

Review

Joint Use of Thermal Characterization and Simulation of AlGaN/GaN High-Electron Mobility Transistors in Transient and Steady State Regimes to Estimate the Hotspot Temperature

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Abstract: Channel temperature has a strong impact on the performance of a microwave power transistor. In this paper, various methods, including electrical measurements, optical analysis, and FEM simulations, were employed to perform both transient and steady-state thermal characterization of GH15 $2 \times 150 \mu\text{m}$ transistors from UMS foundry (United Monolithic Semiconductors, France). The transient study allowed for the extraction of thermal time constants according to which the temperature in the transistor changes. The steady-state study provided the hotspot temperature. As the channel is physically inaccessible, direct thermal measurement at the hotspot is not possible, in order to extract the temperature of this hotspot, different measurement methods are combined by simulation, which is calibrated based on the measurements, resulting in a well-adjusted thermal model. This calibrated model enabled the extraction of temperature at any location within the device's structure, particularly at the hotspot. The measurement and simulation results have shown that the hotspot temperature can be 30% higher than the temperature of the nearest external surface for high dissipated power levels.

Keywords: GaN HEMT; thermal; thermorefectance; simulation; gate-to-gate thermometry



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1. Introduction

GaN-based high-electron mobility transistors (HEMTs) are used in various fields of application, including military and space domains. These devices provide significant advantages for power and high-frequency applications due to the intrinsic properties of their materials. This is particularly true when utilizing “power-dedicated substrates” like silicon carbide (SiC) or diamond [1,2]. In the long term, we could also imagine using carbon nanotubes, which offer high thermal conductivity and robustness against temperature fluctuations [3]. Such materials enable their use in diverse fields, including microwave power amplification and power electronics. However, the GaN HEMTs can deliver very high power densities, resulting in thermal energy dissipation. In radar applications, object detection relies on receiving signals reflected from targets. These reflected signals originate from a modulated pulse train emitted by the radar source. A signal pulse train with a duration of τ allows the rest of the period to be used for detecting echoes from the detected targets. To reach distant targets, the pulse signal is transmitted with high energy. This increases the significance of thermal effects, which can impact system stability and degrade detection quality [4]. Thus, temperature reliability is critical to determine the choice of the GaN HEMT device and the architecture of the power amplifier.

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