratings. However, at light loads, the switching loss becomes dominant and the overall power conversion efficiency drops sharply. To reduce the light-load switching loss, this paper proposes a desynchronizable paralleling scheme. The midpoint of each paralleled half bridge is connected with a commutation inductor for two operation modes: synchronous and asynchronous. The synchronous mode is activated at heavy loads to share the high current; the added commutation inductors lead to better current sharing than the direct parallel. At light loads, the paralleled devices are desynchronized to generate a circulating current flowing through the commutation inductors. The circulating current enables the lagging HEMTs to achieve the zero-voltage switching (ZVS) and allows the leading ones to turn on at a lower current, thereby significantly reducing the total switching loss. In addition, a thermal balancing scheme is proposed to alleviate the thermal stress imbalance between the desynchronized GaN HEMTs. The operating principle and design guidelines of the desynchronizable paralleling scheme are detailed. Experimental results from multi-pulse and continuous tests are provided to verify the advantages of the proposed paralleling scheme in reducing light-load switching loss and improving light-load efficiency.

Powered by KnowMade

Quasi-Vertical GaN Schottky Barrier Diode on Silicon Substrate with 1010 High On/Off Current Ratio and Low Specific On-Resistance

Institute of Microelectronics, Peking University, Beijing, China
School of Physics, Peking University, Beijing, China

IEEE Electron Device Letters
https://doi.org/10.1109/LED.2020.2968392

In this letter, we report a quasi-vertical GaN Schottky barrier diode (SBD) fabricated on a hetero-epitaxial layer on silicon with low dislocation density and high carrier mobility. The reduction of dislocation is realized by inserting a thin layer with high density of Ga vacancies to promote the dislocation bending. The dislocation density is 1.6×108 cm-2 with a GaN drift layer thickness of 4.5 □m. The fabricated prototype GaN SBD delivers a high on/off current ratio of 1010, a high forward current density of 1.6 kA/cm2@3 V, a low specific on-resistance of 1.1 mΩ·cm2, and a low ideality factor of 1.23.

Effects of Interface Traps and Self-Heating on the Performance of GAA GaN Vertical Nanowire MOSFET

School of Electronics Engineering, Kyungpook National University, Daegu 41566, South Korea
Institute of Microelectronics, Electromagnetism and Photonics, Grenoble Institute of Technology, 38016 Grenoble, France

IEEE Transactions on Electron Devices
https://doi.org/10.1109/TED.2019.2963427

In the past couple of years, GaN-based vertical FETs have been explored to complement their potential logic applicability along with its well-known advantages in high-power and RF applications. In this article, the performances of short-channel gate-all-around (GAA) GaN vertical nanowire MOSFETs, fabricated for a possible low-voltage logic application, have been investigated via simulation, assuming the multilevel trapping effects at the gate interface and the self-heating effects. The simulation results reveal that shallow traps at the interface increase the off-state current, the subthreshold swing, and the drain-induced barrier lowering, while deep traps at the interface lower the on-state current and cause the threshold voltage instability. When the gate voltage is higher than the flat-band voltage of the nanowire channel in the saturation region of operation, the mobility degradation, related to the self-heating, becomes significant due to the increased incorporation of the optical phonon scattering.

Characterization of Threshold Voltage Instability Under Off-State Drain Stress and its Impact on p-GaN HEMT Performance

Department of Electrical and Computer Engineering, The University of Texas at Dallas, TX, 75080 USA

IEEE Journal of Emerging and Selected Topics in Power Electronics
https://doi.org/10.1109/JESTPE.2020.2970335

The p-GaN gate technology is commonly implemented to achieve normally-off GaN devices. Nonetheless, the threshold voltage instability under off-state stress remains a concern. In this article, the characterization technique of threshold voltage shift is proposed and the V th shift's impact on device performance is investigated. Specifically, a fast V th measurement circuit is introduced and validated to successfully characterize both the magnitude and the time-constant of the V th shift. According to the experimental results, the V th increases by more than 50% within several μs after the high drain voltage is applied. In contrast, the V th slowly (tens of seconds) gets back to the static value after the stress is removed. Following the characterization, the threshold voltage instability's impact on the device's static/switching performance is studied experimentally. A knee point shift is observed at low gate voltage, and the static on-resistance value remains unchanged. Regarding the switching performance, the turn-on loss increases by > 20% after the high drain voltage stress. The change in turn-on loss can be reduced when the gate resistance is decreased from 20 Ω to 0 Ω. In terms of the turn-off loss, the impact of V th shift is negligible. It is concluded that time-dependent threshold voltage shift needs to be considered in p-GaN device's modeling, and high gate drive voltage together with low gate resistance is recommended to mitigate the V th instability's effect on p-GaN HEMT's performance.

Powered by KnowMade

GaN Power Integration for High Frequency and High Efficiency Power Applications: A Review

State Key Laboratory of Electronic Thin Films and Integrated Devices, University of Electronic Science and Technology of China, Chengdu, China

IEEE Access
https://doi.org/10.1109/ACCESS.2020.2967027

High frequency and high efficiency operation is one of the premier interests in the signal and energy conversion applications. The wide bandgap GaN based devices possess superior properties and have demonstrated exceeding performance than Si or GaAs devices. In order to further exploit the potential of GaN electronics, monolithic power integration is proposed. Firstly, this paper discusses the structure and properties of GaN power devices to explain the choice of lateral integration in the view of GaN power ICs. Then the state-of-the-art performance of GaN power integration in two major application areas is reviewed, which are the microwave power amplification and DC-DC power conversion. The GaN power integration technologies in MMIC platforms are summarized in terms of the gate length, operation frequency and power added efficiency of ICs. On the other hand, the smart GaN power IC platforms have boosted the development of DC-DC power converters. Demonstrations of high frequency (>1 MHz) and high efficiency (>95 %) converters with various kinds of integration technology and topology are reviewed. Lastly novel integration schemes and methods are introduced to stimulate new thoughts on GaN power integration road.

W-Band Power Performance of SiN-Passivated N-Polar GaN Deep Recess HEMTs

Electrical and Computer Engineering Department, University of California Santa Barbara, Santa Barbara, CA, 93106 USA
Qorvo, Hillsboro, OR, 97124 USA
University of Michigan, Ann Arbor, MI 48109 USA

IEEE Electron Device Letters
https://doi.org/10.1109/LED.2020.2967034

This letter reports on the improvement of the large-signal W-band power performance of nitrogen-polar gallium nitride deep recess high electron mobility transistors with the addition of a 40-nm-thick ex-situ silicon nitride passivation layer deposited by plasma enhanced chemical vapor deposition. The additional passivation improves the dispersion control allowing the device to be operated at higher voltages. Continuouswave load pull measurements performed at 94 GHz on a 2×37.5µm transistor demonstrated an improvement in the peak power-added efficiency (PAE) to 30.2% with an associated output power density of 7.2 W/mm at 20 V drain bias. Furthermore, at 23 V, a new record-high W-band power density of 8.84 W/mm (663 mW) was achieved with an associated PAE of 27.0%.

Demonstration of a 2 kV Al0.85Ga0.15N Schottky Barrier Diode with Improved On-current and Ideality Factor

Key Laboratory of Wide Band Gap Semiconductor Materials and Devices, School of Microelectronics, Xidian University, Xi'an 710071, P. R. China
Enkris Semiconductor, Suzhou Nanoplis 20#517, Suzhou, 215000, P.R. China
State Key Lab of Crystal Materials, Shandong University, Jinan, 250100, P. R. China

IEEE Electron Device Letters
https://doi.org/10.1109/LED.2020.2967895

In this letter, we report on demonstrating a Schottky barrier diode (SBD) with high reverse blocking voltage by incorporating an ultra-wide bandgap semiconductor Al0.85Ga0.15N channel. Benefited from the lower activation energy of the Si in GaN, the net carrier concentration of Al0.85Ga0.15N can be essentially enhanced to 2×1017 cm-3 level with surface roughness of 0.33 nm. Due to the good material property, a reverse blocking voltage of 2 kV and room temperature ideality factor of 2.3 are demonstrated. Combined with the significantly improved on-current and on/off ratio of more than 106 when compared with other AlN SBDs, Al0.85Ga0.15N turns out to be a competitive AlN counterpart by considering the compromise among ultra-wide bandgap, dopant activation, and material property.

Powered by KnowMade

Multi-channel AlGaN/GaN in-plane-gate field-effect transistors

Power and Wide-band-gap Electronics Research Laboratory, Ecole Polytechnique F´ed´erale de Lausanne, CH-1015 Lausanne, Switzerland

IEEE Electron Device Letters
https://doi.org/10.1109/LED.2020.2967458

In this letter, we present a multi-channel in-planegate field effect transistor (MC-IPGFET). In the proposed device, multiple vertically stacked two-dimensional electron gases (2DEGs) are simultaneously controlled by lateral in-plane gates formed with the same multi-2DEG stack. The multi-channel heterostructure allows to increase carrier density in the channel while keeping high electron mobility. Besides, the in-plane gate geometry provides an effective control of multiple channels with a smaller intrinsic gate capacitance. As compared to singlechannel IPGFETs, multi-channel structure resulted in a threetime enhancement in current density and transconductance, offering opportunities for efficient scaling up of in-plane gate devices. High current density of 4.35 A/mm along with 2.05 S/mm transconductance are achieved in an optimized device. The effective control of the multiple high-mobility channels along with the reduced intrinsic capacitance of the in-plane gate open a pathway for new device concepts.

Modeling of Enhancement-Mode GaN-GIT for High-Power and High-Temperature Application

Department of Electrical Engineering and Computer Science, University of Missouri, Columbia, MO, USA
AECOM Supporting NSWC Crane, Crane, IN, USA

IEEE Transactions on Electron Devices
https://doi.org/10.1109/TED.2019.2961908

This article presents an analytical model for enhancement-mode GaN devices for high-power application. The model is developed specifically for a GaN gate injection transistor (GIT) device in which a positive threshold voltage is achieved by inserting a p-type GaN layer underneath the gate electrode that is incorporated in the analytical model presented in this article. In addition, the operation of enhancement-mode GaN transistors for high-power application is significantly impacted by carrier spill-over at higher gate bias. Therefore, this model also includes the impact of carrier spill-over by considering parallel conduction in the barrier layer adjacent to the two-dimensional electron gas (2DEG) channel of the transistor and the degradation of mobility and charge density on device operation. In addition, due to high power dissipation and low thermal conductivity of GaN material, the device performance degrades at high temperature. In this article, high-temperature operation of the device is modeled by taking into account the temperature exponents of the device parameters that vary with temperature. At high current density, the device shows significant self-heating effect, which is also modeled using a similar approach. The overall model is compared with the experimentally measured data that shows an excellent match.

Effect of proton irradiation on the mobility of two-dimensional electron in AlGaN/AlN/GaN high electron mobility transistors at low temperature

School of Physical Science and Technology, Lanzhou University, Lanzhou 730000, China

Journal of Vacuum Science & Technology B
https://doi.org/10.1116/1.5134840

The authors simulated the damage caused by proton irradiation to the device and analyzed the effect of proton irradiation on two-dimensional electron mobility taking various scattering mechanisms into account. Proton-irradiation simulation of the AlGaN/AlN/GaN HEMT device was carried out to obtain the irradiation simulation results by using SRIM software. Then, considering various scattering mechanisms, the authors established a model to simulate two-dimensional electron mobility under different proton energy and irradiation doses at low temperature. The theoretical data show that proton irradiation significantly decreased the mobility of a two-dimensional electron in a GaN-based HEMT at low temperature.

Powered by KnowMade

Nanoscale electro-thermal interactions in AlGaN/GaN high electron mobility transistors

Department of Mechanical Engineering, The Pennsylvania State University, University Park, Pennsylvania 16802, USA
Department of Mechanical Engineering, Boğaziçi University, Bebek, Istanbul 34342, Turkey
Nanoscale Sciences Department, Sandia National Laboratories, Albuquerque, New Mexico 87185, USA
Materials and Manufacturing Directorate, Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio 45433, USA
Microsanj, LLC, Santa Clara, California 95051, USA
School of Electronic and Electrical Engineering, Hongik University, Seoul 04066, South Korea

Journal of Applied Physics
https://doi.org/10.1063/1.5123726

Self-heating in AlGaN/GaN high electron mobility transistors (HEMTs) negatively impacts device performance and reliability. Under nominal operating conditions, a hot-spot in the device channel develops under the drain side corner of the gate due to a concentration of volumetric heat generation leading to nonequilibrium carrier interactions and non-Fourier heat conduction. These subcontinuum effects obscure identification of the most salient processes impacting heating. In response, we examine self-heating in GaN-on-Si HEMTs via measurements of channel temperature using above-bandgap UV thermoreflectance imaging in combination with fully coupled electrothermal modeling. The methods together highlight the interplay of heat concentration and subcontinuum thermal transport showing that channel temperature cannot be determined solely by continuum scale heat transfer principles. Under conditions of equal power dissipation (PDISS = VDS × IDS = 250 mW), for example, a higher VDS bias (~23 V) resulted in an ~44% larger rise in peak junction temperature compared to that for a lower VDS (~7.5 V) condition. The difference arises primarily due to reduction in the heat generating volume when operating under partially pinched-off (i.e., high VDS) conditions. Self-heating amplifies with this reduction as heating now takes place primarily over length scales less than the mean free path of the phonons tasked with energy dissipation. Being less efficient, the subcontinuum transport restricts thermal transport away from the device hot-spot causing a net increase in channel temperature. Taken together, even purely thermally driven device mean-time-to-failure is not, therefore, based on power dissipation alone as both bias dependence and subcontinuum thermal transport influence device lifetime.

Interfacial Thermal Conductance across Room-Temperature Bonded GaN-Diamond Interfaces for GaN-on-Diamond Devices

George W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332, USA
Collaborative Research Center, Meisei University, Hino-shi, Tokyo 191-8506, Japan
Kagami Memorial Research Institute for Materials Science and Technology, Waseda University, Shinjuku, Tokyo 169-0051, Japan
School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332, USA

ACS Appl. Mater. Interfaces
https://doi.org/10.1021/acsami.9b16959

The wide bandgap, high-breakdown electric field, and high carrier mobility makes GaN an ideal material for high-power and high-frequency electronics applications such as wireless communication and radar systems. However, the performance and reliability of GaN-based high electron mobility transistors (HEMTs) are limited by the high channel temperature induced by Joule-heating in the device channel. Integration of GaN with high thermal conductivity substrates can improve the heat extraction from GaN-based HEMTs and lower the device operating temperature. However, heterogeneous integration of GaN with diamond substrates presents technical challenges to maximize the heat dissipation potential brought by the ultrahigh thermal conductivity of diamond substrates. In this work, two modified room-temperature surface-activated bonding (SAB) techniques are used to bond GaN and single crystal diamond. Time-domain thermoreflectance (TDTR) is used to measure the thermal properties from room temperature to 480 K. A relatively large thermal boundary conductance (TBC) of the GaN-diamond interfaces with a ~4-nm interlayer (~90 MW/m2-K) was observed and material characterization was performed to link the interfacial

Powered by KnowMade

structure with the TBC. Device modeling shows that the measured TBC of the bonded GaN-diamond interfaces can enable high-power GaN devices by taking full advantage of the ultrahigh thermal conductivity of single crystal diamond. For the modeled devices, the power density of GaN-on-diamond can reach about 2.5 times as that of GaN-on-SiC and about 5.4 times as that of GaN-on-Si with a maximum device temperature of 250 oC. Our work sheds light on the potential for room-temperature heterogeneous integration of semiconductors with diamond for applications of electronics cooling, especially for GaN-on-diamond devices.

Design and Implementation of a GaN-Based Three-Phase Active Power Filter

Department of Electrical Engineering, CEECS, National United University, Miaoli 36063, Taiwan

Micromachines
https://doi.org/10.3390/mi11020134

Renewable energy (RE)-based power generation systems and modern manufacturing facilities utilize a wide variety of power converters based on high-frequency power electronic devices and complex switching technologies. This has resulted in a noticeable degradation in the power quality (PQ) of power systems. To solve the aforementioned problem, advanced active power filters (APFs) with improved system performance and properly designed switching devices and control algorithms can provide a promising solution because an APF can compensate for voltage sag, harmonic currents, current imbalance, and active and reactive powers individually or simultaneously. This paper demonstrates, for the first time, the detailed design procedure and performance of a digitally controlled 2 kVA three-phase shunt APF system using gallium nitride (GaN) high electron mobility transistors (HEMTs). The designed digital control scheme consists of three type II controllers with a digital signal processor (DSP) as the control core. Using the proposed APF and control algorithms, fast and accurate compensation for harmonics, imbalance, and reactive power is achieved in both simulation and hardware tests, demonstrating the feasibility and effectiveness of the proposed system. Moreover, GaN HEMTs allow the system to achieve up to 97.2% efficiency.

Understanding $ɣ-Ray Induced Instability in AlGaN/GaN HEMTs Using a Physics-Based Compact Model

International College of Semiconductor Technology, National Chiao Tung University, Hsinchu 30010, Taiwan
MMIC Fabrication Division, Solid State Physics Laboratory, New Delhi 11084, India
Department of Physics, IIT Delhi, New Delhi 110016, India
Department of Information Engineering, University of Padova, 35131 Padua, Italy

IEEE Transactions on Electron Devices
https://doi.org/10.1109/TED.2020.2965555

In this article, we demonstrate that a physics-based compact model can facilitate to analyze the reliability using an example of ɣ-ray induced instability in AlGaN/GaN HEMTs. First, the typical AlGaN/GaN HEMTs are subjected to the cumulative ɣ-ray irradiation, exhibiting the drain current (ID) increase. In order to further elucidation, the root cause, the compact model is implemented and calibrated with the pristine case. Then, ID-VG and ID-VD characteristics subjected to the ɣ-ray irradiation are fitted with the compact model. The extracted μ and Rc are consistent with the results obtained by the Hall measurement and circular transmission line measurement (C-TLM). By comparing the fitted curves with considering: 1) fitted μ Rc is fixed as the pristine case) and 2) fitted Rc (μ is fixed as the pristine case), the shift of μ is identified as the root cause leading to the ID increase because of the better fitting results. Therefore, with the assistance of the physics-based compact model, the shift of the parameter can be further analyzed to understand the origin of the instability.

Investigations on Electrical Parameters Degradations of p-GaN HEMTs under Repetitive UIS Stresses

National ASIC System Engineering Research Center, School of Electronic Science and Engineering, Southeast University, Nanjing 210096, China

IEEE Journal of Emerging and Selected Topics in Power Electronics
https://doi.org/10.1109/JESTPE.2020.2970786

Electrical parameters degradations of p-GaN HEMTs under repetitive unclamped inductive switching (UIS) stresses have been investigated in this paper. With the

Powered by KnowMade

helps of the TCAD simulations, the experimental frequency dependent conductance analyses (Gp/ω), and the experimental capacitance analyses (Cds), it is demonstrated that the trapping effects near the gate region and in the gate to drain access region dominate the degradations. Due to the extremely high voltage bias during UIS stresses, the trapping of electrons happens near gate region, resulting in the positive shifts of threshold voltage (Vth), the degradations of on-state resistance, the reductions of the gate leakage current, and the reductions of off-state leakage current (Idss). Two experimental methods, the Cds analyses and the Gp/y analyses, are introduced to characterize the trapping effects in p-GaN HEMT for the first time. Nonetheless, the large current surging during UIS stresses enhances the impact ionization and leads to the increase of Idss. The analyses above have been validated by the TCAD simulation successfully. For switching parameters, such as the voltage rises/falls time, which should be considered when designing power electronic systems, the increase of Vth induced by the UIS stresses dominates the changes.

Charge Transport in Vertical GaN Schottky Barrier Diodes: A Refined Physical Model for Conductive Dislocations

Engineering Research Center of IOT Technology Applications (Ministry of Education), Jiangnan University, Wuxi 214122, China
School of Mechano-Electronic Engineering, Xidian University, Xi'an 710071, China
National Laboratory of Microstructures, School of Electronic Science and Engineering, Nanjing University, Nanjing 210093, China
Department of Electrical Engineering and Computer Science, Vanderbilt University, Nashville, TN 37212 USA

IEEE Transactions on Electron Devices
https://doi.org/10.1109/TED.2020.2965953

Charge transport mechanisms of forward and reverse leakage currents in vertical GaN Schottky barrier diodes are investigated by measuring the temperature-dependent current-voltage characteristics. The results show that the leakage current is primarily governed by dislocation-associated thermionic field emission (TFE). The primary transport path is the reduced, localized conduction band around the dislocation core rather than the continuum defect states. A refined phenomenological physical model is developed for conductive dislocations in GaN, emphasizing that: 1) surface donors, surrounding the core of dislocations, can significantly shrink the barrier region after ionization, causing severe TFE leakage; 2) the ON donors likely to be responsible for TFE have a typical density of ~1 x 10i8 cm-3 at 300 K and activation energy of 78 meV; and 3) the barrier height at donor sites is ~0.65 eV at 300 K, which is reduced by ~0.4 eV with respect to the dislocation-free region.

Strengthening of DBA substrate with Ni/Ti/Ag metallization for thermal fatigue-resistant Ag sinter joining in GaN power modules

Department of Adaptive Machine Systems, Graduate School of Engineering, Osaka University, Suita-shi, Osaka, 565-0871, Japan
The Institute of Scientific and Industrial Research, Osaka University, Ibaraki-shi, Osaka, 567-0047, Japan
Department of Advanced Materials Engineering, Korea Polytechnic University, Siheung, 15073, Republic of Korea

Journal of Materials Science: Materials in Electronics
https://doi.org/10.1007/s10854-020-02930-w

This study was carried out to develop a DBA (direct bonded aluminum) substrate with Ni/Ti/Ag metallization to achieve highly functional thermal shock stability of Ag sinter joining in GaN (Gallium Nitride) power modules. GaN /DBA die-attached module structures by Ag sinter joining was performed during harsh thermal shock cycling tests within a temperature range of − 50/250 °C. In the case of DBA without a Ni metallization layer (Ti/Ag), severe degradation occurred at the interface between the sintered Ag and Al due to significant plastic deformation of the Al layer. The shear strength decreased from an initial value of 33.1 MPa to 22.3 MPa after 500 cycles. With EBSD investigation, it was determined that the Al layer underwent sub-grain rotation recrystallization during thermal shock cycles. This led to a non-uniform grain orientation distribution at center and corner locations. On the other hand, Ni/Ti/Ag metallization showed that it can prevent severe Al deformation due to the superior rigidity achieved by Ni metallization. The die-shear strength maintained almost the same value as its initial value,

Powered by KnowMade

even after 500 cycles. In addition, a numerical simulation analysis determined that the Ag sinter joining structure on the DBA substrate with Ni/Ti/Ag metallization had high functionality in stress relaxation. This study provided a novel approach to design thermal shock stability Ag sinter joining for next-generation power modules in high-temperature applications.

Features of Radiation Changes in Electrical Properties of InAlN/GaN Hemts

National Research Tomsk State University, Tomsk, Russia

Russian Physics Journal
https://doi.org/10.1007/s11182-020-01888-w

The effect of the proton, electron, gamma - rays, and fast neutron irradiation on the parameters of InAlN/GaN HEMT structures is analyzed. The features of initial electronic properties of the InAlN and AlGaN barrier layers with a change in their composition, as well as the change in these properties when exposed to high-energy radiation are considered with taking into account the compositional dependence of the charge neutrality level energy position in the energy spectrum of these barrier layers.

Analysis on Trap States in p-Metal-Oxide-Semiconductor Capacitors with Ultraviolet/Ozone-Treated GaN Interfaces Through Frequency-Dispersion Capacitance–Voltage Measurements

Department of Electronics and Electrical Convergence Engineering, Hongik University, Sejong, 30016, Republic of Korea

Electronic Materials Letters
https://doi.org/10.1007/s13391-019-00194-z

The trap states at ultraviolet/ozone (UV/O3)-treated Al2O3/GaN interfaces of p-type metal-oxide-semiconductor capacitors (pMOSCAPs) are analyzed through a frequency-dispersion capacitance–voltage (C–V) measurements. X-ray photoelectron spectroscopy and high-resolution transmission electron microscopy are applied to confirm a formation of ultrathin oxide layer (Ga2Ox) on GaN surface by the UV/O3 treatment. The trapped charge density and interface trap density improved from 7.30 × 1011 to 2.79 × 1011 cm−2 eV−1 averaged over the bandgap of GaN and from 1.28 × 1013 to 4.08 × 1012 cm−2 eV−1 near the conduction band edge of GaN, respectively, owing to the passivation of Ga2Ox layer at the Al2O3/GaN interfaces. Mechanism for the improved trap states in pMOSCAPs is identified based on the reduced defect states at both Al2O3/Ga2Ox and Ga2Ox/GaN interfaces.

Powered by KnowMade

PRESS RELEASE

Technical and economic information selected by Knowmade

ELECTRONICS

Advantech receives orders worth $2m for GaN-based Engage Class FlyAway military-grade SatCom terminals

SemiconductorToday

Advantech Wireless Technologies Inc of Montreal, Canada (which manufactures satellite, RF equipment and microwave broadband communications systems) has received over $2m in orders of its satellite communication (SatCom) Engage Class 1.2m and 2.4m FlyAway SatCom Terminal from a NATO member country.

The flexible and transportable satellite terminal is a fully integrated tri-band system designed for strategic applications, easy deployment and operation under harsh environmental conditions. It is based on high-efficiency, ruggedized tri-band-ready 1.2m and 2.4m Flyaway Antennas that can cover the X-band, Ku-band or Ka-band by replacing the feed only. The antenna is fully motorized, with an integrated satellite finding controller. The RF section includes Advantech's gallium nitride (GaN)-based technology solid-state power amplifiers (SSPAs)/block-upconverters (SSPAs/BUCs), with power output in the X-band from 20W to 100W, Ku-band from 16W to 125W, and Ka-band from 10W to 40W. The entire SatCom terminal has been tested for the highest level of performance and compliance with military requirements.

"These advanced satellite terminals include state-of-the-art digital and RF technology," says says Cristi Damian, VP business development at Advantech Wireless Technologies. "Within a completely modular and integrated solution, the terminals can uplink two independent carriers (up to 50Mbps each), allowing simultaneous communication with both upper and lower echelon," he adds. "These systems have been part of a complex modernization program for this active NATO member, and have already been deployed in the field since 2017."

Pasternack launches Class AB high-power amplifiers up to 200W for bands from 20MHz to 18GHz

SemiconductorToday

Pasternack Inc of Irvine, CA, USA (an Infinite Electronics brand that makes both passive and active RF, microwave and millimeter-wave products) has launched a series of high-power Class AB broadband amplifier modules that incorporate gallium nitride (GaN), LDMOS or VDMOS semiconductor technology. The combination of high linearity and efficiency with low distortion over a wide dynamic range makes them suitable for applications including communications systems, military radio, radar, signal jamming, test & measurement and base stations, says the firm.

The 18 new high-power class AB amplifiers span frequency bands from 20MHz to 18GHz, and feature saturated output power levels ranging from 10W to 200W and power gain up to 53dB. Designs operate in a 50Ohm environment and are unconditionally stable. The compact coaxial packages use SMA or N-type connectors and have integrated D-Sub control connectors for DC bias, enabled with TTL logic control, current sense and temperature sense functions.

The rugged assemblies operate over a wide temperature range from -20°C to +60°C and can withstand relative humidity exposure up to 95% maximum. To ensure optimum baseplate temperature for highly reliable

performance, Pasternack offers two new heatsink modules with DC-controlled cooling fans that are specifically designed for these power amplifiers.

“The addition of these new high-power amplifiers offers our customers more choices to address applications requiring a small-form-factor, high-power RF amplifier that utilizes leading-edge semiconductor technology, with the benefit of high linearity and efficiency, and wide dynamic range over a broad frequency range,” says product line manager Tim Galla.

UMS’ GaN & GaAs PDKs for Pathwave ADS support enhanced thermal capability

SemiconductorToday

United Monolithic Semiconductors (UMS), which designs and produces RF and millimeter-wave components and ICs at its facilities in Orsay, France and Ulm, Germany, says that the Pathwave ADS process design kit (PDK) for its 0.25µm gallium nitride (GH25) process will now support the new ElectroThermal capability (ETH) offered by Pathwave ADS (Advanced Design System) from Keysight Technologies Inc of Santa Rosa, CA, USA. This new functionality is not only included for the GH25 GaN PDK but also on the UMS PPH15X-20 gallium arsenide (GaAs) power pHEMT process PDK.

Designing packaged high-power amplifiers is a challenging task, since GaAs and GaN devices dissipate large amounts of power in a very small area, notes UMS. There are hence considerable thermal challenges. Device temperature can rise based on continuous-wave (CW) or pulsed operating conditions, different package materials used or the assembly process used. In addition, the temperature inside the transistor can also impact its properties and performance.

ADS’ thermal simulation coupled with its electrical simulation allows full and complete analysis of the electro-thermal behavior of the device and optimization of the monolithic microwave integrated circuit (MMIC) inside its package, enabling users to extract the best performance from the RF GaN devices, says UMS.

Foundry customers can get the full electro-thermal simulation of their systems by specifying thermal parameters of their own assembly solution. UMS says that this provides an elegant method to simplify the calculation of the junction temperature, which is a critical step of MMIC design assessment. Implementation of thermal data in UMS’ PDKs has been possible due to a strong partnership with Keysight experts and development teams. UMS says that this partnership with Keysight is a key element that contributes to its foundry customers’ satisfaction through regular innovative upgrades of the MMIC design tools.

GaN Systems’ power transistors used in Siemens’ new low-voltage Simatic Micro-Drive product line

SemiconductorToday

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) says that Siemens is integrating part of its Simatic Micro-Drive product line with GaN Systems’ power semiconductors.

“The Simatic Micro-Drive is an extremely versatile, seamless and safety-integrated servo drive system that covers a wide range of applications in the extra-low-voltage range for EC motors from 24V to 48V,” says Christian Neugebauer, Simatic Micro-Drive product manager, at Siemens. “With the GaN Systems devices, we are now able to increase the efficiency of the drives,” he adds. “With GaN, Siemens can switch to a higher frequency, thereby enabling a faster motor response time compared with high-voltage drive systems.”

Recently, Siemens entered the low-voltage drive market with the creation of its new Simatic Micro-Drive safety and extra-low-voltage family. The integrated Simatic Micro-Drive system comes in two different housing sizes for motor outputs of between 100W and 1000W. The fundamental building block is the GaN power transistors made by GaN Systems. This 4-quadrant drive system can be used either with the integrated brake chopper on a power supply or directly in battery operation.

The servo drive system is suited to a wide range of diverse applications in moving, processing and positioning such as conveyor systems and stacker cranes, positioning of individual or multiple coordinated axes, shuttles for storage and retrieval machines or warehousing systems, automatic guided vehicles (AGVs) and medical technology.

“Many industrial customers have leveraged the benefits of GaN in their production products,” notes GaN Systems’ CEO Jim Witham. “We have designed and tested the high quality and performance requirements needed to earn the confidence in GaN technology required by our customers and are thrilled to see that the efforts that Siemens and GaN Systems have invested are now being realized.”

Qorvo launches highest-performance wideband GaN power amplifier for mission-critical defense applications

SemiconductorToday

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has introduced what it claims is the highest-performance wideband power amplifier (PA).

Designed for electronic warfare, radar and test instrumentation applications, the TGA2962 (available now as a die to qualified customers) is fabricated using Qorvo’s gallium nitride (GaN) QGaN15 process technology, and provides 10W of RF power over the 2-20GHz frequency range, 13dB large-signal gain and 20-35% power-added efficiency (PAE). This combination delivers the flexibility that system designers need to improve system performance and reliability while reducing component count, footprint and cost, reckons the firm.

“Qorvo has taken a significant step forward in the wideband space with the TGA2962, enhancing not just frequency range but every other performance aspect,” says Roger Hall, general manager of Qorvo’s High Performance Solutions business. “No other company offers a single PA with this output power, bandwidth, power-added-efficiency and large-signal gain,” he claims.

In addition, improved component integration – and use of a smaller driver amplifier enabled by the 13dB large-signal gain – result in a smaller device, benefitting programs that require size, weight, power and cost (SWAP-C) improvements.

“The defense market, primarily radar and communications applications, is seeing strong growth from new systems and major platform upgrades,” comments Eric Higham, director of the Advanced Semiconductor Applications service and the Advanced Defense Systems service for market research firm Strategy Analytics. “This is also providing fuel for the GaN growth engine and should bode well for companies like Qorvo.”

Empower RF Systems launches compact 4kW S-band GaN-on-SiC solid-state power amplifier for SatCom uplinks

SemiconductorToday

Empower RF Systems Inc of Inglewood, CA and Holbrook, NY, USA (which produces RF and microwave power amplifiers for defense, commercial and industrial applications) says that its new model 2176 is a compact high-power gallium nitride on silicon carbide (GaN-on-SiC) continuous-wave (CW) solid-state power amplifier (SSPA) producing a minimum 4kW CW and 2kW RMS at 3.6 PAR at frequencies of 1750-2120MHz.

Standing 27-inches tall, it is less than half the size of the typical legacy uplink high-power amplifiers (HPAs) that it replaces. The slightly broader band brings flexibility to transmit in either of the two uplink channels. Besides the dramatic size reduction, the upgrade from legacy design to a next-generation SSPA brings greater reliability and improved spectral purity for increased data rates.

The 2176 is based on Empower's established and field-proven next-generation architecture that is tactically deployed and operating on multiple levels in support of a variety of critical US Department of Defense (DOD) missions.

The 2176 comes complete with internal directional coupler, external forward and reverse sample ports, and an easy-to-use web graphical user interface (GUI). In-depth health monitoring with alarms visible on the front panel are also pushed out via the LAN port. Output modes include manual gain control (MGC), automatic gain control (AGC) and automatic level control (ALC), which provide flexibility when integrating into legacy uplink systems. For critical 'on air' applications, the 2176 provides 'Graceful Output Power Degradation', backing down power to a safe operating level in the event of component failure or excessive load VSWR (voltage standing wave ratio) condition.

Product highlights include higher availability, higher efficiency, a 2x improvement in SWaP, waveform flexibility, ruggedness for mobile deployment, remote monitoring and control, and active RF device redundancy (Graceful Output Power Degradation).

US Marine Corps orders additional Northrop Grumman AN/TPS-80 radar systems

SemiconductorToday

Northrop Grumman Corp has received an order from the US Marine Corps for two additional AN/TPS-80 Ground/Air Task-Oriented Radar (G/ATOR) systems as part of the full-rate production Lot 2 award received in December. This order completes the planned Lot 2 procurement for a total of eight systems for the Marine Corps.

"We are continuing to provide an advanced, multi-mission capability that meets the evolving needs of our customers," says Mike Meaney, vice president, land and maritime sensors, Northrop Grumman. "This order also enables us to keep the G/ATOR production pipeline full in anticipation for a Lot 3 award next year." The Marine Corps awarded Northrop Grumman a $958m full-rate production contract for 30 of the gallium nitride (GaN)-based G/ATOR systems in June 2019.

The AN/TPS-80 G/ATOR is an active electronically scanned array (AESA) multi-mission radar that leverages GaN to provide comprehensive real time, full-sector, 360° situational awareness against a broad array of threats.

Developing complementary p-channel transistors for GaN-on-silicon power

SemiconductorToday

Hong Kong University of Science and Technology (HKUST) report on p-channel metal-oxide-semiconductor field-effect transistors (MOSFETs) produced on gallium nitride (GaN) on silicon (Si) substrates [Zheyang Zheng et al, IEEE Electron Device Letters, vol.41, p26, 2020]. The researchers used commercial 8-inch-diameter GaN-on-Si wafers with epitaxial structures designed for 650V normally-off p-GaN gate power high-electron-mobility transistors (HEMTs) (Figure 1).

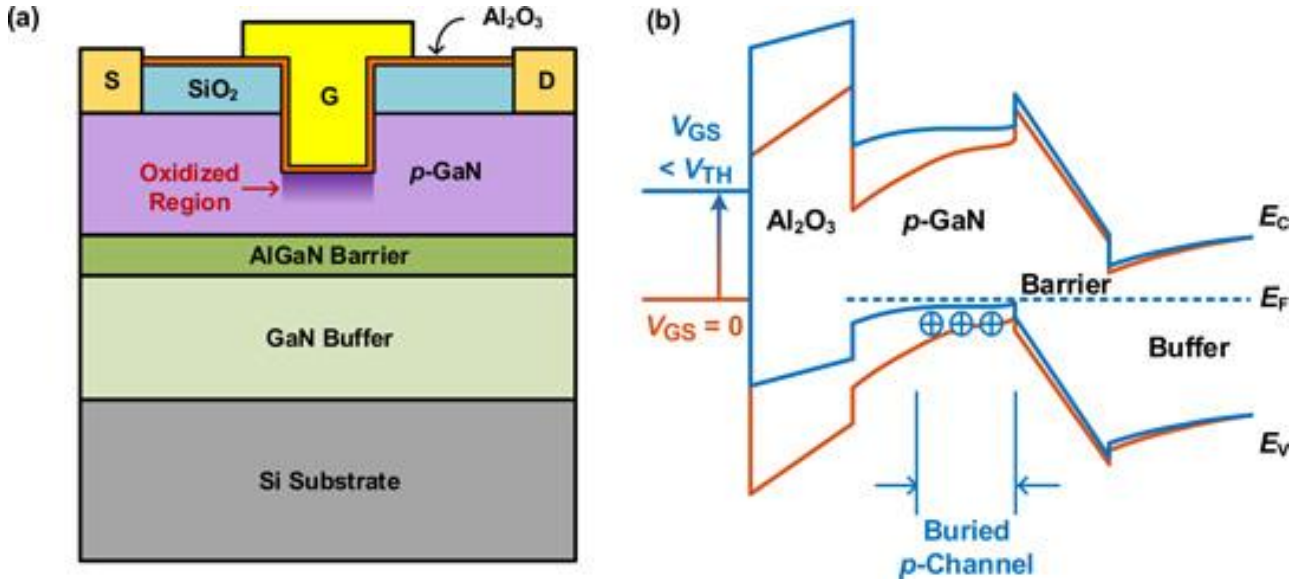


Figure 1: Schematic of (a) E-mode GaN pFET (LGS/LG/LGD = 4/2/4µm) and (b) energy band diagram at gated region of buried p-channel with 0V (OFF) and beyond threshold (ON) gate potentials (VGS).

GaN is being developed for high voltage and power handling based on the material's high critical electric field before breakdown. Devices with n-type channels with negatively charged carriers (electrons) have been intensively developed in recent years. Much progress has been made in developing devices with normally-off 'enhancement-mode' (E-mode) characteristics, rather than the more easily achieved normally-on 'depletion-mode' (D-mode). The E-mode is desired for lower power consumption and for fail-safe features.

The n-channel devices largely depend on the creation of 'two-dimensional electron gas' (2DEG) channels, which arise near the interface between GaN and a barrier layer, often aluminium gallium nitride (AlGaN). The 2DEG occurs due to band-bending effects arising from contrasts in the charge distribution in the chemical bonds holding the Ga, Al and N atoms together.

Devices with p-channels would enable complementary integrated circuit (IC) designs, which would further reduce power loss in logic control systems. Although some progress has recently been made in developing an analogous 2D hole gas for p-channels, effective devices remain to be achieved. The HKUST work focuses instead on using p-GaN material achieved using magnesium doping.

The team comments: "The p-GaN/AlGaN/GaN-on-Si platform paves the way to monolithically integrating E-mode pFET and nFET for possible GaN complementary and more robust GaN power ICs."

The GaN-on-Si material included a ~12nm AlGaN barrier and a ~85nm p-GaN top layer. The undoped GaN buffer was ~4.5µm thick. The structure was found to have a hole sheet density of 1.23x1013/cm2 and mobility 10.2cm2/V-s, according to Hall measurements.

Powered by KnowMade

Standard p-GaN gate E-mode n-channel HEMTs realized on the substrate typically have threshold voltages of +1.7V and an on-current of 350mA/mm with 5V drain bias. The on/off current ratio is usually of order 109.

The HKUST p-channel devices were fabricated with 500°C-annealed nickel/gold ohmic source-drain (S-D) contacts evaporated onto the p-GaN, which had previously been subjected to a 5-minute buffered oxide etch, presumably to improve the surface and remove contaminants.

The gate (G) recess was defined by a 200nm plasma-enhanced chemical vapor deposition (PECVD) silicon dioxide (SiO2) hard mask, which also served as surface passivation. The p-GaN recess was formed using inductively coupled plasma reactive-ion etch.

An oxygen plasma treatment increased the surface roughness at the bottom of the recess from 0.36nm root-mean-square to 0.41nm, according to atomic force microscopy. The recess depth was found to be about 54nm, leaving ~31nm of p-GaN material above the AlGaN barrier for the channel.

The gate structure was completed with 20nm atomic layer deposition (ALD) aluminium oxide (Al2O3) insulation and 400°C-annealed nickel/gold metal electrode. The electrical isolation of the devices was from fluorine ion implantation rather than mesa etching. The researchers used fluorine implant to avoid current leakage along rough mesa sidewalls. The implant occurred between the Al2O3 and gate metal deposition steps.

The device demonstrated a threshold voltage of -1.7V, giving normally-off enhancement-mode behavior at 0V gate. The oxygen plasma treatment enabled the negative threshold – without the treatment, the device became depletion-mode (normally-on at 0V gate) with the threshold at +2.2V. The on-current of the enhancement-mode device was 67% that of the depletion-mode transistor without oxygen plasma treatment.

The on-resistance for the E-mode device was a “relatively large” 2.4kΩ-mm at low drain bias. This reduced somewhat at -5V drain to 1.6kΩ-mm. The maximum drain current was 6.1mA/mm at -10V drain. The off-current with 0V gate was 1.2x10-7mA/mm. The team sees this low off-current as “delivering an ultra-low static power consumption required in CMOS logic gates.”

The researchers explain the action of the oxygen plasma treatment: “It is known that oxygen induced into p-GaN could either behave as shallow donors to compensate the Mg acceptors or form inert Mg-O complexes to de-activate the Mg acceptors, both of which would result in depletion of holes. Hence, it is plausible to assume that the top oxidized GaN has its Mg doping compensated and the energy band bent downward to form a hole barrier that buries the p-GaN channel away from the top GaN surface.”

The downward band bending pushes the depletion region under the recessed gate to extend through the p-GaN layer, reaching the AlGaN barrier. This enables enhancement-mode operation by turning off the buried p-channel at 0V gate potential.

The researchers compared their device with others previously presented in the scientific literature (Table 1). The team comments: “Among all the p-channel GaN MOS-FETs, the one from this work exhibits the combination of high ION, high ION/IOFF, the lowest subthreshold swing (SS) and E-mode operation. Devices implemented on the platform with quaternary back-barrier and Schottky gate exhibit outstanding SS and ION, but suffers large gate leakage at the ON state.”

Table 1: Benchmark of p-channel GaN FETs.

Affinity	Platform	V_{TH} [a] (V)	lg(I_{ON}/I_{OFF}) [b]	I_{ON} [c] (mA/mm)	*SS* (mV/dec)
Notre Dame [10]	*p*-/*i*-GaN /AlN Al_2O_3 MOS gate	0.89 (−80 V)	3 (−80 V)	3.87 (−80 V)	1415
RWTH [9]	*p*-/*i*-GaN/AlInGaN/ GaN/AlN, Schottky gate	−1.12 (−8V)	7 (−8V)	6.79 (−8V)	91.3
AIST [5]	*p*-/*i*-GaN/AlGaN/GaN Al_2O_3 MOS gate	> 4	N.A.	4.00	N.A.
RWTH [11]	*p*-/*i*-GaN/AlInGaN/ GaN/AlN, Schottky gate	−0.5	8	1.81	77
HRL [6]	*p*-/*i*-GaN/AlGaN/GaN AlN/SiN_x MIS gate	−0.36 (−0.1V)	6 (−0.1V)	1.65	304
AIST [7]	*p*-/*i*-GaN/AlGaN/GaN SiO_2 MOS gate	−0.75	3	0.09	817
Cornell [12]	*p*-/*i*-GaN/AlN SiO_2 MOS gate	1.32	4	9.10	1027
MIT [13]	*p*-GaN/AlGaN/GaN Al_2O_3 MOS gate	2.60 (−0.5V)	5 (−0.5V)	1.40	399
This work	*p*-GaN/AlGaN/GaN Al_2O_3 MOS gate	**−1.7**	**7**	**3.38**	**230**

[a] extracted at $|I_D|$ = 10 μA/mm and V_{DS} = −5 V unless otherwise specified.
[b] (orders of magnitude) with V_{DS} = −5 V unless otherwise specified.
[c] at V_{DS} = −5 V and with overdriven V_{GS}, unless otherwise specified.

Powered by KnowMade

OPTOELECTRONICS

Osram's new Oslon Boost HM LED enables ultra-slim designs for headlights

SemiconductorToday

In recent years, technological progress in car lighting has led to light becoming an essential design element in modern cars. Smaller and brighter light sources are leading to more compact and versatile headlamps. Germany's Osram says that its powerful new Oslon Boost HM LED furthers this trend by enabling ultra-slim headlamp designs in vehicles.

In addition to numerous features such as adaptive front lighting (often called bend lighting or matrix lighting), the miniaturization of this component plays a particularly important role. With the Oslon Boost HM, Osram developers have achieved brightness of 415lm at a drive current of 1.5A with a very small chip area of just 0.5mm2.

The LED's package is also particularly compact at 1.9mm x 1.5mm x 0.73mm, providing a finger-width front headlamp solution, without compromising light output. The luminance of 255cd/mm2 at 1.5A is reckoned to be a best-in-class performance value for this type of LED.

In addition to headlamps, the Oslon Boost HM can also be used in combination with other LEDs to provide an additional high beam. Due to its luminance, the LED is also suitable for use in MEMS-based adaptive front lighting systems.

Osram Opto Semiconductors says that it was able to draw on its expertise in package design to create the new product. The robust ceramic package of the Oslon Boost HM allows for easy thermal management within the component due to an electrically insulated pad. The special internal design structures mean that heat can be easily dissipated from the LED. Furthermore, the LED has a particularly low thermal resistance of only 4.62K/W.

"With the Oslon Boost HM, we are not only expanding our Oslon Boost product family to include particularly high luminance levels but are also helping our customers create ultra-slim headlamp designs," notes Florian Fink, marketing manager for Automotive Exterior at Osram Opto Semiconductors.

Osram launches new generation of Oslon Square Hyper Red LEDs for horticulture lighting

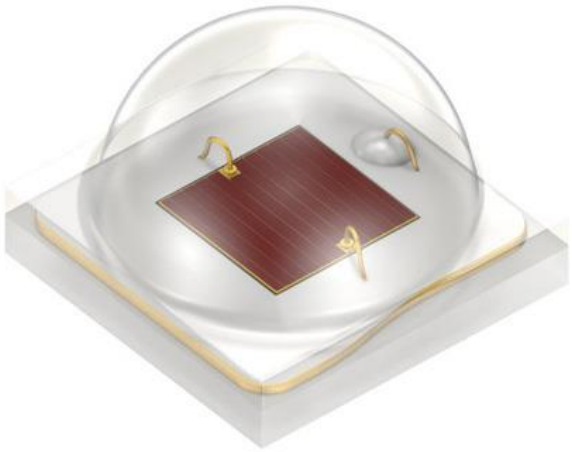
SemiconductorToday

Osram Opto Semiconductors GmbH of Regensburg, Germany claims that its new generation of Oslon Square Hyper Red is the most efficient LED for horticulture lighting to date

As the world population grows, metropolitan areas are attracting more and more people. So, in places where farmland is limited and delivery must be quick, horticulture lighting offers a major advantage. With the help of lighting technology, it is possible to provide the exact light composition that various plants need for ideal growth or to develop certain characteristics. Due to tailor-made lighting solutions, plants can be grown in a very space-saving manner and with considerably higher yields. For greenhouse owners, energy footprint is essential to production. The new generation of Oslon Square Hyper Red is claimed to contribute to improving efficiency more effectively than comparable products currently available on the market.

During dark season, many people experience the effects of not getting enough light, feeling more tired and exhausted as the days get shorter. Similarly, when plants don't get enough light, their photosynthesis does not

work sufficiently. Plants predominantly need red (640-700nm) and blue light (400-490nm) for their growth. For example, red light promotes the production of biomass in plants.



Picture: Osram's new generation of Oslon Square Hyper Red.

The new generation of the Oslon Square Hyper Red with a wavelength of 660nm is the flagship product in Osram Opto Semiconductors' comprehensive horticulture portfolio. In addition to the efficiency values, greenhouse operators benefit from a radiant flux of 1.030mW at 73% WPE (wall-plug efficiency) and a photon flux of 5.7µmol/s at an efficacy of 4.0µmol/J at a drive current of 700mA. For applications with higher efficacy requirements, the LED provides 78% at a drive current of 350mA and 80% at 250mA with an efficiency of 4.6µmol/J. Besides the best-in-class efficiency, benefits include a long lifetime of over 100,000 hours even at high temperatures. The surface-mountable component has a ceramic package that is completed by a robust silicone lens.

"The significantly improved efficiency values help our customers save energy," says product manager Yong Sheng Chew. "Thanks to the proven compact footprint of 3.0mm x 3.0mm, greenhouse owners can easily bring existing lighting systems up to date with the latest LED technology."

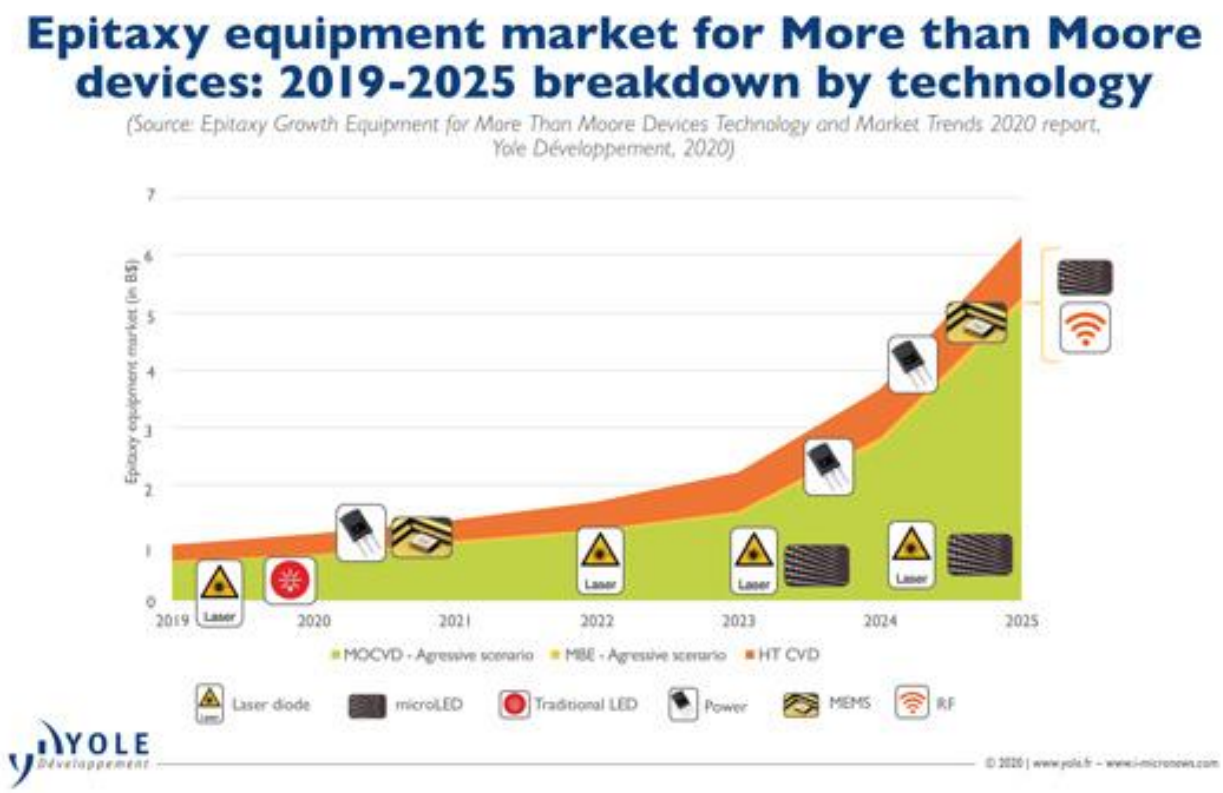
Epitaxy equipment market to grow from $940m to over $6bn by 2025, driven by VCSEL and disruptive LED devices

SemiconductorToday

The epitaxy growth equipment market for 'More than Moore' devices was worth nearly $940m in 2019, and is expected to exceed $6bn by 2025 (in an aggressive scenario), according to Yole Développement's technology & market report 'Epitaxy Growth Equipment for More Than Moore Devices'.

From a technical point of view, metal-organic chemical vapor deposition (MOCVD) serves most of the III-V compound semiconductor epitaxy industry, such as gallium arsenide (GaAs)- and gallium nitride (GaN)-based devices. High-temperature (HT) chemical vapor deposition (CVD) serves the majority of mainstream silicon-based components and silicon carbide (SiC) devices.

The semiconductor industry has been traditionally dominated by silicon substrates. Although silicon is still by far the most dominant material (with more than 80% market share), alternative non-silicon-based substrates like GaAs, GaN, SiC and InP (indium phosphide) are gaining momentum within the 'More than Moore' industry. Indeed, new applications are emerging along with stringent requirements where silicon solutions are not able to provide the performance expected. Innovative substrate materials are hence being considered by semiconductor manufacturers.



GaN material represents the main epitaxy market after silicon substrates, driven mostly by traditional GaN-based light-emitting diode (LED) devices. However, the overall visible LED industry is currently diversifying towards more specialized ultraviolet (UV) and infrared (IR) LEDs based on GaAs substrates. Additionally, manufacturers are developing new types of LEDs to continue creating value in consumer displays, such as mini-LEDs and micro-LEDs. Apple is initiating this with adoption in its higher-end 2021 smartwatch model. In the best-case scenario, micro-LEDs could also spread into smartphone products, which will definitely reshape the epi-ready wafer market, says Yole.

On the other hand, wide-bandgap (WBG) materials like SiC substrates have found opportunities in the power electronics market. Here, power consumption reduction is required for electrification of transportation, renewable energy, motor drives and some power supply applications. Despite the high price of SiC, such substrates represent a strong asset for high-voltage applications, and are thus considered to be a technology choice for some metal-oxide-semiconductor field-effect transistor (MOSFET) and diode products.

Looking ahead, photonics products like vertical-cavity surface-emitting lasers (VCSELs) operating in the IR spectrum (typically processed on GaAs) are making serious inroads into the epitaxy market. In addition, GaAs is especially advantageous for radio-frequency (RF) products such as small-cell implementation, for both sub-6GHz frequencies and the first millimetre-wave (mmWave) small cells in the 28-39GHz range. With the cellphone transition from 4G to 5G, Yole hence expects GaAs to remain the mainstream technology for sub-6GHz frequencies instead of complementary metal-oxide-semiconductor (CMOS) silicon, since it is the only technology able to meet increasing power level and linearity requirements imposed by antenna board-space reductions as well as carrier aggregation and multiple-input multiple-output (MIMO) technology.

Choosing the appropriate substrate technology will depend strongly on the technical performance associated with device requirements, as well as the cost, notes Yole.

“As of today, the epitaxy growth equipment market is mainly driven by LED and power applications,” says Amandine Pizzagalli, technology & market analyst, Semiconductor Manufacturing, at Yole. “In fact, massive subsidies in China have led to an excessive LED capacity build-up. The MOCVD market is now in a situation of significant overcapacity for GaN LED production compared to what is actually produced,” he adds. “MOCVD investment is particularly tough to forecast in the next few years and could change year to year. The situation could be reversed if the government decides to strictly prevent the major LED manufacturers from producing more GaN wafers.”

The report has therefore considered different scenarios for the traditional LED and micro-LED markets.

For traditional GaN-based LEDs, MOCVD investment trends will not follow LED wafer demand. Specific upsides and downsides with respect to GaN LEDs might arise, as used to happen in the past.

Nevertheless, given recent competitive trends in China, the general lighting and backlighting markets have become commoditized. Hence, epitaxy vendors do not expect significant revenue from these markets going forward.

However, requirements for micro-LED epitaxy in terms of defects and homogeneity are more stringent than for traditional LEDs. There are credible roadmaps for improvement in tools and equipment to reach approximately 0.1 defects/cm2 or less, based on defects larger than 1µm. Tighter operating conditions are needed in cleanrooms, including for automation and wafer cleaning, compared with traditional LED manufacturing. This is especially true for the smallest dies (below <10µm), which will have smaller killer defects.

Meanwhile, laser diodes represent an additional fast-growing opportunity as the consumer goods industry massively adopts edge-emitting lasers and VCSELs.

Yole notes that, for compound semiconductor-based devices such as laser diodes, micro-LEDs and VCSELs, the MOCVD reactor market could be affected by possible technology transitions to molecular beam epitaxy (MBE). In fact, MBE could bring greater advantages in terms of yield and uniformity for VCSELs as well as for high-frequency 5G RF applications. In the case of SiC power devices, MOCVD manufacturers are trying to identify and develop new MOCVD technologies to address the SiC market, where HT CVD is currently predominant.

Enhancing AlGaN hole injection with germanium-doped tunnel junctions

SemiconductorToday

Université Côte d’Azur and MINATEC Campus in France have used germanium (Ge) doping to improve current injection into aluminium gallium nitride (AlGaN) ultraviolet (UV) light-emitting diodes [V. Fan Arcara, J. Appl. Phys., vol126, p224503, 2019].

The Ge-doped layers were used to create the n-type side of tunnel junctions (TJs) to supply the holes for injection and recombination with electrons in quantum well (QW) light-emitting active regions. Ge doping has attracted increasing interest, compared with the more established silicon (Si).

The team comments: “Claims in favor of Ge-doping are their similar size to Ga atoms (introducing less stress in the structure than Si at high doping levels, also being compressive instead of tensile, which is the case for the latter) and the shallow behavior of its donors in GaN.”

A further advantage is that, in molecular-beam epitaxy (MBE), silicon tends to react with the ammonia (NH3) used as the nitrogen source, limiting its doping effectiveness. Ge is less prone to such reactions.

III-nitride semiconductors like AlGaN suffer from poor p-type performance since the magnesium (Mg) dopant used has a high activation energy, which increases with higher aluminium content. Even Mg-doped GaN has a poor p-type conductivity relative to many other semiconductor systems.

The AlGaN range of semiconductors have potential for UV wavelength light emission from 365nm (GaN) to 200nm (AlN). Mixed with indium (In), InGaN semiconductors are used in the visible light range (380-740nm).

LED structures: (a) GaN reference (without TJ); (b) GaN TJ; (c) AlGaN reference (without TJ); (d) AlGaN TJ; (e) AlGaN IL TJ.

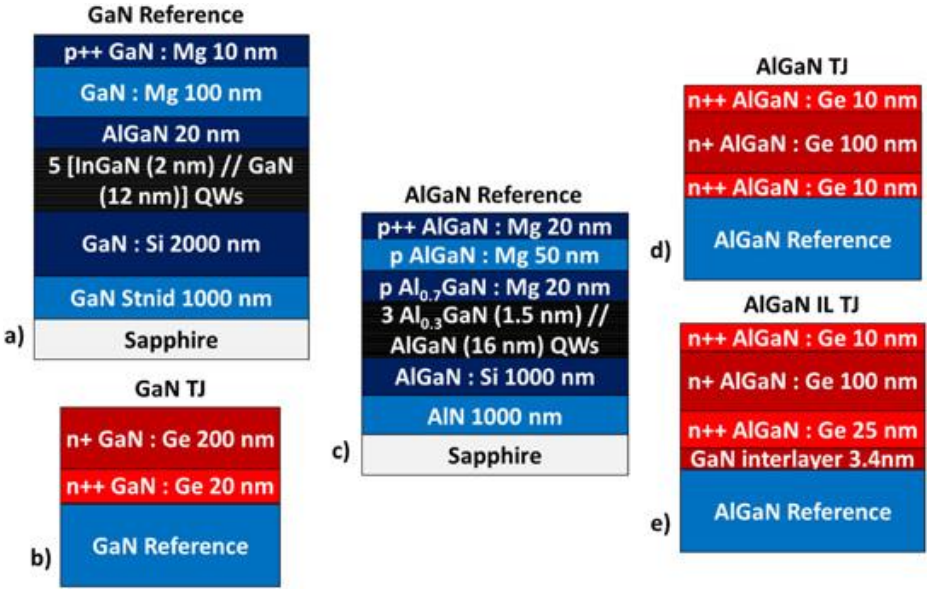


Figure 1: LED structures: (a) GaN reference (without TJ); (b) GaN TJ; (c) AlGaN reference (without TJ); (d) AlGaN TJ; (e) AlGaN IL TJ.

The researchers used metal-organic chemical vapor deposition (MOCVD) on 2-inch sapphire up to and including the last heavily-doped p++-AlGaN/GaN layer of the LED structure – i.e. the 'reference' sections of the devices (Figure 1).

In the MOCVD process, Si and Mg were used as n-type and p-type dopants, respectively. The light-emitting region consisted of AlGaN or InGaN QWs. After the MOCVD, the samples were annealed at 700°C for 20 minutes in nitrogen to drive out hydrogen, activating the p-type layers.

The n-type tunnel junction portions of the relevant structures were grown by molecular-beam epitaxy. The Ga and Ge came from solid sources. (Al is not mentioned, but one suspects a solid source for that metal too.) The nitrogen came from NH3.

The mesa LEDs were fabricated using reactive-ion etching and electron-beam evaporation of titanium/aluminium/nickel/gold and nickel/gold n- and p-contacts, respectively. The p-contacts of the reference devices included a 5nm/5nm semi-transparent nickel/gold layer covering the whole top of the mesa to enable better current spreading from the main 20nm/200nm p-electrode. The n-contact was rapidly annealed at 700°C in nitrogen. The semi-transparent p-contact was rapidly annealed at 450°C.

Powered by KnowMade

To develop the Ge-doping technology, the researchers performed calibration experiments, producing n-GaN samples with 5.5x1020/cm3 carrier concentration and 67cm2/V-s mobility. These values are described as 'state-of-the-art'. The resistivity of the material was 1.7x10-4Ω-cm.

Continuous-wave electroluminescence spectra gave peaks around 304nm and 436nm for the AlGaN and InGaN QW devices, respectively. The emissions were attributed to band-edge electron-hole recombination rather than deep-level transitions. The 304nm wavelength falls in the UV-B 280-315nm range, which has medical applications such as in the treatment of psoriasis, and is also used in the curing of photoresist layers.

In the visible 436nm-wavelength blue LEDs, the use of tunnel junctions reduced the voltage needed for a given current injection: for 100 and 500A/cm2 current densities, the GaN LEDs with and without TJs showed voltages reduced from 5.6V to 5.3V, and from 7.0V to 6.6V, respectively. The corresponding light output powers increased from 0.7mW to 0.9mW, and from 2.3mW to 2.9mW.

The researchers comment: "The slight improvement in optical power between the GaN TJ and its reference is attributed to a better transparency of the TJ-based LED since the semi-transparent Ni/Au electrode has been suppressed."

For the AlGaN QW devices, the TJs increased the voltage for given current injection: However, inserting a GaN interlayer (IL) reduced the voltage penalty over the reference LED at 1000A/cm2 from 4.6V to 2V. The team believes that using an InGaN IL could reduce the penalty further by increasing the tunnel current, "due to a larger band-bending across the space charge region, thus decreasing the barrier width and increasing the tunneling probability".

In terms of AlGaN QW LED optical performance, the TJ structures increased output power at 1000A/cm2 injection: 12µW for the TJ with IL, and 5.3µW without IL, compared with 1.9µW for the reference device. The team admits: "These values are low compared to the current state of the art due to the high dislocation density in the AlN buffer layer (>1010/cm2), which decreases the internal quantum efficiency (IQE) of the AlGaN/AlGaN QWs."

Current density versus bias (a) and optical power (b) for AlGaN TJs and AlGaN reference without TJ. LED areas 0.0016mm2.

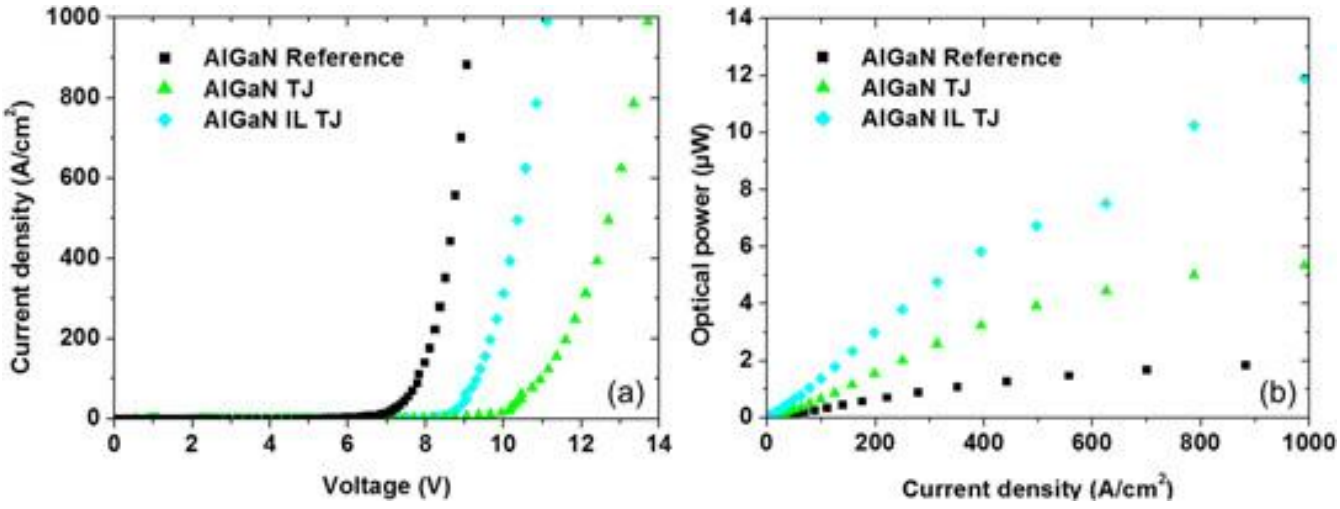


Figure 2: Current density versus bias (a) and optical power (b) for AlGaN TJs and AlGaN reference without TJ. LED areas 0.0016mm2.

Powered by KnowMade

The researchers believe the improved output power derives from enhanced electrical injection efficiency promoted by the use of the TJs. They comment: "As the TJ injects out of equilibrium holes into the LED, the balance between electrons and holes in the quantum wells is improved, which enhances the injection efficiency. In other words, while electrons tend to overflow above the QW in the standard UV LED due to the lack of holes and recombine in the p region, electrons recombine in the quantum wells with holes injected from the TJ in TJ-based UV LEDs."

TDK Ventures invests in GaN laser light firm SLD Laser

SemiconductorToday

Electronics company TDK Corp of Tokyo, Japan says that subsidiary TDK Ventures Inc has added to its growing portfolio of companies by investing in SLD Laser of Goleta, near Santa Barbara, CA, USA (a spin-off from LED lighting firm Soraa Inc of Fremont, CA that is commercializing visible laser light sources for automotive, mobility, medical, LiFi communication, sensing, specialty lighting and consumer applications).

SoraaLaser was spun off in 2013 from Soraa Inc of Fremont, CA, USA - which develops solid-state lighting technology built on 'GaN on GaN' (gallium nitride on gallium nitride) substrates - and was co-founded by Dr Shuji Nakamura (the 2014 Nobel Laureate in Physics), Dr Steve Denbaars, Dr James Raring and Dr Paul Rudy.

SLD Laser is TDK Ventures' third investment from its $50m fund since its July 2019 launch with a mission to invest its expertise in startups in innovative materials science, energy/power and related areas (typically underrepresented in venture capital portfolios) for a sustainable world.

"Their vision of digital and energy transformation matches our vision of developing real-world applications for intelligent illumination, sensing and communication that weren't thought possible," comments said SLD Laser's CEO & cofounder Steve Denbaars about TDK Ventures. "We have already identified a number of areas where TDK will help us pioneer the future of light faster," he adds.

"We look for fundamental solutions to the hardest problems, and offer our expertise, experience and industry connections to startups and growth-phase companies to help them more quickly achieve their full potential to make a positive world impact," says TDK Ventures' managing director Nicolas Sauvage. "SLD Laser is a true pioneer in innovative and meaningful applications leveraging semi-polar GaN materials, and we are very impressed by their team and their ambitious roadmap of a wide spectrum of applications around the future of light," he comments.

SLD Laser holds an intellectual property portfolio with over 500 patents. Their recently released products are claimed to be more than ten times brighter than existing LED lights, capable of illuminating objects 1km away while using less power than traditional technology. Their Beyond Lighting technology combines dynamic illumination with high-resolution sensing and ultra-high-speed LiFi communication. Products are used in applications including automotive & mobility, specialty & portable lighting, entertainment & outdoor, projection & AR/VR displays, biomedical instrumentation & therapeutics, industrial imaging & material processing.

Nitride Semiconductor wins UV LED patent lawsuits in USA against RayVio

SemiconductorToday

Nitride Semiconductor Co Ltd of Tokushima, Japan says that it has won a patent infringement lawsuit against RayVio Corp of Haywood, CA, USA, which is commercializing deep-ultraviolet (UV) LEDs and consumer disinfection solutions for health and hygiene applications.

On 13 January, the California Northern District federal court issued a judgment declaring that RayVio had infringed Nitride Semiconductor's patent and that the asserted claims of Nitride's patent are not invalid.

A month ago, the US Patent Office also confirmed the validity of the key claims of Nitride's patent in its final judgments of the Inter Parte Review case filed by RayVio.

Together with professor Shiro Sakai at Tokushima University, in 2000 Nitride Semiconductor developed what it claims were the first highly efficient UV-LEDs, and it has since continued to manufacture and sell UV-LED, involving huge investment in R&D.

Nitride Semiconductor says that it regards its intellectual property rights as vitally important assets, and it will accordingly take resolute actions against infringers in any country where appropriate and necessary to protect its patents and other intellectual property rights.

Patterned sapphire silica substrate for ultraviolet light-emitting diodes

SemiconductorToday

Researchers based in China and the USA have used a patterned combination of sapphire substrate and silica (SiO_2) layer to improve the performance of ultraviolet light-emitting diodes (UVLEDs) [Hongpo Hu et al, Nano Energy, vol69, p104427, 2020]. The enhanced light output was due to a combination of improved crystal quality of the III-nitride light-emitting material and a boost in light extraction efficiency (LEE) from reducing internal reflection and absorption of the generated photons.

The team from Wuhan University, HC SemiTek Corp, University of Science and Technology of China, Huazhong University of Science and Technology in China and University of Michigan in the USA see the technology as having potential for increasing the performance of LED-based solid-state UV light sources for curing, water purification, sterilization and phototherapy.

The researchers used three types of sapphire substrate: flat (FSS), patterned (PSS) and patterned with silica array (PSSA). The pointed cones of the PSS were created using thermal reflow of patterned photoresist and inductively coupled etching. With the PSSA the pointed cones were etched into a 2µm plasma-enhanced chemical vapor deposition (PECVD) silica layer. The etch was continued down into the sapphire substrate.

The effect of the patterned sapphire was to redirect dislocations in aluminium gallium nitride (AlGaN) growth, bending their path so that they annihilate rather than threading through the indium gallium nitride (InGaN) light-emitting active layers. Such dislocations become centers for electron-hole recombination without the emission of UV photons, sapping efficiency.

The patterned sapphire technique is not as effective in AlGaN, compared with GaN-based devices. This is related to the stronger sticking of Al, compared with Ga, in the growth process. This generates misoriented crystal growth. One effect of the silica array layer is to reduce misoriented crystal regions.

The nucleation for III-N deposition consisted of 20nm sputtered AlN. Further growth was by metal-organic chemical vapor deposition (MOCVD) with trimethyl-metal and ammonia precursors. The n- and p-type doping were via silane (SiH_4) and bis(cyclopentadienyl)magnesium (Cp_2Mg), respectively. Hydrogen and nitrogen were used as carrier gases.

The final epitaxial structure (Figure 1) was completed with a 720°, 20 minute thermal anneal to activate the Mg doping.

Powered by KnowMade

Contact	p^+-GaN	5nm
Contact	p-GaN	35nm
Electron blocking superlattice	4x(p-$Al_{0.2}Ga_{0.8}N$/GaN)	
	p-$Al_{0.2}Ga_{0.8}N$	20nm
Quantum barrier	$Al_{0.1}Ga_{0.9}N$	13nm
Multiple quantum well	8x($In_{0.05}Ga_{0.95}N$/ $Al_{0.07}Ga_{0.93}N$)	8x(1.6nm/ 6.5nm)
Superlattice	12x($In_{0.02}Al_{0.03}Ga_{0.95}N$/ $Al_{0.05}Ga_{0.95}N$)	12x(3nm/ 3nm)
	$Al_{0.05}Ga_{0.95}N$	15nm
Superlattice	6x($In_{0.01}Al_{0.03}Ga_{0.96}N$/ $Al_{0.05}Ga_{0.95}N$)	6x(3nm/ 3nm)
	n-$Al_{0.05}Ga_{0.95}N$	78nm
	n^--$Al_{0.065}Ga_{0.935}N$	170nm
	n-$Al_{0.16}Ga_{0.84}N$	30nm
	n^+-$Al_{0.065}Ga_{0.935}N$	2.5µm
	n-$Al_{0.12}Ga_{0.88}N$	100nm
Buffer	undoped-$Al_{0.05}Ga_{0.95}N$	4.5µm
Nucleation	AlN	20nm
Substrate	FSS/PSS/PSSA	

Figure 1: UVLED epitaxial structure.

The material was fabricated into LEDs with a 1.25µm mesa etch to expose the n-AlGaN contact layer. The p-GaN contact layer was covered with an annealed indium tin oxide (ITO) transparent conductor current-spreading layer. Chromium/platinum/gold were evaporated to create both the n- and p-electrodes of the diode structure. The wafer was thinned to 120µm by grinding and polishing. The 254µmx685µm chips were then singulated.

The threading dislocation density (TDD) was assessed using x-ray diffraction (XRD) and scanning transmission electron microscopy (STEM). The TDD in III-N material grown on flat sapphire is typically of the order of 1010/cm2. The estimate from the STEM analysis gave values for the PSS and PSSA samples of 5.63x108/cm2 and 2.80x108/cm2, respectively. These results were consistent with the less reliable XRD data.

Powered by KnowMade

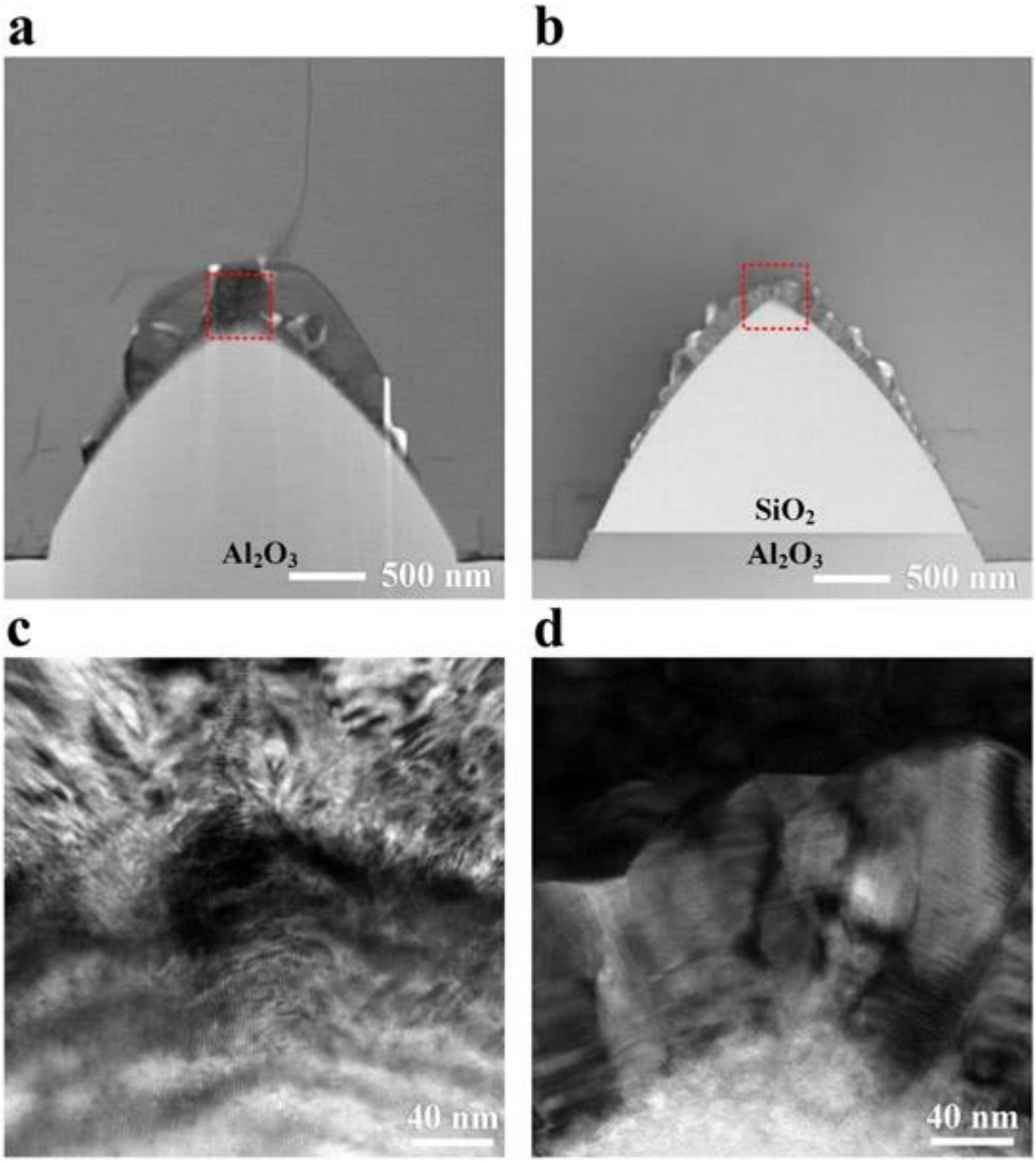


Figure 2: Cross-sectional STEM images of AlGaN grown (a) on PSS and (b) PSSA. (c) Enlarged STEM images of the marked areas in (a) and (d) that in (b).

The STEM studies also suggested that the dislocations formed at the sapphire interface became bent and terminated at the cones (Figure 2). The PSSA further reduced the upward propagation of dislocations. The PSSA sample also suffered less from parasitic crystal formation on the cones. The researchers comment: "The AlGaN epilayer grown on PSSA had a lower TDD than that grown on PSS by taking advantages of the more preferred vertical growth in the 3D growth stage and reduced misfit at the coalescence boundary."

Under photoluminescence the peak wavelength was 368nm. Electroluminescence from the FSS, PSS and PSSA UVLEDs resulted in light output powers of 68.3, 153.8 and 193.9mW, respectively, at 150mA injection (Figure 2). The researchers attribute the enhanced performance of the PSSA device to "improved crystal quality and higher LEE". The corresponding peak external quantum efficiencies were 23.1%, 44.9% and 50.4%. The researchers claim that the 50.4% is "better than those reported in previous publications". The current-voltage performance of the devices was similar.

Powered by KnowMade

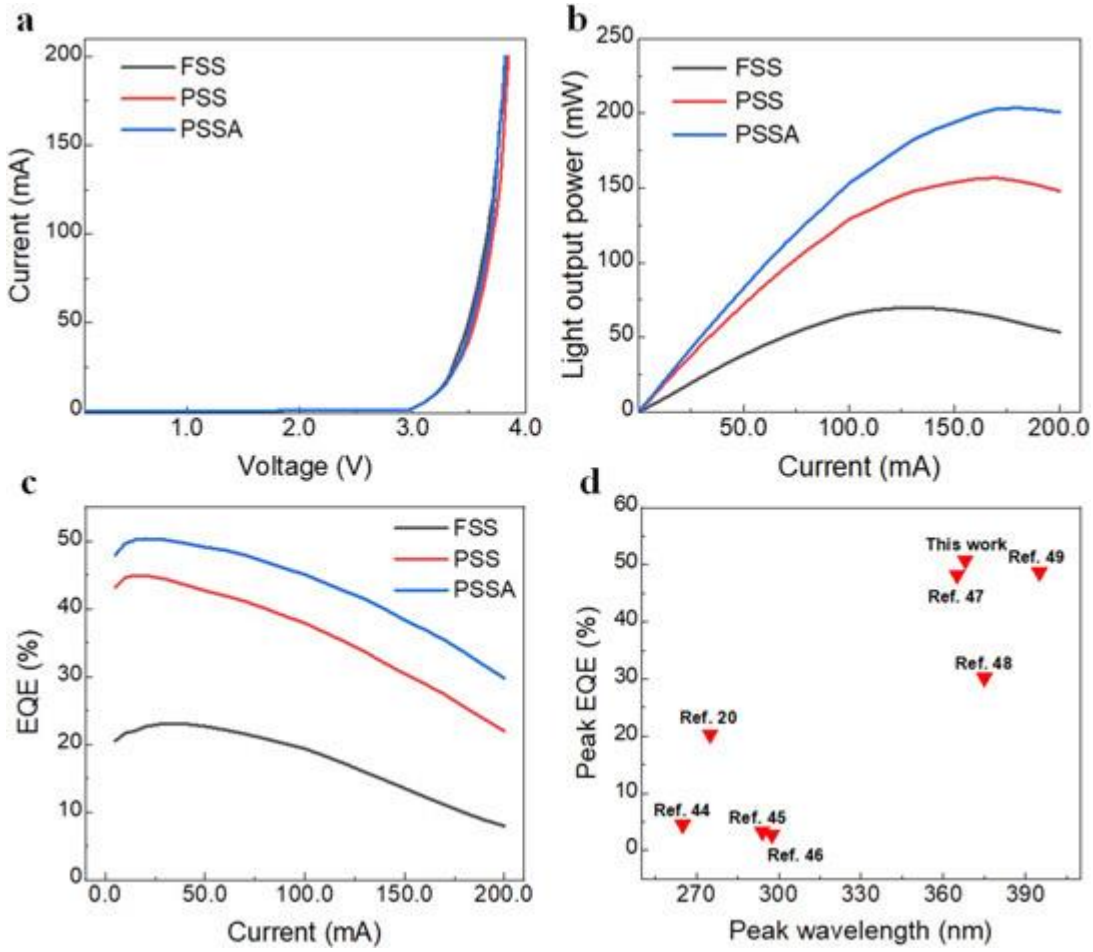


Figure 3: (a) I–V and (b) L-I characteristics of UVLEDs grown on FSS, PSS and PSSA. (c) EQEs of UVLEDs grown on FSS, PSS and PSSA versus current curves. (d) State-of-the-art in EQE for UVLEDs.

The LEE factor in the improved performance was explored using numerical simulations of the light reflection at interfaces. With the FSS substrate the flat interface tends to reflect most of the light back into the diode due to the refractive index contrasts, drastically reducing light extraction. Reflectivity measurements suggested improved reflectivity and transmittance at 368nm over FSS diodes of 10.2% for PSS devices and 15.8% for PSSA.

UVphotonics showcasing custom UV LEDs and modules at Photonics West

SemiconductorToday

Together with Berlin-based Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) in the German Pavilion (booth 4545) at Photonics West 2020 in San Francisco, CA, USA (4-6 February), UVphotonics NT GmbH – a spin-off from FBH and Technische Universität Berlin (TU Berlin) – is presenting novel UV LED developments with emission wavelengths ranging from 330nm down to as low as 230nm.

UVphotonics notes that UV LEDs have opened up new prospects due to benefits such as increased design flexibility, energy savings and reduced overall cost. Their customizable wavelengths, low operation voltages, ability to be rapidly switched and dimmed along with their compact size make them versatile light sources configurable to a multitude of applications, including water purification, disinfection, medical diagnostics, phototherapy, plant growth, UV curing and sensing.

Specifically, UVphotonics is presenting UVB and UVC LEDs with 10,000hr lifetime and output powers of up to 45mW at 310nm and 30mW at 265nm. Also showcased are fully packaged UVC LEDs with single emission peak at

Powered by KnowMade

230nm and an output power of 1.6mW at 100mA. Moreover, the firm's product portfolio has been expanded to UV LED modules with integrated driver circuits.

UVphotonics spin-off tailors its products to customer-specific needs in terms of emission wavelength, emission area and spatial emission characteristics. Together with the FBH, the firm covers the full UV LED technology chain: R&D on (Ga,Al,In)N UV LEDs with all stages of device fabrication in-house. The portfolio ranges from design to epitaxial growth to chip processing, packaging and up to complete turn-key modules, which are ready to use in applications. Also, in the neighboring booth, FBH is presenting its diode laser developments.

BluGlass presenting paper at Photonics West on manufacturing high-performance lasers using RPCVD

SemiconductorToday

BluGlass Ltd of Silverwater, Sydney, Australia – which develops remote-plasma chemical vapor deposition (RPCVD) technology for the manufacture of high-performance semiconductor devices – says that its head of epitaxy, Dr Josh Brown, is presenting 'High brightness MOCVD-grown laser diodes using RPCVD tunnel junctions' (paper 11262-26) at the SPIE Photonics West 2020 conference at 10:30am on 3 February (room 203, Level 2 South, Moscone Center) in San Francisco, CA, USA. BluGlass is also exhibiting at booth 4783.

In October, BluGlass launched a new direct-to-market business unit (managed by VP of business development Brad Siskavich in the firm's US office) to leverage the advantages of RPCVD tunnel junctions for GaN laser diode applications.

"The potential to apply what we've learned with LED tunnel junctions has been validated by a university partner, modelling our design for RPCVD epitaxial growth techniques," says Siskavich. "This collaboration has also stress-tested some of the assumptions and some of the results of our own lab work in Sydney," he adds.

"We continue that work and we'll be sharing more at Photonics West. At the same time, we will start manufacturing laser diodes using existing MOCVD techniques later this calendar year, using the expertise we have developed over the past decade, and we will continue to research how tunnel junctions grown using RPCVD can be deployed in the future in laser diode manufacture," continues Siskavich.

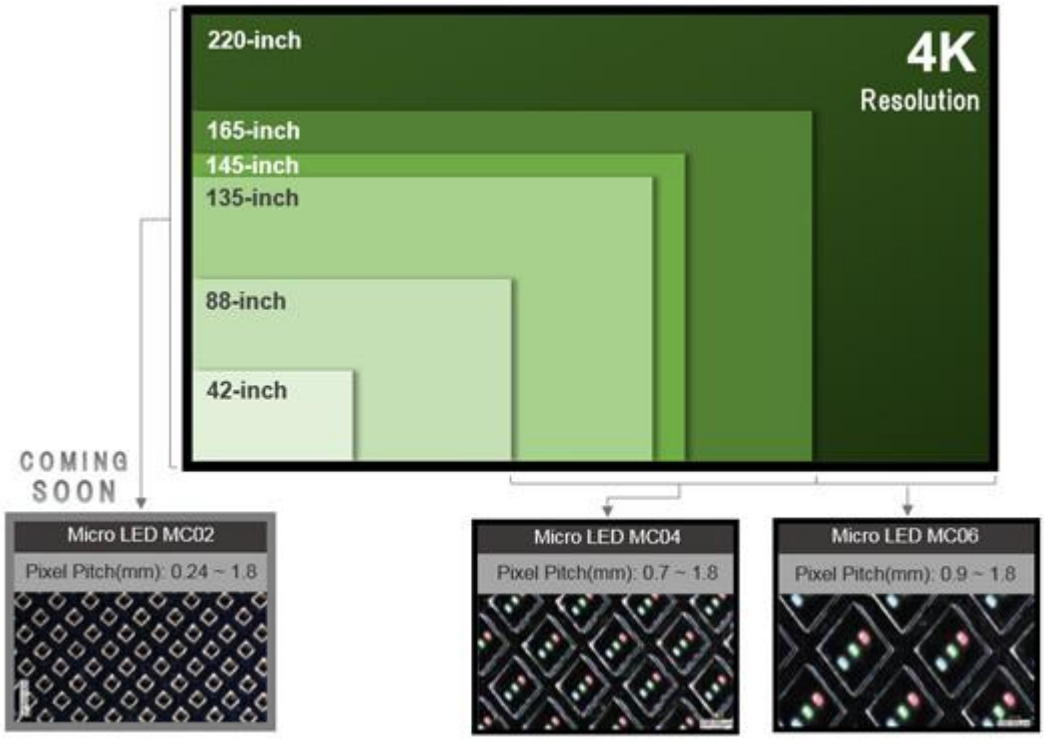
"BluGlass is also building the downstream supply-chain that will allow us to launch our new test facility in the US later this year. Together, these operations form the core of a customizable, end-to-end market approach that will enable BluGlass to generate growing revenues in the high-value laser diode market," he believes.

The focus of the paper is high-brightness MOCVD-grown laser diodes using RPCVD tunnel junctions. BluGlass says that its RPCVD process has already delivered breakthroughs in the growth of tunnel junctions for high-performance LEDs, and that these also apply to laser diode devices. RPCVD tunnel junctions can hence enable a novel way of growing laser diodes, addressing optical losses and resistive losses in particular.

Seoul Viosys and Seoul Semiconductor showcase single-pixel RGB 'Micro Clean LED' enabling 42-220" 4K-resolution TV displays

SemiconductorTodayv

South Korean LED maker Seoul Semiconductor Co Ltd and its ultraviolet (UV) LED product manufacturing subsidiary Seoul Viosys Co Ltd have showcased Micro Clean LED, a single-pixel RGB micro-LED technology that enables the design of 4K-resolution TVs with 42" to 220" displays. Unveiled at the Consumer Electronics Show (CES 2020) in Las Vegas in early January, the Micro Clean LEDs are ready for mass production.



Combining technology capabilities from Seoul Viosys – epitaxial growth of red, green and blue LED chips as well as proprietary mass transfer technology for single-pixel RGB µ-level chips – and Seoul Semiconductor – optimized surface-mount technology (SMT) to increase production capacity, and tiling technology for substrate connectivity – enables the production of customized display screen sizes.

Targeting the $100bn display market, micro-LEDs are said to deliver superior color rendering and optimal off-angle viewing compared with conventional LED/LCD technology. Also, unlike with organic light-emitting diiodes (OLEDs), micro-LEDs offer 1000x faster response time and up to a 30% reduction in internal/external power consumption, as well as infinite contrast range. In addition, display panels manufactured with micro-LEDs can be combined into larger displays. This modular approach means that display manufacturers can easily customize the size of their screens.

“The Micro Clean LED technology resolves several challenges in the manufacturing of micro-LEDs, which will bring cost reductions by combining three (RGB) LEDs in a single-pixel package, including transfer technology, consistent color mixing, and the ability to control individual color and light intensity,” says Seoul Viosys’ CEO Young Joo Lee.

University of Sheffield spins off EpiPix to develop and commercialize micro-LED technology

SemiconductorToday

The UK’s University of Sheffield has officially launched the spin-off company EpiPix Ltd, which is developing and commercializing micro-LED technology for photonics applications such as micro-displays for portable smart devices, augmented reality (AR), virtual reality (VR), 3D sensing and visible light communications (Li-Fi).

Underpinned by research from professor Tao Wang and his team at the Department of Electronic and Electrical Engineering, the firm is collaborating with global corporations on next-generation micro-LED product development.

The pre-production technology has already been demonstrated for multi-colour micro-LED arrays on single wafers with high light efficiency and uniformity, the university says. EpiPix is developing robust micro-LED epiwafers and product solutions for red, green and blue wavelengths with micro-LED pixel size ranging from 30µm down to 10µm, and has demonstrated prototypes with a diameter of less than 5µm.

EpiPix operates as a commercially driven technology center with worldwide exclusive commercial rights to all the micro-LED intellectual property that has been licensed by the company from the university.

"This is an exciting opportunity, and great timing in the micro-LED markets, for turning excellent science into profitable micro-LED products," reckons EpiPix's CEO & director Dennis Camilleri. "We are already engaged with industry customers to ensure that EpiPix aligns with their short-term product requirements and future technology roadmaps."

Plessey partners with Axus to process GaN-on-Si monolithic micro-LED displays

SemiconductorToday

At Photonics West 2020 in San Francisco, CA, USA (4-6 February), UK-based Plessey, which develops embedded micro-LED technology for augmented-reality and mixed-reality (AR/MR) display applications, has announced a partnership with Axus Technology of Chandler, AZ, USA (a provider of CMP, wafer thinning and wafer polishing surface-processing solutions) to bring high-performance gallium nitride (GaN)-on-silicon monolithic micro-LED technology to the mass market.

Plessey says that it continues to invest heavily in its manufacturing facility to boost its proprietary micro-LED display capabil ities with the purchase of metal and oxide chemical-mechanical polishing (CMP) and associated tools from Axus to enable the wafer-scale bonding of micro-LED wafers to high-performance CMOS backplanes.

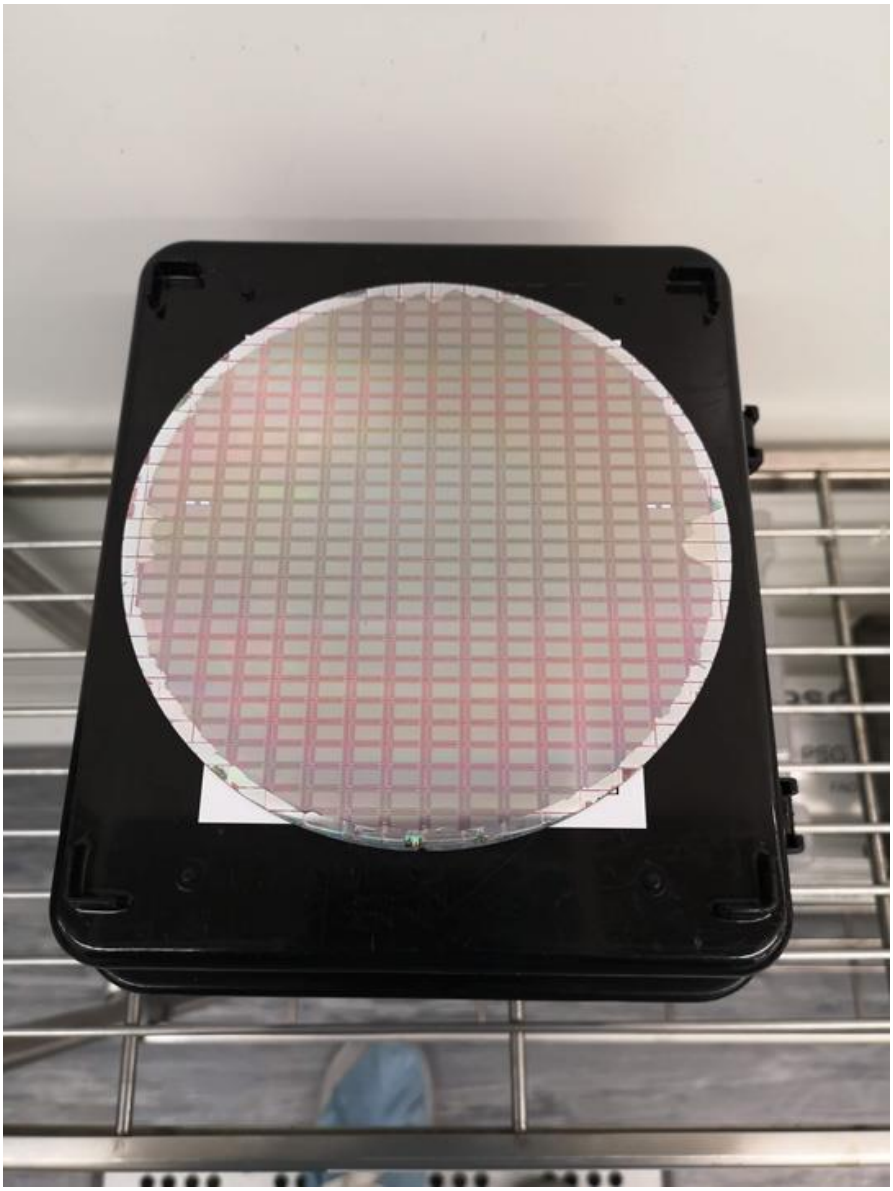


Picture: CMP tool from Axus Technology.

Axus' CMP and scrubber systems have been deployed to enable critical wafer planarization and preparation for wafer-scale bonding. Wafer-level bonding poses significant technical challenges and, even with the right

equipment, requires extensive know-how and refined processes, notes Plessey. Shortly after installation of the systems in 2019, Plessey achieved what is claims was the first functional wafer-level-bonded GaN-on-Si monolithic 1080p 0.7" diagonal 8µm-pixel-pitch micro-LED active-matrix display.

Plessey has further optimized these systems and processes to achieve wafer-to-wafer bonding of a much smaller monochrome native-green 1080p micro-LED display 0.26" diagonal to a 3µm-pixel-pitch backplane display system engineered by Compound Photonics US Corp (CP) of Vancouver, WA, USA (a provider of compact high-resolution microdisplay technologies for AR/MR applications), creating over 2 million individual electrical bonds.



Picture: Electrically and mechanically bonded micro-LED array wafer to 3-micron pixel-pitch backplane.

The formation of the Plessey/Axus partnership has led to the development of critical CMP processes for various materials key to enabling Plessey's proprietary monolithic GaN-on-Si technology.

Engineers from both firms have collaborated to accomplish these objectives at both Axus' CMP foundry in Chandler, Arizona and Plessey's semiconductor fabrication facility in the UK.

Going forward, the partnership will support scaling the technology for high-volume manufacture on the existing Axus equipment set and, in the near future, Axus' new high-flexibility/throughput Capstone CMP system (launched in late 2019).

"We'll be working closely with Plessey's engineers for upgrades to their current tooling and subsequently scaling the technology on Capstone," says Axus' president Dan Trojan. "Our ever-expanding investment in our manufacturing facility in the UK is allowing Plessey to innovate rapidly and deliver leading-edge technology for AR and other display applications," adds Plessey's chief operating officer Mike Snaith.

Plessey and WaveOptics partner on micro-LED display technology for smart glasses

SemiconductorToday

At Photonics West 2020 in San Francisco, CA, USA (4-6 February), UK-based Plessey, which develops embedded micro-LED technology for augmented-reality and mixed-reality (AR/MR) display applications, has announced a partnership with WaveOptics Ltd of Milton, Abingdon, UK, a designer and manufacturer of diffractive waveguides founded in 2014.

The partnership will focus on creating a new optical module, designed specifically for the next generation of smart glasses. The module will incorporate Plessey's high-brightness micro-LED native-green full-HD display along with WaveOptics' latest waveguide technology Katana (unveiled at Photonics West) and projector design. Critically, the module aims to be the smallest and lowest-mass AR display module on the market. The full-HD micro-LED display from Plessey is the result of its partnership with Compound Photonics (announced in October) to combine Plessey's gallium nitride/silicon (GaN/Si) micro-LED display technology with Compound Photonics' digital low-latency backplane and high-performance NOVA display driver architecture.

The next generation of AR and MR systems depends on a technological leap in the performance of the optical module, says Plessey. Advances in image quality, brightness, resolution and efficient power consumption are sought to make these new AR and MR systems a compelling practical and visual experience. The collaboration between Plessey and WaveOptics aims to deliver the necessary innovation by bringing together Plessey's GaN/Si micro-LED display technology and WaveOptics new-generation waveguide technology and projector design.

The substantial reduction in size and power requirements in this module enables enhanced features such as wireless transceivers for true, untethered AR applications, which are key for technology and mobile companies looking to launch smart glasses as a mobile accessory.

"This partnership will create a new product opportunity for companies building AR wearables," says WaveOptics' CEO David Hayes. "For the first time, customers will be able to buy the lightest, ultra-low-power module which combines the unique combination of WaveOptics and Plessey technologies. This is a crucial development to enable this technology to reach the consumer market in 2020," he adds.

"Our partnership with WaveOptics is a significant endorsement of Plessey's GaN-on-silicon micro-LED approach," states Mike Lee, Plessey's president of corporate and business development. "Our micro-LED displays are recognized as being at the forefront in delivering the high-performance display panels demanded by AR and MR devices."

AR headsets that allow the user to seamlessly transition between the bright outdoors to darker indoor environments require a display technology that can deliver both very high brightness and low power consumption for long battery life. Plessey says that its displays with WaveOptics technology can meet the challenge of this demanding requirement.

Osram launches 3W blue laser for stage lighting applications

SemiconductorToday

Osram Opto Semiconductors GmbH of Regensburg, Germany has launched a new blue high-power laser to expand the range of options available to manufacturers of show lasers and stage spotlights.

The PLPT9_450LA_E is a multi-mode laser diode mounted in a hermetically sealed TO metal can package. Lasers combine an outstanding form factor with excellent beam quality, making them particularly suitable light sources for show lasers and stage lighting, says Osram.

Offering advantages over LEDs in terms of brightness, the PLPT9_450LA_E laser diode achieves an optical power of 3W (at a typical operating current of 2A) and emits blue light with a wavelength of 447nm. In a typical optical system, the laser light is focused to a point only a few microns in diameter. The laser can be directly used as a blue light source or in combination with a special phosphor for white conversion. The achieved luminance of the white light source is around three times higher than that of a comparable LED.

The PLPT9_450LA_E comes in the proven, robust TO90 package. Compared with the first TO56 generation that included three pins, the new TO90 package contains only two pins for contact. Due to the simpler cooling, the generated heat can be easily dissipated from the component. In addition, integration of the laser into the final lighting solution is much less complicated.

“The PLPT9_450LA_E completes our broad portfolio of indium gallium nitride (InGaN) lasers with a 3W version,” says Christoph Walter, product manager for Visualization & Lasers. “Thanks to the easier cooling, an application range up to 85°C and an operating voltage of less than 5V, we are able to offer our customers particularly small and lightweight designs of high-quality lighting solutions for show lasers, endoscopy, professional laser torches and other numerous applications.”

OTHER

Shin-Etsu licenses Qromis’ GaN substrate technology

SemiconductorToday

Shin-Etsu Chemical Co Ltd of Tokyo, Japan has agreed to license the patented gallium nitride (GaN)-related technology of fabless firm Qromis Inc of Santa Clara, CA, USA (spun off from Micron Technology in 2015) as Shin-Etsu moves ahead with its development of GaN-related products.

Together with its silicon wafer manufacturing subsidiary Shin-Etsu Handotai Co Ltd, Shin-Etsu Chemical has been developing and selling substrates such as silicon-on-insulator (SOI) wafers and GaN-on-silicon wafers besides its usual line of silicon wafers for power and high-frequency semiconductors.

Qromis’ substrate technology (QST) is said to be fully diameter-scalable (6”, 8”, 12” and beyond) and engineered to alleviate stress from epitaxial layers, allowing the deposition of tens of microns of high-quality and low-dislocation-density bulk-like GaN on 6” or larger diameters.

Shin-Etsu aims to further expand its product portfolio by utilizing Qromis’ patented substrate technology in addition to advancing the line-up of its existing products, and will address a wide range of customer needs by offering multiple materials and substrates solutions.

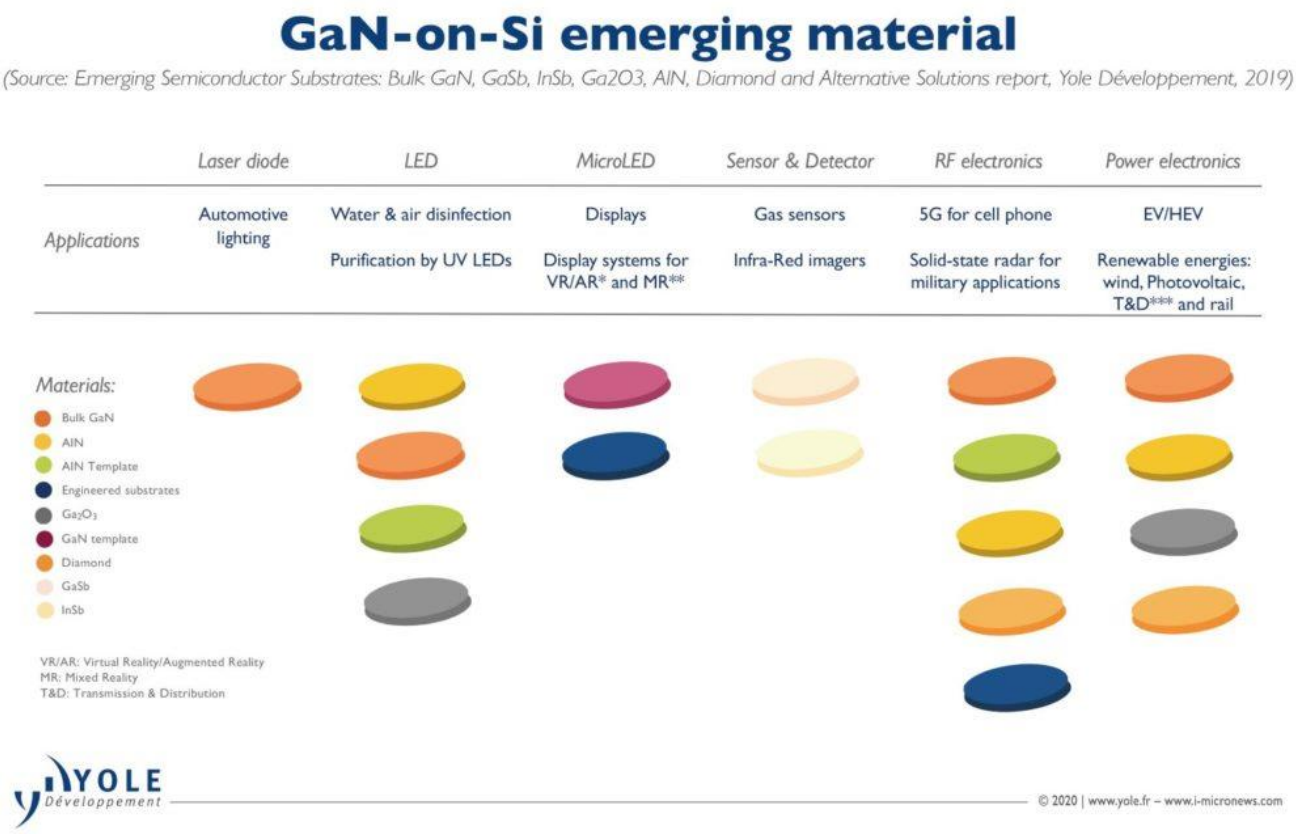
Shin-Etsu notes that the GaN market is expected to grow rapidly because the devices can help to resolve the conflicting issues of the need for energy conservation and the high-performance requirements essential for mobility evolution in areas such as autonomous driving, 5G communication and deeper digitalization.

Shin-Etsu Group (which includes Shin-Etsu Chemical and Shin-Etsu Handotai) says that, by supplying large-diameter GaN-related products, it aims to contribute to the realization of an energy-efficient, sustainable society.

GaN-on Si: many opportunities are driven by microLED, power electronics and RF electronics…

i-micronews

"2015-2020 period has shown tremendous and decisive changes within the GaN-on-Si landscape, especially the strategy of players involved," affirms Nicolas Baron, CEO and Co-founder of KnowMade. He adds: "For example, Toshiba's withdrawal from white LED market and the acquisition of IR by Infineon Technologies in 2015". (Read a dedicated article focused on the power electronics consolidation on i-Micronews.com.)



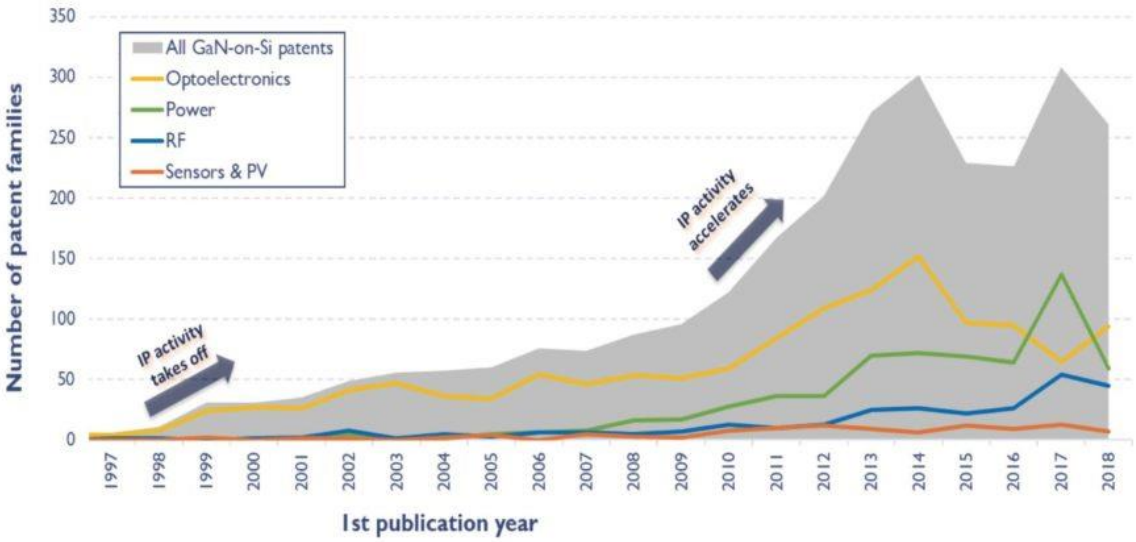
At that time, Toshiba and IR were already leading the GaN-on-Si patent landscape, while several historical IP players including Panasonic, Sanken Electric, Toyoda Gosei, etc. had already slowed down their patenting activity in this field. Furthermore, after IR, Transphorm, Panasonic and GaN Systems started sampling/commercializing their first GaN-on-Si power devices between 2010 and 2015, a second wave of companies has entered the playground in the last few years: ON Semiconductor, Dialog, Navitas, VisIC. More companies, such as STMicroelectronics, are expected soon, demonstrating the growing interest for GaN-on-Si technology in the power electronics business.

Yole Group of Companies, including Yole Développement, KnowMade and System Plus Consulting, are deeply engaged in the analysis of the overall GaN industry. The three companies are working together day by day to get a deep understanding of the market and its status. They follow innovations, evaluate their impact on the market and analyze the strategy of the leading players. Their aim is to get a comprehensive overview of the transformation of this industry.

Today, KnowMade announces its patent landscape analysis focused on GaN-on-Si technologies: GaN-on-Silicon Patent-Landscape Analysis. This report enlarges the collection of reports performed by Yole Group of Companies in this domain. It is part of the full GaN reports collection, including today, Power GaN: Epitaxy, Devices, Applications & Technology Trends, RF GaN Market: Applications, Players, Technology and Substrates and MicroLED Displays from Yole, RF GaN – Patent Landscape Analysis, Power GaN – Patent Landscape Analysis and GaN Power & RF – Patent Monitoring Service from KnowMade, and Medium Voltage GaN HEMT vs Superjunction MOSFET Comparison from System Plus Consulting.

GaN-on-Si patent landscape, time evolution of patent publications split by applications

(Source: GaN-on-Silicon patent landscape Analysis, KnowMade, 2020)



In addition, the Group proposes a special focus on the power electronics industry with a dedicated online event on January 30: “First Milestone for GaN Power Devices”. This webcast powered by Yole, System Plus Consulting and KnowMade is a great opportunity to understand and get a better vision of the GaN ecosystem and its supply chain, collect market figures and trends and discover a spotlight on the IP strategy of the key players.

“Intel and Macom are leading the GaN-on-Si patent landscape for RF electronics applications,” says Remi Comyn, PhD, Compound Semiconductors and Electronics at KnowMade. Intel’s RF GaN-on-Si patent portfolio mainly relates to III-N transistors used in SoC , RF switches, ultra-short channel lengths, field plates, and III-N/Silicon monolithic IC . Still, about 75% of Intel’s portfolio are composed of pending patent applications distributed mainly between USA with 17 patents and Taiwan with 20 patents.

Fujitsu with more than 40 patents and Macom with more than 20 patents for its side, are leading the patent landscape in terms of enforceable IP in the field of GaN-on-Si RF. Fujitsu’s portfolio focused on GaN-on-Si materials, especially on buffer layers, with inventions that might be implemented on others substrates including SiC or for other applications. Likewise Intel, Fujitsu has adopted a global patenting strategy. In contrast Macom’s portfolio is more focused on GaN-on-Si devices for RF, addressing specific technological challenges at epitaxy, device, module and package levels. For instance, a strong patenting effort was made in 2015 in order to address the parasitic channel via counter dopants in HEMT epi-structures. KnowMade’s analysts identified more than 10 related patent applications in its new GaN-on-Silicon patent analysis. Furthermore, Macom’s patenting activity related to GaN-on-Si is essentially focused on US, although it has now requested foreign extensions for a significant number of newly published inventions.

Regarding the power electronics field, Rémi Comyn from KnowMade comments: “The growing interest in GaN-on-Si technology for power applications has not translated into a remarkable acceleration of the patenting activity. However, we observed a steady patenting activity from Infineon following IR’s acquisition, and a remarkable strengthening of Transphorm’s portfolio after Fujitsu’s decision to transfer its power supplies businesses to the US startup”, Transphorm’s IP position has been further reinforced following the licensing agreement established in 2014 with Furukawa Electric, a key IP player in GaN-on-Si patent landscape. Likewise, Infineon Technologies closed an important IP licensing agreement with another historical player of GaN-on-Si and power electronics patent landscapes, Panasonic. Furthermore, KnowMade will keep monitoring closely GaN-on-Si IP activity in the next month, since another major power electronics player, STMicroelectronics, announced in 2018 an extensive R&D program in collaboration with CEA Leti a well-positioned player in the GaN-on-Si patent landscape.

From a technical point of view, Ezgi Dogmus, PhD, Technology & Market Analyst Compound Semiconductors & Emerging Materials at Yole asserts: “Over the last years, in the power electronics industry, we have witnessed an increasing interest for GaN HEMTs, which bring attractive performance and cost-competitive compared to Si MOSFETs. In addition to innovative start-up companies, almost all integrated device manufacturers in the Power Electronics business propose currently GaN-on-Si devices enabling systems with higher power, higher efficiency and smaller foot print than their Si MOSFET solutions.”

In power electronic sector, GaN -on-Si devices are direct competitors of Silicon SJ MOSFETs at medium voltage.
“SJ MOSFETS are still cost effectives and technologically interesting,” explains Elena Barbarini, Head of Department Devices at System Plus Consulting. “But the increase of players as the development of attractive performances at GaN epitaxy level drove an acceleration of available solutions. Its regards die design, driver integration and packaging.” This competition is analyzed in details the Medium Voltage GaN HEMT vs Superjunction MOSFET Comparison report performed by System Plus Consulting.

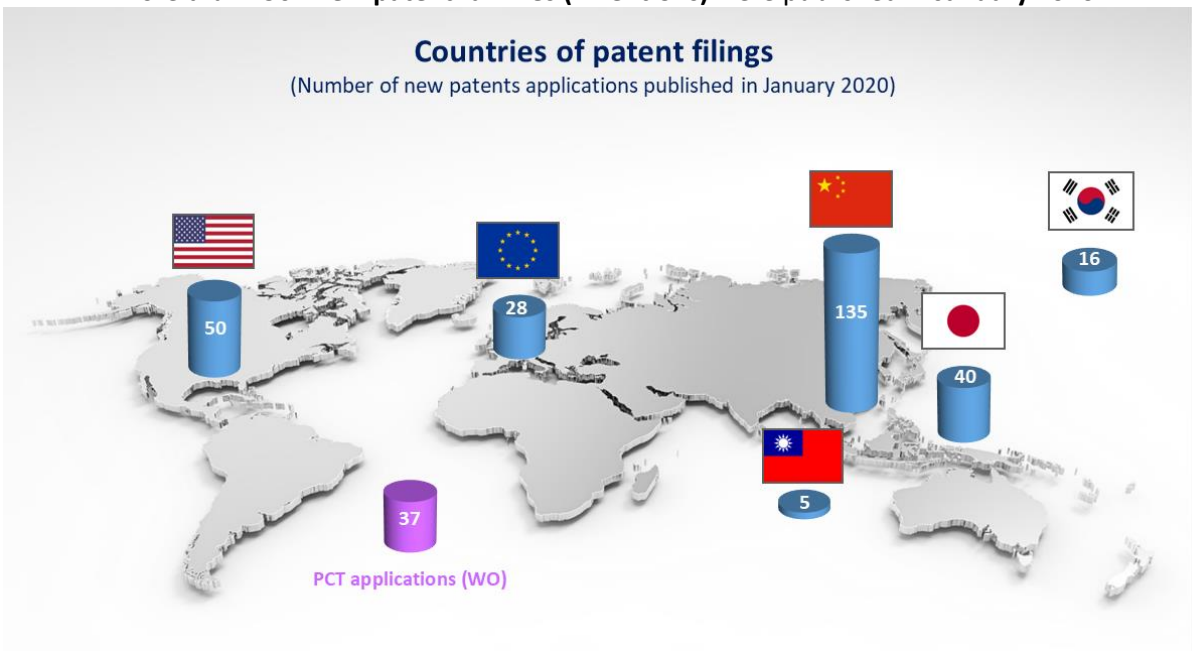
After a spotlight highlighting the GaN-on-Si patent activities in RF and Power electronics sectors, another interesting application has to be pointed out. Indeed, the increasing GaN-on-Si activity within the microLED activities is step by step becoming more attractive and leads to huge volume opportunities.
As of 2019, a significant contribution to the patenting activity (in terms of new inventions) stems from the development of a low cost and scalable GaN-on-Si nanowires-based microLED technology, which are promising for the next-generation display technology and smart lighting applications. Most microLEDs related patents included in the landscape are related to the fabrication of GaN nanostructures.

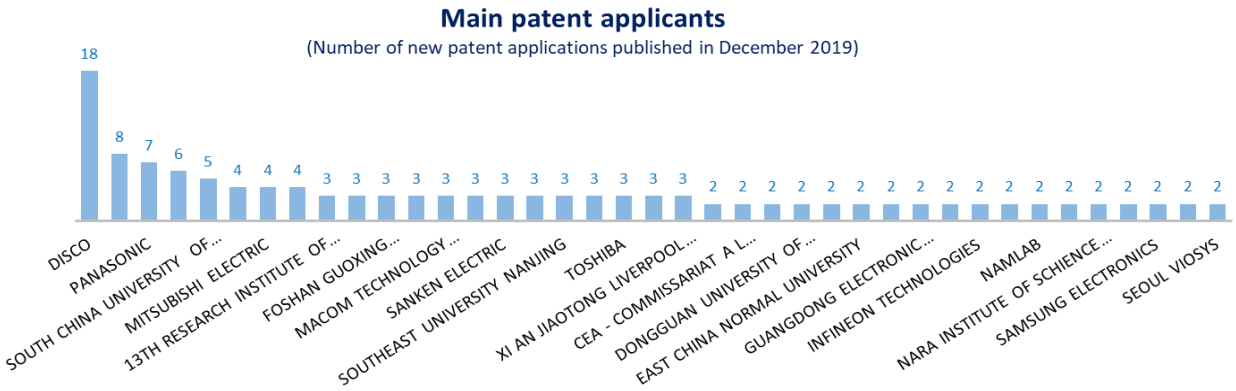
Eric Virey, PhD, Principal Analyst, Technology & Market, Displays at Yole tells us the story: “The technology was first developed and patented by glō between 2010 and 2016. However, glō’s patenting activity does not put the emphasis on GaN-on-Si, although it is a preferred embodiment”. For more information about glō’s developments, discover its interview conducted by Eric Virey and published on i-Micronews.
In parallel, since 2014, CEA and Aledia started patenting their own – jointly developed – technology with numerous requests for extending its priority patents worldwide indicating a global IP strategy/competition.

In this dynamic ecosystem, GaN-on-Si technologies look attractive and promising. This phenomenon is highlighted with the numerous patents incoming. Under this context, KnowMade, as a technology intelligence and IP strategy consulting company specialized in the analysis of patents and scientific information, and its partners, Yole and System Plus Consulting will pursue their investigations in this field and keep you update about the latest technical innovations, patents and industrial news.

PATENT APPLICATIONS

More than 250+ **new patent families (inventions)** were published in **January 2020**.





Other patent applicants Shaanxi Reactor Microelectronics, Shanghai Huali Microelectronics, South China Normal University, Sumitomo Electric Industries, Taiwan Semiconductor Manufacturing, Technische Universitaet Dresden, Toyota Central Research & Development Labs, Toyota Motor, Zhejiang Jiake Electronics, Actron Technology, Akoustis, Alcatel Lucent, Analog Devices, Anker Innovations Technology, Beijing Zhongke Youwei Technology, Bolb, Comba Telecom Systems Holdings, Cornell University, Dalian University of Technology, Dalian Xinguan Technology, Doshisha University, Dynax Semiconductor, Ecole Polytechnique Federale De Lausanne (EPFL), Efficient Power Conversion, Facebook Technologies, Fraunhofer, FREC N System, FREC Nsys, Fujian Beidian New Material Technology, Fujian Institute Research STR Matter CAS, Fuyang Electronic Information Research Institute, Fuzhou Internet of Things Open Laboratory, GANO Optoelectronics, General Motors, Guangxi Guangming Seedling, Hanyang University Industry University Cooperation Foundation, Hefei Irico Epilight Technology, Hefei Yuanxu Chuangsin Semiconductor Technology, Hitachi High Technologies, HRL Laboratories, Huawei, Hubei Duvtek, Hunan University, Innoscience Technology, Institut National Polytechnique De Grenoble, Institute of Physics Chinese Academy of Sciences, Integra Technologies, International Ecodesign & Microelectronic Packaging Research Institute, Invensas Bonding Technologies, Jiangxi Zhaochi Semiconductor, Jiaxing Super Lighting Electric Appliance, Jilin University, Julicheng Semiconductor, Korea Advanced Institute of Science & Technology, Kunshan Govisionox Optoelectronics, Kyung Hee University, Leroy Somer Moteurs, Luoyang Guangdu Intelligent Technology

Powered by KnowMade

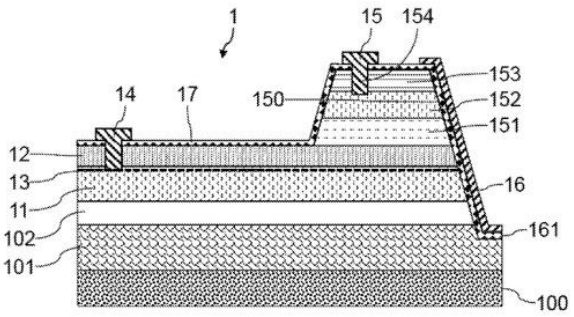
Notable new patent applications

Heterojunction transistor of the normally-off type with reduced transition resistance

Publication Number: FR3083647, EP3591709, US20200013887

Patent Applicant: CEA

A normally-off heterojunction field-effect transistor is provided, including a superposition of a first layer, of III-N type, and of a second layer, of III-N type, so as to form a two-dimensional electron gas; a stack of an n-doped third layer making electrical contact with the second layer, and of a p-doped fourth layer placed in contact with and on the third layer, a first conductive electrode and a second conductive electrode making electrical contact with the two-dimensional electron gas; a dielectric layer disposed against a lateral face of the fourth layer; and a control electrode separated from the lateral face of the fourth layer by the dielectric layer.

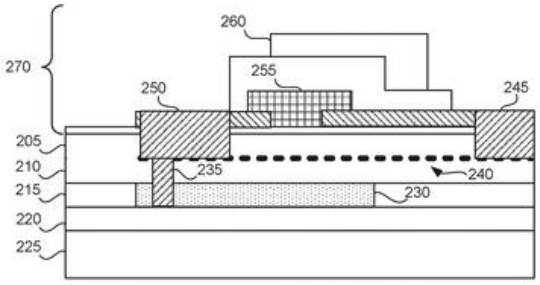


Compound device with back-side field plate

Publication Number: US20200013862, WO2020/010253

Patent Applicant: ANALOG DEVICES

A semiconductor device having a back-side field plate includes a buffer layer that includes a first compound semiconductor material, where the buffer layer is epitaxial to a crystalline substrate. The semiconductor device also includes field plate layer that is disposed on a surface of the buffer layer. The semiconductor device further includes a first channel layer disposed over the field plate layer, where the first channel layer includes the first compound semiconductor material. The semiconductor device further includes a region comprising a two-dimensional electron gas, where the two-dimensional electron gas is formed at an interface between the first channel layer and a second channel layer. The semiconductor device additionally includes a back-side field plate that is formed by a region of the field plate layer and is electrically isolated from other regions of the field plate layer.

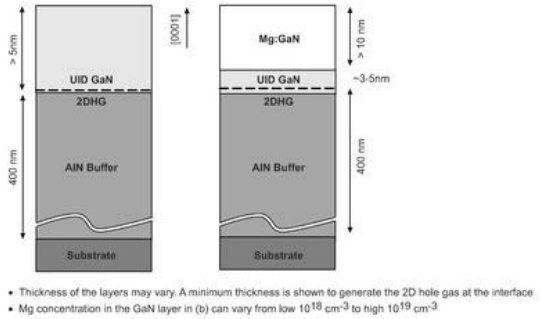


Polarization-induced 2D hole gases for high-voltage p-channel transistors

Publication Number: WO2020/018895

Patent Applicant: CORNELL UNIVERSITY

The long-missing polarization-induced two-dimensional hole gas is finally observed in undoped Group III nitride semiconductor structures and in undoped Group II or Group III oxide semiconductor structures. Experimental results providing unambiguous proof that a 2D hole gas in GaN grown on AlN does not need acceptor doping, and can be formed entirely by the difference in the internal polarization fields across the semiconductor heterojunction are presented.



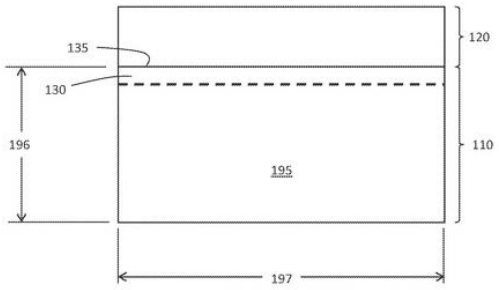
Powered by KnowMade

III-nitride material semiconductor structures on conductive substrates

Publication Number: WO2020/018915

Patent Applicant: MACOM

Material structures comprising Ill-nitride material regions (120) (e.g., gallium nitride material regions) are described herein. The material structures also comprise substrates (110) having relatively high electrical conductivities to reduce the degree to which thermal runaway occurs, which can enhance device performance including at elevated flange temperatures. Some embodiments include one or more features that reduce the degree of capacitive coupling exhibited during operation. For example, in some embodiments, relatively thick Ill-nitride material regions and/or relatively small ohmic contacts are employed.

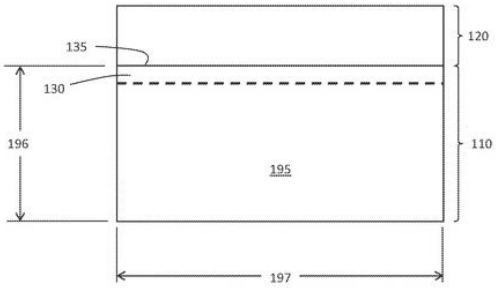


Semiconductor device, and manufacturing method for semiconductor device

Publication Number: WO2020/003436

Patent Applicant: MITSUBISHI ELECTRIC

The technology indicated in the present specification relates to a semiconductor device and a manufacturing method therefor, and a purpose thereof is to provide a semiconductor device that has a high heat dissipation ability. A semiconductor device according to the technology indicated in the present specification comprises a diamond substrate (23) and nitride semiconductor layers (2, 3). The diamond substrate (23) comprises diamond. The nitride semiconductor layers (2, 3) are formed in the interiors of recesses (17) that are formed in an upper surface (109) of the diamond substrate (23).

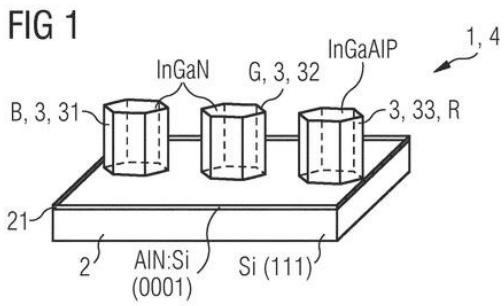


Method for producing optoelectronic semiconductor components

Publication Number: WO2020/007920

Patent Applicant: OSRAM

In one embodiment, the method is configured for producing optoelectronic semiconductor components and comprising the steps of: A) providing a growth substrate (2), and B) growing a plurality of light-emitting semiconductor columns (3) on the growth substrate (2), wherein an average diameter of the semiconductor columns (3) is max. 1µm, a first group (31) and/or a second group (32) of the semiconductor columns (3) on the growth substrate (2) is grown from a III-nitride material, and a third group)33) of the semiconductor columns (3) on the growth substrate (2) is grown from or with a III-phosphide material.



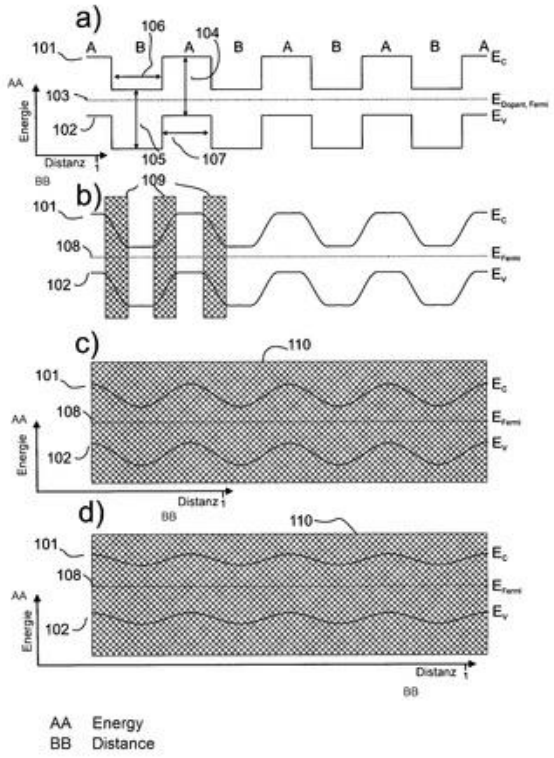
Powered by KnowMade

Semiconductor layer stack and method for producing same

Publication Number: WO2020/001694

Patent Applicant: UNIVERSITY MAGDEBURG

The invention relates to a semiconductor layer stack, to a component made therefrom and to a component module, and to a production method, the semiconductor layer stack being characterized by at least two layers (A, B), which, as individual layers, each have an energetic position of the Fermi level (103) in the semiconductor band gap (104, 105), formula (I) applying to the layer (A) and formula (II) applying to the layer B, with E F the energetic position of the Fermi level (103), E V the energetic position of a valence band (102), E L the energetic position of a conduction band (101) and E L - E V the energy difference of the semiconductor band gap E G (104, 105), the thickness (106, 107) of the layers (A, B) being selected in such a way that a continuous space charge region (110) over the layers (A, B) results.

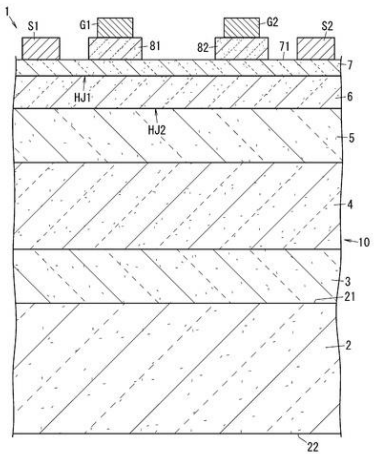


Bi-directional switch element

Publication Number: WO2020/004021

Patent Applicant: PANASONIC

The present invention addresses the problem of reducing current collapse. A bi-directional switch element (1) includes a substrate (2), an AlzGa1-zN layer (GaN layer 6), an AlbGa1-bN layer (first AlGaN layer 7), a first source electrode (S1), a first gate electrode (G1), a second gate electrode (G2), a second source electrode (S2), a p-type Alx1Ga1-x1N layer (first p-type AlGaN layer 81), a p-type Alx2Ga1-x2N layer (second p-type AlGaN layer 82), an AlyGa1-yN layer (second AlGaN layer 5), and an AlwGa1-wN layer (third AlGaN layer 4). The AlzGa1-zN layer is formed on the substrate (2). The AlbGa1-bN layer is formed on the AlzGa1-zN layer. The AlyGa1-yN layer is interposed between the substrate (2) and the AlzGa1-zN layer. The AlwGa1-wN layer is interposed between the substrate (2) and the AlyGa1-yN layer, and has a concentration of C that is higher than that of the AlyGa1-yN layer.



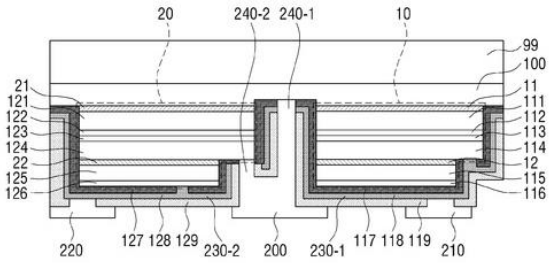
Powered by KnowMade

LED, LED manufacturing method, and display device including LED

Publication Number: WO2020/013595

Patent Applicant: SAMSUNG ELECTRONICS

A light emitting element, a manufacturing method therefor, and a display device including the light emitting element are disclosed. Particularly, disclosed are a multi-tunnel junction light emitting element having two or more light emitting regions, which are horizontally separated from each other, and a manufacturing method therefor, and disclosed is a display device which includes the light emitting element so as to efficiently arrange pixels and independently control the light emitting regions.

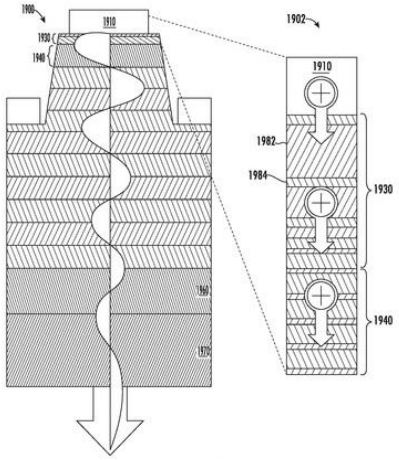


Semiconductor-metal contacts with spontaneous and induced piezoelectric polarization

Publication Number: WO2020/012392

Patent Applicant: SILANNA UV TECHNOLOGY

In some embodiments, a semiconductor structure comprises a semiconductor layer, a metal layer, and a contact layer adjacent to the metal layer, and between the semiconductor layer and the metal layer. The contact layer can comprise one or more piezoelectric materials comprising spontaneous piezoelectric polarization that depends on material composition and/or strain, and a region comprising a gradient in materials composition and/or strain adjacent to the metal layer. In some embodiments, a light emitting diode (LED) device comprises an n-doped short period superlattice (SPSL) layer, an intrinsically doped AlN/GaN SPSL layer adjacent to the n-doped SPSL layer, a metal layer, and an ohmic-chirp layer between the metal layer and the intrinsically doped AlN/GaN SPSL layer.

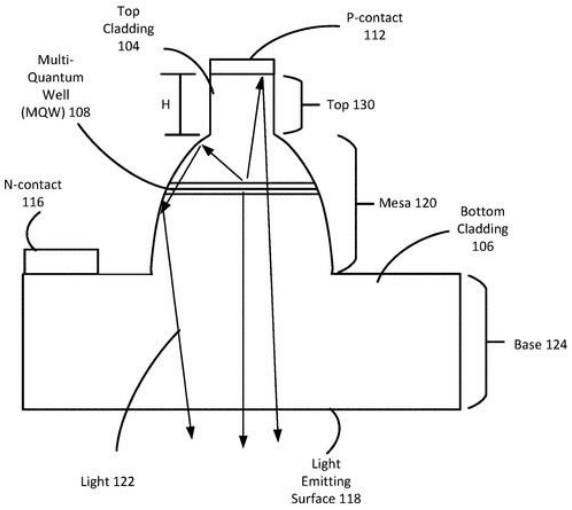


Parabolic vertical hybrid light emitting diode

Publication Number: US10535800

Patent Applicant: FACEBOOK

A micro-light emitting diode (LED) includes an epitaxial structure having a mesa and a top portion on the mesa. The epitaxial structure further includes quantum wells within the mesa configured to emit light, claddings surrounding the quantum wells, and a light emitting surface on a side opposite the mesa and top portion. A reflective contact is on the top portion of the epitaxial structure. Light emitted from the quantum wells are transmitted through the mesa and the top portion in first directions, and reflected by the reflective contact back through the top portion and the mesa in second directions toward the light emitting surface. The top portion allows the quantum wells to be positioned at a parabola focal point of the mesa without limiting cladding thickness.



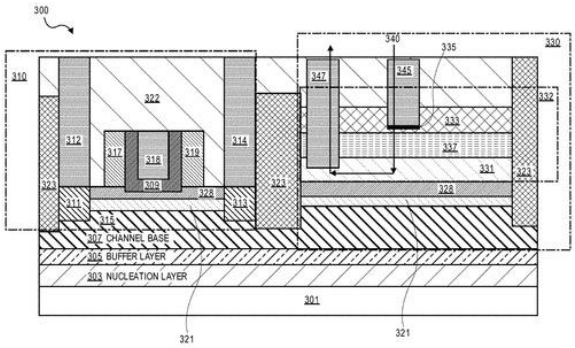
Powered by KnowMade

Schottky diode structures and integration with III-V transistors

Publication Number: US20200006322, DE102019114239, CN110660870

Patent Applicant: INTEL

Embodiments herein describe techniques, systems, and method for a semiconductor device. Embodiments herein may present a semiconductor device having a channel area including a channel III-V material, and a source area including a first portion and a second portion of the source area. The first portion of the source area includes a first III-V material, and the second portion of the source area includes a second III-V material. The channel III-V material, the first III-V material and the second III-V material may have a same lattice constant. Moreover, the first III-V material has a first bandgap, and the second III-V material has a second bandgap, the channel III-V material has a channel III-V material bandgap, where the channel material bandgap, the second bandgap, and the first bandgap form a monotonic sequence of bandgaps. Other embodiments may be described and/or claimed.

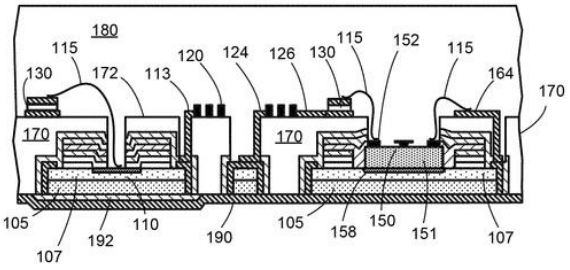


Heterolithic microwave integrated circuits including gallium-nitride devices on highly doped regions of intrinsic silicon

Publication Number: US20200020681

Patent Applicant: MACOM

Apparatus and methods relating to heterolithic microwave integrated circuits HMICs are described. An HMIC can include different semiconductor devices formed from different semiconductor systems in different regions of a same substrate. An HMIC can also include bulk regions of low-loss electrically-insulating material extending through the substrate and located between the different semiconductor regions. Passive RF circuit elements can be formed on the low-loss electrically-insulating material.

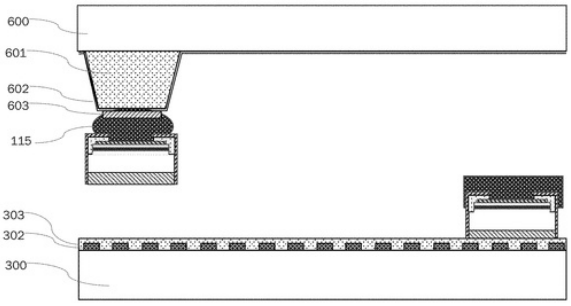


Micro light emitting diode

Publication Number: US20200020825

Patent Applicant: RAYSENT TECHNOLOGIES

Embodiments generally relate to micro-device arrays. In some embodiments, an array comprises a substrate and a plurality of micro-devices. Each micro-device is suspended over a cavity in the substrate by at least one lateral hinge attached to a side post formed into the substrate. Each micro-device comprises a bonding layer; a metal contact; semiconductor device layers; and a buffer layer. The semiconductor device layers may comprise GaN-based LED layers; wherein the buffer layer comprises AlGaN; and wherein the substrate comprises (111) oriented Silicon. In other cases, the semiconductor device layers may comprise InGaAsP-based LED layers; wherein the buffer layer comprises InGaP; and wherein the substrate comprises GaAs.



Powered by KnowMade

2405 route des Dolines, CS 10065
06902 Sophia Antipolis, France
contact@knowmade.fr
www.knowmade.com