Transient Thermal Analysis of GaN-Based Transistors for High-Power Applications

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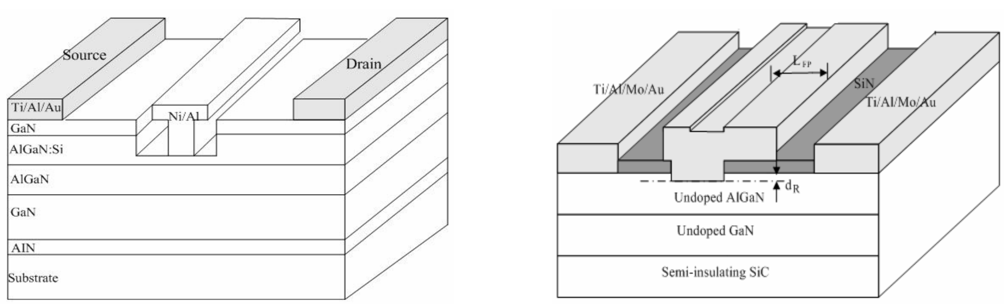
Nowadays, Gallium Nitride (GaN) and GaN-based materials have gained much interest for applications in high-power electronics, which are capable of operating at high temperature and frequencies. Compared to other semiconductors, GaN-based active devices have many advantages, such as wide bandgaps, high electron saturation velocity, good thermal stability, and strong breakdown field strength.

However, due to the high operating temperature and power where the GaN-based transistor applied, self-heating effects must be investigated thoroughly, because the increase in temperature will decrease the channel electron mobility and the maximum drain current, increase the gate leakage, and degrade the performance of transistors seriously.

In this work, the transient thermal investigation of GaN-based heterojunction field-effect transistors (HFETs) was carried out based on the nonlinear Finite Element Method (FEM), where the pulsed-bias electrical sources are approximately replaced by an equivalent pusled thermal source in the gate channel. Using our developed nonlinear FEM code, the temperature increase and heat transfer into the each substrate layer of the GaN HFETs are characterized, including two gate recessed configurations, as shown in the Figs.1(a) and 1(b), respectively. In our simulation, the effects of temperature-dependent thermal conductivities of GaN and the other substrate materials, such as sapphire, silicon, and SiC, are all treated appropriately using Newton-Raphson iterative method. The maximum temperature of the device versus input power and time are captured and compared, under two bottom and top-side cooling schemes, respectively.



(a) (b)

Fig.1. The geometries of two gate recessed GaN HFET devices.