IEEE ENERGY CONVERSION CONGRESS & EXPO Nashville, TN | OCT.29-Nov.2

Tutorial Title

Reliability Requirements and Qualification of Automotive Power Semiconductors

Instructor Team

Prof Layi Alatise from the University of Warwick

Dr Jose Ortiz Gonzalez from the University of Warwick

Dr Don Gajewski from Wolfspeed

Abstract

Wide bandgap devices are increasingly penetrating the automotive market and are becoming prime candidates for implementation in automotive applications, whether in traction inverters or battery chargers. The mission profile of the traction inverter is a particularly aggressive one since the electrothermal stresses on the power devices vary significantly in amplitude and frequency as the motor drive goes through various stages of the drive cycle including acceleration, deceleration, stalling etc. Historically, the traction converter has been implemented using silicon devices where the performance and reliability is well known and understood. Application of WBG devices like SiC MOSFETs and GaN power devices in automotive applications requires understanding of the reliability and qualification procedures especially according to the automotive standard. SiC and GaN power devices have varying internal physics and modes of operation with vastly varying robustness and reliability performance compared to silicon devices. Given the sensitive nature of the application, these devices must pass stringent automotive reliability tests and guidelines defined by the Automotive Electronics Council (AEC), the Joint Electron Device Engineering Council (JEDEC-JC70) and the European Center of power electronics (AQG).
This tutorial aims to introduce the subjects related to

(i) **WBG device physics and operation**: This includes details of how these WBG devices differ from traditional silicon IGBTs and MOSFETs
(ii) **WBG device reliability and robustness**: This includes details on what aspects of these WBG technologies make them more or less robust than traditional silicon devices.
(iii) **Application specific reliability requirements**: This includes details of how to translate the mission profile of the application into stresses on the power devices. This is essential given the fact the devices used in electric chargers will be subject to very different electrothermal and thermo-mechanical stresses compared to devices in the traction converter or the load servicing dc/dc converter.
(iv) **Test methodologies and specifications**: This includes details of the circuits and systems used to implement these tests. Discussions will include the differences between standard end-of-line production tests, screening tests and qualification tests.Due to the nature of these WBG devices, some of these testing methodologies have to be adapted to the peculiarity of WBG device physics.

The testing circuits, equipment and facilities required to implement these tests will be discussed. At the end of the tutorial, it is intended that all attendees will become conversant with the reliability and robustness requirements of power devices used in automotive applications. The tutorial is a joint lecture delivered by power device experts from Academia (University of Warwick) and industry (Wolfspeed).

Instructor Biography

Layi Alatise (PhD, CEng, FIET, SMIEEE), is currently a Professor and Royal Society Industry Fellow in Power Electronics at the University of Warwick. He received the B.Eng. (first class Hons.) degree in electrical/electronic engineering and the Ph.D. degree in microelectronics and semiconductors from Newcastle University, Newcastle upon Tyne, U.K., in 2005 and 2008, respectively. In June 2008, he joined the Innovation R&D Department, NXP Semiconductors, as Development Engineer where he designed, processed, and qualified discrete power trench MOSFETs for automotive applications and switched-mode power supplies. In November 2010, he joined the University of Warwick as Science City Research Fellow to investigate advanced power semiconductor materials and devices for improved energy conversion efficiency. Since February 2019, he has been a Professor in Electrical Engineering with the University of Warwick, Coventry, U.K. He has led several EPSRC projects in Power Electronics and is currently working on an UK government funded Project with a major automotive manufacturer for the development of automotive powertrains based on Silicon Carbide traction inverters. He was a recipient of the 2021 best paper award in the IEEE Transactions in Industrial Electronics. He has the authored or co-authored more than 100 publications in journals and international conferences. Prof. Alatise is a Chattered Engineer, Fellow of the IET and a Senior member of the IEEE.

Dr Jose Ortiz Gonzalez, is currently an Assistant Professor at the UoW. He has worked Research Fellow in several EPSRC and Innovate UK projects at the UoW (UK) and the University of Vigo (Spain). His expertise is in power semiconductor device characterisation, reliability and condition monitoring in Power Electronics. He received his PhD from the UoW in December 2017 and is the author or more than 80 journal and conference papers. JOG has developed novel methodologies for assessing the threshold voltage instability of Silicon Carbide and Gallium Nitride power devices was awarded the 2020 IEEE Transactions on Industrial Electronics Outstanding Paper Award for the journal article “Performance and Reliability Review of 650 V and 900 V Silicon and SiC Devices: MOSFETs, Cascode JFETs and IGBTs”. JOG was a Researcher Co-Investigator on a major £1.2M EPSRC project and has worked in several collaborative research projects. He was part of the online training initiative Powerful Knowledge, together with Electronic Minds Ltd and has also developed strong industrial collaborations with companies like ChargePoint UK, AVL Powertrain Ltd and Bourns Ltd and he has worked on research projects involving Dynex Semiconductors UK Ltd, Turbo Power Systems UK Ltd, Amantys Ltd and Borgwarner UK. He is an associate editor of Elsevier Microelectronics 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