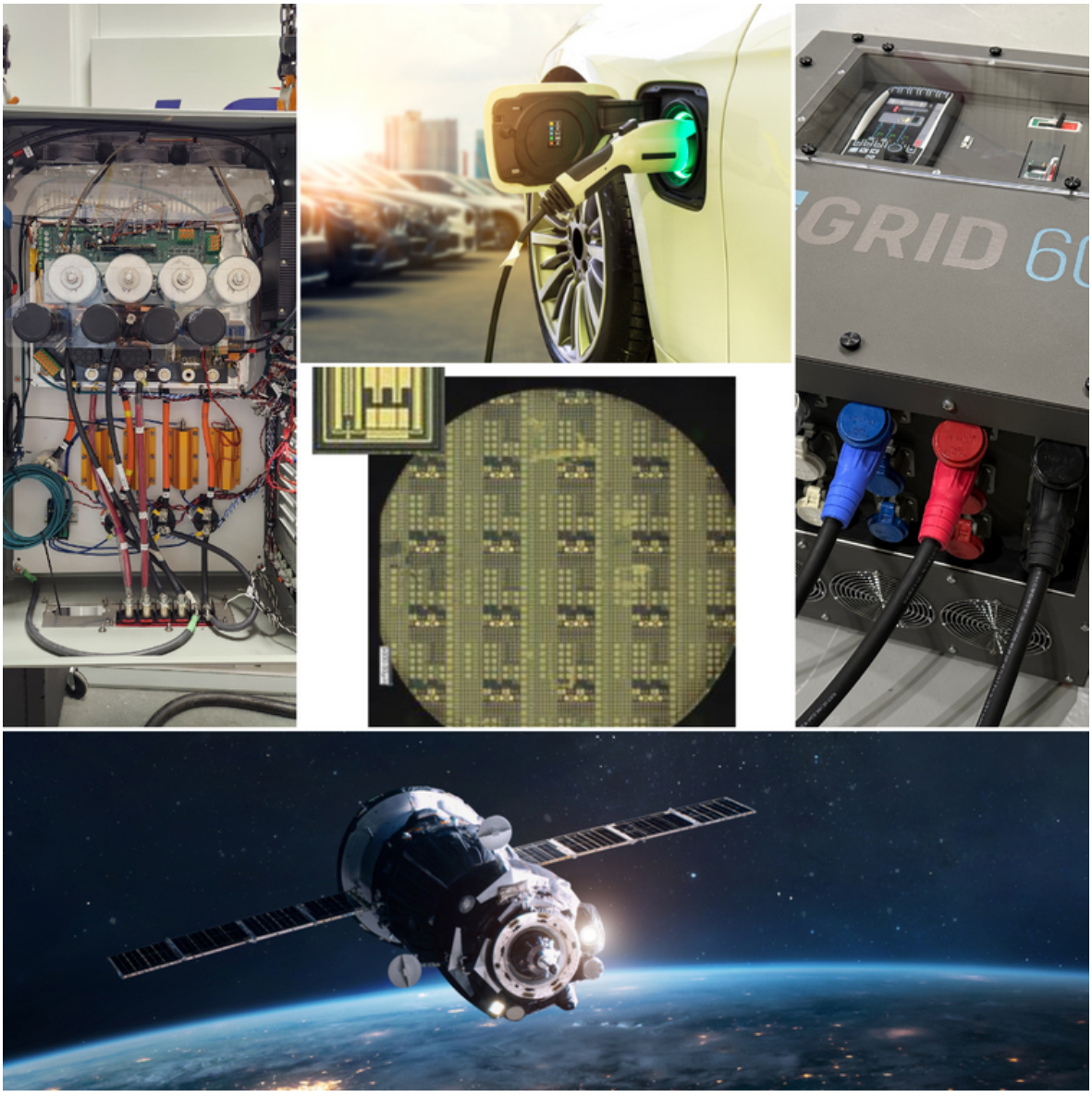
The 10th IEEE Workshop on Wide Bandgap Power Devices & Applications

Dec. 4-6, 2023 | UNC Charlotte Marriott Hotel & Conference Center

Technical Program



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Schedule-At-A-Glance: Monday, December 4, 2023

PRE-CONFERENCE EVENTS: TUTORIALS		
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8:15 AM – 9:10 AM	Vertical GaN Power Devices: Material, Processing, and Design Considerations	Crown V
9:10 AM – 10:05 AM	Dynamic RDS(on) in GaN HEMTs: Physical Origins and Measurement Techniques	Crown V
10:00 AM – 5:00 PM	*Exhibition*	*Main Hallway*
10:05 AM – 11:00 AM	Silver Sintering for Power Device/Module Packaging: The Science and Practice	Crown V
11:00 AM – 12:00 PM	Technologies for WBG Power Semiconductor Characterization: Static to Dynamic Characterization	Crown V
12:00 PM – 1:00 PM	*LUNCH*	*Crown I + II + III*
1:00 PM – 1:55 PM	Reliability Challenges in Silicon Carbide and How to Overcome Them with Dynamic Testing Methods	Crown V
1:55 PM – 2:50 PM	Current Sensors for WBG Applications	Crown V
2:50 PM – 3:45 PM	Application of GaN HEMTs in Switching Power Supplies	Crown V
3:45 PM – 4:40 PM	Current Source Inverter for EV Traction Drive Applications	Crown V
4:40 PM – 5:35 PM	Power Conversion Systems Enabled by SiC Based Monolithic Bidirectional Switch (BiDEFT)	Crown V
6:00 PM – 8:00 PM	Reception & Optional Tours	EPIC
7:00 PM – 10:00 PM	JEDEC Meeting (By Invitation)	Toby Creek

Schedule-At-A-Glance: Tuesday, December 5, 2023

MAIN CONFERENCE, DAY 1 – KEYNOTE PRESENTATIONS		
Time	**Topic**	**Location**
8:00 AM – 8:30 AM	Opening Remarks and Welcome	Crown IV + V
8:30 AM – 9:00 AM	The Omnidirectional Grid, Courtesy of High-Voltage SiC	Crown IV + V
9:00 AM – 9:30 AM	GaN: The New Frontier of Performance and Reliability of Power Devices	Crown IV + V
9:30 AM – 10:00 AM	From Power Adaptor for Laptops to Power Distribution on the Moon: A Ten-Year Journey of Wind Bandgap Based Power Electronics	Crown IV + V
10:00 AM – 10:30 AM	Overview of the WBG Market in the Past Decade and What We Can Anticipate in the Next 10 Years	Crown IV + V
10:30 AM – 10:45 AM	*BREAK*	
10:45 AM – 12:00 PM	Panel 1 – 10th Year Anniversary	Crown IV + V
12:00 PM – 1:30 PM	*LUNCH*	

MAIN CONFERENCE, DAY 1 – TECHNICAL SESSIONS		
Time	**Location and Topic**	
	Crown V	Crown IV
1:30 PM – 3:10 PM	GaN Devices 1	SiC and UWBG Applications
3:10 PM – 3:30 PM	*BREAK*	*BREAK*
3:40 PM – 5:20 PM	SiC Device Reliability	GaN Applications 1
6:00 PM – 9:00 PM	Poster Session and Reception	Crown IV + V
6:00 PM – 9:00 PM	Banquet	Crown IV + V

Schedule-At-A-Glance: Wednesday, December 6, 2023

MAIN CONFERENCE, DAY 2 – KEYNOTE PRESENTATIONS		
Time	**Topic**	**Location**
8:00 AM – 8:30 AM	Emerging Technologies to Push the Limits of GaN Electronics	Crown IV + V
8:30 AM – 9:00 AM	Qorvo SiC JFET-Based Power Switch Topologies Optimized for Switching and Circuit Protection	Crown IV + V
9:00 AM – 9:30 AM	Solid State Transformer and DC Grids: From Concept to Pilot Demonstration in a Decade Enabled by HV SiC 10-15kV IGBTs, MOSFETs, and BiDFET	Crown IV + V
9:30 AM – 9:45 AM	*Break*	
9:45 AM – 10:15 AM	GaN Roadmap and Expected Adoption in Automotive Applications	Crown IV + V
10:15 AM – 10:45 AM	Advancing Power Electronics with Silicon Carbide: Unlocking Efficiency and Sustainability in Clean Energy	Crown IV + V
10:45 AM – 12:00 PM	Panel 2 – High-Reliability Designs of Wide Bandgap Power Electronics Applications	Crown IV + V
12:00 PM – 1:30 PM	*LUNCH*	

MAIN CONFERENCE, DAY 2 – TECHNICAL SESSIONS		
Time	**Location and Topic**	
	Crown V	Crown IV
1:30 PM – 3:10 PM	SiC Devices: Modeling, Packaging, and Modules	Application (Switching) Reliability
3:10 PM – 3:40 PM	*Break*	*Break*
3:40 PM – 5:20 PM	GaN Devices 2	GaN Applications 2

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RENEGADE CONTENT CREATION

Welcome From the General Chair

Dear WiPDA Participants, Esteemed Colleagues, and Industry Leaders,

I extend a warm welcome to each of you as we gather for the 10th Annual IEEE/PSMA Workshop on Wide Bandgap Devices and Applications (WiPDA'23) in Charlotte, NC. It is truly an honor to convene this distinguished community once again.

As we celebrate the 10th anniversary of WiPDA, we reflect on the tremendous progress witnessed in the field of wide bandgap power electronics over the past decade. Since our inception, the landscape has undergone significant transformation, witnessing the emergence of numerous cutting-edge products. WiPDA, with its distinctive characteristics and allure, has played a pivotal role in propelling this growth by uniting researchers, academicians, industry experts, and policymakers in a collaborative forum. It's heartening to see many familiar faces returning to contribute to our shared journey!

WiPDA has become a beacon for advancements in wide bandgap technologies. Our commitment to education and workforce development aligns seamlessly with the broader goals of fostering a highly educated workforce. The impact of this community is evident in the expansive growth witnessed, and the journey continues with WiPDA'23. This year, we introduced a student travel assistance program, further emphasizing the importance of cultivating a knowledgeable workforce in this dynamic field.

The conference program has been meticulously crafted to showcase the latest advancements, foster engaging discussions, and provide a platform for networking that transcends boundaries. WiPDA’23 kicks off on Monday, December 4, 2023, and concludes on Wednesday, December 6, 2023. The first day, December 4, 2023, features nine tutorials covering a broad spectrum of topics—from WBG materials, devices, packaging, testing and qualification, sensing and instrumentation, to applications. The workshop reception will be hosted at the Energy Production and Infrastructure Center (EPIC) of the University of North Carolina at Charlotte. The JEDEC JC-70 committee meeting on Monday evening offers members an opportunity to synchronize efforts in advancing wide bandgap power technologies. Over the next two days, we have planned nine keynote presentations, two panel discussions, and eight technical sessions during the afternoon sessions. Notably,

this year includes a special session on Application Reliability. Don’t miss the poster session, coinciding with the banquet, a celebration of WiPDA's 10th anniversary with a Southern feast. The conference floor will also host several exhibitors showcasing products and services, providing ample opportunities for interaction within the community.

On behalf of the organizing committee, I extend my sincere gratitude to all participants, sponsors, and contributors who have been integral to the success of WiPDA. Together, let us continue to propel the field of wide bandgap power electronics to new heights.

Welcome to WiPDA’23! Welcome to Charlotte!

Babak Parkhideh, PhD
General Chair, IEEE/PSMA WiPDA’23

WiPDA 2023 Committees

Function	Name	Organization
General Chair	Babak Parkhideh	UNC Charlotte
Vice Chair	Dong Cao	University of Dayton
Local Chair	Jim Gafford	EPIC - UNCC
Technical Program Chairs		
GaN Devices Chair	Zhikai Tang	Texas Instruments
SiC Devices Chair	Aivars Lelis	ARL
GaN Apps Chair	Stefan Moench	Fraunhofer Institute for Applied Solid State Physics IAF
SiC Apps Co-Chair	Mohammed Agamy	University of Albany
SiC Apps Chair	Xu She	Lunar Energy
Application Reliability	Sandeep Bahl	Texas Instruments
ITRW track Chair	Victor Veliadis	PowerAmerica
Publications Chair	Soma Essakiappan	QM Power
Tutorials Co- Chair	Brij Singh	John Deere
Tutorials Co-Chair	Lingxiao Lincoln Xue	Tianjin University
Plenary Sessions Co-Chair	Victor Veliadis	PowerAmerica
Plenary Session Co-Chair	Alain Charles	ABC Consulting
Panel Discussions Co-Chair	Andrew Binder	Sandia National Lab
Panel Discussions Co-Chair	Stephanie Butler	Wattsbulter
Panel Discussions Co-Chair	Paul Rankin	Astranis Space Technologies
Publicity Chair	Renee Yawger	EPC
Website Chair	Lingxiao Lincoln Xue	Tianjin University
Treasurer	Namwon Kim	ORNL
Registration Website	Namwon Kim	ORNL
PSMA Representative	Tim McDonald	Infineon
PELS Representative	Jin Wang	Ohio State University

Detailed Schedule: Monday, December 4, 2023

Tutorial Sessions

Time	Topic
8:15 AM – 9:10 AM	**Vertical GaN Power Devices: Material, Processing, and Design Considerations** *Robert Kapler, Sandia National Lab*
9:10 AM – 10:05 AM	**Dynamic RDS(on) in GaN HEMTs: Physical Origins and Measurement Techniques** *Edward Jones and Nicholas Dellas, Infineon*
10:05 AM – 11:00 AM	**Silver Sintering for Power Device/Module Packaging: The Science and Practice** *GQ Lu, Virginia Tech*
11:00 AM – 12:00 PM	**Technologies for WBG Power Semiconductor Characterization: Static to Dynamic Characterization** *Ryo Takeda, Keysight*
12:00 PM – 1:00 PM	*LUNCH*
1:00 PM – 1:55 PM	**Reliability Challenges in Silicon Carbide and How to Overcome Them with Dynamic Testing Methods** *Frank Heidemann, SET/NI*
1:55 PM – 2:50 PM	**Current Sensors for WBG Applications** *Babak Parkhideh and Ali Parsa, UNC Charlotte*
2:50 PM – 3:45 PM	**Application of GaN HEMTs in Switching Power Supplies** *Haachitaba Mweene, Nexperia*
3:45 PM – 4:40 PM	**Current Source Inverter for EV Traction Drive Applications** *Gui-jia Su, Oak Ridge National Lab*
4:40 PM – 5:35 PM	**Power Conversion Systems Enabled by SiC Based Monolithic Bidirectional Switch (BiDEFT)** *Subhashish Bhattacharya, NC State University**

***** *Indicates Keynote Speaker*

Detailed Schedule: Tuesday, December 5, 2023

Keynote Sessions

Title: The Omnidirectional Grid, Courtesy of High-Voltage SiC

Time: 8:30 AM – 9:00 AM in Crown IV + V

Abstract: With the main focus in SiC being electric vehicles, discussed less often is the further development of SiC toward higher voltages. This is critical because moving to 3.3 kV device ratings and above will expand the benefits of this disruptive semiconductor technology into areas where it's just as badly needed as automotive. One example is the electric grid. According to the U.S. Energy Information Administration, nearly 250 terawatt-hours of electricity is lost each year – wasted energy that could have powered 2.5 million American homes through all four seasons.

This talk will focus on how Microchip's high voltage mSiC™ solutions can enable an omnidirectional power flow—to port power from anywhere to anyone at any time—for an increasingly sustainable world. Whether SiC is used to dramatically improve the efficiency of our grid's power flow, or to design compact, air-cooled solid-state transformers that better incorporate distributed energy resources like solar, wind and energy storage, SiC's future goes well beyond the car.

Dr. Kevin Speer is the technology director of Microchip Technology's silicon carbide (SiC) business unit. He leads the technology development for Microchip's SiC power solutions including device design, applications, advanced packaging and materials.

Since 1999 Dr. Speer has published a range of SiC research spanning materials science to applications, including crystal growth, defect-related device degradation, SiC MOSFET and diode device design and processing, and advanced power packaging. Dr. Speer has held strategic technical marketing roles with SemiSouth Laboratories, Infineon, and Littelfuse. Prior to Microchip, Dr. Speer founded Speer Semiconductor, a business aimed at empowering stakeholders across the value chain through product development and road-mapping, customer outreach, strategy and investment diligence, and market analysis.

Dr. Speer holds a Bachelor of Science in Electrical Engineering (BSEE) from the University of Arkansas, a Master of Science in engineering from Case Western Reserve University (CWRU), and a Ph.D. in electrical engineering from CWRU as a NASA Research Fellow.

Title: **GaN: The New Frontier of Performance and Reliability of Power Devices**

Time: 9:00 AM – 9:30 AM in Crown IV + V

Abstract: The power devices field has seen tremendous changes in the last decade. The traditional power MOSFET has been largely replaced by a new class of power devices based on the Silicon Sueprjunction concept, while the Insulated Gate Bipolar Transistors (IGBTs) are now fabricated on 12 inch wafers and have access to the latest thin wafer/trench/fine dimension technologies. However most of the innovation and flavor in the field comes from the emergence of Wide Band Gap semiconductors – and in particular the Gallium Nitride and Silicon Carbide. Extensive research is also carried out in single crystal Diamond and Gallium Oxide materials. The market of power devices has reached ~$45M with exponential growth in wide bandgap materials reaching CAGRs in excess of 30% in the next 3-5 years. This talk will focus on GaN technology and its extraordinary advances in performance and reliability, conquering new territories in diverse applications such as data centre, motor control, photovoltaic inverters. Integrated and multiple channel technologies for Gallium Nitride will be discussed. The talk will finish with a description of Cambridge GaN Devices (CGD)'s ICeGaN™ technology, its exceptional ruggedness and its opportunities in the market.

Florin Udrea is the CTO and the co-founder of Cambridge GaN Devices Ltd and a professor in semiconductor Engineering at University of Cambridge. He has worked on power devices for over three decades with specific research on wide bandgap materials since 1997. He has published over 600 papers in journals and international conferences and is an inventor of 200 patents) in power semiconductor devices and sensors. Prof. Florin Udrea founded five companies, Cambridge Semiconductor (Camsemi) in power ICs – sold to Power Integrations, Cambridge CMOS Sensors (CCS) in the field of smart sensors – sold to ams, Cambridge Microelectronics in Power Devices, Cambridge GaN Device in high voltage GaN technology and Flusso in Flow and temperature sensors. For his 'outstanding personal contribution to British Engineering' he has been awarded the Silver Medal

from the Royal Academy of Engineering. In 2015 Prof. Florin Udrea was elected a Fellow of Royal Academy of Engineering. In 2023 he was inducted in the ISPSD hall of fame "for inspiring a generation of engineers to excel in power device and his numerous contributions to the field".

Title: **From Power Adaptor for Laptops to Power Distribution on the Moon: A Ten-Year Journey of Wind Bandgap Based Power Electronics**

Time: 9:30 AM – 10:00 AM in Crown IV + V

Abstract: This talk will walk the audience through few key projects during the last ten-years at the Ohio State University that helped the implementations of GaN and SiC devices in a wide range of applications, starting from GaN based 65-W power adaptors which was first presented at WiPDA2013, to a 1.8-kW GaN based motor drive, to a 7-kV 1-MVA SiC based modular multilevel converter as a motor drive, to a 2-kV 1-MVA integrated modular motor drive for the propulsion of aircraft, and to medium voltage dc power transfer on the lunar surface, which is part of the ongoing Watts on the Moon competition that is hosted by NASA. Major remaining challenges for WBG devices in different applications will be discussed along the way.

Jin Wang (IEEE Fellow) received his Ph.D. degree from Michigan State University in 2005. He worked at Ford for two years before joining Ohio State University (OSU) in 2007 as an Assistant Professor. He became a Full Professor at OSU in 2017. His current research interests include wide bandgap power device-based high-voltage and high-power converters, renewable energy integration, and transportation electrification. Dr. Wang has over 200 journal and conference papers and 10 patents.

Dr. Wang received the PELS Richard M. Bass Young Engineer Award in 2011, the National Science Foundation's CAREER Award in 2011, the Nagamori Award in 2020, the First Place Prize Paper Award from IEEE Transactions on Power Electronics in 2021, and the IEEE Power Electronics Emerging Technology Award in 2022. Dr. Wang initiated and served as the inaugural General Chair for the IEEE Workshop on Wide Bandgap Power Devices and Applications (WiPDA) in 2013 and the IEEE Workshop on Power Electronics for Aerospace Applications (PEASA) in 2022.

Title: **Overview of the WBG Market in the Past Decade and What We Can Anticipate in the Next 10 Years**

Time: 10:00 AM – 10:30 AM in Crown IV + V

Abstract: Over the past decade, SiC and GaN, two Wide Band-Gap materials, have emerged as key technological drivers, ushering in revolutionary advancements in power electronics. SiC finds predominant use in electric vehicles and industrial applications, for high-power and high-voltage requirements, while GaN plays a pivotal role in the development of compact chargers for consumer electronics in our daily lives. As of 2023, these two WBG materials represent a multi-billion-dollar market.

Given the imperative of achieving higher power conversion efficiency for zero-emission goals, the utilization of SiC and GaN is poised for continued acceleration in the next decade. This acceleration not only transforms the technological landscape but also reshapes the supply chain to meet the robust demand across diverse applications.

Beyond the promising applications of SiC and GaN, there is a notable development of ultra-wide band-gap materials for use at higher voltage ratings. Examples include bulk GaN, Ga2O3, AlN, among others. This presentation by Yole will delve into the forecasted opportunities for various WBG materials over the next 10 years, shedding light on the evolving landscape and potential breakthroughs in power electronics.

Poshun Chiu is a Technology & Market Senior Analyst specializing in Compound Semiconductor and Emerging Substrates at Yole Intelligence, part of Yole Group. As a member of the Power Electronics & Wireless division at Yole, Poshun focuses on power, RF, and opto-electronics. He is engaged in the development of technology and market reports and is also involved in custom projects.

Before joining Yole, Poshun had 9 years' experience in R&D and product management at Epistar (TW & CHN). He is the author or co-author of more than 10 patents in solid-state-lighting. Poshun was also engaged in the development and evaluation of novel applications of process technology and components based on relevant semiconductor material systems.

Poshun received an MSc degree in Microelectronics from National Cheng Kung University (TW) and an MBA from IESEG School of Management (FR).

Panel Discussion

Title: **Panel 1 – 10th Year Anniversary: Assessing the Last 10 Years and Forecasting the Next 10**

Time: 10:45 AM – 12:00 PM in Crown IV + V

Moderator: **Stephanie Watts Butler**, WattsButler LLC

Panelists:

- **Poshun Chiu**, Technology & Market Senior Analyst (Yole Group)
- **Victor Veliadis**, Executive Director & CTO (PowerAmerica), Chair (IEEE PELS ITRW)
- **Tim McDonald**, Sr. Consulting Advisor to CoolGaN Program (Infineon), Chair (JC-70)
- **Jin Wang**, Professor (The Ohio State University), General Chair (1st WiPDA Conference (2013))

Abstract: Participate in this special decadal session as expert panelists and the audience share learnings from the 10-year history of WiPDA in order to predict the next 10 years.

- Reflect on the achievements and misses of the past decade;
- Forecast the disruptors for the next decade;
- Assess quality of past predictions and their root causes;
- Evaluate market and applications size and growth; and
- Appraise progress and impact of reliability, standards, and roadmaps.

Technical Sessions

Time: 1:30 PM – 3:10 PM

Session Name: GaN Devices 1

Location: Crown V

Session Chairs: Florin Udrea (Cambridge GaN Devices Ltd) and Zhikai Tan (Texas Instruments)

Time	Topic
1:30 PM – 1:55 PM	**Innovations in GaN Four Quadrant Switch Technology** (Paper ID 7007) *Authors: Geetak Gupta, Carl Neufeld, Davide Bisi, Yulu Huang, Bill Cruse, Peter Smith, Rakesh Lal, Umesh Mishra*
1:55 PM – 2:20 PM	**Reduced GaN Half-Bridge IC Switching Loss on Biased Si p-n Junctions** (Paper ID 7010) *Authors: Stefan Moensch, Richard Reiner, Michael Basler, Patrick Waltereit, Rüdiger Quay*
2:20 PM – 2:45 PM	**Impact of Process Variations on Back-Bias Effect in 100V p-GaN Gate AlGaN/GaN HEMTs** (Paper ID 7021) *Authors: Marcello Cioni, Giovanni Giorgino, Alessandro Chini, G. Marletta, Cristina Miccoli, Maria Eloisa Castagna, Giuseppe Luongo, Maurizio Moschetti, Cristina Tringali, Ferdinando Iucolano*
2:45 PM – 3:10 PM	**Fabrication AlGaN/GaN Fin-HEMTs with Hexagon Nano-Scale Fin Channel** (Paper ID 7070) *Authors: Yuhsuan Lu, Yu-Cheng Chang, Wei-Ju Lu, Feng-Ting Lin, Bo-Hsun Xu, Chao-Hsin Wu*

Session Name: SiC and UWBG Applications

Location: Crown IV

Session Chairs: Yuhao Zhang (Virginia Polytechnic Institute and State University)

Time	Topic
1:30 PM – 1:55 PM	**Co-Optimization Design and Analysis of WBG and UWBG Power Diodes with Operational Regimes** (Paper ID 7045) *Authors: Lee Gill, Jonah Shoemaker, Jack Flicker, Stephen Goodnick, Robert Kaplar, Alan Michaels*
1:55 PM – 2:20 PM	**A Partial Soft-Switching SiC-Based ANPC Single-Phase Inverter with Low THD for Grid-Tied PV Systems** (Paper ID 7033) *Authors: Wenjie Ma, Hui Li, Shan Yin, Xiaohu Pang, Jiayue Fang*
2:20 PM – 2:45 PM	**Electro-Thermal Design of MV SiC JFET Based Solid State Circuit Breaker** (Paper ID 7054) *Authors: Sima Azizi Aghdam, Mohammed Agamy, Zhongda Li, Peter Losee*
2:45 PM – 3:10 PM	**A Si IGBT Circuit Breaker for Protection of 10 kV SiC MOSFET Power Module** (Paper ID 7060) *Authors: Ruirui Chen, Min Lin, Dingrui Li, Zihan Gao, Fred Wang, Hua Bai, Leon M Tolbert*

Time: 3:40 PM – 5:20 PM

Session Name: SiC Device Reliability

Location: Crown V

Session Chairs: Alvars Lelis (ARL) and Anant Agarwal (The Ohio State University)

Time	Topic
3:40 PM – 4:05 PM	**An Effective Screening Technique for Early Oxide Failure in SiC Power MOSFETs** (Paper ID 7025) *Authors: Limeng Shi, Jiashu Qian, Michael Jin, Monikuntala Bhattacharya, Hengyu Yu, Atsushi Shimbori, Zhuxian Xu, Marvin H. White, Anant Agarwal*
4:05 PM – 4:30 PM	**Investigation of the Constant Current Stress for Charge-to-Breakdown Extraction in Commercial SiC Power MOSFETs** (Paper ID 7026) *Authors: Jiashu Qian, Limeng Shi, Michael Jin, Monikuntala Bhattacharya, Hengyu Yu, Atsushi Shimbori, Zhuxian Xu, Marvin H. White, Anant Agarwal*
4:30 PM – 4:55 PM	**Pulse-Voltage Time-Dependent Dielectric Breakdown of Commercial 1.2 kV 4H-SiC Power MOSFETs** (Paper ID 7027) *Authors: Michael Jin, Limeng Shi, Jiashu Qian, Monikuntala Bhattacharya, Hengyu Yu, Atsushi Shimbori, Zhuxian Xu, Marvin H. White, Anant Agarwal*
4:55 – 5:20 PM	**The Effect of Cryogenic Temperature on Subthreshold Hysteresis of Commercial SiC Power MOSFETs** (Paper ID 7013) *Authors: Monikuntala Bhattacharya, Michael Jin, Jiashu Qian, Limeng Shi, Hengyu Yu, Marvin H. White, Anant Agarwal*

Session Name: GaN Applications 1

Location: Crown IV

Session Chairs: Jin Wang (The Ohio State University) and Elison Matioli (EPFL)

Time	Topic
3:40 PM – 4:05 PM	**Highly-Integrated, Low-Noise, Dual-Output GaN DC/DC for GaN Solid State Power Amplifier Supplies in Space Applications** (Paper ID 7056) *Authors: Dominik Koch, Jeremy Nuzzo, Michael Bosch, Manuel Ruess, Dominik Wrana, Benjamin Schoch, Ingmar Kallfass*
4:05 PM – 4:30 PM	**Multi-MHz Auto-Resonant Power Oscillator in a 650 V GaN-on-SOI Technology for Compact Wireless Power Transfer Systems** (Paper ID 7052) *Authors: Manuel Ruess, Dominik Koch, Ingmar Kallfass*
4:30 PM – 4:55 PM	**Performance Comparison of GaN-Based Multilevel Converters for Electric Vehicle Powertrain Application** (Paper ID 7036) *Authors: Seyed Iman Hosseini Sabzevari, Armin Ebrahimian, Nathan Weise*
4:55 PM – 5:20 PM	**Comprehensive Investigation on Effects of Anti-Parallel Diodes in GaN-Based Converters** (Paper ID 7063) *Authors: Kazuma Sakamoto, Yosuke Kato, Kenji Natori, Yukihiko Sato*

Poster Session

Time: 6:00 PM – 9:00 PM

Session Chairs: Hyeongnam Kim, Yuhao Zhang, Aivars Lelis, and Geetak Gupta

Application Reliability
Study of GaN HEMTs Robustness to Application-Like, Software-Controlled Overshoots Emulating Different Gate Routings in Original 50 Ohms Environment (Paper ID 7016) *Authors: Ludovic Roche, David Trémouilles, Emmanuel Marcault, Corinne Alonso*
Investigation on ESD Robustness of 20-V GGNMOS and GDPMOS in 4H-SiC Process with 100-ns TLP Pulse (Paper ID 7022) *Authors: Chao-Yang Ke, Ming-Dou Ker*
Investigation of the Impact of Low Thermal Conductivity on Gallium Oxide Power Module Packaging (Paper ID 7032) *Authors: Mohammad Dehan Rahman, Xiaoqing Song*
GaN Applications 3
Wide Bandgap Semiconductors for LVDC Solid State Circuit Breaker Applications (Paper ID 7018) *Authors: George Govaerts, Urmimala Chatterjee, Johan Driesen, Wilmar Martinez*
Reduction of DC/DC Converters EMI Emission Using Bi- and Unidirectional QR-ZVS Topologies (Paper ID 7019) *Authors: Abdelmoumin Allioua, David Krause, Andrea Zingariello, Gerd Griepentrog*
SiC Applications
Accurate Prediction of Incomplete Zero-Voltage Switching Dynamics and Losses (Paper ID 7011) *Authors: Mike Zäch, Szymon Beczkowski, Asger BjÃ¸rn JÃ¸rgensen, Stig Munk-Nielsen*
Switching Loss Reduction on Cascaded H-Bridge Converter with Diode Clamped Transformer Grounding Scheme (Paper ID 7048) *Authors: Zihan Gao, Ruirui Chen, Dingrui Li, Fred Wang*

Gate Driver with Dynamic Drive Strength on High-Temperature CMOS Process for Heterogeneous Integration Inside the SiC Power Module (Paper ID 7057) *Authors: Asif Faruque, Ayesha Hassan, Yuyang Wang, H. Alan Mantooth*
SiC Devices
Avalanche Capability of SiC MOSFET Under High Current (Paper ID 7030) *Authors: Xuning Zhang, Ehab Tarmoom, Ali Shahabi, Linda Starr, Dennis Meyer*
A Physical-Based 3rd-Quadrant Behavioral Model for Power SiC MOSFET (Paper ID 7034) *Authors: Yuzhi Chen, Chi Li, Yifan Wu, Zedong Zheng*
SiC MOSFET Device for Radio Frequency Power Conversion (Paper ID 7038) *Authors: Amaury Gendron, Dumitru Sdrulla, Nathaniel Barr, Su-Wen Chen, Dick Frey, Albert Gu*
Edge Termination Design Considerations for 1.2kV 4H-SiC MOSFETs While Utilizing Room Temperature Ion Implantations (Paper ID 7040) *Authors: Stephen Mancini, Seung Yup Jang, Zeyu Chen, Dongyoung Kim, Balaji Raghothamachar, Michael Dudley, Woongje Sung*
Enhanced Conduction and Switching Performance of 1.2 kV 4H-SiC MOSFETs Through High JFET Doping Concentration (Paper ID 7043) *Authors: Dongyoung Kim, Skylar Deboer, Seung Yup Jang, Adam Morgan, Woongje Sung*
Exploring the Impact of Implant Temperature and a Novel Aluminum Ion Source on the Electrical Performance of 4H-SiC Pin Diodes (Paper ID 7051) *Authors: Justin Lynch, Ryoto Wada, Nobuhiro Tokoro, Takashi Kuroi, Woongje Sung*
Analysis of 10 kV SiC MOSFET Module Baseplate Parasitic Capacitance Impact on Switching Loss (Paper ID 7059) *Authors: Ruirui Chen, Min Lin, Dingrui Li, Zihan Gao, Fred Wang, Hua Bai, Leon M. Tolbert*
Short-Circuit Ruggedness Characterization of State-of-the-Art 3.3 kV SiC MOSFETs (Paper ID 7071) *Authors: Yizhou Cong, Peiwen Jiang, Ke Wang, Pengyu Fu, Jin Wang, Ashish Kumar, Kraig Olejniczak*

WBG Devices
Cost-Effective Test Setup for Measuring Threshold Voltage Shift of GaN-HEMTs Under Long-Term Drain-Voltage Stress (Paper ID 7008) *Authors: Daniel Breidenstein, Benedikt Kohlhepp, Thomas Dürbaum*
Scaled Projections of Empirically Verified Hybrid Edge Terminated Vertical GaN Diodes to 20 kV (Paper ID 7031) *Authors: Tolen Nelson, Prakash Pandey, Daniel Georgiev, Michael Hontz, Raghav Khanna, Alan Jacobs, James Gallagher, Andrew Koehler, Karl Hobart, Travis J. Anderson*
Monitoring Current of a GaN HEMT at Ultra-High Magnetic Fields (Paper ID 7046) *Authors: Brett Setera, Aristos Christou, Natalia Gudino*
P-Type Doping Control of Magnetron Sputtered NiO for High Voltage UWBG Device Structures (Paper ID 7067) *Authors: Matthew Porter, Yunwei Ma, Yuan Qin, Yuhao Zhang*

Detailed Schedule: Wednesday, December 6, 2023

Keynote Sessions

Title: Emerging Technologies to Push the Limits of GaN Electronics

Time: 8:00 AM – 8:30 AM in Crown IV + V

Abstract: The demand for electricity as a form of end-use energy is rapidly growing with the electrification of our society, which substantially rely on power devices. Additionally, radio-frequency (RF) electronics play a vital role in many aspects of our daily lives, including wireless communications, imaging, and sensing. However, the development of next-generation electronic devices is hindered by the inherent inefficiency, limited frequency performance, and high-power density of these devices, which present significant electronic and thermal challenges.

In this presentation, we will explore the latest advancements and emerging technologies in III-Nitride semiconductors that aim to address challenges in power and RF electronics. In the realm of power electronics, we will discuss the significant improvements in device performance achieved through the use of multi-channel structures, resulting in figures of merit that far surpass current state of the art. For RF devices, we will examine innovative technologies designed to overcome their inherent limitations in cut-off frequencies, potentially extending the operation of GaN electronics into the THz band. Additionally, to tackle the challenge of managing high heat fluxes in compact devices, we will delve into recent advancements in the thermal management of GaN devices. This includes the co-design of microfluidics and electronics within the same semiconductor substrate, a technology that offers significantly greater cooling capabilities than currently available and enables denser integration of GaN devices on a single chip. These emerging technologies present exciting opportunities for the future development of III-nitride electronic devices.

Elison Matioli is a professor in the institute of electrical and micro-engineering at Ecole Polytechnique Fédérale de Lausanne (EPFL). He received a B.Sc. degree in applied physics and applied mathematics from Ecole Polytechnique (Palaiseau, France), followed by a Ph.D. degree from the Materials Department at the University of California, Santa Barbara (UCSB), and a post-doctoral at the Massachusetts Institute of Technology (MIT). His research interests lie in

power and RF electronics, particularly based on wide-band-gap semiconductors, as well as on their thermal management. Among his prizes, he received the 2013 IEEE George Smith, 2015 ERC Starting Grant, 2020 University Latsis Prize, and the 2022 IEEE Transaction of Power Electronics Prize Letter Awards.

Title: **Qorvo SiC JFET Based Power Switch Topologies Optimized for Switching and Circuit Protection**

Time: 8:30 AM – 9:00 AM in Crown IV + V

Abstract: The normally-on construction of the SiC JFET is known to provide excellent RdsA benefits in the 650-1200V range, with substantial reduction in chip size compared to current SiC MOSFET structures, due to the much higher channel mobility. Normally-off devices are formed using the cascode arrangement, and have found success in a range of charger and power supply circuits. Recently, a dual gate arrangement of the cascode was demonstrated, which allows a lot of flexibility in controlled switching of inverters, highly paralleled operation, as well as in circuit breaker applications. We will delve into these topologies and the outlook for SiC JFET based technologies from Qorvo.

Dr. **Anup Bhalla** received his Ph.D. from Rensselaer Polytechnic Institute in 1995. In 2000, he co-founded Alpha and Omega semiconductor, where he served in engineering leadership roles until 2012. From 2012-2021, Dr. Bhalla was Vice President of Engineering at UnitedSiC, overseeing the development of Silicon Carbide Devices. In October 2021, UnitedSiC was acquired by Qorvo, where he now serves as Chief Engineer for Power Devices. He is the primary or co-inventor of over 100 US patents.

Title: **Solid State Transformer and DC Grids: From Concept to Pilot Demonstration in a Decade enabled by HV SiC 10-15kV IGBTs, MOSFETs, and BiDFET**

Time: 9:00 AM – 9:30 AM in Crown IV + V

Abstract: The Solid State Transformer journey from concept to pilot demonstration in a decade will be presented. The MV SST for grid interconnection is enabled by advances in HV 10-15kV SiC power devices. The design, control,

development, and testing of SST with HV SiC 10kV MOSFETs and 15kV SiC IGBTs, wih a pilot demonstration for the Navy of an MV 4160V, 100kVA SST with SiC 10kV MOSFETs will be presented. The HV 10kV SiC MOSFET enabled SST for "Mobile Utility Support Equipment" [MUSE] based Applications was focused on integrating an MV to an LV grid and enable DC grids. The most impactful effect of using SST lies in the reduced material usage compared to conventional 60 Hz transformers, especially copper and aluminum, which have CO2 production emissions of up to 25 kgCO2/kg. With an increased focus on climate change and greenhouse gas emissions, it is imperative to minimize the carbon footprint of transformers. Advances in Power Electronics always take a quantum leap with the advent of new power semiconductor device with unique characteristics that enable new power conversion topologies and systems. A new SiC based Monolithic Bidirectional Switch [BiDFET] that enables new power conversion systems such as AC-AC Matrix Converters will be presented.

Subhashish Bhattacharya is currently Duke Energy Distinguished Professor in the Department of ECE at NC State University. He received B.E. from IIT-Roorkee, India, M.E. from IISc, India, and Ph.D. from University of Wisconsin-Madison, all in electrical engineering. He was with FACTS and Power Quality Division at Westinghouse R&D and Siemens Power Transmission & Distribution, from 1998 to 2005. He joined NCSU in August 2005, where he is a founding faculty member of NSF FREEDM Center, ATEC, and DoE PowerAmerica Institute. A part of his PhD research on active power filters was commercialized by York Corporation [now Johnson Controls]. His research interests are Solid-State Transformers with HV SiC devices, Integration of renewable energy resources, Microgrids, high-frequency magnetics, active filters, and the application of new power semiconductor devices such as SiC and GaN for power converters. His research is funded by several industries, NSF, DoE/ARPA-E, Navy, NASA, and others. He has over 700 publications, 12 patents, H-index of 70, and 20,900+ citations.

Title: **GaN Roadmap and Expected Adoption in Automotive Applications**

Time: 9:45 AM – 10:15 AM in Crown IV + V

Abstract: Gallium Nitride (GaN) devices are experiencing increased adoption as a preferred technology for high power applications due to their exceptional electrical and thermal properties. GaN based solutions offer higher efficiency and power

density compared to Si and SiC benchmarks. We review the system level benefits and challenges of state-of-the-art GaN based designs, focusing on traction motor control, On Board Chargers (OBC) and energy storage applications. Moreover, we discuss anticipated GaN device and fabrication roadmap improvements in terms of cost-performance, increased voltage capability and associated reliability figures of merit, and improved thermal management.

Marco Zuniga serves as GaN Systems' Chief of Technology. He joins the company as a distinguished technical leader with over 25 years of experience in product and process in high-performance power management solutions. Most recently, he was Managing Director at Maxim Integrated (recently acquired by Analog Devices), where he was the power architect of a company-wide platform process and achieved best-in-class efficiency metrics in the automotive, data center, mobility, and industrial markets.

Previously, Marco served as the Vice President of IC Technology and Process Development and was the co-founder at Volterra Semiconductor. In this capacity, he successfully developed and executed a foundry-based power process strategy, resulting in six product generations with over 20X cost-performance improvement from initial inception. Volterra Semiconductor was acquired by Maxim Integrated. Marco holds a Ph.D. and M.S. in Electrical Engineering from the University of California at Berkeley and a BSEE in Electrical Engineering from the University of Texas at Austin.

Title: **Advancing Power Electronics with Silicon Carbide: Unlocking Efficiency and Sustainability in Clean Energy**

Time: 10:15 AM – 10:45 AM in Crown IV + V

Abstract: Silicon carbide (SiC) stands as a revolutionary material in power electronics, boasting a wider bandgap, higher thermal conductivity and the ability to handle higher voltages and temperatures. This keynote will highlight how SiC power devices enable reduced power losses, higher efficiency and faster switching, helping to usher in compact, lightweight and efficient power electronic solutions for electric vehicles, renewable energy and high-voltage systems. This keynote will also address how SiC's excellent thermal and chemical performance makes it perfect for challenging environments. In clean energy technologies, SiC's contributions are

evident in solar inverters, wind turbines and energy storage systems, and ensure higher efficiency and reliability. As global clean energy initiatives gain momentum, SiC's role in advancing sustainability and enabling clean power solutions is becoming increasingly vital and is paving the way for a greener future for all. The presentation will conclude by highlighting the ongoing research and development focused on overcoming challenges such as manufacturing costs, wafer size, material defects and interface quality. Overall, this keynote will inform and showcase SiC's immense potential in driving innovation and fostering sustainable and energy-efficient applications across a wide variety of industries.

As Chief Technology Officer, **Elif Balkas** focuses on pioneering breakthrough semiconductor technology for Wolfspeed's Power and RF commercial applications. She joined Wolfspeed in 2006 and has more than 20 years of experience in various leadership positions within the wide bandgap (WBG) materials field in the technology industry. Prior to Wolfspeed, Elif served as a scientist at Intrinsic Semiconductor where she was responsible for GaN and silicon carbide epitaxy product development with a focus on high-quality, efficient and effective processes.

Elif co-founded the Women's Initiative at Wolfspeed, has served as the leader of the Professional Development Focus, and continues to serve on the Women's Initiative Steering Committee. She has a Ph.D. in materials science from North Carolina State University and has completed several executive education programs at The Wharton School focusing on product management and strategy, scaling a business, and leadership development.

Panel Discussion

Title: **Panel 2 – High-Reliability Designs of Wide Bandgap Power Electronics Applications**

Time: 10:45 AM – 12:00 PM in Crown IV + V

Moderator: **Paul Rankin** (Astranis Space Technologies)

Panelists:

- **Mike Harris**, Chief Technology Officer (Atom Power)
- **Brij Singh**, Fellow (John Deere)
- **Matt Francis**, Founder and President/CEO (Ozark Integrated Circuits, Inc)
- **Sriram Chandrasekaran**, Principal Engineering Fellow (Raytheon Technologies)

Abstract: Wide bandgap semiconductors have seen widespread adoption across many industries and applications. As silicon carbide and gallium nitride devices continue to mature and demonstrate highly reliable operation, they have garnered significant interest in the aerospace and automotive industries. In applications where performance and reliability are paramount, wide bandgap semiconductors are quickly becoming the devices of choice. Benefits of these devices such as high operating temperatures and inherent radiation tolerance are enabling new technologies and performance levels in these industries which are not possible with silicon devices. This panel will discuss the role of wide bandgap technologies in high-reliability applications, how their adoption has changed the industry, and what effect they will continue to have in high-reliability designs.

Technical Sessions

Time: 1:30 PM – 3:10 PM

Session Name: SiC Devices: Modeling, Packaging, and Modules

Location: Crown V

Session Chairs: Alvars Lelis (ARL) and Victor Veliadis (The Ohio State University)

Time	Topic
1:30 PM – 1:55 PM	**SiC MOSFETs Performance Modeling in Simulink Simscape Environment** (Paper ID 7049) *Authors: Jacopo Ferretti, Giacomo-Piero Schiapparelli, Enrico Sangiorgi, Andrea Natale Tallarico*
1:55 PM – 2:20 PM	**Packaging of 15 kV Silicon Carbide Half-Bridge Module Enabled by a Polymer Nano-Composite Field-Grading Coating** (Paper ID 7005) *Authors: Zichen Zhang, Shengchang Lu, Carl Nicholas, Justin Lynch, Adam Morgan, Woongje Sung, Khai Ngo, Guo-Quan Lu*
2:20 PM – 2:45 PM	**Single and Double-Sided Jet Impingement Cooling for SiC-Based Power Modules** (Paper ID 7023) *Authors: Himel Barua, Shajjad Chowdhury, Jon Wilkins, Burak Ozpineci*
2:45 PM – 3:10 PM	**Improved Non-Destructive Mutual Inductance Estimation Method for Multi-Chip Power Modules** (Paper ID 7037) *Authors: Arthur Boutry, Sergio Jimenez, Andrew Lemmon*

Session Name: **Application (Switching) Reliability**

Location: Crown IV

Session Chairs: Sandeep Bahl (Texas Instruments) and Don Gajewski (Wolfspeed)

Time	Topic
1:30 PM – 1:55 PM	**Gate Lifetime of P-Gate GaN HEMT Under DC and Switching Overvoltage Stress** (Paper ID 7068) *Authors: Bixuan Wang, Ruizhe Zhang, Qihao Song, Qiang Li, Yuhao Zhang*
1:55 PM – 2:20 PM	**Output Capacitance Loss in Wind-Bandgap and Superjunction Power Transistors: Impact of Switching Voltage and Current** (Paper ID 7062) *Authors: Qihao Song, Qiang Li, Yuhao Zhang*
2:20 PM – 2:45 PM	**Scalable Test System for Long Term Reliability Assessment of SiC MOSFET Stability in Extreme dV/dt Stress Condition** (Paper ID 7042) *Authors: Lisi Zhu, David Sheridan, Kiran Chatty, Zhan Liu, Arash Salemi, Jin Zhang, Madhur Bobde*
2:45 PM – 3:10 PM	**Finite Control Set Model Predictive Control Based on in-Situ Junction Temperature for Reliability Enhancement of Power Converters** (Paper ID 7066) *Authors: Jiale Zhou, Ali Parsa Sirat, Chondon Roy, Qiang Mu, Zaheen Mustakin, Luocheng Wang, Babak Parkhideh, Tiefu Zhao*

Time: 3:40 PM – 5:20 PM

Session Name: **GaN Devices 2**

Location: Crown V

Session Chairs: Geetak Gupta (Transphorm) and Zhikai Tang (Texas Instruments)

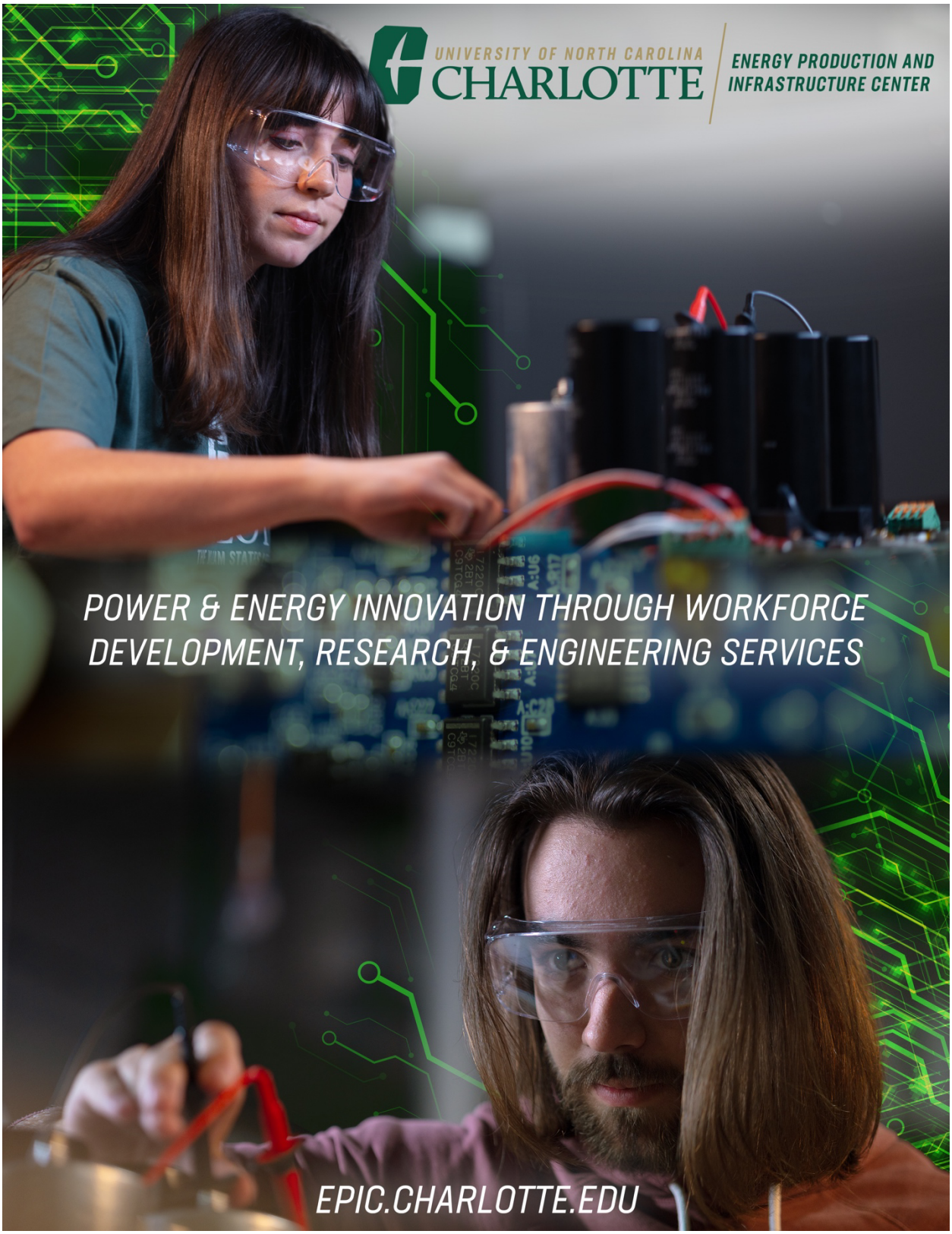
Time	Topic
3:40 PM – 4:05 PM	**Planar Implantation Edge Termination for Vertical GaN Power Devices** (Paper ID 7061) *Authors: Yifan Wang, Ming Xiao, Matthew Porter, Ruizhe Zhang, Qihao Song, Albert Lu, Nathan Yee, Hiu Yung Wong, Yuhao Zhang*
4:05 PM – 4:30 PM	**Thermo-Mechanical Analysis of a 650 V/150 A e-GaN HEMT Sandwiched Between a PCB and a DBC Substrate** (Paper ID 7029) *Authors: Carl Nicholas, Filip Boshkovski, Emmanuel Arriola, Zichen Zhang, Guo-Quan Lu*
4:30 PM – 4:55 PM	**Etch Depth Study for Step-Etched Junction Termination Extensions in Vertical GaN Devices** (Paper ID 7014) *Authors: Andrew Binder, Jeffrey Steinfeldt, Andrew Allerman, Brian Rummel, Caleb Glaser, Luke Yates, Robert Kaplar*
4:55 PM – 5:20 PM	**Comparison of the Static Characteristics of GaN HEMTs with Different Gate Technologies and the Impact on Modeling** (Paper ID 7006) *Authors: Xiaomeng Geng, Nick Wieczorek, Carsten Kuring, Oliver Hilt, Mihaela Wolf, Sibylle Dieckerhoff*

Session Name: GaN Applications 2

Location: Crown IV

Session Chairs: Llewellyn Vaughan-Edmunds (Navitas)

Time	Topic
3:40 PM – 4:05 PM	**Ultra-Wideband Surface Current Sensor Topology for Wide-Bandgap Power Electronics Applications** (Paper ID 7053) *Authors: Ali Parsa Sirat, Hossein Niakan, Babak Parkhideh*
4:05 PM – 4:30 PM	**Common Mistakes in Practical Power Supply Design with Wide Bandgap Devices** (Paper ID 7028) *Authors: Shengyang Yu, Fei Yang*
4:30 PM – 4:55 PM	**Thermal Performance Investigation of a High-Current & High-Power Density GaN-Based Motor Drive for All Electric Aircraft Applications** (Paper ID 7012) *Authors: Armin Ebrahimian, Seyed Iman Hosseini Sabzevari, Waqar A. Khan, Nathan Weise*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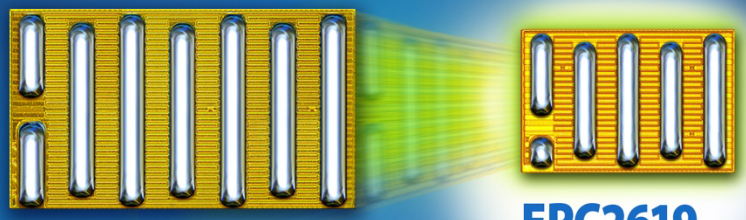

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