TCAD and physical modeling for failure and aging mechanism investigations on GaN-on-Si transistor for power electronic applications

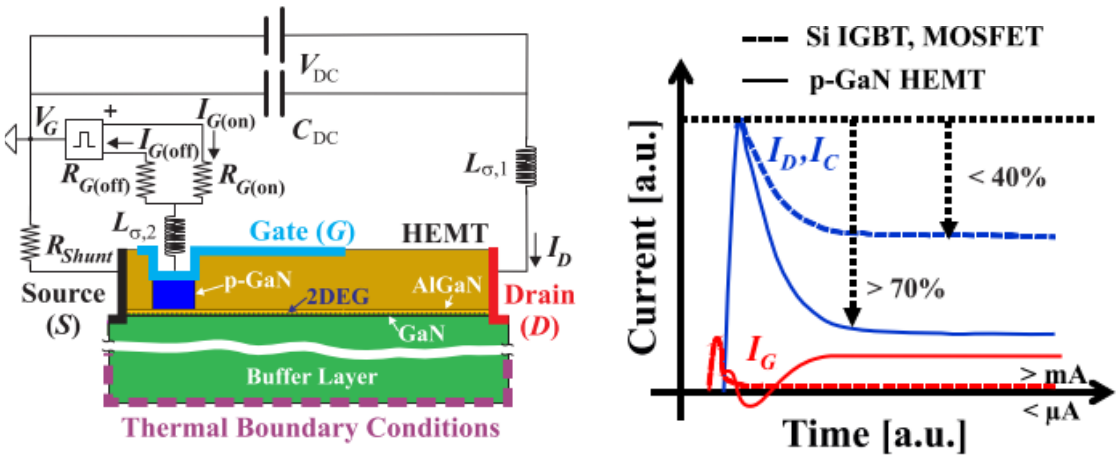
2024 – 2027 PhD Scholarchip – University of Toulouse

Overview of the subject

"Urgent climate action can secure a liveable future for all" [1].
Electrification of energy is critical for decarbonization and reduction of greenhouse gas emissions, with an increasing role of electricity as an energy carrier. Renewable energy, transportation, smart home, etc, require therefore efficient and reliable power electronics. Wide band-gap power semiconductors like GaN high electron mobility transistor (HEMT) for energy conversion suit many of these applications and attract more and more interests. Nevertheless such advanced technologies will require to reach high reliability levels over a long-time use to growth as a real alternatives and to break lifespan records, necessary to be truly sustainable.

Reliability investigation and fundamental understanding of the physical phenomenon are required today to advance and mature wide band-gap power electronics. Due to their lower maturity and intrinsic properties, defects and interfaces play a major role in these novel materials and need to be understood in the point of view of reliability and failure mechanisms. Functional extreme conditions, like short circuit caused by faulted gate-control, steady state or switching transient over-voltages, as well as nominal and accelerated cycling stress condition needs to be addressed. Physical modeling is paramount to achieve these goals [2].

In this PhD topic, you will construct physical and TCAD electro-thermal models based on experimental characterizations of GaN-on-Si transistors. The proposed work relies on the use of state-of-the-art semiconductor simulators and eventually extend the capability of open source tools. Rapid developments in this area will be continuously monitored [3]. You will assess spatial distribution of physical quantity like the density of the two dimensional electron gas or electric field in various operating conditions like off and on state as well as transient behavior for hard and soft switching conditions by following a progression of increasing complexity. You will evaluate physical models and eventually improve them. You will interact with technology and reliability experimentalists to support your modeling work that will be based on already available results and analysis and you will guide future experimental explorations. For example, technological dimensions and analysis will be available through a current partnership with Thales and CNES neighbor laboratories. You will innovate in reliability physics modeling and understanding while mastering GaN power component physics.



Left figure: Physical structure of a GaN power device to be modeled connected to a power circuit for short circuit test from [2].
Right figure: Typical waveforms during short circuit operation from [2]

References

[1] Intergovernmental Panel on Climate Change (IPCC),March 20, 2023, https://www.ipcc.ch/2023/03/20/press-release-ar6-synthesis-report/
[2] M. Fernández et al., "P-GaN HEMTs Drain and Gate Current Analysis Under Short-Circuit," in IEEE Electron Device Letters, vol. 38, no. 4, pp. 505-508, April 2017, doi: 10.1109/LED.2017.2665163.
[3] Z. Stanojević, J. M. González-Medina, F. Schanovsky, and M. Karner, "Quasi-Fermi-Based Charge Transport Scheme for Device Simulation in Cryogenic, Wide Bandgap, and High-Voltage Applications," IEEE Transactions on Electron Devices, vol. 70, no. 2, pp. 708–713, Feb. 2023, doi: 10.1109/TED.2022.3232321.

Required background

Master's degree in electrical engineering, electronic, physics or material scientist, with a solid background in semiconductor physics and interest in power electronics.

Starting date and funding

PhD position is opened for September/October 2024.
Public Doctoral contract.
Gross monthly salary: 2100 € + possible teaching stipend at University.
https://www.enseignementsup-recherche.gouv.fr/fr/le-financement-doctoral-46472

Localisation and Supervision

The PhD student will be mainly located in the "Laboratoire d'Analyse et d'Architecture des Systèmes" (LAAS-CNRS), in Toulouse, France. He/She will be working in the ISGE team in collaboration with CS team in "Laboratoire Plasma et Conversion d'Energie" (LAPLACE / CNRS – INP Toulouse).

Applications have to be sent by mail at: the supervisor Dr. David TRÉMOUILLES - david.tremouilles@laas.fr and co-supervisoir Dr. Frédéric Richardeau - frederic.richardeau@laplace.univ-tlse.fr
The application will include a complete CV, a motivation letter, transcripts of Master 1 and 2, references and 2 recommendation letters.