L4: Laboratory of micromachined structures, microwave circuits and devices

- Mission
- Main areas of expertise
- International projects
- International bilateral cooperation
- National projects
- Research Team
- Specific facilities

The laboratory is one of the promoters of the RF - MEMS topics in Europe and had participated in the FP6 network of excellence **"AMICOM"** (2004 -2007) with new and original results obtained in cooperation with key players in the European research in this topic (LAAS-CNRS Toulouse, VTT Helsinki, FORTH Heraklion).

The laboratory has successful applied to a FP7 project in the REGPOT 1 /2007 call becaming (together with the microphotonics Lab a "European Centre of Excellence in Microwave, Millimetre Wave and Optical Devices, based on Micro-Electro-Mechanical Systems for Advanced Communication Systems and Sensors".

Mission: scientific research and technological development of micromachined microwave and millimetre wave devices and circuits. The new RF MEMS technologies (including the "membrane supported circuits technologies") represent a solution to manufacture high performance microwave and millimeter wave devices and circuits devoted to the emerging communication systems and sensors. Lately the laboratotry has also stared the research to develop acoustic devices using micromachining and nano-processing of wide band gap semiconductors (GaN/Si, AlN/Si) and experimental devices based on Carbon nanotubes and graphene.

Main area expertise:

- Development of a new generation of circuits devoted to the millimeter wave communications based on semiconductor (Si, GaAs, GaN) micromachining;
- Acoustic devices (FBARs and SAWs) based on micromachining and nanoprocessing of wide band gap semiconductors (AlN , GaN);
- Micowave devices based on carbon nanotubes;
- Microwave devices using CRLH materials (metamaterials);
- MEMS and NEMS technologies developement;

International projects - FP7 "MIMOMEMS" - FP7 SCA action, IMT coordinator, (2008-2011);
MEMS 4 MMIC Strep (2008-2011) - IMT member.

International bilateral cooperations: The laboratory has bilateral governmental cooperation with University of Pretoria, South Africa.

National projects: In the PN II programme, the laboratory has 6 projects (5 Partnership and 1 Capacities) as coordinator and one as partner. The laboratory had finished three CEEX projects (INFOSOC and RENAR programme) as coordinator, two CEEX projects as partners and four projects in the MINASIST+.

Research team: has multidisciplinary expertise in physics and electronics of microsystems and is composed of 8 senior researchers (6 of them with PhD in physics, electronics, microwave and chemistry), 1 early stage researcher (PhD in electronics), one PhD student in physics.

Specific facilities: "On wafer" measurement system in the 0.1 -65 GHz range: microwave network analyzer Anristu in the range 0.04-65 GHz, and Karl SUSS Microtec Probe Station, obtained through a successful CEEX project (Module 4), Keithley Semiconductor characterization system 4200 SCS, Millimeter wave powermeter in 0.1 - 40 GHz range and measurement accessories., software for microwave electromagnetic simulations (IE3D and Fidelity from ZELAND software packages); Vector network analyzer Hewlett Packard 0.1-18 GHz; Süss Microtech EP 4 prober;

Team from left to right: Alina Cismaru; Alexandru Muller; Gheorghe Sajin; Mircea Dragoman; Dan Neculoiu; Cristina Buiculescu; Ioana Petrini; Dan Vasilache;

Laboratory Head — Dr. Alexandru Muller (alexandru.muller@imt.ro)

He obtained M.Sc. in Physics at Bucharest University (1972) and PhD in physics at Bucharest University in 1990;

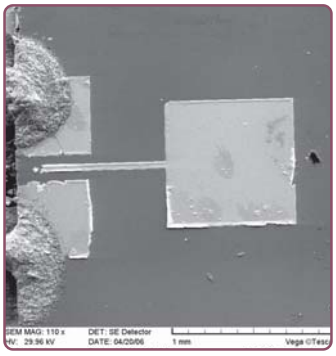
Competences: Silicon, GaAs and GaN micromachining and nanomachining: manufacturing of RF MEMS components and circuits, technological process in GaAs MMICs, design, modeling and manufacuring of microwave passive membrane supported circuits (1997-European priority), micromachined inductors, filters and antennae, monolithically as well as hybrid integrated receiver front end modules, acoustic devices (FBARs and SAWs) based on micromachining and nanoprocessing of wide band gap semiconductors (AlN , GaN).

Dr. Müller is the coordinator of the European project FP7 REGPOT (2008 - 2011). Dr. Müller has coordinated the European Project FP 4 MEMSWAVE (1998-2001), and was the leader of the Romanian team in the FP6 NoE AMICOM and member of the Board of Directors of this project He is member of Micromechanics Europe Workshop and MEMSWAVE workshop steering committees. He is an expert in project evaluation in the national program Research for Excellence (started in 2005). He is member of IEEE and EuMA. Dr Muller is member of PhD Jury in Politechnica Univ. Bucharest and Univ. Paul Sabatier/LAAS Toulouse. Co-editor of the Micro and Nanoengineering Series (Romanian Academy). He had invited papers at important European conferences. He has more than 150 contributions in books and international journals/conferences.

Dr. Müller is finalist of the Descartes Prize competition 2002 of the European Community with the MEMSWAVE Project, Romanian Academy Prize "Tudor Tanasescu" second prize for the MATNANTECH project, SIRMEMS (at CONRO 2003).

Membrane supported GaN FBAR structures obtained by micromachining of high resistivity silicon

GaN membrane supported F-BAR structures were manufactured and characterized. The 2.2 m thin GaN layer was grown using MOCVD techniques, on a high resistivity <111> oriented silicon substrate. Conventional contact lithography, e-gun Ti/Au evaporation and lift-off techniques were used to define top-side metallization of the FBAR structures. Bulk micromachinig techniques were used for the release of the GaN membrane. The bottom side metallization of the micromachined structure was obtained by means of sputtered gold. S-parameter measurements have shown a resonance around 1.2 GHz. Microwave measurements have proved the viability of these types of FBAR structures. The extracted value of acoustic velocity is in good agreement with that reported by other authors on materials fabricated by other methods.



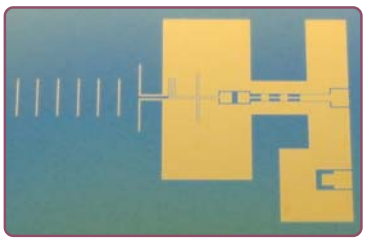
SEM photo (top side) of the GaN membrane supported F-BAR structure. The silver epoxy on the left side is used in order to provide a connection of the ground electrode to the bottom metallization of the FBAR membrane and allow measurements with GSG probes

Achievements: An GaN based resonator on high resistivity <111> silicon substrate for operation around 1.2 GHz has been fabricated using micromachining techniques. Resonator structures of this type can be used as building blocks for the fabrication of high Q and wide bandwidth filters, for use in reconfigurable front-ends of various mobile and wireless applications.

CEEX INFOSOC Project "Integrated RF-MEMS circuits based on silicon, gallium arsenide and wide band gap semiconductors for advanced communication systems - ACOMEMS" (2006-2008)
Co-ordinator IMT-Bucharest, **Project Manager: Dr. A Müller (alexandru.muller@imt.ro)**
Partners: National Institute for Material Physics, "Politehnica " Univ. Bucharest, "Valahia" Univ. Targoviste, "Ovidius" Univ. Constanta, Institute of the Macromolecular Chemistry "Petru Poni", Iasi

77 GHz millimeter wave receiver module based on the hybrid integration of a SiO_2/Si_3N_4 membrane supported Yagi-Uda antenna with GaAs Schottky detector diode

The membrane supported millimeter wave receiver operating in the 60 GHz frequency range was and characterized. The receiver structure is based on the hybrid integration of a Yagi-Uda antenna with a Schottky diode, the antenna having as support a 1.5 μm thin SiO_2/Si_3N_4 dielectric membrane. The fabrication processes is based on silicon micromachining. The experimental characterization of the Yagi-Uda antenna receiver was performed using a measuring set-up designed and realized in the laboratory.



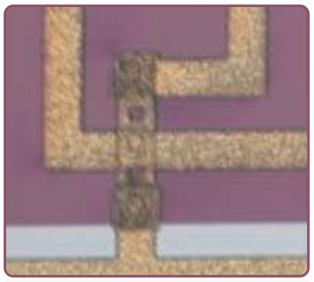
Optical photo of the 77 GHz receiver structure micro-machined on SiO_2/ Si_3N_4 membrane

Achievements: Design, modeling and manufacturing of 77 GHz silicon micromachined receiver structures. The design procedure, the technological processing and characterization techniques open a window of opportunity for the development of innovative architectures for circuits and systems operating at higher frequency, up to the sub-millimetre wave frequency range.

CEEX INFOSOC Project "Integrated RF-MEMS circuits based on silicon, gallium arsenide and wide band gap semiconductors for advanced communication systems - ACOMEMS" (2005-2008)
Co-ordinator, IMT-Bucharest, Project Manager: Dr. A Müller (alexandru.muller@imt.ro)
Partners: National Institute for Material Physics, "Politehnica " Univ. Bucharest, "Valahia" Univ. Targoviste, "Ovidius" Univ. Constanta, Institute of the Macromolecular Chemistry "Petru Poni", Iasi.

New reconfigurable micromachined filters dedicated to reconfigurable frontends for mobile communication systems 3G and "beyond" 3G" which endure the DCS 1800MHz and WLAN 5.2 GHz. Standards- - technological experiments

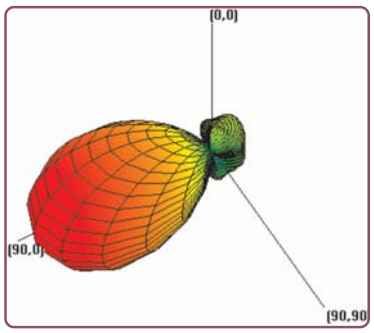
The band pass filters includes resistive switch for standard selection and complex L-C structures suspended on micromachined dielectric membrane and also on the bulk. The switches will modify the values of L-C components. 1.5 μm thick $SiO_2/Si_3N_4/SiO_2$ membranes were obtained by micromachining of <100> high resistivity silicon. Experiments for spiral inductors and interdigitated capacitors suspended on membrane were performed. The first technological experiments deals with obtaining air bridges of the membrane supported spiral inductors. Achievements: Modeling, electromagnetic simmulations of band pass filter and technological experiments for LC membrane supported components.



Detail of the air bridge of the membrane supported spiral inductor

PN II Partnership Project "Advanced circuits for microwave, millimeter wave and photonics based on MEMS technologies MIMFOMEMS" (2007-2010)
Co-ordinator, IMT-Bucharest,
Project Manager: Dr. A Müller (alexandru.muller@imt.ro)
Partners: National R&D Institute for Material Physics, "Politehnica" Univ. Bucharest, Institute of the Macromolecular Chemistry "Petru Poni" Iasi, SITEX 45 Bucharest

Modelling of the monolithically integrated receiver on GaAs to be used as MMID TAG



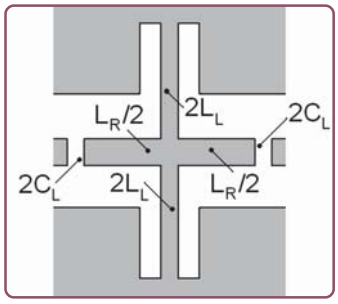
Simmulated radiation pattern for the membrane supported Yagi-Uda antenna from the receiver

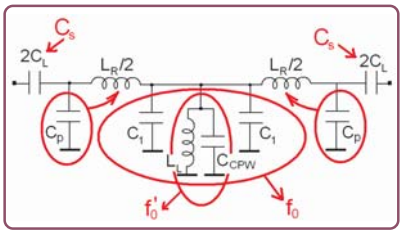
The receiver is modeled and designed considering components supported on membrane, on bulk GaAs and on the transition region. Yagi-Uda antenna monolithically integrated with the Schottky diode is suspended on the micromachined membrane and the band pass filter is on the bulk region. IE3D electromagnetic simulator from Zeland Ltd. was used in design of the membrane supported components.

Achievements: Modeling and design of the monolithically integrated rceiver module from the TAG

PN II Partnership Project "Advanced circuits for microwave, millimeter wave and photonics based on MEMS technologies MIMFOMEMS" (2007-2010) Co-ordinator, IMT-Bucharest, Project Manager: Dr. A Müller (alexandru.muller@imt.ro)
Partners: National R&D Institute for Material Physics, "Politehnica" Univ. Bucharest, Institute of the Macromolecular Chemistry "Petru Poni" Iasi, SITEX 45 Bucharest.

Modeling CLRH structures and devices in the milimetric waves domain.





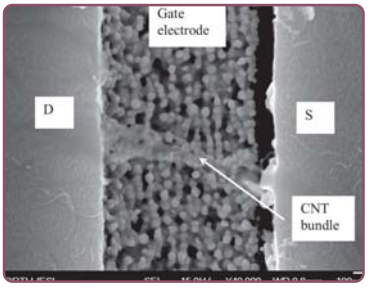
Lay-out of a CRLH structure and it's equivalent circuit.

CRLH (Composite Right-Left-Handed) lines are artificial lines, namely circuits made with concentrated and / or distributed inductors and capacitors. The CRLH balanced line is used to made directional couplers, leaky-wave antennas, pass band filters and non-linear.
In this respect was elaborated a methodology for modeling the millimeter wave propagation through CRLH structures.

Achievements: modeling of the capacitors and inductors in CRLH approach for millimeter waves in CPW (CoPlanar Waveguide) configuration assuring the compatibility with MMIC.

PN II Partnership Prj: Millimeter wave devices on metamaterials microprocessed by laser ablation-METALASER (2007-2010), **Co-ordinator, IMT Bucharest. Project Manager: Dr. Gheorghe Ioan Sajin-(gheorghe.sajin@imt.ro);**
Partners: INCDIE ICPE CA Bucharest; "Politehnica" University Bucharest, INCD-FLPR Bucharest.

Nanoelectronics based carbon nanotubes



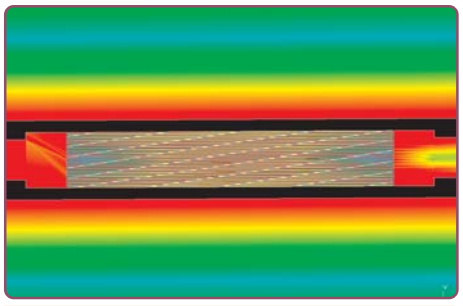
A FET-like configuration based CNT.

The design of test structures for CNT characterization, experiments regarding CNT manipulation of CNT and dc characterization technological implementation of the microwave test structures were succesflly performed.

Achievements: the interconnection of a CNT bundle over a dielectric trench.

PN II Partnership Project "Nanoelectronic devices for high frequencies based on carbon nanostructures for communications and environment monitoring" (2007-2010)
Co-ordinator, IMT-Bucharest.
Project Manager: Dr. M. Dragoman (mircea.dragoman@imt.ro)
Partners: National R&D Institute for Material Physics, "Politehnica" Univ. Bucharest, SITEX 45 Bucharest

Sensing DNA using carbon nanotubes


Current distribution at 10 GHz for interdigital structure on Si with (L =1 μm) and a CNT-DNA thin film of 200 nm (red coulour is asigned to the most intense propagated power.

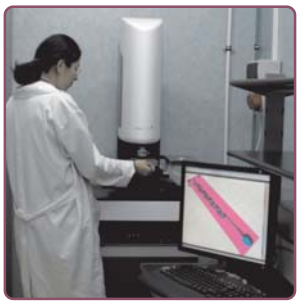
The aims of the first research step of the project finalized at the end of February 2009 were to identify the solutions to functionalize CNT with DNA and design of the test structures for detection of CNTs functionalized with DNA.

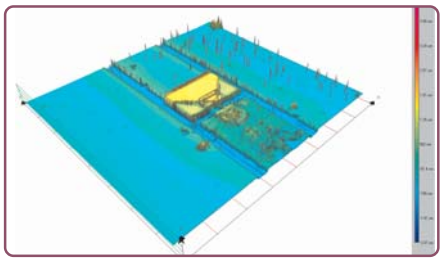
Achievements: The simulation of electromagnetic test structures to sense CNT functionalized with DNA.

PN II Partnership Project (2008-2011) "Biosensors based on carbon nanotubes for the real-time detection of nucleic acids with oncogenic potential"
Co-ordinator, IMT-Bucharest,
Project Manager: Dr. M. Dragoman (mircea.dragoman@imt.ro)
Partners: Institute of Oncology, National R&D Institute for Material Physics, "Politehnica" Univ. Bucharest

Acquisition and installing of FOGALE Pilot 3D while light interferometer

The white light interferometer is an equipment that perform optical, non-contact profiling of rough surfaces, that uses interferometric techniques as well as digital signal processing algorithms produce fast, accurate, repeatable three-dimensional surface profile measurements. When combined with more traditional phase-shifting measurement techniques, this produces an instrument capable of profiling surfaces with roughness ranging from 1Å to 20 µm, and measurement steps up to 2mm

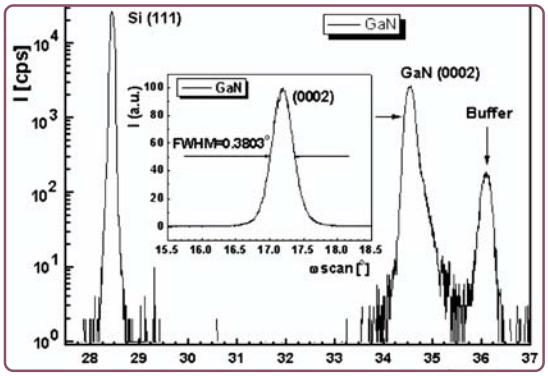




The instaled white light interferometer and a resulting 3D image of a membrane supported Schottky diode

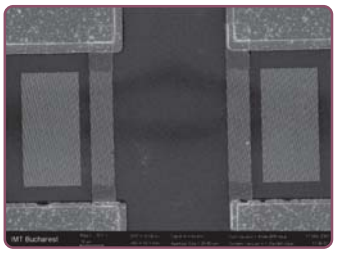
PN II Capacities Project "System of microphysical and millimeter wave characterization of components and circuits for advanced communications SIMMCA" (2007-209)
Co-ordinator, IMT-Bucharest, **Project Manager: Dr. Alexandru Müller** (alexandru.muller@imt.ro)

LATE NEWS: Recently first acoustic devices operating at frequencies higher then 4 GHz, based on GaN/Si processing developed for the first time in the world by IMT- Bucharest in cooperation with FORTH Heraklion

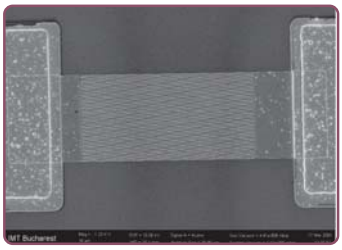


XRD analysis of the FBAR structures manufactured on GaN/Si wafers. The inset presents the rocking curve of the GaN layer

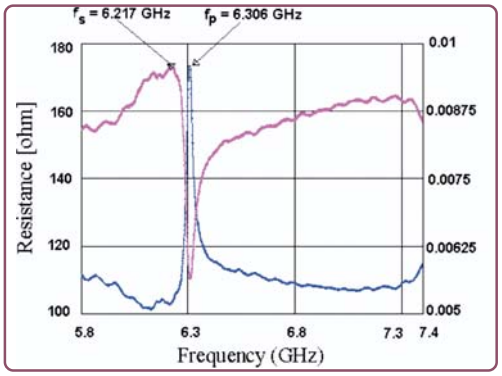
Optical photo of the series connection of the FBAR structures (a) top view top illumination; (b) top view bottom illumination



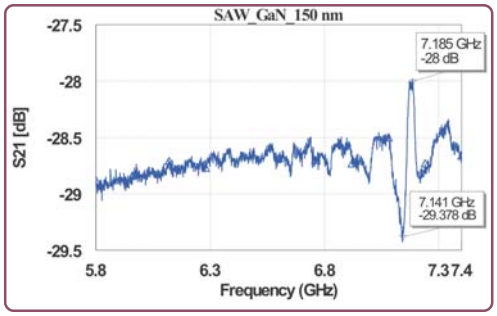
Face to face SAW resonators structures with 150nm fingers



Series connection of SAW structures with 250nm fingers and interdigits



Resistance and conductance of the FBAR series connection structure manufactured on the 0.54µm thin GaN membrane, resulted from the S parameter measurements. Series and parallel resonance frequencies were determined from these curves



Transmission between two SAW IDTs spaced at 50 µm. The structures have IDT with fingers and interdigits of 150 nm and have no reflectors

DISSEMINATION

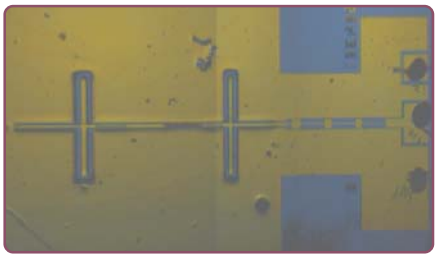
The volume **"Recent developments in MEMS technologies for microwave and millimeter waves circuits"** - editors L Pradell, L Jofre, (Universitat Politenica de Catalunya), A. Müller (IMT), D. Dascalu (IMT), R Plana (LAAS Toulouse) - was launched at Fodele in July 2008, during the **9th edition of the International Conference on RF MEMS "MEMSWAVE".** The volume was printed in the **Micro and Nanoengineering Series** coordinated by Prof Dan Dascalu and was edited by the Romanian Academy Press. The volume contains the extended papers of the 8th MEMSWAVE Conference, Barcelona, 2007. The international MEMSWAVE conference was generated by IMT Bucharest in 1999, in the frame of the MEMSWAVE project.

L4 - FP7 projects

"European Centre of Excellence in Microwave, Millimetre Wave and Optical Devices, based on Micro-Electro-Mechanical Systems for Advanced Communication Systems and Sensors" (MIMOMEMS)

Project No 202897 financed (2008-2011) through the "Regional potential" part (REGPOT call 2007-1) of the European Framework Pogramme (FP7), starting date May 2008 (**www.imt.ro/mimomems**).

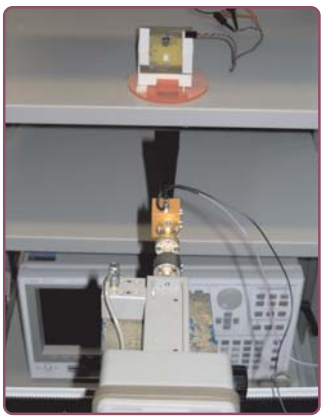
Co-ordinator: **Dr. Alexandru Muller**, **alexandru.muller@imt.ro**



The optical photo of the fabricated receiver structure

The overall aim of the MIMOMEMS project is to bring the research activity in Radio-Frequency (RF) and Optical-MEMS at the National Institute for R&D in Microtechnologies (IMT-Bucharest) to the highest European level and create a European Centre of Excellence in Microwave, Millimetre Wave and Optical Devices, based on Micro-Electro-Mechanical Systems (MEMS) for Advanced Communication Systems and Sensors.

The main objectives of the MIMOMES project are:
- "Exchange of know-how and experience". This activity will be done by twinning with two research centres: a) LAAS-CNRS in Toulouse which has strong expertise in silicon based RF and millimetre wave microsystems, photonic devices, and circuits manufacturing and characterization, and b) FORTH-IESL-MRG in Heraklion which has excellent knowledge of IIIVs (GaAs and related semiconductors) and wideband gap semiconductor processing (GaN, AlN).



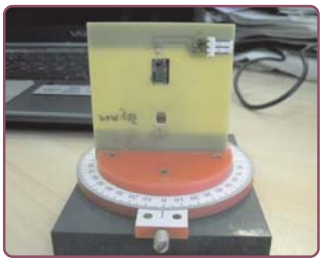


Photo of the experimental set-up and detail

The first experimental "test vehicle" was a GaAs monolithic integrated micromachined receiver module for 60 GHz with double folded slot antenna, technological developed together with FORTH - IESL - MRG and measured together with LAAS Toulouse and VTT Finland.

The GaAs monolithic integrated micromachined receiver module was processed at FORTH-IESL-MRG by IMT together with FORTH-IESL-MRG scientists. The design was performed by IMT and the microwave characterization was performed together with LAAS Toulouse and VTT Finland.
- **"Recruitment of incoming experienced researchers"** will allow IMT to hire 2 Post-Doctoral researchers with expertise in nanophotonics and microwave millimetre wave devices, and MEMS for advanced communication systems and sensors The researchers will be initially hired for 20 month fellowships with 6 monthly reviews. At the end of the period, the researchers will have the possibility to become full time IMT employees. An announcement regarding the hire intention for 2 postdocs was posted on the website of the project..
- "Acquisition, development or upgrading of research equipment" 50% of the total funding of the project is dedicated to this objective: ♦ Near field scanning optical microscope (SNOM): Acquisition finished in August 2008, delivered in October 2008. It was installed at IMT Minafab Facility and is fully operational; ♦ Upgrade to 110GHz the 1-65 GHz set-up for "on wafer" characterization: Acquisition finished in December 2008. It will be installed in April 2009; ♦ Frequency synthesiser up to 65GHz-110 GHz. Acquisition finished in December 2008. It will be installed in April 2009; ♦ Au plating facility for semiconductor wafers will be purchased in 2009. In the same time a spectrum analyser working up to 110 GHz was purchased using the national 'Capacities' program founds.
- "Organisation of workshops and conferences" will support knowledge transfer at national and international levels through organisation of scientific international sessions and seminars: The MIMOMEMS project has organized the first International Scientific Session at the CAS Conference 2008 (13-15 October 2008): 3 oral sessions and 1 poster session with invited lecturers: G. Konstantinidis (FORTH Heraklion); T. Vähä Heikkilä (VTT Helsinki)
- **"Dissemination and promotional activities"** will consist in publication of research results in peer reviewed journal and presentation at international conferences (Project web page; Promotional article in the Romanian Journal "Market Watch"). Connected to the MIMOMEMS project a proposal for the 2nd Space Call in FP7program was submitted: the STREP "MIcrowave Nitride nOvel Technologies for Advanced tUnable and RecOnfigurable Satellites - **MINOTAUROS**" The consortium is composed of 7 partners from 5 European countries; Project leader: Thales Alenia Space (Toulouse-France), a leading actor in the space industry. Members in the consortium: LAAS CNRS (France), IMT-Bucharest (Romania), FORTH Herakion(Greece) FEMTO ST (France) EPFL (Switzerland), Azurro (Germany). We are waiting for the evaluation result.

MEMS-4-MMIC "Enabling MEMS-MMIC technology for cost-effective multifunctional RF-system integration" acronym MEMS-4-MMIC, FP7-ICT-2007-2, No.204101.

STREP project financed (2008-2010) through the ICT Challenge 3: Components, Systems and Engineering, Micro/Nanosystems of the FP7.

Coordinator: **R. Baggen, IMST GmbH**. ***Partners:*** *IMST GmbH, Germany, Swedish Defence Research Agency- FOI, Sweden, Technical Research Centre of Finland-VTT, Finland, OMMIC, France, National Institute for research and Development in Microtechnologies-IMT Bucharest, Romania, Institut d'Electronique de Microélectonique et de Nanotechnologie, IEMN, France*.

Contact person for IMT: **Dr Dan Neculoiu, dan.neculoiu@imt.ro**