Success story: GaN circuit research → radar and electronic warfare products

Microwave circuit research on GaN HEMT Technology and MMIC design between Saab AB and Chalmers has produced publications, 7 PhDs (yr 2012) and several state-of-the-art MMIC designs. MMIC circuit designs have then successfully been transferred to the soon to be released GaN process GH25 at UMS and then integrated into the next generation transmit-receive modules intended for future AESA-based radar and electronic warfare systems.

"GHz Centre, and its predecessor CHACH, has offered an important possibility to gain early design experience in an emerging semiconductor technology even before it is commercially available. The lead time in introducing this new technology into several new systems has thus been shortened by several years." **Johan Carlert, Manager Technology Strategies & MMIC design, Microwave & Antennas, Saab AB**

Research Chalmers-Saab:


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An AlGaN/GaN HEMT-Based Microstrip MMIC Process for Advanced Transceiver Design

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***Abstract*—A MMIC process in AlGaN/GaN technology for advanced transceiver design has been developed. The process is based on microstrip technology with a complete model library of passive elements and AlGaN/GaN HEMTs. The transistor technology in this process is suitable for both power and low noise design, demonstrated with a power density of 5 W/mm, and an NF_{min} of 1.4 dB at X-band. Process stability of subcircuits, complementary to power amplifiers and LNAs, in a transceiver system have been investigated. The results indicate that an all AlGaN/GaN MMIC transceiver is realizable using this technology.**

***Index Terms*—Amplifier, gallium nitride (GaN), mixer, monolithic microwave integrated circuit (MMIC), switch.**

I. Introduction

WIDE-BANDGAP electronics show great potential to become the next generation of solid-state technology for high-power microwave applications. With power densities far beyond that of traditional technologies, i.e., GaAs pseudomorphic HEMT (pHEMT) and Si LDMOS, and high efficiencies [1]–[3], AlGaN/GaN-based circuits are well suited for radar and base-station systems.

AlGaN/GaN HEMT-based high-power microwave electronics have been extensively researched over the past years. Power amplifiers in code division multiple access (CDMA) operation at 2 GHz [4], [5], as well as monolithic microwave integrated circuits (MMICs) operating at Ka-band [2], [3], [6] have shown excellent performance. The high power-handling capabilities also makes GaN suitable for receiver electronics where the high component breakdown voltage makes the circuits inherently robust [7]–[10]. The high linearity of circuits based on AlGaN/GaN HEMTs also ensures a high dynamic range of the receiver electronics [11]. The demonstration of low-loss switches in AlGaN/GaN technology [12] indicates the possibility to fabricate entire transceivers on one chip.

The combination of high power density, high efficiency, moderate noise figure, and robustness opens up new possibilities in the design of radar transceivers. For example, even though the noise figure of GaN technology is inferior to that of an optimized GaAs pHEMT, the overall transceiver noise performance may be much improved over the GaAs implementation. This is possible since the robustness of a GaN-based low-noise amplifier (LNA) may facilitate the omission of limiter/protection circuitry in the receiver path.

To realize multifunction chips, process repeatability and uniformity are essential. Demonstrator circuits have been fabricated using an in-house process, which represent transceiver functions such as transmit/receive (T/R) switches, wideband gain blocks, and mixers. The output power and low noise performance of the in-house technology are demonstrated by load–pull and noise-figure measurements. The results indicate that a fully integrated transceiver is feasible.

In this paper, we present a GaN MMIC process in detail (process, uniformity), together with a set of transceiver MMIC fabricated on the same epi-wafer in the same batch. This comprehensive presentation of both process and MMIC results facilitates assessment of a fully integrated GaN transceiver.

II. MMIC Process

The research is based on the previous development of an in-house SiC MMIC process [13]. As the substrate technology and electrical requirements of SiC MESFETs and AlGaN/GaN HEMTs are similar, a common back-end process is feasible.

The transistor is fabricated using an AlGaN/GaN heterostructure grown on semiinsulating SiC. The material is supplied by commercial vendors (Cree Inc., Durham, NC, and NTT-AT, Tokyo, Japan) and through the Korrigan project [14]. The epi-structure consist of a 25-nm $Al_{0.25}Ga_{0.75}N$ layer on top of a 2-μm undoped GaN buffer on semiinsulating SiC. This structure typically results in a sheet carrier density of $1.0 \cdot 10^{13}$ cm^{-2} and a mobility of 1200 cm^2/Vs according to Hall measurements.

The photo lithography is made using an ASML PAS 2500/40 stepper modified for processing of 2- and 3-in wafers, giving an overlay accuracy of 150 nm and a resolution of 0.7 μm.

The HEMT is defined and isolated through mesa etching using a chlorine-based inductively coupled plasma (ICP) reactive ion etching (RIE) process. The source–drain separation

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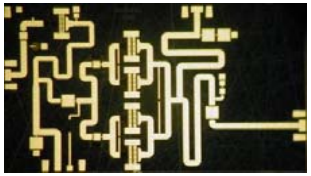
MMIC high power amplifier design by Saab and Chalmers, and processed in the GH25 process at UMS



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