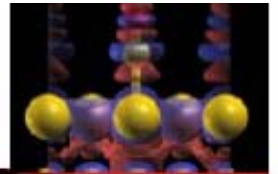
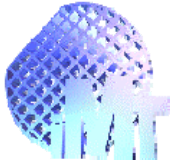


IMT-MINAFAB: a Technological Platform for integrating Education, Research and Innovation

Dan Dascalu, Raluca Müller and Radu Popa

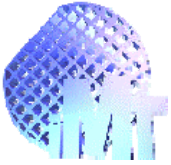


National Institute for R&D in Microtechnologies
126A, Erou Iancu Nicolae, 077190, Bucharest, Romania
Tel: +40 21 269 07 78
Fax: +40 21 269 07 72
www.imt.ro - www.imt.ro/MINAFAB



● **Summary**

- About IMT-MINAFAB in brief.
- Main facts, main figures.
- Major fields of research.
- Current projects.
- Equipment overview.
- Collaboration and perspectives.



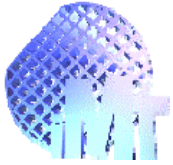
The policy of the **National Institute for R&D in Microtechnologies (IMT-Bucharest)** is to concentrate the operation of experimental resources in the so-called **IMT-MINAFAB (IMT Centre for Micro- and NAnoFABrication).**

This is done for technical reasons (the need to install and operate many equipments in a clean room environment) and also for organizational reasons – the need to have a concentration of resources open for utilization of both internal and external (non IMT) customers.

IMT operates a variety of resources, from CAD and a mask shop to reliability testing.

Of particular importance are the equipments for nanostructuring and characterization.

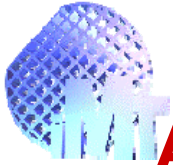
This allows IMT to participate in various international projects, including in nanoelectronics (such as CATHERINE from FP7 and a couple of projects from ENIAC-JU).



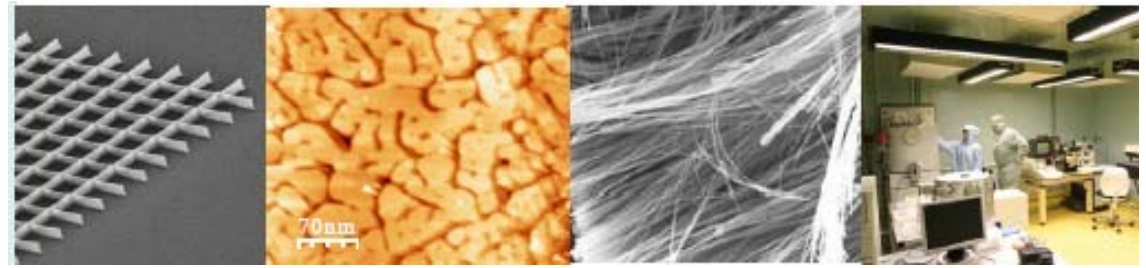
The experimental facility **IMT-MINAFAB** is not only devoted to partnership in **research**: the centre is also open to **education** and **industry** and this opens the way for very fruitful interactions in the so-called „knowledge triangle”

IMT will benefit from the interaction envisaged with companies like **Infinion Technologies** or **Honeywell** (providing services and/or cooperating in research projects closer to the real needs of industry),

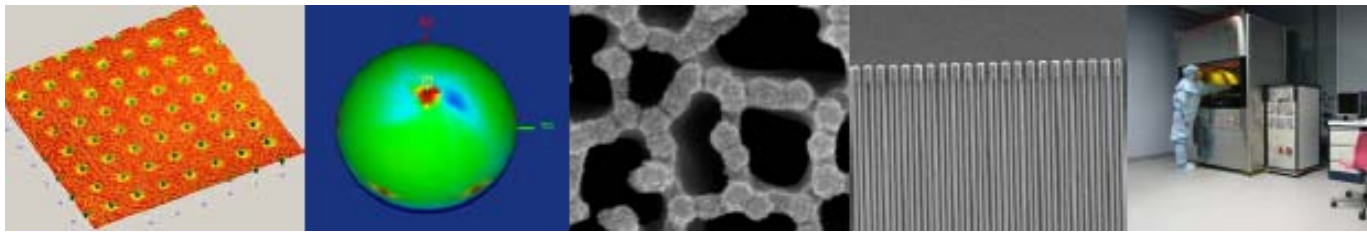
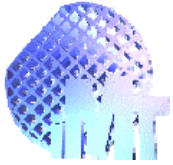
as well as from its involvement in **educational** and **training activities** (providing full support for a number of four disciplines related to the new M.Sc. courses from University „Politehnica” of Bucharest or rulling the new IMT post doctoral **programme in micro- and nanotechnologies** with 35 students).



About IMT-MINAFAB, in brief

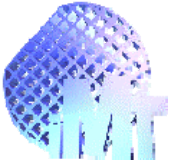


- **State of the art research infrastructure**, operating since September 2008.
- **Center of services** for **micro- and nanofabrication**
- **Platform** of interaction as open-centre for **research and education-by research**, focused on **multidisciplinary innovation** and **knowledge transfer to industry**.
- Enables highly efficient exploitation of IMT's existing tangible and intangible assets in nano-science/technologies (**clean-room facility, advanced equipments, knowledge and experience, partners and clients**).
- **Complex technological platform**: CAD tools, mask shop sector, analysis and characterization, nano-bio-fabrication, reliability tests.
- **Access** is facilitated in a variety of ways, with notable accent on developing common R&D projects and on offering direct access of innovative companies



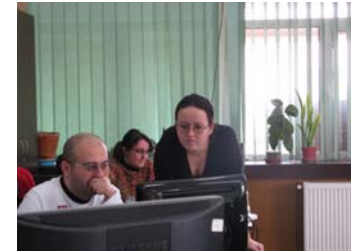
Main facts, main figures [1]

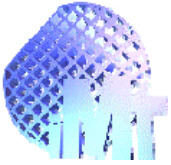
- **Class 1000 clean room** (220 sqm) for the mask shop and the most demanding technological processes.
- **Class 100,000 clean room - so called “Grey area”** - (200 sqm), mostly for the characterization equipments.
- **Class 10,000 clean room** (120 sqm) for thin films by CVD techniques, RTP, etc. (to become operational).
- Accumulated total investment in equipments and infrastructure: about 9 M Euro (2006-2009: 7 M Euro; 2008: 3.5 M, mainly from Capacities projects).
- **Large range of services. *Main categories:***
 - ▶ micro/nanofabrication for devices and systems
 - ▶ inspection, analysis and characterization of surfaces, films, crystals, nanostructures
 - ▶ design, modeling and simulation
 - ▶ complex RDI services - from design, to reliability testing



Main facts, main figures [2]

- **Over 60 national users as partners in consortia**, or based on bilateral agreements: 30 companies, 15 research institutes, 15 universities.
- **Over 30 industrial users**, as partners in consortia or contracted service users: Austria(1), Finland(1), France(1), Germany(8), Greece(1), Hungary(2), Italy(3), Poland(1), Slovakia(2), Spain(1), Sweden(6), The Netherlands(3), etc.
- **Over 30 partners in research - FP6-7**, bilateral projects: Belgium(2), Finland(1), France(2), Germany(11), Greece(1), Hungary(1), Italy(2), Ireland(1), Israel(1), Poland(1), Spain(1), The Netherlands(3), UK(1), Singapore(1), etc.
- **Master courses and hands-on training for students of Polytechnic University of Bucharest**
- Operation of IMT-MINAFAB conforms with best technical/technological/management standards (e.g., degree of decontamination, safety of operation)





Main facts, main figures [3]

- **Accumulated funding based on:**

- ▶ three projects for **technological networks** (2005-2008) - **NanoScaleLab** and **NanoBioLab**, labs created in this context: nuclei of some current experimental labs

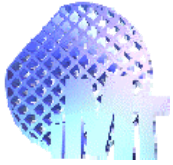
- ▶ **four infrastructure projects** (2006-2008) - extension of capabilities

- ▶ **eight infrastructure projects from the “Capacities”** programme (2007-2009) - five of them consolidated the “Centre of Nanotechnologies”; reconstruction/updating of the premises.

- ▶ **MIMOMEMS (FP7- REGPOT –call1)** project : a Centre of Excellence in **Microwave, Millimetre Wave and Optical Devices, based on Micro-Electro-Mechanical Systems for Advanced Communication Systems and Sensors**, in funded by the EU project No. **202897**

- ▶ Various **research projects** in **national programmes**.

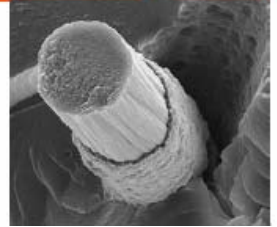


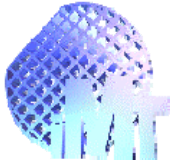


Main facts, main figures [4]

Results:

- **IMT- MINAFAB** as an integrated cluster of new experimental laboratories initiated and operated by various research groups. Other equipments that can be used for production (mask shop, wafer processing etc.) are managed by execution personnel, in a dedicated department.
- Provides the experimental support for a number of interdisciplinary groups, such as:
 - **Centre of Nanotechnology** (CNT-IMT) under the aegis of Romanian Academy.
 - **MIMOMEMS Centre of Excellence** in RF and Opto MEMS(2008-2011) - **LEA (Associated European Laboratory)** “Smart MEMS”, **IMT-Bucharest** in association with **LAAS/CNRS, Toulouse** (France) and **IESL-FORTH, Heraklion** (Greece)
- **Infrastructure providing state of the art services in micro-nanotechnology and hands on education and training.**





Major fields of R&D

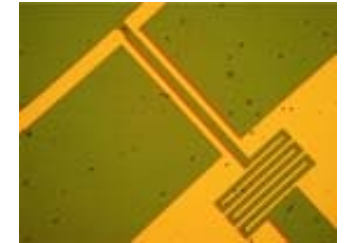
- **Collaborative multidisciplinary research, focusing on convergent micro-nano-bio technologies**, based on **structuring and characterization at the nanoscale**.

- **Components for nanoelectronics, photonics and microwaves**

- new fabrication technologies in Si, as well as in wide bandgap semiconductors, dielectrics, polymers.

- CNT/graphene-based nanostructures for nanoelectronics (transistors and chip interconnections).

- new concepts and structures for optical MEMS and RF-MEMS.



- **Advanced nanomaterials and nanostructures for therapies, biosensing, energy and other industries**

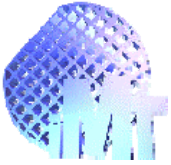
- functionalized nanoporous materials, nanocomposite particles, microarrays.

- nanocomposite and film assemblies for fuel cells and photovoltaics.

- SAM's, immobilization and combined studies of molecular interactions.

- microfluidic components and biochips for biosensing and monitoring.

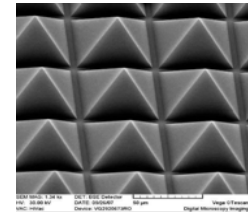
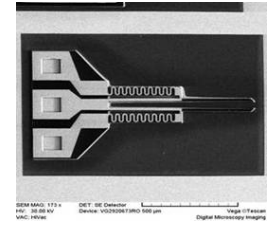
- functional films and nanocomposites for: neurosensing, constructions.



Major fields of R&D

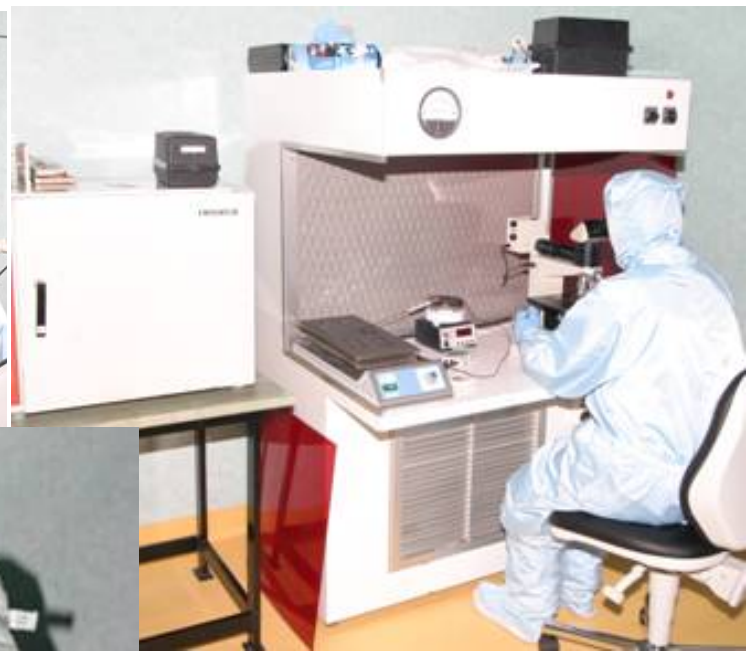
- **New technologies for fabrication and characterization**

- nanolithography, mask-free nano-connections, high aspect-ratio nanostructures.
- silicon nanoelectrodes, functional porous silicon, bio-active materials, field emission nanostructures.
- soft-lithography and replication.
- rapid prototyping: dip-pen nanolithography, laser micromachining, 3D and inkjet printing.
- nanomechanical characterization of materials.

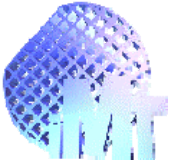


IMT-MINAFAB currently provides a complex technological platform for basic research, application-oriented R&D and even small-scale production.

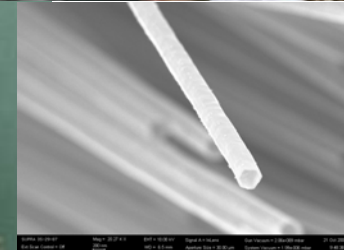
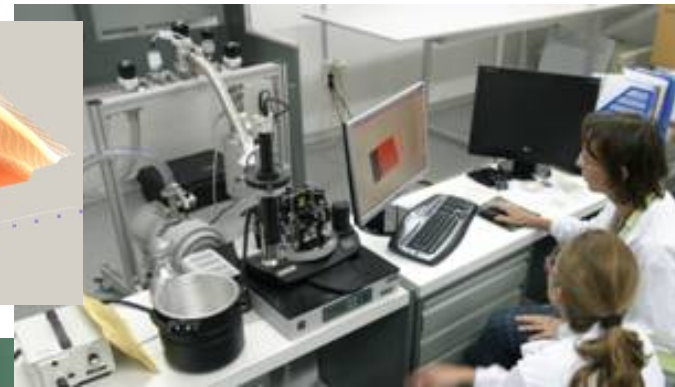
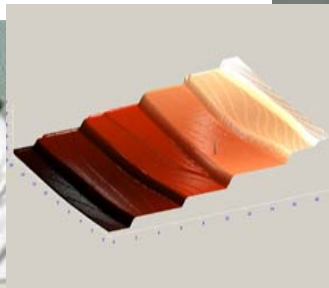
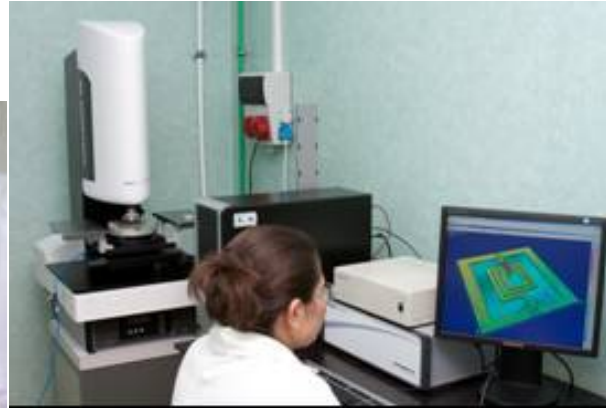
.

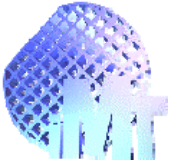


Clean room,
class 1,000

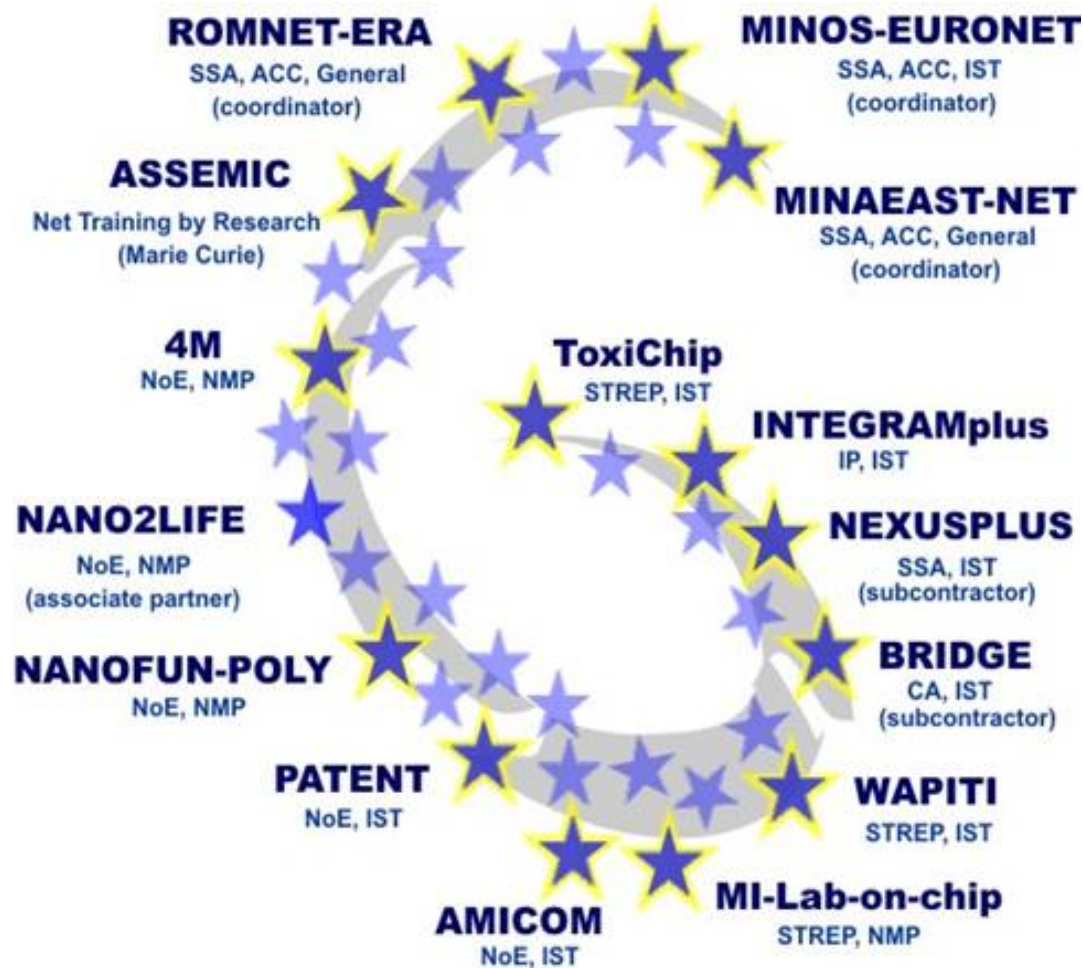


Gray Area





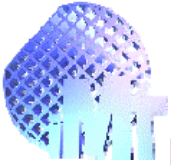
IMT- Bucharest participated in FP6 EU Projects



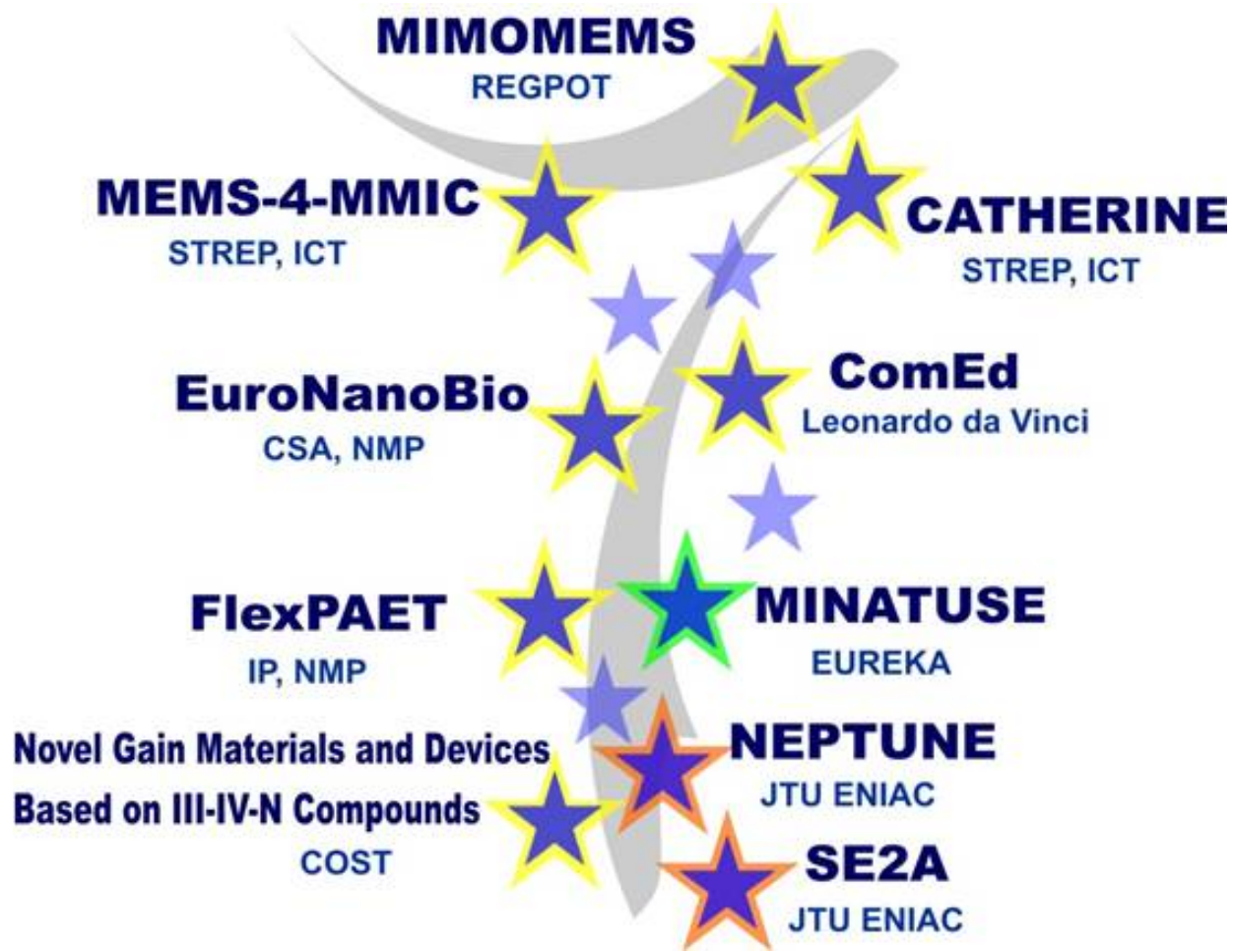
IMT- Bucharest

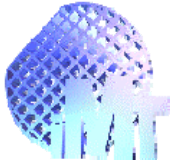
participated in different types of EU projects:

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



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



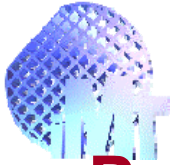


Participation of IMT- Bucharest in EU FP7 Projects

▶ **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).

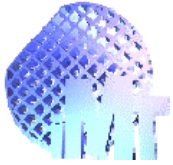


Participation of IMT- Bucharest in EU FP7 Projects

▶ **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 Produktionstechnologie (IPT), Germany. IMT role Partner; IMT Contact: Dr. Dana Cristea (dana.cristea@imt.ro);

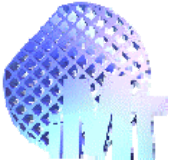
▶ **European scale infrastructure in NanoBiotechnology - EuroNanoBio, CSA, NMP, 2009-2010**; Coord: Patrick Boisseau CEA (France). IMT role; partner; IMT contact: Prof. Dan Dascalu (dan.dascalu@imt.ro);

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



EU projects related to FP 7

- ▶ **Nanoelectronics for Safe, Fuel Efficient and Environment Friendly Automotive Solution – SE2A; ENIAC (nanoelectronics)** 2008-2011, Coordinator: NXP Semiconductor Netherlands BV, The Netherlands. IMT role; partner; IMT contact: Dr.Alexandru Muller (alexandru.muller@imt.ro).
- ▶ **MERCURE, ENIAC (nanoelectronics), Coordinator: Thales TRT, France**; contact person: Dr.Alexandru Muller (alexandru.muller@imt.ro); accepted Oct 2009
- ▶ **Micro Nano Technology Use by SME's- MINATUSE, EUREKA**, coord: Christophe Bruynseraede, IMEC, Belgium, 2005-2010, IMT role Partner; IMT Contact: Eng.Ionica Miresteanu, (ionica.miresteanu@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: Dr.Alexandru Muller (alexandru.muller@imt.ro)



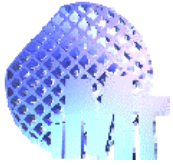
EU projects related to FP 7

► **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).

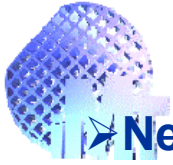
“Nanostructural carbonaceous films for cold emitters” (NANOCAFE), Coordinator: Industrial Institute of Electronics, Poland, Dr. Elżbieta Czerwosz, role of IMT – partner, contact: Phys. Florea Craciunoiu (florea.craciunoiu@imt.ro).



International partnership

- Apart of cooperation with dozens of organizations from Europe in EU projects **IMT- Bucharest** is involved in a great number of **bilateral European** projects (especially with Italy, France, Belgium),
- **Outside Europe, IMT- Bucharest** has also cooperation with organizations from:
 - Japan
 - Korea
 - Singapore;
 - South – Africa.

Education



➤ **New Master (M. Sc. Courses)** at the Faculty for Electronics, Communications and Information Technology, University “Politehnica” of Bucharest starting October 2009 and held in IMT (with access to experimental facilities).

- **Microsystems:**

- Intelligent sensors and microsystems;
- Microphysical characterization of structures;

- **Micro- and Nanoelectronics:**

- Advanced Technological Processes

- **Electronic Technology for Medical Applications:**

- Micro- and Nanotechnologies for Medical Applications



➤ **Postdoc program:** A Postdoc program in the areas of RF MEMS and MOEMS financed by FP7 MIMOMEMS project was launched in 2009 in IMT. Three postdocs were employed in IMT up to now.

➤ **Postdoc program Human Resource Development by Postdoctoral Research on Micro and Nanotechnologies**

➤ **Other educational actions within different projects:**

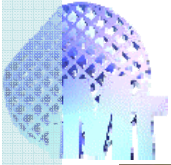
- **FP 6: ASSEMIC - Marie Curie Training Network (2004-2007), Contract No. MRTN-CT-2003-504826**, supervising the activity of PhD students and post doc.

- **2 Leonardo da Vinci - Life Long Learning projects, where IMT was partner:**

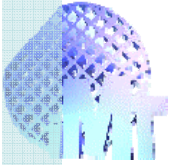
- *“Microteaching Project” (2004-2007), coordinated by RWTH Aachen University*

- *“Development of competences of educational staff by integrating operational tasks into measures of vocational training and further education” ComEd, (2008-2010) coordinated by BWAW Thüringen gGmbH, Germany*

- **Short courses regarding microtechnologies were developed and presented to SMEs.**



View from the **new clean room**



Reactive Ion Etching (RIE), SENTECH equipment

Working **gases**: CF₄, CHF₃, SF₆, O₂, 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, SiO₂, polySi, Si₃N₄, TiO₂, 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:

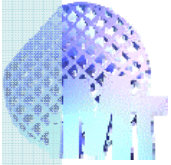
- DC sputtering
- e-beam

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)





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





Dip Pen Nanolithography system

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

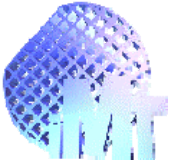
Enables deposition of tracks of various materials (polymers, sol-gel precursors, nanopowder, complex molecules, quantum dots) with a thickness down to **30 nm.**



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

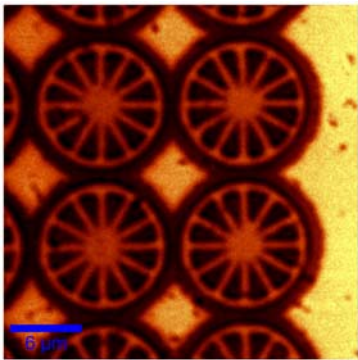


Operating Modes:

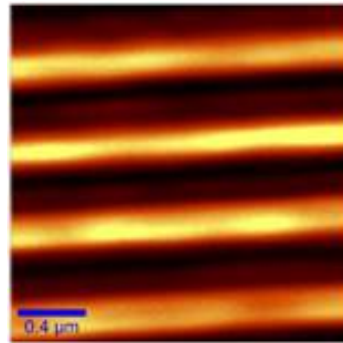
Near-field microscopy: transmission, reflection, collection, fluorescence

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

Atomic Force Microscopy contact and AC-Mode



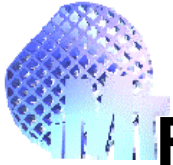
Confocal image of round structure 30X30 μm scanning area



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 .



Field Emission Gun Scanning Electron Microscope (FEG-SEM) *Nova NanoSEM 630* FEI Company,

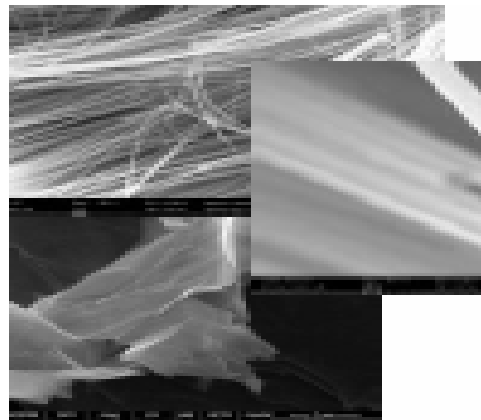
-ultra high resolution in the nanoscale range, for a variety of applications that involve sample characterization, analysis for S/TEM sample preparation

Research

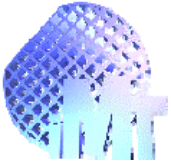
- Materials Qualification
- Surface morphology inspection
- Nanometrology
- Device Characterization

Main current cooperation

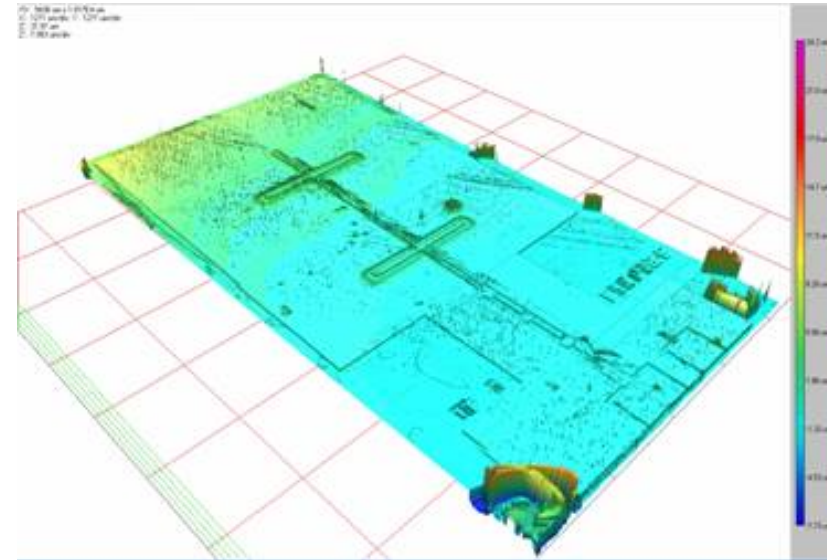
- *INFN Rome*
- *FORTH Heraklion*
- *Univ. Salerno*
- *Univ. Kyoto*



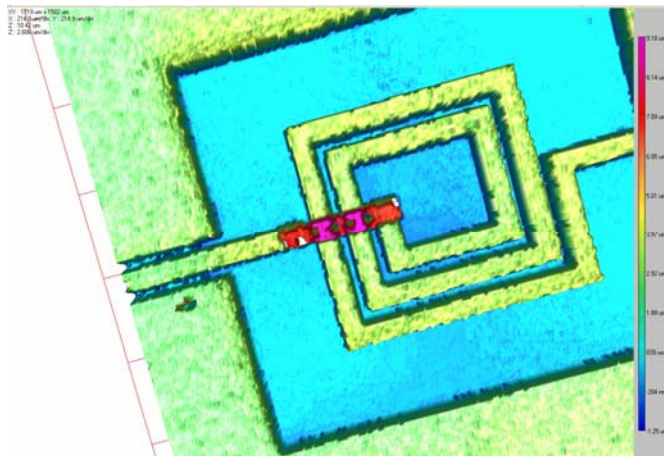
CNT and graphene



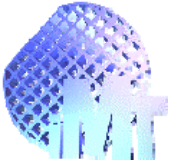
White Light Interferometer (WLI) - *Photomap 3D Standard 2006* (FOGALE NANOTECH);



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



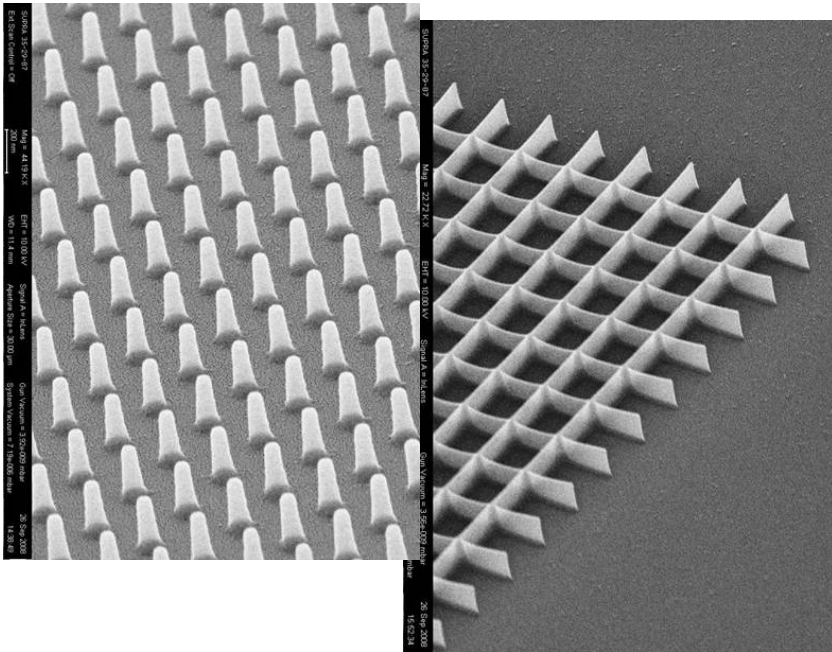
Detail of a silicon micromachined filter



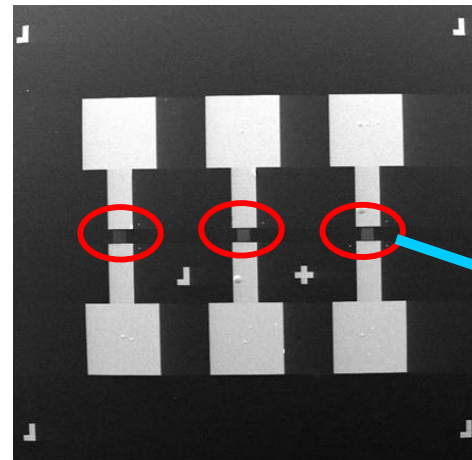
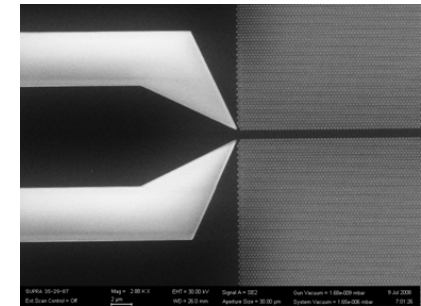
NANOSCALE LAB

High aspect ratio (12:1) structures in PMMA

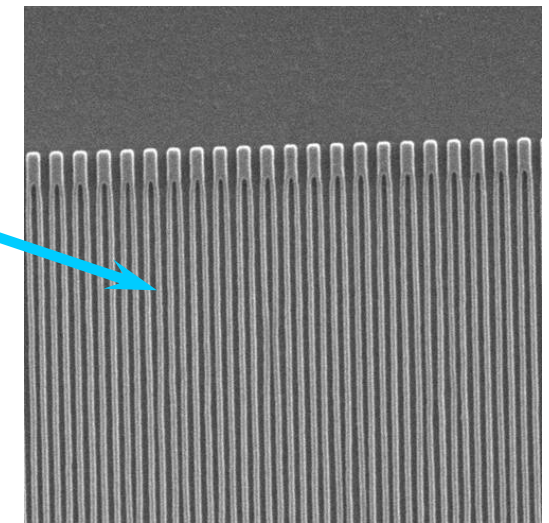
Diffractive Optical Element (DOE) for photonics applications



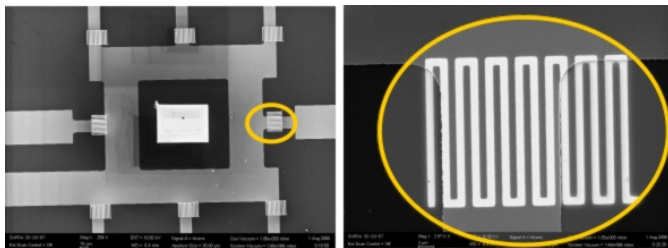
Photonic crystals in PMMA on silicon for near IR applications



SEM MAG: 61 x
HV: 29.60 kV
VAC: HiVac
DET: SE Detector
DATE: 05/20/07
Device: VG2920673RO
1 mm
Vega ©Tescan
Digital Microscopy Imaging

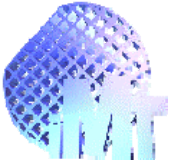


SEM MAG: 25.92 kx
HV: 29.60 kV
VAC: HiVac
DET: SE Detector
DATE: 05/20/07
Device: VG2920673RO
2 μm
Vega ©Tescan
Digital Microscopy Imaging

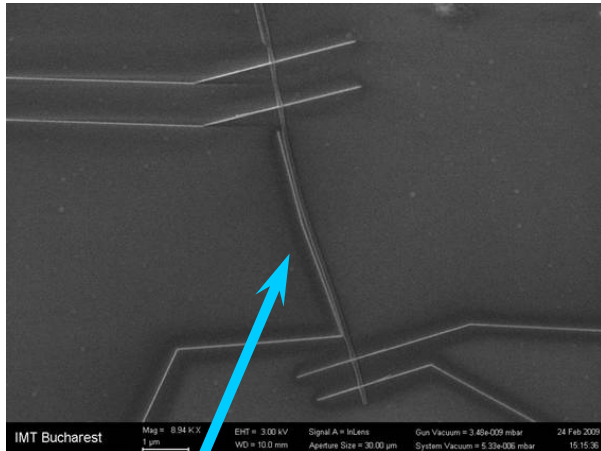


Mix-and-match lithography for biomedical applications: optical lithography (left), combined with EBL (right)

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

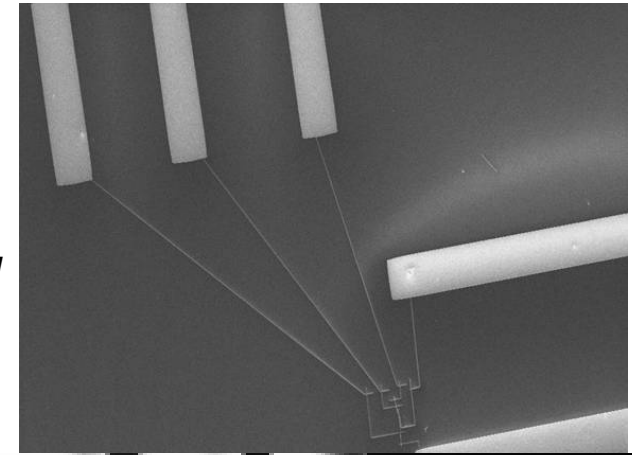


NANOSCALE LAB



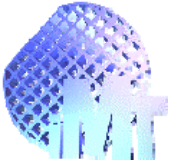
Polymer nanowire electrically contacted using EBID
(Coopertaion IMT Bucharest – UCL)

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



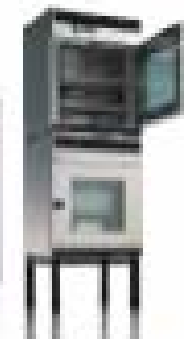
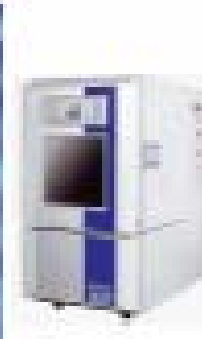
- Nanolithography with sub 20 nm resolution;
- Three-dimensional nanostructures;
- CNT based interconnections for next-generation integrated circuits
- CNT based nanodevices
- SAW devices with nanometer interdigitated electrodes;
- Optical devices, holograms, micro lenses, gratings
- Development of Nanodevices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

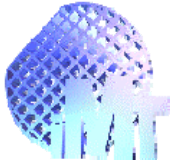
Contact Person: Phys. Adrain Dinescu



Reliability Tests

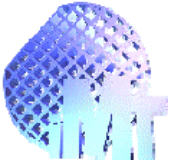
- **Semiconductor Characterization System (DC) with Wafer Probing Station - 4200SCS/C/-**
- **various modules-** (Keithley Instruments, USA)
- **Mobile Thermal Airstream System - ThermoStream TP04300A-8C3-11** (Temptronic, USA)
- **Damp heat Climatic chamber** (Angelantoni, Italy)
- **Electrodynamic vibration system with thermal and electrical tests**
- **TV 55240/LS** (TIRA, Germany)
- **Thermal shock chamber - TSE-11-A** (Espec Europe, Germany)
- **Universal Ovens with electrical testing - UFB 400** (Mettler, Germany)
- **Highly Accelerated Stress Test Chamber - temperature, humidity, pressure, polarization - EHS-211M** (Espec Europe, Germany)
- **Free Fall Shock Machine - 0707-20** (MRAD, USA)





Modelling and Simulation Tools

- **COVENTOR 2009** (modules: Architect; FlowMM; MemHenry; MemPackage; Designer; Analyzer Std. ; MemOptics)
 - **MATLAB 7:** Optimization Toolbox; Extended Symbolic Math Toolbox; Partial Differential Equation Toolbox; Genetic Algorithm and Direct Search Toolbox; Statistics Toolbox; Neural Network Toolbox; Curve Fitting Toolbox; Spline Toolbox; Signal Processing Toolbox; Image Processing Toolbox; Simulink
 - **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
-
- ▶ **Computer aided design and simulation for passive and active micro-phonic components using Opti-FDTD6.0 and OptiBP**
 - ▶ **Microwave electromagnetic simulations using IE3D and Fidelity from ZELAND software**



IMT-MINAFAB full info - www.imt.ro/MINAFAB/

IMT-Bucharest - Brochure for scientific-technological services - [www.imt.ro/brosura imt bucuresti 2009.pdf](http://www.imt.ro/brosura_imt_bucuresti_2009.pdf)

Quick list of capabilities and tools - <http://www.imt.ro/MINAFAB/description.htm>

Thank you for your attention!