WiPDA 2022

The 9th IEEE Workshop on Wide Bandgap Power Devices & Applications
Nov 7-9, 2022 | Sonesta Redondo Beach & Marina, California

Technical Program

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IEEE ELECTRON DEVICES SOCIETY

Schedule-at-a-Glance: November 7th

	Monday, Nov 7th, Tutorials	
8:00 AM -9:00 AM	**Breakfast (Seascape)**	
	Session 1A, SiC	**Session 1B, GaN**
	Session Room: Redondo 1	**Session Room: Redondo 2,3**
9:00AM – 10:20AM	Packaging and integration of wide bandgap power semiconductors	Emerging Gallium Oxide power semiconductor materials and devices
10:20AM – 10:40AM	***Break***	
10:40AM – 12:00PM	Managing EMI of SiC power electronics	GaN power devices: current Status, challenges, and emerging technologies
12:00PM – 1:00 PM	***Lunch – Sponsored by Infineon***	
1:00 PM – 2:20 PM	Reliability of SiC power devices for power conversion applications	Application trends for LV GaN power transistors
2:20PM – 2:40PM	***Break***	
2:40 PM – 4:00 PM	Evolution of SiC substrate production understanding and managing defects in SiC	Bidirectional WBG Switch Technology

Schedule-at-a-Glance: November 8th

	Tuesday, Nov 8th, Main Conference – Day 1	
7:00 AM - 8:00 AM	**Breakfast (Seascape)**	
	Keynotes day 1 (Pacific)	
8:00 AM - 8:15 AM	Welcome address	
8:15 AM – 8:45 AM	An Academic's Perspective on SiC Power Devices: Retrospection and Prognostication	
8:45 AM – 9:15 AM	Toward Vertical Integration to Scale the Supply of High-Performance SiC Power Modules for Demanding Applications	
9:15 AM – 9:45 AM	New high throughout solutions for Wide Bandgap power semiconductors	
9:45 AM – 10:15 AM	Vertical GaN "Technology of Future" – Now a Reality with NexGen Power Systems	
10:15AM – 10:45AM	Ultra-Wide Bandgap AlGaN Alloys for Power Electronics	
10:45 AM - 11:00 AM	**Break- Sponsored by EPC**	
11:00 AM- 12:30 PM	Panel Session: Supply and Cost of Substrates for Compound Semiconductors	
12:30 PM- 1:30 PM	**Lunch**	
	Day 1 Technical Sessions	
	Session Room:Redondo 1	Session Room:Redondo 2,3
1:30 PM - 2: 50 PM	1.A. SiC Devices - Novel Devices	1.B GaN Devices – Advanced Characterization
2:50 PM -3:10 PM	**Break- Sponsored by Aixtron**	
3:10 PM -4:30 PM	1.C SiC Devices - Device Reliability and Robustness	1.D GaN Devices – Industry and Others
6:00 PM - 8:30 PM	Poster Session & Reception- Sponsored by Focused Test (Peninsula/Pacific Reception140)	

Schedule-at-a-Glance: November 9th

	Wednesday, Nov 9th, Main Conference – Day 2	
7:00 AM - 8:00 AM	**Breakfast (Seascape)**	
	Keynotes day 2 (Pacific)	
8:00AM - 8:15AM	Welcome address	
8:15AM - 8:45AM	Reliable wide-bandgap (WBG) products for safety-critical automotive applications – what are expected	
8:45AM - 9:15AM	What is the Right Level of Integration for GaN Power Devices?	
9:15AM - 9:45AM	Designing with GaN to Solve Today's Global Power Challenges	
9:45AM - 10:15AM	High-speed GaN and SiC: $22B of pure-play power semiconductors	
10:15AM - 10:30AM	**Break- Sponsored by Wolfspeed**	
10:30AM - 11:00AM	GaN lateral devices: technology advantages and key application benefits	
11:00AM - 11:30AM	Bringing RF & Power closer through GaN Technology	
11:30AM - 12:00PM	GaN device innovation matched with manufacturing capacity and quality propels GaN to new markets	
12:00 PM - 1:00 PM	**Lunch**	
	Session Room: Redondo 1	Session Room: Redondo 2,3
1:00 PM - 2:15 PM	Panel: Wide-bandgap Device and related technology to Enable Medium Voltage Distribution Power Grid	Panel: GaN Growth Beyond Consumer Applications: What is the Right Level of Integration?
2:15 PM - 2:30 PM	**Break**	
2:30 PM - 4:10 PM	2.A SiC Applications – 1	2.B GaN Applications – 1
4:10 PM - 4:30 PM	**Break**	
4:30 PM -5:50 PM	2.C SiC Applications – 2	2.D GaN Applications – 2

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Welcome from General Chair

Dear Colleagues,

It is my pleasure to welcome you to the 9th annual IEEE workshop on Wide-Bandgap (WBG) Power Devices and Applications (WiPDA) sponsored by the IEEE Power Electronic Society (PELS), the IEEE Electron Devices Society, and the Power Sources Manufacturers Association (PSMA).

WiPDA has become one of the key gatherings for the WBG technical community where device scientists, application and system engineers, university professors and students share and exchange information on their recent research findings, report on key results, and discuss the main challenges for both Gallium Nitride (GaN) and Silicon Carbide (SiC) based technologies, devices, applications and systems. It also became the home for some of the key face-to-face annual gatherings such as the meetings of both the JEDEC JC-70 committee, responsible for WBG standardization, and the International Technology Roadmap for Wide-bandgap (ITRW).

In the last few years, we have seen many startups, as well as established semiconductor companies, release WBG products in the market, and many customers use those devices to deliver unprecedented performance in their products. WiPDA is uniquely positioned to bring together industry and academia to discuss the current state of the art and future trends that will be able to capture the increased levels of national and regional funding for WBG research and development in Europe, Asia, and the US.

This year's workshop will be a light hybrid model due to uncertainties associated with COVID-19, but also to enable a more flexible approach in attending the Conference. We are excited about the technical program based on the quality of paper manuscripts, keynotes, tutorials and panel sessions.

WiPDA 2022 starts on November 7th with a tutorial program consisting of eight-80 minutes sessions running over two parallel tracks and covering both WBG devices and applications for both SiC and GaN. The organizing committee is privileged to host exceptional keynote speakers of industry leaders from large semiconductor manufacturers, dynamic and fast-emerging startups, academia, and national research laboratories. We wanted this key component of WiPDA 2022 to highlight the vision and the direction that industry leaders are projecting and share their high-level roadmaps and their plans for the future.

Sincerely,

Andrea Gorgerino,

General Chair, IEEE WIPDA 2022

WiPDA 2022 Committees

Function	Name	Organization
General Chair	Andrea Gorgerino	EPC
Vice General Chair	Robert Kaplar	Sandia National Lab
Plenary Session Co-Chair	Alain Charles	ABC's World Consulting
Panel Discussion Co-Chair GaN	Peter Di Maso	GaN Systems
Panel Discussion Co-Chair SiC	Hua "Kevin" Bai	University of Tennessee Knoxville
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Tutorial Sessions: Monday, Nov 7th, 2022

Session 1.A. SiC

9:00 AM – 10:20 AM	**Packaging and integration of wide bandgap power semiconductors** *Cristina DiMarino, Virginia Tech*
10:20 AM – 10:40 AM	*Break*
10:40 AM – 12:00 PM	**Managing EMI of SiC power electronics** *Bulent Sargliolu, UW Madison*
12:00 PM – 1:00 PM	*Lunch-Sponsored by Infineon*
1:00 PM – 2:20 PM	**Reliability of SiC power devices for power conversion applications** *Don Gajewski, Wolfspeed*
2:20 PM – 2:40 PM	*Break*
2:40 PM – 4:00 PM	**Evolution of SiC substrate production understanding and managing defects in SiC** *Raghavan Parthasarathy, Onsemi*

Session 1.B. GaN

9:00 AM – 10:20 AM	**Emerging Gallium Oxide power semiconductor materials and devices** *Sriram Krishnamoorthy, UC Santa Barbara*
10:20 AM – 10:40 AM	*Break*
10:40 AM – 12:00 PM	**GaN power devices: current Status, challenges, and emerging technologies** *Yuhao Zhang, Virginia Tech*
12:00 PM – 1:00 PM	*Lunch*
1:00 PM – 2:20 PM	**Application trends for LV GaN power transistors** *Michael de Rooj, EPC*
2:20 PM – 2:40 PM	*Break*
2:40 PM – 4:00 PM	**Bidirectional WBG Switch Technology** Victor Veliadis, Executive Director & CTO PowerAmerica, Professor, NCSU

Title: An Academic's Perspective on SiC Power Devices: Retrospection and Prognostication

Time: 8:15AM – 8:45AM

Abstract: The role of an academic in the area of SiC power devices can be categorized as: (1) Fundamental Theoretical Predictions; (2) Fundamental Scientific Knowledge; (3) Fundamental Device Structures; (4) Device Structural Innovations; (5) Device Physics and Analysis; and (6) Technology Feasibility Studies. This paper provides examples of these activities during my past 40 years of effort in this field as a retrospective. New prospective device ideas that will have a strong impact on power electronics in the future are then discussed.

Jayant Baliga (F'83-LF'14) received the M.S and Ph.D. degrees in electrical engineering from Rensselaer Polytechnic Institute, Troy, NY, in 1971 and 1974, respectively. He spent 15 years at the General Electric R&D Center, Schenectady, NY, leading their power device effort and was bestowed the highest rank of Coolidge Fellow. He joined NC State University in 1988 as a Full Professor, was promoted to Distinguished University Professor in 1997, and became Progress Energy Distinguished University Professor in 2018. Dr. Baliga has authored 22 books, over 700 publications in international journals and conference digests, and holds 122 U.S. patents. He has been honored with the National Medal of Technology and Innovation in 2011 from President Obama, the IEEE Medal of Honor in 2014, the Global Energy Prize in 2015, and was inducted into the National Inventors Hall of Fame as the sole inventor of the IGBT in 2016.

Title: Toward Vertical Integration to Scale the Supply of High-Performance SiC Power Modules for Demanding Applications

Time: 8:45AM – 9:15AM

Abstract: The adoption of SiC Schottky diodes and then SiC MOSFETs in solar inverter applications was the first wave to evaluate the capabilities of these new devices in challenging applications and environments. With the observed and projected growth of demand for high-efficiency, high-voltage power semiconductor devices in automotive traction and EV chargers, challenges arise to supply SiC devices into these demanding applications. Current and emerging SiC power device manufacturers are developing strategies to be able to support the accelerating need for SiC power device supply. Onsemi is building on its strength in end-to-end solutions of silicon power semiconductor devices, starting with silicon crystal growth and epitaxy, through die fabrication and final package and module assembly. Onsemi has extended its existing silicon-based power semi portfolio into SiC-based power modules. To achieve this, we continue to invest heavily in SiC wafer and epitaxy, as well as expanding wafer fab capacity to meet the growing demand. Additionally, Onsemi continues to develop advanced SiC power modules to meet the specific needs of automotive and industrial

customers. At Onsemi, we strongly believe that this vertically-integrated strategy will help meet the growing customer needs for high-efficiency SiC power modules.

Dr. **Kevin Matocha** is Senior Director, Design for Reliability and Manufacturability at Onsemi, Phoenix, AZ. Kevin's career has focused on the development of wide bandgap devices, including GaN and SiC devices, with particular emphasis on SiC MOSFET performance and reliability. His professional career began at GE Global Research in 2000, where he developed SiC harsh environment sensors, including UV sensors and gas sensors. From 2008-2011, he led GE's effort to develop SiC power MOSFETs, including enhancing the performance and improving gate oxide reliability. In 2011, Kevin joined SemiSouth as VP of Product Engineering, leading efforts to scale to production SiC Schottky diodes and SiC JFETs. In 2012, Kevin co-founded Monolith Semiconductor Inc. (Round Rock, TX), which included developing the first domestic foundry for 150mm SiC power device fabrication. Monolith Semi released commercial SiC MOSFETs and diodes in 2016. Kevin served as President and CTO of Monolith Semiconductor until 2018, when the company was acquired by Littelfuse, Inc. (Chicago, IL). Kevin received his PhD degree in 2003 from Rensselaer Polytechnic Institute (Troy, NY), focused on the development of lateral GaN power MOSFETs. Kevin has been awarded 42 US patents and has delivered 95 technical publications in technical journals and conferences, including several invited talks.

Title: New high throughout solutions for Wide Bandgap power semiconductors

Time: 9:15AM – 9:45AM

Abstract: There is little debate nowadays about the merit of GaN or SiC material for Power Electronics applications compared to the Silicon-based technologies. Power supplies and power inverter continue to drive most of the Wide Bandgap material adoption with Gallium Nitride used nowadays in nearly every power supply and Silicon Carbide as the material of choice for high efficiency power inverters for long range Electric Vehicle (EV). To enable such widespread adoption into new applications, MOCVD equipment needs to ensure not only to meet the tightest material performance requirements but also to provide solutions enabling cost reduction year after year. In addition, the current semiconductor ramps, and material constraints are accelerate the transition to larger substrate size and the focus on integrability into Silicon factory as well as tool productivity per unit for clean room floor area. We will present how AIXTRON is addressing those markets with new series of high throughput solutions for Wide Bandgap materials and how this contribute to bolst the output of existing factories.

Vincent Meric is Vice President of Marketing of AIXTRON SE. After spending a few years at Air Liquide in France and Japan as a researcher, he joined AIXTRON in Germany, where he has grown as a material enthusiast. First as a process engineer and then taking different roles in Sales and Marketing, he has been involved in the development of new equipment to enable the adoption of Compound Semiconductors into more and more applications. After spending several years in

Japan to support the early demand for gallium nitride and silicon carbide power semiconductors he leads since 2020, he leads the global product management team, covering all compound semiconductor applications from power & RF devices, to lasers, Micro LED or 2D material devices He graduated from the National School of Chemistry of Toulouse, France (ENSIACET) in 2002.

Title: Vertical GaN "Technology of Future" – Now a Reality with NexGen Power Systems
Time: 9:45AM – 10:15AM

Abstract: As the world looks beyond silicon for the next generation of power electronics, NexGen Vertical GaN™, the world's first GaN-on-GaN power semiconductor, unlocks the full potential of Gallium Nitride (GaN). It is the only wide band gap power semiconductor that provides high-voltage capabilities up to 4kV, switching frequencies up to 10MHz, and avalanche and short-circuit robustness. This makes it an ideal power semiconductor for applications from LED Lighting and Computing to Data Centers and Electric Vehicles. NexGen is reinventing power electronics by leveraging this breakthrough technology and building a scalable, software-configurable power platform that enables the smallest, lightest, and most efficient power systems.

Dr. **Shahin Sharifzadeh** is the Co-CEO of NexGen Power Systems. Prior to joining NexGen, Sharifzadeh was the Senior Vice President of Worldwide Operations at Atmel Corporation. Before Atmel Corporation, Dr. Sharifzadeh has served as the Executive Vice President of Worldwide Manufacturing and Operations at Cypress Semiconductor Corporation and its President of China Operations. He worked for Cypress Semiconductor from 1989 to 2012 in various capacities – EVP of Worldwide Wafer Fabrication and Technology, and VP of Process R&D. In these roles, Dr. Sharifzadeh directed Cypress Semiconductor Corporation's process technology research and development, wafer manufacturing, assembly and test, and planning worldwide. Dr. Sharifzadeh received his bachelor's degree in Electrical Engineering from the University of Southern California and his MS and Ph.D. degrees in Electrical Engineering from Stanford University.

Title: Ultra-Wide Bandgap AlGaN Alloys for Power Electronics
Time: 10:15AM – 10:45AM

Abstract: Ultra-wide-bandgap (UWBG) AlGaN alloys (Eg > 4 eV) are appealing for the next-generation of high-voltage power devices due to their superior material properties. Most notable is that the critical electrical field scales as the bandgap to the ~ 2.0-2.5 power. Thus, power diodes employing Al-rich AlGaN alloys (4.0 < Eg < 6.2 eV) are expected to operate at higher breakdown voltages with thinner and more heavily-doped drift regions, leading to lower resistive losses and higher power density compared to Si-, SiC- and even GaN-based devices. Additionally, the formation of AlGaN-based heterojunctions and the utilization of polarization fields for doping offer device design options not currently possible for devices based on SiC and other ultra-wide bandgap semiconductors such as diamond and b-Ga2O3. We will present polarization doping of both p- and n-type AlGaN alloys in compositions where conventional impurity doping fails and employ polarization doping to fabricate $Al_{0.7}Ga_{0.3}N$ PN diodes with kilovolt breakdown voltages. In addition to appealing material properties such has high critical electric field, we have found that the electrical characteristics of Schottky diodes and regrown PN junctions in AlGaN alloys show a surprising robustness to residual, sub-surface etch damage that degrades the performance and thus complicates the fabrication of GaN devices. This robustness to etch damage has led to the demonstration of PN diodes where the p-anode was formed by regrowth in an etched well which resulted in diodes that exhibit reverse breakdown voltages of 1.8 kV and are indistinguishable from continuously grown PN diodes. A major challenge to realizing vertically conducting AlGaN power devices is the lack of a native, conducting substrate. To address the need for vertically conducting device architectures, we present an AlGaN overgrowth process on previously-patterned, conducting GaN substrates that have been used to fabricate PN diodes with 7 mm thick drift layers in $Al_{0.3}Ga_{0.7}N$ that reach breakdown voltages of 1 kV. These and other examples to be presented illustrate the potential of AlGaN alloys for realizing kilovolt-class power diodes and transistors for next generation power systems.

Andrew Allerman is a Distinguished Member of Technical Staff in the Advanced Electronic and Optoelectronic Materials Department at Sandia National Laboratories in Albuquerque, NM. Throughout his career, he has specialized in the development of MOCVD processes for a wide range of compound semiconductor materials and device technologies. His work on AlGaN alloys has spanned more than 20 years and enabled UV laser diodes and LEDs, UV-sensitive photodetectors, intersubband, electro-absorptive modulators at 1550 nm, and more recently Al-rich AlGaN-channel HEMTs and power diodes along with high temperature MOCVD growth processes for h-BN. His prior work includes MOCVD growth of As-P-Sb and dilute nitride III-V compound semiconductors for mid-IR laser diodes and LEDs, near-IR VCSELs, HBTs, HFETs, HEMTs, solar cells (1 eV) and photonic integrated circuits. Andy is a member of several international advisory boards for III-Nitride semiconductor conferences and has been program co-chairs of numerous conferences over the past 27 years. He received his B.S. and Ph. D degrees in Physics from Auburn University.

Keynote Sessions: Wednesday, Nov 9th, 2022

Title: Reliable wide-bandgap (WBG) products for safety-critical automotive applications – what are expected

Time: 8:15AM – 8:45AM

Abstract: To reduce global warming / human health impacts, governments around the globe have been committed to reduce greenhouse gas and pollutant emissions. To achieve these goals, vehicles with internal combustion engines (ICEs) are being replaced at very fast pace by vehicles with electrified power trains, (e.g., battery-electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), fuel-cell electric vehicles (FCEVs), etc.) To offer electrified functions, many power-electronic (PE) modules are incorporated on these vehicles (e.g., traction inverters, DC/DC converters, on-board / off-board chargers, etc.) In these PE modules, WBG devices have shown promising potential to replace Si ones to achieve better performance, smaller footprints, lighter weights, etc. However, from many view angles, many WBG products are working under higher stresses than the Si ones to deliver better performance, leading to concerns of lower long-term reliability / higher parameter drifts. To convince automotive manufacturers/suppliers, WBG vendors should disclose the raw-wafer / epi-layer defect info (e.g., densities, failure mechanisms, long-term aging effects, etc.), quality assurance processes and qualification results, EOL screening processes and pass/fail criteria, production yields, test-to-failure data (e.g., Weibull charts, bath-tub curves), and actual field return results. For comparison, Si experience will be shared in this presentation.

Chingchi Chen received a Ph.D. degree in 1994 from the University of Wisconsin-Madison, in Electrical Engineering. Since then, he has been with Ford Research & Advanced Engineering, leading power electronics research for on-vehicle applications. He has been working on various areas in power electronics for automotive applications, including topology evaluation, dynamic analysis, reliability assessment, WBG technology evaluation, and package design.

Title: What is the Right Level of Integration for GaN Power Devices?

Time: 8:45AM - 9:15AM

Abstract: GaN power devices have been in mass production for over 12 years [1] and have arguably crossed over the tipping point in adoption with such end-uses as cell phone fast chargers, DC-DC converters for servers, motor drives for electric bicycles and scooters, class-D audio amplifiers, and lidar sensors for autonomous vehicles and robots. Some of these applications first started using discrete GaN transistors and later converted to GaN integrated circuits. Others have stayed with discrete devices. This paper will discuss the reasons for different adoption rates in different applications and will speculate on the changes that will occur due to new GaN transistor performance and new capabilities in integrating functions in GaN.

Alex Lidow is CEO and co-founder of Efficient Power Conversion Corporation (EPC). Prior to founding EPC, Dr. Lidow was CEO of International Rectifier Corporation. A co-inventor of the HEXFET power MOSFET, Dr. Lidow holds many patents in power semiconductor technology and has authored numerous publications on related subjects, including co-authoring the first textbook on GaN transistors, *GaN Transistors for Efficient Power Conversion*, now in its third edition published by John Wiley and Sons. Lidow earned his Bachelor of Science degree from Caltech and his Ph.D. from Stanford.

Title: Designing with GaN to Solve Today's Global Power Challenges

Time: 9:15AM - 9:45AM

Abstract: Our world's sustainable future is linked to energy efficiency and GaN's innovative technology. The world is witnessing a data explosion. The demand for a cleaner and healthier global environment clearly shows that sustainability must be more than a footnote in a company's annual report. Yet, the energy-driven world is leading to historically high-power consumption due partly to our increased dependence on power-reliant industries, including data centers, electric vehicles, renewable energy systems, and consumer electronics. Technology helped create this problem. Now, it's time for technology – specifically *'GaN-Powered'* technology – to help solve this problem. From the humble chargers to the all-important EV powertrain, GaN power systems are solving today's technical, economic, and environmental challenges. During this session, Jim Witham, CEO of GaN Systems, will discuss how GaN plays a crucial role in changing our relationship with power by enabling the creation of new sustainability solutions.

Jim Witham, CEO GaN Systems Jim Witham's career has focused on bringing new technology, like GaN Systems' innovative GaN (gallium nitride) power semiconductors, to the global electronics market. Mr. Witham joined GaN Systems from Neoconix, a manufacturer of high density, miniature connectors. As CEO of Neoconix, he successfully implemented strategic changes which dramatically increased revenue and resulted in the company's acquisition by Unimicron Technology. Prior to Neoconix, Mr. Witham was CEO of Fultec Semiconductor, where his team made circuit protection devices using high voltage silicon, silicon carbide and gallium nitride (GaN) transistors. Fultec was acquired by circuit protection market leader Bourns. Mr. Witham has also held VP Sales & Marketing positions at Aegis Semiconductor, a tunable filter semiconductor manufacturer and Genoa, a semiconductor optical amplifier manufacturer. Other notable career highlights include senior executive positions at Raychem, including General Manager of the Raychem Interconnect Division and Director of Asia Sales & Marketing, based in Japan, for the Raychem Circuit Protection Division. As an Engineering Specialist at General Dynamics' Space System Division during the eighties, Mr. Witham designed fluid systems for the

Space Shuttle and was on Mission Control for interplanetary missions. Mr. Witham holds an MBA from Harvard and both M.S. and B.S. with distinction in Mechanical Engineering from Stanford.

Title: High-speed GaN and SiC: $22B of pure-play power semiconductors
Time: 9:45AM - 10:15AM

Abstract: Wide bandgap semiconductors are expanding rapidly into legacy silicon applications, with a combined market opportunity over $22B by 2026. The voltage and power range where silicon MOSFETs are the preferred solution is now limited to less than 100V and less than 1kW, and even that range is shrinking. GaN is now preferred from 100V to 750V ratings and up to 20kW due to its extremely low losses, reduced chip sizes, and integrated solutions driving low system costs. SiC is a clear winner in high-efficiency and high-density applications for 800V and higher power rails, with power FETs and diodes ranging from 650V to 6,500V. Switching frequencies are increasing in new topologies with GaN power ICs in applications such as data-center PFC and DC-DC stages, solar micro-inverters, and home appliance motor drives, with SiC FETS in advanced BLDC industrial motor drives and solar string-inverters. GaN device and application examples include new GaNSense half-bridge power ICs with loss-less current sensing and high-speed over-current protection enabling an advanced 140 W USB PD 3.1 fast-charger design, and a 'Titanium Plus' 2.7 kW CRPS AC-DC. Navitas' GeneSiC FETs enable high-frequency totem-pole PFC and motor drive while lowering energy loss compared to both silicon IGBTs and other SiC MOSFETs. Both technologies deliver cutting-edge performance in support of the mission to "Electrify Our World™" and reduce CO2 emissions.

Dan Kinzer: For 30 years Dan has led R&D at semiconductor and power electronics companies at the VP level or higher. His experience includes developing advanced power device and IC platforms, wide bandgap GaN and SiC device design, IC and power device fabrication processes, advanced IC design, semiconductor package development and assembly processes, and design of electronic systems. Before Co-founding Navitas, Dan served as VP R&D, VP Advanced Product Development, and Chief Technologist at International Rectifier (IR sold to Infineon for $3B), and SVP Product & Technology Development & CTO at Fairchild Semiconductor (Fairchild sold to Onsemi for $2.4B). In 2018, Dan was an inaugural inductee to the International Symposium on Power Semiconductor Devices and ICs (ISPSD) Hall of Fame. Dan holds over 180 US patents, and a BSE degree in Engineering Physics from Princeton University.

Keynote Sessions: Wednesday, Nov 9th, 2022

Title: GaN lateral devices: technology advantages and key application benefits

Time: 10:30AM - 11:00AM

Abstract: The GaN devices market growth is expected to be in excess of 60% following the demand for energy-efficient and high-power-density system solutions. Several players have already adopted GaN in the consumer electronics market and there is a significant demand for GaN in the higher power segments, including data centres and solar inverters. This talk will go through the most recent GaN and power devices market variations and it will then focus on the reasons why the lateral technology will succeed in both low and high power markets. Examples of current solutions and their applications will be given.

Dr. **Giorgia Longobardi**, CEO of CGD, is an experienced engineer with international practice working on GaN power devices design and characterisation. As the inventor of high impact patents in the field of GaN power devices, Giorgia made the unique blend of academic and business know-how one of her biggest strengths. During her PhD in power devices at Cambridge University, Giorgia worked on international projects with top semiconductor companies, through which, she learned about different cultures operating in this field and gained experience managing and budgeting multi-partner projects. Curious and knowledgeable, Giorgia leads an experienced diverse team of passionate people working with enthusiasm and continuous drive to do things better. She never forgets why she founded CGD: to change how energy is used and protect the environment with efficient power electronics. She is a member of the energy management committee at PSMA (power Sources manufacturers association) and Strategic Advisory Board at the Henry Royce Institute for materials.

Title: Bringing RF & Power closer through GaN Technology

Time: 11:00AM – 11:30AM

Abstract: Radio frequency (RF) engineers and power (Power) electronics engineers are increasingly using gallium nitride (GaN) in their products replacing Si technology. While there are differences in RF and power GaN technology, such as substrate, GaN epi thickness, etc., the core properties of GaN, that leads to advantages over Si are the same, such as higher breakdown voltage, high electron mobility in 2DEG compared to Si MOSFET. In a typical company, RF and power electronics engineers operate in separate silos, rarely interact with each other except to discuss power supply specs and are literally decoupled by bypass capacitors or capacitor banks. At Tagore Technology, we have brought together RF and Power engineers under the same roof with the common thread being GaN. Our goal is to explore co-design of GaN power supply and GaN power

amplifiers to create a compact solution at the PCB/Module level now and possibly on the same wafer in future. This talk will highlight one such application where pulsed radar power amplifiers are supplied by a high frequency GaN converter leading to 20x reduction in capacitor bank size without impacting noise properties of the RF signal. The challenges of co-design such as mixing of power supply switching noise as a phase noise of the RF signal as well as thermal management challenges will be highlighted.

Amitava Das is a co-founder and CEO of Tagore Technology. Tagore Technology's products include power GaN as well as RF GaN devices and IC's. Amitava obtained his Ph.D. in EE from Purdue University. Amitava spent 14 years at Motorola/Freescale working at various aspects of semiconductor technology such as frontend integration of 0.18um CMOS technology at APRDL (Advanced Product Research and Development Lab) to RFIC design at WITC (Wireless Integration Technology Center) to managing product operation at Freescale, Tempe. Prior to joining Motorola, Amitava was an associate professor of EE at IIT-Bombay. Amitava has published more than 30 papers and patents including several invited papers.

Title: GaN device innovation matched with manufacturing capacity and quality propels GaN to new markets

Time: 11:30AM – 12:00 PM

Abstract: The first GaN power devices has been commercialized over a decade ago. These devices have been demonstrated in multiple end applications including chargers for cell phones, motor drives, DC/DC converters for servers or class-D audio amplifiers. GaN devices delivers clear benefits in system performance or cost in those end applications, but true commercial success has been mostly limited to chargers for cell phone or other portable devices. This limited commercial success so far is at least partly due to a restricted supply of GaN device production at a competitive cost point. The various fabless startups are facing the issue of high GaN wafer price at foundries (6-inch today) and limited value adder of discrete device design. More functionality integration on GaN die aims to increase their value adder of these products vs. discrete devices with mixed results and market adoption success. This presentation will argue that true integrated device manufacturer with high volume 8-inch internal manufacturing, fully focused on GaN is the game changer required to bring GaN power devices out of peripheral applications and into mainstream high-volume end-products, including mobile phones. In such ecosystem, roadmap based on discrete devices from 650V down to 30V and system-in-package integration is highly attractive for foreseeable future. This talk will give examples of latest device innovation including 40V bi-directional GaN switch reducing on-state resistance by 50%, chip size by 70% and temperature rise by 40%. First ever GaN product designed directly into mobile phone handset.

Jan Sonsky is a Vice president of Engineering at Innoscience, the world's largest Integrated Device Manufacture (IDM) company fully focused on GaN technology with the largest dedicated 8-inch GaN-on-Si wafers manufacturing capacity. We design, develop and manufacture highly performing and reliable GaN devices for a wide range of applications and voltages (30V-650V). Jan is the global leader of Device R&D teams at Innoscience. Prior to joining Innoscience, Jan has worked at NXP Semiconductors for nearly 20 years in different R&D functions including project and program management, and technical leadership roles with responsibility over a broad range of technologies from discrete Si and GaN power devices to integrated (BCD) power and analog technologies. Jan has authored or co-authored over 25 patents and 30-plus papers in technical journals and conferences. He received his Ph.D. degree from the Delft University of Technology in the Netherlands in 2002.

Panel Sessions

Day 1: November 8th, Tuesday

Topic: Supply and Cost of Substrates for Compound Semiconductors

Location: Pacific

Time: 11:00AM – 12:30PM

Moderators: Peter Di Maso, GaN Systems Inc.

Panelists:

Vincent Meric, Vice President Marketing, Aixtron

Shahin Sharifzadeh, CEO, Nexgen

Christina DiMarino, Assistant Professor, Virginia Tech

Victor Veliadis, Executive Director & CTO PowerAmerica, Prof. NC State

Day 2: November 9th, Wednesday

Topic: GaN Growth Beyond Consumer Applications: What is the Right Level of Integration?

Time: 1:00PM-2:15PM

Location: Redondo 1

Moderator: Peter Di Maso, GaN Systems Inc.

Panelists:

Rohan Samsi, VP Products, GaN Systems

Lingxiao “Lincoln” Xue, Subprogram Manager, Oak Ridge National Laboratory

Dan Kinzer, CTO, Navitas

Paul Rankin, Power Electronics Engineer, Astranis

Panel Sessions

Topic: Wide-bandgap Device and related technology to Enable Medium Voltage Distribution Power Grid

Time: 1:00PM-2:15PM

Location: Redondo 2,3

Moderator: Victor Veliadis, PowerAmerica & NC State

Panelists:

Ahmed Elasser, Principal Engineer, GE Research Center

Jing Xu, Senior Principal Scientist, ABB

Subhashish Bhattacharya, Professor, NCSU

Paul Ohodnicki, Associate Professor, University of Pittsburgh

1:30 PM – 2:50 PM

1.A. SiC Devices - Novel Devices
Location: Redondo 1
Session Chairs: Aivars Lelis, U.S. Army DEVCOM
Victor Veliadis, PowerAmerica

1:30 PM – 1:50 PM **A New Cell Topology for 4H-SiC Planar Power MOSFETs**
Shengnan Zhu, Tianshi Liu, Arash Salemi, Marvin White, Hema Maddi, David Sheridan, Anant Agarwal, Ohio State University

1:50 PM – 2:10 PM **Exploring Optimum Designs for 1.2kV 4H-SiC JBS Diode-Integrated MOSFETs (JBSFETs)**
Stephen Mancini, Seung Yup Jang, Dongyoung Kim, Woongje Sung, State University of New York Polytechnic Institute

2:10 PM – 2:30 PM **Design Optimization and Surge Current Capability of 4H-SiC Lateral Deep P+ JBS Diode on Thin RESURF Layer**
Atsushi Shimbori, Alex Huang, University of Texas at Austin

2:30 PM – 2:50 PM **Characterization of Near Conduction Band SiC/SiO2 Interface Traps in Commercial 4H-SiC Power MOSFET's**
Hema Lata Rao Maddi, Suvendu Nayak, Vishank Talesara, Yibo Xu, Wu Lu, Anant Agarwal, Ohio State University

1.B GaN Devices – Advanced Characterization
Location: Redondo 2,3
Session Chairs: Robert Kaplar, Sandia National Lab
Cristina Miccoli, STMicro

1:30 PM – 1:50 PM **Reverse Breakdown Time of Wide Bandgap Diodes**
Jack Flicker, Emily Schrock, Robert Kaplar, Sandia National Laboratories

1:50 PM – 2:10 PM **Symmetrical VTH/RON Drifts Due to Negative/Positive Gate Stress in p-GaN Power HEMTs**
Nicolò Zagni, Marcello Cioni, Maria Eloisa Castagna, Maurizio Moschetti, Ferdinando Iucolano, Giovanni Verzelles, Allessandro Chini, University of Modena and Reggio Emilia

2:10 PM – 2:30 PM **Peak Channel Temperature Determination for an AlGaN/GaN HEMT with Raman Thermography and MTTF Extraction for Long Term Reliability**
Cristina Miccoli, Leonardo Gervasi, Viviana Cerantonio, Ferdinando Iucolano, Martin Kuball, James Pomeroy, ST Microelectronics

2:30 PM – 2:50 PM **High Temperature Robustness of Enhancement-Mode p-GaN-Gated AlGaN/GaN HEMT Technology**
Mengyang Yuan, Qingyun Xie, John Niroula, Mohamed Fadil Isamotu, Nitul Rajput, Nadim Chowdhury, Tomás Palacios, Massachusetts Institute of Technology

3:10 PM – 4:30 PM

1.C SiC Devices - Device Reliability and Robustness
Location: Redondo 1
Session Chairs: Aivars Lelis, U.S. Army DEVCOM
Victor Veliadis, PowerAmerica

3:10 PM – 3:30 PM **Effects of Oxide Electric Field Stress on the Gate Oxide Reliability of Commercial SiC Power MOSFETs**
Limeng Shi, Tianshi Liu, Shengnan Zhu, Jiashu Qian, Michael Jin, Hema Lata Rao Maddi, Marvin H White, Anant K Agarwal, Ohio State University

3:30 PM – 3:50 PM **A Comparison of Ion Implantation at Room Temperature and Heated Ion Implantation on the Body Diode Degradation of Commercial 3.3 kV SiC Power MOSFETs**
Jiashu Qian, Tianshi Liu, Jake Soto, Mowafak Al-Jassim, Robert Stahlbush, Naeemulah Mahadik, Limeng Shi, Michael Jin, Anant Agarwal, Ohio State University

3:50 PM – 4:10 PM **A Comparison of Short-Circuit Failure Mechanisms of 1.2 kV 4H-SiC MOSFETs and JBSFETs**
Dongyoung Kim, Skylar Deboer, Seung Yup Jang, Adam Morgan, Woongje Sung, State University of New York Polytechnic Institute

4:10 PM – 4:30 PM **Failure Rate Calculation Due to Neutron Flux with SiC MOSFETs and Schottky Diodes**
Dennis Meyer, Xuning Zhang, Reenu Garg, Bruce Odekirk, Steve Chenetz, Ehab Tarmoom, Kevin Speer, Microchip Technology Inc.

1.D GaN Devices – Industry and Others
Location: Redondo 2,3
Session Chairs: Robert Kaplar, Sandia National Lab
Cristina Miccoli, STMicro

3:10 PM – 3:30 PM **High Volume GaN Production and Reliability Methods**
Anthony Schiro, Darshan Gandhi, Navitas Semiconductor

3:30 PM – 3:50 PM **Scaling of EPC's 100 V Enhancement-Mode Power Transistors**
Gordon Stecklein, Jordan Green, Christopher Wong, Joe Cao, Bob Beach, Efficient Power Conversion, Corp.

3:50 PM – 4:10 PM **Advancement in Integration for GaN Power ICs: Autonomous Protection and Loss-Less Sensing**
Tom Ribarich, Stephen Oliver, Marco Giandalia, Llew Vaughan-Edmunds, Navitas Semiconductor

4:10 PM – 4:30 PM **Threshold Voltage Behavior and Short-Circuit Capability of p-Gate GaN HEMTs Depending on Drain- and Gate-Voltage Stress**
Thorsten Oeder, Martin Pfost, Technical University Dortmund

2:30 PM – 4:10 PM

2.A SiC Applications – 1
Location: Redondo 1
Session Chairs: Babak Parkhideh, University of North Carolina Charlotte
Zhao Yuan, Apple

2:30 PM – 2:50 PM **Advantages of SiC-Based Devices on the Design of Dual-Active Bridge DC/DC Converter for DC Faults**
Shrivatsal Sharma, Yos Prabowo, Subhransu Satpathy, Subhashish Bhattacharya, North Carolina State University

2:50 PM – 3:10 PM **Active Gate Driving of Cascoded SiC JFETs**
Arijit Sengupta, Sima Azizi Aghdam, Mohammed Agamy, University at Albany - State University of New York

3:10 PM – 3:30 PM **High Frequency High Power Integrated Transformer Design for Resonant Converters with SiC Devices**
Feng Jin, Tianlong Yuan, Zheqing Li, Qiang Li, Virginia Tech Center for Power Electronics Systems

3:30 PM – 3:50 PM **A Highly Integrated Sensorless Field Oriented Control BLDC / PMSM Inverter with 99% Efficiency Enabled by an All-in-One System Integrated Full SiC Intelligent Power Module (sIPM)**
Fu-Jen Hsu, Cheng-Tyng Yen, Hsiang-Ting Hung , Guan-Wei Lin, Chih-Feng Huang, Lung-Sheng Lin, I-Chi Lin , Chih-Fang Huang, Ta-Yung Yang, Fast SiC Semiconductor Inc., National Tsing Hua University

3:50 PM – 4:10 PM **Noise Analysis of Current Sensor for Medium Voltage Power Converter Enabled by Silicon-Carbide MOSFETs**
Morten Rahr Nielsen, Mathias Kirkeby, Hongbo Zhao, Dipen Narendra Dalal, Michael Møller Bech, Stig Munk-Nielsen, Aalborg University

2.B GaN Applications – 1
Location: Redondo 2,3
Session Chairs: Jason Zhang, Navitas Semiconductor
Nabil Akel, Navitas Semiconductor

2:30 PM – 2:50 PM **Next Generation of GaN Single-Board High-Power Modules for Datacenter**
Rahil Samani , Juncheng Lu, Ignacio Galiano Zurbriggen, University of Calgary

2:50 PM – 3:10 PM **100V GaN for Highly Efficient 1kW Motor Drive Applications**
Asantha Kempitiya, Hrach Amirkhanian, Srikanth Yerra, Kapil Kelkar, Infineon Technologies

3:10 PM – 3:30 PM **Compact Three-Level GaN Power Module Suitable for Active-Neutral-Point-Clamped (ANPC) Three-Level Converter**
Ziwei Liang, Liyan Zhu, Yue Sun, Hua Bai, University of Tennessee, Knoxville

3:30 PM – 3:50 PM **Design of High Current, High Power Density GaN Based Motor Drive for All Electric Aircraft Application**
Waqar A. Khan, Armin Ebrahimian, Iman Hosseini, Nathan Weise, Marquette University

3:50 PM – 4:10 PM **Design of Three-Level Flying Capacitor Totem Pole PFC in USB Type-C Power Delivery for Aircraft Applications**
Tianyu Zhao, Rolando Burgos, Bo Wen, Andrew McLean, Rodrigo Fernández Mattos, Virginia Polytechnic Institute and State University

4:30 PM– 5:50 PM

2.C SiC Applications – 2
Location: Redondo 1
Session Chairs: Babak Parkhideh, University of North Carolina Charlotte
Zhao Yuan, Apple

Technical Sessions: Day 2 (Wednesday, November 9)

4:30 PM – 4:50 PM **Design of High Power Converter with Single Low Ron Discrete SiC Device**
Alex Huang, Qingyun Huang, Chen Chen, Zibo Chen, University of Texas at Austin

4:50 PM – 5:10 PM **Comparative Investigation of Current-Source Inverters Using SiC Discrete Devices and Power Modules**
Bulent Sarlioglu, Thomas Jahns, Sangwhee Lee, Feida Chen , University of Wisconsin-Madison

5:10 PM – 5:30 PM **A Medium-Voltage Transformer with Integrated Leakage Inductance for 10 kV SiC-Based Dual-Active-Bridge Converter**
Zihan Gao, Haiguo Li, Fred Wang, University of Tennessee, Knoxville

5:30 PM – 5:50 PM **Development of a 250°C 15kV SuperCascode Switch Using SiC JFET Technology**
David Sanabria, Randy Appert, Steven Pronko, Joshua Major, Douglas DeVoto, Jane Lehr, Nicolas Gonzalez, David Ginley, Karen Heinselman, Tetra Corporation

2.D GaN Applications – 2
Location: Redondo 2,3
Session Chairs: Jason Zhang, Navitas Semiconductor
Nabil Akel, Navitas Semiconductor

4:30 PM – 4:50 PM **GaN Power Converter Applied to Electrocaloric Heat Pump Prototype and Carnot Cycle**

Stefan Moench , Richard Reiner , Kareem Mansour , Michael Basler , Patrick Waltereit , Rudiger Quay , Kilian Bartholome, Fraunhofer Institute for Applied Solid State Physics IAF

4:50 PM – 5:10 PM **Design Considerations of a GaN-Based Three-Level Traction Inverter for Electric Vehicles**
Subhransu Satpathy, Partha Pratim Das, Subhashish Bhattacharya, Victor Veliadis, North Carolina State University

5:10 PM – 5:30 PM **Novel High-voltage-Gain High-Frequency Non-Isolated Three-Port dc-dc Converter with Zero Input Current Ripple and Soft-Switching Capability**

Zahra Saadatizadeh, Pedram Chavoshipour Heris, Alan Mantooth, University of Arkansas

5:30 PM – 5:50 PM **Comparison of Thermally Optimized SMD Packages for 100 V GaN HEMTs in 300 kHz Buck Converter High Current Applications**
Dominik Koch, Ankit Sharma, Till Huesgen, and Ingmar Kallfass, University of Stuttgart

Session Room: Peninsula/Pacific Reception140. 6:00 PM – 8:00 PM

Session Chairs: Sameh Khalil, Infineon Technologies

Robert Kaplar, Sandia National Lab

GaN Applications Posters

A 5 to 50 V, -25 to 225℃, 0.065 %/V GaN MIS-HEMT Monolithic Compact 2T Voltage Reference
Ziqian Li, Yi Shen, Ang Li, Wen Liu, Xi'an Jiaotong-Liverpool University, China

Three-Level ANPC Inverter Common-Mode Voltage Analytical Characterization
Yang Huang, Xin Xia, Hua Bai, Fanning Jin, Xiaodong Shi, Bing Cheng, University of Tennessee, Knoxville

Bidirectional High Voltage Conversion Ratio High-Frequency DC/DC Converter with Low Number of Components
Pedram Chavoshipour Heris, Zahra Saadatizadeh, Alan Mantooth, Rahul Biswash, University of Arkansas

Analysis of a Switching Event and its Impact on Gate Drive in Gallium-Nitride Based Bi-Directional Switches
Mustafeez Hassan, Yuxuan Wu, Fang Luo, Stony Brook University

SiC Devices - Posters

3kV 6.7mOhm·cm2 4H-SiC BJT with Highly Effective Four-step Junction Termination Extension (JTE)
Xixi Luo, Alex Huang, University of Texas at Austin

Area-Efficient High-Voltage (HV) Lateral MOSFETs for Discrete Device Development and Power IC Integration
Sundar Babu Isukapati, Seung Yup Jang, Woongje Sung, State University of New York Polytechnic Institute

A New Layout Method for Junction Field Effect Transistors (JFETs) on 4H-SiC that Provides a Significant Reduction in On-Resistance
Justin Lynch, Nick Yun, Seung Yup Jang, Adam J. Morgan, Woongje Sung, State University of New York Polytechnic Institute

Source Turn-off (STO) MOSFET
Zhicheng Guo, Alex Huang, University of Texas at Austin

SiC Applications - Posters

Short Circuit Fault Induced Failure of SiC MOSFETs in DC SSCBs
Shuyan Zhao, Reza Kheirollahi, Hua Zhang, Fei Lu, Rowan University

In-Situ Ultrafast Isolated Sensing Techniques for Real-Time Diagnostics, Prognostics, and Protection of SiC Devices
Ali Parsa Sirat, Chondon Roy, Daniel Evans, James Gafford, Babak Parkhideh, University of North Carolina at Charlotte

Series Compensation Using T-Type Modular Dc Circuit Breaker (T-Breaker) to Improve DC Microgrid Stability
Faisal Alsaif, Yue Zhang, Nihanth Adina, Khalid Alkhalid, Jin Wang, Ohio State University

Thermal Design and Experimental Evaluation of a 1kV, 500A T-Type Modular DC Circuit Breaker
Baljit Riar, Jeffrey Ewanchuk, Hailing Wu, Yue Zhang, Xiao Li, Dihao Ma, Rob Borjas, Jin Wang, Ohio State University

Embedding Solutions for Vertical SiC and GaN Power Devices
Hoang Linh Bach, Anqi Huang, Yue Teng, Hubert Rauh, Andreas Schletz, Michael Jank, Martin März, Fraunhofer Institute for Integrated Systems and Device Technology IISB

Busbar Design and Optimization for High Power Three-Phase Inverter with WBG Device
Yuxuan Wu, Mustafeez Hassan, Fang Luo, Stony Brook University

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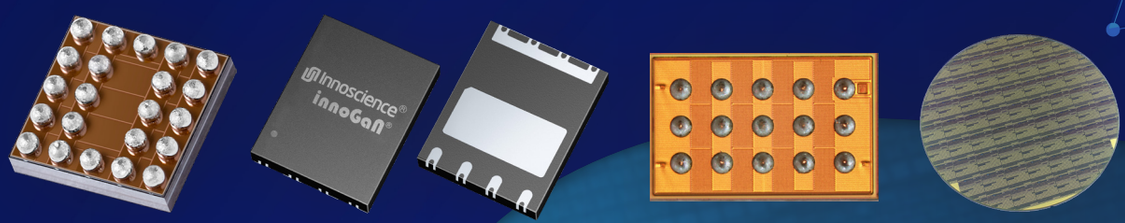

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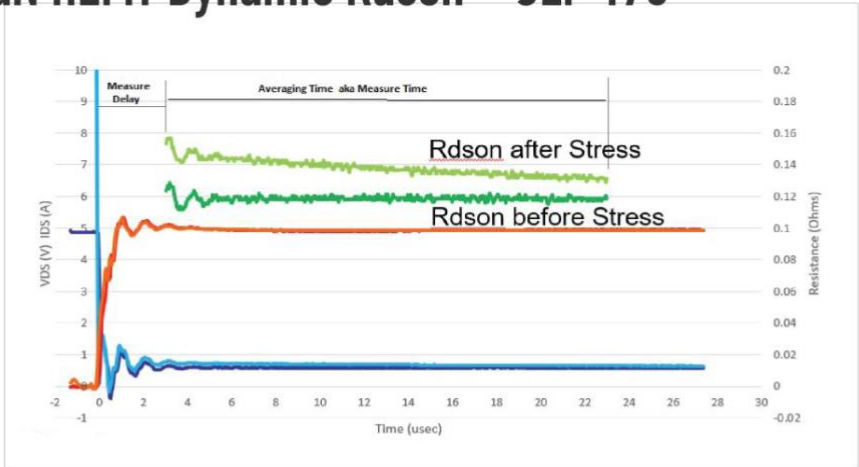
Characterization and Production Test – Wafer Sort and Final Test

- DC – 5kV BV; 200A Id
- UIS – 5kV+ Vav; 200A Id
- Delta Vsd
- Rg/Ciss/Coss/Crss

GaN HEMT Dynamic Rdson – JEP 173



SiC MOSFET, JFET and Schottky Diode

- On Wafer Reliability Tests – TDDB, HTRB and HTGS
- Voltage Threshold Hysteresis JEP 183

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