GaN Unleashed: The Benefits of Microfluidic Cooling

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Abstract

This paper will compare measured RF performance of a GaN high power amplifier (HPA) cooled conventionally via remote cooling versus an embedded microfluidic cooling approach. It will be shown that embedded cooling directly beneath the base of the die is not only compatible with RF operation, but that it greatly improves thermal and RF performance. The thermal and RF benefits of embedded cooling will be quantified in terms of reduced junction temperature, and the corresponding increases in gain, output power, and efficiency when compared to the conventionally cooled die. Detailed computational fluid dynamics simulations will also be shown to compare very favorably with measured data.

INTRODUCTION

Modern GaN RF amplifiers are capable of operating at far higher power levels than can be supported by existing thermal management techniques. Conventional thermal management techniques, termed "remote cooling", limit the allowable RF output power to levels far below the inherent electrical capabilities of the chip when suitably cooled. In addition to reducing operating life, elevated junction temperatures reduce the gain and output power of RF amplifiers and degrades efficiency considerably. The RF impact is evident in the performance degradation often seen when comparing short pulse, short duty cycle results to longer pulse, longer duty (or even continuous) results. The thermally induced performance degradation becomes even more pronounced when GaN HPAs are packaged into tactical systems, with their non-ideal thermal paths and relatively large thermal resistances between chip and heat sink.

In order to fully utilize the potential of GaN, improvements must be made to existing thermal management techniques. Embedded microfluidic cooling, utilizing a compact jet-impingement based microfluidic manifold, has recently been shown to dramatically reduce operating temperatures or, alternatively, maintain the same junction temperatures for significantly higher die heat fluxes [1-2]. This paper will extend these results by comparing measured RF performance of a GaN HPA cooled conventionally via remote cooling versus the ICECool embedded microfluidic cooling approach. The thermal and RF benefits of embedded cooling will be quantified in terms of reduced junction temperature, and the corresponding increases in gain, output power, and efficiency. Detailed computational fluid dynamics simulations will also be shown to compare very favorably with measured thermal and pressure drop measurements.

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ACRONYMS

HPA: High Power Amplifier.