L1: Laboratory of Nanotechnology

Affiliated to the Romanian Academy (of Sciences)

- Mission
- Main areas of expertise
- International participation
- Research Team
- Awards

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*.

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

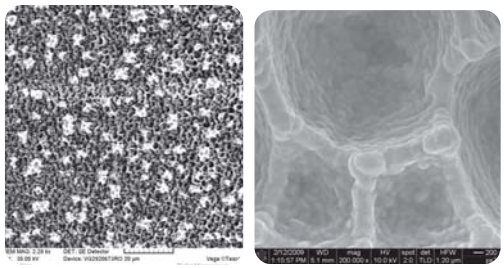
Laboratory Head - Dr. Irina Kleps (irina.kleps@imt.ro)

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.

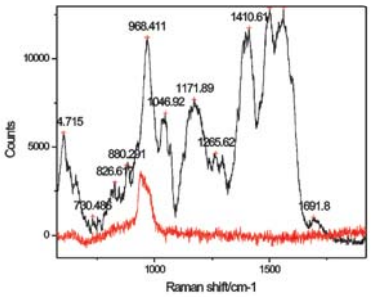
Dr. Kleps participated in several European projects: INCO-COPERNICUS SBLED (1998-2001), EMERGE (guest experiments at IMM, Germany) Metallics (2000-2003), PHANTOMS (Network of Excellence on Nanoelectronics) (2001-2004), NANOFUN-POLY (2004-2008). She was involved as expert for project evaluation in the EC-FP5 (IST; Growth, Improving programmes), FP6, FP7 (NMP and Marie Curie) and MATNANTECH, CEEX and PN2 national programs. Other activities: Golden medal (2001, 2007, 2008) 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 6 Romanian patents. Dr. Kleps IMT representative in ETP-Nanomedicine and expert for nanotechnology risk assessment at national level.

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

The aim of this project is to realise and characterise Si(111)- and Si(100) - protein interfaces, for application in biomolecule detection. We have demonstrated that different morphologies of porous silicon (PS) as-prepared or coated with gold nanoparticles have an important role in biomolecule detection, due to its large internal surface combined with specific optical properties, being in the same time sensing element/support for immobilization of sensing biomolecules as well as transducer for biochemical interactions. Thus macroporous silicon constitutes an appropriate substrate for very sensitive SERS biosensors. RAMAN signal of 11-mercaptoundecanoic acid was investigated on Au/macroporous silicon.



SEM images of different Au/PS substrate for SERS



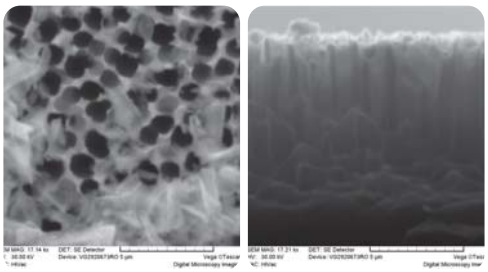
SERS spectrum - 785nm - of 11-MUA on PVD-gold substrate/porous silicon (black) and PVD- gold substrate/silicon (red) obtained by immersion of the gold substrates in 2mM 11-MUA aqueous solution for 24h.

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

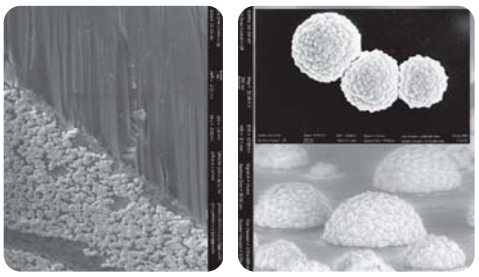
STUDY OF MEMBRANE - ELECTRO-CATALYST NANOCOMPOSITE ASSEMBLIES ON SILICON FOR FUEL CELL APPLICATION

The project "Study of membrane - electro-catalyst nanocomposite assemblies on silicon for fuel cell application" scope is fabrication of a nanostructurated silicon based electrocatalytic proton exchange membrane.

The silicon substrate has been subjected to an electrochemical porosification process for nanostructuration and after a chemical functionalisation of internal surface to achieve the appropriate chemical bondings, a further impregnation with Nafion protonic solution led to specific characteristics for ionic and electronic conduction (1). The enhancement of platinum catalytic function has been obtained by deposition of a metallic nanoparticle array conform to the figure 2.



1. SEM images of PS + DMF + Nafion

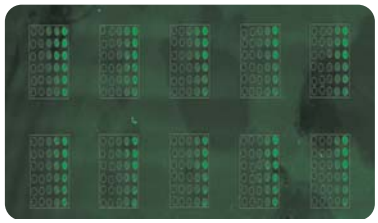


2. The XRD – SAXS analyses confirm the (111) predominant texture of particles representing an advantage for envisaged applications in fuel cell complex devices.

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 work is to test more types of compatible materials with the biological material. Three types of substrates: glass, silicon and porous silicon were tested. All these materials were chemically modified in order to obtain active groups for covalent or physical bonding with the biological material. These modifications are made to uniform the surfaces hydrophobicity, to decrease the noise produced by LASER excitation and to improve the spots morphology. Taking in consideration the good results obtained in the case of porous silicon treated with dehydrogenated water and knowing the optimal printing parameters, the next step was to use the protein in different concentrations in order to improve the right dilution necessarry to print the allergens, to determin the minimum limit of the detection and the scanning parameters. Then, the BSA (Bovin Serum Albumin) protein fluorescent marked with Cy3 in PBS (Phosphate buffered saline solution) was printed. It was used ten serial dilutions of the BSA protein and the concentrations were between 2^{-9} and 1mg/ml. Every dilution was printed for 3 times and it were obtained 2 columns with 5 subarray on every columns. Every subarray have 6 columns and 5 lines and it were printed 2 dilutions on every line.



The design of an array printed with a protein using serial dilutions

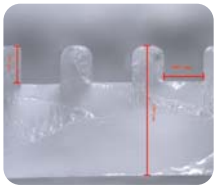
PNCDI Program (2007- 2010)
Coordinator: IMT Bucharest, Dr. Irina Kleps, Irina.kleps@imt.ro
Partners: "Carol Davila" University of Medicine and Pharmacy- Bucharest; Bucharest University, Faculty of Chemistry; Telemedica SA and DDS Diagnostic SRL;

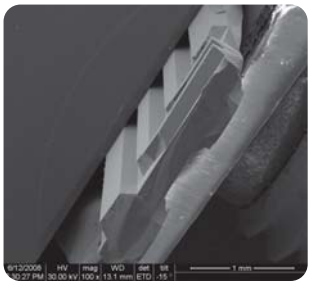
MINIATURISED POWER SOURCE FOR PORTABLE ELECTRONICS REALISED BY 3D ASSEMBLING OF COMPLEX HYBRID MICRO- AND NANOSYSTEMS (MINASEP)

Since the 1990s, the direct methanol fuel cell (DMFC) has gained importance mainly because of its potential for direct utilization of methanol, which is a low-cost, renewable liquid fuel, without the need for reforming; in addition, the operation takes place at ambient temperatures, with high energy density and lower ecologically harmless CO_2 emissions.

The project"Miniaturised power source for portable electronics realised by 3D assembling of complex hybrid micro- and nanosystems (MiNaSEP)" proposes the development of fabrication technology to achieve 3D device architectures at the micrometer-scale, to increase the total area of reactive surfaces per unit volume without increasing the footprint area. The standard design of fuel cell comprises an anode part, a cathode part and a proton exchange membrane sandwiched in between the anode and the cathode, usually built on 2D geometries and assembled into 3D shapes.

The scope of research is development of an integrated fuel cell hybrid system, as a 3D assembly, using specific processes from MEMS technology – miniaturised direct methanol fuel cell (micro-DMFC).



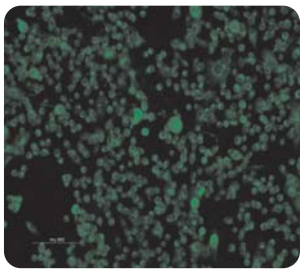


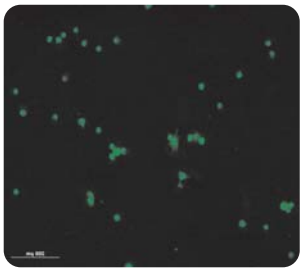
Test structures for microfluidic system: silicon and PDMS components

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)

We have developed new methods for nanostructured PS microparticle and protocols for their functionalised and impregnation with different substances, such as chondroitin sulfate, lactoferrin and N-butyldeoxynojirimycin for drug delivery applications. The microfabricated particles were have been tested in vitro at the Intitute of Biochemistry. Morphological changes and viability in cells attached to the devices were visualized by fluorescence microscopy, following NBD-C6 ceramide labeling. This dye is a specific marker for Golgi apparatus and the integrity of this compartment reflects the normal cell behaviour.Our preliminary biocompatibility experiments revealed that all the devices tested allowed the cell adhesion but cell viability are decreased compared to control.



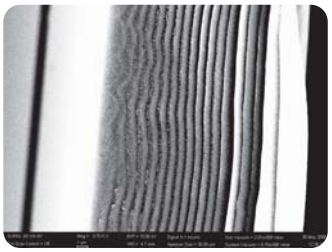


Mouse melanoma B16 F10 cells proliferation on different PS devices: A- control cells; B- PS-terapeutic substance.

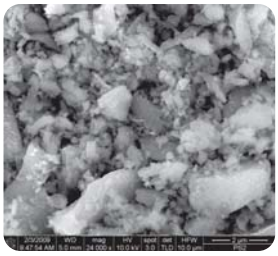
CEEX Project (2006- 2008)
Coordinator: Institute of Biochemistry, Bucharest, Dr. Mihaela Trif, trif@bichim.ro
Partners: IOB; INSB; University of Bucharest Faculty of Biology; IMT- Bucharest; ICECHIM;

SILICON BASED MULTIFUNCTIONAL NANOPARTICLES FOR CANCER THERAPY (NANOSIC)

The aim of this project is to optimise the experimental conditions for nanostructured Si particles fabrication, and to find the best methods for attaching on its surface cytotoxic molecules of therapeutic interest. Micro- and nanofabrication methods were experimented in order to prepare silicon microparticles with sizes between 2 and 10 microns on x/y/z axis with nanoporous structure (10-50 nm). It was demonstrated that PS multilayer structuration is a high productivity of method for microparticles fabrication. The alternance of ultrathin layers with different morphologies and corresponding pore diameters ranging from few nanometers to tens of nanometers determine a cleavage phenomenon when a simple ultrasonation treatment is applied. Smaller microparticles were obtained by ball milling treatment. Iron oxides nanoparticles of 50 nm on PS microparticle surface and smaller inside the pores were chemically deposited to assure imaging and targeting functions.



PS multilayers obtained on p+ Si

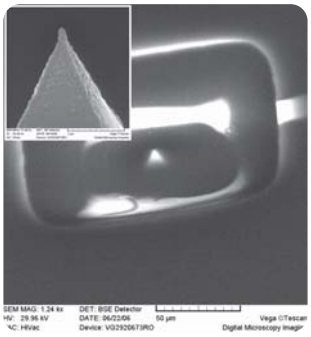


Microparticles with nanoporous structure lower than 8 μm

Gold, silver, and iron oxides were chemically or deposited by evaporation on porous silicon in order to assure biocompatibility, targeting, antimicrobial and terapeutic properties.

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

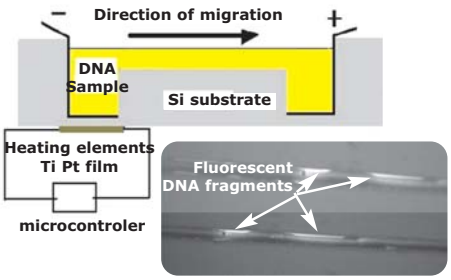
DEVELOPMENT OF NEW COMPLEX TOOLS FOR PROTECTING HEALTH: LABORATORY-ON-A-CHIP SYSTEM (TOOPROLAB)



SEM images of the NE elements on the bottom of reactor system and electrical recording of the neuron transmembranal current

The first objective of this project was the development of a new laboratory-on-a-chip (LOC) device for biomedical studies that consists on a microfluidic system coupled to microelectronic or optical transducers with nanometric features, commonly called biosensors. This device is a hybrid system with sensing element on silicon (Si) chip and microfluidic system on polydimethylsiloxane (PDMS) substrates, taking into account their particular advantages. Different types of nanoelectrode arrays were positioned in the reactor. The experimental structures have been tested for neuronal electrophysiological recording and it was demonstrated their capacity to measure one cell signal. Also, the silicon surface nanostructuration allowed us to perform optical measurements, PL and FL, which revealed the interaction appeared in biohybrid system (biological material / inorganic material). In this way, by bringing together the results from two sets of measurements, optical and electrical, recorded with the same chip, a better understanding of the cell behavior has been achieved. The recorded extracellular potential shows that: at the largest distance between cell and sensitive element is a capacitive coupling and a rectifying inward component appears at further approaching, leading finally to a resistive response.

The second objective of the project was the development of a new silicon micro-bio-chip for rapid testing of DNA material. This chip integrates two classical processes for DNA analysis: polymerase chain reaction – PCR – technique for fragments amplification and electrophoresis for separation of DNA fragments respectively.



Optical fluorescent images of DNA fragments separated along the channel by electrophoresis (straight channels).

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;

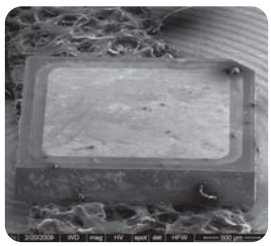
INTEGRATED MICROFLUIDIC SYSTEM FOR ADVANCED IN VITRO BIOCHEMICAL ANALYSIS FOR DIAGNOSTIC AND TREATMENT IN MEDICAL APPLICATIONS (MICRO-DIAG)

Micromixer (bottom)
Microsplitter (top)

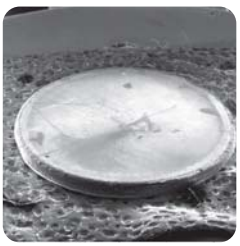
The microfluidic device incorporates a sampling, dispensing and delivering system for magnetic marked biomolecules or with intrinsic magnetic properties, and it consists of two main modules. The first module contains: a rotary viscosimeter, for viscosity measurements; microchannels with input and output reservoirs for fluid transport and a microfluidic platform that can trap, measure, manipulate and sort magnetic marked biomolecules in an array of magnetophoretic spin valves. The second module is the detection and measurement magnetoelectronic system consisting of a double Wheatstone bridge with four sensing GMR resistors and four reference shielded GMR resistors. This magnetic microsystem could detect the presence of bioparticles or microbeads. These microdevices enjoy the advantage of being compatible with silicon IC fabrication technology. It is possible to build an array of GMR sensing elements that can simultaneously tests multiple biological molecules. The originality consists of extracting information regarding molecular interactions and rheological properties of the biological non – Newtonian fluids from a single microsystem.

CEEX Project (2005- 2008); 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;

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



SiC sensor diode



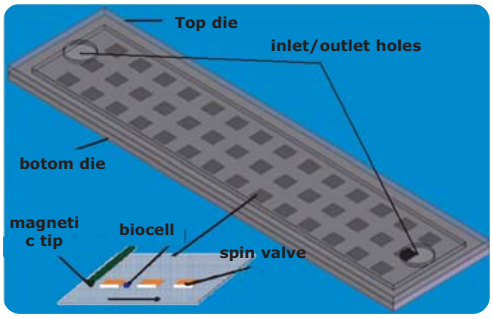
Diamond sensor diode

SiC and diamond are the most promising materials for power devices, because their dielectric breakdown field is ten times greater than that of silicon, they can be used at high temperatures, because they have a high thermal conductivity. The SiC and diamond devices reduce power loss and equipment size. We have developed the technology of fabrication sensors on SiC and diamond based on high power Schottky diodes. The fabrication process of the diamond and SiC devices were implemented on the silicon processing facilities.

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;

MICROFLUIDIC BIOCHIP FOR RHEOLOGICAL CHARACTERIZATION OF NON-NEWTONIAN BIOLOGICAL FLUIDS WITH APPLICATIONS IN MEDICAL DIAGNOSIS AND TREATMENT (MELANOCHIP)

Within this project, we want to create efficient and accurate analysis instruments necessary for medical diagnosis and development of new therapies for thrombosis and malignant diseases (basal cell carcinomas and malignant melanoma), pathologies in which modifications in the flow of biological fluids appear. The results obtained within the project have direct applicability in the medical area, in the detection of the pathogens implicated in thrombosis, malignant pathology, histopathological aspects and etiopathogeny data, as well as therapeutic decision. The biochip realized in this project will impose itself in clinical laboratory research by its importance and complexity of the delivered information for fast indication of the diagnosis and therapy to be followed.



The design of the microfluidic platform for magnetophoretic blood cells separation

PNII Project 12-094/2008; Coordinator: IMT-Bucharest,
Dr. Marioara Avram, marioara.avram@imt.ro;
Partners: "Politehnica" University of Bucharest, "Transilvania" University of Brasov, ICPE - CA; Universitary Hospital

MICRO- ELECTRO- MECHANICAL SYSTEM WITH APPLICATIONS IN RECONSTRUCTIVE MICRO-SURGERY OF PERIPHERAL NERVES - RECONECT

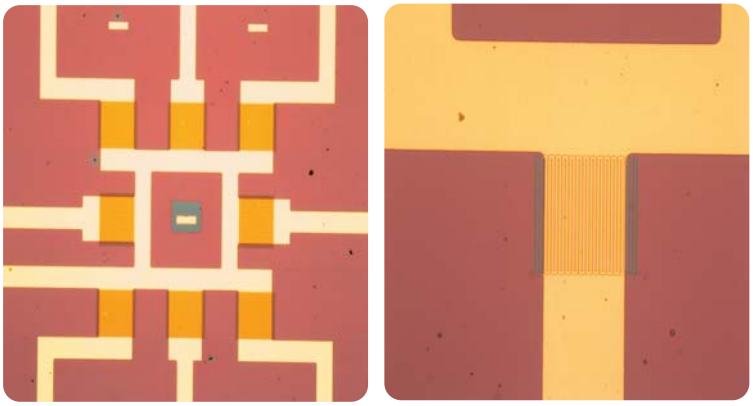
The proposed intelligent microsystem can be used to: immobilize the peripheral nerves inside microchannels; investigate the interactions in supramolecular systems; reveal some new interactions and solve the mechanisms through which these interactions can trigger the behavior of peripheral nerve fascicles (on the molecular level).

The microsystem is a combination between a microfluidic system and a microelectronic-bionic one. With the help of the microsystem realized during this project we will be able to conduct studies closer to the truth about the peripheral nerve and it's capacity of regeneration and reconstruction. Also, we will be able to study what is happening to the section heads of the nerve and the segment added to rebuild the nerve's continuity and we will be able to study the physiological function and it's physiopathology. Thus, we will be able to predict, by comparison with the modern state of the art reconstruction techniques, the future of reconstructive microsurgery for any of these components. In this project we want to develop a technique able to identify the exact position of each type of nervous fiber at the nerve's head. In order to determine the fiber nerve types we will use the variation of the rest potential, the variation of the activity potential, the variation of the velocity of the nervous impulse and also the electrical capacity of the membrane, the transmembrane currents and the ion channel currents. The rest potential can be directly measured with the help of microelectrodes, or indirectly by using ionized fluorescent substances (for example the tiocianate).

PNII Project 72-160/2008; Coordinator: IMT-Bucharest, Dr. Marioara Avram, marioara.avram@imt.ro;
Partners: "Politehnica" University of Bucharest, "Transilvania" University of Brasov, Universitary Hospital**.**

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

The aim of this project is to control the interaction between the human and bacterial cells with nanostructurated surfaces. In order to investigate the cell culture, it was used two different methods (SPR- Surface Plasmon Resonance and impedance measurements), and it was developed a device with submicrons interdigitates electrodes, made in a 100 nm gold film. In the area of the microscale interdigitates electrodes the gold layer is about 40-50 nm in order to make SPR measurements. The areas of the interdigitates electrodes are accessible by the circuits and metal pads in order to make the interface with the measurements devices. The interested elements are 8 areas of the interdigitates electrodes, made in a 50 nm gold layer, deposited on silicon so that there are three size digitates: 1 micrometer, 0.5 micrometer and 0.2 micrometer.


"mix and match" lithography: EBL nanooelectrodes config on SiO_2/Si substrate (general view and detail)

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;

SERVICES OFFER AND CONSULTANCE ACTIVITIES:

(i) MICRO- AND NANOSTRUCTURED SILICON FABRICATION

• Fabrication of porous silicon (PS) layers (2-500 mm 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.
• Fabrication of Si nanostructured microparticles (2-10 μm with pore/fibrils diameters of 10-50 nm);
• Fabrication of PS multilayered structures with various thicknesses;
• Fabrication of Si nanowires;

Florea Craciunoiu (florea.craciunoiu@imt.ro)

(ii) MICROARRAY BIOCHIPS:

Development of technologies/devices (microarrays, biosensors) for biological material investigation and detection (proteins, DNA, enzymes) on various substrates (silicon, glass, polymers).
• Fundamental research for study of biomelecular recognition reaction;
• Development of applications for medical diagnosis;
• Controlled deposition of biologic material;
• DNA and protein microarrays fabrication according to the user specifications.
• Nanostrutured support surfaces fabrication for microarray chips.
• Chemical surface functionalisation for biological samples immobilisation (DNA, protein, cells);
• Microarray microsystem analysis by fluorescence spectroscopy.

Contact person: Monica Simion (monica.simion@imt.ro)

(iii) ELECTRICAL/ELECTROCHEMICAL CHARACTERISATION AND APPLICATION DEVELOPMENT

Material characterization; biosensors and electro-chemical sensors development; bio-systems and bio-surfaces analysis.
• Microelectronics: development of new processes and materials with improved electrical properties;
• Energy: development of new fuel cell devices as clean energy sources; development of solar cells with improved parameters;
• Development of electrochemical immunosensor devices for clinical diagnostics;
• Detection of compounds/toxins/pathogens for water, food, environmental quality control;
• Biomedical field: implant biocompatibility studies;
• Fundamental studies of physico-chemical phenomena at bio-hybrid interfaces.
Contact person: Dr. Mihaela Miu

(iv) NANOPARTICLE CHARACTERISATION

Zeta Potential and Submicron Particle Size Analysis

Contact person: Chem. Teodora Ignat (teodora.ignat@imt.ro)

(v) X-RAY DIFFRACTION CHARACTERISATION

• Investigation of crystal structure (HR RSM, HR RC);
• film thickness, density, roughness;
• characterization of the ultra thin film (XRD);
• particle/ pore size analysis (reflection SAXS, transmission SAXS);
• phase identification, crystal structure (powder/thin film/poly/ mono/ crystall, trace, small area/quantity);

Contact person: Phys. Mihai Danila (mihai.danila@imt.ro)

INSTRUMENTS AND EQUIPMENTS

Laboratory of Nanotechnology is in charge with the NanoBioLab (Protein Microarrays) equipped with Plotter microarray (GeneMachines OmniGrid Micro) and Scanner microarray (GeneTAC UC4);

In 2008 Laboratory of Nanotechnology has set up other Experimental Laboratories and new equipments were acquisitioned:

(i) Laboratory for Surface Spectroscopy equipped with Electrochemical Impedance Spectrometer PARSTAT 2273–Princeton Applied Research; Scanning Electrochemical Microscop (SECM), VOLTALAB10 and Trace Master 5;

(ii) Laboratory for x-ray diffraction equipped with Rigaku SmartLab X-ray thin film difraction system;

(iii) Laboratory for Nanoparticles equipped with DelsaNano Zeta Potential and Submicron Particle Size Analyzer and Fluorescence Spectrometer.

Other available facilities are:
- AMMT wet etching system with software for 4” silicon wafers, potentiostat MC and etching power supply;
- Fluorescence set-up for LEICA DMLM with images acquisition and measurement system; computers for simulation; instruments and software for electrical characterisation of nanostructures.

Moreover, we have full access to IMT technological and characterisation facilities.