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)

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(www.imt.ro)

Project financed (2008-2011) through the Capacities "Research potential" part of the European Framework Programme - FP7 (REGPOT-2007-1)

Activity: 4.1.Unlocking and developing the research potential in the EU´s convergence regions and outermost regions

(start date May the 1st 2008)

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

The F7 REGPOT "MIMOMEMS" project objectives:

-Exchange of know-how and experience

-Increase IMT's Human Potential

-Increase IMT's Technology Potential. The "MINAFAB" centre of IMT

-Increase IMT's Scientific Visibility

-Increase IMT's technology transfer for economic needs

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) for GHz applications based on micromachining and nanoprocessing of WBG semiconductors (GaN, AlN)

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

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 recently approved 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.

MIMOMEMS – Objectives (1)

i. 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.

FP 7 proposals: May 2009 – an ERA Net and an ENIAC JTU proposals

ii. Increase IMT's Human Potential

- 2 experienced scientists will be hired (for post-docs) using the project budget (starting from the second year). The researchers will be initially hired for 20 months fellowships with 6 monthly reviews. At the end of the period, the researchers will have the possibility to become full time IMT employees.

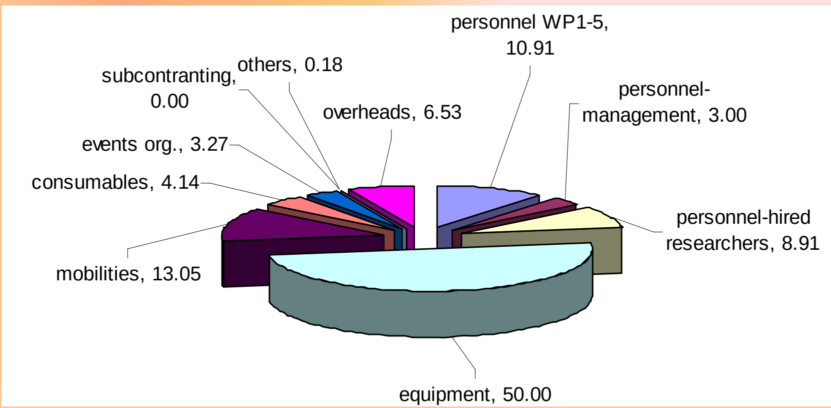
MIMOMEMS – Objectives (2)

iii. Increase IMT's Technology Potential

List of equipments:

- **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; already arrived; It will be installed in April 2009**
- **Au plating facility for semiconductor wafers , 2009**

These new equipments will be used to provide services into the new IMT-MINAFAB facility



Budget distribution in the MIMOMEMS Project

MIMOMEMS – Objectives (3)

iv. Increase IMT's Scientific Visibility

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

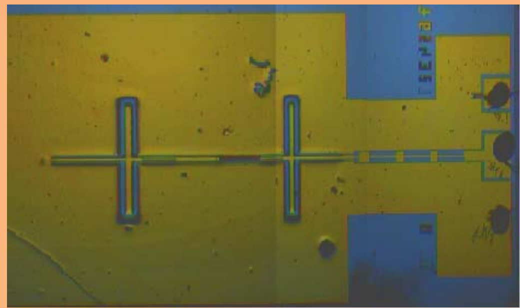
This will be achieved through IMT's organisation of scientific events and seminars. Also, through the organisation of research policy workshops involving researchers, research policy experts and research policy makers from Romania and the EU.

v. Increase IMT's technology transfer for economic needs

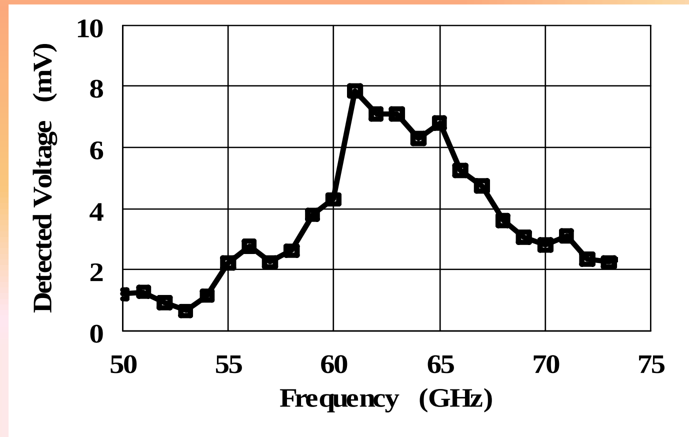
The objective is to maximise the transfer and promotion of project results and activities of the MIMOMEMS project in Romania and across the EU. Actions: publication of research results in peer reviewed journal and presentation at international conferences; organisation of workshops to make research proposal submissions to relevant calls from the FP7 ICT Work Programme.

GaAs Membrane-Supported 60 GHz Monolithic Receiver Module with Double Folded Slot Antenna

IMT (design, masks manufacturing, characterization) – FORTH (manufacturing) – VTT (characterization)



Optical photo of the fabricated receiver structure



The experimental detected voltage across the Schottky diode as a function of frequency

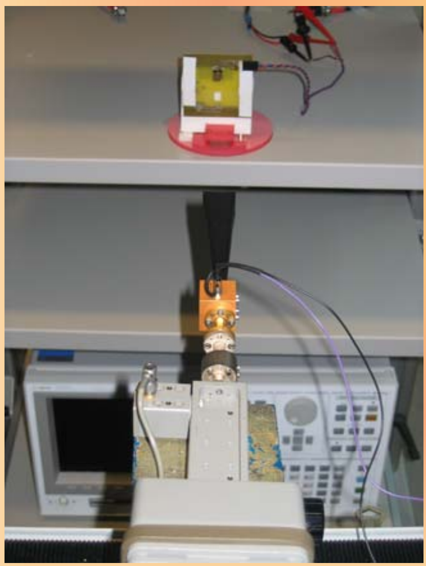
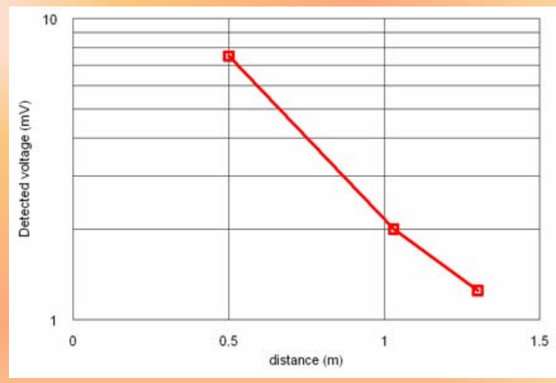


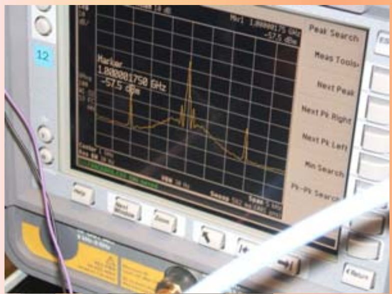
Photo of the experimental set-up used for receiver measurements



The experimental detected voltage across the Schottky diode as a function of distance (at 61 GHz)

GaAs micromachined 60 GHz Yagi-Uda antennae based receiver module

A new application: A millimeter wave identification (MMID) system using the receivers as “tag”

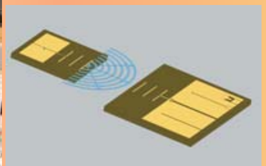


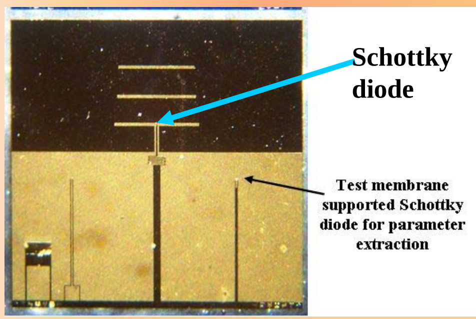
•The MMID concept was demonstrated at distances between 0.5 … 2.5 m two passive tags:

-60GHz monolithic integrated micromachined receiver structure with Yagi-Uda antenna

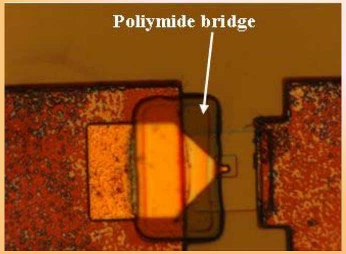
-60 GHz monolithic inegrated micromachined receiver structure with a folded slot antenna

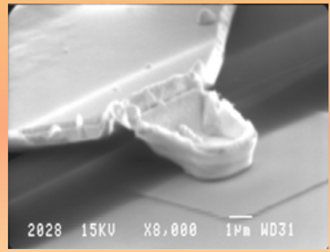
-77 GHz receiver structure based on the hybrid integration of a membrane supported folded slot antenna with two types of detector diodes (GaAs Schottky diode and InSb based quantum backward diode)



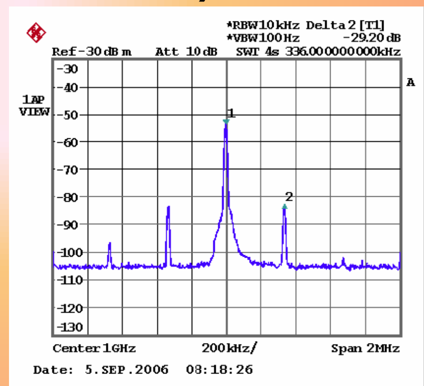


The receiver structure

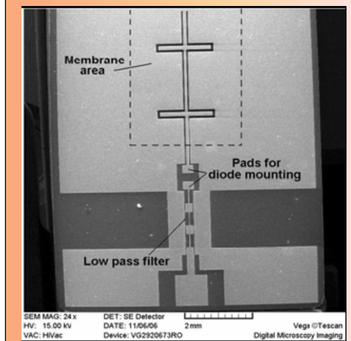




Details of the Schottky diode region



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



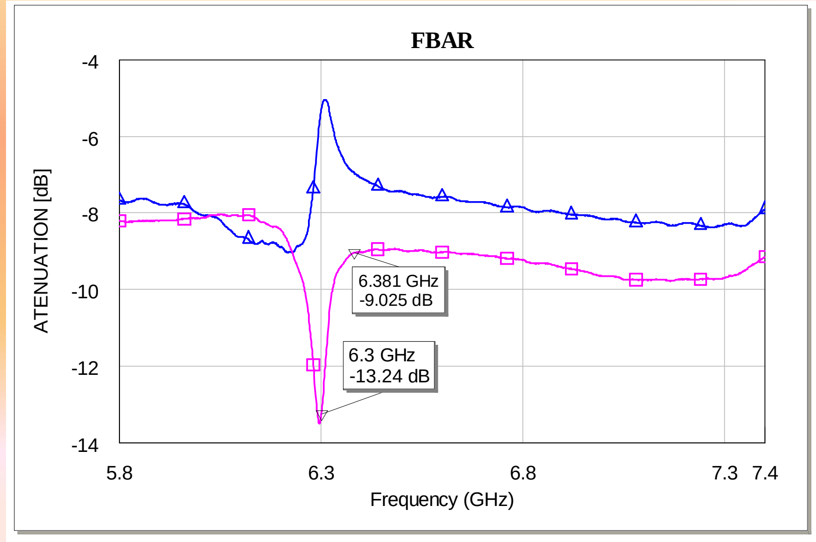
Top SEM photo of the micromachined receiver structure for 77 GHz (before the flip chip detector diode mounting).

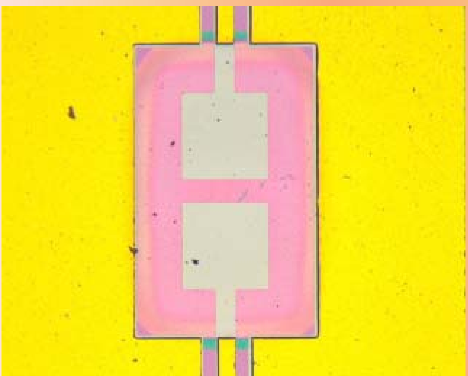
GaN FBARs

340 nm (GaN) +200nm (buffer) thin membrane supported FBAR structure based on GaN micromachining

50nm thin Mo metallization

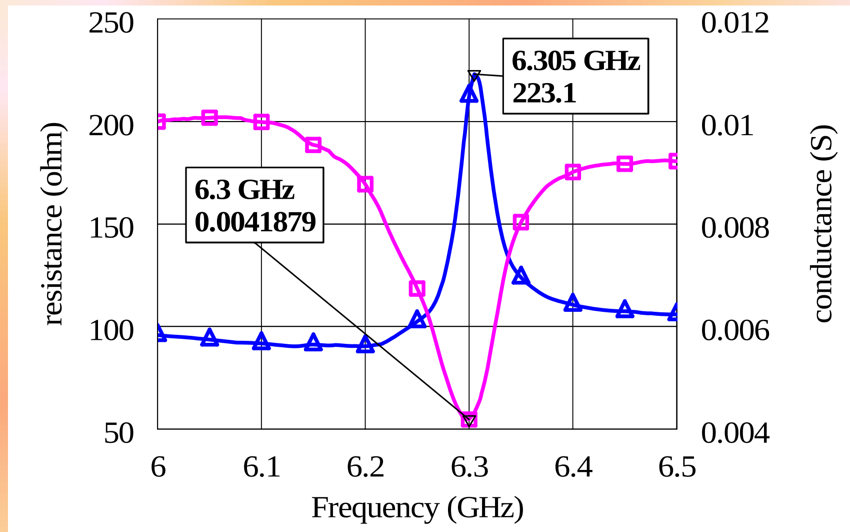
GaN/Si wafers from NTT AT Japan





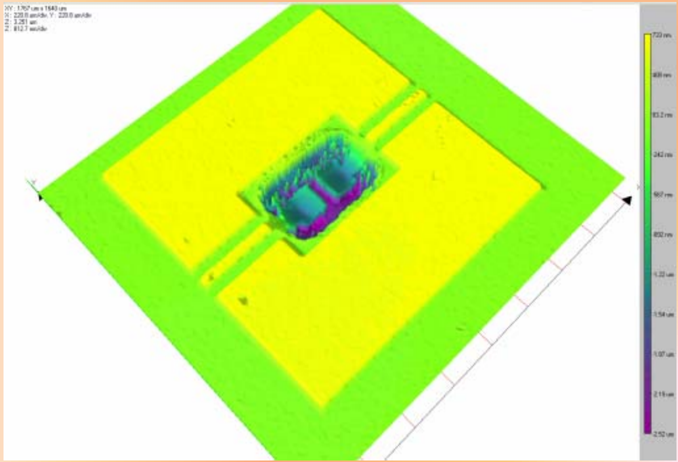
Top view with top illumination

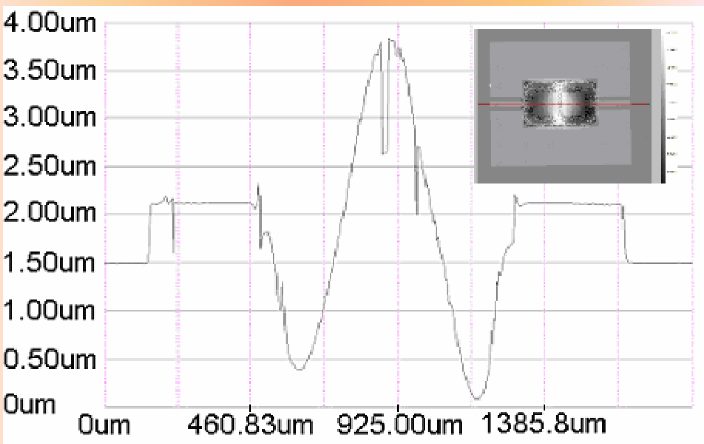
Bottom view with top illumination



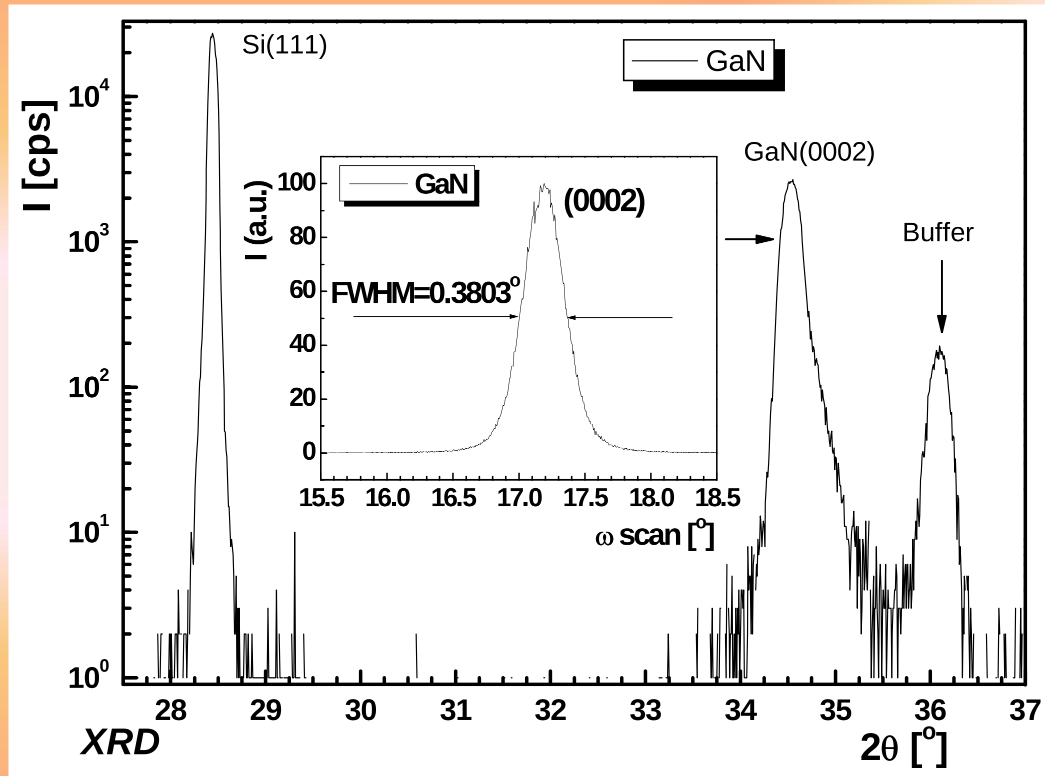
GaN FBAR physical characterization

WLI





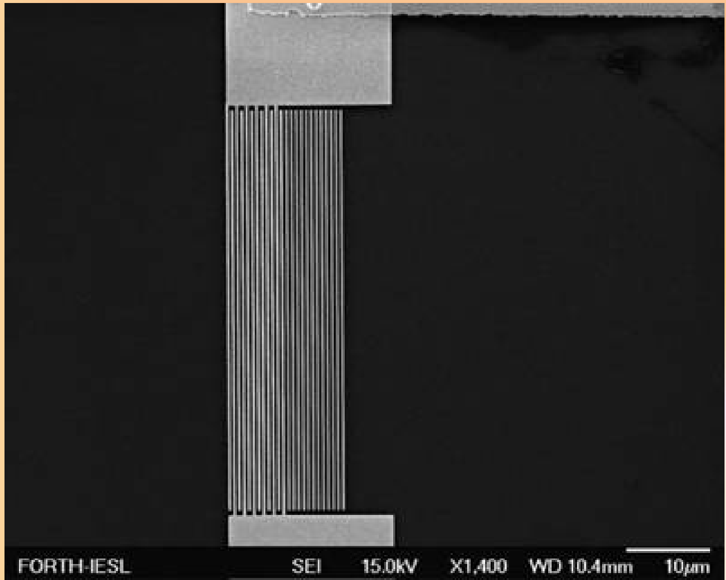
Maximum deflection 2.7μm

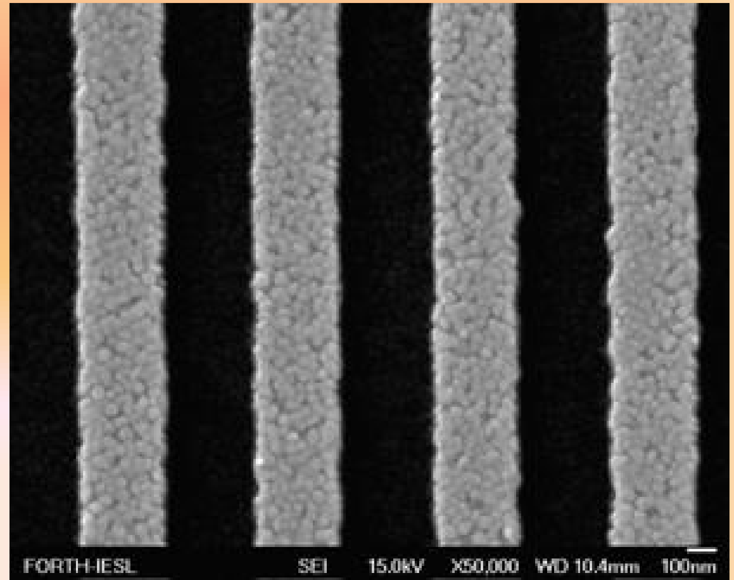


$$\varepsilon=\Delta c/c_o=1.9*10^{-3}$$

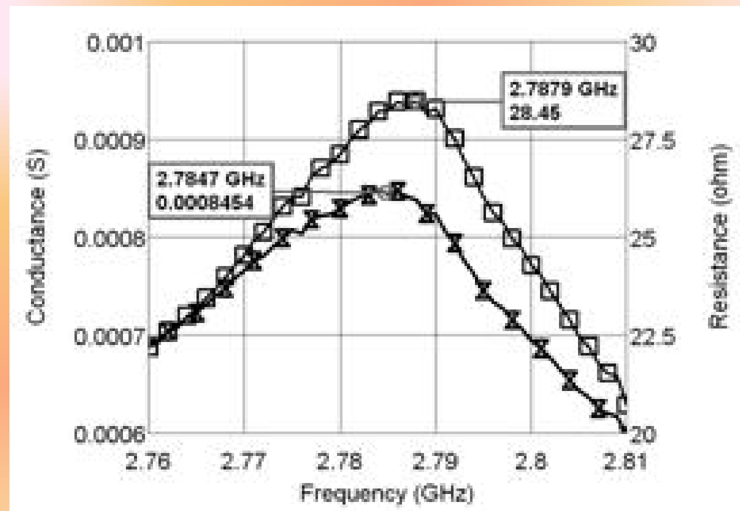
SAW devices for GHz applications with nanolithographic IDTs

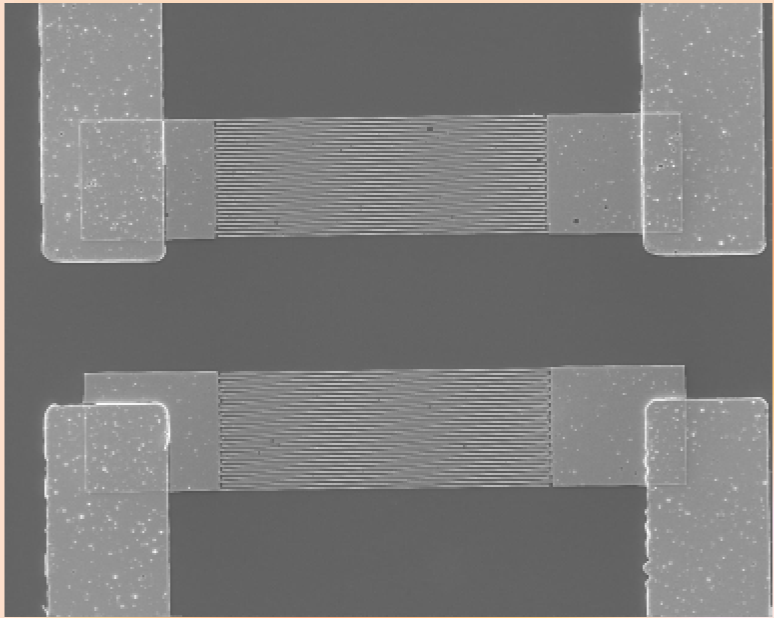
AlN

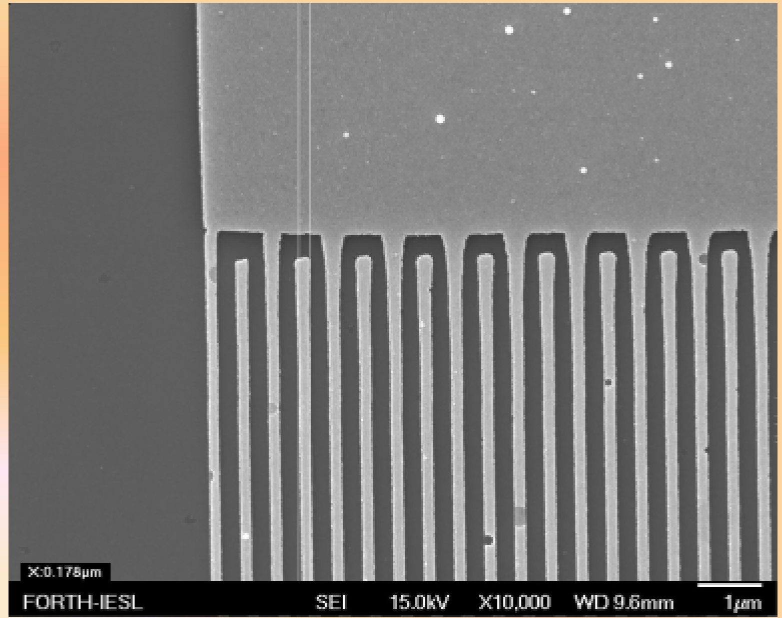


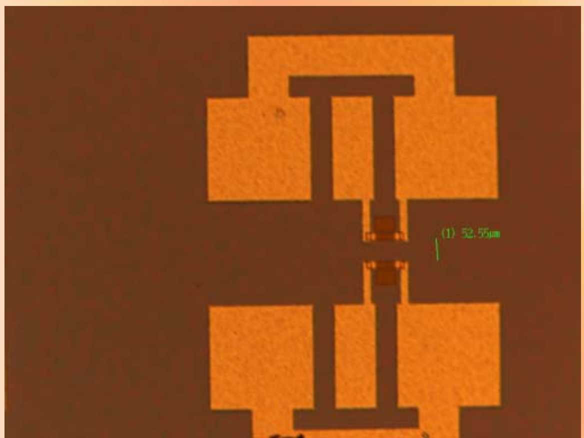


Experimental AlN SAW structure for GHz applications manufactured and measured at IMT-Bucharest . Fingers and pitches with a width on 300 nm have been obtained with the nanolithographic equipment (Vega-SEM and Elphy Plus EBL









Optical photo of the test structure

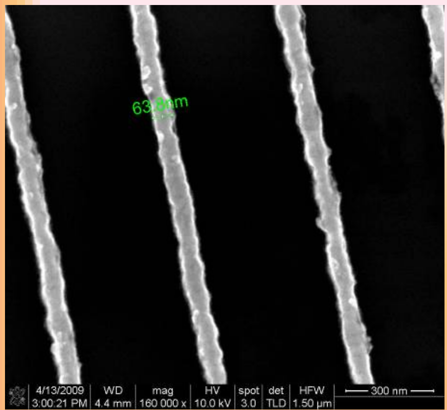
***Late news:* SAW structure on GaN having digits and interdigits of 300 nm and 150 nm patterned in IMT on the "E-Line" equipment**

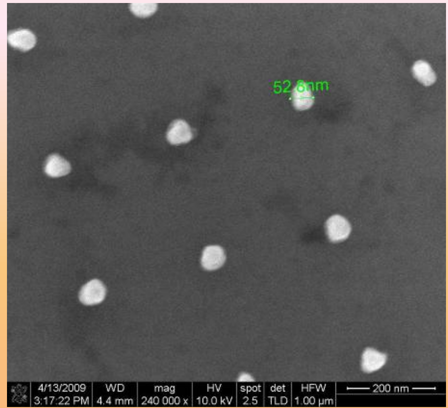
7 GHz rezonance on GaN

IMT- FORTH 2009

Metallic nanostructures (process development)

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





Cooperation IMT-FORTH Heraklon Greece

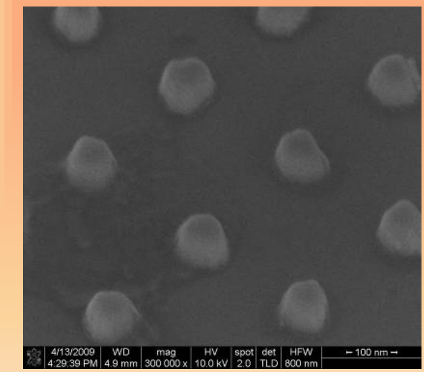
Applications:

-Plasmonics

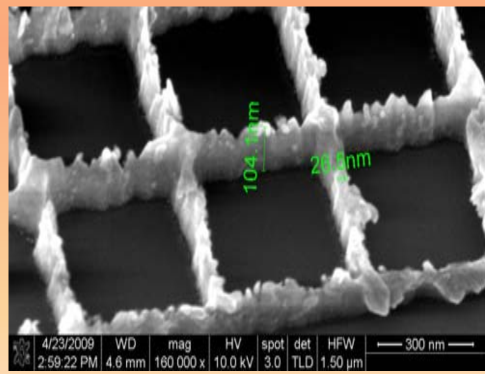
-Photonic crystals

-Master for replication of polymeric optical structures

Metalic nanostructures for plasmonics and for nanoelectrodes



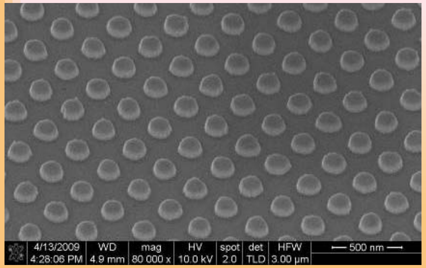
Metallic master for photonic crystals (ϕ << 100 nm)

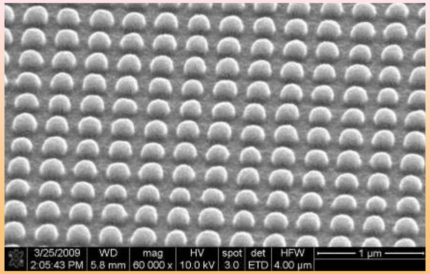


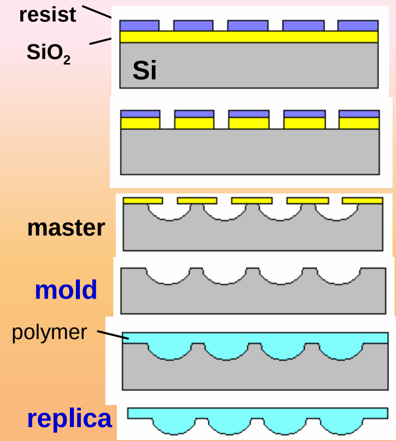
Metallic master for high aspect ratio grating obtained by EBL in PMMA by-layer, metal deposition and lift-off

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.

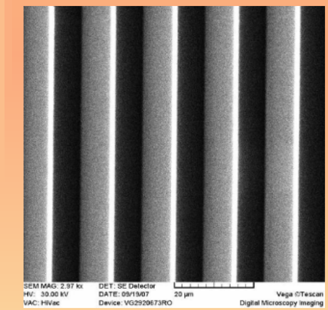




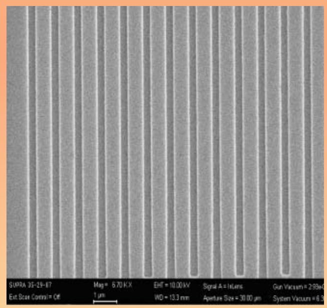


a) b)

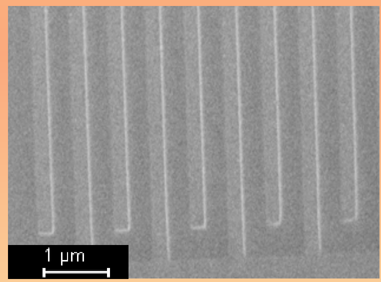
Lenses in epoxy resin obtained by replica molding with a master obtained by EBL in a) a thin layer of PMMA -950K layer; b) double PMMA layer (ϕ~150 nm, h ~200-300 nm).



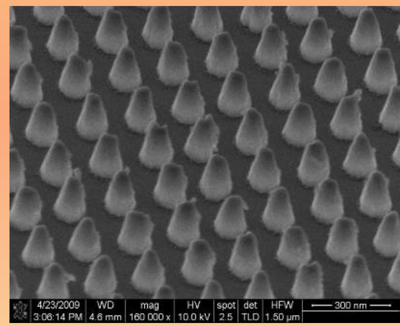
Difraction grating line 8 µm



Difraction grating line 8 µm



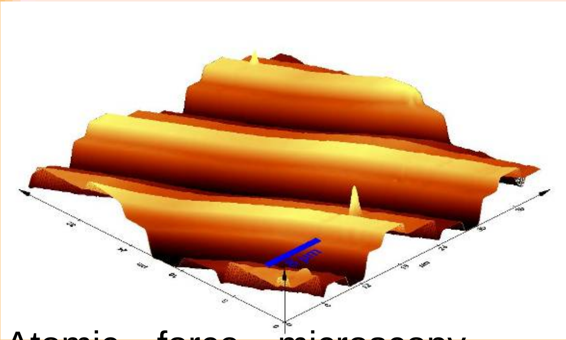
Microfluidic channels in PDMS width ~ 250 nm



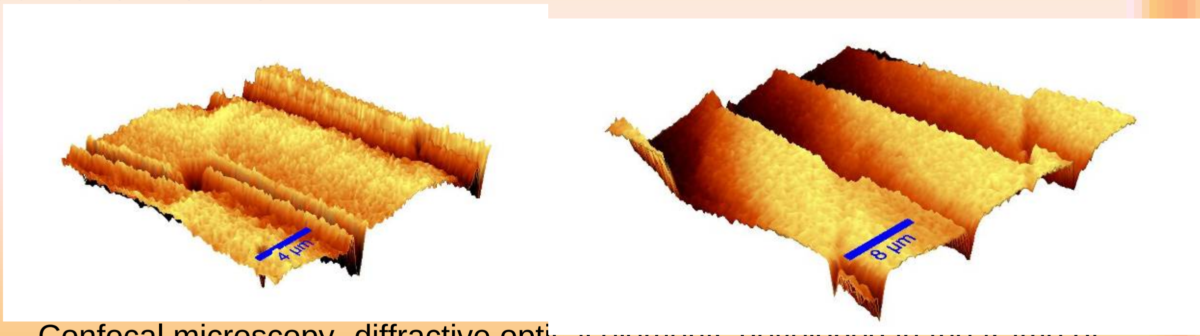
Antireflective layer obtained by replication of a metallic master (ϕ < 100 nm , H ~250 nm)

Characterization with Alpha300 S System

Characterization of micro-optical elements

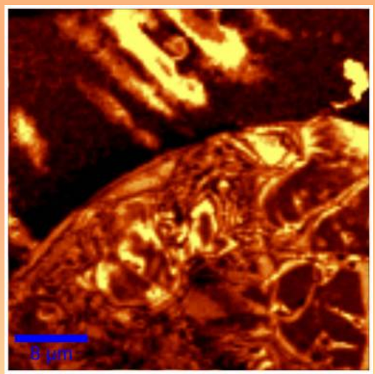


Atomic force microscopy image of a four level diffractive optic element (relised in IMT).



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

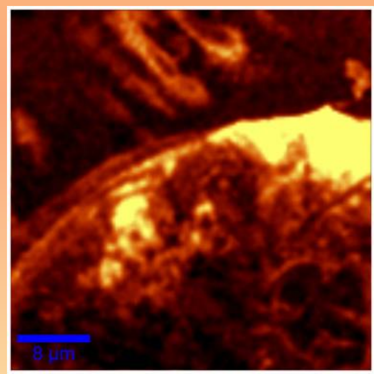
Application in biology



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**

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.