Dispositivi e Tecniche di Caratterizzazione a Microonde ed Onde Millimetriche

CNR-IMM Roma

Proposta di Tesi di Laurea Triennale e Magistrale per il Corso di Laurea in Fisica di Tor Vergata

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National Research Council
Institute for Microlectronics and Microsystems
(CNR -IMM)

The Institute for Microelectronics and Microsystems (IMM) belongs to the Department for Physical Sciences and Technologies for Matter (DSFTM) of CNR, and it is currently organized on Seven Sites and four different main Research Lines:

a) materials, processes and devices for microelectronics;

b) sensors and micro-systems;

c) optoelectronics and photo-voltaics;

d) development of advanced characterization techniques for material and process analyses.

More details on: http://www.imm.cnr.it for the entire Institute and on http://www.artov.imm.cnr.it for IMM Roma.

More than 200 units of permanent personnel + several contract staff units are involved in the above defined areas (micro-electronics and micro-systems) encompassing design, technology, test and modeling, and characterization activities.

Reliability criteria valid for space as well as defence and commercial applications are followed for releasing the feasibility of processes, devices and sub-systems.

Facilities

Medium Size Clean Room capabilities (300 – 500 m^2) in Class from 100.000 down to 100, equipped for micro- and nano-electronics as well as for micro- and nano-systems, are available in all the sites of IMM. Thin film deposition techniques with multi-layer mask processes are routinely done.

Potential small size production of on-wafer sub-systems can be pursued, and full characterization including on-line and off-line measurements can be performed (mask manufacturing, chemical and physical etching techniques, micromachining, …).

Morphology, mechanical characteristics, doping profiles, etc . for sub-micron and nano-devices are evaluated by means of purposely built setups and commercial instruments (SEM, TEM, Digital Holography, Micro-analysis, Scanning Probe Microscopy, …).

Electrical DC and RF characterization is provided by using calibrated and remotely controlled network equipments (Time and Frequency Domain for IR, Microwave, mm-wave and Optical Devices and Sub-Systems).

Modeling by means of home made and commercial codes for specific problems, including thermal and power handling, fluido-dynamics, EM propagation , charging processes, …. are part of the skill in every IMM site.

Some highlights of the IMM activities (not exhaustive)

- Telecom Applications in the Microwave and Millimeter Wave Range (Roma)
- Structural characterization for avionics by means of optical fiber sensing (Napoli)
- Photo-voltaic ground applications suitable of Space implementations (Bologna, Catania, Roma)
- Material Science on nano-structured materials for nano-interconnections, sensing and radiation hardness improvement (Agrate Brianza, Catania, Roma)
- High K materials (Agrate Brianza, Catania, Lecce)
- Sensing for life quality in ground and on-board environments (Lecce, Roma)
- Novel concepts in detection and signal processing of RF and optical signals (Roma, Napoli, Lecce)

TAXONOMY

(following EU, EDA, ESA Definitions)

Applicative Domains: **Telecommunications** | **Aerospace** | **Security** | **Health**

Enabling Technologies: **Materials** | **Electronics** | **Optics** | **Photonics**

TRL (Technology Readiness Level) up to 4
(Laboratory demonstration and preliminary environmental test)

General Aims

- Micro- and Nano-Systems for low and high frequency components and sub-systems with functionalities quite different between them *(electrical or electromagnetic, electro-mechanical, and chemical-physical)* to be integrated in the same configuration.
- Feasibility of Micro- and Nano-Systems and Material Science especially minded for high frequency applications and reliability in harsh environments with special care to :

i. Optimization of bulk and surface micromachining techniques for different substrates which can host configurations for guided and free space propagation as well as resonating structures and nano-devices (wafers of Si and GaAs, alumina, substrates of LTCC and LTCF, magnetic materials, photo-sensitive polymers, based also on liquid crystals;

ii. Design and realization of innovative components, for which no commercial software solution exists for the full design, especially when different and/or combined solicitations are involved;

iii. Reliability of Micro- and Nano-Systems as a function of their applications, for ground as well as for space and security applications for on-wafer and packaged devices.

→ SMART SYSTEMS, *high number of components and functions, network-embedded*

→ INTERNET OF THINGS

Tools and Issues

Owing to the complexity of MEMS/NEMS a multidisciplinary approach is needed

Software:

- Commercial 2D and 3D RF Design Techniques, supported by circuital modelling for complicated configurations (*matrices, phase shifters, delay lines, …)*
- Multiphysics simulations, involving commercial and purposely developed software codes for non-RF and RF properties or harsh environment evaluations (*Temperature, RF Power, DC Actuation, Mechanical Response, Charging*…)

Technologies:

- Clean Room Thin Film Deposition and Processing (evaporation, DC and RF sputtering, PECVD, …. For metal and dielectric layers).

Characterization:

- Morphological and Mechanical
- DC and RF Electrical Measurements for on-wafer and packaged devices
- Development of specific Calibration Techniques for on-wafer measurements when low-loss RF transmission line devices are considered

Device Feasibility in Terms of Short- and Medium-Term evaluation involving:

- Physical and Circuital Modelling of structures under combined solicitations (like power and temperature, or number of actuations, technology yield, …)
- Specific reliability tests for ground and space applications, charging, failure mechanisms and aging, radiation hardness, …

Advanced Technologies and Characterization Techniques for Microwave and Millimeter Waves Microsystems

Microsystems for telecommunications and the related characterization techniques has led to a growing demand on the feasibility of the technologies needed, especially when very different functionalities (electrical or electromagnetic, mechanical, chemical and physical) must be integrated into the same system.

The definition of Smart System, coined to identify micro- and nano-systems characterized by a high integration of components and functions, fully meets these requirements.

Develop advanced characterization techniques and measurement protocols for micro- and nano-systems working at microwave and millimeter waves, by means of: (i) identification of the criteria to optimize the technologies for different materials, even integrated into complex configurations (Si and GaAs, LTCC and LTCF, Rogers / Duroid, magnetic materials, photosensitive polymers, ...); (ii) design and implementation of innovative components; (iii) definition of the reliability of micro- and nano-systems depending on their application, both for ground and space, for devices on-wafer and packaged.

RF MEMS and Metamaterials for Space and Security

General Skill on Materials, Processes and Devices:

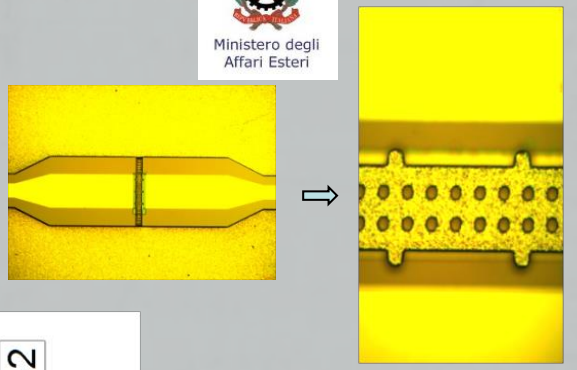
Microelectronics; RF sensors and micro-systems; high frequency characterization techniques for materials and devices.

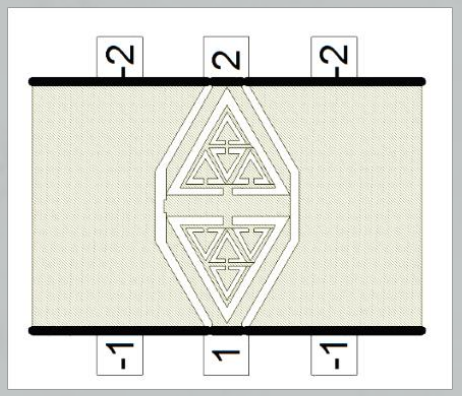
Simulation and Technology Tools focused on Space and Security Applications concern with temperature and radiation hardness studies, EM design, multi-physics modeling, and Clean Room Technology for Microelectronics/MEMS/NEMS and Metamaterials.

Characterization Techniques for materials and devices are minded for failure definition when measuring novel and classical space components, including technology yield, failure, aging, and statistical methods. Testing capability up to 50 GHz.

Current TRL=3-4 max, with laboratory feasibility demonstration including on-wafer and packaged devices in Clean Room environment. To be improved with external contributions for specific tests like mechanical and thermal shocks.

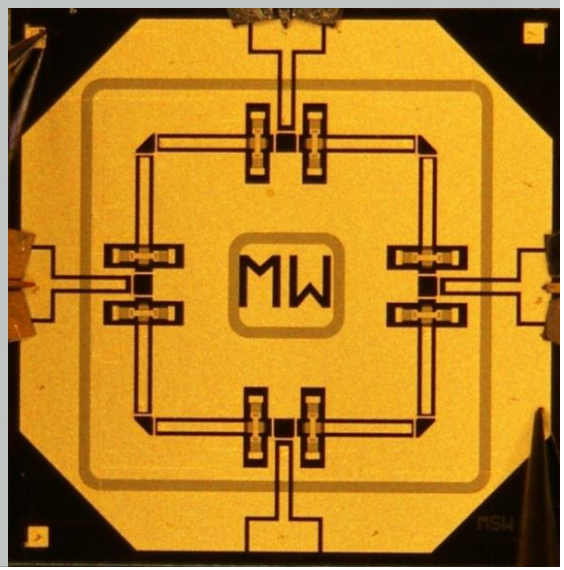
RF MEMS for all-passive signal routing





Metamaterial components for wide-band, multi-band RF applications

On-wafer measurement on a RF Matrix Structure for Space Applications in MEMS technology. RF MEMS switches for signal routing and redundancy purposes are studied in collaboration with TAS-I, FBK Trento, TU Munich, UNI Perugia.



Scanning Microwave Microscopy for Materials Science

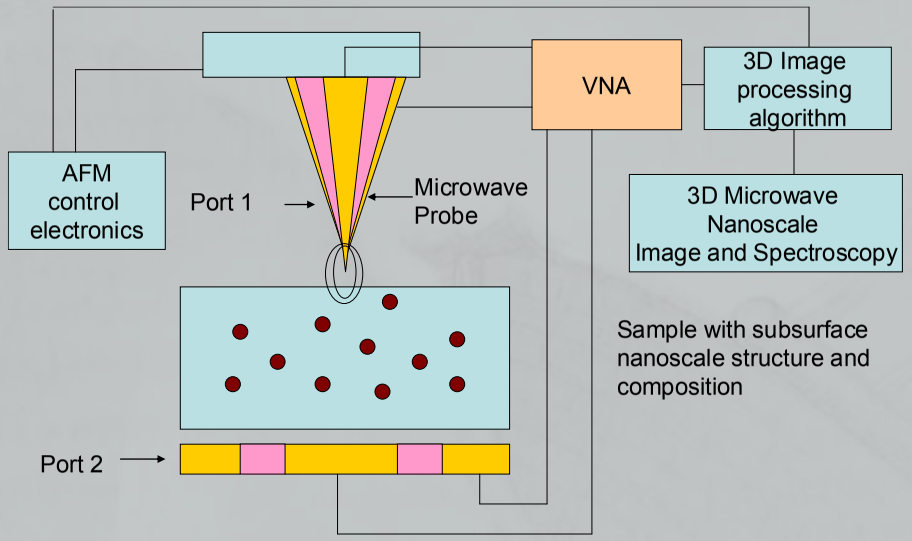
Aim of this research activity is to develop Volumetric Scanning Microwave Microscopes (VSMM), for non-destructive 3D nanoscale structural characterisation. The VSMM will probe the local reflection and transmission microwave spectroscopy of key materials properties, measuring complex permittivity, conductivity, resistivity, and magnetic response, and hence structural and chemical material constitution with 3D nanoscale resolution. The Work-Flow will address the technical development of the tool and demonstrate its ability to characterise the 3D structure in situ at the nanoscale with application also to relevant real life systems. Methods for calibration and provision of traceability are incorporated into the project from the start: this will ensure that VSMM measurements will be quantitatively meaningful and optimised for accuracy. The VSMM will utilise SPM cantilever-probe technology, to ensure that it is readily compatible with a full range of other SPM-based tools, opening up its future role in integrated multi-physical materials characterization at the nanoscale. Additional efforts will be performed to manufacture novel probes to be interfaced with commercially available instruments.

Microwave Nanotechnology for Semiconductor and Life Sciences

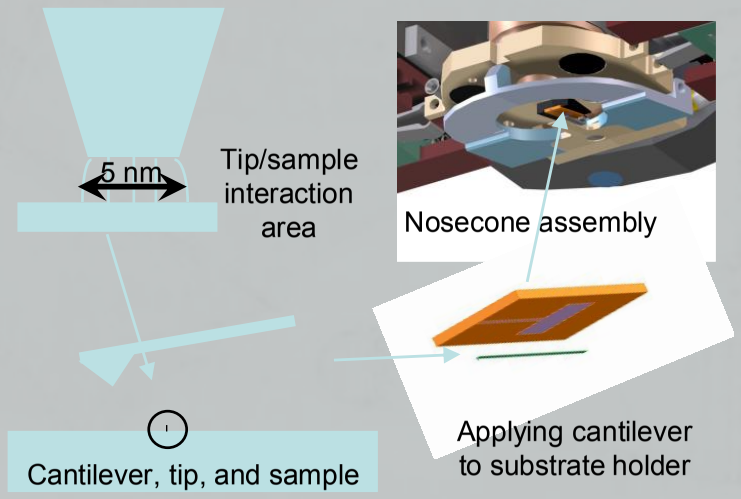
Current applications of microwave technologies in communications, remote sensing and in industry are based on the properties of the interaction of microwaves with matter at supra-wave length scales (above centimetres). The developments performed in Nanotechnology in recent years makes now conceivable to explore the interaction of microwaves with matter at much smaller scales, from micrometres to nanometres. At these sub-wave length scales it is expected that fascinating new physical phenomena may appear, which will give rise to new applications of microwave technologies with high added value, in particular, in field such as nano-electronics, nano-spintronics, nanobiology and nano-medicine. Being an emerging technology there is a need for training early stage researchers in this field of research so that enough critical mass can be achieved. The main objective of this activity is to train a whole generation of researchers in the field of nanoscale microwave technologies and related emerging applications in the fields of semiconductor industry and life sciences.

Scanning Microwave Microscopy

V-SMMART NANO is a multinational project funded by the European Commission under the FP7 NMP Programme, which aims to develop a Volumetric Scanning Microwave Microscope (VSMM) for non-destructive 3D nanoscale structural characterisation of samples.



NANOMICROWAVE is a FP7-ITN «Marie Curie» Project . The main objective of this network is to train a whole generation of researchers in the field of nanoscale microwave technologies and related emerging applications in the fields of semiconductor industry and life sciences.



Tesi 1

Caratterizzazione in frequenza di materiali magnetici e dielettrici

- Misure a microonde di film e multistrati dielettrici/magnetici mediante analizzatore di rete vettoriale.
- Determinazione della permeabilità magnetica e della costante dielettrica del materiale e suo andamento in frequenza fino a 18 GHz

Tesi 2

Design e Tecnologie per la realizzazione di strutture polimeriche per applicazioni ad alta frequenza

- Tecnologie di base per la fotolitografia di SU8
- Progettazione di dispositivi per il loro utilizzo in strutture per la propagazione ed il trattamento di segnali a microonde

Tesi 3…N

- Argomenti legati, in genere, alla realizzazione di configurazioni ad alta frequenza, modellizzazione fisica e circuitale, per applicazioni nel trattamento del segnale (dispositivi) e caratterizzazione ed imaging di materiali e configurazioni micro- e nano-strutturate
- **Sbocchi Lavorativi:** Industrie nel Settore delle Telecomunicazioni e della Strumentazione ad Alta Frequenza, Istituti di Ricerca, …

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