Vertical Gallium Nitride FinFETs for RF Applications

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From wireless communication systems like 4G and 5G cellular services that enable 4K video streaming, to the high-resolution radars that are vital to national defense, RF systems have become a ubiquitous part of modern life. A fundamental building block within these systems is the RF power amplifier. As amplifier technology progresses, the relentless demand for improved performance necessitates new transistor technologies be developed that are capable of operating at higher power levels and over larger bandwidths. While traditional planar processing techniques have led to countless successful RF amplifiers, the fact that all conduction takes place very near the wafer's surface fundamentally limits their performance. Instead, by utilizing a compact vertical transistor design, the bulk material can be used to withstand large voltages in the vertical direction as opposed to lateral designs that need large device areas. Additionally, bulk conduction improves thermal spreading, therefore reducing cooling needs, and vertical gate patterning techniques trade expensive high-resolution lithography for relatively easy etch depth control.

This work presents a vertical GaN RF transistors. As shown in the cross-sectional diagram in Figure 1(a), the vertical GaN RF finFET consists of narrow fins to confine the current and has sidewall gates to modulate the conductivity within the fins. To enable high frequency system integration, these devices were fabricated on sapphire, a highly insulating substrate, with a top-side drain contact to remove the need for through-wafer vias. To reduce costs and allow easier integration with existing technology, the same devices can be fabricated on GaN on Si as well. An SEM cross section of a fabricated device is shown in Figure 1(b) . These devices achieve a current density of over 7 kA-cm^{-2} and a power gain cut-off frequency, $f_{max,}$ of 5.9 GHz, demonstrating a promising first step toward vertical GaN transistors in RF applications.

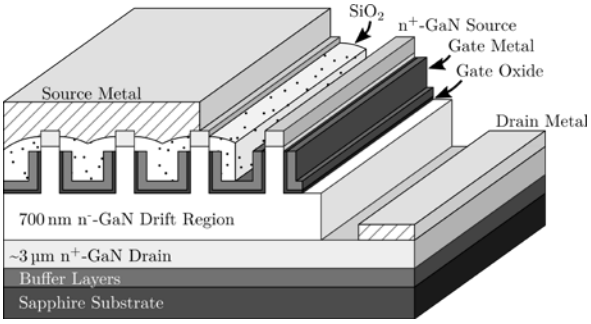

Figure 1: Cross-sectional schematic of the vertical GaN RF FinFET.

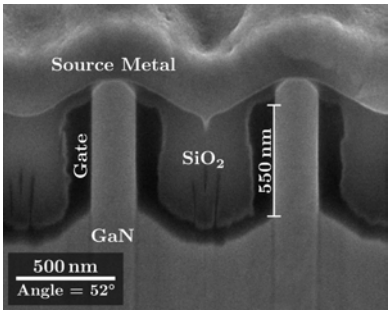

Figure 2: Scanning electron microscope cross-section of the fabricated devices taken in a focused ion beam system.

Further Reading

- Y. Zhang *et al.*, "Large Area 1.2 kV GaN Vertical Power FinFETs with a Record Switching Figure-of-Merit," *IEEE Electron Device Lett.*, vol. 3106, no. c, pp. 1–1, 2018.
- M. Sun, Y. Zhang, X. Gao, and T. Palacios, "High-Performance GaN Vertical Fin Power Transistors on Bulk GaN Substrates," *IEEE Electron Device Lett.*, vol. 38, no. 4, pp. 509–512, Apr. 2017.