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 silicon based nanostructured or composite materials, from preparation to surface functionalisation and integration in complex systems like sensors with improved detection limit or miniaturised fuel cell for clean renewable energy. 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 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 inter disciplinary areas, and recently results in biochips, or microfluidic systems as laboratory-on-a-chip were obtained with applications in biomedicine and environmental monitoring.

• **INTERNATIONAL PARTICIPATION**

• Partner in international projects: FP6-NoE: Nanostructured and Functional Polymer-Based Materials and Nano composites (NANOFUN-POLY) (2004-2008);

• "Drug delivery system based on microreservoirs array with porous silicon resorbable membrane caps", Romanian-Greece International Cooperation, December 2005-2007;

• "Nanostructured silicon for optical biosensors", Romanian-Italian Cooperation, 2005-2008;

• **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).

• **INSTRUMENTS AND EQUIPMENT** Computers for simulation; instruments and software for electrical characterisation of nanostructures; Keithley model 6487-picoammeter/ voltage source- 2004; VOLTALAB10 and Trace Master 5; AMMT: Wet etching system with software for 4' silicon wafers, potentiostat MC, silicon etching power supply; Fluorescence set-up for LEICA DMLM with images acquisition and measurement system. We have full access to IMT technological and characterisation facilities.

• **AWARDS:** Marioara Avram, Anca Angelescu, Irina Kleps, Gold medal to the International Salon of Inventions and New techniques from Geneve: Un procédé de réalisation d`un magnetotransistor á valve de spin April 2007;
Marioara Avram, Anca Angelescu, Irina Kleps, Silver medal to the INVENTIKA 2007 : Technology for spin valve transistor fabrication, Bucharest, October 2007

Team from left to right: Florea Craciunoiu; Adina Bragaru; Mihaela Miu;Monica Simion; Irina Kleps; Marioara Avram; Teodora Ignat; Mihai Danila; Andrei Avram;

Laboratory Head - Dr. Irina Kleps irina.kleps@imt.ro)

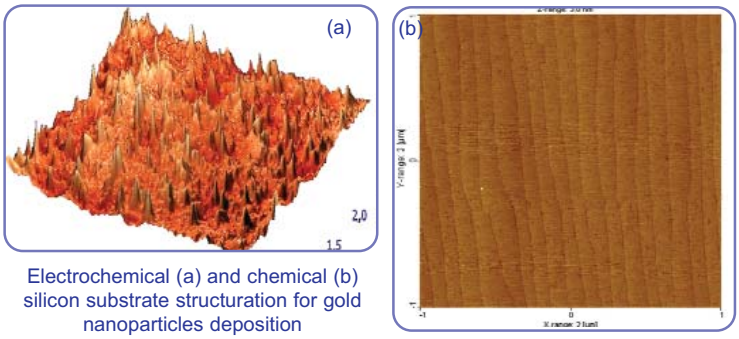
She obtained her MSc. in Chemistry Engineering, in 1973, and the PhD in chemistry in 1998 at Politehnica University of Bucharest. Her competence domains are: nanomaterials, nanostructures, nanotechnology, new materials and technological development for MEMS/NEMS, bio-medical devices, protein microarray.

Dr. Kleps participated in several European projects: INCO-COPERNICUS SBLED (1998-2001), EMERGE (guest experiments at IMM, Germany) Metallics (2000-2003), PHANTOMS (Network of Excellence on Nanoelectronics) (2001-2004), NANOFUN-POLY (2004-2008). She was expert for project evaluation in the EC-FP5 (IST; Growth, Improving programmes), FP6 (NMP and Marie Curie) and MATNANTECH, CEEX and PN2 national programs. Other activities: Golden medal (2001 and 2007) Salon International des Inventions-Geneve; Chapter Electrochemical Nanoelectrodes, in Encyclopedia of Nanoscience and Nanotechnology; Co-editor of the Nanoscience and Nanoengineering (2002), Advances in Micro and NanoEngineering (2004), Convergence of Micro-nano-Biotehnologies (2006), Progress in nanoscience and nanotechnologies (2007), Series in Micro and Nanoengineering, (Romanian Academy). More than 150 papers published in international journals/conferences, 90 technical reports, and 5 Romanian patents.

STUDY OF SILICON-PROTEIN TYPE BIOHYBRIDE NANOSTRUCTURED SURFACES WITH APPLICATIONS IN BIO(NANO)SENZING

This project contains multidisciplinary experimental researches which lead to changes of the silicon surface chemistry, in view to obtain biomolecule microdevice interface.

The aim is the investigation and optimization of protein immobilization methods on silicon substrate in order to obtain structures with properties in bionanodetection. For protein immobilization, we are proposing the preparation of Au/Si nanostructured surfaces (Au/Si nanodots; Au/Si thin layers; Au/nanostructured Si thin layers).



Electrochemical (a) and chemical (b) silicon substrate structuration for gold nanoparticles deposition

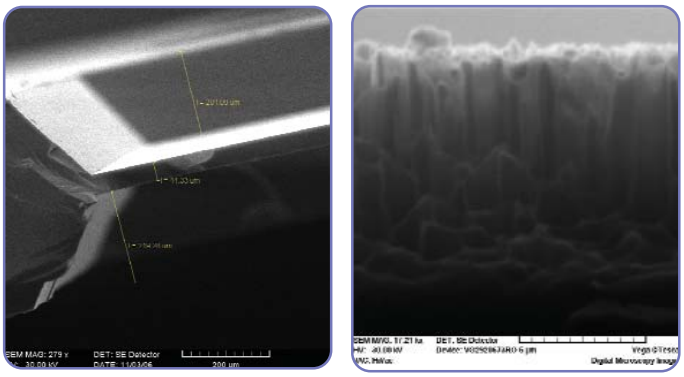
The main objectives of the project are:
(i) acheiving the self assembly monolayer (SAM) on Si substrate. (ii) development of a method to control the molecule attacment (imobilisation). (iii) using of SERS substrates for bio(nano) detection.

Financed by the National University Research Council (2007- 2010); Coordinator: Dr. Irina Kleps, irina.kleps@imt.ro

STUDY OF MEMBRANE - ELECTRO-CATALYST NANOCOMPOSITE ASSEMBLIES ON SILICON FOR FUEL CELL APPLICATION

The aim of the project is design and fabrication of some new membrane/electro-catalyst architectures using micro-nanotechnologies for miniaturized fuel cells development, with potential for applications in some priority domains, like: portable electronics, military industry, implantable medical devices industry.

The main objectives of the project are: (i) A nanocomposite membrane will be obtained by proton polymer impregnation (Nafion) of porous silicon (PS) layers. (ii) different physico chemical methods will be studied for PS pore walls grafting to behave like a good proton conductive material. (iii) will be deposited metallic nanocatalyst.


Porous silicon membrane on Si-n+ substrate which has proton exchange function after proper chemical grafting

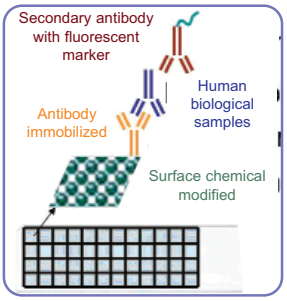
This project is offering important information to obtain an integrated device, with longer autonomy in the functioning than classical batteries, and also the relatively simple supply with the liquid fuel.

Financed by the National University Research Council (2007- 2010)
Coordinator: IMT Bucharest, Dr. Mihaela Miu, mihaela.miu@imt.ro

MULTI ALERGEN BIOCHIP REALISED BY MICROARRAY TECHNOLOGY - MAMA

The aim of this project is to make biochips using Microarray Technology (TMA) for allergies diagnosing. The research area is a cutting edge one, and is absolutely new in Romania.

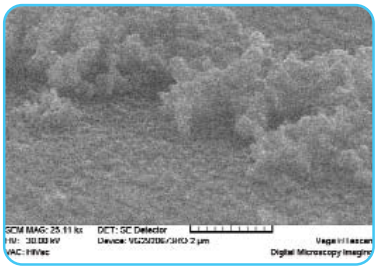
The detailed objectives of this project are: 1. a biochip for quick diagnosis of the allergies by specific immunoglobulin (Ig E) immobilisation on technological micro fabricated surfaces; and 2) a Biohybrid Interfaces platform (PIB) for the electrical/ electrochemical reactions investigation at the interface between the substrate and biological material. The advantages of the proposed biochip are: the increase of the analyzed data number in real time; a good specificity and sensitivity and the absence of the false positive and false negative reactions; quick diagnosis. The allergens immobilization by covalent bonding on the biochip surface is faster and more stable and it needs a smaller incubation time. The bio-chips are designed and made in such way to allow the simultaneous analysis of a great number of allergen proteins on a small surface, giving the possibility to identify the specific IgEs by a unique determination using small serum volumes (nano-grams).

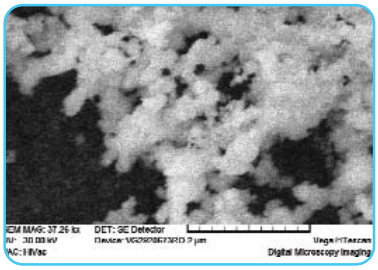


Biochip schematic representation

PNCDI Program (2007- 2010). Coordinator: IMT Bucharest, Dr. Irina Kleps, Irina.kleps@imt.ro
Partners: "Carol Davila" University of Medicine and Pharmacy- Bucharest; Bucharest University, Faculty of Chemistry; Telemedica SA and DDS Diagnostic SRL;

MINIATURISED POWER SOURCE FOR PORTABLE ELECTRONICS REALISED BY 3D ASSEMBLING OF COMPLEX HYBRID MICRO- AND NANOSYSTEMS - MINASEP





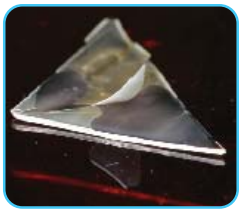
Pt nanoparticles chemical deposited from H_2PtCl_6 precursor solution on Si nanostructured surface to work as electro-catalyst

This project is making a connection between the researches from micro- and nanotechnologies and the portable electronic devices requirements and it is envied the development of a new power sources as a hybrid micro- and nanosystems assembly.

The theme represents an important research subject in the recent years at international level, and in our country is for the first time when it is proposed the development of a 3D assembly technology in order to miniaturise the actual fuel cell systems and also to simplify and to optimise their working performances. In this scope, the following components are proposed:
1. originally structures - membrane / electro-catalyst nanosystems, with new catalyst geometries, which will lead to improvement of: (i) the low temperature methanol / ethanol electro-oxidation activity of the anode; (ii) the oxygen reduction activity of cathode and increase its selectivity.
2. complex microfluidic system, on silicon (Si) and polydimethylsiloxane (PDMS), microsystem for fuel / water management (supply/storage).

PNCDI Program (2007- 2010)
Coordinator: IMT Bucharest, Dr. Mihaela Miu, mihaela.miu@imt.ro
Partners: University of Bucharest, Faculty of Physics and Petroleum- Gas University of Ploiesti;

NANOSTRUCTURES FOR ACTIVE DRUG DELIVERY WITH THERAPEUTICAL POTENTIAL - NANOCONTER



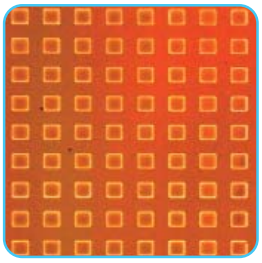
Porous silicon membrane obtained stripped off the silicon surface

The aim of the project is to investigate the potential of some nanostructures (NS) for active drug delivery with therapeutical potential.

Nano-porous silicon (PS) functionalized with antitumoural substances are prepared. Two processes were experimented: (i) porous silicon membrane and (ii) nanostructured PS microparticle fabrication using a controled process with a photolotographic mask. The as-prepared micro-particles functionalised with different substances, such as chondroitin sulfate, lactoferrin and N-butyldeoxynojirimycin are tested at the Intitute of Biochemistry.

CEEX Project (2006- 2009). Coordinator: Institute of Biochemistry, Bucharest, Dr. Mihaela Trif, trif@bichim.ro
Partners: IOB; INSB; University of Bucharest Faculty of Biology; IMT- Bucharest; ICECHIM;

SILICON BASED MULTIFUNCTIONAL NANOPARTICLES FOR CANCER THERAPY - NANOSIC



Nanostructured Si microparticles (50 μmx 50 μm) on Si before separation

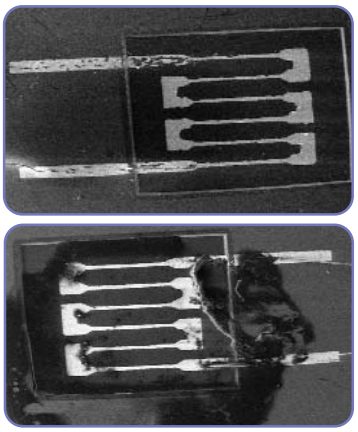
This project, offers a new approach in the domain of nanobiotechnologies and nanomedicine, joining the existing concerns in these domains, at national and international level. The proposed systems consists from superparamagnetic microparticules of nanostructured silicon carriering iron oxides (Super Paramagnetic Iron Oxide Nanosized Particles -SPION) and drugs integrated in an organic matrix in order to facilitate the controlled delivery process direct to specific sites (normal or pathologic) from the human body or animals. In this project the research is oriented towards two innovative systems with applications in cancer therapy, as follows: (1)The first system consists from Si based multifunctional microparticles which contains the active substance (chemotherapeutic agent) covered by a polymeric-gel membrane with the aim to hinder the active substance diffusion during vectorisation; this system could be injected and vectorised by the EM external field, in this way avoiding the surgical operation; (2) The second system is a sandwich structure that consists of three layers: two polymeric membranes and between them, a Si microparticle layer; this system is like a plaster with extern application, allowing a transdermic diffusion and vectorisation of active substances direct to the affected organ. It was proposed fabrication of smart microparticles which combines in a synergetic way the incorporation of the active substance, vectorisation, and imagistic function by magnetic resonance (RMI).

PNCDI Program (2007- 2010). Coordinator: IMT Bucharest, Dr. Irina Kleps, irina.kleps@imt.ro
Partners: INSB Bucharest and IOB Bucharest;

DEVELOPMENT OF NEW COMPLEX TOOLS FOR PROTECTING HEALTH: LABORATORY-ON-A-CHIP SYSTEM (TOOPROLAB)

The aim of this project is to design and fabricate two devices for health applications, using microfluidics and microarray probes technologies: (i) CELL-Lab-on-a-chip for in-vitro drug testing and (ii) DNA - Lab-on-a-chip for genetic diagnosis.

The first device is dedicated to both optical and bioelectrochemical analyses of biological materials - different type of cells - subjected to external stimuli. The test structure contains an electrical circuit integrated in a microfluidic network, and nanoelectrodes microfabricated on the reactor base for the enhacement of sensitivity in electrochemical processes detection. The second device is designed to act as a micro-PCR (microreactor, resistor for thermal cycling, and temperature sensor) in conection with an microfluidic electrophoretic system for DNA separation (microchannel and microelectrodes). For a good heat dissipation, the heating resistor was made inside the reservoir. The back of the reservoir was porosified in order to assure the thermal isolation to reduce the environmental effect.

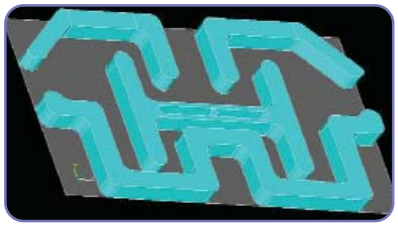


SEM image of the final device: a) before using; b) after using for PCR reaction

CEEX Project (2005-2007).
Coordinator: IMT-Bucharest, Dr. Irina Kleps Irina.kleps@imt.ro;
Partners: InterNET SRL; DEXTER Com SRL; Faculty of Medicine Faculty of Biology, METAV SA; Faculty of Chemistry, Faculty of Physics, INCDFLPR, LABOR&SOFT, ROMES SA;

INTEGRATED MICROFLUIDIC SYSTEM FOR ADVANCED IN VITRO BIOCHEMICAL ANALYSIS FOR DIAGNOSTIC AND TREATMENT IN MEDICAL APPLICATIONS - MICRO-DIAG

The biodynamic analysis microsystem consists of two main modules. The first module is the microfluidic system consisting of the microgearing wheels and microchannels (for the determination of molecular transport coefficients in biological fluids), microchannels with high-doped walls and nanoelectrodes (for the detection, sorting and differentiating of suspended bioparticles) and heaters. The second module is the detection and measuring system.



The selector for low pressure (SI logical gate).

The central element is the piston which is moving under the applied pressures of the piston. The devices entries are located to the right and the left related to the piston.The SI logical gate functionality is presented in next table 1.

The image selector for high pressure (SAU logical gate). The central element is the piston which is moving under the applied pressures at the entry. The devices entries are located to the right and the left related to the piston. The SAU logical gate functionality is presented in table 2.

table1

Imput 1	Imput 2	Output
0	0	0
0	1	0
1	0	0
1	1	1

table2

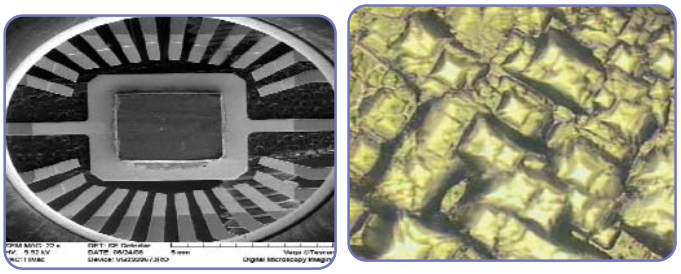
Imput 1	Imput 2	Output
0	0	0
0	1	1
1	0	1
1	1	1

Coordinator: IMT-Bucharest, Dr. Marioara Avram, marioara.avram@imt.ro;
Partners: "Politehnica" University of Bucharest, "Transilvania" University of Brasov, ROMES SA, Genetic Lab SRL, Bucharest;

SENSOR DIODES DIODE ON DIAMOND AND SIC WITH APPLICATIONS IN CEMENT INDUSTRY - DIASENZOR

In the frame of this project the following technological steps for SiC and diamond syntesis and processing were analyzed:
(i) methods for crystals growth; (ii) methods for epitaxial layers growth; (iii) doping techniques; (iv) oxidizing techniques; (v) plating techniques for ohmic contacts/ Schottky barriers techniques;
(vi) etching techniques.

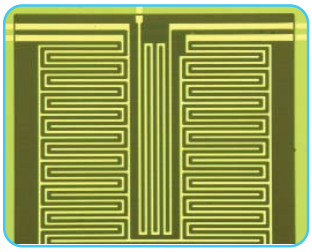
The fabrication process of the diamond and SiC devices were implemented on the silicon processing facilities.



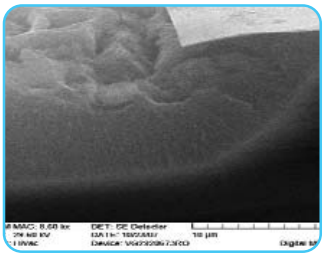
CrAu deposited on diamond

PNCDI Program (2007- 2010). Coordinator: Politehnica University of Bucharest, Prof. Dr. Brezeanu Gheorghe;
Partners: IMT Bucharest, Dr. Marioara Avram, marioara.avram@imt.ro; METAV SA, CEPROCEM, CARPAT-CEMENT;

FABRICATION TECHNOLOGY OF NANOSTRUCTURED SILICON MEMBRANES WITH APPLICATIONS IN SENSORS AND BIOMEDICAL DEVICES



Plan view of the humidity sensor chip

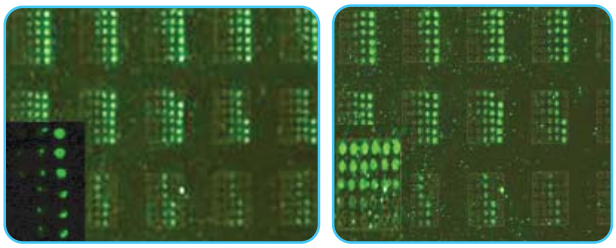


Cross- section detail of the sensitive PS layers

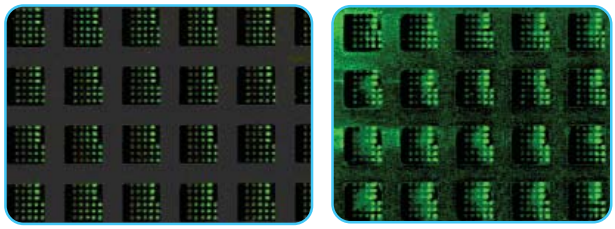
One of the project objectives is to establish a fabrication technology for a silicon based capacitive humidity sensor using porous silicon nanostructurated membrane as sensitive layer. The process flow and corresponding photolithographic masks have been designed to integrate on the same chip both the interdigitated recording microelectrodes, the heating resistor to achieve rapidly desorption and temperature sensor for its monitoring. In order to obtain a better fiability of the sensor, to increase its response, two types of metals for desorbtion resistivities and for the temperature sensor, gold and platinum, have been used; the interdigitated electrodes will be made of gold. The test structure were characterised after each experimental process. The advantage of using Au for all the electrical circuits is the simplicity of process flow, a single process being enough to obtain all the features.

MINASIST-Program (2006-2007). Coordinator: IMT-Bucharest, Dr. Mihaela Miu, mihaela.miu@imt.ro;

SILICON AND GLASS SURFACE FUNCTIONALIZATION IN ORDER TO OBTAIN BIOCHIPS FOR PRINTING MICROARRAY



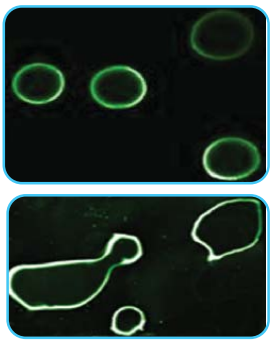
Silicon slides functionalized with poly-L-lysine: a) after spotting and b) washed after 60 minutes



Silicon skides functionalized with APTS: a) after spotting and b) after washing for 60 minutes

The microarray technology allows the simultaneous investigation of several parameters in one single experiment. It is important to choose a proper chemistry of the substrate for spot uniformity, signal intensity and low evaporation rate of the biological material.

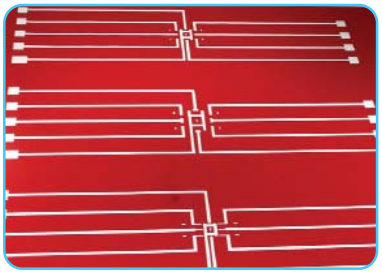
BSA (Bovine Serum Albumin) fluorescent marked was immobilised on porous silicon functionalization with APTS (3 - aminopropyltriethoxysilane) using OmniGrid Micro printer machine controled by Genomic Solutions software.



Microarray Scaner images of APTS on deoxidized PS, (a) before washing in water and (b), after washing

MINASIST-Program (2006-2007). Coordinator: IMT-Bucharest, Phys. Monica Simion monica.simion@imt.ro;

THE INTERACTION BETWEEN HUMAN AND BACTERIAL CELLS WITH NANOSTRUCTURED SURFACES; STRATEGIES FOR ACHIEVEMENT "INTELLIGENT" BIOSURFACES, NANOINT



Electrodes microfabricated on SiO_2/Si substrate

The aim of this project is to control the interaction between the human and bacterial cells with nanostructurated surfaces. A device with submicrons interdigitates electrodes, made in a 100 nm gold film was developed. In the area of the microscale interdigitates electrodes the gold layer is about 40-50 nm in order to make SPR (Surface Plasmon Resonance) measurements it was developed.

The areas of the interdigitates electrodes are accessible by the circuits and metal pads which assure the interface with the measurement devices. The interested elements are 8 areas of the interdigitates electrodes (1 micrometer, 0.5 micrometer and 0.2 micrometer), made in a 50 nm gold layer, deposited on silicon

Program CEEX (2006-2008).
Coordinator: International Centre of Biodynamics, Bucharest, Dr. Eugen Gheorghiu, egheorghiu@biodyn.ro;
Contact person for IMT Bucharest: Phys. Florea Craciunoiu, florea.craciunoiu@imt.ro;

SERVICE OFFER:

(i) MICRO- AND NANOSTRUCTURED SILICON FABRICATION

• Fabrication of porous silicon (PS) layers (2-500 μm thickness) on n^+ or p^+ Si, 4inch diameter.
• Fabrication of meso- and macroporous silicon membrane (thickness 500 μm) on n^+ or p^+ Si, 4inch diameter.
Contact person: Mihaela Miu (mihaela.miu@imt.ro)

(ii) MICROARRAY BIOCHIPS

Microarray technology includes applications for functional genomics, pharmacogenomics, SNP genotyping, proteomics and cell signaling. We have expertise for microarray manufacturing, processing, surface chemistry, detection reagents, scanning and analysis. Specific preparation protocols and probe design workflow can be developed in function of requested application. We are working using the new facilities, nano-plotter and microarray scanner from **NanoBioLab**.
Contact person: Monica Simion (monica.simion@imt.ro)

CONSULTANCE ACTIVITIES:

• Nanostructures/nanomaterials integration into the microsystems structures;
• Technological processes on silicon;
• Luminescent properties of the porous silicon;
• nanostructured bioactive silicon for biomedical applications; porous silicon biocompatibility;
• functionalization of silicon surface;
• microsystems for drug delivery;
• Magnetic sensors and magnetic nanostructurated nanomaterials;
• CVD processes using liquid precursors;
• Project evaluation for national/ international competitions.

L1: Participation to NoE's in FP6

NANOSTRUCTURED AND FUNCTIONAL POLYMER-BASED MATERIALS AND NANOCOMPOSITES

Acronym: NANOFUN-POLY

Coordinator: Prof. José M. Kenny; Italian Consortium for Science and Technology of Materials (INSTM);
E-mail: kenny@unipg.it; Fax: 39 0744 492925, Tel: 39 0744 492939 / 39 3292332268

Contact person for IMT Bucharest: **Dr. Irina Kleps (irina.kleps@imt.ro)**;

IMT collaboration proposal for nanobiomaterials internal projects **in the frame of NANOFUNPOLY**:
Surface engineering techniques to investigate inorganic-biomolecular interfaces

Information on mobility

(i) **Teodora Ignat**, was effectuated a working stage in **INASMET, San Sebastian, Spain, *on SERS characterization*** of the Au/Si samples realised in IMT Bucharest, September 6th- October 20th, 2007;
(ii) Participation in the **3rd International Symposium on Nanostructured and functional polymer-based materials and Nanocomposites** (Corfu, Greece, May 13-15, 2007) organised by **NANOFUN-Poly** project with the following papers:
- **Protein attachment via polymers in microarray technology**, Monica Simion, Lavinia Ruta, Teodora Ignat, Irina Kleps, Dana Stan, Carmen Mihailescu, Codruta Paraschivescu, Florin Craciunoiu, Mihaela Miu;
- **Investigation of nanocrystalline s-layers, mesoporous silicon matrix for sensors and biomedical applications**, Irina Kleps, Teodora Ignat, Mihaela Miu, Monica Simion, Adrian Dinescu, Dan Dascalu, Gabriela Teodosiu Popescu, Madalin Enache, Lucia Dumitru;
- **AFM method for investigation of the piezoelectric properties of the polymeric thin films**, Florea Craciunoiu, Mihaela Miu, Raluca Gavrila, Adrian Dinescu, Elena Hamciuc;
(iii) Participation in the **1st Workshop - Polymers in Nanotechnology,** September 27th - 28th , 2007, Salerno, Italy, **"Silicon surface functionalization for biomolecules attachment"**, Adina Bragaru, Mihaela Miu, Monica Simion, Teodora Ignat, Irina Kleps, Andrei Avram, Veronica Schiopu, Florin Craciunoiu.