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
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National Institute for R&D in Microtechnologies (IMT-Bucharest)
(www.imt.ro)

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)

Two IMT- Bucharest laboratories, for RF-MEMS and Microphotonics, respectively, already active in previous European programmes, have joint their efforts to achieve this excellence centre.

- ***The Laboratory of RF-MEMS*** **has coordinated one of the first European projects in RF-MEMS:**

- Micromachined Circuits for Microwave and Millimetre Wave Applications (MEMSWAVE, 1998-2001, FP4-INCO); coordinator: Dr. Alexandru Müller, alexandru.muller@imt.ro, IMT-Bucharest. The project was nominated in 2002 among the top ten European projects for the Descartes Prize (awarded for the best European co-operative research projects). Also, the RF-MEMS Laboratory was a key partner in the FP6 NoE:
-RF-MEMS "Advanced MEMS for RF and Millimetre Wave Communications" (AMICOM, 2004-2007 FP6 NoE),
and is also involved in the FP7 STREP
-MEMS 4 MMIC FP7 STREP (2008-2011) call ICT-2007-2.

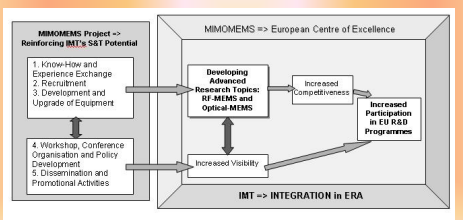
- ***IMT's Laboratory of Microphotonics*** **(Dr. Dana Cristea, dana.cristea@imt.ro) was also participating in several FP6 projects:**

-Waferbonding and Active Passive Integration Technology and Implementation (WAPITI, STREP, 2004-2007, FP6-IST);
-Multi-Material Micro Manufacture: Technologies and Applications (4M, NoE, 2004-2008, FP6-NMP);
-Advanced Handling and Assembly in Microtechnology (ASSEMIC, Marie Curie Action, 2004-2007, FP6-Mobility),
and it is now involved in the FP 7 Integrated Project
-FlexPAET (2008-2010), FP7 IP call NMP-2007-1.

Outline

- **-Introduction/history**
- **-Objectives of the MIMOMEMS Project**
- **-Scientific results obtained with the support of the MIMOMEMS project after 17 month (exchange of know how and experience with twinning partners)**
- **- Status of other "MIMOMEMS" project objectives after 17 months**
- ***-Increase IMT's Human Potential***
- ***-Increase IMT's Technology Potential.***
- ***-Increase IMT's Scientific Visibility***
- ***-Increase IMT's technology transfer for economic needs***

The overall aim of the MIMOMEMS project is to bring the research activity in RF and Optical-MEMS at the National Institute for R&D in Microtechnologies (IMT) 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.



History

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.

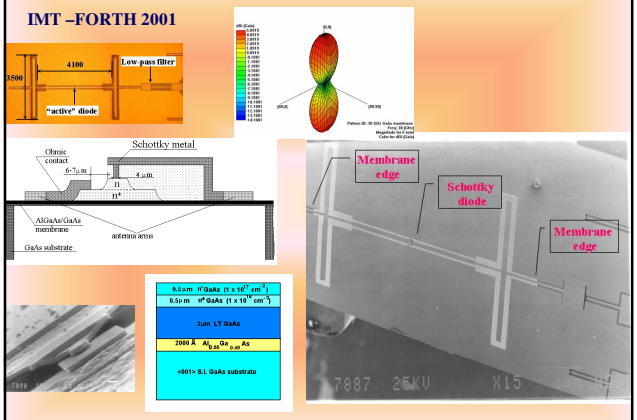
TARGETS

- 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.

MEMSWAVE was one of the first RF MEMS projects financed by the EC and was the first IST project coordinated by a East European country

38GHz monolithic receiving module on GaAs membrane

IMT –FORTH 2001



History

- 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

The **MEMSWAVE Workshop**

- In 1999 it was organized the first "MEMSWAVE" workshop in Sinaia with participation also from outside the Consortium
- In 2001 it was organized the second MEMSWAVE" workshop in Sinaia
- In 2010, after Heraklion, Toulouse, Uppsala, Laussane, Barcelona, Orvieto, Heraklion, Trento the 11th 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)

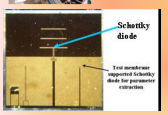
MIMOMEMS, FP 7 Project

Bilateral cooperation projects

- CNR Rome, Italy
- HAS MFA Budapest, Hungary
- Tor Vergata Univ Rome, Italy
- FORTH Heraklion, Greece
- LAAS-CNRS Toulouse, France
- Univ. of Athens (Communication Dept), Greece
- ITC Trento, Italy
- Keri Changwon, Republic of Korea
- Univ. of Pretoria, South Africa

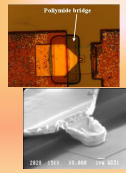
GaAs micromachined 60 GHz Yagi-Uda antennae based receiver used as millimeter wave identification tag

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

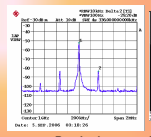


The receiver structure

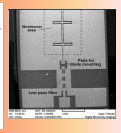
•The MMID concept was demonstrated at distances between 0.5 … 2.5 m two passive tags:
-60GHz monolithic integrated micromachined receiver structure with Yagi-Uda antenna
-77 GHz receiver structure based on the hybrid integration of a membrane supported folded slot antenna with two types of detector diodes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



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, FP 7 Project

Research topics to be developed in the frame of the MIMOMEMS project

A: RF-MEMS

A1. Development of silicon micromachined circuits for microwave and millimetre wave communication systems
A2. Development of GaAs monolithic integrated micromachined receiver modules
A3. Development of Surface Acoustic Wave (SAW) and Bulk Acoustic Wave (BAW) structures on GaN and AlN membranes

B: Optical-MEMS

B1. Heterogeneous integration of silicon and polymer-based micro-photonic devices to improve the functionality and the performance of Optical-MEMS
B2. Sub-wavelength photonic structures for highly integrated optical systems

MIMOMEMS, FP 7 Project

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).

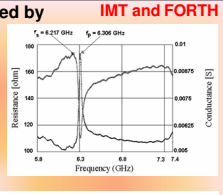
These cooperation will contribute to the development of IMT's Strategic Research Partnerships one of the major objectives (1) of the project.

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

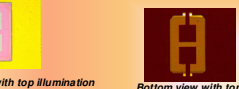
IMT and FORTH

- 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*

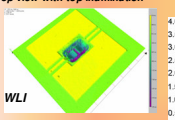
Q=1130

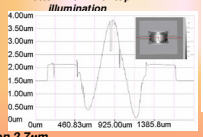


Top view with top illumination

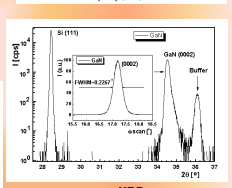


Bottom view with top illumination





Maximum deflection 2.7μm



XRD

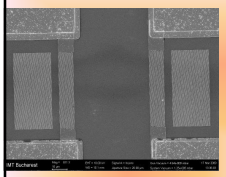
$\varepsilon=\Delta c/c_o=1.9*10^{-3}$

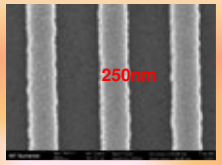
Microwave characterization, deflection measurements, stress and material analysis could be performed in IMT with the new purchased equipments

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

Scientific results obtained with the support of the MIMOMEMS project

GaN SAW structures manufactured using nanolithography

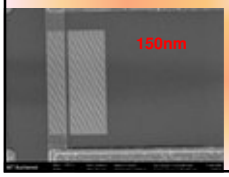


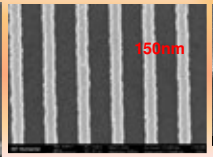


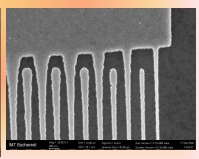
SAW resonators on GaN/Si with fingers and interdigits 250nm wide (up) and 150nm wide (down) *patterned in IMT on the new "E-Line" equipment*

PMMA 200nm thick metaization Ti/Au 100nm thick

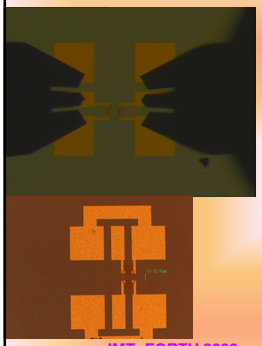
GaN/ Si from Azzuro Magdeburg (1μm thin GaN layer)

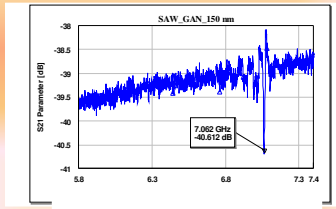


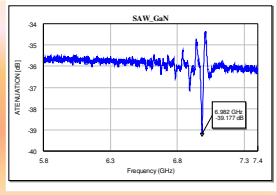




7 GHz rezonance on a SAW structure manufactured on GaN/Si







IMT- FORTH 2009

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

Reconfigurable band-stop filter IMT-LAAS

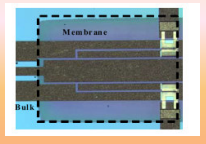
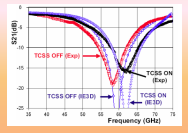


***Photo of the manufactured reconfigurable band stop filter* for 60GHz**

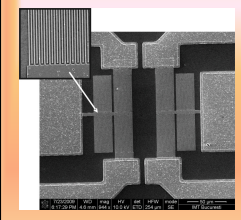


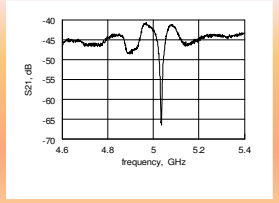
Experimental (Exp) and simulated (IE3D) results for the reconfigurable band stop filter

A Takacs, et al. Proc MME 2009

AlN/Si SAW structure resonating at 5.03 GHz

Fingers and interdigits 250nm wide processed at IMT





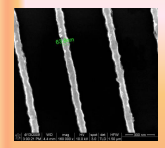
IMTBucharest-FORTH Heraklion 2009

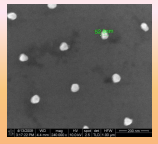
D. Neculoiu, A. Müller, G. Deligeorgis, A. Dinescu, A. Stavrinidis, D. Vasilache, A. Cismaru, G. E. Stan and G. Konstantinidis. Submitted to publication Electronic Letters

AlN layer deposited at NIMP -Bucharest

Metallic nanostructures (process development)

The process combines : ***2D and 3 D Electon Beam Litography in a PMMA bi-layer, metal depozition and lift-off***

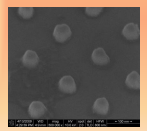




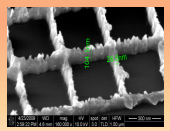
IMT-FORTH Heraklion Greece

Applications:
-Plasmonics
-Photonic crystals
-Master for replication of polymeric optical structures

Metalic nanostructures for plasmonics and for nanoelectrodes



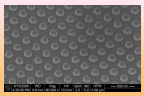
Metallic master for photonic crystals
(φ << 100 nm)

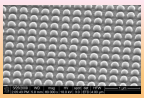


Metallic master for high aspect ratio grating obtained by EBL in PMMA by-layer, metal deposition and lift-off

Replication techniques for micro and nano-optical components

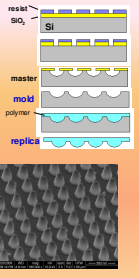
The techniques combine 2D and 3 D optical electon beam litography in a resist bi-layer, lift-off, and replication processes: cast molding, replica molding, nanoimprint.

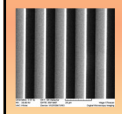




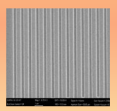
a) b)

Lenses in epoxy resin obtained by replica molding with a master obtained by EBL in a) a thin layer of PMMA -950K layer; b) double PMMA layer (ϕ~150 nm, h ~200-300 nm).

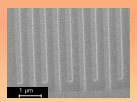




Difraction grating line 8 µm



Difraction grating line 8 µm



Microfluidic channels in PDMS width ~ 250 nm

Antireflective layer obtained by replication of a metallic master (ϕ < 100 nm , H ~250 nm)

MIMOMEMS – Objectives (3)

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)
- Upgrade to 110GHz the 1-65 GHz set-up for on wafer characterization
- Frequency synthesiser up to 65GHz-110 GHz
- Au plating facility for semiconductor wafers

MIMOMEMS – Objectives (2)

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.

This task has been solved in September/October 2009

6 applications have been received.

-Dr. Mihai Pavelescu, Univ Kassel
-Dr. Mihaela Carp, Nanyang Technical Univ. Singapore
-Alexandra Stefanescu, Politehnica Univ. Bucharest (programmed to sustain the dissertation in December)

Status of equipment purchased

- -The SNOM: Acquisition finished in August2008 the SNOM was delivered in October 2008. It was installed at IMT Minalab Facility and is fully operational.

Co-financed by a national project

- Upgrade to 110 GHz the 65 GHz "on wafer" characterization set-up:
- -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

- The frequency syntheziser (generator) up to 110 GHz (65 GHz expandable to 110 GHz)
- Oprational since June 2009

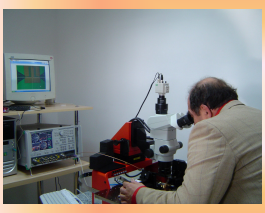
- Spectrum analyzer up to 110 GHz
- Operational since July 2009

Financed (only) by a national project.

- The Au plating facility- purchase planed at the beginning 2010

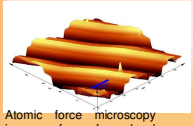
The SNOM

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

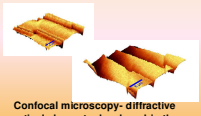


Characterization with Alpha300 S System

Characterization of micro-optical elements

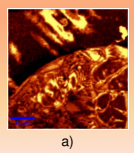


Atomic force microscopy image of a four level diffractive optic element (relised in IMT).



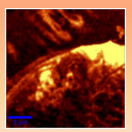
Confocal microscopy- diffractive optical elements developed in the frame of FP7 integrated project (NMP) FLEXPAET (IP- FP7/NMP) 2008-2011

Application in biology



a)

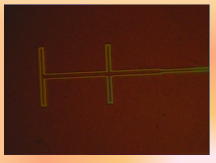
(a) *Confocal* and (b) *fluorescence* imaging of a fluorescent marked BSA proteine.



b)

Work in progress

- set-up for **SNOM** characterization of nanophotonics and nanoplasmonic structures and devices *(imaging of propagating optical field)* in the **photon scanning tunneling microscope (PSTM) mode**



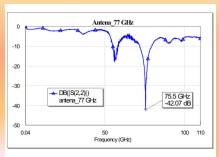


Photo image of 77 GHz antenna and its S_{22} parameter measured with the new equipment

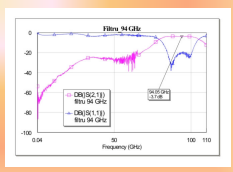
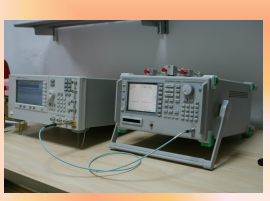
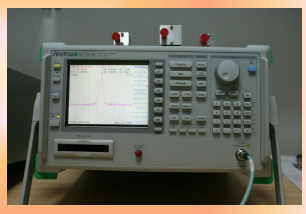


Photo image of 94 GHz filter and its S parameter measured with the new equipment

The frequency syntheziser (generator) up to 110 GHz and spectrum analyzer up to 110 GHz





Spectrum analyzer measuring a 30 GHz signal

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.

- **8 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)**
- **3 papers published in journals**
- **Project web page**
- **Promotional article in the Romanian Journal "Market Watch"**
- **Promotional article in Parliament Magazine**
- **1 Common European Lab proposal (with FORTH and LAAS): in progress, hope to be established officially very soon.**
- **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.***

MIMOMEMS – Objectives (4)

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 Sessios at the CAS Conference 2008 (13-15 October 2008): 3 oral sessions and 1 poster session.

2 invited lecturers: G. Konstantinidis (FORTH Heraklion); T. Vähä Heikkilä (VTT Helsinki)

All papers are available on the web page.

The MIMOMEMS project is organizing the present strategic workshop

FP7 and FP7 related calls proposals

- **STREP SPACE Call 2** (FP7-SPACE-2009-1) **"Microwave nitride novel technologies for advanced tunable and reconfigurable satellite - MINOTAUROS"**Coordinator: Thales Alenia Space, France;Partners: FORTH and NKUA Greece, IMT Romania, LAAS-CNRS and FEMTO-ST France, AZZURO Germany, EPFL Switzerland.
- **STREP ICT Call 2** (FP7-ICT-2007-2) "Carbon nanotube based smart systems for wireless applications – NANOTEC"Coordinator: Thales Research and Technology, France;Partners: EPFL Switzerland, Cambridge Univ. UK, FORTH and NTX Greece, IMT Romania, LAAS-CNRS and TAS France, Uppsala Univ. Sweden,
- **ENIAC Call 2008** (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,
- **ENIAC Call 2008** (ENIAC-2008-1) "Nanoelectronics for Safe, Fuel Efficient and Environment Friendly Automotive Solutions - SE2A"Coordinator: NXP Semiconductors Netherlands BV;21 partners from: Netherland Greece, Romania, Hungary, Poland,, Portugal, Sweden; **Financed**
- **MNT ERA-NET (call 2009)** « MEMS Based Millimetrewave Imaging System-MEMIS »Coordinator; LAAS Toulouse; Partners: LAAS, IMT, VTT, 31 Degree **Project proposed to be financed (1 Oct 2009)**
- **ENIAC (Call 2009),** (ENIAC-2009-1) "Harvest Ambient RF energy Via novel Seebeck (thermoelectric) nanostructures – HARVEST"Coordinator; LAAS Toulouse; Partners: LAAS, IMT, FORTH, Technical Univ Darmstadt, Novamems SA, France, Cidete Ingenerios Spain, Panco, Physics Technology, Development and Consulting GmbH, Germany
- **Large-scale integrating collaborative project Proposal for NMP-2009-4.0-3** "Mass Produced Lab-on-a-Chip Platform for Early Diagnosis of Diseases (ProChip)"Coordinator: Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.
- **SME- Targeted Collaborative call NMP-2009-4.0-5** "High Density and Multi-Dimensional Digital Representation and Simulation of Physically Manufactured Tools, Parts and Processes for Knowledge-Based Design Optimisation (DIMENSIONS)"Coordinator: NECO Spain
- **MANUNET ERA-NET Project** "Advanced Life-Cycle Tool Performance Characterisation for Optimisation Composite Machining Process" Coordinator: Datapixel- Spain
- **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, IMTBucharest **Project proposed to be financed (1 Oct 2009)**

Conclusions

- The **MIMIOMEMS project** has an important contribution to the increasing of the **scientific and technological potential** of the two labs of **IMT- Bucharest** involved, to their infrastructure and visibility. It facilitates the high level scientific cooperation with European partners and not only
- The **facilities** which are or will be installed through the **MIMOMEMS project** together with those obtained from other national projects (the Capacities Program, Module 4) will contribute to the development of **IMT- Bucharest** as a **European Center of Excellence** in **Micro and Nanotechnologies**
- **MIMOMEMS** contributes to the integration of our group in ERA.

Thank you for your attention!

WELCOME TO THE STRATEGIC WORKSHOP OF THE MIMOMEMS PROJECT!