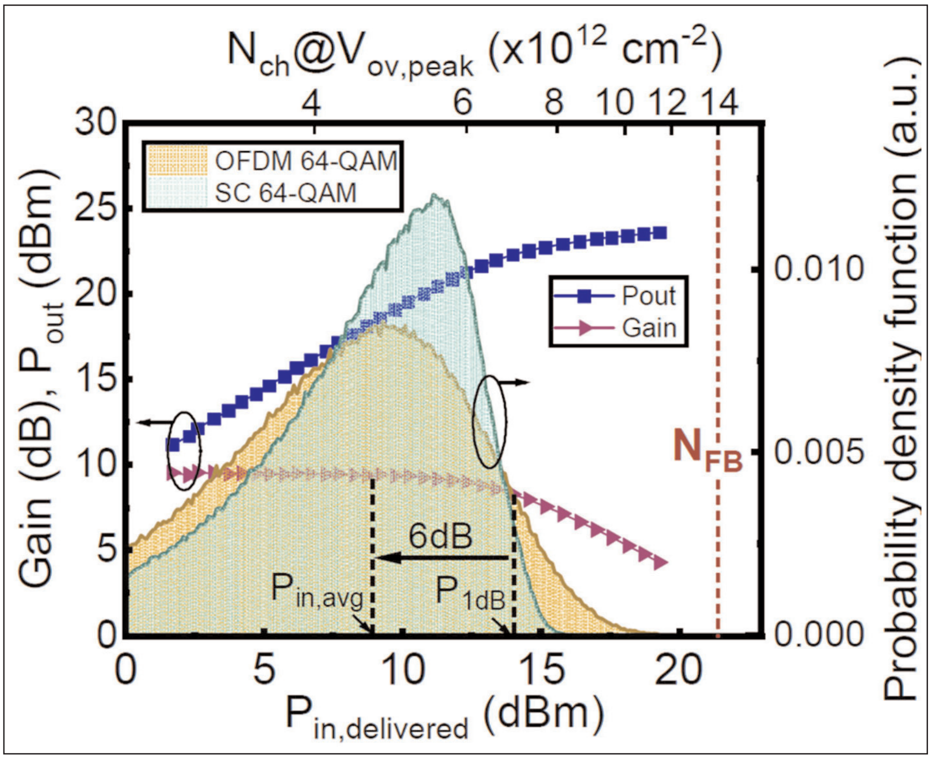
Imec identifies stable operating range for GaN MISHEMTs in RF power amplifiers

Findings support GaN-Si's potential for high-reliability 5G+/6G communication systems.

At the IEEE International Reliability Physics Symposium (IRPS 2025) in Monterey, CA, USA (30 March–3 April), nanoelectronics research center imec of Leuven, Belgium demonstrated that, despite their positive bias (on-state) instability, gallium nitride MISHEMTs (metal-insulator-semiconductor high-electron-mobility transistors) maintain consistent performance when operating within a well-defined range. These findings support the design of reliable GaN-based power amplifiers to avoid positive bias instability and thus enable handset applications for 6G communication.

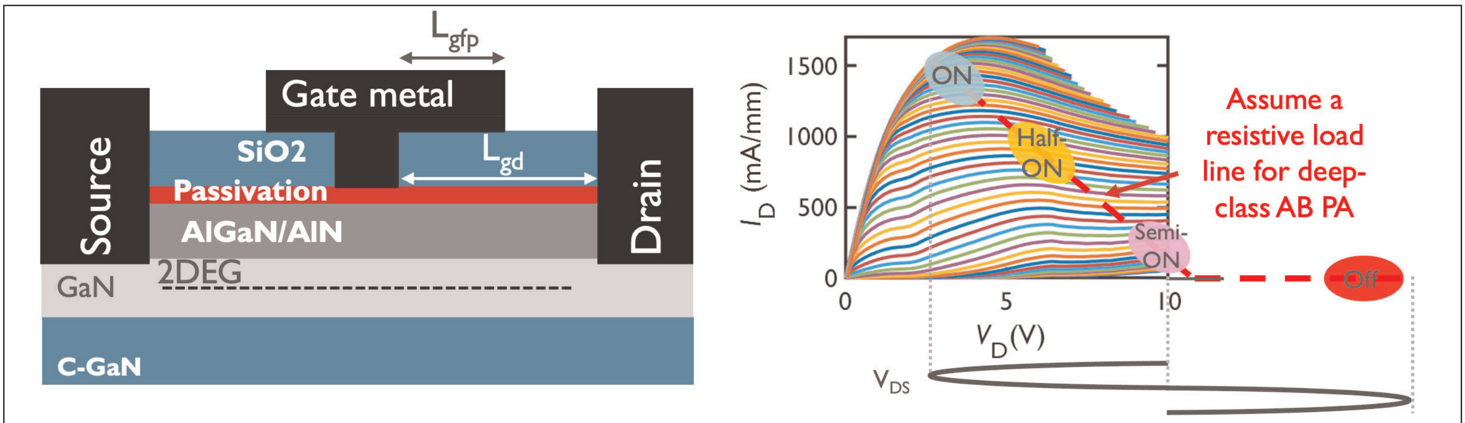


Simulated probability profiles indicating the operational range of a power amplifier. The region where Nch<NFB is the safe operating range of a MISHEMT PA without on-state Vth instability concern.

GaN MISHEMTs are being explored for use in 5G+/6G RF systems due to their excellent efficiency and power-handling capabilities. However, these devices face challenges, particularly with positive gate bias instability (ΔV_{th}), where shifts in the threshold voltage under certain conditions can affect the performance and long-term reliability of the power amplifier. Gate bias instability in GaN MISHEMTs is a complex and largely unexplored phenomenon that can occur in the different operational states — off, semi-on, and on state— each exhibiting distinct instability mechanisms. Moreover, its role in the power amplifier operation has not been widely studied, partly because traditional RF power amplifiers typically use gallium arsenide (GaAs) heterojunction bipolar transistors (HBT) or high-electron-mobility transistors (HEMTs) without a dielectric gate.

To bridge this gap, imec introduced a pragmatic analytical approach that directly compares a stable range of gate voltages in DC conditions with the actual gate modulation range in the RF power amplifier operation. Their analysis reveals a strong overlap between these two ranges, confirming that GaN MISHEMTs remain stable within the typical voltage swing of RF power amplifiers. This allows linearly operating power amplifiers to be designed that avoid a ΔV_{th} concern.

"Our research goes beyond identifying challenges. It offers practical solutions, demonstrating that GaN



	Aarti	Yi (NYCU)	Amratansh	Hao
Application	High-voltage	High-voltage	High-voltage	Low-voltage
III-N stack	AlGaN/AlN/GaN	AlGaN/AlN/GaN	AlGaN/AlN/GaN	AlGaN/AlN/GaN
Bias state	Semi-on	On, semi-on, off	Half-on	On
Features	Small-signal RF vs DC measurement	3-state current collapse	High degradation	Evaluate PBTI concerns (or not) with gate modulation analysis of MOSHEMT/MISHEMT
	GaN cap vs SiN	MISHEMT vs HEMT	High-power state	
	L_{gd}, L_{gfp} dimension effect	SiN thickness	Spacer, recess, MIS, passivation	

(Top left) Schematic of the MISHEMT device, and (top right) critical stress states during power amplifier operation. (Bottom) Comparison of the four papers presented at the 2025 IEEE IRPS conference from imec's advanced RF program in collaboration with professor Tian-Li Wu's team at NYCU.

MISHEMTs can be reliably used in power amplifier applications for 5G+/6G technology," says Hao Yu, principal member of the technical staff at imec. "By integrating fundamental device reliability research with real-world RF system assessments, our team at imec is bridging the gap between theoretical studies and practical applications, ensuring that GaN technology can meet the demands of next-generation communication systems."

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The researchers also show that the presence of naturally occurring positive interfacial polarization charges at the material interface plays a key role in preventing unwanted shifts in operating voltage over time. This finding is significant because it highlights a unique feature of GaN MISHEMTs that makes them more immune to on-state threshold voltage (V_{th}) instability compared with other gate dielectric contained devices, such as MISFETs. Simulations further demonstrate that, even under real-world RF input signals, the on-state V_{th} instability is mitigated. These combined insights provide crucial guidance for designing robust, high-performance power amplifiers.

The research was presented as a highlight at the 2025 IEEE IRPS conference, alongside three complementary papers from imec's advanced RF program in collaboration with professor Tian-Li Wu's team at Taiwan's National Yang Ming Chiao Tung University (NYCU). These additional papers delve into fundamental research, exploring different degradation mechanisms and reliability challenges of GaN HEMTs and MISHEMTs under various stress conditions, including semi-on, off and half-on states, and for both high- and low-voltage applications. Together, they contribute to a comprehensive understanding of GaN-Si device performance, believes imec.

"We are very glad to work on the reliability evaluation and degradation analysis in RF GaN MISHEMTs with imec since reliability is the key bottleneck toward the successful commercialization," says Wu. "Through this collaboration, we are able to address the challenges in the industries with cultivating the talents for advanced semiconductor R&D." ■

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