KORRIGAN: Development of GaN HEMT Technology in Europe

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Abstract

This paper reports on the joint multinational initiative KORRIGAN launched in 2005 to accelerate the development of independent GaN HEMT foundries in Europe. The project addresses several key research areas such as materials, processing, reliability, thermal management and advanced packaging solutions. The benefits of GaN technology will be evaluated at system level with the fabrication of circuit, MMIC and module demonstrators. The project is supported by the MOD of seven nations and is primarily dedicated to defence applications. The KORRIGAN consortium consists of major European system houses and research laboratories, under the lead of Thales Airborne Systems, providing all the necessary competence for the establishment of the future GaN HEMT supply chain.

INTRODUCTION

Defence radar and communication systems as well as wireless communication systems have a drastic need for increased RF performance and particularly for high power, high efficiency, high linearity and low-cost monolithic amplifiers operating in the 1-40 GHz frequency range. Mainstream III-V solid-state technology, mainly GaAs and more recently SiGe devices, and alternative solutions such as vacuum tubes, fall short of satisfying these requirements simultaneously. Therefore there is an increased interest in newer wide band-gap materials, which can potentially fulfil these requirements thanks to superior inherent material properties including high breakdown electric field, high electron mobility and saturation carrier velocity, and high thermal conductivity. The higher breakdown electric field allows operation at higher voltages, which means that for the same power level, much higher matching impedances, lower power recombination losses in multi-transistor amplifiers and better energy efficiencies at lower circuit complexity will be possible. The intrinsic high thermal stability of the material should allow operation at higher temperatures, requiring less stringent (and less expensive) thermal management solutions for the packaging of high power amplifiers. Also thanks to the very high power-density of GaN devices, there is a real necessity to evaluate the technology reliability and to explore packaging and heat sink solutions, which will provide optimum thermal management.

During the past decade, GaN HEMT technology has attracted considerable interest and rapid and impressive progress has been made mainly in the US and Japan in the development of GaN materials and GaN-based processes and devices [1-3]. The GaN semiconductor materials show a large potential for high power amplification at microwave and millimetre-wave frequencies [4-6]. Adequate MMIC integration technologies are now available on different types on substrates [7-9]. Also, GaN power HEMTs should ultimately show very high reliability due to the chemical inertness of the material and very high robustness and low sensitivity to space radiation, due to the large breakdown field and temperature stability.

KORRIGAN BACKGROUND

KORRIGAN is a large-scale European joint Research and Technology Project performed within the EUROPA framework and targeting CEPA2 objectives aiming at the development of microelectronics components.

Seven nations are contributing to KORRIGAN: France also acting as the MOD management group, Italy, The Netherlands, Germany, Spain, Sweden and the United Kingdom. The KORRIGAN consortium, placed under the lead of Thales Airborne Systems (France), consists of 29 partners from the 7 contributing nations providing all the necessary competence in all key areas dedicated to semiconductor technologies such as substrate growth, device processing, circuit design and modelling, circuit packaging and integration. Also, in order to increase the project efficiency, the KORRIGAN consortium will share a very large number of test equipment, as well as characterisation and evaluation means.

KORRIGAN OBJECTIVES

The main objective of KORRIGAN is to develop a stand alone European supply chain and capability for GaN

HEMT technology which will provide all major European defence industries with reliable state-of-the-art GaN foundries services.

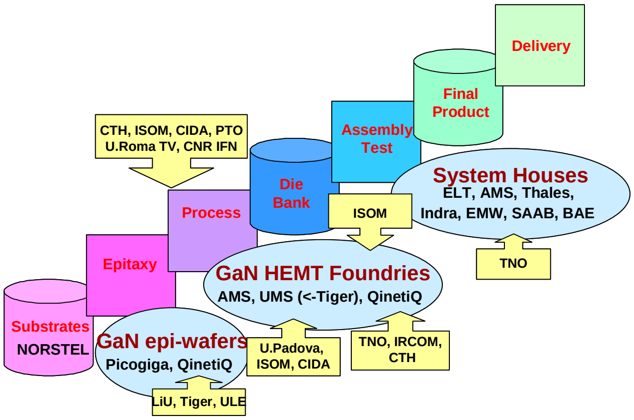

Fig. 1. European supply chain for GaN HEMT process.

For that purpose, there are four major technical objectives:

- To establish a European supply chain for the manufacture of GaN HEMT devices and MMICs.
- To assess the reliability and reproducibility of existing GaN device technologies within Europe in order to identify preferred processing options.
- To demonstrate the technology and the supply chain through the fabrication and testing of selected demonstrators for key S-band, X-band and wide-band applications.
- To evaluate the benefit of the technology at system level.

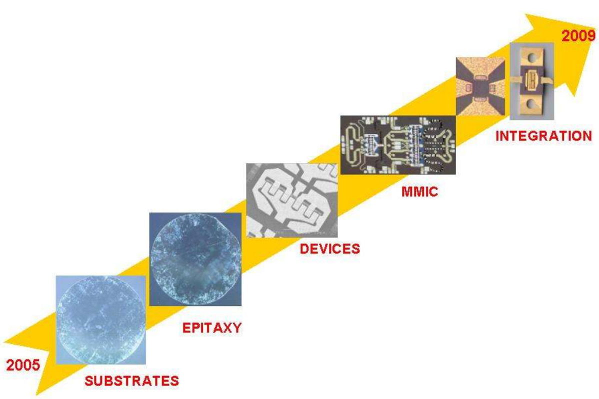

Fig. 2. GaN HEMT technology development roadmap.

METHODOLOGY AND WORK PLAN

In order to successfully achieve the project goals and enable the development of leading GaN technology at the horizon of 2009, an integrated methodology has been set-up and the project has been organised into 4 subprojects dedicated to materials, device and circuit processing technologies, reliability evaluation, thermal management and packaging solutions. Several demonstrators will be designed to validate GaN technology for various applications: S-band HPA, X-band and wideband HPA, LNA and switches.

A. Materials

Wideband gap semiconductor substrates will provide the foundation for the GaN HEMT technology. Silicon Carbide (SiC), Sapphire and Silicon materials will be considered, with a stronger focus on the growth of bulk crystal of SiC subtrates using HTCVD techniques. Substrate diameter expansion will be a key issue to ensure the economic maturation and to guarantee cost-effective industrial access to the technology. Also for each material, several types of epitaxial growth using both MBE and MOCVD techniques will be studied and characterised using a common approach.

B. Processing

The development activities will aim at establishing the access to a global manufacturing process of GaN HEMT devices and MMICs on SiC, Silicon and Sapphire substrates. The work packages will cover the development of main technological aspects of circuit manufacturing including: generic technologies for active devices and passive circuits; design and manufacturing of devices; design and manufacturing of MMICs; and extraction of models from DC-RF characterisation. A common PCM will be exploited.

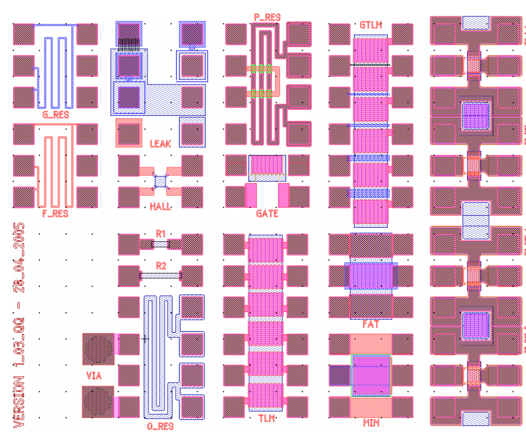

Fig. 3. KORRIGAN PCM.

C. Reliability

The work is focused on the assessment of GaN technology regarding reliability aspects. Work packages will include: the study of parasitic effects, such as current collapse, which result from trapping effects occuring in the substrate; the systematic evaluation of the long-term reliability of GaN HEMT devices and passives; the identification and understanding of failure mechanisms based of the analysis of failed devices; and the evaluation of device robustness to extreme operating regime.

D. Thermal management and packaging

The objective of this subproject is to develop the suitable thermal environment for the use and integration of GaN power devices if current systems. The work will address the following issues: the design of optimised thermal cells and the improvement of heat sinking efficiency by reducing the device thermal resistance; the study of advanced assembly solutions and power packages; the simulation of the thermal environment of devices and circuits.

LIST OF PARTNERS

The KORRIGAN consortium consists of 29 partners, including 19 industrial companies and reseach laboratories, and 10 universities:

THALES AIRBORNE SYSTEMS, France
THALES RESEARCH AND TECHNOLOGY, France
THALES AIR DEFENCE, France
CNRS, France
IEMN, France
PICOGIGA International, France
XLIM, France
SELEX SISTEMI INTEGRATI, Italy
ELETTRONICA, Italy,
CNR IFN, Italy
INFM-NNL LECCE, Italy
UNIVERSITY OF ROMA - TOR VERGATA, Italy
POLITECNICO DI TORINO, Italy
UNIVERSITY OF PADOVA, Italy
UMS, Germany
THALES NAVAL NEDERLAND, The Netherlands
TNO, The Netherlands
ERICSSON MICROWAVE SYSTEMS AB, Sweden
CHALMERS UNIVERSITY, Sweden
LINKÖPING UNIVERSITY, Sweden
NORSTEL, Sweden
SAABTECH, Sweden
INDRA, Spain
CIDA, Spain
UNIV. POLITECNICA MADRID-ISOM, Spain
SELEX SENSORS & AIRBORNE SYSTEMS, UK
BAE SYSTEMS INSYTE, UK
THALES DEFENCE LIMITED, UK
QINETIQ, UK

CONCLUSIONS

The KORRIGAN consortium is the largest organisation ever established in Europe for research in the field of microelectronics. The success of the project will be guaranteed by a very high degree of cooperation between partners relying on the use of common test plans, PCM and design strategies, and on the sharing of characterisation equipment. Such a large-scale project anticipates the future EDA organisation of research in Europe.

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ACRONYMS

EDA: European Defence Agency
HEMT: High Electron Mobility Transistor
HPA: High Power Amplifier
LNA: Low Noise Amplifier
MBE: Molecular Beam Epitaxy
MMIC: Microwave Monolithic Integrated Circuit
MOCVD: Metal-Organic Chemical Vapor Deposition
MOD: Ministery Of Defence
PCM: Process Control Monitoring