L1: Laboratory of Nanotechnology

Affiliated to the Romanian Academy (of Sciences)

Mission: Nanomaterials and nanostructures: design, modelling/ simulation and technological experiments.

Main areas of expertise: The research activities carried on in Laboratory of Nanotechnology can be divided into four areas which are: Functional nanomaterials, Nanobiosystems, Nanophotonics and Microelectromechanical Systems.

The main research direction in Functional nanomaterials area is study of nanostructured silicon based or composite materials, from preparation to surface functionalisation and integration in complex systems.

The Nanobiosystems area focuses on utilizing the various technologies developed in nanofabrication and MEMS to study and solve biological issues. Biomolecular patterns in microarrays, integration of sensing elements onto biochips for study of bioreactions, and implantation of active device elements in cells to study cellular biochemistry are examples of research activities being carried out.

The Nanophotonics area is represented by two directions, porous silicon with emission in the visible spectrum for microparticles visualisation in vitro and for optical biosensors and metallic nanoparticles (Au, Ag) on silicon substrates for SERS/ SEIRS applications.

The Bio-Micro- Electromechanical Systems (Bio-MEMS) area focuses on the design, modelling/simulation and fabrication of new complex devices on silicon for applications in many interdisciplinary areas; recently new results in biochips, or microfluidic systems as laboratory-on-a-chip with applications in biomedicine and environmental monitoring as well as in the development of new fuel cell devices as clean energy sources were obtained.

International participation

- "Drug delivery system based on microreservoirs array with porous silicon resorbable membrane caps", Romanian-Greece International Cooperation, Decembrie 2005-2008;
- "Nanostructured silicon for optical biosensors", Romanian-Italian International Cooperation, 2006-2008;
- "Suface engineering techniques to investigate inorganic-biomolecular interfaces", research project in the frame of NoE-NANOFUN-POLY; "European FP6 Network: Nanostructured and Functional Polymer-Based Materials and Nano-composites;
- A "system-in-a-microfluidic package" approach for focused diagnostic DNA microchips-DNASIP, MNT-ERA, 2008-2010.

Research team has multidisciplinary expertise and is composed by 4 senior researchers (with background in physics, chemistry), 5 PhD students (with background in physics, chemistry, computers and specializations in pharmacy and bio-chemistry).

Award: Marioara Avram, Irina Kleps si Anca Angelescu,Gold medail to the EUREKA 2008- The Belgian and International Trade Fair for Technological Innovation, Brussels, *Procedure of realization a spin valve magnetotransistor*.

Laboratory Head
Dr. Irina Kleps
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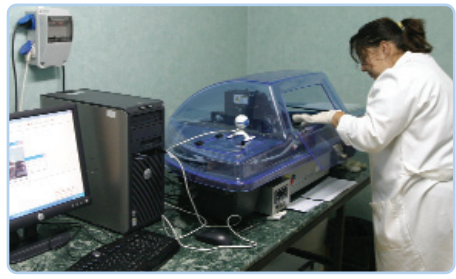
EXPERIMENTAL LABORATORIES

On the next pages one may find information about the main equipments available in IMT.

In some cases an equipment, or a group of equipments are located in a special room and they are managed by a certain RTD laboratory, part of the organizational structure. In such a case we are speaking about an "experimental laboratory". The person in charge is usually a researcher, with his/her own research interest and motivation. However, apart from the usual cooperation between labs, the "experimental laboratories" should be accessible (directly or indirectly) to any researcher from IMT. Moreover, the "services" provided by these "experimental labs" should be also available outside IMT.



Monica Simion (monica.simion@imt.ro) working on the Micro Plotter to prepare a protein C reactive microarray slide

A typical situation is that of experimental labs created by some research laboratories in the characterization area (class 100,000), which has a special support infrastructure for providing demanding operating conditions of delicate equipments. All looks like a "joint venture" of individual research laboratories in an special area provided by the institute.

Mihaela Miu (mihaela.miu@imt.ro) investigating the electrocalalytic activity of the gold nanoparticle electrode array with SECM

Another important concept is that of an interdisciplinary group working as a "research centre", due to interactions of two or more research labs. The MIMOMES Centre of Excellence financed by EU provides such an example: it is the result of combined activities of RF MEMS and Photonics laboratories, respectively. The second case corresponds to the so-called "Centre for nanotechnologies", grouping other laboratories. This centre, also mentioned below, is functioning "under the aegis" of the Romanian Academy (this is a "purely scientific" interaction, without administrative or financial consequences).

EXPERIMENTAL LABORATORIES

A. Experimental laboratories in the characterization area (class 10,000 to 100,000).

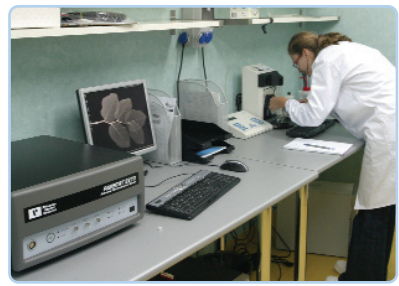
Centre of Nanotechnologies an interdisciplinary group, involving a few RTD laboratories, was developed as follows:
Laboratory of nanotechnology (L1) created the following experimental laboratories:

Experimental laboratory for "Microarrays", or NanoBioLab, with the following main equipments:
- Microarray Scanner - GeneTAC UC4 (Genomic Solutions Ltd., UK)
- Micro Plotter - Omni Grid (Genomic Solutions Ltd., United Kingdom);
Project: Integrated Research Network Devoted to Nanobiotechnology for Health (Romanian Nanomedicine Network) RO-NANOMED (2005-2008).

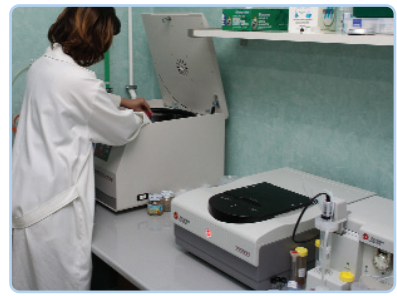
Experimental laboratory for surface spectroscopy, with:
- **Electrochemical Impedance Spectrometer PARSTAT 2273** (Princeton Applied Research);
- **Scanning electrochemical microscope** (SECM);

Experimental laboratory for X-Rays diffraction, with:
- **X-ray Thin film Diffraction System** (triple axis rotating anode) - SmartLab - 9kW rotating anode, in-plane arm (Rigaku Corporation Japan);

Experimental laboratory for nanoparticles, with:
- **DelsaNano Zeta Potential and Submicron Particle Size Analyzer** - Allegra X-22 (The Beckman Coulter);
- Fluorescence spectrometer;
- Centrifuge - Allegra X-22 (Beckman Coulter);



Teodora Ignat (teodora.ignat@imt.ro) is working for gold electrode cleaning by cyclic voltammetry



Adina Bragaru (adina.bragaru@imt.ro) working for nanoparticle centrifugation and characterization

Mihai Danila (mihai.danila@imt.ro) introducing in the sample in the XRD for investigation the Pt nanocystallite orientation and size

L6: Microphysical characterization laboratory

Mission: Research and development in the field of characterization methods for materials and processes at micro and nanometric scale. Application of high resolution surface investigation techniques to solve engineering problems at these scales, especially investigation of correlations between technological process parameters-structure and structure-properties order to obtain materials for specific applications etc. The lab is the first one in Romania developing research and providing services for nanolithography, using EBL technique.

Main areas of expertise: Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM), Electron Beam Lithography for nanoscale devices, Optical Microscopy, Electrical characterization of materials and devices.

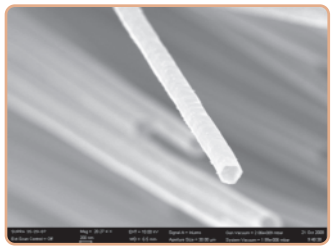
Research Team: 3 senior researchers - background in Physics and Electronic Engineering an early stage researcher (Physics) and 2 MS students in Electronics.

Specific facilities:
- Scanning Probe Microscope (AFM, STM, EFM, KPM etc) - NTEGRA (NT-MDT).
- SEM: TESCAN VEGA II LMU-General Purpose Scanning Electron Microscope
- FEI Nova NanoSEM 630- Ultra High resolution Field Emission Gun Scanning Electron Microscope
- EBL - Raith Elphy Plus - pattern generator for Electron Beam Lithography.
- Raith e_Line - Electron beam lithography dedicated equipments.

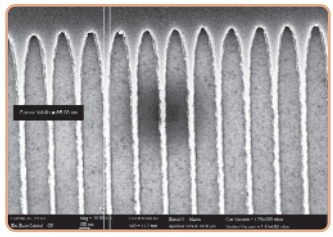
International projects: **FP7 *CATHERINE*** "Carbon nAnotube Technology for High-speed nExt-geneRation nano-InterconNEcts"- STREP- FET proactive (2008-2010), ***Coordinator*** **Consorzio Sapienza Innovazione, Italy.** ***Partners:*** CNIS-Italy, TUD-Netherlands, CIRIMAT-France, USL-Italy, ULV-Lativia, IMT- Bucharest- Romania, FOI- Sweden, INFN-Italy, PHILIPS-Netherlands, Smoltech- Sweden.
IMT-Bucharest: contact person Phys. Adrian Dinescu- (adrian.dinescu@imt.ro)

CATHERINE project aims to provide a new unconventional concept for local and chip-level interconnects that will bridge ICT beyond the limits of CMOS technology.

The main goals of CATHERINE are:
- To develop an innovative cost-effective and reliable technological solution for high-performance next-generation nanointerconnects.
- To develop proof-of-concept nanointerconnects to assess and verify the new proposed solution.



High resolution CNTs imaging



Electric contacts at nanoscale- 65 nm width lines

Laboratory Head:
Phys. Adrian Dinescu
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EXPERIMENTAL LABORATORIES

Laboratory for nanoscale structuring and characterization (L6), created the following experimental labs:

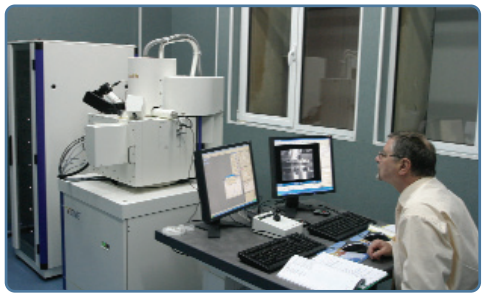
Experimental laboratory for Electron Beam Lithography (EBL)/ Scanning electron Microscopy Laboratory (SEM), or NanoScaleLab;

- Scanning Electron Microscope SEM - Vega II LMU and Pattern Generator - PG Elphy Plus (TESCAN s.r.o and RAITH GmbH); - A Nanolithography Equipment composed of a SEM and EBL pattern generater which can investigate different samples at nanometric range (SEM resolution 3 nm, smallest geometry line in the range of 30-50 nm) is used for different samples investigations, for direct writing in PMMA of nanometric configurations and for students training in microscopy and nanolitography.

Experimental laboratory for e-line nano engineering work station;

- Electron beam lithography and nanoengineering workstation - e_Line (RAITH GmbH);

EBL - Direct writing Electron Beam nanoLithography is an ideal tool for nanotechnology research and is a versatile equipment with specific requirements for interdisciplinary research: options for nanomanipulations; EBID-Electron Beam Induced Deposition; EBIE-Electron Beam Induced Deposition;



nanoengineering workstation e_Line (RAITH)

Applications: • Nanolithography with under 20 nm resolution; • 3D 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;

FEG-SEM - Nova NanoSEM 630

Experimental laboratory for SEM/FEG (Field Emission Gun);

- **Field Emission Gun Scanning Electron Microscope/FEG-SEM-Nova NanoSEM 630 (FEI)**; The FEI Nova NanoSEM 630 is a high-quality nanoscale research tools for a variety of applications that involve sample characterization, analysis, prototyping, and S/TEM sample preparation. It features a superior low voltage resolution and high surface sensitivity imaging in the range of Ultra high Resolution Field Emission Scanning Electron Microscopes (UhR FE-SEM).

EXPERIMENTAL LABORATORIES

Experimental laboratory for SPM;

Scanning Probe Microscope SPM-NTEGRA

- **Scanning Probe Microscope** (AFM, STM, EFM, KPM etc)**-NTEGRA (NT-MDT)**;

Applications: • Surface morphology inspection; • Quantitative measurement of surface features at 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; • Morphological studies of biological and biocompatible materials;

Nano Indenter G200

- **Nano Indenter G200, Agilent Instruments (former MTS Nano-Instruments)**: Instrument for characterizing the mechanical properties of materials at the nano and micro scales, mainly by performing depth-sensing indentation experiments, but also by other modes of testing such as scratch testing etc. Accuracy and repeatability of the measurements are guaranteed by implemented methods according to ISO 14577.

Technical specifications: • Displacement resolution: 0.01 nm; • Load resolution: 50 nN; • Maximum load: 500 mN; • Max indentation depth: 500 μm; • Position accuracy: 1 μm;

Applications: Studies of mechanical properties of materials on small scales or near surfaces with high spatial resolution. The measurable properties include hardness, elastic modulus, nano-scratch critical loads, stress-strain data. The provided information is useful for developing and/or optimizing application specific materials and processes and also could be used as input data for running simulations of the material behavior by finite-element analysis.

L9- Laboratory for Molecular Nanotechnology

- Interdisciplinary laboratory established in 2009, relying on state of the art equipment (belonging to various labs).

- 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)

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** available in various IMT-Bucharest laboratories.

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**.

Head of Laboratory: Dr. Radu Popa (radu.popa@imt.ro)

OTHER EXPERIMENTAL LABORATORIES

MIMOMEMS - EU Excellence Centre (grouping the RF MEMS lab and the Photonics lab) have been created the following experimental laboratories:

- **Scanning Near-field Optical Microscope** (SNOM) - Witec alpha 300S (WITEC GmbH, Germany);
- **High Resolution Raman Spectrometery** - LabRAM HR 800 (HORRIBA Jobin Yvon);
- **White Light Interferometer (WLI)** - Photomap 3D Standard 2006 (FOGALE NANOTECH, FRANCE);

Scanning Near-field Optical Microscope (SNOM)

- **Witec alpha 300S (WITEC GmbH, Germany)**; It allows the optical characterization of various samples (nanostructures, biological samples, polymers) with a resolution of 50-90 nm in visible spectral range with the possibility of extension in the infrared spectral range.

Working in the collection or photon scanning tunneling microscope (PSTM) mode the alpha 300S SNOM allows the imaging of propagating optical field in various metalic and dielectric waveguides providing a powerful method to caracterize and investigate nanophotonics and nanoplasmonic structures and devices.

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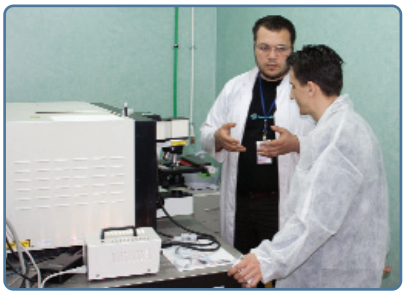
High Resolution Raman Spectrometery

- **LabRAM HR 800 (HORRIBA Jobin Yvon)**;

Application for the analysis of solids, liquids and solutions:

- chemical identification, characterization of molecular structures;
- to determine the composition and phase (crystalline/amorphous) of composites materials;



- environmental stress on a sample and crystal quality and composition of alloy semiconductors; • 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), self assembled molecule (SAM) on functionalized substrate and other.

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EXPERIMENTAL LABORATORIES

"On wafer" microwave characterization up to 110 GHz (MIMOMEMS and "Capacities" program SIMMCA)

• Recently in the microwave laboratory the existing 65 GHz set-up for on wafer S parameter measurements (the Anritsu VNA and the Karl Suss probe station) has been upgraded to 110 GHz.
• A frequency generator up to 110 GHz (from Agilent Technologies) was acquired
• A spectrum analyzer up to 110 GHz (from Anritsu) was acquired

Upgraded to 110GHz set-up for "on wafer" S parameters measurements (top), Generator up to 110 GHz and the Spectrum Analyzer up to 110 GHz (bottom).

Applications:
• Characterization of microwave and milimeter wave circuits in the 0.5 – 110 GHz frequency range;
• "On wafer" S parameters measurements for microwave and millimeter wave devices and circuits;
• Characterization of micowave devices based on carbon nanotubes (CNT) and graphene;

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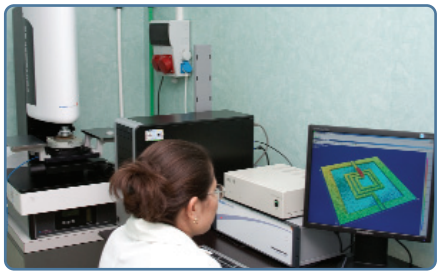
E-mail: **alexandru.muller@imt.ro; mircea.dragoman@imt.ro**

White Light Interferometer (WLI) - Photomap 3D Standard 2006 (FOGALE NANOTECH, FRANCE) ("Capacities" program (SIMMCA));

Optical profiler allows measuring the surface topography of different materials (such as metals, plastics, semiconductors, biological materials etc). The photo below presents the WLI equipment (Photomap 3D, microscope, electronic module) and as a results of the characterization a 3D topography of a MEMS device.



White Light Interferometer (WLI), Photomap 3D Standard 2006 (FOGALE NANOTECH, France);

Applications: • Characterization of residual stress for different thin film deposition layers;
• Measurements for thickness of transparent layers (plastics, glasses or varnish) with known refraction indices;
• Conceived not only for statistical surface roughness measurements but also for high precision measurement of mechanical or chemical micromachining;
• Can be used for MEMS dynamic measurements;

Contact person: Dr. Alina Cismaru. E-mail: alina.cismaru@imt.ro;