ECSEL Joint Undertaking

Electronic Components and Systems for European Leadership


# Advanced RF Transceivers for 5G base stations based on GaN Technology

**Project Acronym:** 5G_GaN2
**Type of action:** ECSEL-RIA
**Start date of the project:** 01/06/2018
**Duration of the project:** 36 month
**Grant agreement (GA) number:** 783274

## January 2020 – Newsletter #1

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This project has received funding from the ECSEL Joint Undertaking (JU) under grant agreement No 783274. The JU receives support from the European Union's Horizon 2020 research and innovation programme and France, Germany, Slovakia, Netherlands, Sweden, Italy, Luxembourg, Ireland.

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## Content



## Consortium members

United Monolithic Semiconductors

cea

ERICSSON

mpg. molecular plasma group

STU SLOVENSKÁ TECHNICKÁ UNIVERZITA V BRATISLAVE

Benetel

FAB MIXED-SIGNAL FOUNDRY EXPERTS

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Università degli Studi di Padova

UCD DUBLIN

MEC

sencio functional packaging center

III-V lab

SweGaN

THALES

TESAT SPACECOM

# Introduction

The fifth generation (5G) communications technologies will provide internet access to a wide range of applications: from billions of low data rate sensors to high resolution video streaming. The 5G network is designed to scale across these different use cases and will use different radio access technologies for each one.

To support very high data rates 5G will use wide bandwidth spectrum allocation at mm-wave frequencies. The offered bandwidth at the mm-wave frequencies (above 24 GHz) is more than 10 times as large as that in the lower bands (sub 6 GHz). However, the move to mm-waves comes at a cost – increased path loss. This makes it extremely challenging to provide coverage at mm-wave frequencies.

A partial remedy is to use beamforming to direct the radio energy to a specific user. For some deployment scenarios beamforming is not enough and the output power must also be increased. A major challenge is to bring affordable, high-performance mm-wave active antenna arrays into production. There is currently a market pull for this systems but there exists a capability gap.

5G_GaN2 project will substantially lower the cost and power consumption, and increase the output power of mm-wave active antenna systems. The maximum output power and energy efficiency results will be possible thanks to the use of advanced Gallium Nitride (GaN) technology. In addition, low-cost packaging techniques for digital applications will be further developed to reach the cost and integration targets.

The capabilities of the developed technology will be shown in a set of demonstrators. The application driven demonstrators will be used to guide the technology development towards maximum impact and exploitation in the post project phase. The consortium spans the complete value chain: from wafer suppliers, semiconductor fabrication and system integrators. In addition, key universities and research institutes guarantees academic excellence throughout the project.

# Project objectives

The final goal of the project is to demonstrate the capability to integrate heterogenous microwave dies in a single package. To reach this goal, the project is divided in work packages, which cover various activities such as:

o Definition of specifications at system level
o Development of front-end technology (integrated circuit, die)
o Development of back-end technology for System in Package (the die assembly)
o Design of circuit and modelling of transistor
o Manufacturing and evaluation of demonstrators

# Project progress

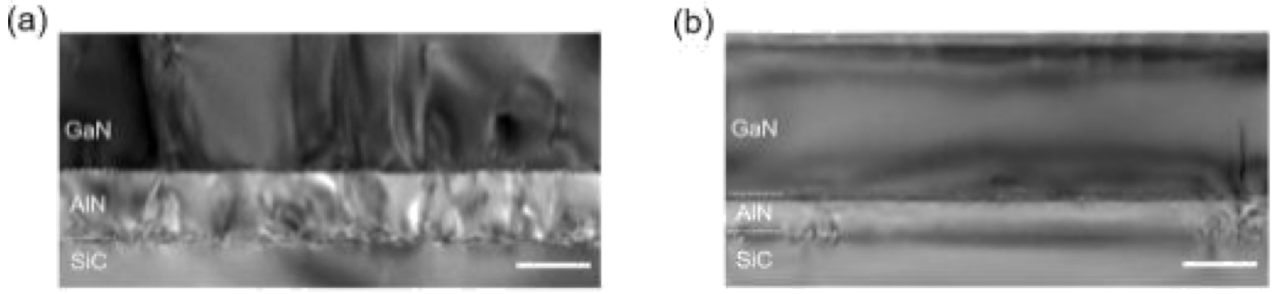
## Definition of specifications at system level

5G mm-wave base station system demonstrator properties have been defined and sub-system requirements have been specified. Document defines 5G mm wave BTS demonstrator specification from die to SIP (System in Package) level. The report contains specifications for Front-End architecture and active antenna system architecture with very accurate figures. The subsystem analysis includes detailed electrical, RF (Radio Frequency), environmental and SiP specifications resulting into devices performance requirements. The definitions of the demonstrator vehicles, which are to be tested as part of manufacturing and evaluation objective were provided.

# Project progress

## Development of front-end technology

SweGaN company plans to deliver AlGaN-based epiwafers to UMS and IAF and InAl(Ga)N-based epiwafers to III-V Lab. In particular, SweGaN supplies its revolutionary GaN-on-SiC buffer-free HEMT heterostructures, QuanFINE™ to the 5G_GaN project for the consortium to evaluate. The QaunFINE™ structure has a clear merit in terms of a low thermal resistance, which is considerably lower than that of standard GaN-on-SiC HEMT heterostructures. This primarily results from the SweGaN proprietary grain-boundary-free AlN nucleation layer, which can be seen in the Figure below. On top of that, the AlN nucleation layer also effectively serves as a back barrier in the QuanFINE™ structure since it is followed by a thin GaN channel layer directly. As a result, the entire HEMT heterostructure has no intentional carbon or iron doping. But the vertical breakdown voltage (Vb) has no compromise.




TEM images of the Conventional (left) and SweGaN QuanFINE™ GaN-on-SiC interface.

LETI company has managed to optimize the AlGaN barrier layer on Si to achieve required specifications, and also identified a buffer and back barrier combination which is compatible with RF applications and with flat CMOS compatible wafers. The largest part of the current work is therefore the optimization and reduction of losses in the silicon substrates occurring due to growth processes.

# Project progress

## Development of back-end technology for System in Package

Details of the requirements and targets of the SiP (system in package) solutions have been evaluated. QFNP (Quad Flat No-leads package) has been specified as most suitable packaging for Ka-band SATCOM applications at 30 GHz, where thermal and shielding management will be the main challenges to address. On the other hand, FOWLP (Fan-out wafer-level packaging) is considered for 5G BTS at 30 GHz. The main challenges of this solution are thermal and stress management (especially molding-induced stress during process integration and while operating).

Different moisture-sensitive materials have been selected to assess the hermetic properties of coating layers in a second step. WN has been selected for 200 mm line at LETI, and WTiN for 100 mm line at UMS. Then, coatings from MPG have been assessed during thermal humidity storage at 85°C and 85% RH.

The tests performed during this study evidenced that a complete solution by using only atmospheric plasma cannot be used as moisture protection for microchip devices. Density of coatings achieved by using such methods are not sufficient to protect the substrates from humidity, especially regarding the gas and water vapor barrier effect. In conclusion, there are potentially efficient solutions for moisture protection coatings applied on RF devices, for instance a combination of an organic buffer layer with a highly compliant ALD coating. However, the simplified test protocol for their assessment is not suitable, because protection layers can act differently as a function of the layer on which it is deposited (interface issue, microstructure…). Therefore, the implementation of protection layers has to be achieved as much as possible on real devices, in order to focus on the real issues and to be able to properly characterize it.

# Project progress

## Design of circuit and modelling of transistor

First design iteration of MMIC circuits on all MMIC technologies including GaN/SiC have been done. Consequential report summarizes the main performances of the MMICs circuits in the frame of the 5G-GAN2 project. The following Table presents the summary of MMIC designs.

MMIC Table Summary

| Function | Process | Designed by | Status |
|---|---|---|---|
| **T/R switch for 39-GHz FEM SiP** | ***45-nm RF SOI (LETI)*** | ***LETI*** | ✓ |
| **E-Band GaN/SiC MMIC Amplifier** | ***GaN10 (IAF)*** | ***IAF*** | ✓ |
| **Power Amplifier – SATCOM down link** | ***GH15 (UMS)*** | ***MEC*** | ✓ |
| **Power Amplifier + switch – SATCOM up link** | ***GH15 (UMS)*** | ***UMS*** | ✓ |
| **High Efficiency Power Amplifier for 5G BTS** | ***GH15 (UMS)*** | ***ERICSSON*** | ✓ |

Each device meets the criteria defined within the project demands. The simulation results of E-Band GaN/SiC MMIC Amplifier clearly show that the present technology allows for a competent high-power E-band PA design, successfully meeting the minimum design specifications of 32 dBm output power and 25 dB gain. Two versions of the HPA for SATCOM down link, packaged and bare die, show very promising expected performance in all the operating conditions considered. Four circuits are already completed and under manufacturing phase and one other is ready for the tape out. After completion of the wafer fabrication the devices will be characterized on-wafer.

# Dissemination activities

## Communication kit targeted towards middle school students

E-learning course “Advanced RF Transceivers for 5G base stations based on GaN Technology” is an on-line course created on platform Moodle. The aim of this course is to present basic info about RF transceivers for 5G base stations problematics and the approach proposed by consortium of 5G_GaN2 project for 5G networks solution. The course is divided into six parts providing a wide range of information. The course was primarily prepared for middle school students, but we found it very helpful also for all interested community.

Content page of the communication kit

This course was a first step to support 5G_GaN2 dissemination plan. It introduces the reader to RF transceivers for 5G base stations problematics and the approach proposed by consortium of 5G_GaN2 project for 5G networks solution. Each lesson gives an explanation to a selected topic connected with RF Transceivers for 5G base stations and the approach of project consortium to this topic.

Individual chapters advise the answers for questions that students may have to gain balanced knowledge. The link to the course is available at project web side.

# Dissemination activities

## Other dissemination activities

The other dissemination activities comprise communication towards scientific audience through scientific papers and conference contributions. The total amount of publications are 2 peer reviewed scientific journal paper and 7 conference contribution:

**Peer reviewed scientific journal papers:**

[1] Chvála A, et al. in ASME. J. Electron. Packag. 2019;141(3):031007-031007-7. doi:10.1115/1.4043477 [open access]

[2] Joël Kanyandekwe, et al. in Journal of Crystal Growth 515 (2019) 48–52

**Workshop and conference contributions:**

IMS2019 Workshop (2-7th June 2019, Boston, USA)

"Heterogeneous Integration for WLP RF Transceivers : Challenges and Issues"

ECSEL JU Symposium 2019 (17-18th June 2019, Bucharest, Romania):

"Heterogeneous integration of state of the art Semiconductor Technology"

WOCSDICE 2019 (17-19th June 2019, Cabourg, France):

"DLTFS study of emission and capture processes in GaN/AlGaN/GaN/SiC HEMT heterostructures with different layer compositions"

"Defect Analysis of InAlGaN/GaN/SiC HEMT heterostructures"

ADEPT 2019 conference (24-27th June 2019, Strbske Pleso, Slovakia):

"Channel temperature determination of HEMT in quasi-static operation"

"DLTFS study of GaN/AlGaN/GaN/SiC HEMT heterostructures with different layer composition"

"Determination of on chip temperature distribution of devices under operation by using Raman microscopy.

MITAV 2019 (Brno, Czech Republic, 20.-21.6.2019)

"Identification of electrically active defects in modern structures based on gallium nitride"

EFFECS 19th-21th Nov 2019 Finland

# Project events

## Project meetings and general assemblies

The coordination of project activities are running through group meetings and general assemblies of consortium members during the whole project execution. The more specific project tasks have been assigned to consortium members on June 26th 2018 at Kick-off meeting in Paris. Three important meetings have been organized so far to evaluate activities and task solving progress: a general assembly workshop on February 19th 2019, a work package leaders meeting on May 23rd, both in Paris, and the 1st review meeting on July 24th 2019 in Brussels. The 1st review meeting apprised the project implementation satisfactory and issued recommended changes to improve the project implementation. The seriousness of the project implementation demands also amendment of project duration from 36 to 48 month.

Project 5G_GaN2 operational team at Kick-off meeting in Paris