GaN Technology for Radars

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***Abstract* — Microwave GaN technology is now in production and poised to revolutionize many of today's radar and communication systems. Simultaneously, mm-wave GaN processes are rapidly being matured to meet the growing needs of high power and efficiency, at higher frequencies. In this paper, we present an overview of GaN development, focusing on reliability and affordability for defense applications.**

***Index Terms* — GaN, gallium nitride, microwave devices, MMICs.**

I. INTRODUCTION

Historically, performance improvements afforded by new microwave semiconductor technologies such as GaAs MESFETs and PHEMTs have been evolutionary, resulting in incrementally more power density, gain, or noise figure. Gallium Nitride (GaN) technology, however, is truly revolutionary, resulting in dramatic (>5X) improvements in RF power density. The revolutionary power improvements afforded by GaN are now being realized in state-of-the-art monolithic microwave integrated circuits (MMICs) assembled in Transmit/Receive (T/R) modules, enabling the next generation of radar and communication systems.

High power semiconductors play an important role in radar performance. In a phased array radar, the RF energy is distributed to each element, phase shifted and then amplified before being radiated. The final amplification of the RF signal at each element is performed by the power amplifier. Traditionally, gallium arsenide (GaAs) has been the semiconductor of choice for efficiently amplifying this signal, creating the desired output power. Throughout the 1990's, Raytheon and others pioneered the insertion of GaAs-based MMICs into phased array radars, providing enabling capabilities. As the performance requirements of these military systems have increased to meet the ever growing threats, so too have the power and efficiency requirements for the power amplifiers. Over that time, GaAs performance was stretched from the unit power density of 0.5 watt per millimeter of transistor periphery to 1.5 W/mm by increasing the drain voltage from 5V to 24V. GaN, however, continued to make dramatic performance improvements, quickly surpassing GaAs capability (Table 1).

Today, with the development of microwave GaN complete, the power, efficiency and bandwidth performance of GaN-based MMICs is unsurpassed, revolutionizing the design of radars by creating not only higher performance but also lower system cost. With over 5 W/mm of power density, GaN RF amplifiers can provide more than 5X the power per element of GaAs, in the same square millimeter area footprint. Fewer high power GaN MMICs can be used to replace many low power GaAs MMICs, or alternatively, equal power GaN chips can be made dramatically smaller than their GaAs equivalent. Both approaches reduce overall system costs while enabling size-constrained systems. The higher drain current that GaN offers makes the broadband matching of high power MMICs simpler and more efficient than GaAs, while the 7-8X improvement in the thermal conductivity enables amplifier cooling. This higher efficiency at high power, combined with better thermal dissipation, is a game changer for solid state electronic warfare systems. Finally, the wide band gap intrinsic to GaN material provides large critical breakdown fields and voltages, making a more robust amplifier, which eases T/R module and system implementation.

Table 1. GaN vs. GaAs Comparison

Parameter	GaAs	GaN
Output power density	0.5 – 1.5 W/mm	4– 8 W/mm
Operating voltage	5 – 20 V	28 – 48 V
Breakdown voltage	20 – 40V	> 100V
Maximum current	~ 0.5 A/mm	~1 A/mm
Thermal conductivity (W/m-K)	47	390(z)/490 (SiC)

This talk will review the advances in GaN device development, starting in the 1990's with the first transistor to its production status today. DC Arrhenius reliability data and RF operating life measurements of Raytheon's microwave process will also be presented. Finally, sample MMIC designs will be reviewed, along with system insertion considerations, including cost and thermal constraints.