Nanostructured materials and RF-MEMS RFIC/MMIC technologies for highly adaptative and reliable RF systems

September 2012

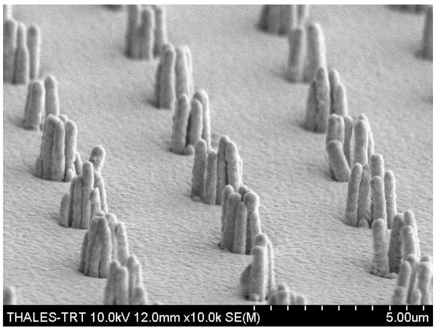
Newsletter #1

Future smart systems for communication and RF-sensing will have to achieve autonomous and self-reconfigurable operations, for real-time and efficient self-optimization of their performance.
The needs for such reconfigurable systems are not only to overcome the design trade-offs that current analogue components must endure, but also to realize new and more efficient systems with improved functionality (i.e. better performance) as well as reduced size, weight, power and cost. The aim of the NANOTEC project is to develop new technology approaches and methodologies for future generations of such highly adaptive and also reliable RF-systems to be integrated within T/R modules, smart active/passive and reflect array antennas, etc.
For this purpose, NANOTEC will aim to significantly enhance the reliability of RF-MEMS switches by using nanostructured materials (e.g. as dielectrics) as well as to demonstrate highly adaptive and miniaturized telecommunication and RF-sensing circuits, antenna front-ends and systems enabled by monolithical integration of low-loss RF-MEMS switches in GaN/GaAs/SiGe IC foundry processes.

In this framework, the two main challenges of NANOTEC are: Use Nanostructured materials as dielectrics in RF-MEMS devices in order to achieve more reliable devices by minimizing charging effects and by improving thermal dissipation under high power. Integrate RF MEMS switches on Wide Band Gap (WBG) semiconductors. RF-MEMS appear as a enabling technology in order to achieve the reconfigurability required for future smart systems due to the highly attractive RF properties such as low insertion loss and power consumption as well as high isolation, power handling capability (linearity) and possibilities for high level of integration. The monolithic integration of MEMS switches and active GaN devices within the same reconfigurable active RF circuit appears to be a next logical step towards the realization of highly adaptive and miniaturized high-power (robust) MMICs and front-ends for emerging applications also within the mm-wave range.

Nanostructured materials integration

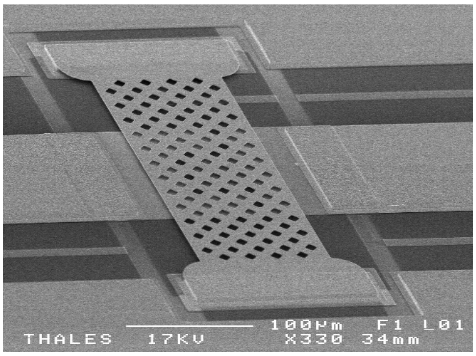
The aim of nanostructured dielectric development is to reduce the major failure mode of stiction due to dielectric charging in RF-MEMS capacitive switches. In NANOTEC different new nanostructured dielectric will be developed, such as: Integration of nanostructured PZT. Development and integration of oriented carbon nanotubes in silicon nitride dielectric. These materials will be characterized in term of electrical and thermal properties.



WBG devices for microwave mm-wave circuit

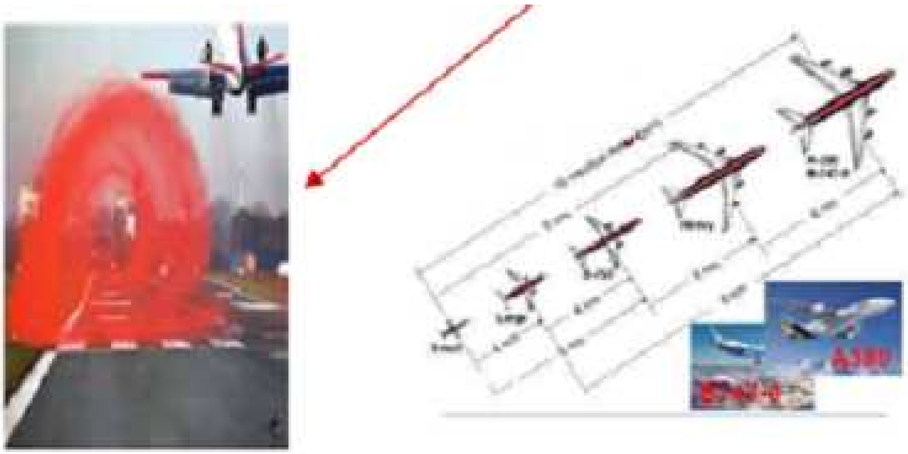
In spite of the recent remarkable progress in microwave and millimeter-wave applications of WBG devices, no results have been reported so far on MEMS switches on GaN/SiC substrates. In scientific literature there is, to this date, no mentioning of any attempt to combine different active and passive RF functions (such Power Amplifier PA, Low Noise Amplifier LNA and switching networks) using GaN MMICs and RF-MEMS based technologies. In NANOTEC we aim at combining:

- GaN Technology
- High power, High efficiency, 1-40 GHz transistors
- RF-MEMS integration :
- High Integration density
- RF performance
- Thermal management
- Reliability
- RF-MEMS process flow compatibility



Demonstrator 1

The demonstrator 1 consists in a robust reconfigurable GaN RF-MEMS based low-cost X-band reflect array for wake vortex detection and weather radar (airport and societal related safety) systems. Goal: Replace circulators by RF-MEMS SPDTs integrated on the same substrate than HPA and LNA.



Demonstrator 2

The demonstrator 2 consists in a 94 GHz passive imaging (for security screening) sensor with improved sensitivity (and potentially also enabling lower cost) by using GaAs/SiGe MMIC technology with on-chip RF-MEMS switches.

Goal :
- Improve sensibility thanks to GaAs/SiGe MMICs and low loss RF-MEMS
- Decrease cost using RF-MEMS SiGe RFIC and on chip antennas

Passive stand-off people screening

Enabler: 94GHz millimetre-wave imager

Demonstrator 3

The demonstrator 3 consists in a 140 GHz miniaturized MIMO radar front-end using low-cost SiGe RFIC technology with on-chip RF-MEMS switches. The semiconductor development will enable the first demonstration of a highly integrated MIMO-radar operating at 140GHz, which will be a cost-efficient, small and high performance solution for mobile applications like:

- Hand-held security sensors for unattended baggage

- Non-destructive testing of GFRP (glass-fiber-reinforced polymer) structures

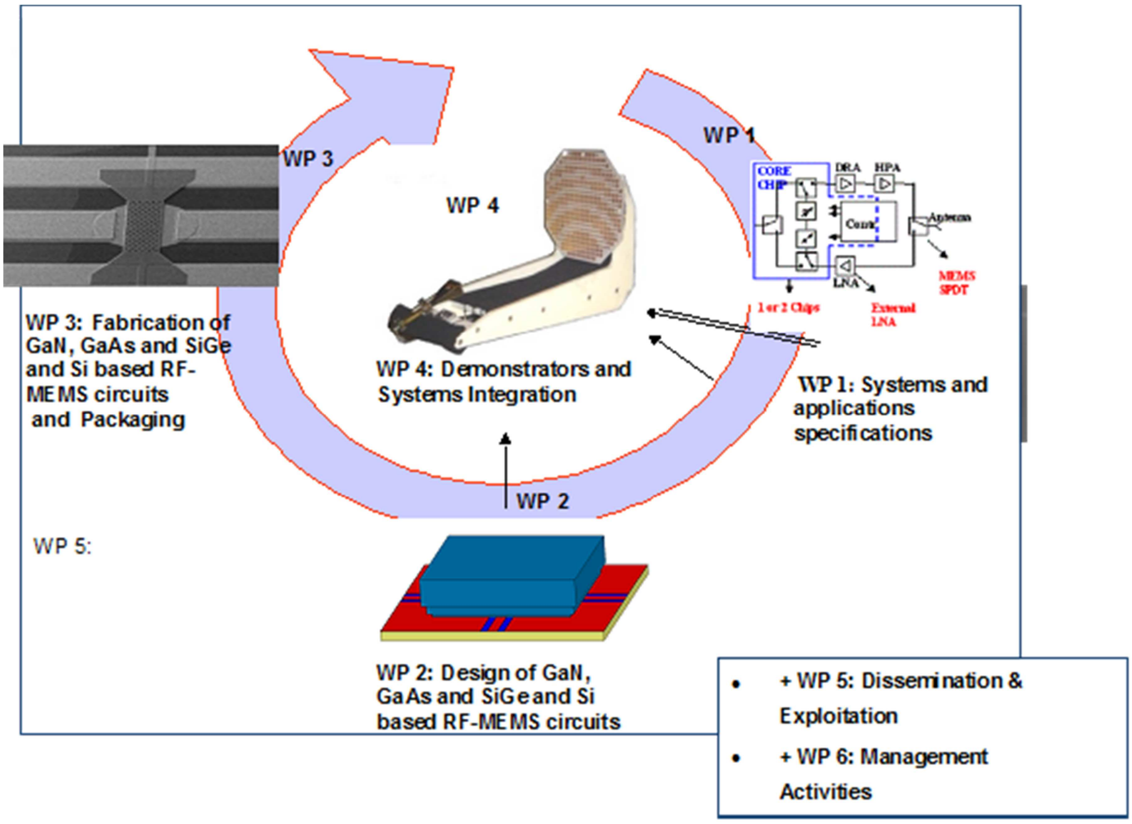
- Imaging sensors for smart robots

Organization of the different steps of the project

The achievement of the proposed objectives can only be fulfilled through a well-coordinated effort. This undertaking involves tasks ranging from deposition and characterization of nanostructured materials to electromagnetic modeling of RF-MEMS, advanced WBG semiconductor technologies to antenna fabrication and component development to system integration. The work plan methodology is based on a top-down philosophy that employs efficiently both the broad expertise of the partners as well as their long-standing collaborative links. The goal is to devise novel technological "vehicles" in order to develop a new type of IMS based on WBG for harsh environment operation and high power handling applications.
In order to achieve the goals that we described previously, the scientific and technical program of NANOTEC will be developed on the main following tasks:

- Integration of new nanostructured materials (as new dielectrics) in the existing MEMS technology :
    - PZT thin layers with improved performances in term of the electrical conductivity
    - Aligned carbon nanotubes within a Si_3N_4 dielectric matrix

- Study and development of the technological process in order to reduce the size of the MEMS Switches. This activity will focus on the development of the technological process with the same material (PZT) than the standard one. Integration of the new nanostructured dielectrics with MiniMEMS technology.
- Design, fabrication and testing of GaN, GaAs and Si/SiGe based RF-MEMS and MiniMEMS circuits (SPDT and T/R modules)
- Design, fabrication and testing of MEMS based switch capacitors and phase shifters on GaN, GaN, GaAs and Si/SiGe.
- Integration of GaAs, GaN MMIC with RF-MEMS technology.
- Fabrication of three demonstrators :
    - demonstrator 1: the high power robust and reconfigurable antenna subsystems for 10-24GHz based on GaN RF-MEMS chips;
    - demonstrator 2: the reconfigurable antenna reflect-array and low-noise blocks based on the GaAs RF-MEMS at 94GHz;
    - demonstrator 3: the MIMO radar modules based on RF-MEMS SiGe BiCMOS chipset.
- Development of measurement tools and lateral resolution enhancement techniques for the electro-thermo-mechanical characterization of small size RF MEMS.


WP 1
WP 3
WP 4
WP 2
CORE CHIP
DRA
HPA
Conv
Antenna
LNA
MEMS SPDT
1 or 2 Chips
External LNA
WP 3: Fabrication of GaN, GaAs and SiGe and Si based RF-MEMS circuits and Packaging
WP 4: Demonstrators and Systems Integration
WP 1: Systems and applications specifications
WP 5:
WP 2: Design of GaN, GaAs and SiGe and Si based RF-MEMS circuits
+ WP 5: Dissemination & Exploitation
+ WP 6: Management Activities