# IEEE Workshop on Wide Bandgap Power Devices and Applications in Europe

# (WiPDA-Europe)


**18th – 20th of September 2022**

**University of Warwick, Coventry, United Kingdom**

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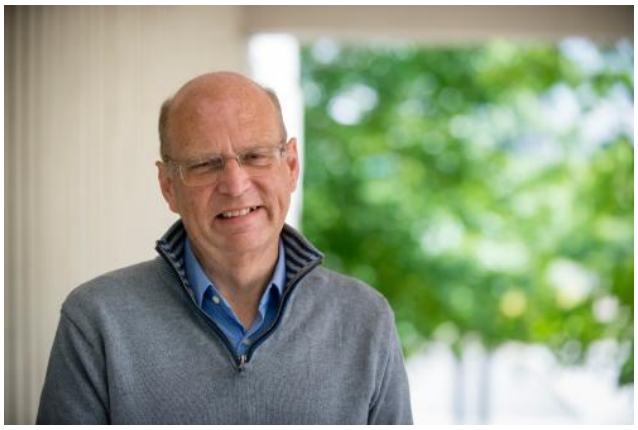
# Welcome Message from the Chair - WiPDA Europe 2022



I am delighted to invite you to attend the inaugural edition of WiPDA Europe 2022, to be held here at the University of Warwick, UK. This workshop originally started in the USA in 2013 and was primarily established to provide a platform for researchers in Wide Bandgap semiconductor devices and applications to share their knowledge and experience with each other. At that time, the community was starting to grow, and interest was certainly picking up. Now however, it has hit mainstream and is here to stay, with all major OEM automotive manufacturers developing a significant investment in the technology, which is spilling over into a whole host of related markets. The technology is developing fast and will have a major contribution to the global ambitions of net-zero carbon.

The interest is global, and the sister version of the conference (WiPDA Asia) was established a few years later, which has grown significantly despite the impact of the pandemic on travel. Now this has moved to Europe with WiPDA Europe, which is intended to be interleaved with the Asian conference on a bi-annual basis.

We are proud to be asked to host this prestigious event at Warwick, which has been researching in Wide Bandgap devices for over 17 years and has become the largest specialist research group in the UK focussing in this area, with a particular emphasis on silicon carbide technology. The event will take place on the university campus which is situated in the heart of England and close to the nearby Birmingham international airport. It will be held on campus at The Slate conference centre, which is located with ample high-quality university hotel accommodation for attendees that wish to stay on site. The tutorial session on Sunday the 18th will be located in the Zeeman building on campus, just a few minutes walk away. The welcome reception will be located in the National Automotive Innovation Centre.

I would like to thank the local organising committee and the IEEE for bringing this event to fruition in such a short time scale especially my co-chairs, Dr Jose Ortiz-Gonzalez and Dr Marina Antoniou, as well as Professor Robert Pilawa-Podgurski and Professor Jian Sun from TC6 in PELS at the IEEE. We would also like to thank Tsuyoshi Funaki from WiPDA Asia for his help and encouragement. Without their help and support, this would not be possible. There are many other individuals that have contributed or have yet to contribute including all the attendees we would like to thank.

The programme we have assembled a superb set of speakers, both for the tutorial and for the keynote speakers. Also, the contributed papers are of very high quality. We hope you have a rewarding experience at the first WiPDA Europe conference, and that as an event it grows from strength to strength.

Professor Phil Mawby, University of Warwick

# Organising Committee

**Conference Chair:** Professor Phil Mawby, University of Warwick

**Conference Vice-Chair:** Professor Mike Jennings, Swansea University

**Technical Program Chair:** Dr Marina Antoniou, University of Warwick

**Technical Program Co-Chair and Publication Chair:** Dr Jose Ortiz Gonzalez, University of Warwick

**Treasurer**: Professor Peter Gammon, University of Warwick

**Co-Treasurer**: Dr Jose Ortiz Gonzalez, University of Warwick

**Tutorials Chair:** Professor Layi Alatise, University of Warwick

**Sponsorship and Exhibition Chair:** Dr Vishal Shah, University of Warwick

**Sponsorship and Exhibition Co-Chair:** Paul Jarvie, CSA Catapult

**Registration Chair:** Professor Li Ran, University of Warwick

# Tracks and Technical Program Committee

WiPDA Europe 2022 is divided in 6 main tracks, with their associated technical committee.

| | |
|---|---|
| **Track 1**<br>**Materials and Device Fabrication/Structures** | **Members:**<br>Jun Zeng, MaxPower Semiconductor, United States<br>Vishal Shah, University of Warwick, United Kingdom<br>Amador Pérez Tomás, Catalan Institute of Nanoscience and Nanotechnology, Spain<br>Fan Li, Nexperia, United Kingdom<br>Andy Withey, Nexperia, United Kingdom<br>Andrei Mihaila, Hitachi ABB, Switzerland |
| **Track 2**<br>**SiC Devices and Application of SiC Devices (including modelling)** | **Members:**<br>Saeed Jahdi, University of Bristol, United Kingdom<br>Neophytos Lophitis, University of Nottingham, United Kingdom<br>Craig Fisher, MaxPower Semiconductor, United Kingdom<br>Oriol Aviñó-Salvadó, Institute of Microelectronics of Barcelona (IMB-CNM), Spain<br>Yegi Bonyadi, Lyra Electronics, United Kingdom<br>Wataru Saito, Kyushu University, Japan. |
| **Track 3**<br>**GaN Devices and Application of GaN Devices (including modelling)** | **Members:**<br>Martin Kuball, University of Bristol, United Kingdom<br>Petar Igic, Coventry University, United Kingdom<br>Florin Udrea, University of Cambridge, United Kingdom<br>Trevor Martin, United Kingdom<br>T. Paul Chow, Rensselaer Polytechnic Institute, United States<br>Kevin Chen, Hong Kong University of Science and Technology, Hong Kong |

| | |
|---|---|
| **Track 4**<br>**Converter Integration and Packaging** | **Members:**<br>Tsuyoshi Funaki, Osaka University, Japan<br>Steve Riches, Tribus-D, United Kingdom<br>Liam Mills, Manufacturing Technology Centre, United Kingdom<br>Alberto Castellazzi, Kyoto University of Advanced Science, Japan<br>Chao Ji, Ricardo, United Kingdom<br>Dean Hamilton, De Montfort University, United Kingdom |
| **Track 5**<br>**Reliability and Robustness (including implications of using WBG materials - windings, EMI, passive components, harsh environments)** | **Members:**<br>Nando Kaminski, Bremen University, Germany<br>Bing Ji, University of Leicester, United Kingdom<br>Andrea Irace, University of Naples Federico II, Italy<br>Asad Fayyaz, University of Nottingham, United Kingdom<br>Frédéric Richardeau, University of Toulouse, France |
| **Track 6**<br>**Applications in Renewable Energy & Energy Storage, Transportation, Industrial Drives, & Grid Power Systems** | **Members:**<br>Haimeng Wu, Northumbria University, United Kingdom<br>Francisco Freijedo, Huawei, Germany<br>Paul Judge, University of Edinburgh, United Kingdom<br>Pete James, Lyra Electronics, United Kingdom<br>Teng Long, University of Cambridge, United Kingdom<br>Enrique Dede, University of Valencia, Spain |

## Supporting organisations, exhibitors and advertising

We would like to thank the following organisations for supporting WiPDA Europe 2022

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@FutureBEV with Warwick University is demonstrating the ability of industry and academic partners to come together to deliver accelerated technologies to market.

The access to a strong academic base with matched development and test hardware enables rapid implementation of ideas from drawing board to real hardware.

The @FutureBEV team directly benefit from quick access to the BEV specific technologies enabling risk reduction as well as improving the change of emerging technologies to be implemented in new designs.

The net benefit is through this collaboration we can bring these $CO_2$ reducing technologies to the road quicker whilst keeping the business case and enabling a next generation of engineers.

@FutureBEV partners enabled through the APC program of funding includes development partners:

BMW, CSAC Catapult, Lyra Electronics, and Warwick University as well as manufacture partners for future powertrain, Custom Interconnect Ltd.

@FutureBEV developing BEV powertrain from concept to UK manufacturing supply chain through Innovate and APC to deliver Accelerated Technologies for Future BEV.

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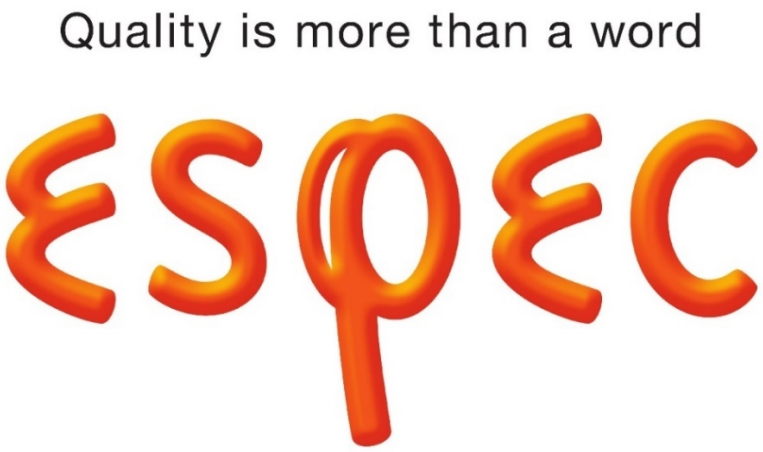


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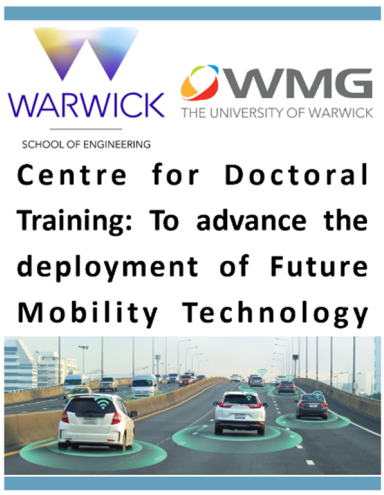
## Exhibitors

**www.der-ic.org.uk**

DER-IC is a UK-wide project developing the UK's manufacturing supply chains in power electronics, machines and drives (PEMD).

Part of the £80M Driving the Electric Revolution Challenge from UK Research and Innovation, DER-IC has received £33m (including £28.5m of capital equipment) to create a UK-wide network of PEMD capability, operating from regional centres in Scotland, the North East, the Midlands, and the South West & Wales.

DER-IC's mission is to fill gaps in the UK's PEMD manufacturing supply chains by providing open access facilities across the UK with state-of-the-art equipment. We work across ten different sectors including energy, industry and transport to facilitate cross-sector collaboration. DER-IC will draw on the strong industrial research expertise of our partner Universities and Research and Technology Organisations (RTOs) to support industry in strengthening PEMD capability, capacity and competitiveness.




**https://warwick.ac.uk/fac/sci/fmt/**

The Centre for Doctoral Training to Advance the Deployment of Future Mobility Technologies (CDT FMT) was established in 2019 by The School of Engineering and WMG – University of Warwick, with an initial cohort of students across two streams: Wide Bandgap Power Electronics (WBG PE) and Connected and Autonomous Vehicles (CAV).

The CDT vision is to develop multidisciplinary future research leaders with the creativity, skills and in-depth knowledge to transform the mobility of people and goods for the benefit of UK society and industry in an electrically intensive energy future.

## Programme and Schedule

## General Information

The technical programme of WiPDA Europe 2022 includes 18 oral presentations and 14 poster presentations, complemented with 5 keynote invited talks and a tutorial day where 6 international experts deliver 1-hour lectures.

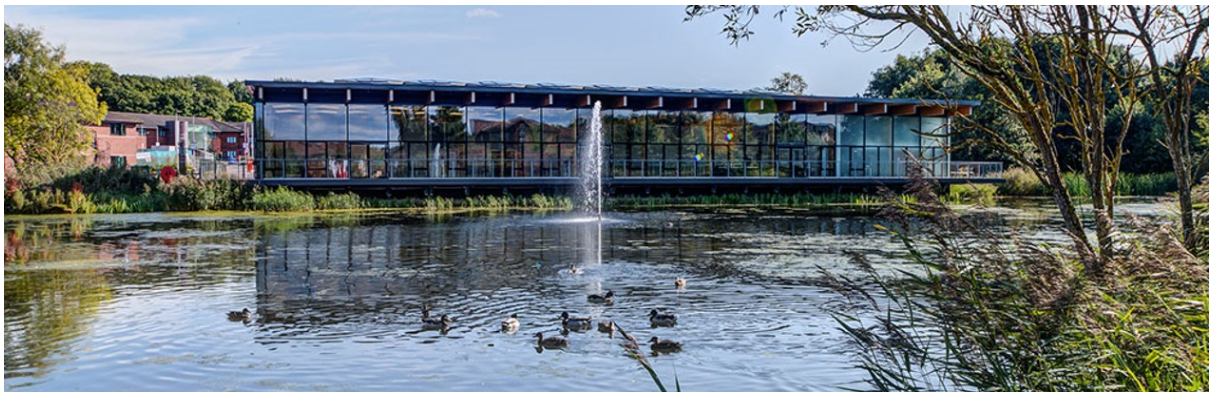
The social programme includes a welcome reception and a gala dinner.

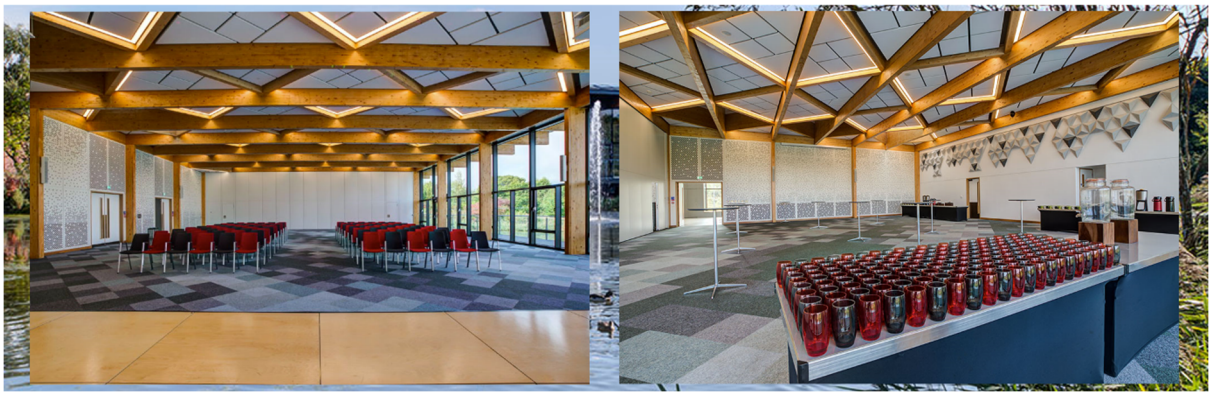
The venue of the tutorials is the Zeeman Building. MS.01- Zeeman Building.

The main venue of the workshop is The Slate, University of Warwick.

The welcome reception will take place at the National Automotive Innovation Centre (NAIC).

The gala dinner will take place at the Chancellors Suite, Rootes Building, University of Warwick.





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# Tutorial Day: Sunday 18th of September

**9:00 Registration – Zeeman Building Foyer**

**10:00 "*Silicon Carbide epitaxy overview and new challenges*" Dr. Marco Mauceri, LPE Epitaxial Technology Center, Catania, Italy**

Abstract

In the last decade the market for SiC-based power devices has been grown rapidly, consequently, the demand for a high quality, defect-free, and uniform SiC materials is increased. Today, the mainstream epitaxy wafer size (to produce SiC devices) is 150 mm while, in order to reduce the production cost per unit device, some device manufacturers are in the early stages of setting up 200 mm fabs. To realize this aim, alongside the need for commercially available 200 mm SiC wafers, the ability of performing uniform SiC epitaxy with low defect density is highly demanded. So, achieved decent quality for 200 mm SiC substrates, the next challenge would be to perform high quality epitaxial growth on them.

The tutorial will give an overview on SiC epitaxy in the last decades pointing out some breakthroughs, which had speed out the SiC market growth. It will be shown the parameters, which influence the SiC epitaxy and the actual status of 150mm epitaxy quality, which is ready for some device (SBD and Mosfet). Nevertheless, improvements are needed further for very high voltage devices. Even if SiC 150mm epitaxy is still the main source for SiC device market, all the mayor SiC players are doing huge investments for 200mm SiC epitaxy. After an overview of the principal 200mm SiC epitaxy reactor suppliers, the tutorial will focus on activity on LPE reactor. The LPE company has designed and manufactured a horizontal single wafer hot-wall fully automatic CVD reactor (PE1O8A) equipped with a multi-zone injection system able to process up to 200 mm SiC substrates, with high performances in both doping and thickness uniformities. Computational fluid dynamics (CFD) simulation is used to achieve the optimum design of the PE1O8 reactor to guarantee comparable gas flow and temperature uniformity both for 150 and 200 mm substrate format. The gas blending system enables the modification of the locally distributed gas chemical composition, further expanding the number of process parameters tunable to optimize epitaxial growth. Finally, it will be shown the activity on 200m epitaxy.

Marco Mauceri actually is a senior process engineer at LPE R&D Lab in Catania. Since 2002 he worked in LPE as process and product engineer. He was involved in several R&D projects on SiC epitaxy and SiC heteroepitaxy (SiCilab, Last Power, Challenge, Reaction, EleGaNte project, etc.). He has a master degree in physics and he was co-author in more than 50 papers.

**11:00 "*Packaging and Integration for Wide Band-Gap Semiconductors*" Professor Lee Empringham, University of Nottingham, United Kingdom**

Abstract

With the universal uptake of commercially viable Wide Bandgap power semiconductors gathering pace, their switching speed, seen as one of their greatest advantages, is also a significant disadvantage

in terms of Electro-magnetic Interference and high DV/DT delivered to the output cables and load. Present packaging technologies, often developed for Silicon devices, limit the performance of the wide bandgap devices. This tutorial will highlight the issues surrounding Electro-magnetic interference, thermal management and high speed circuit layout and outline an integrated approach to facilitate the use of these devices.

Professor Lee Empringham received the B.Eng. (Hons.) degree in Electrical and Electronic Engineering from the University of Nottingham, U.K., in 1996, and the Ph.D. degree in November 2000. He then joined the Power Electronics, Machines and Control Group within the School of Electrical and Electronic Engineering, University of Nottingham, to work on matrix converter commutation techniques.

Since then, he has worked as a Research Fellow to support different ongoing Industrially based research programmes focusing on highly compact power converter applications for Aerospace, renewables and Industrial drives.

In 2010, he was appointed as a Principal Research Fellow within the group and Professor of Power Conversion Technologies in 2017 where he lead multiple integrated power electronic initiatives including the EPSRC Centre for Power Electronics Heterogeneous Integration Theme and was deputy director of both the EPSRC Automotive Challenge Network and the Advanced Propulsion Centre thematic Spoke on Power Electronics.

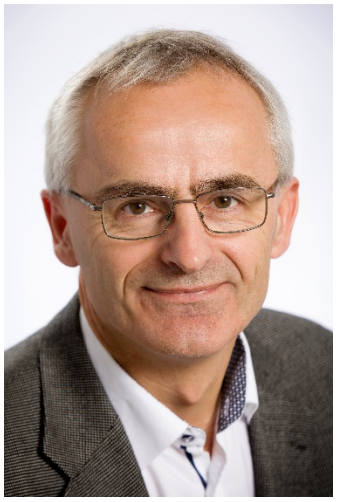
His research interests include direct AC–AC power conversion, variable speed AC motor drives using different circuit topologies, more-electric aircraft applications, power electronics integration, and high power density power conversion techniques. In 2017, he co-founded The thinking Pod Innovations Ltd.

## 12:00 LUNCH BREAK – The Street - Zeeman Building Foyer

### 13:00 "*Wide Bandgap Power Devices – Opportunities and Challenges in Power Electronic Systems*" Professor Frede Blaabjerg, Aalborg University, Denmark

Abstract

In power electronic systems most of the technology development has been relying on the progress in new power semiconductors. This is also the case for Wide Bandgap Power Devices where faster switching speed, lower losses, smaller size have again put the technology forward. In some applications we see ten times faster switching speed with a significant reduction in size as well as system-wise a faster control loop bandwidth. On the other hand the layout of the power electronic circuit design become more critical to meet enough robustness of the designed system. This tutorial will touch on some of the those elements by giving examples from renewable generation and adjustable speed drive systems discussing Opportunities and Challenges of Applying Wide Bandgap Power Devices – as well as discuss future emerging topics having those new opportunities seen from a system perspective



Prof. Frede Blaabjerg has been full professor at Aalborg University for almost 25 years and has been a key person to develop a strong power electronics program at Aalborg University – with a long tradition to work closely with industry – In recent years he has been establishing the Center of Reliable Power Electronic Systems (CORPE) as well as a National Research Infrastructure on reliability (X-Power) – he is Villum Investigator giving him the opportunity to take rather independent research avenues. He has received the IEEE Edison Medal.

**14:00 "*How wide bandgap devices have enabled the development of wireless charging*"**
**Professor Richard McMahon, WMG, University of Warwick, United Kingdom**

Abstract

The convenience or wirelessly charged consumer products is widely appreciated and wireless charging has an important place in industrial automation. More recently much development work has highlighted the benefits for operators of electric vehicles, for example those with disabilities. The first generation of wireless chargers operated at 20 kHz using IGBTs as the switches. These systems were successful and could deliver high powers but were large. The timely arrival of silicon carbide MOSFETs has led to practical 85 kHz systems up to 20 kW or more. Research work is now focusing on megahertz systems using GaN devices to achieve more compact, and potentially lower cost, solutions.

The tutorial will cover the crucial role that wideband gap devices has played in the development of contemporary high-power wireless charging with examples from several application areas.

Richard McMahon is Professor Electrical Power Conversion at WMG, University of Warwick. He joined the university of Warwick in 2016 having previously been at Cambridge University Engineering Department. He leads the Power Electronics, Machines and Drives activity at WMG and his team has been involved in many wireless projects including the complete design and development of an 85 kHz 20 kW system recently demonstrated in Milton Keynes. He is a Chartered Engineer and a Fellow of the IE

## 15:00 BREAK - Zeeman Building Foyer

**15:30 "*An introduction to TCAD device modelling and simulation of wide bandgap power semiconductors"* Dr Marina Antoniou, University of Warwick, United Kingdom**

Abstract

Power devices are the fundamental building blocks of any power electronic system providing an interface between electrical systems or enabling the control of power flow. Technology computer-aided Design (TCAD) is essential for devices technology development, including wide bandgap power semiconductors. This tutorial will deal with TCAD device setup and modelling of power semiconductor devices. Examples of modelling and simulating of 4H-Silicon Carbide (SiC) devices will be presented. Modelling and simulating defects, traps and the effect of these traps on the characteristics will also be discussed

Dr Marina Antoniou holds a PhD, an MEng and BA from the University of Cambridge (Trinity College). She has been the holder of several highly competitive research fellowships and grants including the Royal Society Research Fellowship 2017 (SiC Power Devices for Smart Grid Systems), a Junior Research Fellowship (Selwyn College) and an Early Career EPSRC Centre for Power Electronics award, all of which involved the design and development of SiC or Si high power devices. Marina is the Chair of the IEEE Electron Devices Society, Power Devices & ICs Committee (2022-2023), having previously served as committee member (2020-2021). Marina is also an Associate Editor for the IEEE Transactions of Electron Devices, Elsevier Power Electronic Devices and Components and the Royal Society Philosophical Transactions, the world's longest running science journal. She has previously served as a technical committee member for the IEDM (2020-2021), and the ISPSD (2015-2021), the leading international conferences in the area of electron and power semiconductor devices respectively. She is also an Executive Committee member of the IET's PEMD Technical Network (TN).

**16:30 "*"High Voltage Blocking Stability and Reliability Challenges for Silicon Carbide Power Devices*" Dr. Munaf T. A. Rahimo, mqSemi AG, Switzerland**

Abstract

Power semiconductors differ from other semiconductor devices in their capability to sustain high voltages under extreme conditions. During static blocking (reverse bias), turn-on and turn-off switching and under special overload and fault protection conditions, high voltages are applied across the device. Together with the bulk region, having a wide and low doped drift region to support the electric field required for the high voltage ratings, the junction termination region plays the main role to shape the p-n junction edge and surface profile for obtaining a controlled electric field distribution and the maximum possible reverse voltage blocking capability.

New power devices based on wide bandgap materials such as Silicon Carbide are emerging in many power electronics applications to achieve high performance levels. The SiC material enables the power semiconductor to withstand higher voltage levels due the high critical electric field levels which are nearly ten times that of silicon. This means that the SiC device can be made ten times thinner for lowering the overall losses. The above material advantages enable device designers to employ

narrower junction termination dimensions. The substantially higher cost of SiC devices is another important factor for this trend to minimise the chip size of the final product. On the other hand, stable blocking behaviour is a key target especially with respect to SiC device design through improved junction termination and passivation technologies and the ability of the package to provide extra protection against harsh environmental conditions such as high humidity and temperature variations. The impact of the higher peak electric fields situated very close to the device surface and outside the semiconductor bulk (i.e., passivation layers and package filling materials) will also be more critical than in silicon. Therefore, SiC power devices will require special attention with respect to stable blocking performance by utilizing optimum termination designs and dimensions to take into account effects inside and outside the device bulk with further improvement in passivation and packaging materials for device protection.

This tutorial aims to discuss the impact of local variations due to various extrinsic causes (manufacturing, operational or environmental) on the electrical field profile in the junction termination region and subsequently on the device voltage blocking capability and reliability. Furthermore, means of detection via special test procedures and the development of improved device protection will be included in the tutorial as well.

Dr. Rahimo received his BSc from Baghdad University, Iraq in 1991 and his MSc/PhD from Staffordshire University, UK in 1993/1996. He joined GEC Plessey Semiconductors, UK in 1996 and then Semelab Plc, UK in 1999 where his main task in both companies involved the development of advanced fast recovery diodes technologies and products. In 2000, he joined ABB Switzerland as a power device senior R&D engineer responsible for IGBT development. Due to his many contributions to power device technologies for HVDC systems, he became ABB`s Corporate Executive Engineer in 2012. Since 2018, he is general manager of his consulting firm MTAL GmbH and founder of the power device start-up mqSemi AG in Switzerland. He has more than 30 years of accumulated experience in power devices and applications and is known for pioneering the advanced IGBT, BIGT, IGCT, Thyristor and diode concepts employed broadly in grid systems, traction and industrial drives. He has over 100 patents families including 60 families with patent grants and has authored over 200 publications and given many invited talks and tutorial

## 17:30 END OF THE TUTORIALs

## 18:00 WELCOME RECEPTION

THE NAIC BUILDING, University of Warwick

The welcome reception includes a speech from Dr Kimimori Hamada, canapes, and drinks. The estimated finish time is 20:00. There will be a reception desk where you can obtain your delegate pack/credentials.

# Day 1: Monday 19th of September 2022

**8:00 Registration – The Slate, University of Warwick**

**8:30 – Opening – Professor Phil Mawby**

**8:40 – Keynote talk - *Dr Jun Zeng, Co-Founder and CTO - MaxPower Semiconductor***

***"SiC MOSFETs Manufacturing: key process aspects and supply chain challenges"***

Abstract

Thanks to the superior properties of silicon carbide (SiC) material, it has attracted a great deal of attention from semiconductor academics and industry for decades. As well known, power MOSFETs based on SiC material are highly desired to be used as a power control/handling component in high performance switching power application because of their ability achieving lower on-resistance, reduced switching losses, faster switching speed and higher operation temperature. Currently, majority technical issues of 4H-SiC MOSFET have been either resolved or improved for realizing its commercialization with excellent and reliable electro-thermal characteristics obtained. However, in order to reach and retain its excellent characteristics in high-volume production as its silicon counterpart ( such as Si MOSFET/IGBT) has achieved, the starting material related, fabrication process related and design related challenges are still faced and are demanded to be continuously improved. In power semiconductor industry, the device design and its fabrication process is strongly coupled to each other, and they must work together very closely in order to develop a high performance and cost-efficient product. The fabrication process is a key part of a power semiconductor product. In this talk, these challenges in fabrication of 4H-SiC power MOSFET and its supply chain management, including the self-aligned channel, the gate oxidation/post-oxidation anneal (POA), high temperature implant/post-implant anneal (PIA), trench etch/post-etch anneal (PEA), metallization and wafer dicing as well as the starting material defect control, will be reviewed and discussed.

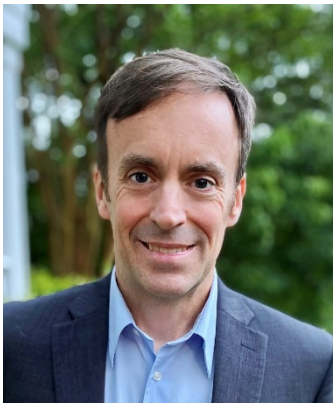
Dr Jun Zeng started his professional career in power semiconductor field in 1989. Since then, he has worked in many aspects of power semiconductor technology and product development, especially in Si and SiC planar and trench MOSFETs, IGBTs and Rectifiers, etc. He has gained a rich experiences from production definition, device design, fabrication process development, and TCAD modeling/simulation to the test and reliability assessment. Notably, in his over 25 years industrial experiences, he has worked with more than dozen power semiconductor fabs and accumulated a broader experience and know-how in manufacturing process development of various Si and SiC based power semiconductor devices for enhancing product performance and reliability as well as reducing manufacturing cost. He is co-inventor of more than 100 issued and pending patents

**9:20 – Keynote talk - *Dr Donald A. Gajewski, Wolfspeed Inc.***

***"SiC Device Reliability for Power Electronic Conversion Applications"***

Abstract

SiC devices offer performance advantages over Si devices for power electronic conversion applications, due to their wide bandgap and other key materials properties. For example, SiC can more easily be used to fabricate MOSFETs with very high voltage ratings (up to 10 kV), and with lower switching losses. The reliability of SiC power devices is excellent and has continued to improve due to continuing advancements in the quality of SiC substrates and epitaxy, as well as maturation and improvement of wafer fabrication. This has enabled the rapidly accelerating adoption of SiC devices, particularly for power electronic conversion applications such as electrified vehicle traction and charging, solar energy and power supplies. In this talk, I will review the wear-out mechanisms and intrinsic reliability performance of today's state-of-the-art commercially available devices, the mission profiles and harsh conditions that are being demanded by applications of interest, and the current state of industry consortia reliability and qualification guidelines and standards that will help assure minimum required quality and reliability.



Dr. Donald A. Gajewski is the Director of the Reliability Engineering & Failure Analysis Department for Wolfspeed, Inc., covering GaN-on-SiC HEMT-MMICs for RF and microwave applications, SiC power MOSFETs, SiC Schottky power diodes, and SiC power modules. He has been in the semiconductor industry reliability profession for 21 years, with previous tenures at Nitronex, Freescale and Motorola. He has experience with other semiconductor technologies including highly integrated silicon CMOS including SiGe HBT and SmartMOS; magnetoresistive random access memory (MRAM); and advanced packaging including flip-chip and redistributed chip package (RCP). He completed a National Research Council Postdoctoral Research Fellowship at the National Institute of Standards and Technology, in the Semiconductor Electronics Division, in Gaithersburg, MD. He earned the Ph.D. in physics from the University of California, San Diego, partially under the auspices of a National Science Foundation Fellowship.

**10:00 - Session 1 <u>Materials and Device Structures</u>**

**Session Chair: Dr Munaf Rahimo, mqSemi AG, Switzerland**

**10:00** - **S1.1 (27)** *"Dopant Incomplete Ionization Role in SiC Schottky Diode Edge Termination under Current Over-Stress"*

**Authors:** Oriol Aviñó[1], Ferran Bonet[1], Miquel Vellvehí[1], Xavier Jordà[1], Philippe Godignon[1] and Xavier Perpiñà[1]

**Affiliations**: [1]Power Devices and Systems Group, IMB-CNM, CSIC, Spain

**10:20** - **S1.2 (5)** *"Impact of Gate Dielectric Deposition Temperature on p-type Inversion Channel MOSFETs fabricated on GaN-on-Si"*

**Authors:** Mirjam Henn[1], Christian Huber[1]

**Affiliations**: [1]Robert Bosch GmbH, Germany

**10:40** - **S1.3 (28)** *"The successful implementation of a phosphorous-based surface passivation treatment into an industrial 650V 4H-SiC JBS fabrication process"*

**Authors:** Arne Benjamin Renz[1]**,** Guy William Clarke Baker[1], Vishal Shah[1], Philip Mawby[1], Marina Antoniou[1] and Peter Gammon[1]

**Affiliations**: [1]University of Warwick, United Kingdom

## 11:00 to 12:00 Break

**12:00 Session 2: <u>SiC Devices</u>**

**Session Chair: Dr Paul Taylor, Dynex, United Kingdom**

**12:00** - **S2.1 (11)** "*Power Conversion Efficiency Improvement of High-Voltage Power Supply with SiC-SBD Module*"

**Authors:** Yuki Nomura[1], Tsuyoshi Funaki[1], Toshio Hanada[2] and Takashi Nakamura[2]

**Affiliations**: [1]Osaka University, Japan [2]NexFi Technology Inc., Japan

**12:20** - **S2.2 (19)** "*Optimization of SiC device topologies for Single Event Immunity*"

**Authors:** Yunyi Qi[1], Marina Antoniou[1], Guy William Clarke Baker[1], Arne Benjamin Renz[1], Luyang Zhang[1] and Peter Gammon[1]

**Affiliations**: [1]University of Warwick, United Kingdom

**12:40** - **S2.3 (23)** "Paralleling of Transient Overvoltage Protection Elements within High Power DC Solid-State Circuit Breaker (SSCB) for Electric/Hybrid-Electric Aircraft"

**Authors:** Asad Fayyaz[1]**,** Matias Urrutia Ortiz[1], Zhenyu Wang[1], Tao Yang[1] and Patrick Wheeler[1]

**Affiliations:** [1]University of Nottingham, United Kingdom

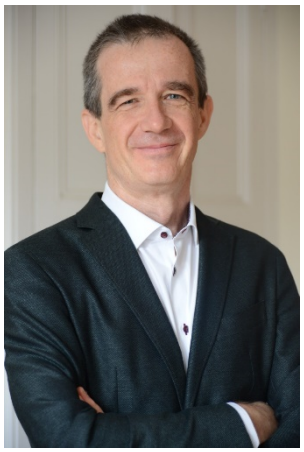
## 13:00 to 14:20 Lunch Break/Networking

**14:20 – – Keynote talk** - ***Professor Martin Kuball, University of Bristol***

***"GaN power devices – Do we understand how they work?"***

Abstract

Gallium Nitride (GaN) has become of major importance for power electronics in the mid-voltage range, with an increasing number of products ranging from laptop chargers, electric vehicles to other applications. GaN is though a very unusual material in that its works for power and many other devices despite it being full of defects, ranging from point defects to dislocations. Devices actually work because of these defects which is quite surprising. In this talk I will review the operation of GaN power electronic devices, limitations, and opportunities, and why they work



Professor Kuball is Royal Academy of Engineering Chair in Emerging Technologies at the University of Bristol, and Director of the Centre for Device Thermography and Reliability focusing on wide and ultrawide bandgap semiconductors including for power electronic applications. He is Fellow of IEEE, SPIE, MRS, IET and IoP, and obtained his PhD from the Max Planck Institute for Solid State Physics, Stuttgart, Germany and joined the University of Bristol after being Feodor Lynen Postdoctoral Fellow at Brown University where he was involved in the first demonstration of US made blue laser diodes

**15:00 - Session 3: <u>GaN Devices</u>**

**Session Chair: Professor Martin Kuball, University of Bristol, United Kingdom**

**15:00** - **S3.1 (2)** "*An experimentally driven assessment of the dynamic-on resistance in correlation to other performance indicators in commercial Gallium Nitride power devices*"

**Authors:** Neophytos Lophitis[1]**,** Samuel Perkins[2], Anastasios Arvanitopoulos[3], Soroush Faramehr[2] and Petar Igic[2]

**Affiliations:** [1]University of Nottingham, United Kingdom, [2]Coventry University, United Kingdom [3]Infineon Technologies Austria AG, Austria

**15:20** - **S3.2 (24)** "*Methodology for designing and testing long-term Hard-switching for GaN power HEMT*"

**Authors:** Muhammad Farhan Tayyab[1], Marco Silvestri[1], Mirko Bernardoni[1], Thomas Basler[2] and Gilberto Curatola[1]

**Affiliations:** [1]Huawei Nürnberg Research Center, Germany [2]Chemnitz University of Technology, Germany

**15:40** - **S3.3 (26)** "*Coil Design for Integration with GaN Hall-Effect Sensors*"

Authors: Vlad Marsic[1], Soroush Faramehr[1] and Petar Igic[1]

**Affiliations:** [1]Coventry University, United Kingdom

## 16:00 Poster Session

**Session Chairs: Professor Mike Jennings, University of Swansea**

**P1 (1)** "*On the 3C-SiC/SiO2 n-MOS interface and the creation of a calibrated model for the Electrons' Inversion Layer Mobility covering a wide range of operating temperatures and applied gate voltage"*

**Authors:** Neophytos Lophitis[1], Anastasios Arvanitopoulos[2], Mike Jennings[3], Philip Mawby[4] and Marina Antoniou[4]

**Affiliations:** [1]University of Nottingham, United Kindgom [2]Infineon Technologies Austria AG, Austria [3]Swansea University, United Kindgom [4]University of Warwick, United Kindgom

**P2 (4)** "*4H-SiC Trench Gate Lateral MOSFET with Deep-Shallow Source Trench for Improved RESURF Dose Window and Reduced Oxide Field"*

**Authors:** Hengyu Wang[1], Baozhu Wang[2], Borong Hu[1], Lingxu Kong[3], Florin Udrea[1] and Teng Long[1]

**Affiliations**: [1]University of Cambridge, United Kingdom [2]ZJU-Hangzhou Global Scientific and Technological Innovation Center, China, [3]Zhejiang University, China

**P3 (6)** "*Electrical conductivity of magnesium implanted in gallium nitride"*

**Authors:** Stefan Regensburger[1] and Jens Baringhaus[1]

**Affiliations:** [1]Robert Bosch GmbH, Germany

**P4 (8)** "*Comparison of a 3.3 kV SiC Hybrid-ChannelTrench MOSFET and a Planar MOSFET"*

**Authors:** Luyang Zhang[1], Tianxiang Dai[1], Peter Gammon[1], Vishal Shah[1], Philip Mawby[1]and Marina Antoniou[1]

**Affiliations:** [1]University of Warwick, United Kingdom

**P5 (12)** "*Short-Circuit Performance Investigation of 10kV+ Rated SiC n-IGBT"*

**Authors:** Ioannis Almpanis[1], Paul Evans[1], Marina Antoniou[2], Peter Gammon[2], Lee Empringham[1], Florin Undrea[3], Philip Mawby[2] and Neophytos Lophitis[1]

**Affiliations**: [1]University of Nottingham, United Kingdom [2]University of Warwick, United Kingdom [3]University of Cambridge, United Kingdom

**P6 (14)** "*Analysis of 1st & 3rd Quadrant Electrothermal Robustness of Symmetrical and Asymmetrical Double-Trench SiC Power MOSFETs Under UIS"*

**Authors:** Mana Hosseinzadehlish[1], Saeed Jahdi[1], Xibo Yuan[1], Chengjun Shen[1], Yasin Gunaydin[1], Ian Laird[1], Olayiwola Alatise[2] and Jose Ortiz-Gonzalez[2]

**Affiliations:** [1]University of Bristol, United Kingdom [2]University of Warwick, United Kingdom

**P7 (15)** "*Impact of Electrothermal Bias Temperature Instability Stress on Threshold Voltage Drift of GaN Cascode Power Modules"*

**Authors**: Yasin Gunaydin[1], Saeed Jahdi[1], Xibo Yuan[1], Juefei Yang[1], Renze Yu[1] and Bernard Stark[1]

**Affiliations:** [1]University of Bristol, United Kingdom

**P8 (18)** "*Parametric nano-electrical analysis for SiC junctions of a packaged device"*

**Authors**: Rosine Coq Germanicus[1], Wadia Jouha[2], Niemat Moultif[2], Peter De Wolf[3], Vishal A. Shah[4], Peter. M Gammon[4], Ulrike Luders[1] and Olivier Latry[2]

**Affiliations:** [1]Normandie Université, UNICAEN, France [2]Normandie Université, UNIROUEN, France [3]Bruker Nano Surfaces, [4]University of Warwick, United Kingdom

**P9 (22)** "*An improved SiC-MOSFET model with focus on internal stray inductance and body diode stored charge for switching transients"*

**Authors**: Constantin-Lucian Radu[1], Ke Li[1], Petar Igic[1], Simon Shepherd[1], Annegret Wörndle[2], Christoph H. van der Broeck[2], Soroush Faramehr[1]

**Affiliations**: [1]Coventry University, United Kingdom [2]FEV Europe GmbH, Germany

**P10 (25)** "*TCAD Analysis of the Impact of the Metal-Semiconductor Junction Properties on the Forward Characteristics of MPS/JBS SiC Diodes"*

**Authors:** Marco Boccarossa[1], Alessandro Borghese[1], Luca Maresca[1], Michele Riccio[1], Giovanni Breglio[1] and Andrea Irace[1]

**Affiliations**: [1]University of Naples Federico II, Italy

**P11 (30)** "*On the Repeatability and Reliability of Threshold Voltage Measurements during Gate Bias Stresses in Wide Bandgap Power Devices"*

**Authors**: Arkadeep Deb[1], Jose Ortiz Gonzalez[1], Erfan Bashar[1], Mohamed Taha[1,2], Saeed Jahdi[3], Phil Mawby[1] and Olayiwola Alatise[1]

**Affiliations:** [1]University of Warwick, United Kingdom [2]Cairo University, Egypt [3]University of Bristol, United Kingdom

**P12 (31)** "*The challenges of determining the optimum transformation ratio for a triangular modulated dual active bridge converter"*

**Authors:** Olutayo Omotoso[1], Oleh Kiselychnyk[1], Richard McMahon[1], Philip Mawby[1], Pete James[2] and Michael Mawby[2]

**Affiliations:** [1]University of Warwick, United Kingdom [2]Lyra Electronics Ltd, United Kingdom

**P13 (32)** "*An Investigation of the Drain-Source Leakage Current Early Transients During HTRB Reliability Tests"*

**Authors:** Heaklig Ayala[1], Mohamed-Amer Karout[1], Jose Ortiz-Gonzalez[1], Olayiwola Alatise[1], Mohamed Taha[1,2], Phil Mawby[1] and Li Ran[1]

**Affiliations:** [1]University of Warwick, United Kingdom [2]Cairo University, Egypt

**P14 (37)** "*The optimisation of a 15 kV 4H-silicon carbide integrated gate commutated thyristor"*

**Authors**: Qinze Cao[1], Peter Michael Gammon[1], Arne Benjamin Renz[1], Luyang Zhang[1], Guy Baker[1], Marina Antoniou[1] and Neo Lophitis[2]

**Affiliations:** [1]University of Warwick, United Kingdom [2]University of Nottingham, United Kingdom

## 18:00 – End of the Poster Session

## 19:30: Gala Dinner – Chancellors Suite -Rootes Building, University of Warwick

# Day 2: Tuesday 20th of September 2022

**8:40 - Registration – The Slate, University of Warwick**

**9:20 – Keynote talk - *Paolo Bargiacchi (Senior Product Manager, Electrification) -McLaren Applied***

***"High Performance 800V Silicon Carbide Inverters for Automotive Applications: The Next Step in Electrification?"***

Abstract

With the automotive electric vehicle market rapidly maturing, OEMs are increasingly focusing their attention on integration and optimisation at a system level. In parallel, legislation is already developing past the basic requirement for zero tailpipe emissions and starting to introduce efficiency measures to determine the taxation of electric vehicles. The advancements being made in power electronics technology meet these requirements as an enabler for a variety of wider downstream powertrain system benefits. Migrating from Silicon IGBTs to Silicon Carbide MOSFETs results in higher efficiency and faster switching speeds, which in turn mean the battery, electric motor and cooling systems can all be optimised. 800V SiC inverters lead to vehicles with faster charging, higher efficiency and longer range – the next step in electrification.

Paolo Bargiacchi received his Master's in Mechanical Engineering from the University of Sheffield, before joining Jaguar Land Rover to work on powertrain research and development. Following on from powertrain R&D, he progressed to the propulsion planning division, defining the powertrain requirements for the next generation of JLR's vehicles and their transition to electrification. He has since worked in various roles defining future whole-vehicle products for JLR and Bentley Motors. He is now responsible for the development of electrification products at McLaren Applied, where he is helping deliver the next step in electrification; empowering customers to introduce new vehicle concepts and technologies that drive differentiation in the market.

**10:00 - Session 4: <u>Applications</u>**

**Session Chair: Dr Kimimori Hamada, Huawei Technologies, Japan**

**10:00** - **S4.1 (7)** "*Design of Medium-Voltage and Medium-Frequency Transformer for Solid State Transformers*"

**Authors:** Diang Xing[1], Qianyi Cheng[1], Yujie Zhang[1], Boxue Hu[1], Anant Agarwal[1], Jin Wang[1] and Robert Guenther[2]

**Affiliations:** [1]The Ohio State University, United States of America [2]GPEM LLC, United States of America

**10:20** - **S4.2 (16)** "*Analysis and Design of UCVB soft-switching buck-boost Converter for energy storage system*"

**Authors**: Qinlong Chen[1], Rishad Ahmed[1] and Christian Klumpner[1]

**Affiliations**: [1]University of Nottingham, United Kingdom

**10:40** - **S4.3 (29)** "*A Measurement of the Power Dissipated due to the Mutual Flux Linking Two Loosely Coupled Coils*"

**Authors:** Alexander Aujla-Jones[1], Juan Manuel Arteaga Saenz[1]; James Gawith[2] and Paul Mitcheson[1]

**Affiliations:** [1]Imperial College, United Kingdom [2]BumbleBee Power Ltd., United Kingdom

## 11:00 to 11:20 Break

**11:20 Session 5: <u>Converter Integration and Packaging</u>**

**Session Chair: Professor Wataru Saito, Kyushu University, Japan**

**11:20** - **S5.1 (17)** "*A Phase-change Material Integrated Power Module for Electric Vehicles with Enhanced Short-term Overcurrent Capability*"

**Authors:** Xu Zhang[1,2], Yaqing Ma[3], Li Ran[1], Jianfeng Li[3], Yuekang Du[3], Nikolaos Iosifidis[1], Philip Mawby[1] and Jianying Li[2]

**Affiliations:** [1]University of Warwick, United Kingdom, [2]Xi'an Jiaotong University, China [3]Zhuzhou CRRC Times Electric UK, United Kingdom

**11:40** - **S5.2 (34)** "*Influence of the SiC JFET Gate Impedance on the Off-State Voltage Balance in Cascode Configuration*"

**Authors:** Simon Mendy[1], Nereus Sunday Agbo[1]; Jose Ortiz Gonzalez[1] and Olayiwola Alatise[1]

**Affiliations:** [1]University of Warwick, United Kingdom

**12:00** - **S5.3 (36) "***A Low Inductance Power Module Packaging Design for High Performance Inverter Using SiC MOSFETS in Automotive Applications*"

**Authors**: Haiyong Wan[1], Marina Antoniou[1], Nikolaos Iosifidis[1], Shanqi Zhao[2] and Philip Mawby[1]

**Affiliations:** [1]University of Warwick, United Kingdom, [2]MacMic Science & Technology Co., Ltd, China

## 12:20 to 13:40 Lunch Break/Networking

### 13:40 - Session 6: Reliability and Robustness

**Session Chair: Professor Nando Kaminski, University of Bremen, Germany**

**13:40** - **S6.1 (3)** "*Cutoff Current Capability of SiC-MOSFETs with Parallel Connected Varistor under UIS Condition*"

**Authors:** Wataru Saito[1], Zaiqi Lou[1] and Shin-ichi Nishizawa[1]

**Affiliations:** [1]Kyushu University, Japan

**14:00** - **S6.2 (9)** *"Gate-damage safe failure-mode deep analysis under short-circuit operation of 1.2kV and 1.7kV power SiC MOSFET using dedicated gate-source / drain-source voltage depolarization and damage-mode optical imaging"*

Authors: Frédéric RICHARDEAU[1], Wadia JOUHA[1] and Stéphane AZZOPARDI[2]

**Affiliations:** [1]University of Toulouse, France, [2]SAFRAN TECH, France

**14:20** - **S6.3 (13)** "*Investigation of Repetitive Short Circuit Stress as a Degradation Metric in Symmetrical and Asymmetrical Double-Trench SiC Power MOSFETs"*

Authors**:** Renze Yu[1], Saeed Jahdi[1], Phil Mellor[1], Juefei Yang[1], Chengjun Shen[1], Li Liu[1], Olayiwola Alatise[2] and Jose Ortiz-Gonzalez[2]

**Affiliations:** [1]University of Bristol, United Kingdom [2]University of Warwick, United Kingdom

### 14:40 – Keynote talk - *Dr. Martin Rittner - Robert Bosch GmbH*

### "Automotive Power Module Qualification Guideline AQG324 – *Now with 'SiC-Inside'; and GaN Is on Its Way Ahead*

Abstract

The evolutionary history, recent work and results of the industry experts' working group founded within the ECPE are illustrated. In this so-called AQG 324 'Automotive Power Module Qualification Guideline' working group, qualification routines for power modules are under expert discussions and investigations for their later usage in automotive vehicles. Considerations take place, which existing routines are incomplete or which ones are missed from the perspective of automotive requirements and what has to be implemented newly to assure automotive high-level reliability and robustness demands.

Since the release of guideline version 3 in May 2021, the new SiC-appendix in the document now respects and describes the qualification requirements on SiC-based power modules in automotive drive inverter applications. Especially the needed adjustments for performing valid power cycle test routines and the extension of several well-established qualification routines to their 'dynamic

varieties' are worth to highlight. Although the descriptions of the SiC-appendix are under further fine-tuning and discussion for the upcoming document release, the ECPE working group now picks up additionally topics and tasks for GaN-based power modules. The demand on suitable and specific qualification routines – according to SiC – is identified meanwhile as urgent.

Dr. Martin Rittner is senior expert for power electronics assembly and interconnection technologies in the Corporate Research unit of Bosch. He studied Physics at the University of Stuttgart/Germany and received his diploma in Nuclear Physics in 1994. Afterwards he conducted his PhD thesis in the field of Semiconductor Physics at same university. Since working as research employee in the Corporate Research sector of Bosch in 2001, he attended several German and EU public funded projects in the field of electronics packaging and assembly technologies for automotive and power electronics applications. For the German automotive supplier industry, he is currently the chairman of the joint ZVEI-ECPE working group 'High Temperature and Power Electronics', and additionally he is the chairman of the ECPE working group 'Automotive Power Module Qualification Guideline (AQG324)'. In the year 2015, he rounded his academic skills by finalizing his economic studies and receiving the degree as Master of Business Administrations (MBA)

*This keynote talk is sponsored by our Gold Sponsor ESPEC.*

**15:20** - **Discussion – Wrap up with Keynote(s)/Sponsors and exhibitors**

**15:50** -**Closing**

**16:00 - End of the Workshop**