Advances in III-N Materials and Devices for Power and RF Applications

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Abstract:
Wide- and ultra-wide bandgap III-N semiconductors are promising for RF and power electronics, particularly for applications requiring operation at high power levels or in harsh environments. Achieving the ultimate performance limits of devices in these materials requires both advancements in our understanding of the material properties, as well as innovations in device design. At the device design level, we find that the use of polarization grading in RF HEMTs can decrease the peak electric field in the channel, increase the breakdown voltage, and improve the power scaling of III-N HEMTs, without the use of field plates that limit high-frequency performance; experimentally-validated power-added efficiency of 50% at 94 GHz has been achieved. For high-power vertical GaN devices, high-field operation is often limited by edge effects; we report a strategy for edge termination that provides a large process window that is tolerant of both fabrication processing and epitaxial layer thickness and doping variations, and enables robust avalanche operation to be achieved in practice. At the materials level, the ultimate limit of high-field operation in III-N devices is governed by impact ionization, but high-field transport in these materials is not fully understood. Our recent progress in characterizing and exploiting impact ionization and avalanche effects in GaN and AlGaN will be discussed. In addition to providing fundamental limits on breakdown voltage, the ability to harness impact ionization and avalanche for device functionality is also critical for avalanche photodiodes and negative-resistance oscillators such as IMPATT diodes. We report the demonstration of experimentally-measured negative resistance at microwave and mm-wave frequencies from GaN-based IMPATT diodes, and the performance potential of ultra-wide bandgap AlGaN IMPATTs and FETs for power applications.

Bio:
Patrick Fay is the Stinson Professor of Nanotechnology and Professor of Electrical Engineering at the University of Notre Dame. He received a Ph.D. in electrical engineering from the University of Illinois at Urbana-Champaign in 1996. His research focuses on the design, fabrication, and characterization of microwave and millimeter-wave electronic devices and circuits, power device design and fabrication, as well as the use of micromachining techniques for the fabrication of RF through sub-millimeter-wave packaging. He established the High-Speed Circuits and Devices Laboratory at Notre Dame, as well as oversaw the design, construction, and commissioning of the 9000 sq. ft. class 100 cleanroom housed in Stinson-Remick Hall at Notre Dame, where he has served as the director of this facility since 2003. Prof. Fay is a fellow of the IEEE, is an IEEE Electron Devices Society Distinguished Lecturer, and has published 11 book chapters and more than 400 articles in scientific journals and conference proceedings.