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 (MIMOMEMS)

Coordinator: Dr. Alexandru Müller
(alexandru.muller@imt.ro)

National Institute for R&D in Microtechnologies (IMT-Bucharest)

(www.imt.ro)

Project Officer: Dr Stefan Weiers

Project financed (2008-2011) through the "Regional potential" part of the European Framework Programme - FP7

Capacities - Part 4 - Research Potential.
Activity: 4.1.Unlocking and developing the research potential in the EU´s convergence regions and outermost regions (REGPOT-2007-1)

(start date May the 1st 2008)

National Institute for Research and Development in Microtechnologies

IMT-Bucharest

(www.imt.ro)


Iceland
Sweden
Finland
Russia
Norway
Estonia
Latvia
Denmark
Lithuania
Ireland
Belarus
U.K.
Neterland
Germany
Poland
Belgium
Ukraine
Luxembourg
Czech Rep.
Slovakia
Moldova
Austria
Hungary
Switzerland
Slovenia
France
Bucharest
Croatia
Bos.& Herz.
Serbia
Bulgaria
Italy
Mont.
Spain
Macedonia
Portugal
Albania
Turkey
Greece
Crete
Malta
Morocco
Algeria
Tunisia

- **IMT- Bucharest** was founded in 1993 as **Institute of Microtechnology** since 1996 is a **National Institute for Research and Development in Microtechnologies**

- **Mission**: **Integrating R&D with education and training and with support for industry** (**services, technology transfer**); **networking at national and international level** (including interaction with European Technological Platforms), **innovation**

Employers: 176 (100 in research)

Funds from contracts : 10 millions Euro in 2008

IMT- Bucharest enjoyed a rich experience in **international co-operation** illustrated by its participation in **15 FP6 EU Projects**, **7 FP 7** and long experience in coordinating: national networks, research and education projects

Organization

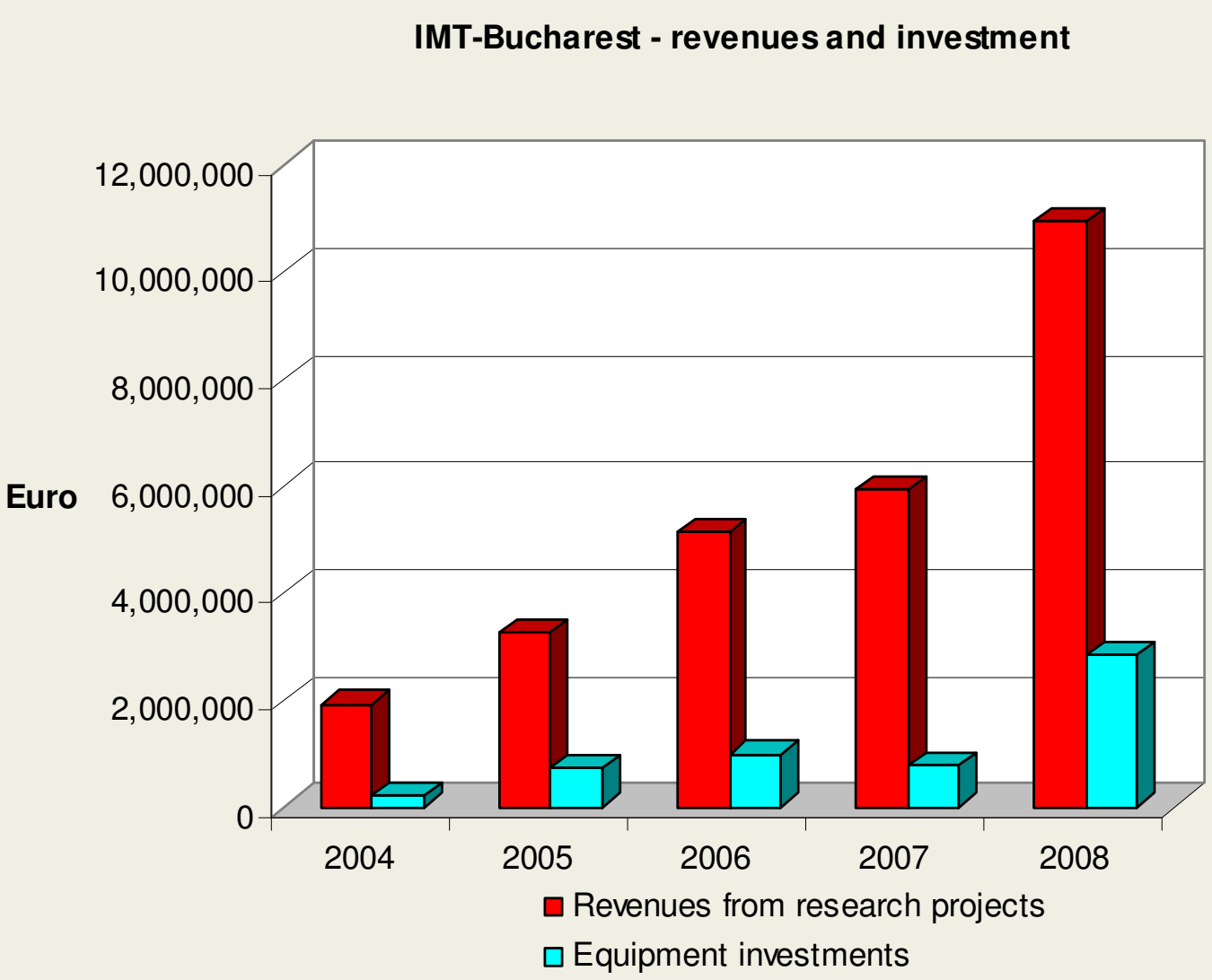
Departments:

1.Scientific and Technological Research Department: L1, L3,L4,
Centre for scientific services (L5, L6, L7),
Center for research and technologies integration (L2, L8, L9)
2. Technical Department: technological laboratories, clean room areas; mask shop, EBL nanolitography
3. Infrastructures
- Centre for Services in micro-nanofabrication: IMT-MINAFAB
- Support Centre for international cooperation in micro-nano-bio-info technologies
-Centre for multidisciplinary training / education

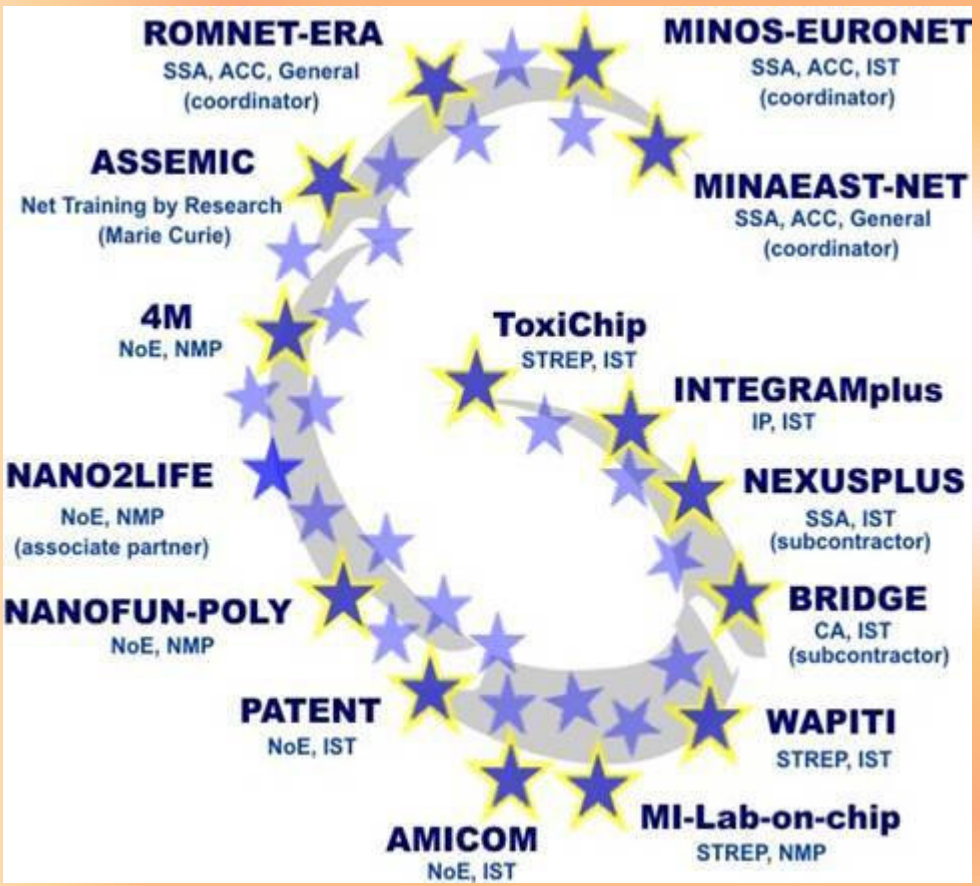
R&D Laboratories:

L1. Laboratory of Nanotechnology
L2. Laboratory for Microsystems in biomedical and environmental applications
L3. Laboratory for Micro- and Nano-Photonics
L4. Laboratory for Microsystems and Micromachined Microwave Components
L5. Simulation, Modelling and Computer Aided Design Laboratory
L6. Microphysical Characterization Laboratory
L7. Reliability Laboratory
L8: Ambiental Technologies Laboratory
L9. Molecular Nanotechnology Laboratory

Turnover and investments



IMT- Bucharest participation in FP6 Projects

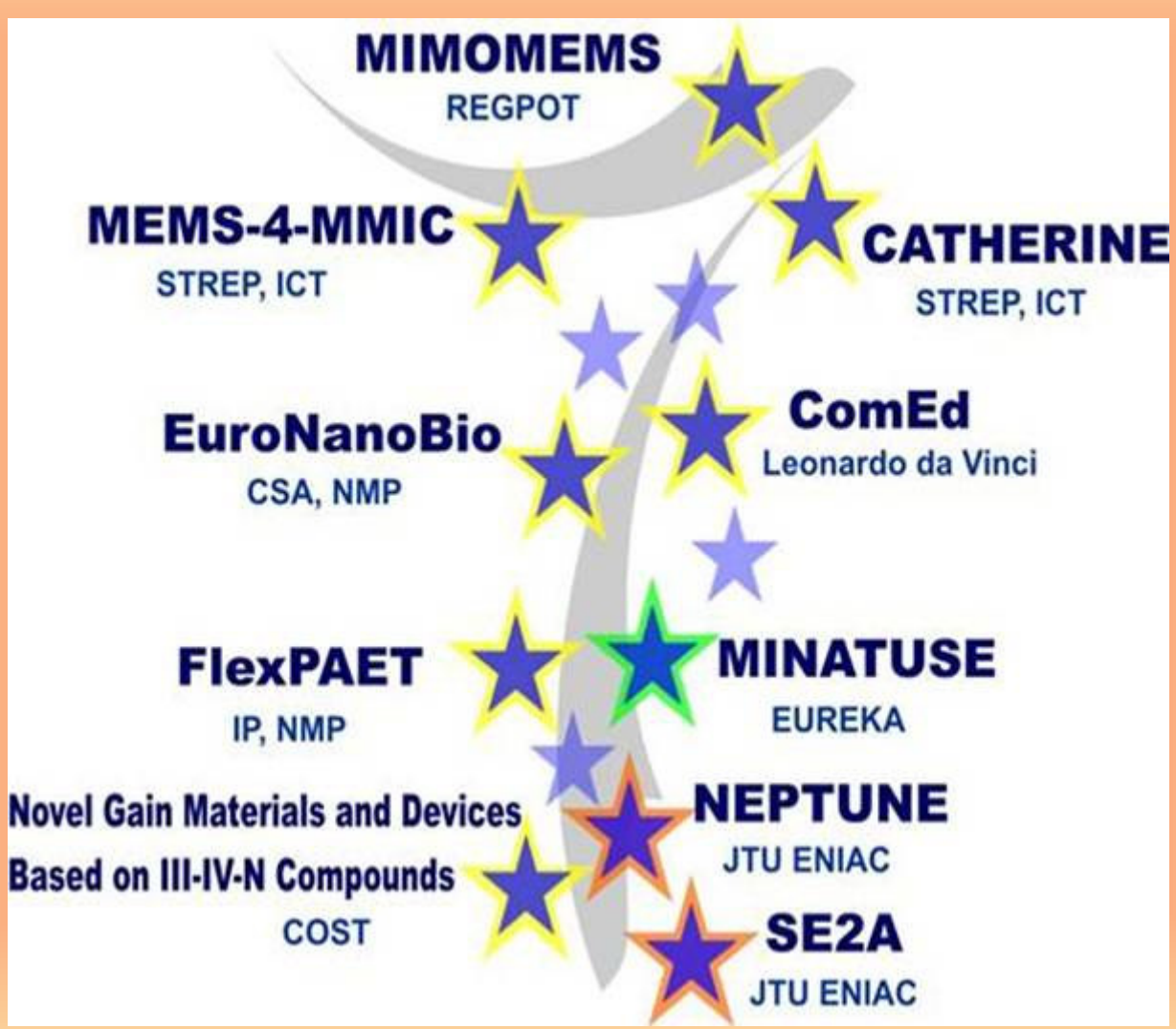


IMT- Bucharest participated in different types of EU projects:

IPs, STREPS, NoEs, RTN- Marie Curie Network, SSA, CA in ICT and NMP Priorities

IMT was acting as coordinator, partner, associate partner or subcontractor

Participation of IMT- Bucharest in EU FP7 (and related) projects



+4 ERA-NET projects

Participation of IMT- Bucharest in EU 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,** Contract no. 202897, **REGPOT call 2007-1**, 2008-2011. Coordinator: IMT-Bucharest. Contact: Dr. Alexandru Muller, (alexandru.muller@imt.ro).

► **Enabling MEMS-MMIC technology for cost-effective multifunctional RF-system integration - MEMS-4-MMIC, Contract no.: 204101, STREP, FP7-ICT-2007-2,** 2008-2011. Coordinator: IMST GmbH, Germany. IMT role Partner; IMT Contact: Dr. Dan Neculoiu, (dan.neculoiu@imt.ro).

► **Carbon nAnotube Technology for High-speed nExt-geneRation nano-InterconNEcts - CATHERINE,** coord: Dr. Stephen Trueman, CONSORZIO SAPIENZA INNOVAZIONE, Italy. Contract no. 216215, **STREP**, ICT, 2008-2011. IMT role Partner; IMT Contact: Adrian Dinescu, email: (adrian.dinescu@imt.ro).

► **Flexible Patterning of Complex Micro Structures using Adaptive Embossing Technology – FlexPAET, IP**, NMP, 2008-2010. Coord: Dr.-Ing. Christian Wenzel, Fraunhofer Gesellschaft zur Förderung der angewandten Forschung e.V. Fraunhofer Institut für Produktionstechnolgie (IPT), Germany. IMT role Partner; IMT Contact: Dr. Dana Cristea (dana.cristea@imt.ro);

► **European scale infrastructure in NanoBiotechnology - EuroNanoBio, CSA, NMP, 2009-2010**; Coord: Patrick Boisseau CEA (France). IMT role; partner; IMT contact: Prof. Dan Dascalu (dan.dascalu@imt.ro);

► **Hazard characterization and human and environment impact assessment of specific nanomaterials and associated products and exploration of new solutions for their sustainable use, re-use, recycling and final treatment and/or disposal – NANOSUSTAIN,** *NMP-2009-1.3-1; ENV.2009.3.1.3.2, Project coordinator: Dr. Rudolf Reuther, NordMiljö AB, IMT role: Partner; IMT contact Dr. Irina Kleps (irina.kleps@imt.ro).*

EU projects related to FP 7

►**Nanoelectronics for Safe, Fuel Efficient and Environment Friendly Automotive Solution – SE2A**; **ENIAC (nanoelectronics)** 2008-1**,** Coord: NXP Semiconductor Netherlands BV, The Netherlands. IMT role; partner; IMT contact: Dr. Alexandru Muller (alexandru.muller@imt.ro).

►**Novel Gain Materials and Devices Based on III-V-N Compounds**; **COST Action MP0805,** Coordinator: Prof. N. Balkan, University of Essex, UK. IMT role; partner; contact person: Alexandru Muller (alexandru.muller@imt.ro)

► **Micro Nano Technology Use by SME's- MINATUSE, EUREKA**, coord: Christophe Bruynseraede, IMEC, Belgium, 2005-2010, IMT role Partner; IMT Contact: Ionica Miresteanu, (ionica.miresteanu@imt.ro)

► **Development of competences of educational staff by integrating operational tasks into measures of vocational training and further education" ComEd,** - **Leonardo da Vinci - Life Long Learning** (2008-2010) Coordinator BWAW Thüringen GmbH, Germany, Contract Number : DE/08/LLP-LdV/TO/147174- (2008-2010) IMT role Partner; IMT Contact: Dr. Raluca Muller (raluca.muller@imt.ro)

ERA-NET projects

•**A "system-in-a-microfluidic package" approach for focused diagnostic DNA microchips (DNASIP)** Coordinator: Université Catholique de Louvain, Belgium, Prof. Denis Flandre, role of IMT – partner, contact person Phys. Monica Simion (monica.simion@imt.ro).

•**"Nanostructural carbonaceous films for cold emitters" (NANOCAFE)**, Coordinator: Industrial Institute of Electronics, Poland, Dr. Elżbieta Czerwosz, role of IMT – partner, contact: Phys. Florea Craciunoiu (florea.craciunoiu@imt.ro).

•**" Multifunctional Zinc oxide-based nanostructures: from materials to a new generation of devices- MULTINANOWIRES" Coordinator: CEMIMAT/I3N,FCT-UNL, Portugal; partners, Dunarea de Jos Univ Galati, IMT-Bucharest** contact Dr Munizer Purica munizer.purica@imt.ro

• **MEMS Based Millimetrewave Imaging System- MEMIS; Coordinator; LAAS Toulouse; Partners: LAAS, IMT, VTT, 31 Degree** contact: Dr. Alexandru Muller (alexandru.muller@imt.ro).

Other International Partnerships

- **A common European virtual lab in RF- MEMS, affiliated to CNRS, was created in 2009, including**:

- **LAAS/CNRS, Toulouse, France;**
- **IMT-Bucharest, Romania**
- **FORTH, Heraklion, Greece**

- **Outside Europe**, **IMT- Bucharest** has also bilateral cooperation with organizations from:
  - South Korea (KERI Changwon)
  - South Africa (Univ. Pretoria)

New Infrastructure

Clean room:

❑ Micro and nanolithography; Nanoprinting

- Mask less lithography system - ***DWL 66 fs***, Heidelberg Instruments Mikrotechnik
- Electron beam lithography and nanoengineering workstation - ***e_Line***, Raith
- Pattern Generator - ***Elphy Plus***, Raith
- Double Side Mask Aligner - ***MA6/BA6***, Suss MicroTec
- Dip Pen Nanolithography Writer - NSCRIPTOR, NanoInk

Technological Processes

- Electron Beam Evaporation an DC sputtering system - ***AUTO 500***, BOC Edwards
- PECVD - ***LPX-CVD, with LDS module***, STS
- LPCVD - ***LC100***, AnnealSys
- RIE Plasma Etcher - ***Etchlab***, SENTECH Instruments
- Rapid thermal processing/annealing - ***AS-One***, AnnealSys
- Micro-Nano Plotter - ***OmniGrid***, Genomic Solutions

CAD and Simulation

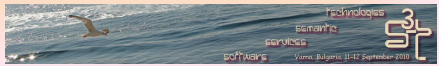
CoventorWare 2008.010, Ansys Multiphysics 11.0, COMSOL
Opti FDTD 8.1, Opti-HS, OptiBPM 9.0, OptiGrating, Optiwave
IE3D, FIDELITY from Zeland, CST

Characterization

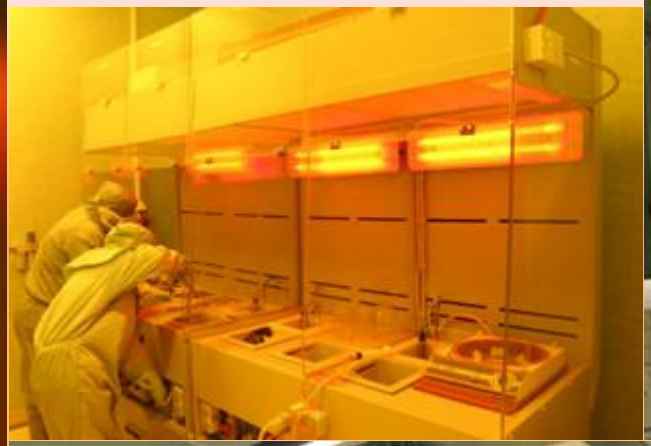
- **Vector Network Analyzer (VNA) up to 110 GHz and on wafer characterization system**
- **Spectrum analyzer up to110GHz**
- **Frequency generator synthesiser up to 110GHz**

Semiconductor Characterization System, Wafer Probing Station - *4200-SCS*/Keithley; Suss MicroTec

- Field Emission Gun Scanning Electron Microscope (**FEG-SEM**) - *Nova NanoSEM*, FEI Company
- **XRD, WLI, SNOM, SPM,** High **Resolution Raman Spectrometer**, **Nanoindenter**




SENTECH
SI 220
Clean room,
class 1,000



Clean room, class 1,000

IMT-Bucharest

Laboratory of

Micromachined structures, microwave circuits and devices- RF MEMS

Alexandru Müller

alexandru.muller@imt.ro www.imt.ro

Membrane Supported Circuits for Millimeter Wave Applications

HISTORY

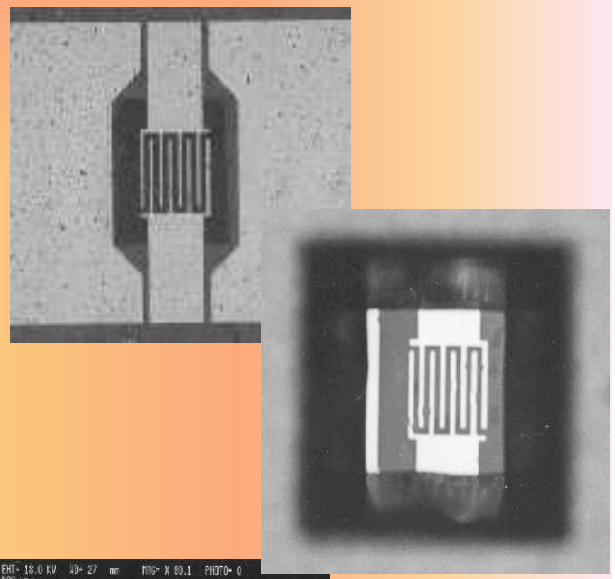
First European results: 1996-1997.

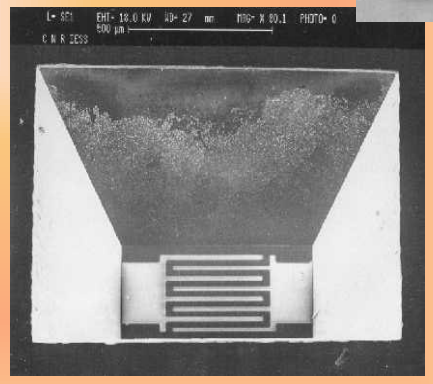
IMT Bucharest and CNR Rome

LAAS/CNRS, Toulouse

IRCOM Limoges

.





Micromachined Circuits for Microwave and Millimeter Wave Applications
(MEMSWAVE)
Project No.977131
1998 - 2001

IMT-Bucharest (Project coordinator)

Partners:

FORTH Heraklion
ITC-IRST Trento
Uppsala University
Tor Vergata Univ. Rome
CNR-M²T Rome
HAS-MFA Budapest
ISP Kiev
Microsensor Kiev Ltd.

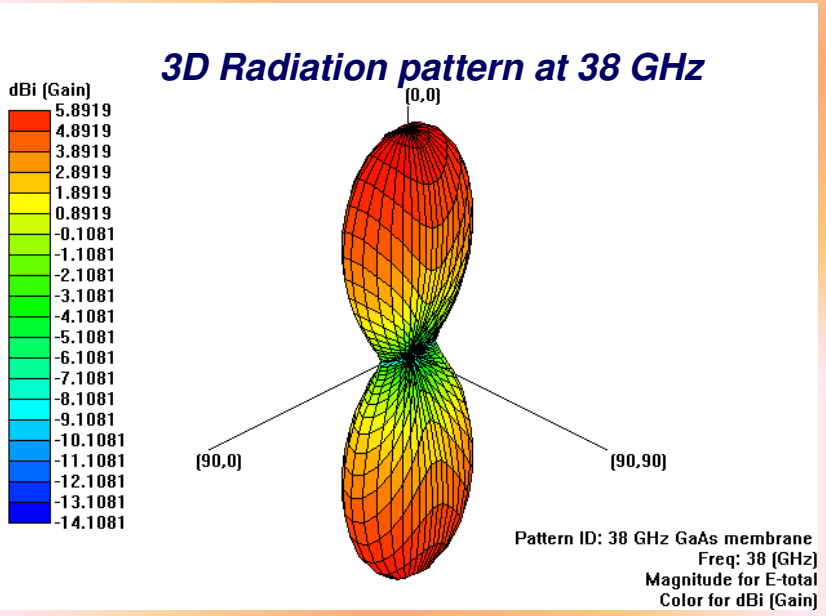
TARGETS

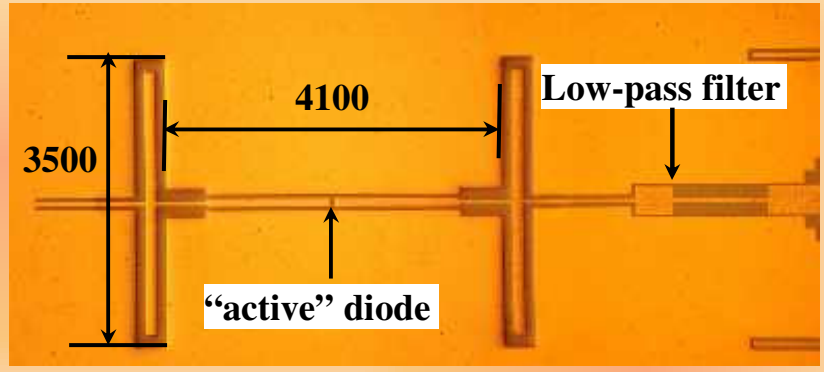
- **Thin dielectric membranes on high resistivity silicon substrate;**
- **GaAs membranes manufacturing;**
- **Micromachined passive circuit elements on silicon and GaAs substrate;**
- **Micromachined millimetre wave band pass filters and antennas;**
- **Receiver modules for 38GHz and 77GHz based on micromachining technology;**
- **Transmitter module for 38GHz.**

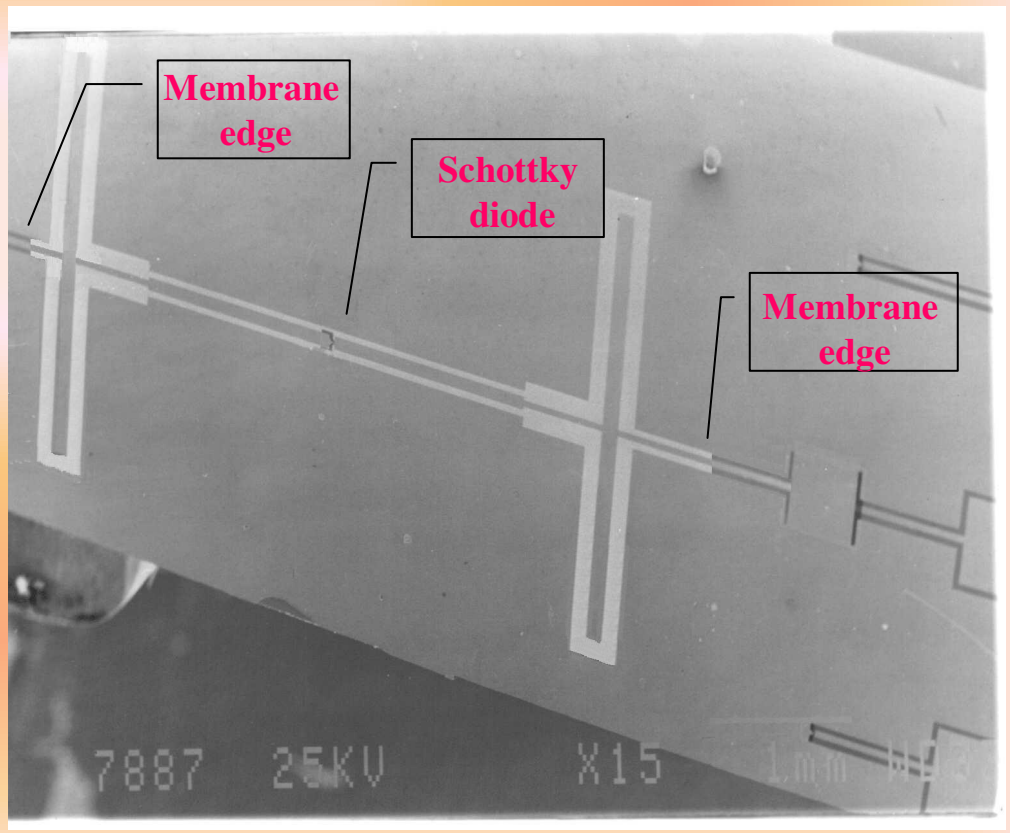
- **The project was nominated between the 10 finalists for the Descartes Prize 2002 of the European Commission**
- **The MEMSWAVE conference became an itinerant European event**

38GHz monolithic receiving module on GaAs membrane

IMT –FORTH 2001

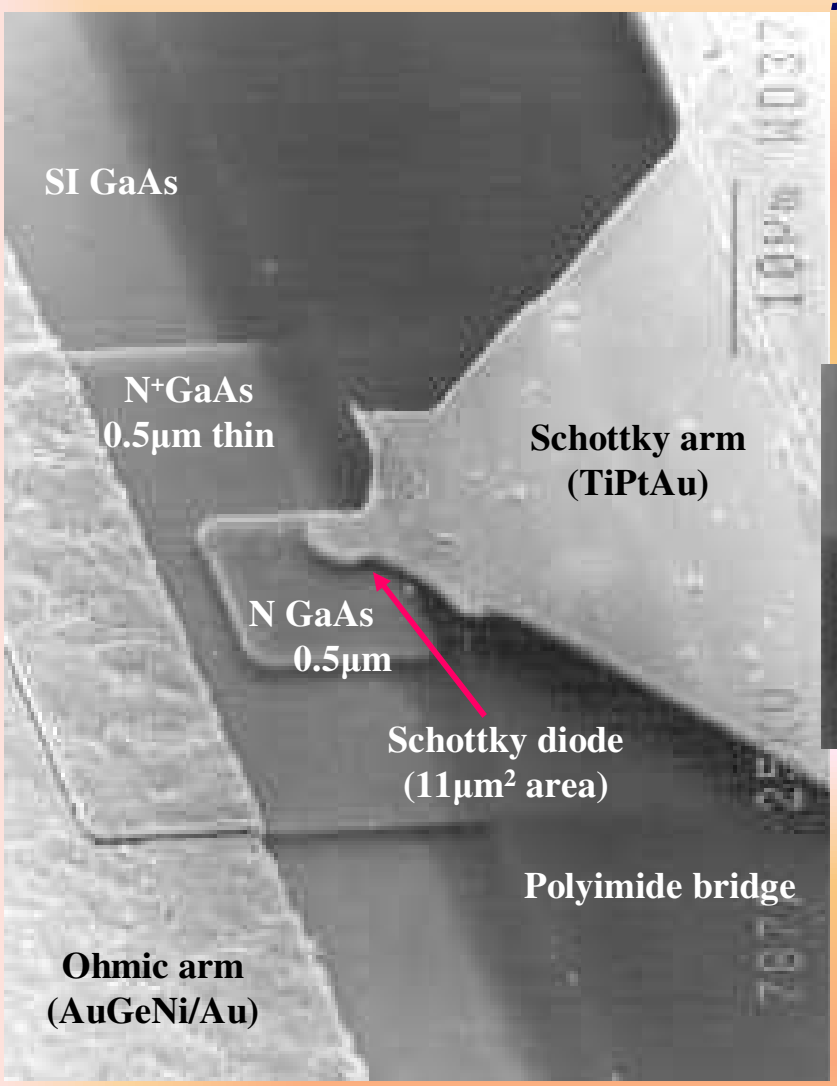


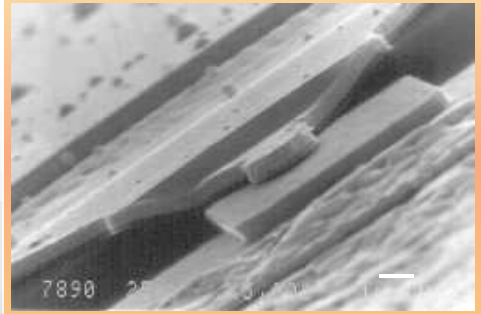


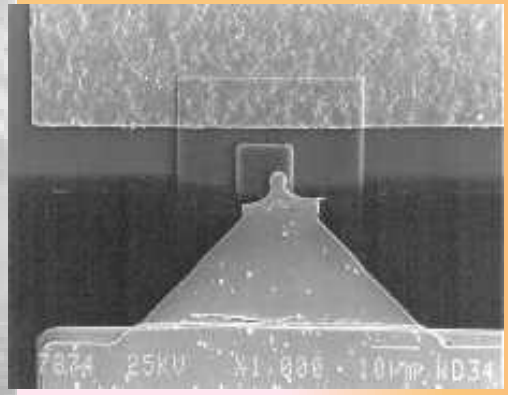


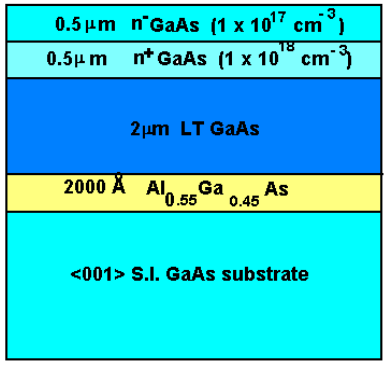
Membrane supported integrated 38 GHz GaAs micromachined receiving module (the antenna as well as the Schottky diode are supported on a 2.2μm thin GaAs membrane). The membrane is transparent in the white areas, which are unmetalized.

Details of the Schottky diode region

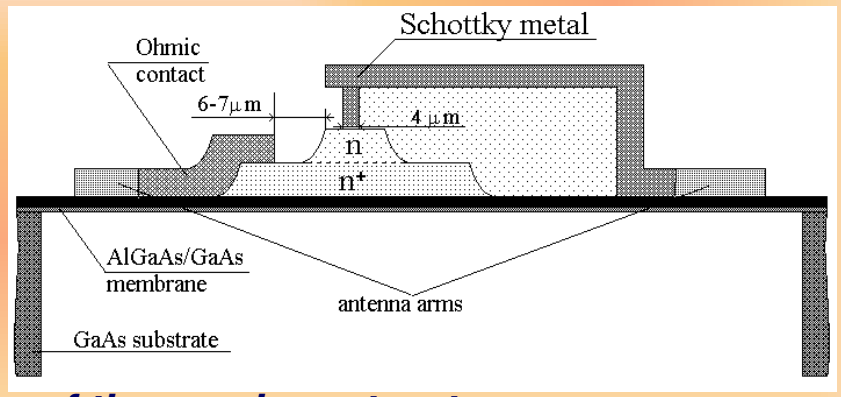








The MBE heterostructure



Cross section of the receiver structure

IMT Bucharest-FORTH Heraklion
in the MEMSWAVE Project
JMM-March 2003

The MEMSWAVE Workshop

- In 1999 it was organized the first “MEMSWAVE” workshop in Sinaia with participation also from outside the Consortium ……LAAS Toulouse
- In 2001 it was organized the second MEMSWAVE” workshop in Sinaia
- Starting from 2002, the MEMSWAVE workshops became an itinerant European event.
- In 2010, after Heraklion, Toulouse, Uppsala, Laussane, Barcelona, Heraklion, Trento the 10th edition will be organized in Lecce.

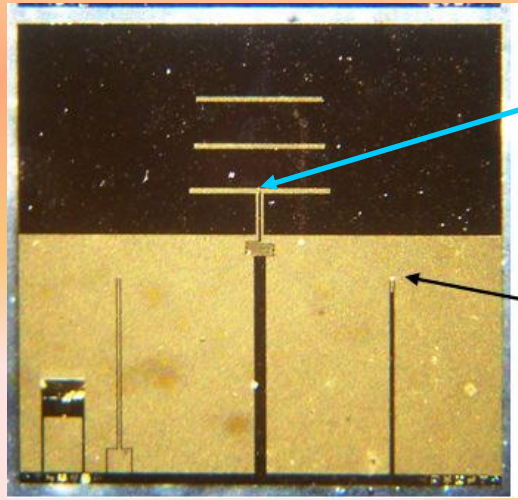
AMICOM FP6 NoE (2004-2007)

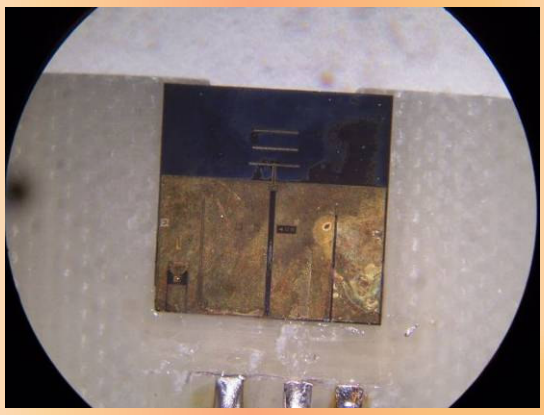
Coordinator – LAAS CNRS Toulouse

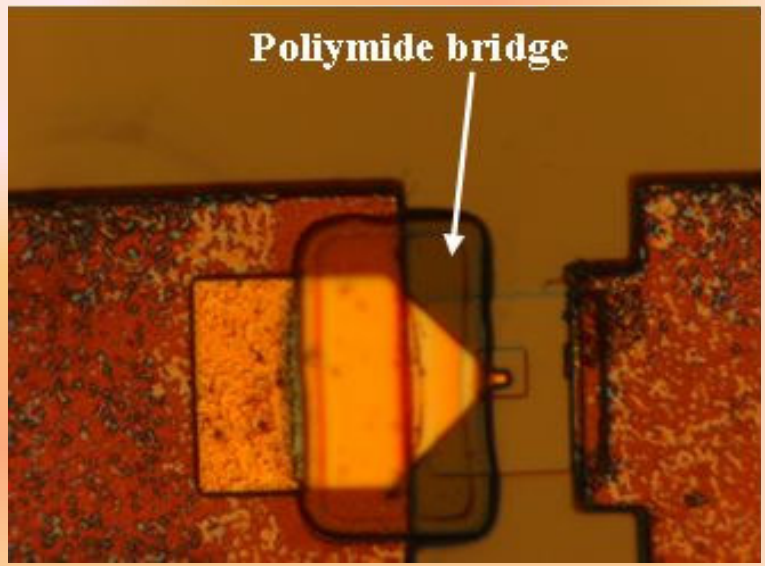
CNRS (France) (LAAS -IEMN-IRCOM)
•CHALMERS (Sweden)
•CRANFIELD (United Kingdom)
•EPFL (Switzerland)
•FORTH (Greece)
•IMEC (Belgium)
•IMPERIAL COLLEGE (UK)
•IMT- Bucharest (Romania)
•ITME (Poland)
•MILLILAB & VTT (Finland)
•PERUGIA (Italy)
•TECHNION (Israel)
•TUD (Germany)
•TUM (Germany)
•ULM (Germany)
•UPPSALA (Sweden)

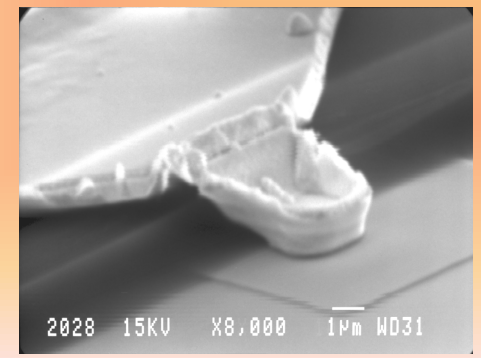
•UNIVERSITY OF ATHENS (Greece)
•ITC-IRST (Italy)
•ARMINES (France)
•METU (Turkey)
•FRAUNHOFER ISIT (Germany)
•FRAUNHOFER IZM (Germany)
•TELEMIC (Belgium)
•LETI (France)
•DIMES (The Netherlands)

The 60 GHz receiver with Yagi-Uda antenna based on GaAs micromachining (IMT-FORTH 2006)



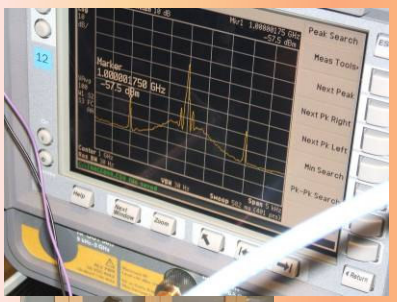




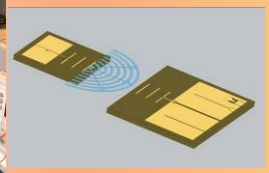


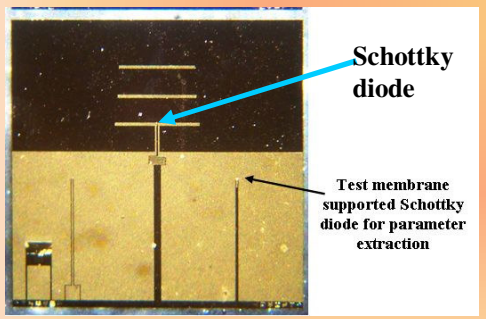
GaAs micromachined 60 GHz Yagi-Uda antennae based receiver used as millimeter wave identification tag

Common work in the of IMT Bucharest, VTT Helsinki, FORTH Heraklion -2007 AMICOM Project

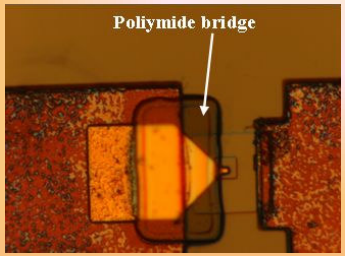


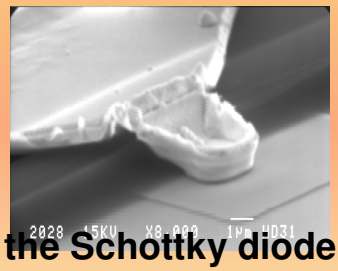
- The MMID concept was demonstrated at distances between 0.5 … 2.5 m two passive tags:
  - -60GHz monolithic integrated micromachined receiver structure with Yagi-Uda antenna
  - -77 GHz receiver structure based on the hybrid integration of a membrane supported folded slot antenna with two types of detector diodes (GaAs Schottky diode and InSb based quantum backward diode)



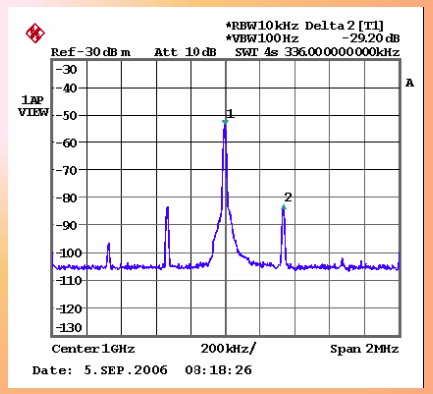


The receiver structure

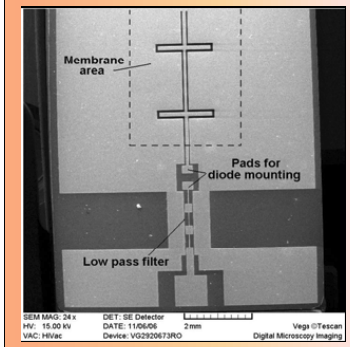




Details of the Schottky diode region



Received backscattered spectrum at a distance of 1.04 m. The transmission power was 34 dBm EIRP.



Top SEM photo of the micromachined receiver structure for 77 GHz (before the flip chip detector diode mounting).

MIMOMEMS – Objectives (1)

1. Exchange of know-how and experience

The Centre of Excellence will be created by developing IMT's existing scientific expertise and capacities and collaborating closely (twining) with specialist research groups from:

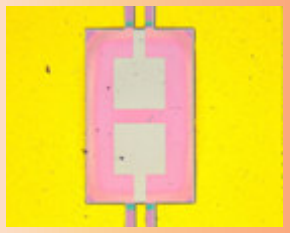
a) LAAS-CNRS Toulouse which has strong expertise in silicon based RF and millimetre wave microsystems, photonic devices, and circuits manufacturing and characterization

b) FORTH-IESL-MRG Heraklion which has excellent knowledge of IIIVs (GaAs and related semiconductors) and wideband gap semiconductor processing (GaN, AlN).

6.3 GHz resonance on a GaN FBAR obtained by micromachining of GaN/Si

IMT and FORTH

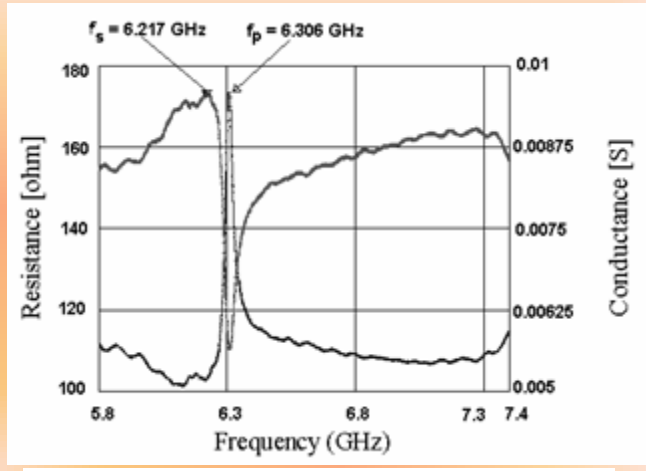
- 340 nm (GaN) +200nm (buffer) thin membrane supported FBAR structure based on GaN micromachining
- 50nm thin Mo metallization *GaN/Si wafers from NTT AT Japan*

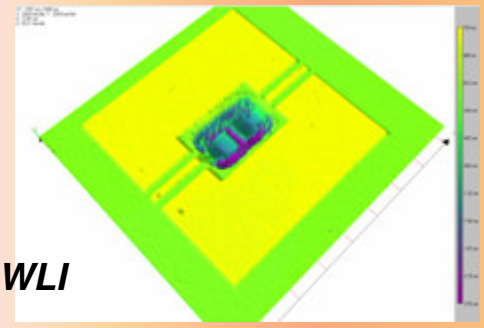


Top view with top illumination

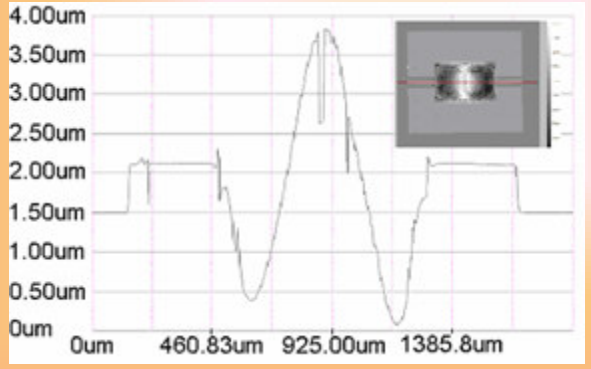
Bottom view with top illumination

Q=1130

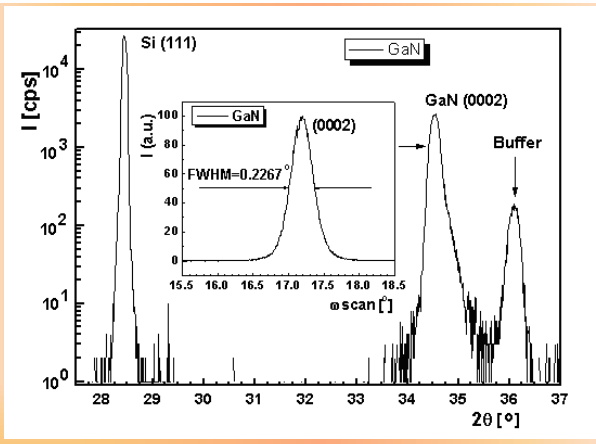




WLI



Maximum deflection 2.7μm



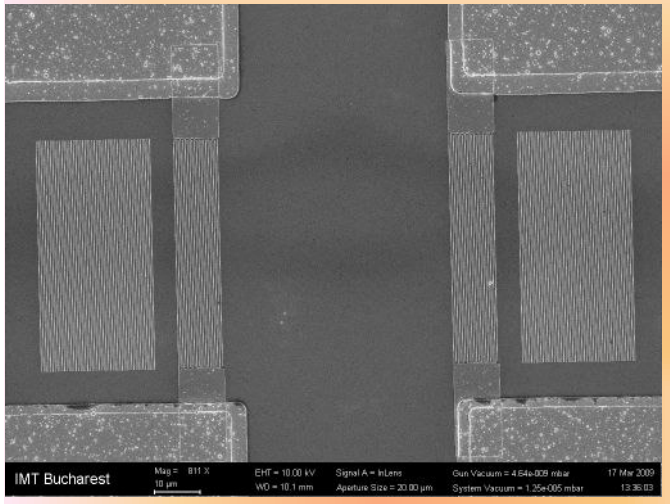
XRD

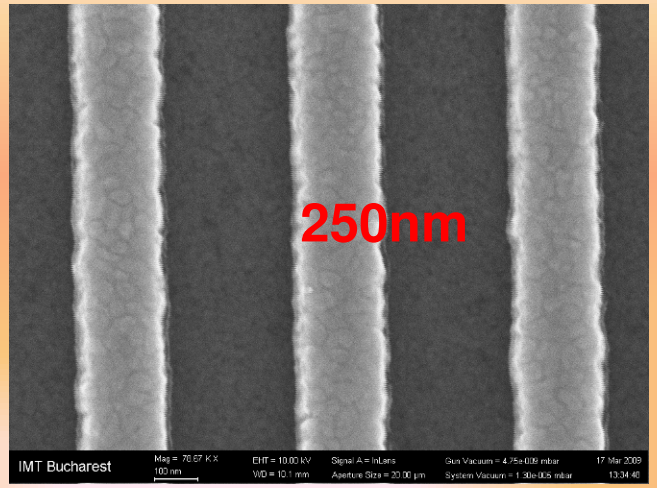
$\varepsilon = \Delta c/c_o = 1.9*10^{-3}$

Microwave characterization, deflection measurements, stress and material analysis could be performed in IMT with the new purchased equipments

A. Müller, D. Neculoiu, G. Konstantinidis et al. "*6.3 GHz Film Bulk Acoustic Resonator Structures Based on a Gallium Nitride/Silicon Thin Membrane*" **Electron Devices Letters , August 2009, pp799-801**

GaN SAW structures manufactured using nanolithography



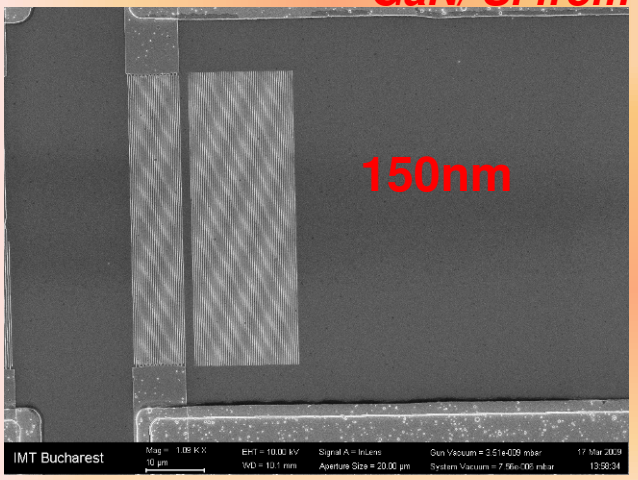


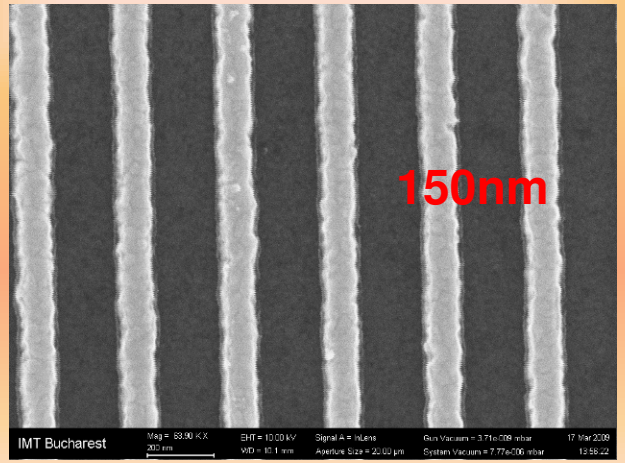
IMT-FORTH

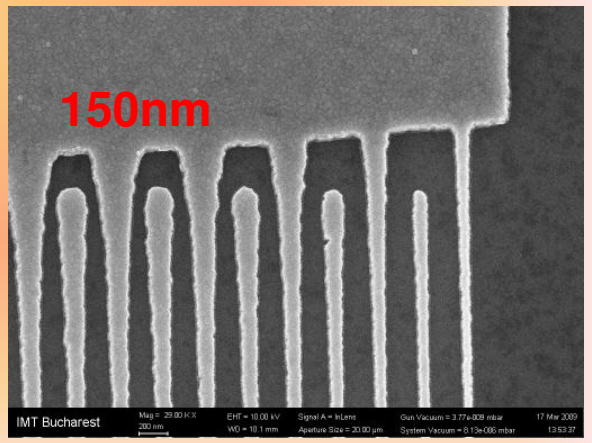
SAW resonators on GaN/Si with fingers and interdigits 250nm wide (up) and 150nm wide (down) *patterned in IMT on the new "E-Line" equipment from RAITH*

PMMA 200nm thick metaization Ti/Au 100nm thick

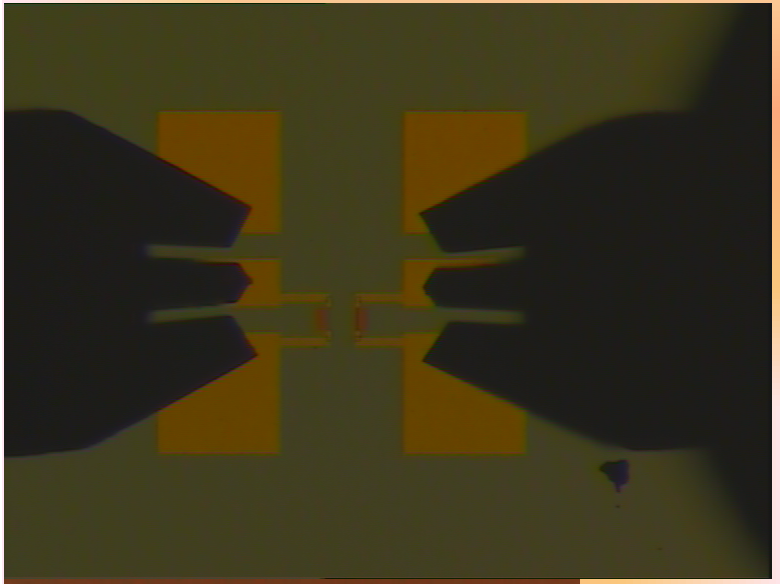
GaN/ Si from Azzuro Magdeburg (1μm thin GaN layer)

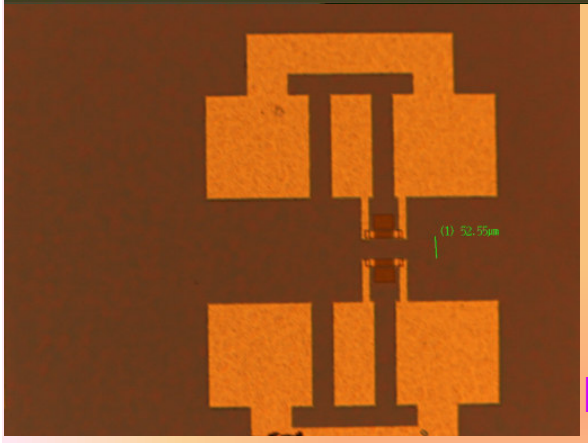




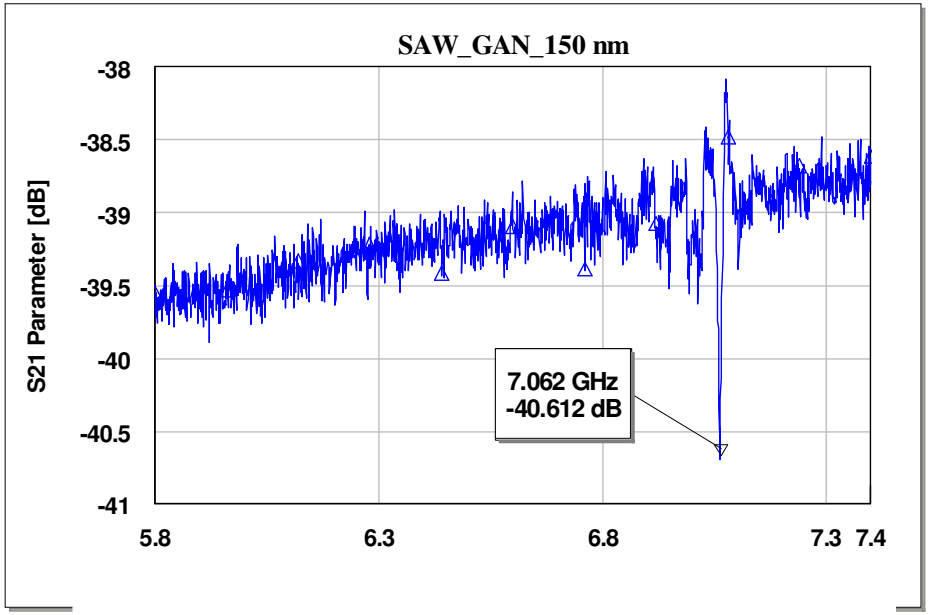


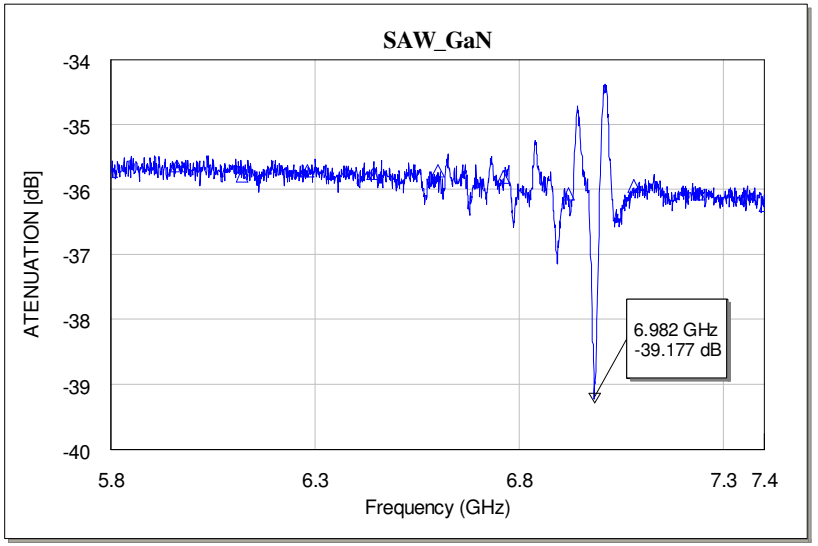
7 GHz rezonance on a SAW structure manufactured on GaN/Si





IMT- FORTH 2009

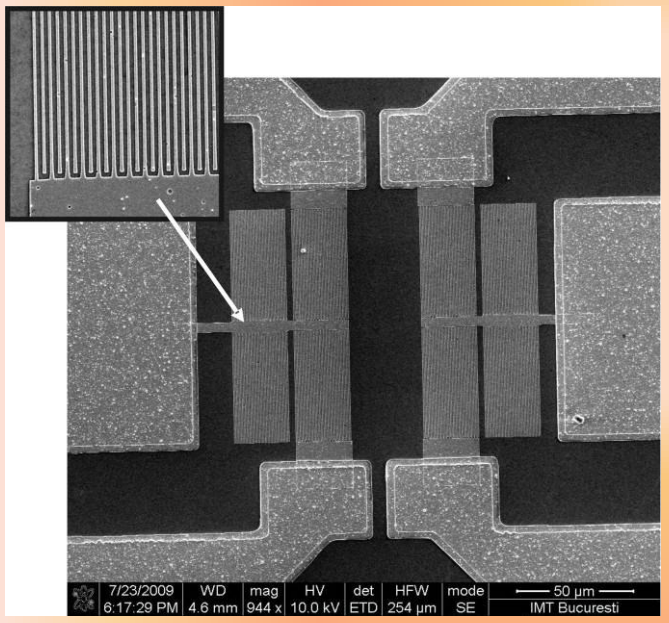


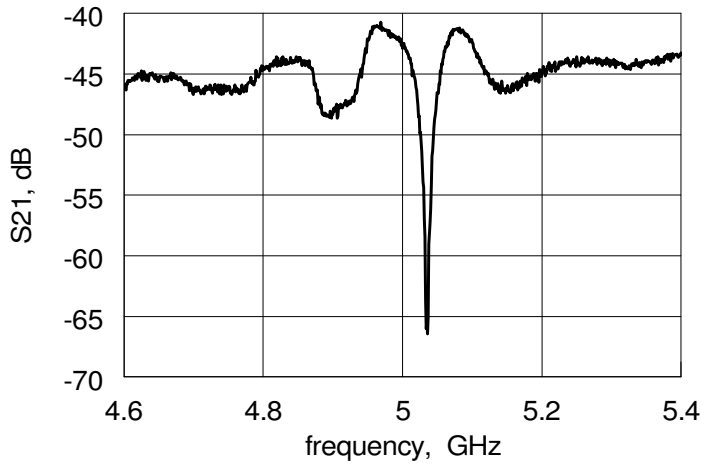


Best results reported up to now on GaN are at about 1 GHz

AlN/Si SAW structure resonating at 5.03 GHz

Fingers and interdigits 250nm wide processed at IMT





IMT-Bucharest-FORTH Heraklion 2009

D. Neculoiu, A. Müller, G. Deligeorgis, A. Dinescu, A. Stavrinidis, D. Vasilache, A. Cismaru, G. E. Stan and G. Konstantinidis, Electron. Lett. 45, 1196 (2009).

AlN layer deposited at NIMP - Bucharest

ii. Increase IMT's Human Potential

-3 experienced scientists (post-docs) have been employed using the project budget. The researchers are initially hired for 18 months. At the end of the period, the researchers will have the possibility to become full time IMT employees.

-6 applications have been received

-Dr. Mihai Pavelescu, Univ Kassel

-Dr. Mihaela Carp, Nanyang Technical Univ. Singapore

-Alexandra Stefanescu, Politehnica Univ. Bucharest

MIMOMEMS – Objectives (2)

iii. Increase IMT's Technology Potential

List of equipments, upgrades etc. already purchased or to be purchased through the MIMOMEMS project:

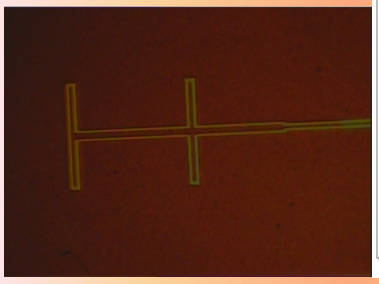
- **Near field scanning optical microscope (SNOM) - It was installed at IMT Minafab Facility and is fully operational (Co-financed by a national project)**

- **Upgrade to 110GHz the 1-65 GHz set-up for on wafer characterization -**
  - **Upgrade of the VNA up to 110 GHz, Operational since May 2009 (Co-financed by a national project)**
  - **Upgrade the on wafer measurements set-up up to 110 GHz, Oprational since June 2009**

- **Frequency synthesiser up to 65GHz-110 GHz, Operational since June 2009**
- **Spectrum analyser up to 110 GHz (finaced by a national project) Operational since June 2009**

- **Au plating facility for semiconductor wafers, contracted in May 2010**

Upgrade to 110 GHz the 65 GHz “on wafer” characterization set-up: -Upgrade of the VNA up to 110 GHz (Anritsu)



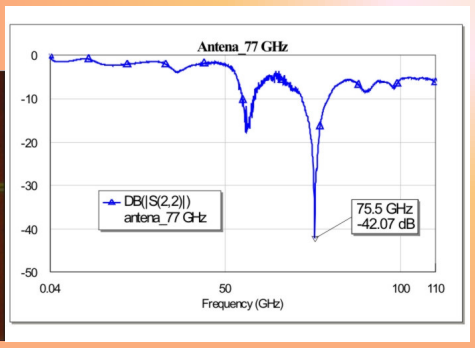
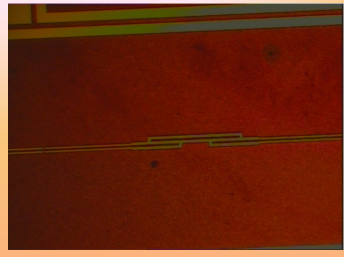


Photo image of 77 GHz antenna and its S_{22} parameter measured with the new equipment



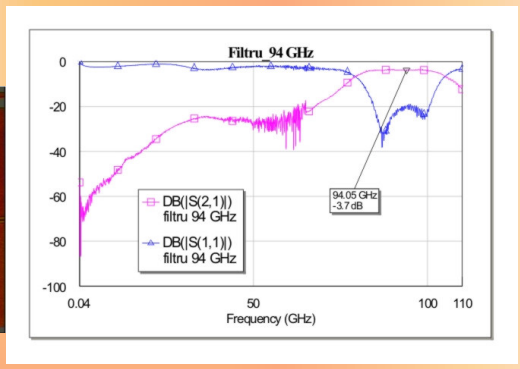
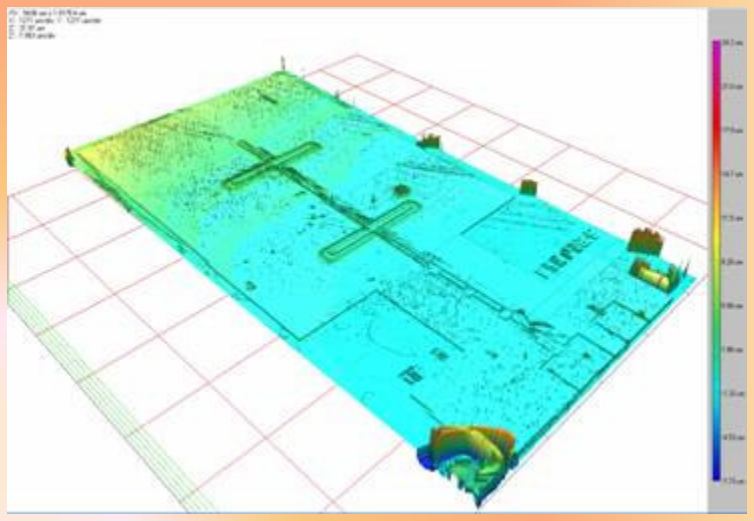


Photo image of 94 GHz filter and its S parameter measured with the new equipment

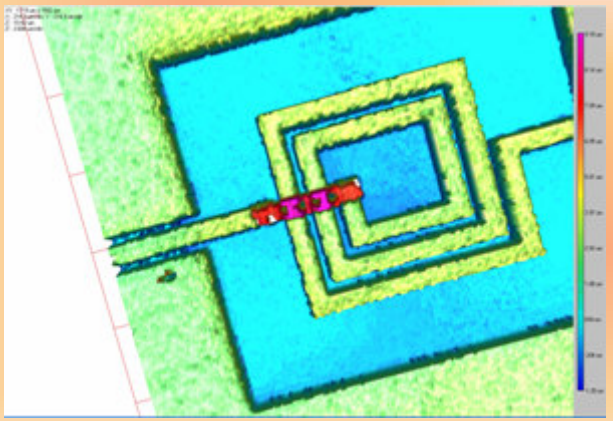
Spectrum analizer (from Anritsu) and frequency syntesiser up to 110 GHz (from Agilent) recently purchased and installed in IMT

Other new equipments in the lab

White Light Interferometer (WLI) - *Photomap 3D Standard 2006* (FOGALE NANOTECH);



3D image of a 60GHz monolithically integrated receiver micromachined on GaAs



Detail of a silicon micromachined filter

MIMOMEMS – Objectives (3)

iv. Increase IMT's Scientific Visibility
v. Increase IMT's technology transfer for economic needs

The objective (iv) is to support knowledge transfer at national and international levels, and facilitate research policy development in the field of RF- and Optical-MEMS.

This will be achieved through IMT's organisation of scientific events and seminars. Also, through the organisation of research policy workshops involving researchers, research policy experts and research policy makers from Romania and the EU.

- **The MIMOMEMS project has organized the first International Scientific Sessions at the CAS Conference 2008 (13-15 October 2008):**

- **The MIMOMEMS project has organized a strategic workshop devoted to the project, in connection with the CAS 2009 Conference (Oct 2009)**

- **The MIMOMEMS project will organize the second International Scientific Sessions at the CAS Conference 2010 (11-13 October 2010)**

v. Increase IMT's technology transfer for economic needs

The objective is to maximise the transfer and promotion of project results and activities of the MIMOMEMS project in Romania and across the EU.

Actions: publication of research results in peer reviewed journal and presentation at international conferences; organisation of workshops to make research proposal submissions to relevant calls from the FP7 ICT Programme.

- **14 papers submitted and accepted to prestigious conferences (Asia Pacific Microwave Conference, EMRS, NATO Workshop, European Microwave Conference, Memswave, CAS)**
- **One chapter in a book (Springer)**
- **5 papers published in journals**
- **Project web page**
- **2 Promotional article in the Romanian Journal "Market Watch"**
- **Promotional article in Parliament Magazine**
- **1 Common European Lab proposal (with FORTH and LAAS) – accepted in 2009; now it is operational**

- **10 projects in FP7 and FP7 related calls were proposed during the first 17 month of the MIMOMEMS project**
- ***3 of these proposals have been successful*.**
- **5 projects submitted for the FP7 call - 26 October 2009 (3 over the threshold)**

Wining FP7 related projects

- **ENIAC Call 2009 (**ENIAC-2008-1**)** "Micro and nano technologies based on wide band gap materials for future transmitting receiving and sensing systems – NEPTUNE" Coordinator: Thales Research and Technology, France;11 partners from: Greece, Romania, France, Germany and Poland, **Financed 2010-2013**

- **MNT ERA-NET (call 2009)** MEMS Based Millimetrewave Imaging System- "MEMIS" Coordinator; LAAS Toulouse; Partners: LAAS, IMT, VTT, 31 Degree **, Financed 2010 - 2012**

- **MNT ERA-NET (call 2009)**" Multifunctional Zinc oxide-based nanostructures: from materials to a new generation of devices-MULTINANOWIRES" Coordinator: CEMIMAT/I3N,FCT-UNL, Portugal; partners, Dunarea de Jos Univ Galati, IMT-Bucharest, **Financed 2010 - 2012**