ISPSD 2020 – SHORT COURSE PROGRAM

Date **Sunday, September 13, 2020**
Venue **Virtual Zeremoniensaal**

13:00 Welcome
Prof. Ulrike Grossner, ETH Zurich

13:10 SiC Super Junction MOSFETs and SiC-IGBTs – State-of-the-art in High- to Ultra-High-Voltage SiC Power Devices
Dr. Yoshiyuki Yonezawa, AIST

14:10 GaN Power IC's: Technology, Dynamic Device Behavior and Design
Prof. Kevin J. Chen, Department of Electronic and Computer Engineering, The Hong Kong University of Science and Technology

15:10 Break

15:50 Silicon IGBTs and Fast Recovery Diodes for High Power Applications
Dr. Munaf Rahimo, MTAL

16:50 Electromagnetic-Circuit Modeling for Advanced Power Semiconductor Devices
Dr. Ivana Kovacevic-Badstübner, Advanced Power Semiconductor Laboratory, ETH Zurich

17:50 Break

18:00 Beyond the Limits of GaN HEMT Technology – Vertical GaN Transistors and Towards AlN Electronics
Dr. Oliver Hilt, Ferdinand-Braun-Institut, Berlin

19:00 End

SC1: SiC Super Junction MOSFETs and SiC-IGBTs – State-of-the-art in High- to Ultra-High-Voltage SiC Power Devices

Dr. Yoshiyuki Yonezawa, AIST

As a counter measure towards the global warming and growing demand of electricity for EVs and ICTs, a large introduction and control of renewable energy and storage, and energy savings are inevitable. Under the circumstances, the role of power electronics becomes more significant in the energy value chain. The evolution of power electronics (PE) has been supported by improvements in Si-IGBTs. But since these improvements have reached their physical limit for Si expectations for SiC devices are increasing. SiC has a ten times higher breakdown electrical field compared to that of Si. Thus despite having the same structure, it is expected that such SiC devices offer breakdown voltages (BVs) ten times higher. By replacing 600V to 3.3kV bipolar Si-IGBTs with unipolar SiC-MOSFETs, low conduction and switching loss which enables a higher operating frequency, thus results in a significant reduction in the size of the passive components, as well as the cost of the power electronics equipment.

Similar to the evolution of power devices in silicon, silicon carbide is now under investigation for more advanced high- to ultra-high-voltage power device structures such as SJ-MOSFETs and IGBTs. SiC super junction MOSFET (SJ-MOSFET) structures that can significantly reduce the on-resistance of the drift layer which is expected to break a SiC on resistance unipolar limit. Current SJ-MOSFETs under development range up to 6.5 kV. Furthermore, when the IGBT structure is applied to SiC devices, MOS-controlled switching devices capable of BVs exceeding 10 kV can be fabricated, which is difficult to obtain with Si devices.

In this course recent progress of these SiC SJ-MOSFT and SiC IGBTs are introduced as a next generation of high- to ultra-high voltage power devices for aiming at application of efficient usage of energies in electric distribution system toward low carbon emission society.

Dr. Yonezawa is a “Principal Research Manager” at National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan, Advanced Power Electronics Research Center. From 1989 to 2013 he was an engineer at Fuji Electric Co., Ltd. He has made research contributions in solid state laser system development, hard disk media, dielectric thin films for DC/DC converter, and SiC power devices, where he led the SiC group, then joined AIST in 2013. He was a visiting scholar at Stanford University from 1996 to 1998. His current research involves SiC high voltage SJ-MOSFET and ultra-high-voltage IGBTs and related fundamental technologies. He received his Ph.D. degree from Tokyo Institute of Technology in 2011, based on his work in SiC devices and solution growth of SiC crystal.

SC2: GaN Power IC’s: Technology, Dynamic Device Behavior and Design

Prof. Kevin J. Chen, Department of Electronic and Computer Engineering,
The Hong Kong University of Science and Technology

Over the past two decades, impressive technological advancements have been made in developing wide-bandgap gallium nitride (GaN) and related semiconductors that now find themselves in a wide range of high-volume commercial applications, such as in light-emitting diodes and lasers, high-frequency power amplifiers, and power switching devices. For power electronics applications, the planar GaN-based hetero structure devices such as HEMTs (high electron-mobility transistors) are especially attractive owing to their high electron-mobility in the hetero junction channel, their small terminal capacitances that benefit high-speed operations, and the proven suitability of their device-quality epitaxial materials on Si substrates for large-scale manufacturing. The planar nature of the GaN HEMTs also provides an inherent benefit of high-level integration, which is key to the development of power integrated circuits (ICs). This short course will focus on the following issues:

1) Integration technology: how to integrate multiple functional devices with cost-effective process
2) GaN-HEMT-specific dynamic behavior relevant to power IC design: systematic characterization and modeling of dynamic threshold voltage and dynamic OFF-state current
3) Examples of GaN power IC’s: Gate driver, over-current protection

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Prof. Chen received his B.S. degree from Peking University, China in 1988, and PhD degree from University of Maryland, College Park, USA in 1993. He has conducted R&D work on III-V high speed device technologies in NTT LSI Laboratories, Japan and Agilent Technologies, USA. Prof. Chen joined Hong Kong University of Science and Technology (HKUST) in 2000, where he is currently a professor in the Department of Electronic and Computer Engineering. Prof. Chen has more than 500 publications in international journals and conference proceedings and has served as a consultant to the semiconductor industry. He has been granted 12 US patents on GaN electron device technologies. His research is currently focused on developing wide-bandgap semiconductor device technologies for high-power and high-frequency applications

SC3: Silicon IGBTs and Fast Recovery Diodes for High Power Applications

Dr. Munaf Rahimo, MTAL

Silicon based high voltage semiconductor devices continue to play a major role in power electronics conversion, the field of traction, transmission and distribution, renewables and industrial applications. In particular, the Insulated Gate Bipolar Transistor “IGBT” and its companion, the fast recovery diode “FRD” have played a major role for enabling more compact, efficient and reliable systems due to the continuous improvements achieved at both device and package levels with respect to the power handling capability, losses and robustness. This development trend is set to continue for the foreseeable future with more advanced device concepts for matching the performance expectations of future power electronics systems in the high-power range.

The tutorial will begin with a brief introduction and historical background of the different power electronics devices and applications with special focus on the IGBT and FRD. This will be followed with the first main part of the tutorial covering the IGBT and starting with the device basic structure, physics and principle of operation under static, dynamic, safe operating area and fault protection conditions. The different device designs and performance trends with respect to the overall electrical characteristics will be explained while outlining the benefits for the targeted applications. The second part of the tutorial will cover the FRD and the session will be structured similar to that of the previous IGBT session. Furthermore, the final part will cover future IGBT and diode technology trends while outlining the potential impact such advanced components will have on the system level performance. In general, the tutorial will also attempt to provide an outlook into the future potentials of Silicon IGBT in particular when compared to the recent advances made for MOSFETs and diodes based on Silicon Carbide (SiC).

The tutorial is suitable as a general introduction for beginners into the field of IGBTs and FRDs. Experienced attendants can also benefit since the tutorial covers important design and development trends such as those related to losses, high safe operating area, and improved controllability.

Dr. Rahimo received his BSc in Electrical Engineering in 1990 at the College of Engineering, Baghdad University, Iraq, his M.Sc. in Electrical and Electronic Engineering with distinction in 1993 for his thesis entitled “Power Diode Switching Transients in GTO Circuits” and his Ph.D. in 1996 with the thesis entitled "Switching Characteristics of Fast Power Diodes in IGBT Circuits”, both at the School of Engineering, Staffordshire University, UK. He has a vast experience from 4 different companies, including the position as ABB Power Grids Corporate Executive Engineer; the highest technical corporate position in ABB. In 2018, he founded MTAL GmbH, Switzerland, focusing on consulting and start-up activities in the field of power devices and applications. Dr. Rahimo currently has more than 28 years of accumulated experience in the field of power semiconductor devices and applications with more than 90 patents families to his name, 50 of which have patent grants. He has authored and co-authored over 150 journal/conference papers and has given many international tutorials and workshops. He is a Member of the IoP / Charted Physicists (UK) and IET / Charted Engineer (UK) and Senior member in the IEEE.

SC4: Electromagnetic-Circuit Modeling for Advanced Power Semiconductor Devices

Dr. Ivana Kovacevic-Badstübner, Advanced Power Semiconductor Laboratory, ETH Zurich

With the faster switching capabilities of advanced power semiconductor devices and higher power densities, the electromagnetic aspects of power electronic systems increase in importance and rise the attention towards the system optimization considering the design of interconnections, the placement of components and their mutual couplings. The software tools enabling the simultaneous modeling of semiconductor devices and electromagnetic system behavior have been frequently used in both industry and academia to evaluate and gain a better understanding of the currents and voltage waveforms of power electronic systems. Electromagnetic modeling problems in power electronics applications frequently set the requirements to solve Maxwell's equations in a wide-frequency range from dc to high frequencies (MHz-GHz) in an accurate and computationally efficient way. The state-of-the-art EM solvers are commonly specialized for either low-frequency (LF) or high-frequency (HF) simulations.

This short course will discuss the modelling capabilities of the state-of-the-art software tools dedicated for LF and HF modeling as ANSYS Q3D Extractor and ANSYS HFSS, respectively, focusing on the characteristics of the numerical solvers being used. Furthermore, the existing ways to export electromagnetic models in circuit simulators will be described in terms of accuracy and computational cost. The modeling capabilities will be demonstrated on the selected examples of the power electronic circuits implementing WBG power semiconductor devices. Finally, promising numerical techniques for power electronics applications allowing virtual prototyping in an efficient and accurate way are going to be reviewed.

The course is intended for all audiences interested in the virtual characterization of advanced power electronics systems implementing WBG power devices.

Dr. Ivana F. Kovacevic-Badstübner received the Dipl.Ing. degree from the Faculty of Electrical Engineering, Department for Electronics, the University of Belgrade, Serbia, in 2006 (with Hons.) and the M.Sc. and Ph.D. degrees in Electrical Engineering and Information Technology from the Swiss Federal Institute of Technology (ETH Zurich), Switzerland, in 2008 and 2012, respectively. From 2008 to 2012, she was a Ph.D. student in the Power Electronic Systems (PES) laboratory at ETH Zurich. From 2012, she continued as Post-Doctoral researcher and further as project scientist in the PES Laboratory working on the lifetime modeling of power semiconductor modules, the multi-domain modeling and optimization of power electronic systems and components, and the prediction of electromagnetic behavior of power electronics circuits based on the developed numerical techniques. In March 2016, she joined the Advanced Power Semiconductor Laboratory at ETH Zurich. Her research interests include novel packaging technologies for SiC devices, the optimization of power module layout with respect to electromagnetic interference, and multi-domain modelling of power semiconductor devices and their modules.

SC5: Beyond the Limits of GaN HEMT Technology – Vertical GaN Transistors and Towards AlN Electronics

Dr. Oliver Hilt, Ferdinand-Braun-Institut Berlin

GaN power switching transistors for blocking voltages up to 900 V became commercially available in the last decade and they excel in particularly low gate charge and a low output capacitance. The associated low switching losses are the key to power converters with increased power density and operating at higher switching frequencies. But drawbacks related to the GaN-on-Si hetero-epitaxy being used and the lateral device concept still keep the devices from reaching their theoretical material limits and introduce additional dispersion-related losses during high-voltage switching operation. Furthermore, the lateral device concept comes to its limits above 1 kV and for currents beyond 100 A.

Re-thinking the nitride-based material stack may overcome the current GaN HEMT performance limitations. An AlN-based lateral HEMT technology shows advantages in terms of current density as well as in terms of dispersion and it has strong potential for the next generation lateral device technology. The lecture will discuss concepts, challenges in device fabrication and present device results.
Extending GaN transistor technologies to voltages > 1 kV favors a shift to vertical device architectures. Different vertical device concepts are currently explored for high-voltage GaN switches. Their pros and cons will be presented together with device results. These are set into relation to competing devices based on SiC and to first Ga_2O_3 device results.

Dr. Hilt received his Ph.D. in Experimental Physics from the Free University Berlin, Germany in 1995 for his work on the charge transport in liquefied rare gases, performed at the Hahn-Meitner-Institut Berlin. He analyzed charge transport in organic conductors and semiconductors for optoelectronic applications at Technical University Delft and University Leiden, both The Netherlands. In 1999 he joined sglux GmbH, Berlin to develop UV photodiodes and promoted to CEO in 2003. Dr. Hilt joined FBH in 2006 for the development of GaN switching transistors for high voltage power applications. He is currently head of the GaN Power Electronic Devices Lab and his work focuses on integration technologies for compact GaN-based power conversion and on explorative ultra-wide bandgap power switching devices.