Postdoctoral Position Offer – 12 months – 2026–2027 at Lab. LAPLACE.

Development of a 2D multiphysics simulation model of a GaN HEMT power transistor in the COMSOL simulation environment.

Application to the study of thermal, metallurgical, and thermomechanical stresses under extreme functional short-circuit conditions.

1) Context and Objectives

Originating from the radio-frequency domain, wide bandgap gallium nitride power transistor technology of the “high electron mobility transistor” (GaN HEMT) type is emerging as an essential solution for low- and medium-voltage (<1000 V) power conversion, at very high switching frequencies (>500 kHz) and very high efficiency (>0.98). Such performance is unparalleled and already enables power densities of 15 kW/kg or even higher, depending on the power level, cooling mode, and at highly competitive cost. Despite advances both in fundamental research (device physics, component architecture) and technological development (fabrication, reliability, and industrialization), very few generic and open physical and multiphysics simulation models are currently available for designers and system integrators. Such models are nevertheless essential to evaluate protection margins and, more generally, device robustness levels under extreme high-temperature stress conditions in accidental situations such as short circuits. A sufficient level of robustness is also required to certify components in many critical application sectors, particularly in embedded systems. These models are TCAD–FEM based and enable physically grounded, geometrically localized, and time-resolved diagnostics of: thermal stress fields (temperature maps), metallurgical effects (dynamic solid–liquid melting front of metal electrodes) and mechanical stresses (incremental cracking and dielectric layer failure).

As illustrated in Figures 1 and 2, lateral GaN HEMT structures exhibit strong inhomogeneity in electric field and current density distribution, leading to highly localized hot spots that may trigger thermal runaway. The stacking of heterogeneous GaN/Si_3N_4 (nitride) layers and metallic field plates also produces differential deformation at interfaces, causing delamination at corners, cracking, and in some cases material lift-off. Only advanced FEM tools allow such mechanisms to be analyzed and quantified. The knowledge gained also supports technology-level reverse design at the materials level to enhance robustness under single intense stress or cyclic moderate stress.

Building on substantial experience developed since 2020 on SiC MOSFETs (*), we propose extending this work to GaN HEMT power devices, supported by a significant experimental results database [3] and in connection with ongoing PhD research on electrical TCAD Sentaurus™ simulation [4].

The central objective of the postdoctoral project is to develop a family of multiphysics models within the 2D COMSOL™ FEM environment for a 100 V / 90 A / 7 mΩ Schottky-gate p-GaN device whose structure and main physical parameters are known [3]. The targeted objectives are: 1) develop a strongly coupled transient electro-thermal and metallurgical model calibrated against existing experimental results, 2) develop a weakly coupled transient thermo-mechanical model driven by previous results, 3) develop an insulating layer cracking model (Rankine energy model) and an interface decohesion model (CZM). Consideration of electromechanical piezoelectric coupling effects is also envisioned, as well as the influence of trapped charge distribution in the AlGaN barrier beneath field plates. These studies should lead to relevant correlations between experimentation (degradation modes) and simulation (physical stress levels), enabling extraction of critical times and critical energy densities under single intense short-circuit stress. This work will result in syntheses and publication of results in leading specialized conferences (ESREF in Europe and IEEE IRPS worldwide) as well as in specialized journals (IEEE and Microelectronics Reliability).

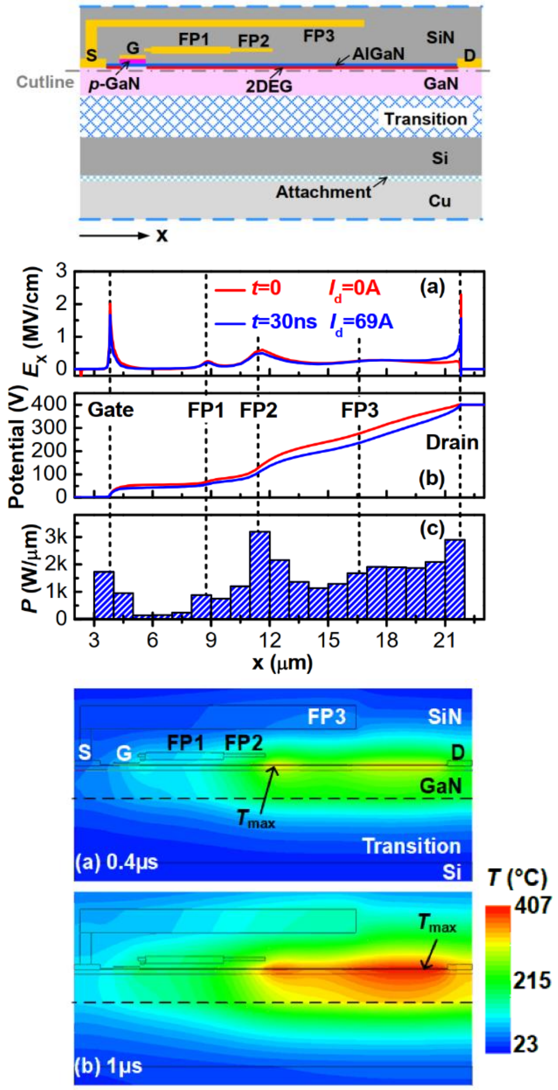

Fig. 1 2D physical structure of the GaN HEMT device, example of lateral distribution of the electric field, potential, and power density. Relation with the transient temperature map under short-circuit conditions. [1] J. Sun, J. Wei, Z. Zheng and K. J. Chen, "Short Circuit Capability Characterization and Analysis of p-GaN Gate High-Electron-Mobility Transistors Under Single and Repetitive Tests," in *IEEE Transactions on Industrial Electronics*, vol. 68, no. 9, pp. 8798-8807, Sept. 2021, doi: 10.1109/TIE.2020.3009603.

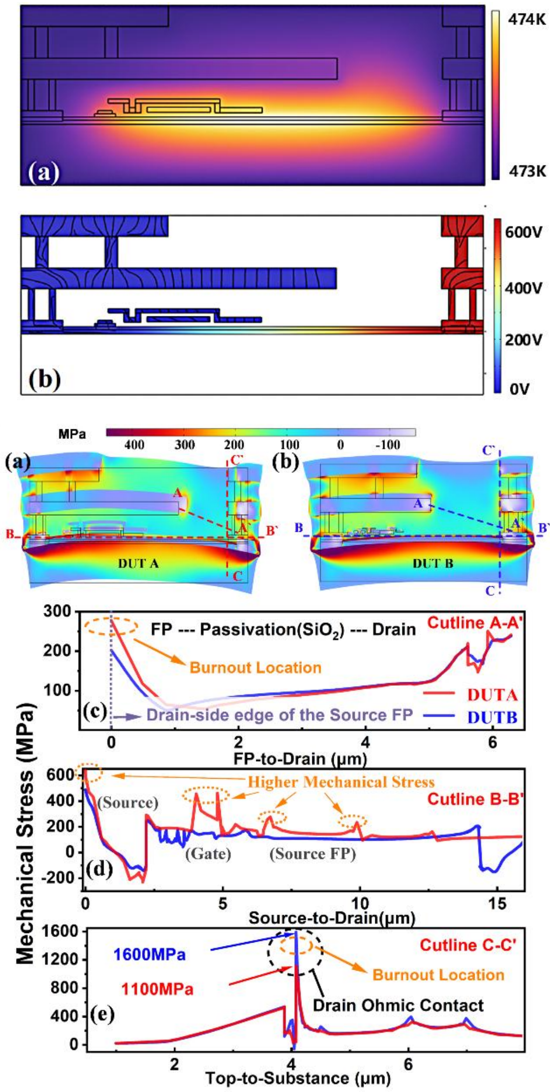

Fig. 2 Example of simulation of thermomechanical deformation and stress field within a GaN HEMT device at 200 °C. [2] J. Zhou *et al*., "Comparative Investigation on Robustness of 650-V p-GaN Gate HEMTs Under HTRB Beyond 150 °C and Device Failure Mechanisms," in *IEEE Transactions on Electron Devices*, vol. 73, no. 1, pp. 215-222, Jan. 2026, doi: 10.1109/TED.2025.3639009.

[3] PhD dissertation by Lucien Ghizzo, LAPLACE – LAAS – THALES – CNES, September 18, 2024, https://theses.fr/2024TLSEP061

[4] Etude en régime extrême du modèle de simulation physique 2D d'un transistor de puissance p-GaN HEMT, Mémoire de PFE Master Recherche de Nora Essobai Meftah, 30 août 2024, LAAS-Laplace (only French text).

(*) As examples and references for the methodology of previous work conducted on SiC MOSFETs, the following sources may be consulted:

https://hal.science/hal-04074503v1

https://hal.science/search/index/?q=mustafa+shqair&rows=30&sort=publicationDate_tdate+desc

2) Scientific Profile Sought

We are seeking a candidate in the final year of a PhD or already holding a PhD in: semiconductor device physics and technology (RF or power), materials science, solid-state physics applied to electronic components, ideally with experience in wide bandgap GaN HEMT technology. Candidates may have either an experimental or TCAD–FEM simulation background. Experience or skills in COMSOL™, TCAD Sentaurus™, or Silvaco™ would be an asset. Curiosity, rigor, and strong motivation to join a high-impact research project with strong dissemination potential (publications and future projects) are expected.

PhD Topic Also Available
Open PhD Position - Starting September 2026
Dates and Period Adaptable During Interview

3) Location, Supervision, and Practical Information

Lab. LAPLACE – ENSEEIHT - FRANCE site, Static Converters research group.

Supervisors: Dr Frédéric Richardeau – CNRS, Toulouse University,
frederic.richardeau@laplace.univ-tlse.fr
and Dr Emmanuel Sarraute – Toulouse University – Jean Jaurès, Toulouse INP,
emmanuel.sarraute@laplace.univ-tlse.fr

Regular interaction with the PhD work of Nora Essobai Meftah (LAAS–LAPLACE co-supervision with Dr David Trémouilles - CNRS).

Postdoctoral salary negotiable depending on experience acquired during the PhD.

4) Recruitment Process

Step 1: Submit a detailed CV (maximum 2 pages) including names of scientific referees and previous internship supervisors (cover letter not required at this stage).

Step 2: Pre-selection and interview (with cover letter).

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