IMT-MINAFAB:
a micro- and nanotechnology centre, open to industry

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Brussels, 8th of May, 2009

Highlights

- IMT was highly successful in participating to various European projects, especially since 2003 (in FP6 and FP7);
- The valorization of this participation was rather difficult due the relatively week experimental infrastructure of IMT;
- A new "clean-room" type infrastructure was operational in September 2008, new equipments are continuously added and – despite economic difficulties - we hope to inaugurate another "clean room" before the end of this year;
- For the first time in the existence of IMT as a national institute, the performance is not longer limited by the obsolete or absent apparatus and equipments, or by improper working conditions;
  - A similar process of consolidation of the experimental infrastructure takes place in other Romanian research organizations
- The basic effort today is to benefit at maximum from the exciting experimental resources available today and speed up the process of generating and using new knowledge. **One key point is to create an "open centre", IMT-MINAFAB**, facilitating the interaction with industry and academia.
- *The management of this centre is partially inspired by the activity of similar centres abroad. With a relatively stable structure of RTD laboratories, we are using two key approaches:*
  - *Providing a critical mass for a common "experimental centre" as a kind of "joint venture" of RTD labs.*
  - *Facilitating interdisciplinary research by creating "groups of laboratories" and attracting in permanent cooperation scientists from other organizations.*

Summary

1. Basic figures about IMT and main fields of research.
2. IMT in European projects and lessons learnt.
3. Investing in infrastructure and making it operational
4. Offensive in the “micro-nano-bio” domain
5. The concept of IMT-MINAFAB as an “open” experimental centre.
6. Does this concept have any future in a country like Romania? Opportunities and challenges.

● **IMT- Bucharest** was founded in 1993 as the **Institute of Microtechnology** - since 1996 a **national institute**

● <u>**Mission**</u>: **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**

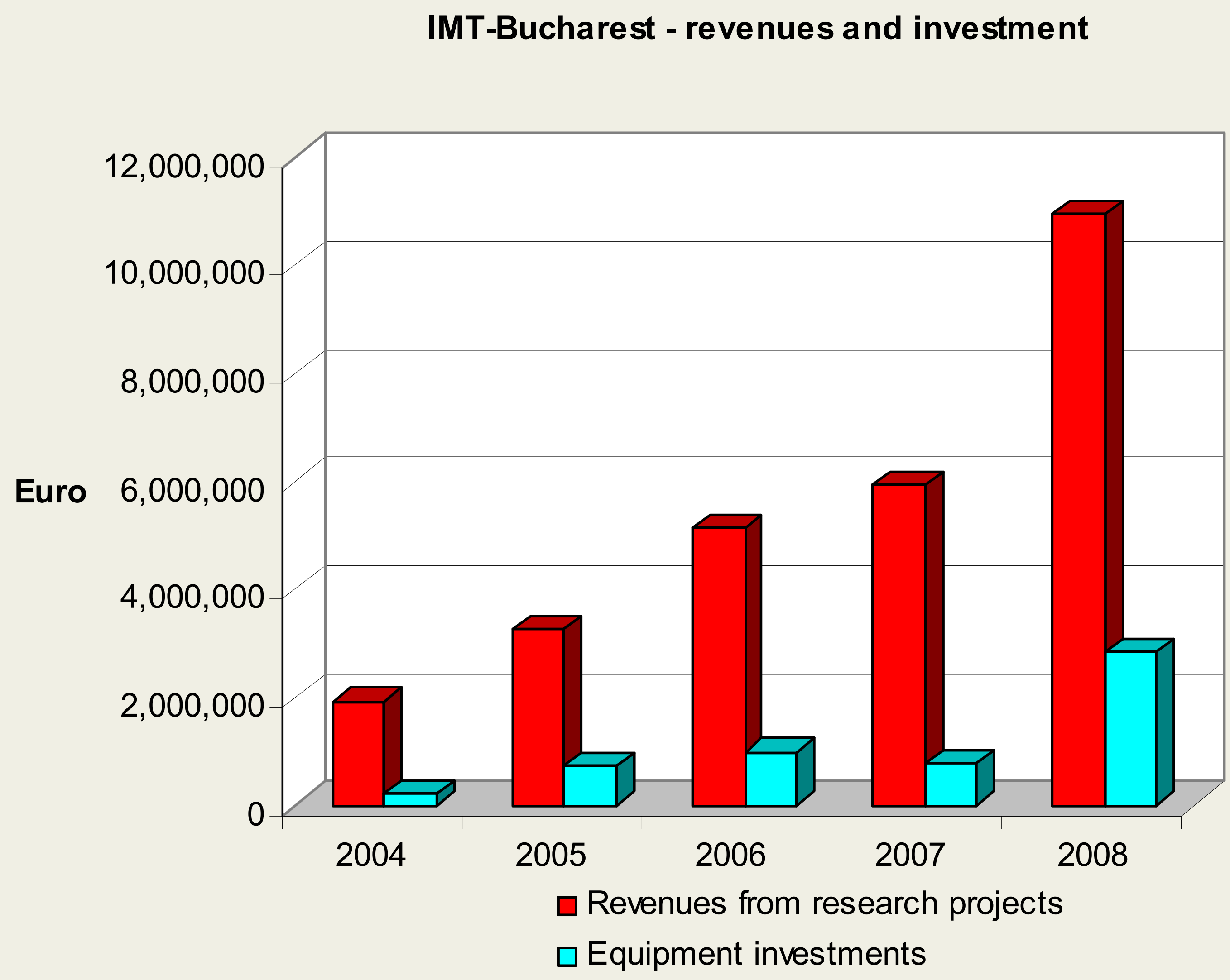
Employers: 170 (100 in research)

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**, **5 FP 7** and long experience in coordinating: national networks, research and education projects; *the EU projects are mentioned on the next slides!*

Dynamics

Turnover and investments



Research topics

The research laboratories of **IMT-Bucharest** are involved in **joint research** with international and national partners, **including companies**, based on a **multidisciplinary** approach, promoting the **convergence** of micro-nano-bio- info technologies.

The main topics of research are:

►**MEMS based microsensors** and **actuators** for bio-medical, environmental applications and robotics: pressure sensors, accelerometers, microgrippers

► **RF-MEMS** devices and circuits: design, modelling and manufacturing of dielectric membrane supported inductors, capacitors, filters and antennae based on silicon and GaAs micromachining; micromachined millimetre and sub millimetre wave receiver modules, SAW interdigitated traducers

► **Photonic** devices and **MOEMS** (waveguides, optical couplers, µring filters and resonators; grating-based microstructures, tuneable interferometers based on movable micromirrors, optical sensors), photonic circuits for optical interconnections

The research laboratories of **IMT-Bucharest** are also developing:

► **CNT** based micro-nanostructures for sensing and interconnections

►**microfluidic** devices

►**biochips** for biological materials investigation and detection (proteins, DNA, enzymes) on various substrates (silicon, glass, polymers), **microarrays, biosensors**

► **silicon nanoelectrode arrays**, porous silicon layers (EI, PL and bio-active properties); field emission nanostructures;

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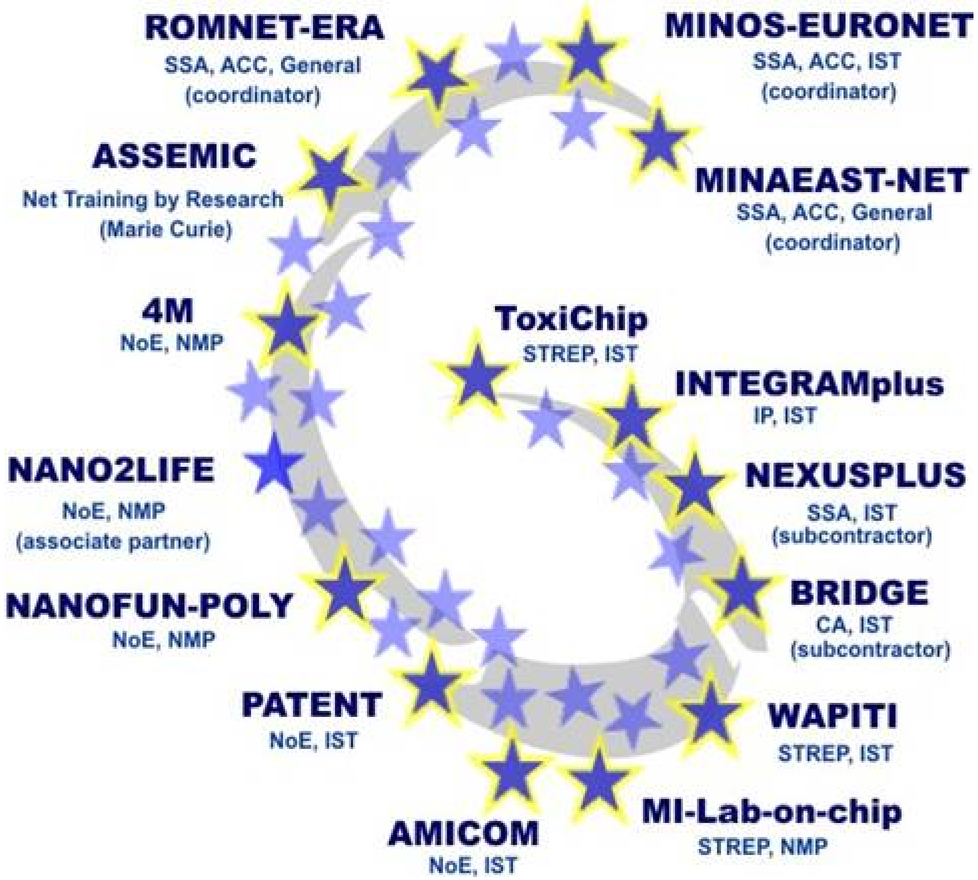
IMT- Bucharest participation in FP6 Projects

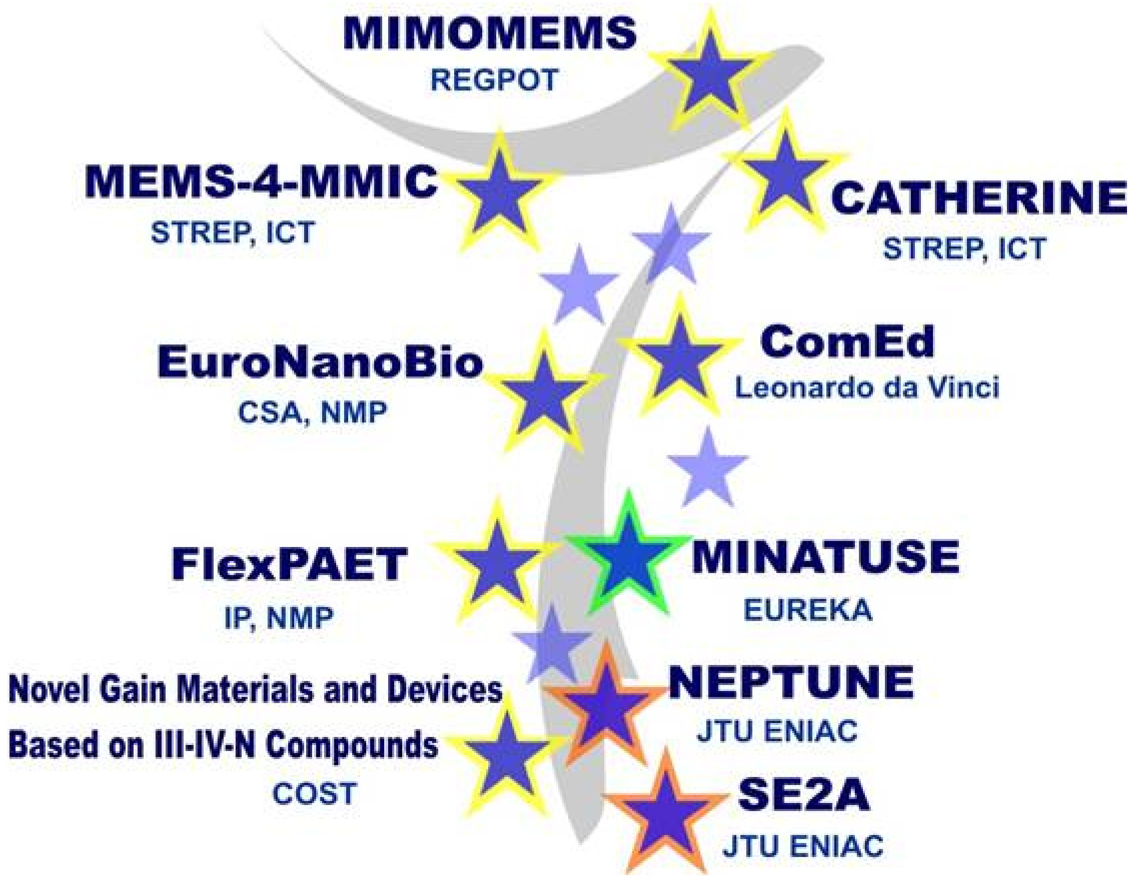


IMT- Bucharest participated in different types of EU projects:

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



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);

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 gGmbH, 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).

Integrated Polymer Chip
for biophotonic and optical interconnections

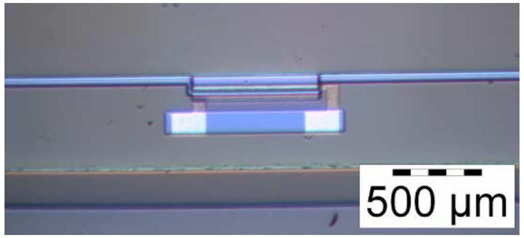
Joint research project in the frame of the FP6 Network of Excellence M

***MULTI-MATERIAL MICRO MANUFACTURE: Technologies and Applications* (4M)**

Co-operation with Institute for Microstructure Technology , Forschungszentrum Karlsruhe (FZK), Germany

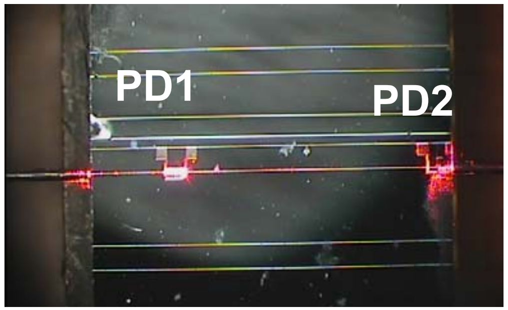
IMT role: chip design, fabrication of silicon photodiodes

FZK role: fabrication of PMMA waveguides on the Si chip with photodiode, characterization, process optimization for integration with microfluidic channels

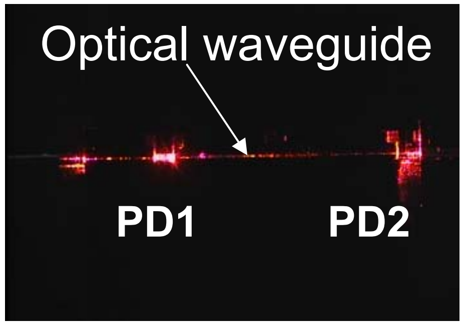


PMMA waveguide coupled with Si photodiode

The goal of this project was to analyze the possibility of realizing compact chips for biophotonic sensors by heterogeneous integration of optical waveguides, photodetectors and electronics within a polymer microfluidic chip

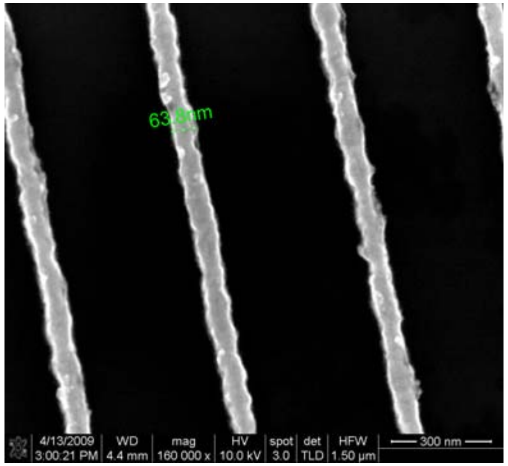


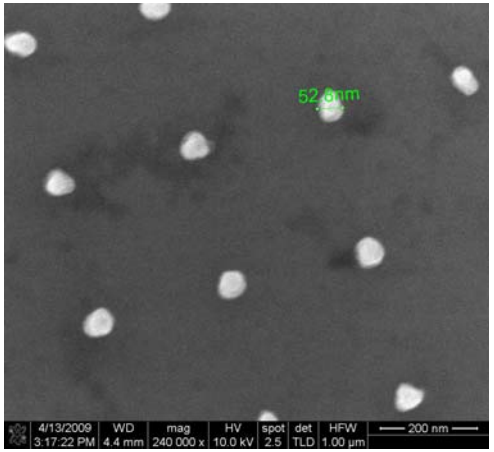
Optical signal detected by the second PD depends on the optical properties of the surrounding medium



Metallic nanostructures- process development

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





Cooperation IMT-FORTH Heraklion Greece

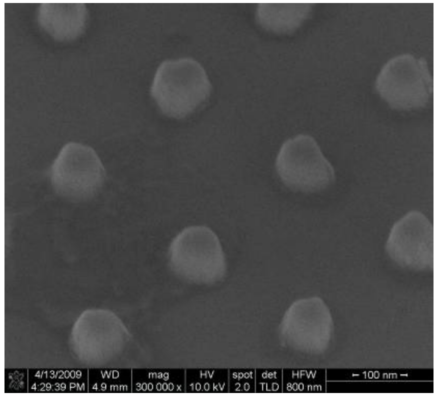
FP7 project MIMOMEMS

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

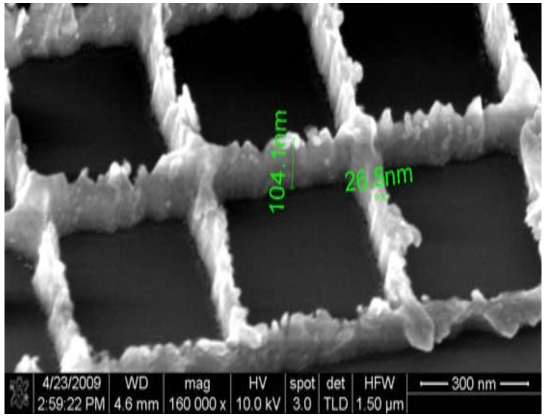
IMT role: process and structure design
Nanolithography, lift-off, characterization

FORTH role: metal deposition

Metallic nanostructures for plasmonics and for nanoelectrodes



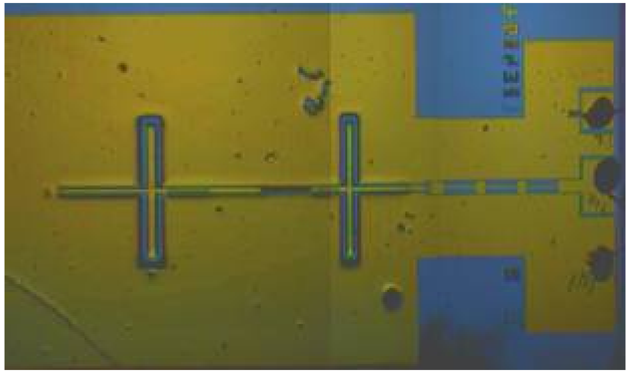
Metallic master for photonic crystals (ϕ << 100 nm)



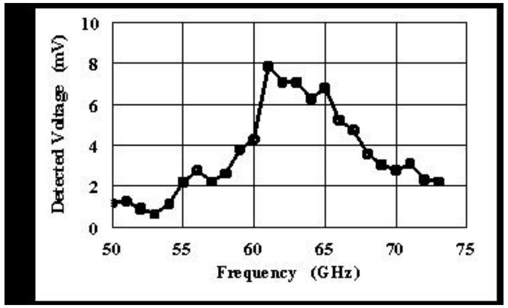
Metallic master for high aspect ratio grating obtained by EBL in PMMA by-layer, metal deposition and lift-off

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

Common work in the frame of FP 7 Project MIMOMEMS of IMT (design, masks manufacturing, characterization) - FORTH (fabrication) – VTT (characterization)



Optical photo of the fabricated receiver structure



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

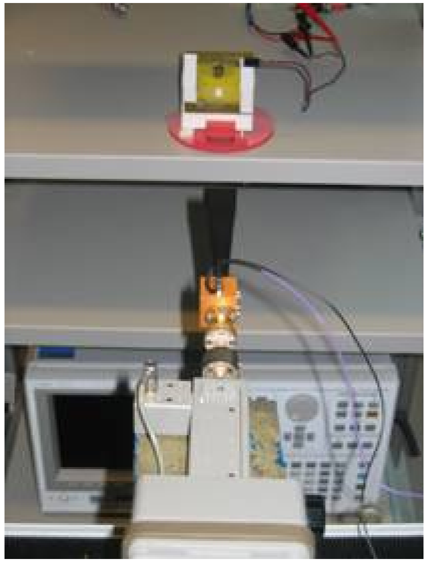
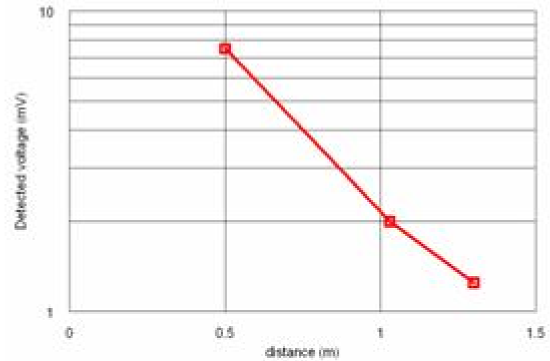


Photo of the experimental set-up used for receiver measurements



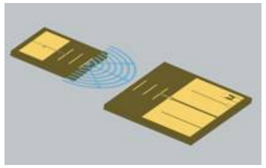
The experimental detected voltage across the Schottky diode as a function of distance (at 61 GHz)

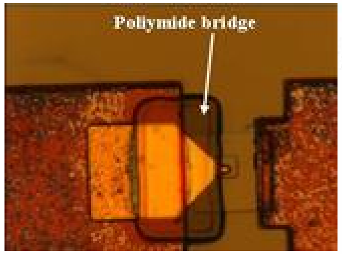
GaAs micromachined 60 GHz Yagi-Uda antennae based receiver module

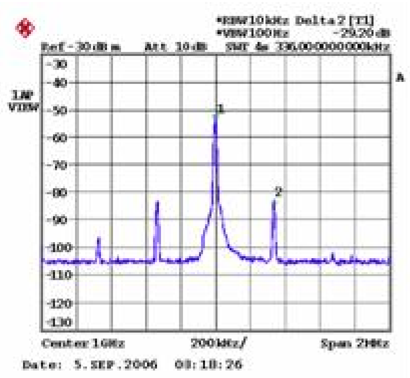
A new application: A millimeter wave identification (MMID) system using the receivers as "tag"

Common work in the frame of FP 6 (ICT) Project AMICOM of IMT (design, masks manufacturing, characterization) - FORTH (fabrication GaAs) – ITC IRST Trento (fabrication Si) - VTT (characterization)

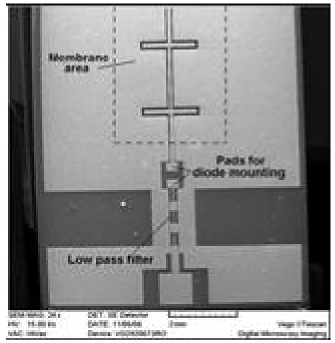
•The MMID concept was demonstrated at distances between 0.5 … 2.5 m
two passive tags:
-60GHz monolithic integrated micromachined receiver structure with Yagi-Uda antenna
-77 GHz receiver structure based on the hybrid integration of a membrane supported folded slot antenna with two types of detector diodes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



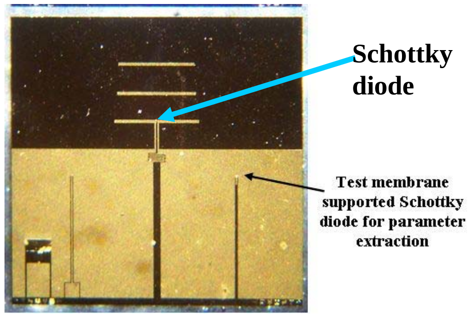




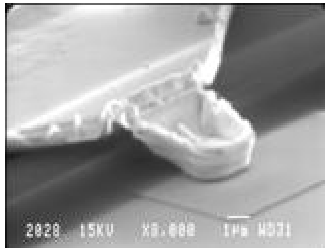
Received backscattered spectrum at a distance of 1.04 m. The transmission power was 34 dBm EIRP.



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



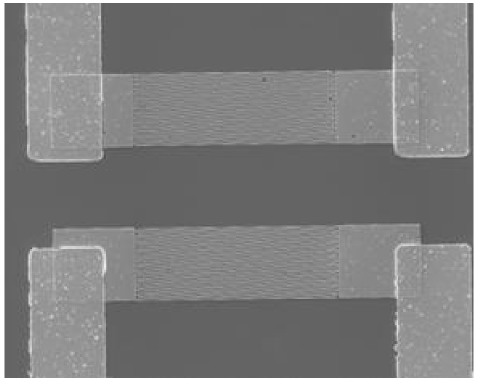
The receiver structure

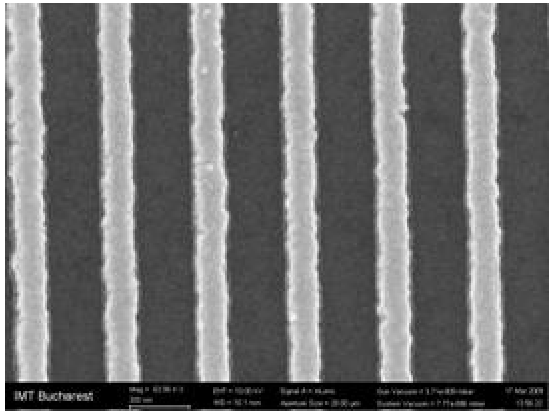


Details of the Schottky diode region

SAW devices for GHz applications with nanolithographic IDTs

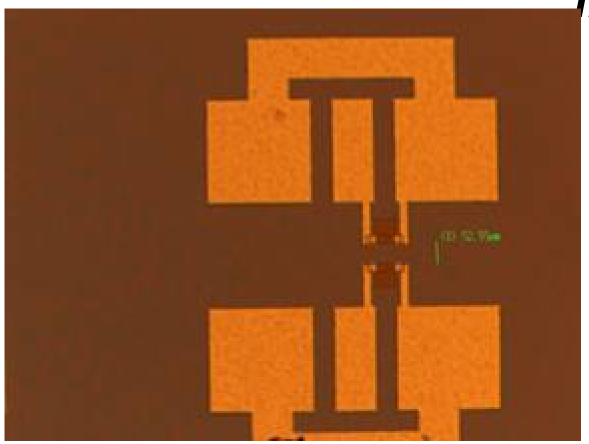
Common work in the frame of FP 7 Project MIMOMEMS of IMT (design, nanolithography, characterization) - FORTH (metallization, lift off)



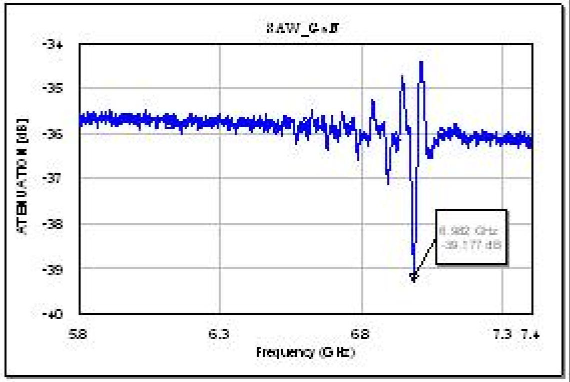


SAW structure on GaN having digits and interdigits 150 nm wide, patterned in IMT on the "E-Line" equipment

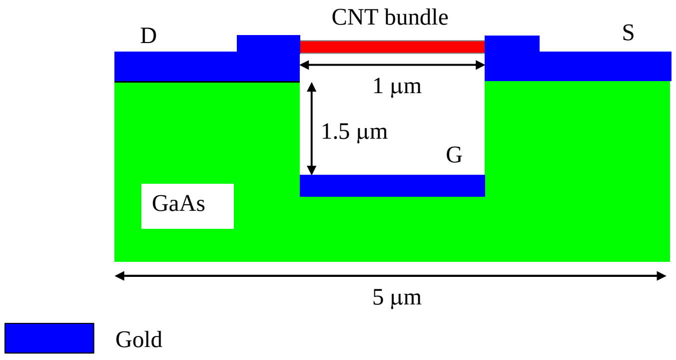
7 GHz resonance on GaN

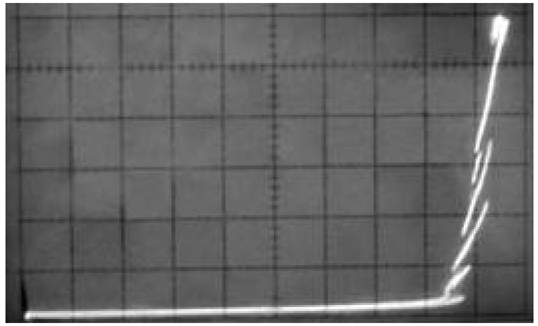


Optical image of the test structure

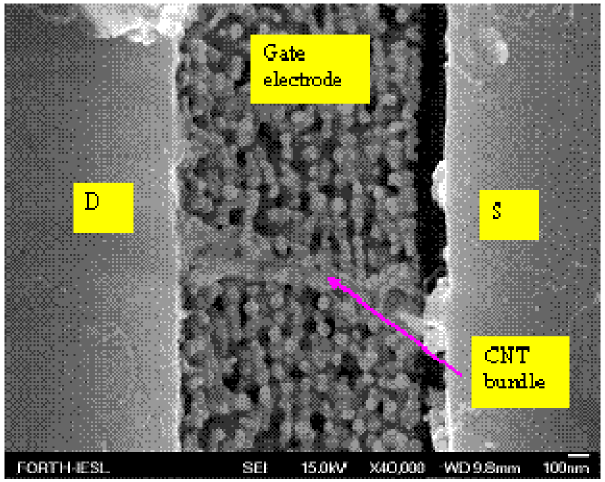


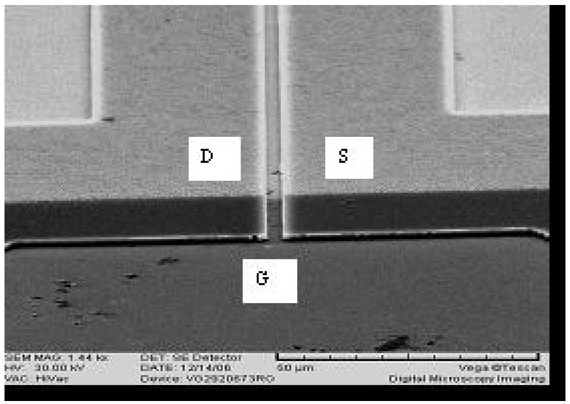
SUSPENDED CNT FET DEVICE





Multiple negative resistances at V_G= 14 V,vertical :500 µA/div, horizontal 2V/div





APPLIED PHYSICS LETTERS 93, 043117 (2008)

Multiple negative resistances in trenched structures bridged with carbon nanotubes

M. Dragoman,[1,a] G. Konstantinidis,[2] A. Kostopoulos,[2] D. Dragoman,[3] D. Neculoiu,[4] R. Buiculescu,[5] R. Plana,[6] F. Coccetti,[6] and H. Hartnagel[7]

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[5]*Department of Chemistry, University of Crete, Vassilika Vouton, Heraklion, Crete 71003, Greece*

[6]*LAAS CNRS, 7 Avenue du Colonel Roche, 31077 Toulouse Cedex 4, France*

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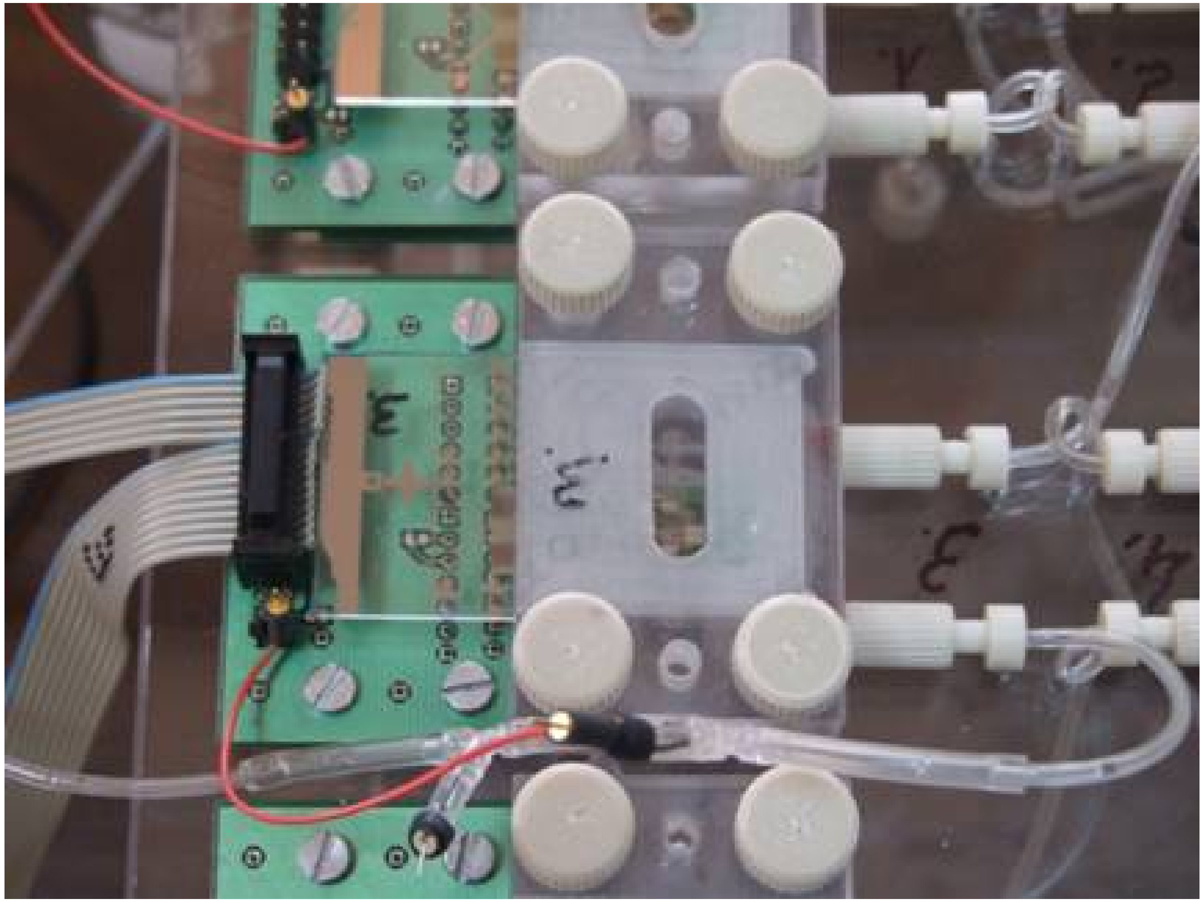
Platform for on-line toxicity monitoring

IMT contribution: Sensors for living cells monitoring

Sensors platform – temperature, pH, O_2 sensors, and miniaturized reference electrodes implemented

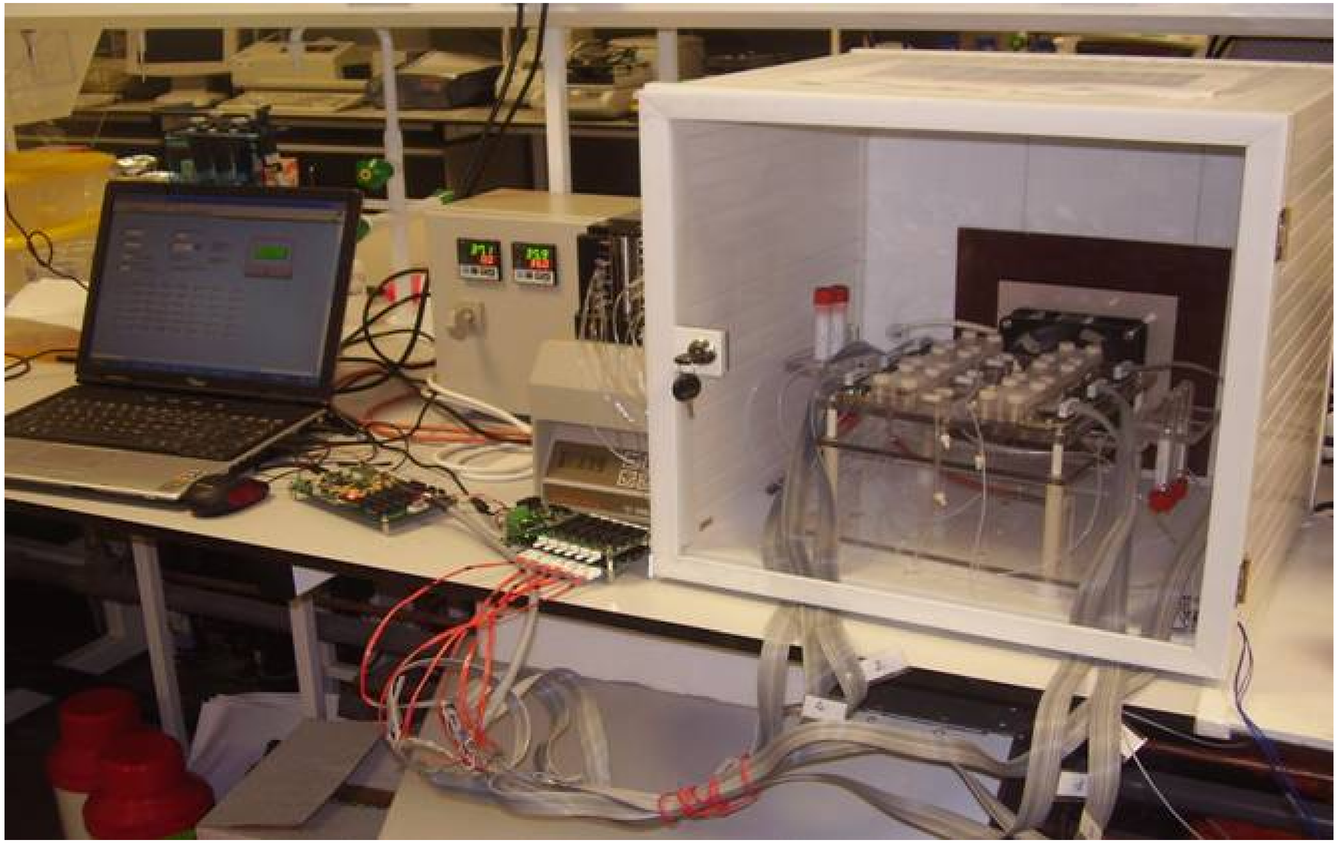


Results within the TOXICHIP project (Development of a toxin screening multi-parameter on line biochip system), FP6 IST STREP, 2006-2009

Platform for on-line toxicity monitoring

IMT contribution: Microfluidic channels

- Heating system
- PCB connections
- Data acquisition

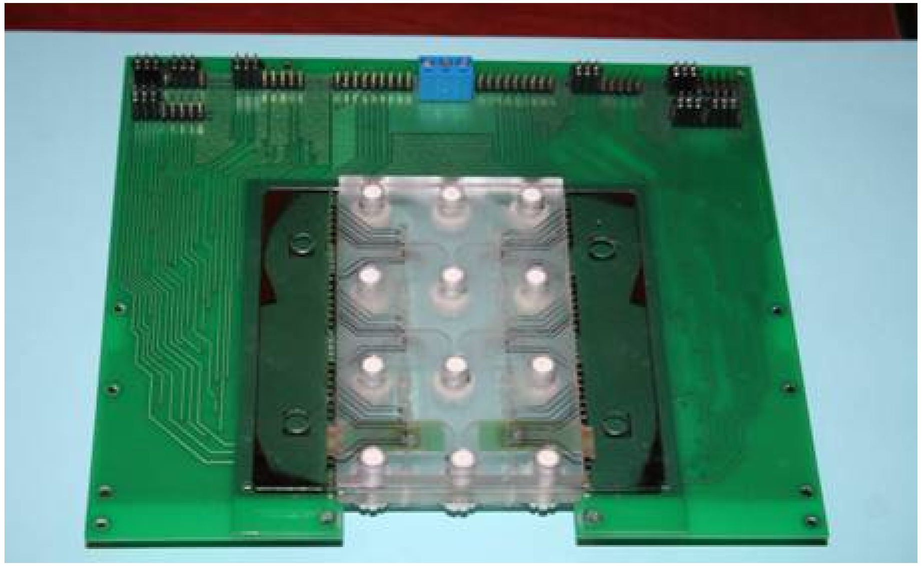


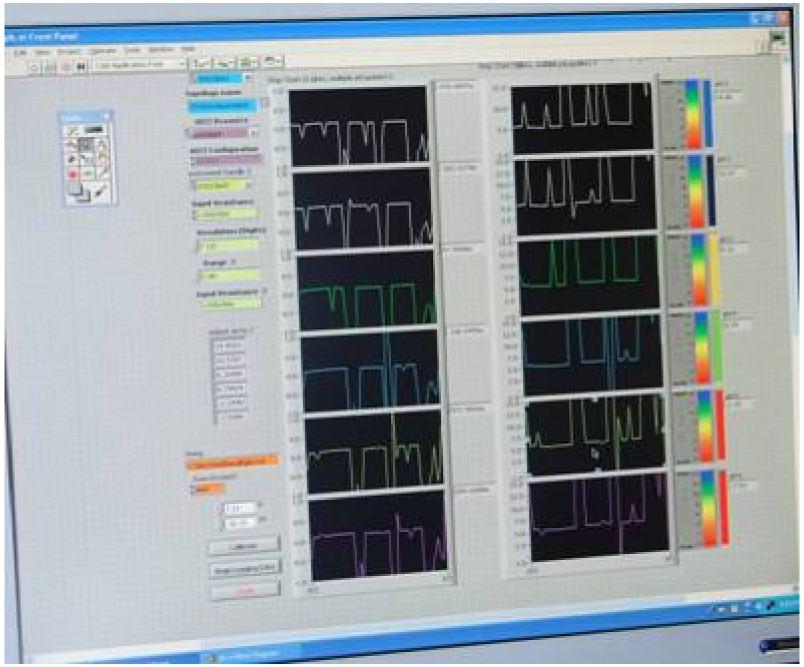
Results within the TOXICHIP project (Development of a toxin screening multi-parameter on line biochip system), FP6 IST STREP, 2006-2009, in Cooperation with: Tyndall National Institute (Ireland), Maria Boelo Institute (Italy)

Platform for on-line toxicity monitoring

IMT contribution:

Complete integration – Sensors, Microfluidics, PSB



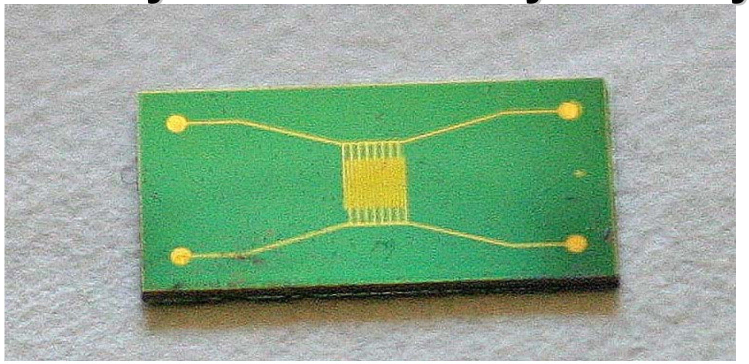


Characterization and Testing platform (LabView based)

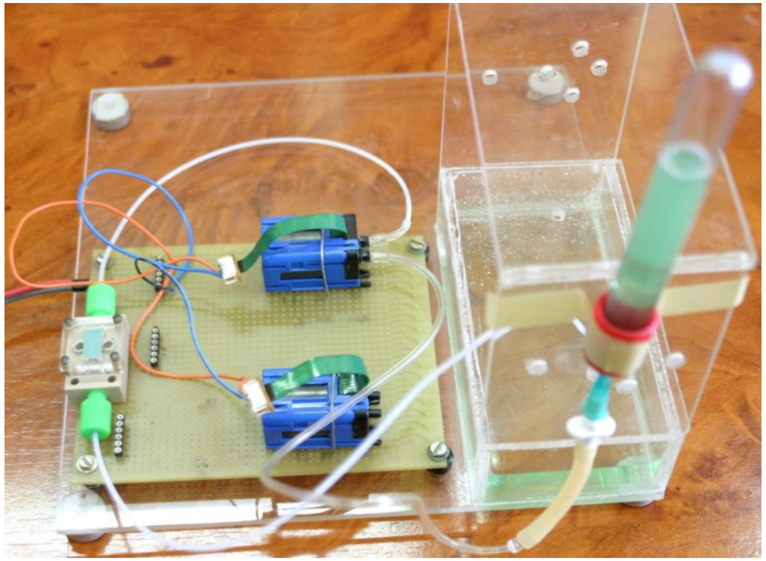
Results within the TOXICHIP project (Development of a toxin screening multi-parameter on line biochip system), FP6 IST STREP, 2006-2009

Biosensors for pesticide detection

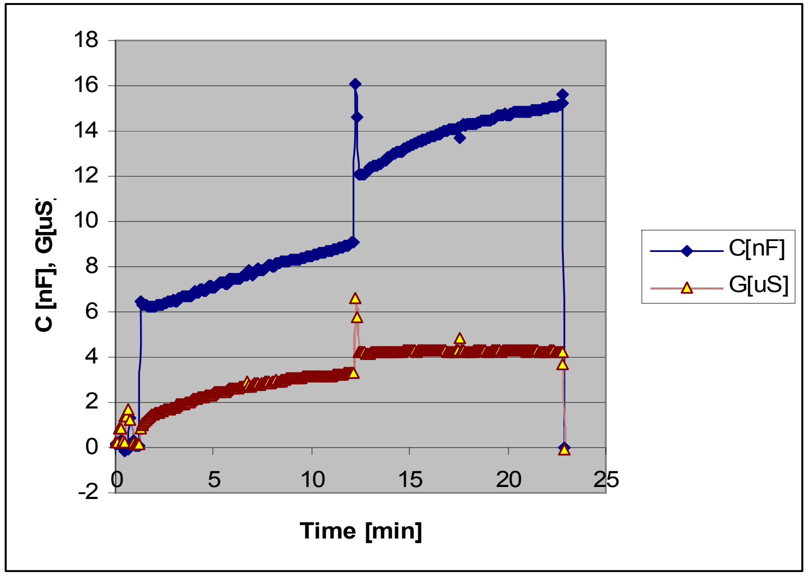
The **biosensor has two gold interdigitated microelectrodes on silicon substrate covered by a sensitive enzymatic layer** placed into a microfluidic module.



Picture of the gold electrodes



Silicon biochip in the microfluidic module, with pumps and reservoir



Conductance and capacitance measurement at 10^{-8} M concentration of Dichlorvos in electrolyte solution

Results within the INTEGRAM*plus* project (Integrated MNT platforms and services – Service Action),
FP6 IST IP, 2006-2008, in Cooperation with Epigem (UK)

Lessons learnt?

Everything seems more or less obvious ……

- To become useful in a big project and in consortium of strong partners you have to be highly specialized;
- The participation to networks of excellence was mostly in the benefit of young people with small projects;
- The most advanced precompetitive research is likely to attract the interest of important companies;
- The experienced researchers can supplement to a certain extent (by mobility) the absence of (certain) experimental facilities;
- **It is difficult to capitalize the results of joint research without a strong experimental basis in your own organization**
- In order to have a chance in a strong competition one has to explore new frontiers, rely on state-on-the-art tools and invest in human potential.

Summary

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2. IMT in European projects and lessons learnt.
3. Investing in infrastructure and making it operational
4. Offensive in the “micro-nano-bio” domain
5. The concept of IMT-MINAFAB as an “open” experimental centre.
6. Does this concept have any future in a country as Romania? Opportunities and challenges.

Investing in infrastructure and making it operational

Sources of funding: To a great extent these are originating from various projects won by researchers, such as:

- *Three projects for technological networks* (2005-2008)
  - The investments from the projects have been concentrated to a great extent in the labs created by IMT, as coordinator.
  - These labs are “open” to the partners in the network
  - NanoBioLab and NanoScaleLab have been created: they nucleated the clusters of experimental labs to be seen today
- *Four infrastructure projects* (2006-2008);
  - Extending the capabilities of RTD laboratories
- *Eight infrastructure projects form the “Capacities” programme* (2007-2009)
  - Most of them (5 from 8) are consolidating the “Centre of nanotechnologies” (see next)
  - Reconstruction of the premises was also possible
- *MIMOMEMS project of centre of excellence*, funded by EU;
- Various *research projects* in national programmes
- *Individual themes* of research in the “core programme” of the institute (institutional funding).

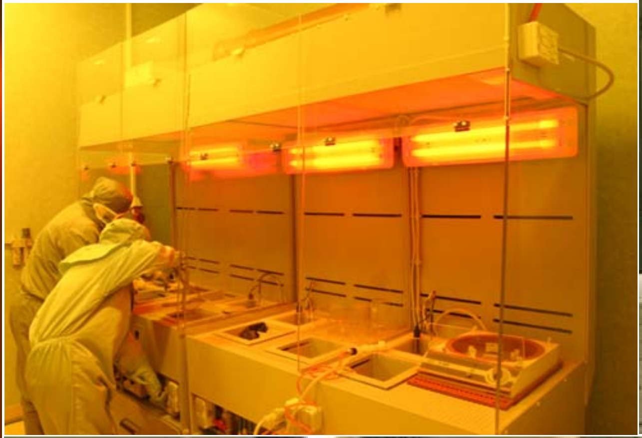
As a result the “picture” is a very fragmented one or even “*the pieces of the puzzle*” seem to be from different pictures!

How to bring them together and compose a coherent and functional experimental centre?

Making the investments fully operational

- **Providing a support infrastructure (clean room area). Main facilities:**
  - **A class 1000 clean room (220 sqm) for the mask shop and the most demanding technological processes (in use since September 2008);**
  - A class 100,000 clean room, the so called "grey area" (200 sqm), mostly for the characterization equipments (in use since September 2008);
  - A class 10,000 clean room (105 sqm) for thin layer growth by CVD techniques, RTP etc. (to become operational in 2009).
- Implementing in the above area new "*experimental laboratories*" (EL) initiated and operated by various research groups. These EL are open for use by all researchers. Therefore, **a "common experimental facility" was created as a kind of "joint venture" of various RTD labs.** This valid for most of the characterization equipments, as well as for nonconventional structuring tools.
- In contrast with the above all equipments which can be used for production (mask shop, wafer processing etc.) are managed by execution personnel, in a separate department.

Clean room,
class 1,000




Clean room, class 1,000

A technological platform

IMT-Bucharest acts as a technological platform, providing tools for design, fabrication (including a mask shop), characterization and reliability tests.

- Design, simulation of MEMS/Microsystems, nanostructures (using COVENTOR WARE, ANSYS, COMSOL OptoiFDTD, IE3D);
- Fabrication of micro- nano structures, microsensors, microsystems (MEMS, MOEMS, RF- MEMS, microfluidics, biochips: microarrays, biosensors) based on semiconductor technology, including also mask fabrication, electron beam lithography (EBL), dip-pen nanolithography and nanoprinting;
- A laboratory for rapid prototyping (with laser) is under development;
- Microphysical characterization (SPM, SEM, XRD, SNOM, WLI, Impedance spectroscopy, Raman, Spectrophotometer; Spectroscopic Ellipsometer, experimental set-up for optoelectric characterisation in UV-VIS-IR spectral range);
- Reliability tests (thermal, mechanical etc.);
- *Important*! Mounting and packaging is provided by small companies (from the science park), with equipments located in the same technological area

Main Tools - 1 -

- lithography – chrome, maskless, nano
- 4-6" processes – e-beam induced, physical/chemical depositions, thermal...
- characterization – electron/contact/X-ray/UV/Vis/NIR/chemical/ mechanical/electrical/thermal
- CAD and simulation – coupled analysis, M(O)EMS, RF-MEMS, microfluidics...

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

Main Tools - 2 -

❑ Characterization

- X-ray Diffraction System - *SmartLab*, Rigaku
- Field Emission Gun Scanning Electron Microscope (FEG-SEM) - *Nova NanoSEM*, FEI Company
- Scanning Electron Microscope - *Vega II LMU*, Tescan
- Scanning Near-field Optical Microscope - *alpha 300S*, Witec
- Scanning Probe Microscope - *NTEGRA*, NT-MDT
- Scanning Electrochemical Microscope - *ElProScan*, HEKA
- Nanomechanical Characterization equipment - *Nano Indenter G200*, Agilent
- High Resolution Raman Spectrometer - *LabRAM*, HORIBA
- Spectroscopic ellipsometer - *800 XUV*, SENTECH
- Combined Time Resolved and Steady State Fluorescence Spectrometer - *FLS920P*, Edinburgh Instruments
- White Light Interferometer - *Photomap 3D,* FOGALE nanotech
- Microarray Scanner, *GeneTAC UC4*, Genomic Solutions
- Microwave network analyzer (0.04 - 65 GHz) with Manual Probing Station - *Lightning VNA*/Anritsu; *PM5*/Suss MicroTec; *to be extended soon to 110 GHz;*
- Semiconductor Characterization System, Wafer Probing Station - *4200-SCS*/Keithley; *Easyprobe EP6*/ Suss MicroTec

❑ CAD and Simulation

- *CoventorWare 2008.010*, COVENTOR
- *Ansys Multiphysics 11.0*, ANSYS
- *Opti FDTD 8.1, Opti-HS, OptiBPM 9.0, OptiGrating*, Optiwave
- *IE3D, FIDELITY*, Zeland

Details ►Scientific Services for Modeling and Simulation

Expertise:

- **design, development and optimization** of **MEMS/MOEMS** components and devices (switches, cantilevers, bridges, membranes, microgrippers); mechanical, thermal, electrical and electrostatic, piezoelectric, fluidic, as well as coupled field (static and transient) analysis;

- modelling and simulations of microfluidic components and systems for biomedical applications and micro-electronic fluidic systems (valves, pumps - with various actuation principle as electrostatic, piezoelectric, pneumatic, electro osmotic- cell reservoirs, microchannels, filters, mixers, heaters, etc.)

– the **microfluidic analyzes** include: fluid dynamics in microstructures (general flow, fluid mixing, thermal analysis); electrokinetic flow (electrophoresis, electroosmosis); electrokinetic with field switching analysis; fluid diffusion; bubble and droplet simulation (transport, merging, splitting); interaction between fluids and mechanical parts; mechanical, electrostatic, piezoelectric analysis for microfluidic actuators-; modelling of optoelectronic devices, neural networks.

Tools available:

● COVENTOR 2006.2 (in 2007 new modules: Architect; FlowMM; MemHenry; MemPackage; Designer; Analyzer Std. ; MemOptics CW 2006 release)

● MATLAB 7:

● ANSYS Multiphysics 11.0- Structural, thermal, acoustic, electromagnetic and coupled field analyses, CFD

● COMSOL Multiphysics 3.3 and 3.4 (enabling parallel computation)

● Workstation with 4 quad-core Intel Xeon MP 2.93 GHz processors, 64 GByte RAM and 584 GByte HDD + 876 GByte external storage

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View from the **new clean room**

Reactive Ion Etching (RIE), SENTECH equipment

Working gases: CF_4, CHF_3, SF_6, O_2, Ar
RF power could be varied between 0 si 600 W,
pressure in reactor between 1 – 100 Pa, and wafers of 3 and 4 inch

Conventional and non-conventional technological processes:

- **Etching:** Si, SiC, SiO_2, polySi, Si_3N_4, TiO_2, SU8, PDMS, PMMA

- Physical-chemical reactions at room temperature for the **modification of the surfaces** (contact angle, superficial polymerization, hydrophilic and/or hydrophobic surfaces).

- Plasma RF treatments for **improving the substrate adherence.**

Vacuum coating system

Processes:
- **DC sputtering**
- **e-beam**

Chamber size: 500mm x 500mm

Coating materials: Al, Ni, Cr, Au, Pt, Ti, W, etc

Up to 6 coatings in a single vacuum process (4 e-beam, and 2 sputtering)

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Pattern generator for mask manufacturing

DWL 66fs Laser Lithography System is produced by Heidelberg Instruments Mikrotechnik GmbH.

APPLICATIONS:

-masks manufacturing **for all semiconductor applications** (minimum pattern : 1 μm

-**direct writing** (wafers, different substrate types) using various photosensitive coatings (positive and negative resists, SU8, photosensitive polyimide) for all semiconductor applications

-**3D structuring** in thick photosensitive materials

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Dip Pen Nanolithography system

This scanning probe lithography technique allows pattering in nanometre range and is a direct writing method that can use molecular and biomolecular “inks” on a variety of substrates

Enables deposition of tracks of various materials (polymers, sol-gel precursors, nanopowder, complex molecules, quantum dots) with a thickness down to **30 nm**.

Summary

1. Basic figures about IMT and main fields of research.
2. IMT in European projects and lessons learnt.
3. Investing in infrastructure and making it operational
4. Offensive in the “micro-nano-bio” domain
5. The concept of IMT-MINAFAB as an “open” experimental centre.
6. Does this concept have any future in a country like Romania? Opportunities and challenges.

Interdisciplinary groups

- **Preliminary considerations.** IMT is dealing with a variety of technologies and a variety of applications in dozens of projects. *The structure of the institute is rather stable*, whereas the new and complex problems are tackled by using a kind of "*variable geometry*", combining the basic research laboratories and their resources in "**interdisciplinary groups**". The most relevant groups are presented below:
- **MIMOMES** is an association of two research laboratories (RF-MEMS and Photonics, respectively) **financed by the European Union** as a "**centre of excellence**"; it has very strong links (including exchange of researchers) by twinning with two important research centres in Europe.
- **Centre of nanotechnologies** (under the aegis of the Romanian Academy of Sciences) is also **an interdisciplinary group**, coupling the activities in nanotechnology and nanobiotechnology:
  - Laboratory of nanotechnology (established in 1996);
  - Laboratory for nanostructuring and nanocharacterization;
  - Laboratory for molecular nanotechnology (set up in 2009);
  - Laboratory for computer simulation and design.
- **CINTTECH** is briefly mentioned here as **a strategic project** developing an approach for integration of technologies (including micro-nano-biotechnologies). It involves most of the research labs from IMT along three thematic lines. It includes plans for the development of a new infrastructure (with a new building, new laboratories, new equipments).

MIMOMEMS - European Centre of Excellence in Microwave, Millimeter Wave and Optical Devices, based on Micro-Electro-Mechanical Systems for Advanced Communication Systems and Sensors –

►**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**)

►**Cooperation** – Theme 3 - Information & Communication Technologies.

Challenge 3: Components, systems, engineering

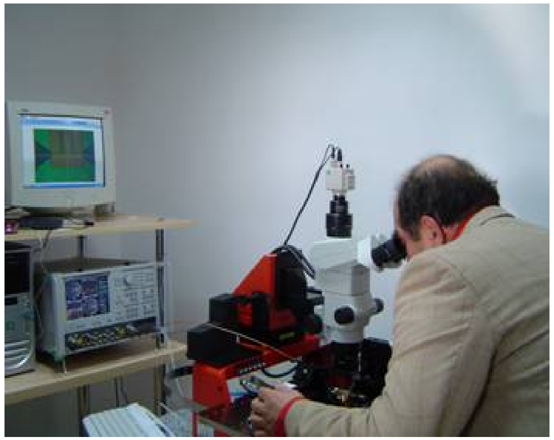
- **The overall aim** of the **MIMOMEMS** project is **to bring the research activity in RF- MEMS and Optical-MEMS at the National Institute for R&D in Microtechnologies (IMT) to the *highest* European level** and **create a European Centre of Excellence** in **Mi**crowave, **Millimeter** Wave and **O**ptical Devices, based on **M**icro-**E**lectro-**M**echanical **S**ystems (MEMS) for Advanced Communication Systems and Sensors.
- **The Centre of Excellence** is created by developing **IMT- Bucharest**'s existing scientific expertise and capacities and by collaborating closely with specialist research groups from **LAAS-CNRS** in Toulouse and **FORTH-IESL-MRG** in Heraklion.

MIMOMEMS

Equipments acquired in the MIMOMEMS project

► **Vector Network Analyzer (VNA) up to 110 GHz** and **on wafer measurement facilities in order to upgrade the 0.8-65 GHz existing on wafer characterization system**

► **Frequency synthesiser up to 65GHz**



► **Au plating facility for semiconductor wafers**

►**White light interferometer- optical profiling system for research applications**

►**Near field scanning optical microscope (SNOM)**

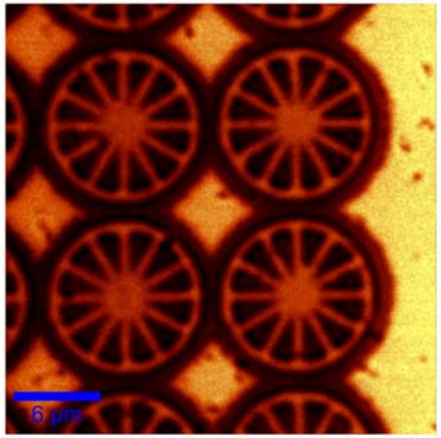
Near field scanning optical microscope (SNOM) – purchased in the frame of FP7 Project MIMOMEMS

Operating Modes:

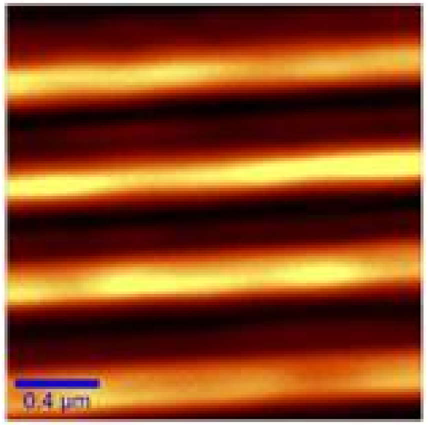
Near-field microscopy: **transmission, reflection, collection, fluorescence**

Confocal microscopy: **transmission, reflection, fluorescence, can be upgraded with a Raman spectrometer**

Atomic Force Microscopy **contact and AC-Mode**



Confocal image of round structure 30X30 μm scanning area



SNOM image in contact mode of an Au array of lines patterned using EBL – 2X2 μm scanning area

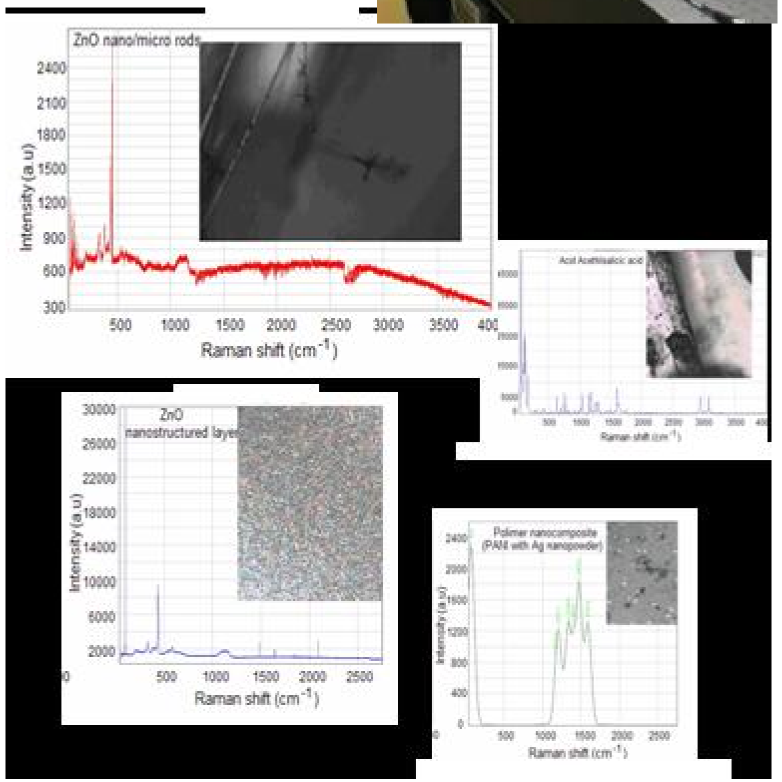
Applications:

- Imaging the optical properties of a sample with resolution *below the diffraction limit* with applications in nanotechnology, nanophotonics , nanooptics and plasmonics
- Life sciences
- Materials research
- Single molecule detection.

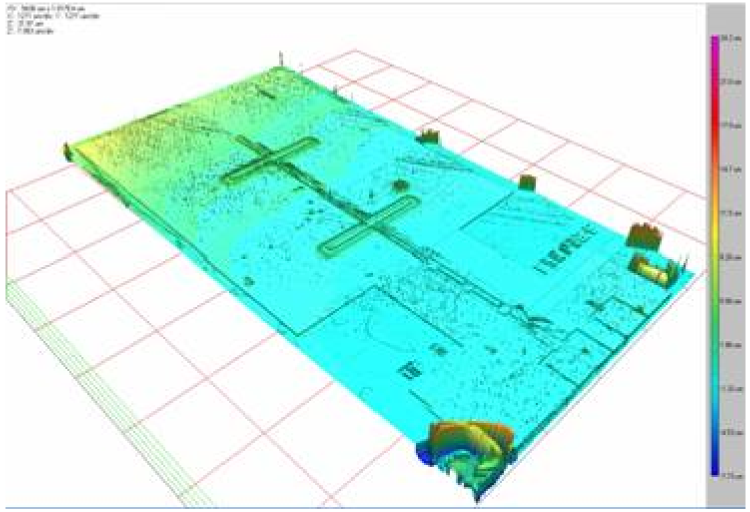
Raman spectroscopy

μ- Raman investigations of micro/nano structures

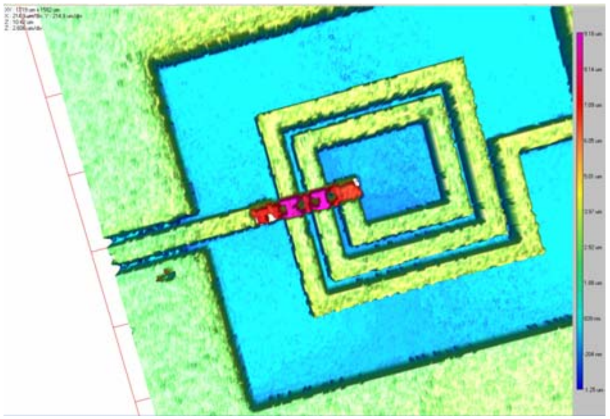
- composition and phase (crystalline/amorphous) of composites materials;
- nature of oxides on compound semiconductors;
- polymers characterizations and polimer nanocomposites;
- chemical and biological detection using SERS technique;
- micro/nano structures characterization - micro/nanorods, carbon nanotubes (CNT), self
- self assembled molecule (SAM) on functionalized substrate for nano- bio applications



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

Laboratory for nanostructuring and nanocharacterization

The recent development of this laboratory
… starting with NANOSCALE LAB

Main Techniques in the Nanostructuring and nanocharacterization Lab:

- ►**EBL**
- ►**AFM/SPM**
- ►**SEM - FEI**
- ►Nanoindentation - New

EBL - Direct writing Electron Beam nanoLithography

- is an ideal tool for nanotechnology research
- **e-line ERL nanoengineering workstation from RAITH** is a versatile equipment with specific requirements for interdisciplinary research:

- options for **nanomanipulations**
- **EBID** : Electron Beam Induced Deposition
- **EBIE**: Electron Beam Induced Deposition

The group was involved in the development of **different applications as**:
- fabrication of nanodevices for SAW and bio applications;
- Difractive Optic Elements (DOE), Photonic Crystals;
- high aspect ration pillars and nanostructures

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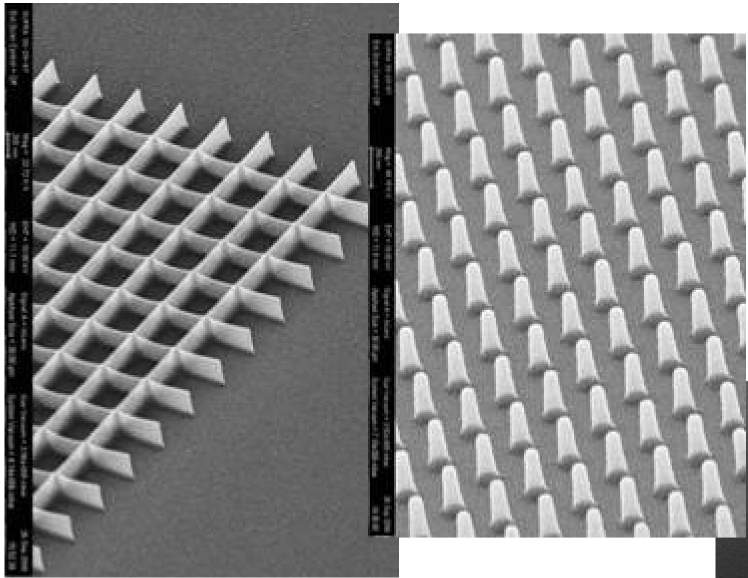
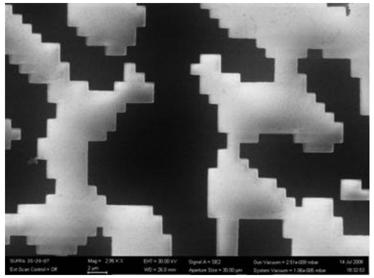
NANOSCALE LAB

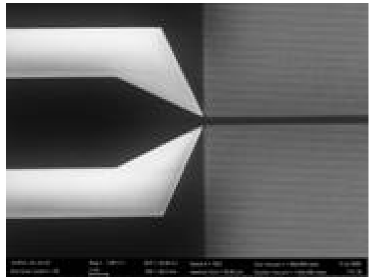
High aspect ratio (12:1) structures in PMMA

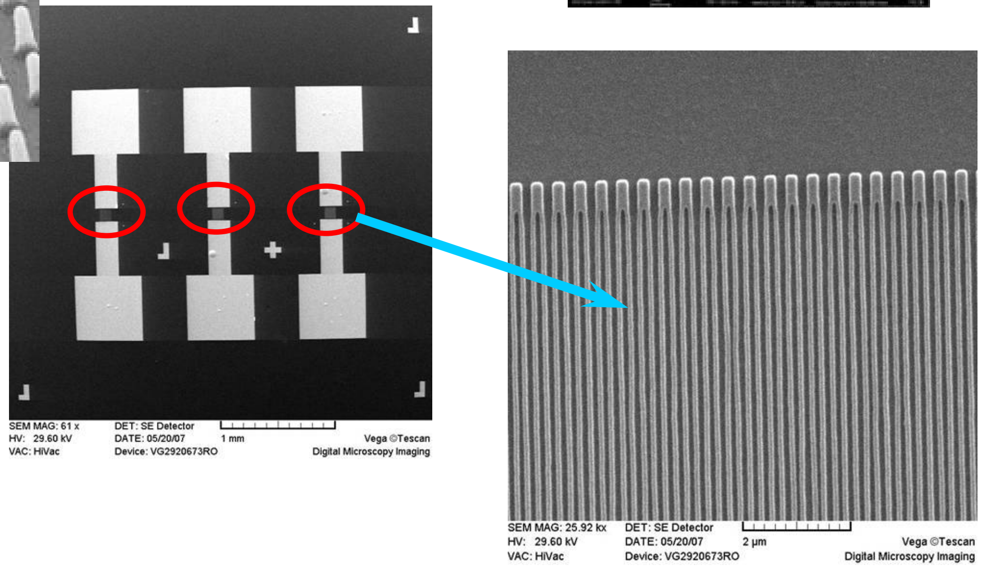


Diffractive Optical Element (DOE) for photonics applications

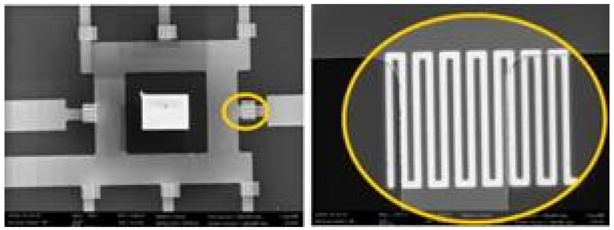


Photonic cristals in PMMA on silicon for near IR applications





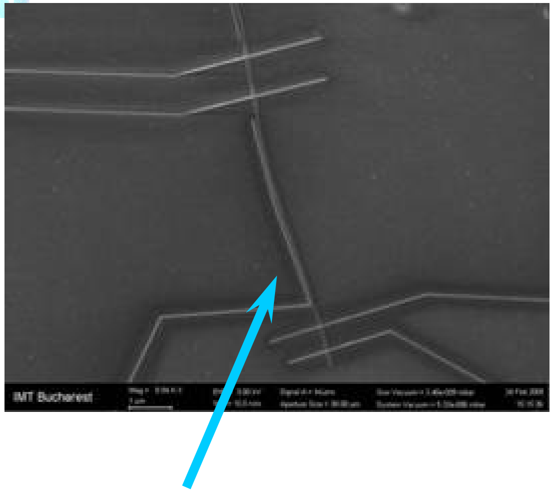
Mix-and-match lithography for 300 nm fingers used for SAW devices (Cooperation IMT Bucharest- IESL FORTH)



Mix-and-match lithography for biomedical applications: optical lithography (left), combined with EBL (right)

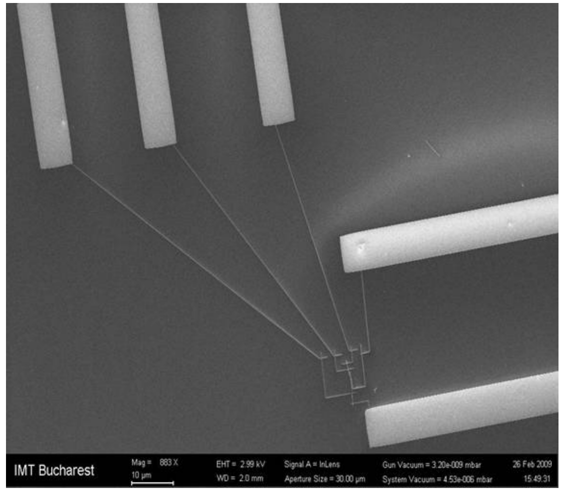
IMT-MINAFAB

NANOSCALE LAB



Polymer nanowire electrically contacted using EBID (Coopertaion IMT Bucharest – UCL)

Structure obtained using conventional lithography and EBID for 4 probes measurements of electrical properties of a polymer nanowire (Cooperation IMT Bucharest – UCL)



Research Topics

- **Nanolithography with sub 20 nm resolution**;
- **Three-dimensional nanostructures;**
- **CNT based interconnections for next-generation integrated circuits**
- **CNT based nanodevices**
- **SAW devices with nanometer interdigitated electrodes;**
- **Optical devices, holograms, micro lenses, gratings**
- **Development of Nanodevices using E-beam induced deposition and etching**
- **Development of circuits for communications based on photonic crystals**

Cooperation

- **FP7 CATHERINE Project FET- STREP:** Carbon nAnotube Technology for High-speed nExt-geneRation nano-InterconNEcts
- **INFN- Roma**
- **MIMOMEMS**
- **UCL**
- **Inst. Biodinamica**
- **INCDFLPR**
- **Zoom - Soft SRL**

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Scanning Probe Microscope (SPM) NTEGRA Aura - NT-MDT

Main applications: in the field of surface **metrology**, for quantitative measurements of the 3D surface topography for a large variety of samples.

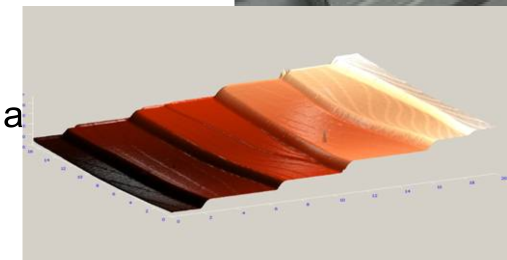
Key advantages:

-ability of measuring the vertical dimensions of the samples together with lateral ones with little or no sample preparation required

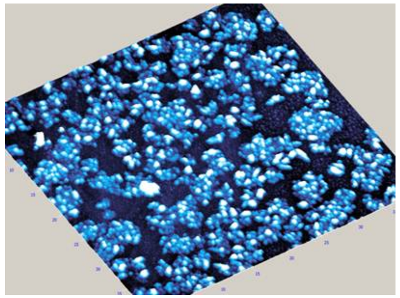
-samples could be measured in various environments (normal ambient, controlled gaseous, liquid, low vacuum)

Research Topics

- Surface morphology inspection
- Quantitative measurement of surface features a nanometric level
- Nano-surface texture/ roughness measurement
- High-resolution surface profilometry
- Evaluation and optimization of thin film coatings for various applications (optical, packaging, paintings, wear-resistant etc)
- Grain and particle size analysis
- Surface cleaning and polishing studies
- Morphological studies of biological and biocompatible materials



AFM image of step patterned Si. Individual step height: 15 nm. Individual atomic planes could be noticed in the 3D rendered image.



AFM image of a ZnO thin film on Si. Scan range: 40x40 microns. The AFM image was used for evaluating the growth pattern of ZnO, for applications in optoelectronic devices and gas sensors.

Partners

- research institutes
- universities
- companies

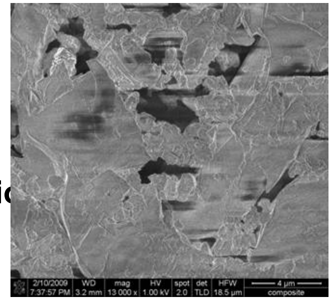
IMT-MINAFAB

Nova™ NanoSEM 630

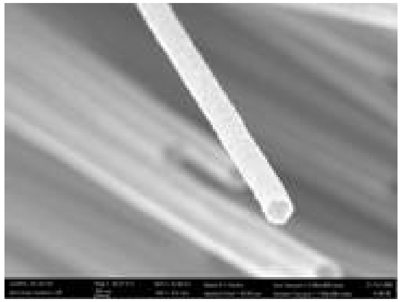
The FEI Nova NanoSEM 630 provides ultra high resolution, in the nanoscale range, for a variety of applications that involve sample characterization, analysis for S/TEM sample preparation.

Research Topics

- Materials Qualification
- Surface morphology inspecti
- Nanometrology
- Device Characterization



The structure of a composite material used in aeronautics- sample from INFN Italy



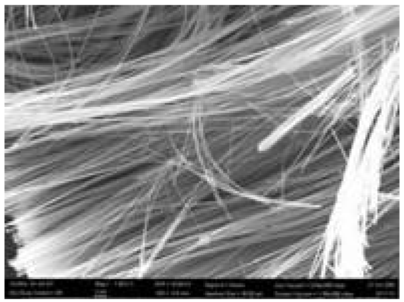
High resolution CNTs imaging

Applications:

We can investigate a variety of challenging nanotechnology materials such as metals, magnetic materials, nano-particles and powders, nano-tubes and -wires, porous materials (e.g. silicon), plastic Electronics, glass substrates, organic materials, diamond films, cross-sections etc

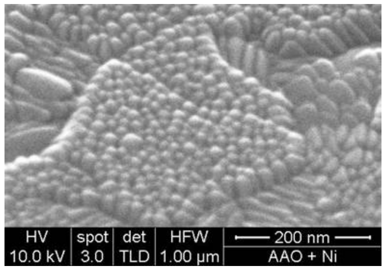
Cooperation:

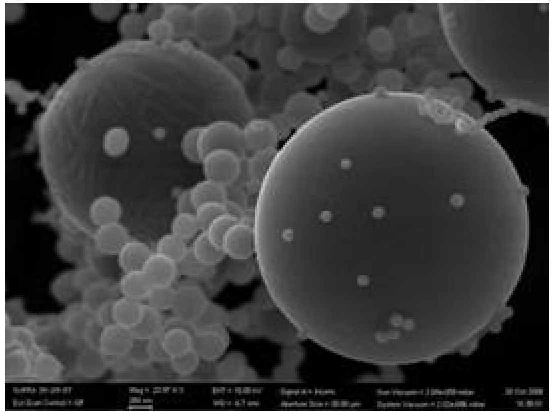
- INFN Rome
- FORTH Heraklion
- Univ. Salerno
- Univ. Kyoto



CNT bundles

High resolution image of a ITO layer deposited on glass





Micro and nanospheres produced in the process of CNTs growth (cooperation with INFN Rome)

Contact persons: Dr. Raluca Muller, raluca.muller@imt.ro; Drd. Adrian Dinescu adrian.dinescu@imt.ro

Laboratory of nanotechnology (bio applications in red)

Visit of the President of the Romanian Academy, 12th of March, 2009

NANOBIOLAB

Laboratory mission: Development of biochips (microarrays, biosensors) for biological materials investigation and detection (proteins, DNA, enzymes) on various substrates (silicon, glass, polymers).

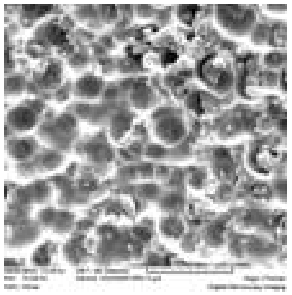
Equipments:

Plotter microarray (GeneMachines OmniGrid Micro)

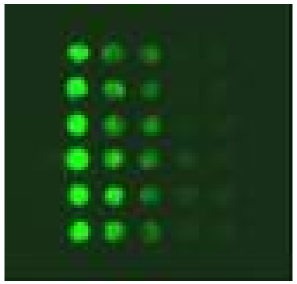
Scanner microarray (GeneTAC UC4)

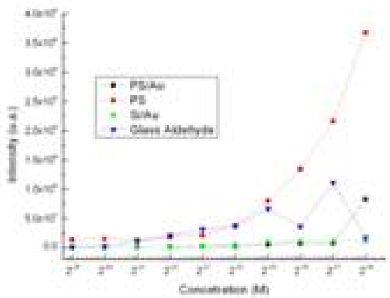
Results

1. Microarray technology: functionalization of different surfaces (glass and silicon wafer) in order to immobilized DNA and Proteins used in medical diagnosis.
2. Enzyme-based sensors for toxins detection. The sensors are made of interdigitated electrodes deposited on a silicon substrate.



SEM images of PS/Au samples
after the BSA printing





Fluorescence intensity as a function of the protein target concentration

Applications

Protein Arrays: (i) study tens of thousands of proteins in as short a time as possible; **(ii)** automated hybridization and imaging of DNA and oligonucleotides allowing antibody / antigen interactions study; **Protein Assays:** immuno-assays, protein-protein interaction assays, enzyme assays

Main Partners: University of Bucharest, Faculty of Chemistry, Diagnostic SA (DDS), Genetic Lab.

Impedance Spectrometer - PARSTAT 2273 (Princeton Applied Research)

General Specifications: hardware capable of ± 10 V scan ranges, 2 A current capability (1.2 fA current resolution), 100 V compliance, >10^{13} Ω input impedance, <5 pF of capacitance and 10μHz to 1 MHz built in analyzer for impedance measurements

Description: *Impedance spectroscopy (IS)* could be applied for:

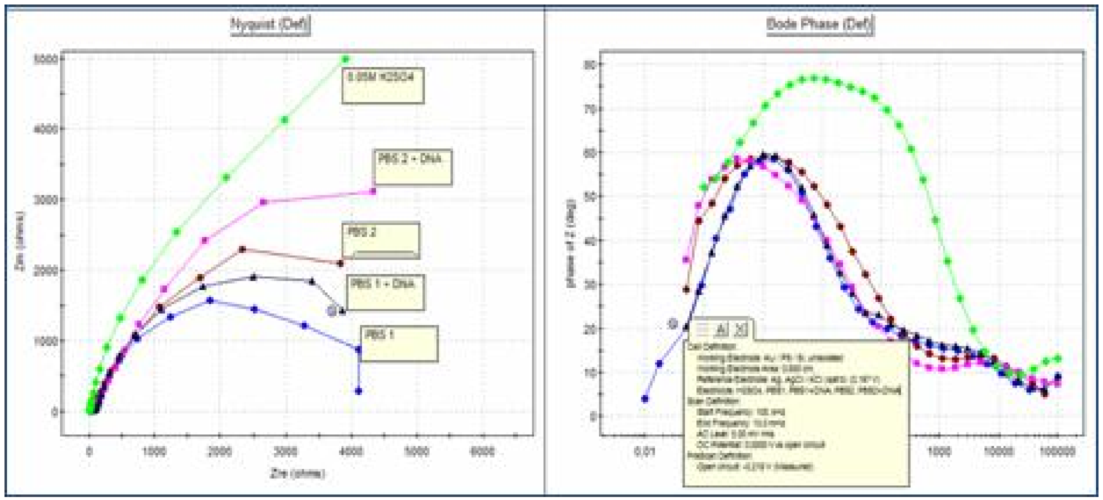
→ **materials and fabrication processes characterization**

→ **electrochemical system interfaces and corresponding physical and chemical phenomena characterization**

→ **bio-electrochemical systems characterization -** label-free detection tool for analyzing of interfacial properties changing by binding of charged biomolecules on surface and for biomolecular interactions studies for biosensor applications - *DNA hybridisation on electrodes analysis; biotin-avidin complex or cellular growing on the electrode surface*

Results (see figures):

Porous silicon as sensing layer for DNA binding



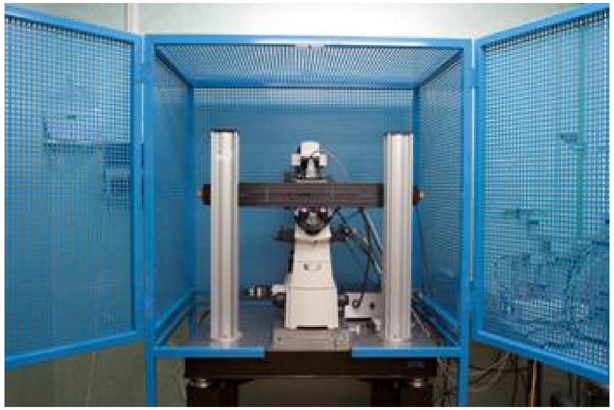
Scanning Electrochemical Microscope - Heka ElProScan

System components

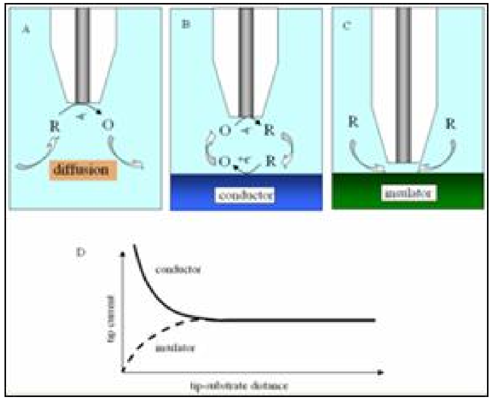
• Positioning system with 3 stepper motors (XY - 100 nm or 15 nm stepper motors) and a piezo translator (5 nm resolution and 100 mm scan range, closed loop regulated) mounted on a granite portal including fundamental plate

• Bipotentiostat/Galvanostat PG 340 with two low current Preamplifiers

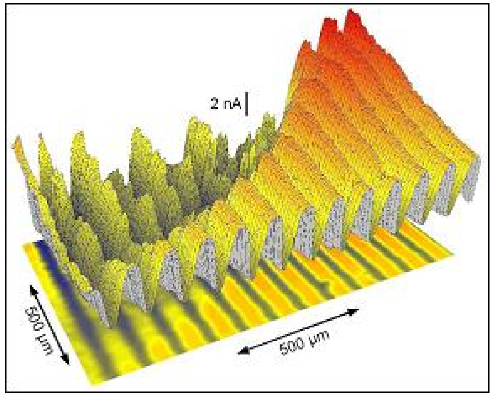
• Software POTPULSE with SCAN extension



Principle of detection



Directly measuring of the catalytic activity of biosensor microelectrode arrays



Applications:

- *Constant - distance Nano-SECM → Substrate imaging (Topography);*
- *Temperature-Controlled SECM;*
- *SECM for local corrosion investigation;*
- *Chemical reactivity → Heterogeneous electron transfer reactions studies; Electrocatalysis*
- *Probing patterned biological systems*
- *Bio SECM - Membrane transport*

Zeta Potential & Particle Size Analyzer - Delsa^{TM} Nano Series

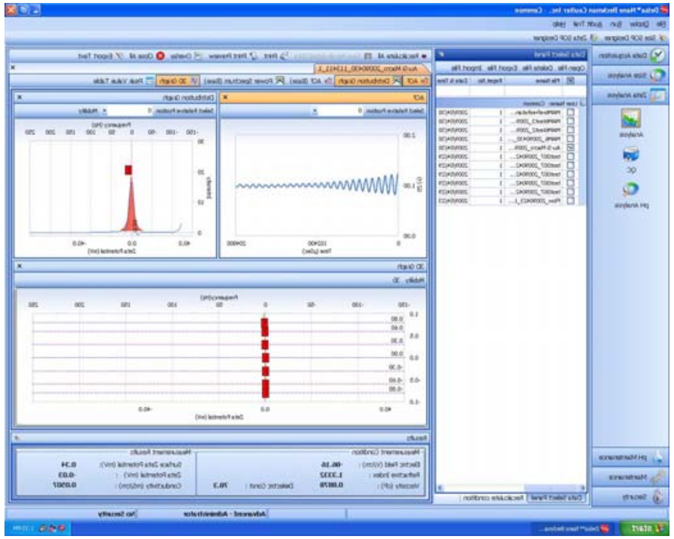
Principle of detection:

Photon Correlation Spectroscopy - Dynamic Light Scattering *for particle size distribution*

Electrophoretic Light Scattering *for Zeta Potential*

Analyses:

- Diffusion coefficient that depends on: temperature, liquid viscosity and particle size
- Particle size distribution (nm – mm)
- Molecular Weight (103-1012 Daltons) and chain conformation
- Micellization;
- *Zeta Potential*



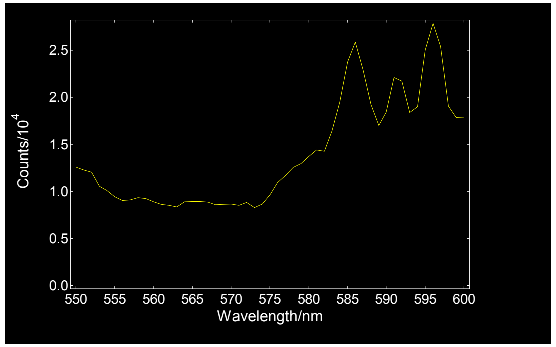
Zeta potential of Au/ macroPS

Applications

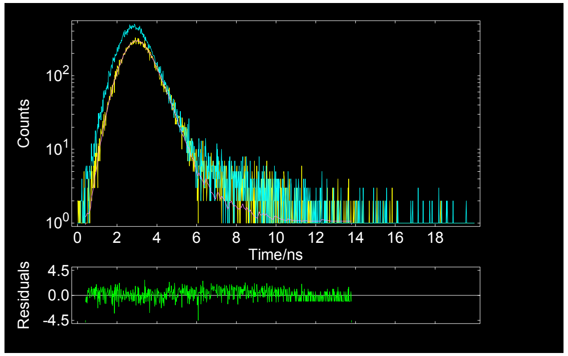
- **Formulation / tableting**
- **Final QC**
- **Formulation stability**
- **Research**
  - **Virus, bacteria**
  - **protein applications (aggregation)**
  - **bio-nanoparticles**
  - **Lyposomes, lipids, polysaccharides**
  - **Colloid drug carrier systems**
  - **Parenteral and oral drugs**
  - **micelles**
- ***Zeta potential of tablet surface***

Fluorescence lifetime and steady-state spectrometer (FLSP 920) - Edinburgh Instruments

Technical characteristics: steady state and time resolved fluorescence spectrometer; the sensitivity of the system guarantees a signal to noise ratio of 6000:1 for water Raman spectrum measured with excitation at 350 nm, emission at 397 nm, with a 1 second integration time and 5 nm spectral bandwidth.



Fluorescence spectra of BSA-PS



Fluorescence decay of BSA-Cy3

Applications: photophysics, photochemistry, biophysics and semiconductor study. Complex intermolecular interactions can be revealed by lifetime measurements

Biomedical field: study of enzymes, dynamics and structure of nucleic acids, protein folding and DNA sequencing;

Pharmaceutical sector: for monitoring drug interactions by studying the energy transfer mechanisms using fluorescence lifetimes as the indicator.

Materials physics: study semiconductors and novel structures such as quantum wells and quantum dots or for the quality control monitoring in a wafer foundry, to characterise the doping or impurity level present.

Rigaku SmartLab X-ray Thin film Diffraction System

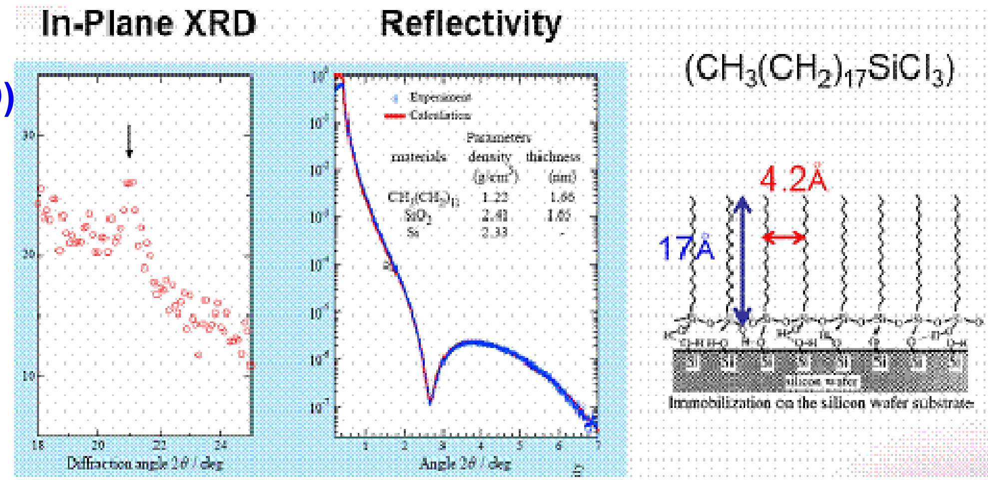
Technical characteristics:

- 9kW rotating anode, 200mm wafer
- Triple axis, vertical goniometer
- Independent Theta - Theta rotation
- Horizontal sample position; X-Y Micro Area Mapping

X- Ray methods and applications for structural Analysis:

- **X-ray Powder diffraction (XRPD)**
- **High resolution X-ray diffraction (HRXRD)** - phase analysis, crystal orientation, thermal stability
- **X-ray reflectometry (XRR, including HRMR XRR)** - layer thickness, density, roughness, interface layers;
- **Grazing incidence diffraction (GIXRD) -** texture analysis and pole figures
- **In-plane grazing incidence diffraction (IPGID)**
- **Small angle X-ray scattering (SAXS)**
- **Single crystal diffraction (SCD)**

Results: Investigation of the $CH_3(CH_2)_{17}SiCl_3$ organic film monolayer



New! Laboratory for Molecular Nanotechnology (1)

• Interdisciplinary laboratory established in 2009, relying on state of the art equipment (belonging to various labs and available through IMT-MINAFAB).

• Combination of top-down techniques (e.g., nanolithography and nanopatterning), bottom-up approaches (e.g., self-assembly), and nano-microscale microscopy tools to study functional properties obtained from the interaction of (bio)molecules with nano/micro objects.

• ***Central idea*: joining theoretical/simulation and experimental approaches in search for new insights on:**

- **electron transport mechanisms in chemically doped (bio)molecules**
- **interaction with nanostructures and enhanced device architectures for optimal signal extraction**

Current focus: theoretical and experimental studies towards physical DNA sequencing technologies:

(i) optimal surface immobilization and chemical modification of DNA single-strand molecules in view of STM/STS-based analysis of nucleobase detectability/identification;

(ii) optical-electrical manipulation of DNA strands and controlled presentation to 1D sensing nanostructures (nanotubes, nanowires)

Laboratory for Molecular Nanotechnology (2) - Main Tools

- **Modeling and simulation**:
  - SIESTA: package for ab-initio molecular dynamics and electronic structure calculations (molecules and solids)
  - CoventorWare, ANSYS: multiphysics analysis for MEMS

- **Processing and characterization**:
  - Dip Pen Nanolithography Writer – *NSCRIPTOR*, NanoInk
  - Electron beam lithography and nanoengineering workstation – *e_Line*, Raith
  - Field Emission Gun Scanning Electron Microscope (FEG-SEM) - *Nova NanoSEM*, FEI
  - Scanning Probe Microscope - *NTEGRA*, NT-MDT
  - Scanning Near-field Optical Microscope – *alpha 300S*, Witec
  - Scanning Electrochemical Microscope – *ElProScan*, HEKA
  - X-ray Diffraction System – *SmartLab*, Rigaku
  - High Resolution Raman Spectrometer – *LabRAM*, HORIBA
  - Micro-Nano Plotter – *OmniGrid*, Genomic Solutions
  - Force-Sensing Optical Tweezers - *NanoTracker*, JPK Instruments (near future)
  - Wafer bonding system - SB6L, SUSS MicroTec (near future)

Summary

1. Basic figures about IMT and main fields of research.
2. IMT in European projects and lessons learnt.
3. Investing in infrastructure and making it operational
4. Offensive in the “micro-nano-bio” domain
5. The concept of IMT-MINAFAB as an “open” experimental centre.
6. Does this concept have any future in a country as Romania? Opportunities and challenges.

IMT-MINAFAB: a center of services for Micro- and Nanofabrication

IMT-MINAFAB is an *interface* created by IMT - Bucharest in order to fully exploit its tangible and intangible assets in micro- and nanotechnologies (clean-room facility, equipments, human resources, partners and clients).

The so-called "fabrication centre" is in fact *a complex technological platform* including also CAD tools, characterization equipments, a mask shop, a reliability lab. The fabrication itself, whenever necessary, is accompanied by specific testing and design.

The present clean-room environment (including class 1000 spaces) is operational since *September 2008*. Most of the equipments in this area are new. Another clean room (basically devoted to CVD of thin layers and thermal processes) is expected to be completed in 2009.

Mission statement.

The micro- and nanofabrication centre from IMT-Bucharest will provide *a platform of interaction* devoted to multidisciplinary research and education-by-research, as well as to innovation and knowledge transfer to industry. As far as innovation is concerned, IMT-MINAFAB allows development of experimental models and prototypes, but also can support small scale production.

	Partnership in RTD activities, sharing the IP resulting from research	Scientific and technological services, including design and consultancy	Direct access, “hands-on” activities (after appropriate training)
Research groups outside IMT	Usually financed by a contract of partnership.	Typically, specific activities performed by IMT as subcontractor (computer design, characterization, technological processing etc.), with no IP rights.	Direct access of researchers from partner organizations, as part of common research and technology development (RTD)
Educational bodies for Ph.D. and postdoctoral studies, M.Sc. studies, “hands-on” training etc.	Supported by an individual grants or following an agreement with universities, specifying the cost and intellectual property issues.	Occasional.	As part of a common research activity, or providing training on a commercial basis.
Companies (industry)	Special NDA and IP (industrial property) use agreements.	Providing services on a commercial basis.	Companies may use their own IP rights.

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“Open centre”: the future of this concept

- At the level of IMT
  - Continuing the policy of attracting the cooperation with industry:
    - Providing room in the technological area for the equipments of companies;
    - Developing joint services with companies working in the field;
    - Attracting the interest of important companies with subsidiaries in Romania
  - Consolidating the connection with universities:
    - Four M.Sc. courses fully sustained by IMT to be implemented next academic year;
    - Increasing the number of Ph.D. students working out their thesis in IMT;
- National
  - **Network of fabrication facilities in the micro- and nanotechnology created by a few institutes;** this initiative of IMT was accepted by other three national institutes; the project of ROMNET-MINAFAB was put forward
  - Financial support from public funding
    - Direct, subsidies for a facility of national interest
    - Indirect, a support programme facilitating the access of SMEs to technological facilities
- European, international
  - Entering in a European network of facilities
  - Finding customers (a policy of collecting and disseminating information on various occasions; extending the area of interest)

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Other information: www.imt.ro

For services: IMT centre for MIcro- and NAnoFABrication (IMT-MINAFAB).

See: www.imt.ro/MINAFAB
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Thank you for your attention!