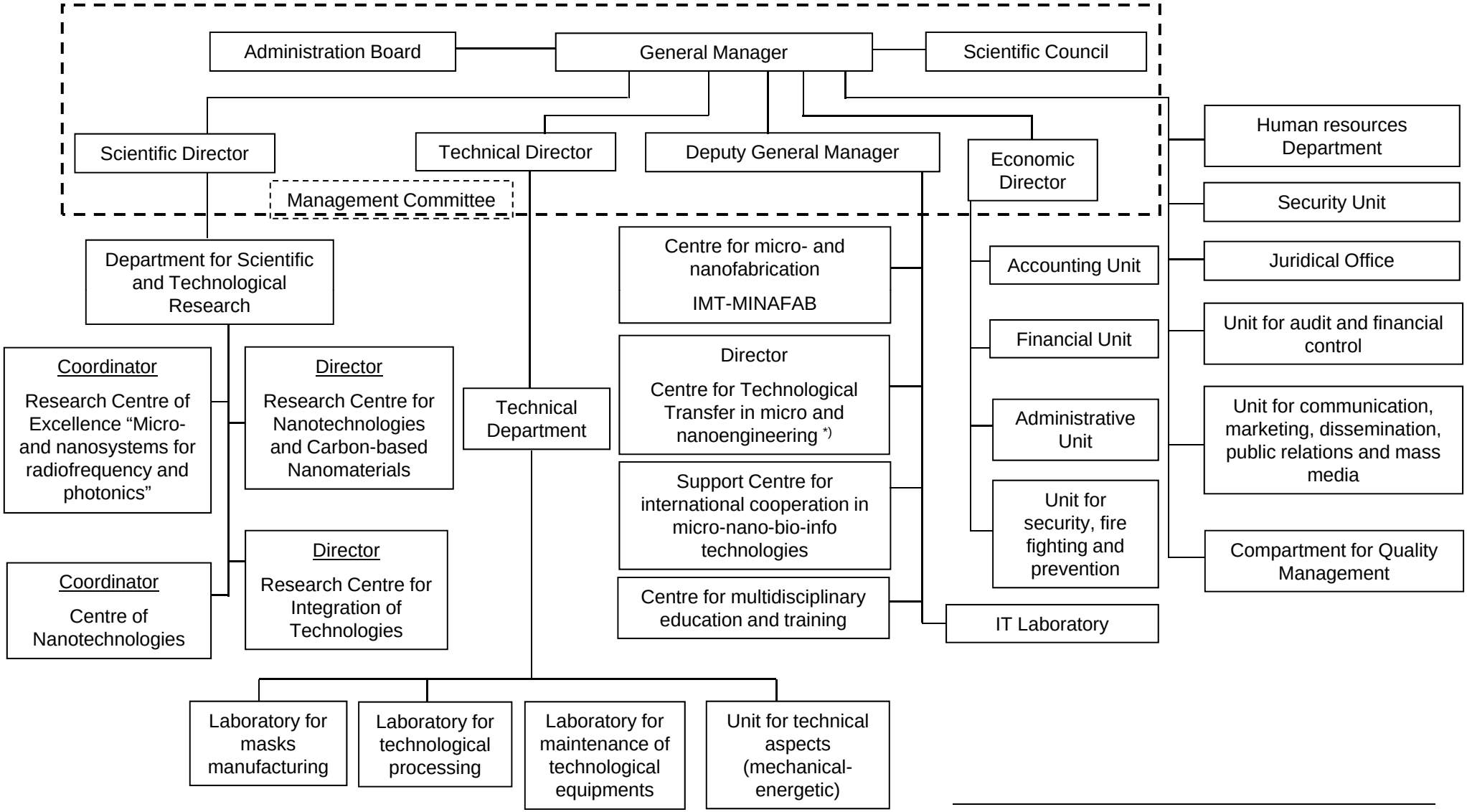
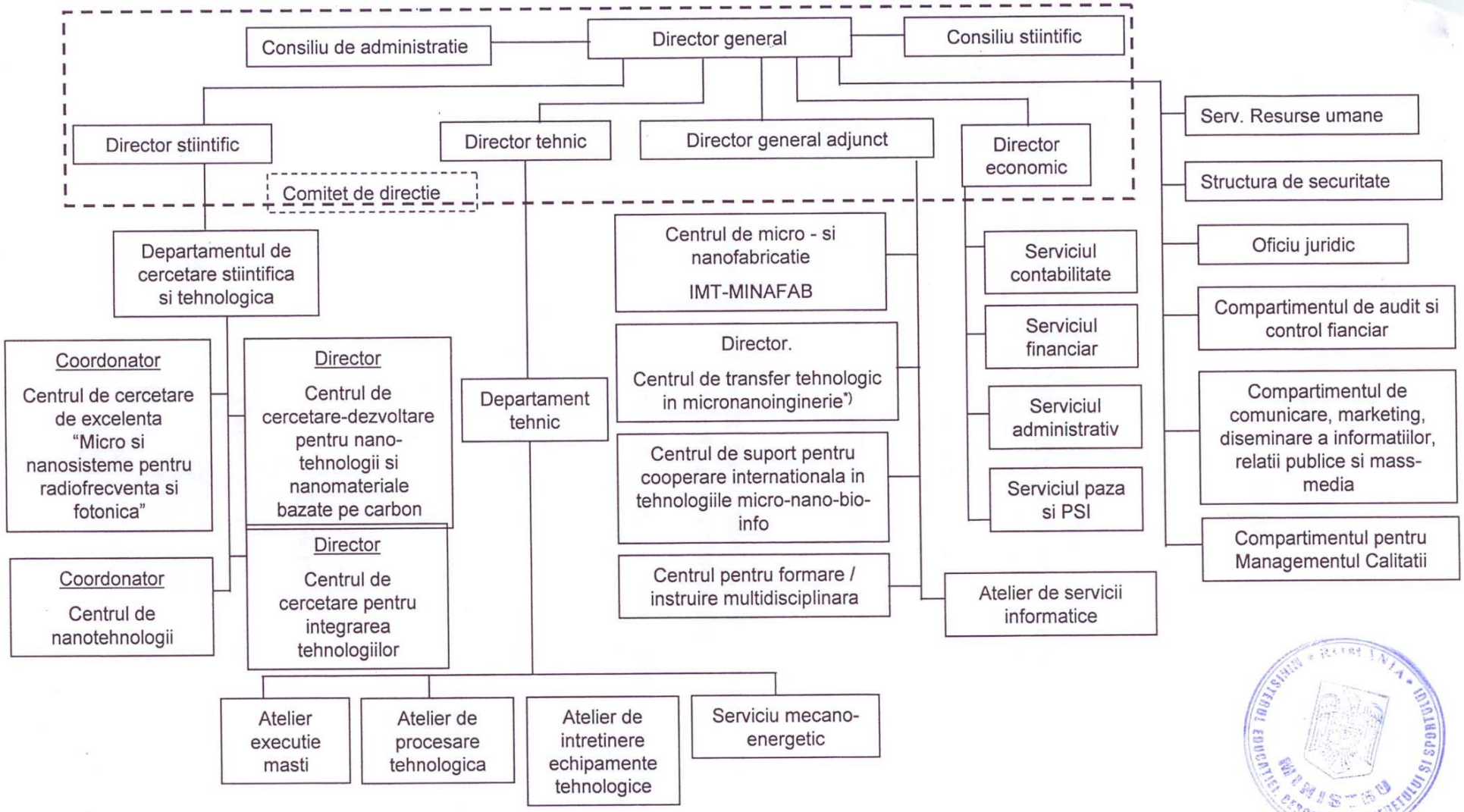
**Administrative structure diagram of the**

**National Institute for R&D Microtechnologies (IMT-Bucharest)**




*) Subunit accredited as the Centre for Technological Transfer in microengineering (CTT-Baneasa)




**Anexă la**
**Ordinul MECTS nr** 5736 / 26.11.2010

*) Subunitate acreditata sub denumirea de Centru de Transfer Tehnologic in microinginerie (CTT-Baneasa)

# 2.2 General Activity Report of IMT

## 2.2 General activity report of the institute

The **National Institute for Research and Development in Microtechnologies –IMT Bucharest** was set up by a Decision of the Romanian Government (HG 1318/1996), exactly 15 years ago.

**The activity domain of the institute** (named below just IMT) is reiterated in another Decision of the Romanian Government (No. 998, from 2nd of August, 2006). IMT performs scientific research and technological development in **micro and nanotechnologies**. The spectrum of activities is very broad, from fundamental to industrial research, also including small-scale production, education etc. The activity domain is detailed elsewhere[1].

**Brief history**. The present national institute continues the activity of the *Institute of Microtechnology* (IMT), created in July 1993 in order to exploit the resources of the local semiconductor industry (especially with "Microelectronica" S.A.) in the development of the new field of microtechnologies, or ***microsystem technologies*** (MST, in US or Japan - MEMS, i.e. Micro-Electro-Mechanical Systems). At that time, IMT was the only institute in Eastern Europe devoted to this field. MST was present in European programmes since 1994. Through the following Framework Programmes (FP) the field become "micro- and nanosystems", and it is complementary to "nanoelectronics" within the priority "Information and Communication Technologies" (ICT). The Strategic Agenda of the European Technological Platform ENIAC includes micro-nanosystems in nanoelectronics.

In 1996, IMT merged with ICCE (a research institute for semiconductor electronics, created in 1969) to create the new national institute. The present activity field of the institute is *micro- nano-bio technologies*, not limited to applications in electronics, as illustrated by participation to FP 6 and FP 7 projects in the thematic areas ICT, but also NMP (nanotechnology, materials, production) and Health.

**Profile**. The main characteristic of IMT is given by *its level of ambition, namely to be a visible actor at the European scale*. Set-up in an attempt to deal with new technologies approached at the European scale (see above), and having received the first nomination for the Descartes prize (the best European project) coming from Eastern Europe (2000), IMT was inaugurating recently the first "open" centre for micro- and nanofabrication in Eastern Europe (**IMT-MINAFAB**, launched in Brussels, on 8th of May, 2009), whereas now is investing (2010-2013) in what seems to be the first European Centre for carbon-based nanomaterials (CENASIC project, structural funding). At the national scale, IMT houses the first Centre of Excellence financed after the country acceded to EU (2008-2011), whereas the Report on Innovation in Europe (10th of June, 2011) places IMT as the most performing national institute, as far as participation to European research is concerned. It is worthwhile to note also that, through IMT, Romania is the only country from Eastern Europe participating every year (since 2007), by invitation, to the *World Micromachine Summit* (devoted to micro- and nanotechnologies), with the main actors in the field from all continents.

**Recent achievements.** The present R&D activities of the institute are structured as indicated by the new diagram of the R&D department (Decision of the Minister, 26th of November, 2010), which evidences *four directions of research* corresponding to *the four "centers"*, focusing the activity of ten R&D laboratories. This new structure is an implementation of the medium-term strategy of the institute (revised in October 2009)[2] and a follow-up of funding of two projects financed by structural funding for competitive development (POS CCE).

The first entity is the ***Research Centre of Excellence "Micro- and Nanosystems for Radiofrequency and Photonics"*** (or RF and Opto MEMS). This centre of excellence (financed by EU, 2008-2011) and its achievements is described in the section "*Representative project*". It is that part of IMT which has reached maturity and full international recognition. It comprises to distinct "teams": *Micro-nano Photonics Laboratory* (L3), and *Micromachined Structures,*

[1] Please see: http://www.imt.ro/evaluation2011/IMT-Activity-domain-A9.pdf
[2] Please see: http://www.imt.ro/evaluation2011/IMT-Medium-term-strategy-2009-2015-English-translation-A1.pdf

*Microwave Circuits and Devices Laboratory* (L4). More information about their results can be found in section *2.4 Representative project*. Here is a list of recent achievements:

- State-of-the-art acoustic devices (SAWs and FBARs) operating in the GHz frequency range, manufactured using micromachining and nano-processing of GaN/Si (*results published in IEEE ED Letters 2009, 2010*); UV photodetectors for backside illumination applications manufactured on GaN membranes. The MSM structure was processed with fingers and interdigit spacing 100 nm wide using advanced nano-lithographic techniques (*Applied Optics 2008, Thin Solid Films 2011)*.
- Novel graphene based transistors with a cutoff frequency of about 80 GHz (*Appl. Phys. Let. 2011*) mm-wave (40 GHz) CRLH antennas for applications in integrated circuits, were designed, processed and characterized.
- A 3D Smith chart which can be used for the design for all passive and active circuits (*IEEE Microwave and Wireless Component Letters, 2011*).
- Simulation and CAD of micro and nana-photonic devices: Optoelectronic GaInAsP/InP active and passive photonic devices based on micro-ring resonator which is vertically coupled to one or two transparent bus waveguides.
- Replication techniques for micro and nano-optical components, 3D lithography; Epoxy replicas of DOEs with sub-micron feature size; multi-level DOEs obtained by grey tone EBL in SU-8 and in PMMA; suspended PMMA grating.
- Development of MSM photodetectors on silicon, based on EBL nanolithography with sub-wavelength interdigitated electrodes, 100 GHz bandwidth.
- UV photo detector based on P3HT-functionalized reduced graphene oxide nanocomposite for UV.
- Integrated position and proximity sensor (photodetectors and optical SU8 waveguides): micro-robotic devices as polymeric grippers (Thin Solid Films, 2009).

The second entity is the ***Centre for Nanotechnologies*** (under the aegis of the Romanian Academy); it represents a big promise for applications of nanotechnology in biology and medicine, with laboratories of *Nanobiotechnology* (L1) and *Molecular nanotechnology* (L9), respectively. The third laboratory *Nano-scale structuring and characterization* (L6) provides support for characterization and structuring at the "nano" scale. Recent results are listed below:

- Multi allergen biochip realized by microarray technology; plasmonic biosensor based on metals-silicon nanoassemblies;
- Lab-on-a-chip for oligonucleotide amplification by PCR and rapid analysis;
- Electro-catalyst nanocomposite assemblies on silicon for fuel cell application;
- Fabrication of functional nanomaterials / nanostructures, control and tuning of their properties towards applications, together with appropriate surface functionalization methods (published in *Journal of Nanoscience and Nanotechnology, Journal of Alloys and Compounds, Fuel Cells, Journal of Biomedical Nanotechnology, Materials Science and Engineering*);
- Memristor effect discovered for a new material including carbon nanotubes (*Appl. Phys. Let. 2011)*
- Biosensors and NADH based sensors (*Microchemical Acta 2011, Bioelectrochemistry 2009, Analytical Letters 2010*);
- First-principles quantum analysis of elastic and inelastic electronic transport properties of all four DNA nucleotides sandwiched between Au electrodes, in various orientations; λ-phage DNA strand stretching and immobilization on molecule-functionalized substrates.
- Synthesis of graphene nanosheets by solution phase exfoliation of graphite in organic solvents.

The third entity is the ***Research centre for Integration of Technologies***, with the following laboratories: *Microsystems in biomedical and environmental applications* (L2), *ambient technologies* (L8) and Micro- *and Nano-fluidics* (L10), the latter being initiated and supported by structural funding. Recent results are:

- New sensors and technology for toxins detection: a platform for toxins detection including integrated sensors on glass substrate, for biological environments monitoring (pH, oxygen and temperature sensors) providing information on the culture cells; microfluidic modules.
- ISFET pH sensor with application-specific selective layers and biosensor chips with interdigitated electrodes, using the chemistry of a deposited enzymatic layer, AChE enzyme.
- Integrated portable platform for pesticides detection, containing an array of disposable biosensors plus pH and temperature sensors, integrated into microfluidic channels.

- Investigation of new classes of advanced materials with application in nanodevices. Nanostructured wide band gap semiconductor oxides ($TiO_2$, ZnO) studied for light emitting, nanoelectronics or transparent electronic devices.
- Microsystem for detecting humidity, temperature and contaminant in grain storage silos and/or industrial plants for small/medium sized farm.
- Wood-polymer composite with components of nanostructured materials and nanosensors for improvement of indoor environment, with broad spectrum antibacterial activity.
- Microbiosensors for monitoring the concentration of organophosphate insecticides in environment and food, allowing single-analysis detection of organophosphate insecticides.
- Magnetophoretic device easily integrated into lab-on-a-chips platform.
- Modelling of the molecular transport in biological fluids and the physical-chemical modelling of biological material.

The last entity is the ***Research Centre for Nanotechnologies and Carbon-based nanomaterials***, which corresponds to the new investment financed from structural funding[3].

Analyzing **the evolution of IMT in the period of analysis** (2007-2011) we can find a number of strong points:

- **Field of research.** Focus on new and relevant topics of research, through a high number of European projects, including public-private partnerships (ENIAC).
- **Infrastructure.** A radical increase in the quality of infrastructure, with a clear perspective of further consolidation (a new experimental centre under development, with financing from structural funding).
- **Human resources**. A significant increase in the number of high-quality researchers (some of them with a Ph.D. abroad).
- **Diversification of financing sources**. After a peak of funding in 2008[4] - a smooth continuation of activity through the current economic crisis (all equipments functioning, no brain-drain), because the financial input comes now from a variety of sources.

**Participation in European research projects.** In the last decade, IMT was involved in dozens of projects of international cooperation. A substantial progress was achieved in *European cooperation* and (apart from the standard lists of projects in this set of documents) a synopsis is presented elsewhere[5]. *In brief*, IMT has been coordinator/partner in 11 FP7 projects (including large research projects). At the time of February 2007, several FP 6 projects were running. In parallel with FP 7, IMT was involved in other European projects, such as in 5 projects in the ERA-NET scheme and in 4 projects in ENIAC-JU (public-private partnership in *nanoelectronics*). The most important IMT participation in FP7, the MIMOMEMS project financing a centre of excellence (2008-2011) is presented separately, as the *Representative project* in section 2.4. The same synopsis[6] is also displaying the ranking of the most successful institutions in Romania, as far as financing from FP7 is concerned (Innovation Union Competitiveness Report of EC, 10th of June, 2011); in the first group of five organizations there is just one National Institute for R&D, which is IMT. IMT has an active participation in European Technological Platforms: ENIAC (nanoelectronics), Nanomedicine, EPoSS (Smart Integrated Systems), MINAM (Micro- And nanotechnologies for conventional industries).

**Infrastructure: a unique experimental facility in micro- and nanotechnologies, open to multidisciplinary research, education and industry.** This infrastructure has a unique position in this area of Europe, due to the following features. First, it integrates "micro" with "nano" in a complete facility, providing tools from computer-aided simulation and design, to wafer fabrication and reliability testing. Secondly, as stated above, is an "open" facility, following the best known models of interaction in the so-called "knowledge triangle". These two points are more clearly explained below.

This experimental facility was initiated in 2008 and launched in 2009 and it is called IMT-MINAFAB (IMT centre for MIcro- and NANOFABrication).

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[3] An article related to CENASIC from the latest Science & Tech. magazine: http://www.imt.ro/evaluation2011/IMT-SciTech-referring-article-Dec-2011-A12.pdf

[4] For details, please see: http://www.imt.ro/evaluation2011/IMT-Revenues-and-investments-dynamics-A7.pdf

[5] Please see: http://www.imt.ro/evaluation2011/IMT-and-European-cooperation-A3.pdf

[6] ibidem

IMT-MINAFAB[7] should be seen as an interface created by IMT in order to fully exploit its tangible and intangible assets in micro- and nanotechnologies (clean room facility, equipments, human resources, partners and users). The so-called "fabrication centre" is in fact a complex technological platform including also CAD tools, characterization equipments, a mask shop, a reliability laboratory. The fabrication itself, whenever necessary, is accompanied by specific testing and design. The term "fabrication" in this context means "physical realization" and not necessarily production. In some cases, the equipments can be used for both research and "small-scale production". Partnerships with external organizations are also extremely important. Existing partners are LAAS/CNRS, Toulouse, France, and FORTH, Heraklion, Greece, the interaction being financed by twinning activities within the MIMOMEMS centre of excellence. As far as the industrial clients are concerned, IMT is promoting cooperation in two ways: first, using MINATECH-RO, the science and technology park for micro- and nanotechnologies (whereby, for example, companies can place their own equipment in the technological area); secondly, by facilitating the interaction with other companies and research groups through the network for knowledge and technology transfer with more than 60 partners (the information is exchanged through the Centre for technology transfer in micro-engineering, part of IMT). Partnership with important foreign companies is promoted, whenever possible. The multinational company Honeywell is leading the way with its presence in the MINATECH-RO park, equipments installed, and services required in the IMT-MINAFAB area. Since 2011, the quality of services in this facility is ISO 9001 certified by TÜV Thüringen e.V. The detailed information for customers is available at www.imt.ro/MINAFAB.

**Infrastructures for Technology Transfer and Innovation** (the *Science and Technology Park for Micro- and Nanotechnologies*, MINATECH-RO[8] and the *Centre for Technology-Transfer in Microengineering*, CTT-Baneasa[9]) have been initiated before 2007.

**Information technology and communication (ITC) infrastructure** is another important asset of IMT, with 100 Mb/s computer network with IBM servers, CISCO routers and firewalls, network switches with management, optical fiber Internet connection, 2 computer networks for courses, training and conferences - one connected to a graphic station; high performance system for computational research, using virtualization in order to allow the simultaneous execution of various applications for simulation and modeling under different operating systems. A number of powerful software packages are facilitating both fundamental research and engineering. *The support team of IMT in ITC* has expertise in: design and creation of web-based applications including static and dynamic web pages, relational databases based on open source software.

**Recruiting and enhancing human resources**. Apart from a *wide recognition of its European performance*, IMT has become in the last years *an attraction for valuable researchers* through the new infrastructures, the multitude of European projects and opening of new positions. At the moment of this evaluation one can count in IMT a number of 40 researchers and engineers with a Ph.D. (researchers with double affiliation are excluded and people having their thesis just approved by the National Council are included); this figure has doubled since 1st of January, 2007. *Doubling the number of Doctors* was accomplished due to both existing and new personnel (hired in the above time interval). It is worthwhile to note that *8 from the 20 new doctors (i.e. 40% of total) obtained their Ph.D. in Universities abroad* (Europe, U.S. and Japan), in comparison with just one researcher before 2007. The new 20 doctors have a different background: engineering (electronics, automation, electrical, mechanical), physics, chemistry, mathematics. They are also lowering the average age of doctors in IMT (only 39 years for the last group). Five other young researchers have just defended their thesis and they are waiting for the final public presentation, or for the final approval from the National Council (CNATDCU).

**Relying upon various resources of financing.** Despite the sharp reduction of financing in national R&D programmes (starting 2009), the activity of the institute had a steady flow due to (a) increase in the core funding; (b) financing from European projects; (c) financing from structural funding. The last source of funding was oriented towards *investments in infrastructure* (the new CENASIC centre), *creation of a technological platform for fabrication of microfluidic*

[7] For details, please see: http://www.imt.ro/evaluation2011/IMT-MINAFAB-General-description-A2.pdf
[8] For details, please see: http://www.imt.ro/evaluation2011/IMT-MINATECH-RO-A8.pdf
[9] For details, please see: http://www.imt.ro/evaluation2011/IMT-CTT-Baneasa-A8.pdf

*devices* and *postgraduate training in micro-nanotechnologies*, respectively. Details on structural funding projects in IMT (2010-2013) are presented elsewhere[10].

**Education** and training by research was constantly part of IMT activities[11], with participation to the European Ma*rie Curie* programme, as well as to *Leonardo* and *Eurotraining*. Next, we have to stress participation of IMT (since 2009) to M.Sc. Programmes of the University "Politehnica" of Bucharest (Electronics Department) covering completely four disciplines (lectures and laboratory classes held by IMT people at IMT premises). We are pointing out that IMT is also contributing to undergraduate activities with laboratory classes and summer stages of technical practice.

A major educational activity is related to training by research within the *postdoctoral programme* in *micro- and nanotechnologies* implemented through the MNT-POSTDOC project financed from structural funding (35 postdoctoral individual grants, half of the researchers are from IMT).

**Communication and dissemination** (events, printed and electronic publications). IMT is organizing annually in Romania the CAS conference (micro- and nanotechnologies), an international IEEE event, and is publishing CAS Proceedings (an IEEE publication). The last edition (the 34th) was organized in Sinaia (17-19 October, 2011). Both the conference itself and the *satellite events* organized almost every year (e.g. European projects meetings) are promoting the international cooperation of the Romanian researchers. IMT is also organizing (through the Centre for Nanotechnologies from IMT, working *under the aegis* of the Romanian Academy) a one-day National Seminar for Nanoscience and Nanotechnology (each year), in 2011 at the 10th Edition. The best papers are published in a volume (in English), in a series for "*Micro- and nanoengineering*", edited by the Publishing House of the Romanian Academy. IMT has a crucial role in the publication not only of the above series, but also of the ISI rated ROMJIST (Romanian Journal for Information Science and Technology) edited by the Romanian Academy. ROMJIST is publishing a number of issues in micro- and nanotechnologies.

IMT is disseminating information about its scientific activity through the Annual Scientific Report (since 2005, on the web page), and information about the services provided by IMT through the brochure "IMT - your reliable partner" (2009, 2010, also on IMT web page). Also IMT is organizing each year "the day of open doors" (in December). On 8th of May 2009, at the headquarter of the Romanian mission at the EU, IMT presented its new infrastructure IMT-MINAFAB in a dedicated workshop with the participation of the European Commission and other country representatives. Selected visits in IMT of foreign representatives (including officials of the European Commission) are listed elsewhere[12].

The electronic communication uses the web page and an e-news bulletin (sent to more than two thousands addresses). Articles about the activity of IMT appeared in local and European magazines[13].

IMT organized (in Romania and abroad) a number of project meetings, info-days, networking and brokerage events in the frame of European and national projects. IMT was the coordinator of the foresight study: "Nanotechnology in Romania: prospective study" (NANOPROSPECT) [14]. Extensive databases (in English) about nanotechnology in Romania have been created and they are available on the project site: www.imt.ro/NANOPROSPECT.

**Finally**, with all its activity in research, education, innovation, communication with partnerships and networking, IMT acts as *a hub of micro- and nanotechnologies at the national scale*. Through various projects (national and European funding) IMT facilitated networking at the national for European cooperation, including development along the lines of European Technological Platforms.

Strength of the national and international cooperation, access to all partners to our infrastructure, the possibility of our researcher for joint work in different places abroad, scientific exchange through mobilities, common papers with EU partners, permanent access to training in advanced fields (participation at numerous Summer Schools, courses) were permanent objectives of our research, which allowed us to achieve a significant growth in the last years.

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[10] Please see: http://www.imt.ro/evaluation2011/IMT-Structural-funding-projects-2011-A10.pdf

[11] For details, please see: http://www.imt.ro/evaluation2011/IMT-Education-activities-A4.pdf

12 Please see: http://www.imt.ro/evaluation2011/IMT-Visit-Events-A6.pdf

[13] A selected list is presented at: http://www.imt.ro/evaluation2011/IMT-about-articles-A13.pdf

[14] An article that refers also the NANOPROSPECT project from the latest Science & Tech. magazine can be seen here: http://www.imt.ro/evaluation2011/IMT-SciTech-referring-article-Dec-2011-A11.pdf

# 2.3 Activity Report by Team

**Nanobiotechnology Laboratory (E1)- activity report**

***Short description of the team:*** The Nanotechnology Laboratory was established since the foundation of IMT in 1996, and from that point a constant evolution has been taken place: it was affiliated to the Romanian Academy in 2001 and represented the base of the IMT's Center for Nanotechnologies (CNT, http://www.imt.ro/CNT/).

Moreover, given the increased importance of the biomedical applications targeted in our research, the name has been tailored to the mission gaining the 'bio' component in 2011 and now we can talk about Nanobiotechnology team ("L1" team - http://www.imt.ro/organisation/research%20labs/L1/index.htm). This extension of interests has been coupled with strong revitalizing of the group, **3 young graduates** joining during the last two years. Also, while before, the background of researchers was in physics or chemistry, the young graduates brought the engineering component, increasing the interdisciplinary potential.

Therefore, the group includes *5 physicists*, *2 chemists*, *2 engineers*, and it has to be mentioned that from the current **9** members of the team, only one is older than 50 years, the average age of the team members being ***36 years***.

Regarding the ***quality of the human resources***, there is a turning point in the laboratory life, during the year 2011 being ***3 PhD theses defended***, in engineering (1) and chemistry (2), the first one receiving by now the clearance from CNATDCU. Also, **2** team members have running projects in the human resources structural funds - POSDRU programs, one in the IMT-led post-doctoral program (PhD in physics) and the second one in the UPB (‚Politehnica' University)-led doctoral program, and **1** is finalizing the Master studies in engineering.

All of the young researchers have capitalized experience on the different **research stages** and **summer schools** in the nanoscience area abroad. For example, there were two FP5 research projects accessed for *Enhancing Microtechnological Education of young Researchers through Guest Experiments* between 2000-2001 (Institute for Microelectronics Mainz) and respectively 2003-2005 (Tyndall, Cork), as well as research grant *"Surface engineering technique to investigate inorganic-biomolecular interfaces"* obtained in the frame of FP6 European Network of Excellence NANOFUN-POLY at INASMET- Tecnalia, Dept. of Biomaterials and Nanotechnologies (2008). Following this practice, in 2012 a one year research stage *"Silicon micro-ribbons for ultimate single-molecule sensing applications"* will be realized at Universite Catholique de Louvain in the frame of the doctoral POSDRU program.

***The L1 mission*** can be summarized as research, development and education in **nano-bio-technologies.** Main areas of expertise can be classified as:

- fabrication of functional nanomaterials / nanostructures, study, control and tuning of their properties towards applications, together with appropriate surface functionalization methods;
- advanced characterization techniques for nanomaterials and thin films envisaging further improvement of their properties to find the optimal solutions for the device' design and also, more recently, addressing the *health risks* of these new nanomaterials and the associated industrial nanoproducts, in order to underpin their safe use.
- design and fabrication of fabrication of new devices on silicon, polymers or hybrid multilevel systems, for applications in many interdisciplinary areas, from biomedicine (optoelectronic biosensors) to energy harvesting (miniaturized fuel cell devices such as clean energy sources).

Based on its multidisciplinary background and experience, the team performs **training activities** representing **master courses** *„Micro and nanotechnologies for medical applications"* in cooperation with 'Politehnica' University Bucharest (UPB) included in the program of "*Electronics and Medical Informatics"*

specialisation, and also **supervising the diploma' research activities** of undergraduate and master students from University of Bucharest, both Faculty of Physics and Chemistry, and UPB.

The team expertise is confirmed by the ***scientific achievements*** obtained over time, the main results being quantifiable in terms of ***(i) the success in national and international project competitions*** and ***(ii) the research articles*** published and cited in peer review journals. These results demonstrate also the ***excellent external scientific collaboration:***

***(i)*** Regarding the ***national funded research***, since 2007, the team members of Nanobiotechnology Laboratory have coordinated as principal investigators **2 PN-II-Ideas projects** (■*"Study of membrane - electro-catalyst nanocomposite assemblies on silicon for fuel cell application"*- Dr. M. Kusko (Miu) and ■*"Study of silicon-protein type biohybride nanostructured surfaces with applications in bio(nano)senzing"*- Dr. I. Kleps) and **3 PN-II-Partnership projects** (■*"Miniaturised power source for portable electronics realised by 3D assembling of complex hybrid micro- and nanosystems – MiNaSEP"* - Dr. M. Kusko (Miu); ■*"Multi Alergen Biochip realised by MicroArray technology – MAMA"* – Dr. M. Simion; and ■*"Silicon based multifunctional nanoparticles for cancer treatment - NanoSiC"* - Dr. I. Kleps), and respectively **2 PN-II-Partnership projects** as partner in consortium. Now, **8 proposals** are under evaluation in the 2011 **PN-II-PCCA framework**, 2 of them being coordinated by the team members (Dr. M. Kusko and Dr. M. Simion are PIs).

The collaboration with groups having similar interests from abroad have been established, resulting the following ***bilateral projects***: ■*"Development of plasmonic biosensor based on metals- silicon nanoassemblies - BIOSENS"* with Institute for Nanoscience – Paris (2008-2010); ■ "*Nanostructured silicon for optical biosensor"* with Faculty of Physics - University of Trento, Italy (2006-2008)**,** and respectively ■*"Nanostructured silicon for biomedical application"* with Institute for Microelectronics – Athens, Greece (2006 – 2008).

Moreover, major funding (over 600.000 Euro) have been obtained from ***European FP7 Projects***, starting with the **2 MNT-ERA FP7 projects:** ■ *"Nanostructural carbonaceous films for cold emitters – NANOCAFE"* – Phys. F. Craciunoiu (2009-2011) and ■ "*A 'system-in-a-microfluidic package' approach for focused diagnostic DNA microchips – DNASiP"* – Dr. M. Simion (2008-2010).

The situation shows that the team is currently involved in other **2 FP7 projects.**

The first one was „*Development of sustainable solutions for nanotechnology based products based on hazard characterization and LCA - NanoSustain"* **–** Acad. D. Dascalu (2010-2013), ongoing collaborative Small or medium-scale focused research project (THEME 4 NMP - Nanosciences, Nanotechnologies, Materials and new Production Technologies and THEME 6 Environment, including Climate Change), focused on developing innovative solutions for the sustainable design, use, recycling and final treatment of nanotechnology-based products.

The quality of research has determined including us in the following Large-scale integrating Collaborative project (THEME NMP.2010.1.3-1 Reference methods for managing the risk of engineered nanoparticles) *"Development of reference methods for hazard identification, risk assessment and LCA of engineered nanomaterials – NanoValid*" - Dr. M. Kusko (2011 – 2014) which has started in November 2011, and aims to go forward to validation of measurements and test methods, for reliable reference methods development, in cooperation with international standardization bodies and the concerned industry.

Most of these projects are based on related industry necessities, small or large enterprises, a long term collaboration being with GeneticLab, which is Romanian SME. The results of common research developed in frame of different national / international projects have been in accord patented – "*Lab-on-a-chip for oligonucleotide amplification by PCR and rapid analysis*" - **Patent Number RO122612-B1** – and published in

research articles; moreover, they represented the encouraging preliminary data for the both **PN-II-PCCA 2011** proposals coordinated by L1-team.

***(ii)*** In last years, from 2007 to now, **38 research articles** have been published in peer review journals with nonzero relative AIS, with a cumulated influence score of ~ **40**, like: *Journal of Nanoscience and Nanotechnology* (3), *Journal of Alloys and Compounds* (2), *Fuel Cells* (1), *Journal of Biomedical Nanotechnology* (1), *Materials Science and Engineering* (3), or *Superlattices and Microstructures* (3). We mention also **30** ISI-indexed proceedings of international conferences.

Moreover, **the quality of the results** had determined and is once more demonstrated by invitation of the group members to presents their work to different international conferences, like **216th ECS Meeting (**First International Symposium on Semiconductor and Plasmonics-Active Nanostructures for Photonic Devices and Systems Session) (2009) - *„Metal – semiconductor nanoassemblies for improving of sensing efficiency"* M. Miu et all - or **NanoMed, 6th International Conference on Biomedical Applications of Nanotechnology** (2009) – "*Study of the micro- and nanostructured silicon for biosensing and medical applications",* I. Kleps et all.

Comparative with the period before, during the last 3 years it was a notable increase of the published scientific papers, this ration being determined by the ***top level quality of the research equipments*** acquired and installed from **2008** to now. Thus, besides of the dedicated national funded PN-II-'Capacitati' project for development of the public infrastructure ***"High resolution X-ray diffractometry laboratory (LADRIX)"*** (2007-2010) won by M. Danila from our team which was the base for establishing of the *experimental X - ray Laboratory – MINAFAB,* the equipment allocated funds of the rest of the **L1 projects** allowed enlarging of the IMT characterization capabilities.

■ *High resolution SmartLab X-ray diffraction system* (Rigaku, Jp. ~ 400 kEuro) from **Experimental X - ray Laboratory – MINAFAB;**
■ *Steady state and life time fluorescence spectrometer* (Edinburgh Instr. ~75 kEuro) and ■ *DelsaNanoC-size and Zeta Potential measurement system* (Beckman Coulter ~ 65 kEuro), part of the **Experimental laboratory for nanoparticles – MINAFAB;**
■ *PARSTAT Electrochemical Impedance Spectrometer* (Princeton Applied Research ~ 25 kEuro) and ■ *Scanning electrochemical microscope* (HEKA ~ 100 kEuro) from **Experimental Laboratory of Biohybrid Interface Characterization – MINAFAB;**

In this context, it has to be mentioned that M. Simion from L1 is responsible for *Microarray ploter* (GeneMachines OmniGrid Micro) and *Microarray scanner* (GeneTAC UC4) equipments, which have been purchased before, now being part of the **Experimental NanoBioLab – MINAFAB**; they are fully exploited, the collaborations with SMEs in nanomedicine domain and also with biochemistry department – Bucharest University – being now established, important common results coming. Also, M. Danila, recognized as specialist in the X-ray analysis, and furthermore helped by the unique built-in capabilities of the SmartLab equipment, has contributed in the last **3** years to more than **10** scientific papers in peer-reviewed journals and even more has been contacted by important companies as Philips to perform structural analyses.

***Laboratory Head:*** *Dr. Mihaela Kusko*,
e-mail: Mihaela.kusko@imt.ro

# Microsystems in Biomedical and Environmental Applications LABORATORY (E2)

## 1. The mission of the laboratory

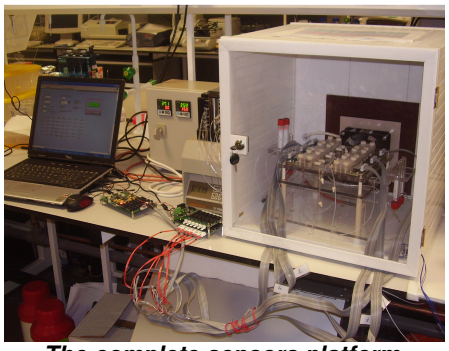
Our **Mission** is to undertake high-quality advanced and innovative interdisciplinary research in the field of MEMS and microfluidics for biomedical and environmental applications.

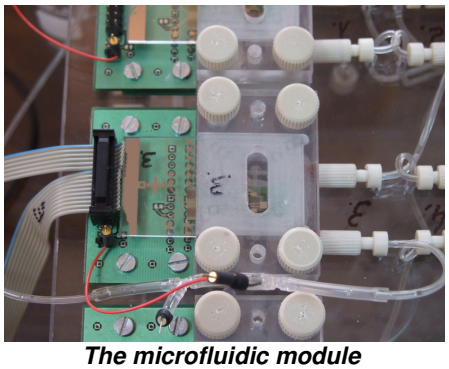
Our **Activities** are focused on **research and development** for microsensors (chemo resistive and resonant gas sensors), electrodes for biological sensors developed on silicon, plastic and ceramic substrate, microprobes for recording of electrical activity of cells and tissues, microfluidics and integrated technologies (silicon, polymers, biomaterials), **education and training** in the field of microsystems and microfluidic technologies, and **services** in design, simulation and mixed technology and system integration for bio and chemosensors.

**Main expertise**: - ***mechanical*** (accelerometers, pressure) microsensors, ***chemo*** (chemoresistive, resonant gas sensors) and ***biosensors*** (microarrays, ISFET - Ion Sensitive Field Effect Transistors, electrodes for biological sensors, microprobes for recording of electrical activity of cells and tissues), in terms of software simulations /modelling, using MEMS–specific CAD software (CoventorWare, CADENCE), technological development and electrical characterisation;
- **Microfluidic platforms** simulation and fabrication; microfluidic and electrical interfaces for microsensors ***integration, data acquisition, interpretation*** and alarming and ***GUI*** (graphical user interface) development
**The team was working the last 5 years in 8 national projects, seven FP6 and two FP7 projects during the last 5 years, both research projects and support actions.**
Our research activities were disseminated in 7 ISI papers (with a cumulative impact factor of almost 23), 26 papers presented within international conferences and 4 patents were registered.

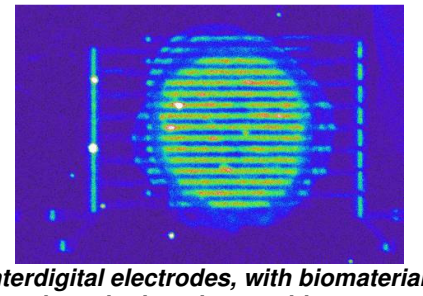
## 2. Brief description of the main results of the laboratory

**New sensors and technology for toxins detection***
The platform for toxins detection includes ***integrated sensors on glass substrate***, for biological environments monitoring (pH, oxygen and temperature sensors) that provide information on the culture cells. The sensors were developed on a glass substrate for the purpose of using both optical and electrical means for the cells screening.
***Microfluidic modules*** have been fabricated and external components have been developed, such as pumps, connection tubes and reservoirs, for transporting the fluids along the sensors chip. The microfluidic system integrates the sensors chip, enabling various cellular responses that occur as a result of toxicity to be monitored closely.
In order to have a fully functional **TOXICHIP*** platform, the ***data acquisition and signal processing*** systems have been defined and developed. These take information from 6 independent modules for toxins detection, minimizing biological noise, processing and transferring the data through a Lab-View system.
***Results obtained within the FP6 STREP project "Development of a toxin screening multi-parameter on-line biochip system" – TOXICHIP (Contract no. 027900).***


***The complete sensors platform***


***The microfluidic module***

**Technology convergence: silicon / polymers / biomaterials***
The Microsystems for Biomedical and Environmental Applications Laboratory developed and validated combined silicon-polymer manufacturing strategies, along with integration of bio-materials and surface functionalisation. An ISFET pH sensor with application-specific selective layers and biosensor chips with interdigitated electrodes was developed, using the chemistry of a deposited enzymatic layer, AChE enzyme, (taking into account the concentration, enzymatic activity measuring and deposition protocol). For the fabrication of enzymatic sensors, the accurately deposition and immobilization only on the surface of the working electrodes has been achieved. The electrical measurements showed and validated the sensor's functionality.


***Interdigital electrodes, with biomaterials deposited on the sensitive area***

**Microfluidic simulation and modelling techniques**

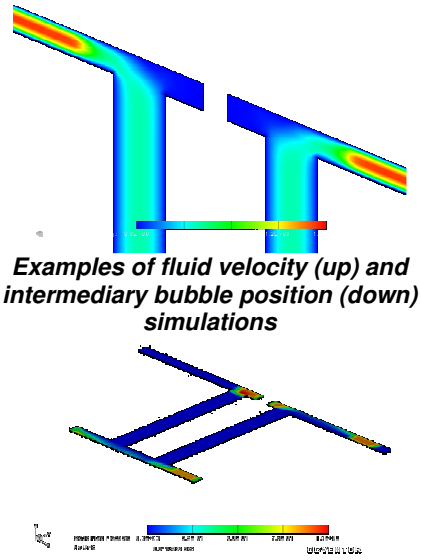
Design, virtual manufacturing and simulation support services for microfluidic structures were developed by our lab.

The expertise includes:

- Continuous flow analysis (velocity, pressure, etc.);
- Slug-flow analysis (fluid bubbles through channels);
- Dead-volumes identification;
- Fluids cross-contamination;
- Other application-specific analysis.

The microfluidic structures to be simulated can be fabricated in two different technologies: standard silicon microfabrication techniques and polymer technologies. Additionally, these two technologies can be combined to develop silicon/polymer integrated microstructures.

***Results obtained within the FP6 IP project "Integrated MNT platforms and services – Service Action" – INTEGAMplus (Contract no. 027540).***



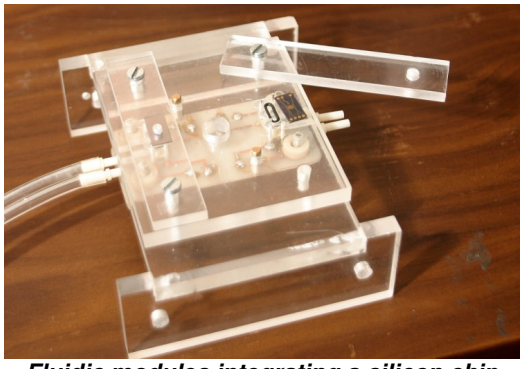
***Examples of fluid velocity (up) and intermediary bubble position (down) simulations***

**Integrated mobile platform for pesticides detection (PESTIPLAT)***

The pesticides detection system will be portable, and will contain an array of disposable biosensors plus pH and temperature sensors, integrated into microfluidic channels. Signal processing, data acquisition and data display will be also integrated.

- Sensors design and fabrication including mask design, mask fabrication, sensor fabrication using silicon technologies; Sensors electrical connections
- Microfluidic design and fabrication, taking into account the requirements from the thermal control and sensor modules

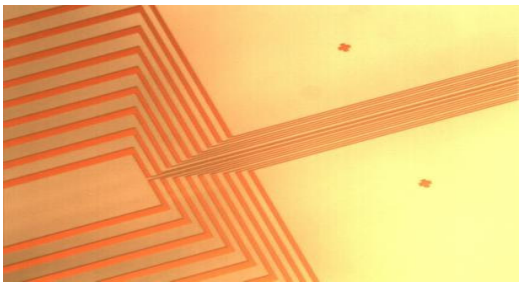
***Results obtained within the FP7MNT ERA-NET project "Integrated Platform for Pesticides Detection" (Contract no. 7-035/2011).***



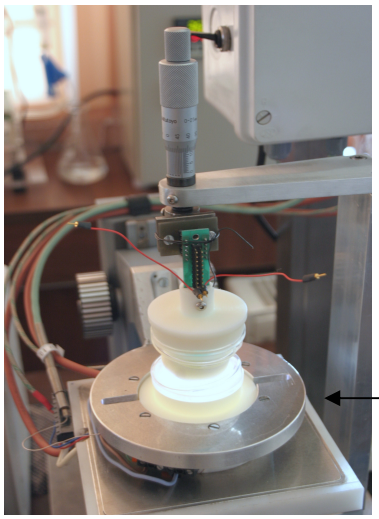
***Fluidic modules integrating a silicon chip***

**Integrated Platform for electrophysiological and chemical neural recording**

Characterization of electrical and chemical activity of the excitable membranes cells is essential for the functional study of the nerves and brain (neurons) and also for the understanding of the brain control mechanisms. In the same time, at application level, this kind of information is absolutely necessary for the diagnosis and treatment of nervous system diseases. Moreover, the measurement of neurotransmitters' pH level and concentration (for dopamine, acetylcholine, etc.) will be performed in order to evaluate the physiological mechanisms of reaction and regulation. Also, the data acquisition system was defined and developed, using a portable electronic unit (including signal generation and measurement, data storage, computer interface).



***Optical photo of the patterned sensors***



**Neurosense Platform: mini incubator, microprobe, micronic stages for alignment**

***Results obtained within the National PN II project "Integrated system for concurrent electrophysiological and chemical recording at neural level" – NEUROSENSE (Contract no. 11-006).***

## 3. Short description of the equipments

The Lab is responsible for the InkJet Printer equipment, for conductive layers deposition, using the Ink Jet method. This allows the direct deposition of metallic and polymeric materials; for National Instruments Platform and Agilent RLC for sensors characterisation; VoltaLab.

## 4. Short description of Laboratory cooperation

The Microsystems for Biomedical and Environmental Applications Laboratory had an excellent cooperation with Romanian and European partners during the successful projects partnerships. Among our most important European collaborators are QinetiQ, and EPIGEM, UK; Tyndall National Institute, Ireland; CoventorWare, France; CSEM, Switzerland; ITE, Poland; Silex Microsystems, Sweden; Vigicell, France, HSG-IMIT, Scienion and IMM-Mainz, Germany; JRC Ispra, Istituto Maria Boelo and University di Torino, Italy; Colibrys, Switzerland; CEA-Leti, and CNRS Besancon France; Cardif University; IVF Sweden, HSG-IMIT, Scienion Germany

Among the Romanian institutions that we collaborate with are The National Institute for Laser Physics, Plasma and Radiation, National Institute for R&D in Pathology and Biomedical Sciences – "Victor Babes", Research Institute for Artificial Intelligence, "Politehnica" University, Bucharest, Institute for Public Health Bucharest, as well as many companies, such as ROMELGEN, DDS Diasgnostic, ROM-QUARTZ, ROMES.

Also, the Laboratory ran a **private contract** with an important domestic appliances manufacturer, for the development of an innovative pressure sensor, to be integrated within washing machines.

## 5. Young scientists

During the last 5 years, 5 young researchers have been employed within the laboratory. 4 young researches are currently involved in our research activities (from a total of 12 people) and 2 of them are PhD students.

The lab was also involved in **education activities**, aimed at attracting young people to the research field from early stage. *Dr. Carmen Moldovan* hosted within IMT Bucharest an important initiative, "*IT Girls*", taken by the European Commission to convey the message that rewarding career opportunities in the ever-growing domain of Information and Communication Technologies (ICT) exist for both men and women. The action was leaded by *Viviane Reding*, former Commissioner for Information Society and Media, EC. Four college students shadowed four female engineers throughout the day as they carried out their regular professional commitments. They spent the day seeing the seniors in action in some of the main departments of IMT and visited the main technological facilities. Two girls and Dr. Carmen Moldovan were invited and attended the "**Shadowing day Conference**" in Brussels. The girls were very impressed by the activities within IMT, and declared that research is, from now, a domain to think about when choosing their future careers.

***Viviane Reding, former Commissioner for Information Society and Media, at the European Commission Shadowing Conference, 6 March 2008, Brussels and the Romanian participants***

## 6. Other activities

- IMT Bucharest was a member of the *Nexus Association Steering Committee (**NEXUS*** - nonprofit Association supported by EC projects, headquartered in Neuchâtel, Switzerland) by it's representative, Dr. **Carmen Moldovan**, working for 4 years to provide microsystems professionals with:
  - access to strategic guidance through reports containing the most up-to-date analysis of markets, technologies, applications and long-term trends.
  - information through the web portal, regular e-mail bulletins, MST News pages, thematic workshops and also conferences.
  - high-level networking opportunities through the regular user/supplier club meetings and other specialist events.

- The Laboratory was actively involved in **Nano2Life** Network of Excellence, **4M** and **PATENT** Networks of Excellence by working in new project within the networks, attending courses and schools and publishing scientific papers in collaboration with network partners.
- Training activity: INTEGRAM*plus*, Microbuilder joint course, December 2008, Bucharest
- Best paper awards on Conferences: Three Diplomas
- Diploma of excellence for FP6 participation received by Dr Carmen Moldovan from the State Secretary of ANCS.

Head of lab.: Dr. Carmen Moldovan (carmen.moldovan@imt.ro)

# Micro-Nano Photonics Laboratory (E3)

**The Microphotonics Lab** is member of"***European Centre of Excellence in Microwave, Millimetre Wave and Optical Devices, based on Micro-Electro-Mechanical Systems for Advanced Communication Systems and Sensors*" *(MIMOMEMS)*,** funded (2008-2011) through the "Regional potential" – FP7 REGPOT call 2007-1.

**Mission:** *Research, development and education* in **micro and nanophotonics**

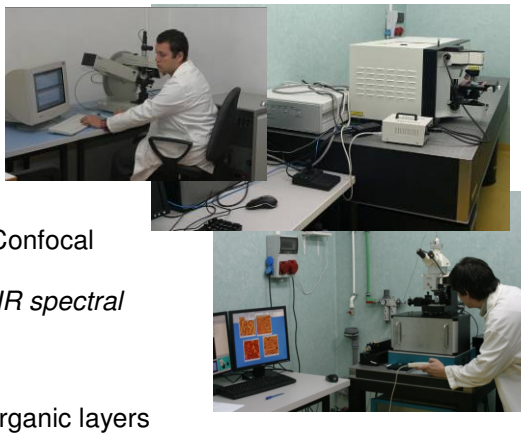
- **Main areas of expertise**
  - **modelling and simulation** of micro and nano photonic structures;
  - **new materials** for micro/nano opto-electro-mechanical systems integration (functional polymer, hybrid organic-inorganic nano-composites, transparent semiconducting oxides, graphene);
  - **passive and active micro-nano-photonic structures** for sensing applications;
  - **organic optoelectronics;**
  - **Micro-optics** - design and fabrication based on replication techniques for DOEs, micro and opto-fluidics;
  - optical and electrical **characterization** of materials and devices.

- **Major funding (over 800 kEuro) from European Projects :**
  - **FP7:** Flexible *Patterning of Complex Micro Structures using Adaptive Embossing Technology* (***FLEXPAET***), IP - NMP; European Centre of Excellence ***MIMOMEMS*** (CSA- Capacities);
  - **MNT EraNet Project:** Multifunctional Zinc-Oxide based nanostructures (2009-2012);
  - **FP6**: **Waferbonding and Active Passive Integration Technology and Implementation - *WAPITI*** - STREP FP6/IST-Photonics (2004-2007), **Multi-Material Micro Manufacture: Technologies and Applications - micro-optic cluster *(4M)-*** NoE FP6/NMP (2004-2008)
  - **Advanced Handling and Assembly in Microtechnology *ASSEMIC*** (Marie Curie Training Network).

- **Specific facilities:**

**Modeling and simulation:**

- ***Opti FDTD 10.0*** - design and simulation of advanced passive and nonlinear photonic devices
- ***OptiBPM 11.0***- design of complex photonic integrated circuits for guiding, coupling, switching, splitting, multiplexing and demultiplexing of optical signals.
- ***OptiGrating***- design software for modelling integrated and fiber optical devices that incorporate optical gratings.
- **LaserMod** - analysis of optoelectronic devices.
- **3Lit** – design of 3D micro-optical elements.
- **Zemax** – optical design.



**Characterization**:

- *spectrophotometers for UV-VIS-NIR and IR spectral range;*
- *spectroscopic ellipsometer*
- *High Resolution Raman Spectrometers LabRAM HR*
- *Alpha300 S System* –Scanning Near-field Optical Microscope, Confocal Microscopy and Atomic Force Microscopy
- *experimental set-up for optoelectric characterization in UV-VIS-IR spectral range*

**Technology**

- glove box for preparation and deposition of nanocomposites and organic layers

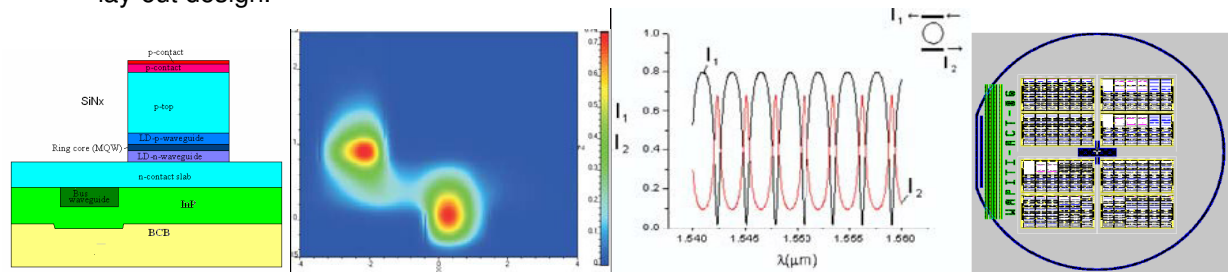
- **Team** with multidisciplinary expertise (optoelectronics, physics, Chemistry): four senior researchers, 2 post-Docs (one with PhD in USA), two PhD students and one master student with background in electronics and physics.

## Research results

### A. Simulation and CAD of micro and nana-photonic devices

*Optoelectronic GaInAsP/InP active and passive photonic devices* based on microring resonator which is vertically coupled to one or two transparent bus waveguides (**FP6 project WAPITI**):

- analysis of the waveguiding properties and spectral characteristic of a microring resonator obtained by wafer-bonding technology;
- design and 3D simulation of microring resonator, all-optical wavelength converters, multifunctional devices;
- lay-out design.

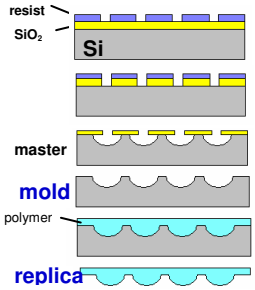



a) b) c) d)

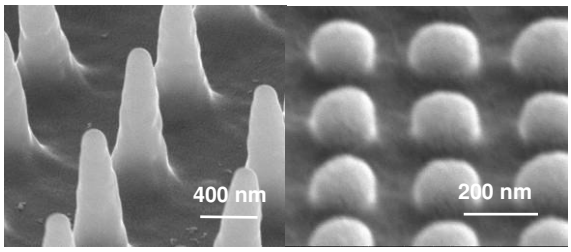
Vertically coupled micro-ring resonator -: a) example of structure; b) radiation coupling from bus to ring; example of transfer characteristics for a passive structure; d) lay-out.

## B. Technology

- ***Replication techniques for micro and nano-optical components***

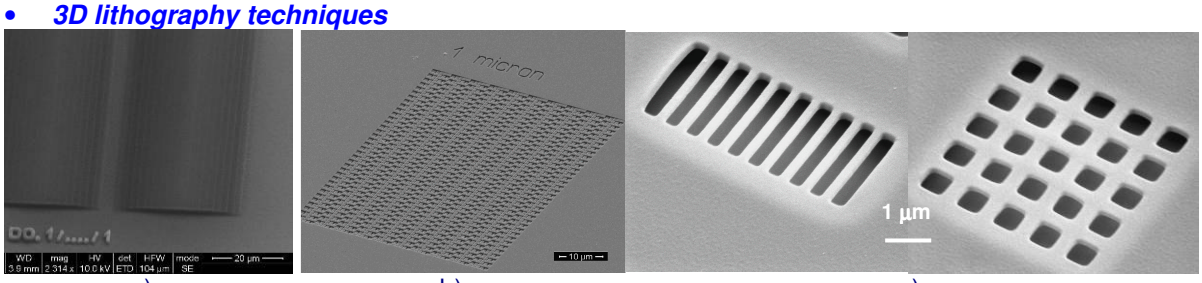



Process




Epoxy replicas of DOEs with sub-micron feature size

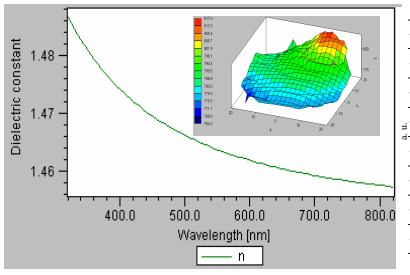
- ***3D lithography techniques***



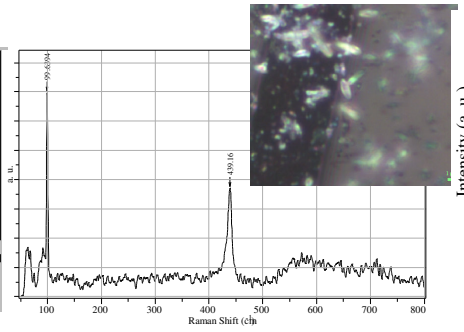

a) b) c)

a)Multi-level DOEs obtained by grey tone EBL in SU-8 and b) in PMMA; c suspended PMMA grating

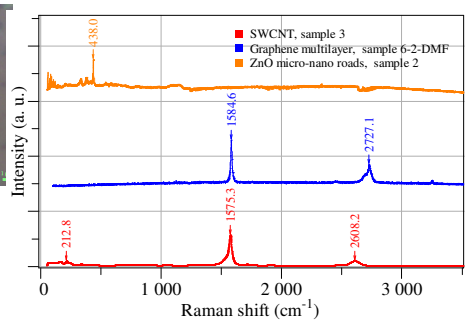
## C. Characterization methods of thin films and nanostructures using optical spectroscopy – spectral ellipsometry, spectrophotometry and Raman spectroscopy




3D representation of SiO2 thickness distribution on 75 mm diameter Si wafer



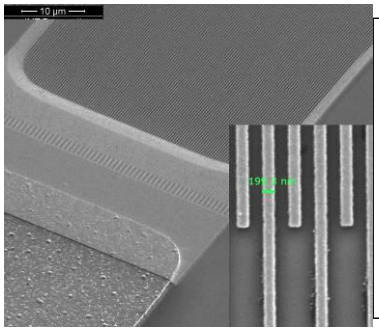

Raman spectra of ZnO microroads grown by sol-gel method.

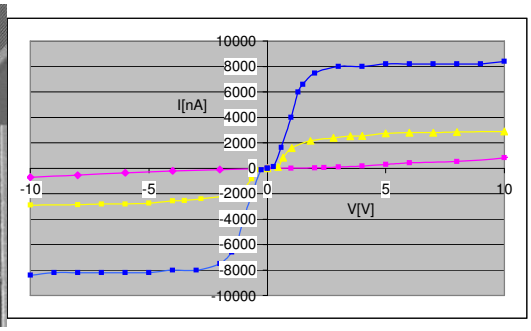



Raman spectra of the single wall carbon nanotubes (SWCNT) network grown by catalytic CVD, (excitation at 632 nm), graphene multilayer a (514 nm laser excitation) and ZnO micro/nano roads grown by MOCVD at 632 nm

## D. Devices

***Silicon metal-semiconductor-metal photodetector with subwavelength interdigitated transparent electrodes***



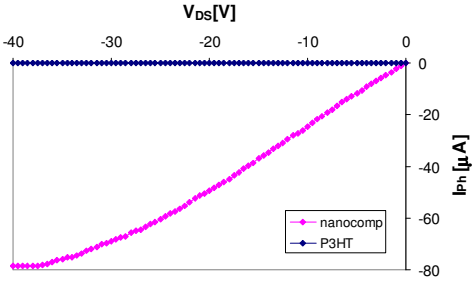




*Silicon MSM photodetector* with subwavelength inter-digitated electrodes, 100 GHz bandwidth**:**
a) structure, b**)** I-V characteristics under illumination (P= 500 µW, λ=630 nm)

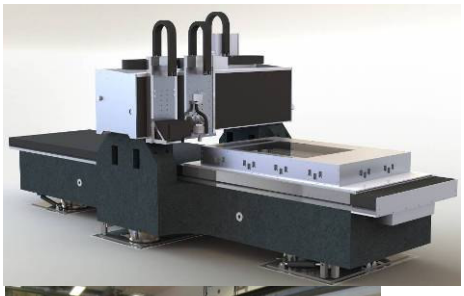
a) b)

***UV photodetector based on P3HT-functionalized reduced graphene oxide nanocomposite for UV***

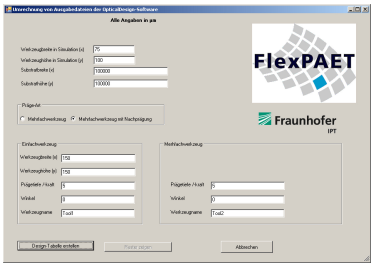
Photocurrent (**$I_{Ph}$ = $I_{DS(light)}$) = $I_{DS(dark)}$**) under illumination with a DUV source (1.44mW/cm$^2$ at 240 nm)
***R~9 mA/W / λ= 240 nm***




- **Cooperation with European industry:**



In the frame of **FP7 project FlexPAET** coordinated by Fraunhofer IPT, we cooperated with one large company- (Zumtobel- Austria), five SMEs from Spain, Germany, Denmark, in the development of a ***machine for adaptive embossing of large area masters for diffractive optical elements***. We developed an optimization method and participated in the development of the of software tool for data processing and CAM-interface that includes optimization software, processing of mathematical functions for one-dimensional density distribution, processing of design data from ray-tracing files.




- **Publications and patents:**

***Papers*** in ISI Journals and Proceedings (37), in important international conferences (over 50) and 3 patents
***Citation*** (2007-2011) – over 150 in ISI journals (including journals with very high impact factors, i.e. Chemical Reviews, Laser and Photonics Review, Advanced Materials, IEEE J. of Quantum electronics, Materials Science and Engineering R-Reports, Critical Reviews in Solid State and Materials Sciences, Applied Physics Letters, Journal of Applied Crystallography, Journal of Nanocrystalline Solids.

- **Training activities:**

- **Master courses** – *Optoelectronics/Integrated optics and Microsystems* in cooperation with "Politehinca" Univ. Bucharest.
- supervising undergraduate, master and PhD students.

**Contact details**

*Laboratory Head: Dr. Dana Cristea*, e-mail: dana.cristea@imt.ro

# Micromachined structures, microwave circuits and devices Laboratory (RF-MEMS) – E4

**Lab Head Dr. A. Müller** (alexandru.muller@imt.ro)

***Mission:*** scientific research and technological development of micromachined microwave and millimetre wave devices and circuits. The new RF MEMS technologies including "membrane supported circuits" represent an emerging solution to manufacture high performance microwave and millimeter wave devices and circuits devoted to the new communication systems and sensors. Lately the laboratory has also started the research to develop acoustic devices using micromachining and nano-processing of wide band gap semiconductors (GaN/Si, AlN/Si) and experimental devices based on carbon nanotubes and graphene.

***Main area expertise:***

- Development of a new generation of circuits devoted to the millimeter wave communications based on the semiconductor (Si, GaAs, GaN) micromachining and nanoprocessing
- Design and manufacturing of micromachined, passive circuits elements, monolithically and hybrid integrated receiver front-ends based on silicon and GaAs micromachining;
- Acoustic devices (FBARs and SAWs) for applications in the GHz frequency range, based on micromachining and nanoprocessing of wide band gap semiconductors, (GaN and AlN);
- UV photodetectors based on GaN/Si membranes
- MEMS and NEMS technologies developement
- Microwave devices based on carbon nanotubes and graphene
- Microwave devices using CRLH materials (metamaterials);

***Specific facilities 2007-2011***

"On wafer" measurement system in the **0.1-110 GHz** range (microwave network analyzer from Anristu with SUSS Microtec Probe Station), Frequency Syntesizer (Agilent) up to 110 GHz; Spectrum Analyzer (Anritsu) up to 110 GHz; Tektronix digital serial analyzer up to 50 GHz with TDR module; Keithley Semiconductor characterization system, Optical profiler WLI – Photomap 3D from Fogale; Millimeter wave power-meter in 0.1 – 40 GHz range, Measurement accessories. Setup for UV responsivity measurements Computers and software for microwave electromagnetic simulations (IE3D, Fidelity, CST, and Comsol software packages)

**ISI ranked papers** (2007-2011) **53**; **Cumulated relative influence factor 106.27**

***History-„MEMSWAVE"(1998-2001) the first European project coordinated by an Eastern European Country***

In 1996-1997 the microwave laboratory from IMT was one of the first European teams which have developed microwave passive circuits having as support a thin dielectric membrane (1.5 µm $SiO_2/Si_3N_4/SiO_2$) obtained by silicon micromachining. This emerging solution, first time developed at Ann Arbor Univ Michigan, has as result a major improvement of circuit performances in term of losses, in the mm wave frequency range. More than this, thin GaAs membranes technology has been developed, to support more complex circuits. In 1997 IMT-Bucharest won, in the last call of the EC FP4 program, as coordinator, the „MEMSWAVE" project (2008-2011) (coordinator Dr. Alexandru Muller), one of the first RF-MEMS projects financed by the EC (partners Upsala Univ, FORTH Heraklion, ITC Trento, CNR and Univ Tor Vergata Rome, HAS Budapest, ISP Kiev). The project was nominated in 2002, between the 10 finalists for the Descartes prize of the EC. This was the first and for a long time the only EC project in the IST topics coordinated by an Eastern European country. For the first time a micromachined direct receiver module for 38 GHz having both the antenna as well as the Schottky diode supported on the same 2 µm thin GaAs membrane, was develped. This succesful project has generated an international workshop in RF-MEMS („MEMSWAVE") which was 2011 at the 12-th edition.

## *Involvment in FP7 Projects (2007-2011)*

### *Participation in the FP6 NoE in RF MEMS AMICOM (2004-2007)*

The IMT RF-MEMS lab. team has participated in the European FP6 NoE in RF MEMS AMICOM. (coordinated by LAAS-CNRS Toulouse). A lot of cooperative research has been developed in this project. IMT has essentially contributed to the design and manufacturing of the first membrane supported Yagi-Uda antenne manufactured by Silicon and GaAs micromaching (cooperation with LAAS and FORTH), the direct receiver based on the monolithic integratin of micomachined Yagi-Uda antenna with a Schottky diode. The Millimeter Wave Identification Concept (MMID)was developed by IMT in cooperation with VTT Helsinki and FORTH Herakion in the frame of the AMICOM project, using a Yagi-Uda antennae based receiver. A WLAN filter for 5.2 GHz was developed using micromachining techniques of Silicon, (cooperation with LAAS).

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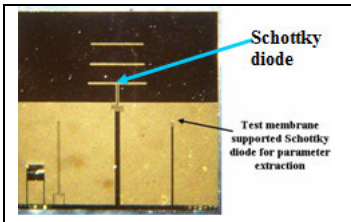
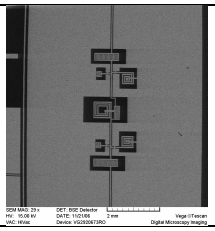
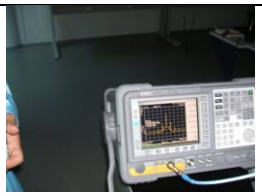
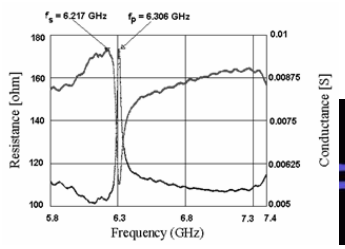
|  |  |  |  |
| *Yagi-Uda antenna in a 60GHz membrane supported receiver* | *SEM photos of the WLAN 5200 filter : top view [A95]* | *Millimeter wave identification system at 60 GHz [A61]* | |

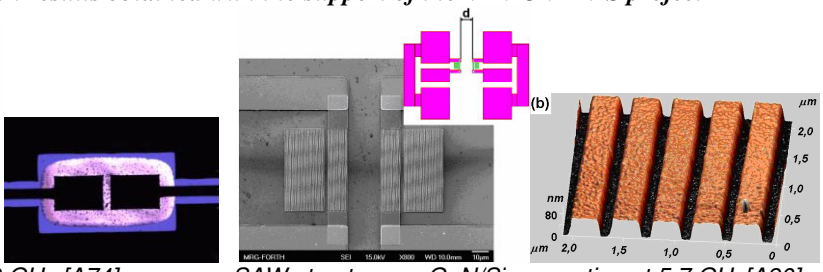
***MIMOMEMS-FP 7 REGPOT call 2007-1 "European Centre of Excellence in Microwave, Millimetre Wave and Optical Devices, based on Micro-Electro-Mechanical Systems for Advanced Communication Systems and Sensors" (2008-2011), coordinator Dr. A. Müller***

This big FP7 project (about 1.1 MEUR) is presented "in extenso" as the representative project of the institute, has facilitate a strong development of the microwave lab team in terms of human potential (3 Post docs, now permanent staff, hired), upgrade research equipment, funding mobilities for: (i) preparing new FP7 and FP7 related projects proposals. **Results**: **6 winning projects: 2 FP7 Integrated Projects (SMARTPOWER and NANOTEC both 2011-2014); 2 ERA- NET and 2 ENIAC projects, (ii)** new research topics development in cooperation with twining partners (FORTH Heraklion and LAAS Toulouse)-**Results**: State of the art results published in high ranked ISI journals have been obtained in cooperation with FORTH Herakloin and LAAS CNRS Toulouse in GaN based acoustic devices for GHz applications.

***State of the art results obtained with the support of the MIMOMEMS project***



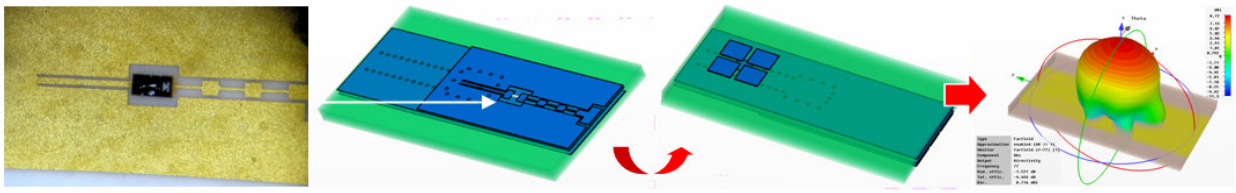

*GaN/Si FBAR resonating at 6.3 GHz [A74]*




*SAW structure on GaN/Si resonating at 5.7 GHz[A90]*

***Participation in FP7 MEMS 4 MMIC STREP (2008-2012)*** *(responsible of IMT team Dr. Dan Neculoiu)*

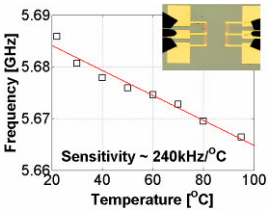
In this STREP coordinated by IMST Camp Linfort (D) with partners VTT Helsinki, Ommic France, FOI Sweden, CNRS France, IMT is involved in the design and characterization of K-band frequency millimeter wave circuits



*77 GHz receiver designed by IMT Bucharest and processed at VTT Finland [C230]*

***Participation in FP7 IP SMARTPOWER (2011-2014) (****responsible of IMT team Dr. Alexandru Müller*)

This project started in September 2011; the IMT team is involved in the manufacturing of a GHz SAW based temperature sensor, which will be integrated with a HPA and a LNA. Work will be performed in cooperation with FORTH Heraklion and **Thales TRT the coordinator of the IP**. The sensing system will be placed close to the GaN MMIC in a radar-system developed by Thales Systemes Aeroportuare, to measure the temperature. Preliminary determinations for the frequency shift for the SAW sensor have been done already.




***Participation of the FP7 IP NANOTEC (2011-2014)*** *(responsible of IMT team Dr. Alexandru Müller*)

This project also started in September 2011 and is coordinated by **Thales TRT** In this project IMT will be involved in design and characterization of 94 GHz front ends manufactured on GaAs and SiGe. IMT will be also involved in characterization MEMS and NEMS based millimeter wave switches

## ***Involvement in FP7 related projects***

***a ENIAC projects:***
**-SE2A coordinator NXP (Nl) (2009-2011).** IMT has demonstrated a true ground speed sensor based on radar type measurements and a gas sensor based on FBAR structures;
**-MERCURE coordinator Thales TRT (2010-2012)** IMT develops a humidity sensor based on FBAR structures;
**-NANOCOM coordinator Thales TRT (2011-2013)** IMT develops RF MEMS circuits on GaAs and GaN**.**

**b ERANET project: "MEMIS" coordinator LAAS CNRS Toulouse partners IMT, VTT Helsinki, 31 Degree, France ( 2010-2012);** An imaging system in the mm wave range (94 GHz) is in progress

**c COST action: MP 0805 "Novel Gain Materials and Devices Based on III-V-N Compounds" 2010-2012**

**Bilateral cooperations:** (i) **Univ. Pretoria South Africa** project "A radio system at 60 GHz" (2009-2011) (ii) **KERI Changwon South Korea** project "Acoustic devices and energy harvesting systems" –(2010-2011)

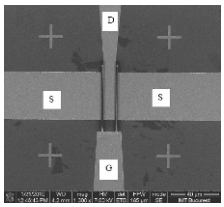
**Associated European Laboratory "SMART MEMS/NEMS for advanced communications and sensing"** ("LEA SMARTMEMS" 2009-2012). LEA brings together the research groups from IMT-Bucharest, LAAS-CNRS Toulouse and FORTH Heraklion. The objectives of this "laboratory without walls" are: free access to the infrastructures of the partners, researchers' exchange (including PhD and Master Students).

**Main scientific cooperation partners: FORTH Heraklion, LAAS Toulouse, VTT Helsinki, Thales (Fr)**

**National projects:** The team coordinated 5 projects PN II "Parteneriate" program (2007-2011) (GIGASABAR; BIOSENSE; MIMFOMEMS; NANO HF; METALASER). In the recent IDEAS competition 3 projects from were successful: *"Nanoelectronic devices based on grapheme for high frequency applications" (Dr M. Dragoman), "Novel technologies based on micromachining and nano-processing of GaN/Si, for advanced microwave and photonic devices" (Dr. A. Müller) and „Millimeter-wave Front-End for Imaging in Security and Medical Applications" (Dr. D. Neculoiu). The three years projects started in October. 2011.*

## New directions:

*-**Graphene nanoelectronics for microwave applicatios (Dr M. Dragoman)***

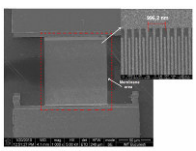



The ballistic regime in graphene takes place at room temperature over a distance of 0.4 μm and the carriers have an intrinsic mobility of 44 000 $cm^2$/Vs. Moreover, microwave devices based on graphene have tunable input impedances around 50 Ω, specific for RF applications. A novel graphene based transistor with a maximum stable gain of 2 up to 4 GHz and a cutoff frequency of 80 GHz has been developed [A71, A78, A82, A93]

***-Metamaterials (Dr. Gh. Sajin)***

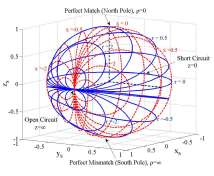
A Composite Right/Left-Handed Coplanar (CRLH) waveguide antenna for 14 GHz was processed on a ferrite substrate [A91]. By magnetically biasing the ferrite substrate, a frequency tuning of about 500 MHz was achieved. Recently, mm-wave (40 GHz) CRLH antennas for applications in integrated circuits were designed, processed and characterized.

***-Membrane supported GaN/Si UV photodetectors (Dr. A. Müller)***



A new type of UV photodetector processed by micromachining technology of GaN/Si has been developed. The device has a very high responsivity under backside illumination conditions [A57, A100]. The work was done in cooperation by IMT and FORTH Heraklion.

***-New methods for microwave circuits design, based on modern mathematical tools***



A 3D Smith chart which can be used for the design for all passive and active circuits, has been developed by PhD student Andrei Müller [A94] (thesis sustained in Oct 2011). Using the concepts of extended complex plane, inversive geometry and Riemann sphere the generalized Smith Chart can include all the complex loads in the reflection coefficient plane. The work was developed together with Polytechnic Univ. of Valencia

***Young scientists***

The lab is composed by 9 PhDs, 2 PhD students, 2 researchers (without PhD), 2 technicians. In the period 2007-2011, 4 PhD students become PhDs. In 2009, 3 young Post-Docs (two from abroad) have been hired and are now permanent staff (2 in our lab). Three members of the lab (2 PhDs and 1 PhD student) are in the age 25-30. Other two PhDs are in the age 30-40.

# Simulation, Modelling and Computer-Aided Design Laboratory – E5

**Mission:** research, **simulation and modeling** activities oriented to collaborative research projects, **education** (short courses, labs for students: hands on training), **services** (offering **access to hardware and software** tools) and consulting (design/optimization) in the field of micro-nano-bio/info technologies. **The lab plays a key role in supporting the research activities of other laboratories of IMT-Bucharest.**
Besides its main mission the lab is developing techniques for **rapid prototyping** from micro- to macro (up to centimetre size structures), **dip pen nanolitogrphy** and investigate new classes of advanced materials with application in nanodevices.

**Main expertise**:
**- design, development and optimization** of **MEMS/MOEMS** components and devices (switches, cantilevers, bridges, membranes, microgrippers); mechanical, thermal, electrical and electrostatic, piezoelectric, **as well as coupled field** (static and transient) **analysis**; modeling and simulation for multi-physics problems**; design, modelling and simulations of microfluidic components and systems** for biomedical applications and micro-electronic fluidic systems (valves, pumps - with various actuation principle as electrostatic, piezoelectric, pneumatic, electroosmotic- cell reservoirs, microchannels, filters, mixers, heaters, etc.) – the microfluidic analyzes include: fluid dynamics in microstructures (general flow, fluid mixing, thermal analysis); electrokinetic flow (electrophoresis, electroosmosis); modelling of optoelectronic devices, neural networks; modelling of electronic structure of materials using **ab initio calculations**.
**- rapid prototyping:** design for and operation of 3D Printer based on selective laser sintering, 3D Printer
- **characterization of physical phenomena** in wide band gap semiconductors (light emission, optical transitions, radiative-nonradiative centers, shallow and deep donors/acceptors, band gap tailoring).

**The team:** has a multidisciplinary expertise in: mathematics (1 PhD and 2 PhD students), physics ( 2 PhD and 2 physicists), electronics (3 PhD), electro-technical (1 engineer). Average age of the team: 42

**Research collaborations (international and national)**.
**Expertise in national and international cooperation**: **FP6 and** FP7 projects: NoE, STREP, CA, IP, RTN Marie Curie, Leonardo da Vinci – and **Related FP7: ENIAC**
***Scientist in charge for Romania*:**
**FP6- NoE: PATENT Modelling and Simulation WP** (2004-**2008**)-
**FP6-STREP: Mi-lab-on-chip** (2005-**2008**), **FP6 - RTN Marie Curie: ASSEMIC** (2004-**2007**), **IPMMAN** (2006-**2009**),
***Leonardo da Vinci***: New teaching and learning methods and basic qualifications in job education (Microteaching) 2004-**2007-** No. 146157; ComEd (**2008-2010**), Ctr.DE/08/LLP-LdV/TOI/147
***Participation***
**FP7-IP: FLEXPAET 2008-2011**(**participation**, **supporting** L3 – Microphotonics Lab of IMT)
**FP7 STREP: CATHERINE 2008-2011** (**participation**, **supporting** L6- Nano-scale structuring and characterization Lab of IMT)
Bilateral cooperation with Institute of Applied Physics, Academy of Science of Moldova (2010-2012);
**ENIAC: Nanoelectronics for Electric Vehicle Intelligent Failsafe PowerTrain" – MotorBrain (2011-**2014)**,** coordinator Infineon Technologies AG Germany

**Projects, Publications and patents**

- National projects: **20** (2007- 2011) coordination, **15** as partner

- 4 Patents and 12 request ; Sientific papers 15 ISI journal, 7 non ISI journals and 77 conference papers.

**Training activities**

- Hands-on course "Microsensors", for students of year IV, Faculty of Electronics, Telecommunications and Information Technology, "Politehnica" University of Bucharest- laboratories

▪ Hands-on course "Intelligent sensors and microsystems", for master students, Faculty of Electronics, Telecommunications and Information Technology, "Politehnica" University of Bucharest- laboratories and lecureres; practical courses for simulation organized in the frame of POSDRU Project (2010-2013) "*Human resources development through postdoctoral research in micro and nanotechnologies domain*."

■ Short simulation courses for companies in the frame of the Leonardo da Vinci projects

■ Simulation Labs for students from different universities from Bucharest and Romania (Ploiesti, Targoviste, Cariova)

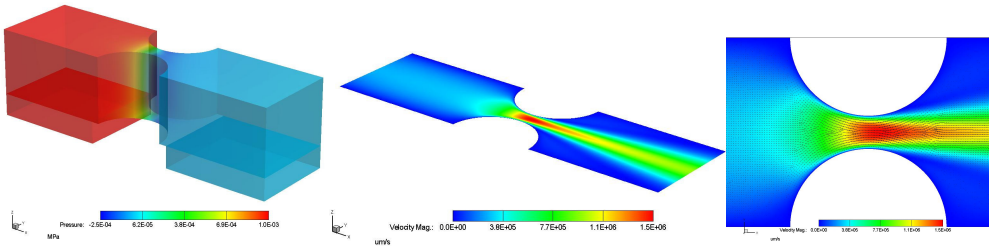
**Brief description of the main results of the laboratory :** The lab was involved in two **CAPACITIES** national projects and was funded for establishing and coordinating two *new experimental entities*:

► **LABORATORY FOR MODELING AND SIMULATION OF MICROSYSTEMS - LAMSYS** (2007-2009) **Project Type: PN II- Capacities; Contract no.7/2007; Project manager: Dr. Oana Tatiana Nedelcu**

The main objective of the project was the development of the research infrastructure in the field of modeling, simulation and computer aided design for microsystems, improvement of the research capabilities, offering scientific services in a dedicated laboratory, by modernization the existing

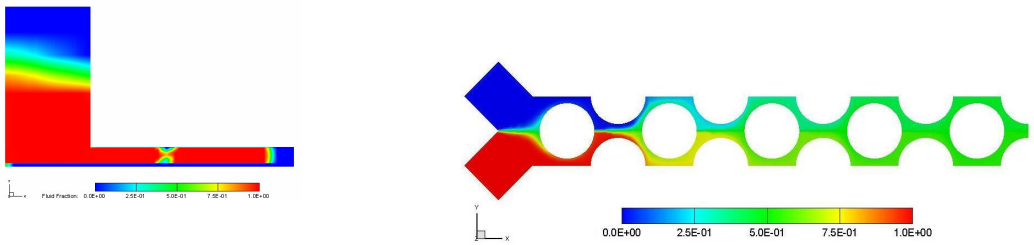
► **INTEGRATED LABORATORY OF ADVANCED TECHNOLOGIES FOR MICRO AND NANOSYSTEMS - MICRONANOLAB** (2007-2009); **Project Type: PN II – Capacities; Contract no.13 / 2007 - Project manager: Dr. Gabriel Moagăr-Poladian**

The main objectives are: services from nanoscale (dip pen nanolithography) to sub-milimeter and normal scale (3D Printing), research in the field (improving or design, proof of concepts) of new technologies for rapid prototyping at these scales, developing new materials and devices base on the above techniques



*Pressure (MPa) and velocity (µm/s) distribution for flow between 2 filter columns, using **COVENTORWARE***

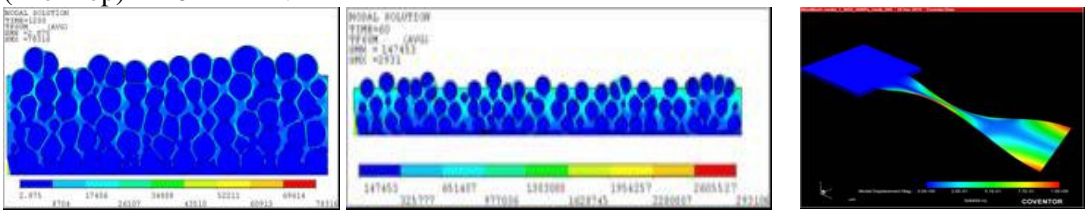
Results in the frame of FP6: MI-Lab on chip- "Lab-on-a-chip implementation of production processes for new molecular imaging agents- STREP NMP-No 516984, (2005-2008), coordinator University of Liege




*COVENTOR 2010 simulation:fluid fraction distribution in micromixers- National Project*

*CoventorWare simulation of droplet formation using the electrowetting principle*

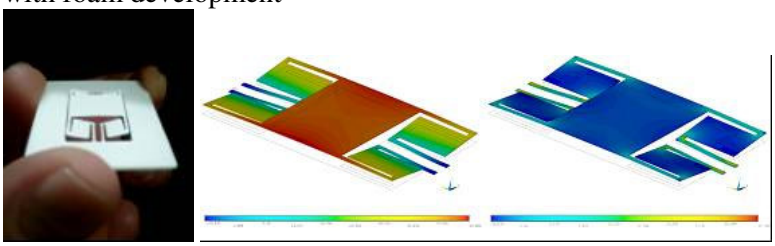
Droplet-Based Micro-Electronic Fluidic Operations for Production and Evaluation Platform BioMEMS (BioDrop)- FP6 PATENT



*COVENTOR 2010 simulation: Simulation of the natural oscilation mode of a cantilever (Torsion Mode) National Project*

*Thermal flux in the initial stage (a) and last (b) of foam formation (note the thermal flux differences)*

**ANSYS** simulation was carried out by IMT, studying initially the development of only one bubble of gas in the layer of protective paint, and then using the result to create home made software in order to deal with foam development



*Polymer microstructure manufactured by p using the 3 D Printer based on selective laser sintering- left; Simulation results of the optimized structure: displacement of the membrane and - the von Mises stress- right*

**Short description of the equipments of the laboratory**

• **COVENTOR 2011**; • **MATLAB 7**; • **ANSYS Multiphysics 11.0 ( 2011)**; • **COMSOL Multiphysics 3.3 and 3.4**; • **Solidworks Office Premium 2008** ; • **Mathematica 7**; • **Origin PRO 8**; • **Visual Studio 2008 Pro**; • **Dual IBM 3750 Server**, 8 quad-core Intel Xeon MP 2.93 GHz processors, 196 GByte RAM and 1 TByte HDD + 876 GByte external storage;
• **Computer network for training**
• Dip pen Nanolitography, Selective Laser Sintering P100 Formiga system for Rapid prototyping, *3D PRINTER BASED ON SINGLE PHOTON PHOTOPOLYMERIZATION MINIMULTILENS SYSTEM FROM ENVISIONTEC*, Semiconductor Characterization System (DC) with Wafer Probing Station - 4200-SCS/C/Keithley Instruments /Suss

**Collaboration:** The team cooperate with all the other labs of IMT Bucharest in the frame of different projects and also has an important number of national partners, as well as internationals.

The expertise of the lab in **MEMS- MOEMS and microfluidic** simulation was recognize in the frame of FP6 PATENT, coordinated by Univ. of Lancaster were young researchers- participated to different **flagship grants ( cooperating** with MESA + Institute for Nanotechnology, Twente, Tyndall Cork, CCLRC- UK, Heriot-Watt University (HWU) – Edinburgh, Warsaw University of Technology, as:
- Droplet-Based Micro-Electronic Fluidic Operations for Production and Evaluation Platform - BioMEMS
- Fault Modelling and System Simulation of FlowFET-Based MEF Arrays ,
- Simulation of the stiction effect in the metal-to-metal resistive contact occurring in MEMS switches,
or in FP6 MI-lab-on- Chip, coordinated by Univ. of Liege.

**Other international cooperation** : ISAS Sensor and Actuators - Tech. Univ. Vienna, companies as Profactor Produktionsforschungs GmbH – Austria, Nascatec Germnay, **Infineon IFRO Romania or Infineon Technologies AG Germany**, in the frame of new **ENIAC project** MOTORBRAIN, started in 2011 and devoted to automotive field (involvement in design of nanostructures based torque sensor).
Johannes Kepler" University of Linz, for characterizing the piezoelectric properties of polymer structures realized at the 3D Printer based on selective laser sintering; University of Le Havre, France.

**National Cooperation with companies**: S.C. Transelectrica S.A, Bagdasar-Arseni" Neurosurgery Hospital, S.C. ICEMENERG S.A, S.C. ProOptica S.A, Sitex 45 SR,.

The team participated to the establish of the **European Technology Platform for Micro- and Nano Manufacturing** MINAM, being active member and actively involved in the editing of the **MNT FUTURE VISION Newsletter** of the platform.

► Many training activities for simulations using different software tools
► Major role in the hardware and software infrastructure of IMT, mainly for MEMS and microfluidic design and simulation of sensors and microsystems

During 2007-2011 period 2 early stage researcher become members of the labs, in 2011 finishing their PhD Thesis.

Head of lab: Dr. Raluca Müller (raluca.muller@imt.ro)

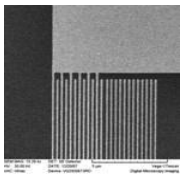
## NANO-SCALE STRUCTURING AND CHARACTERIZATION LABORATORY (E6)

The **Nano-scale structuring and characterization Laboratory** is part of IMT Bucharest Centre of Nanotechnologies (http://www.imt.ro/CNT/) functioning under the aegis of the Romanian Academy.

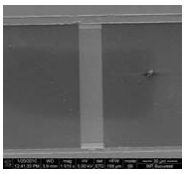
**The mission** of the **Nano-scale structuring and characterization Laboratory** is to:
- support the activity of IMT Bucharest with experimental characterization capabilities consisting of advanced equipment and skilled personnel in the field of characterization methods for materials, processes, structures and devices at micro and nano scale.
- enhance the nanofabrication capabilities of IMT Bucharest by providing nanoscale patterning through electron beam lithography-based techniques
- disseminate the scientific knowledge to the national and international research community

**Main areas of expertise:**

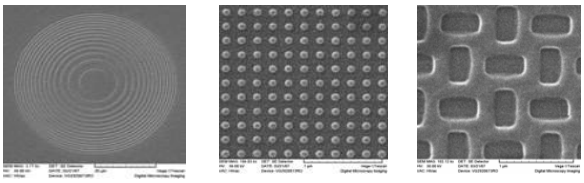
- Nanoscale characterization of surfaces and interfaces by Scanning Probe Microscopy. We were the first team in Romania to use an Atomic Force Microscope (since 1996) and have played a pioneering role at the national level in AFM characterization.
- Small-scale mechanical characterization by depth-sensing nano-indentation techniques. We have acquired and put to use the first Nano Indenter ever installed in Romania
- Scanning Electron Microscopy (both conventional and field emission) and Energy Dispersive X-ray Spectrometry
- Nanoscale patterning by Gaussian beam Electron Beam Lithography (EBL). Our lab was the promoter of this nanolithographic technique at the national level, through the installation in 2006 of the first EBL system in Romania: a SEM (TescanVega II LMU) converted to lithography with a pattern generator (Raith Elphy Plus). This equipment facilitated the fabrication of various nanostructures and nanodevices: MSM-UV photodetectors, AW structures for microwave applications, micro and nanostructures for photonic applications.



*SAW structure with 150nm digits*



*MSM-UV photo-detector on GaN*

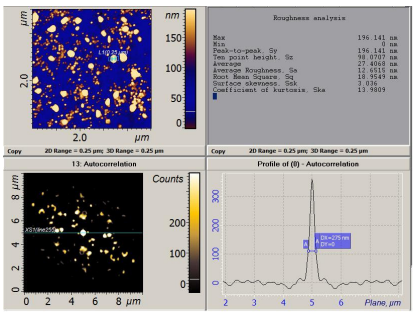


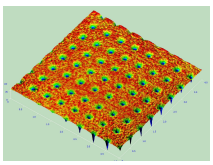
*Micro and nanostructures for photonic applications*

**Brief description of the main results of the laboratory**

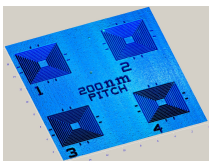
***PN2 projects (2007-2011)***

- **Laboratory for Nanoscale Characterization of Surface Morphology** (CEEX/ Module IV/ P-CONFORM, 2006-2008)





*80 nm pits produced in PMMA by EBL*




*Certified test structure for AFM calibration*

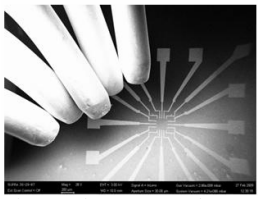
*YBCO layer morphology characterization*

The scope of the project was to establish an accredited laboratory for morphological characterization and analysis of surfaces at nanometric scale. To accomplish this goal a state of the art **Scanning Probe Microscope** (SPM) equipment ( *Ntegra Aura – NT-MDT*) was acquired and also specific technical methods and procedures were

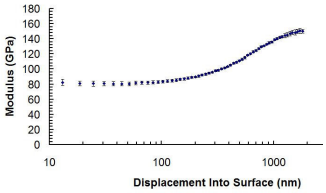
developed in order to ensure the validity and reliability of the measurements. The laboratory provides reliable characterization services for laboratory or industrial research of materials whose surfaces have a nanometric scale structure, ex: optical surfaces (in optical components), biocompatible metals and ceramics, materials for semiconductor industry, coating and protection films etc.

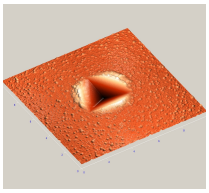
- **Functionality Enhancement of Nanoscale Structuring and Characterisation Laboratory NANOSCALE-LAB - NANOSERV** (PN II/CAPACITIES, 2007-2009)

The project aim consists in extending the capabilities of **NanoScaleLab** of IMT Bucharest by completing its infrastructure in order to enhance the performance of existing technological (structuring) equipments and also complement its characterization capabilities. Under the project up-grading modules were acquired for the *e-line Ultra High Resolution Electron Beam Lithography and Nanoengineering Workstation, Raith GmbH* that allow to use the EBL installation at maximum performance*:* **nanomanipulation system, gas injection system** and **fixed beam moving stage (FBMS).** The acquisition of a **nano-mechanical characterization equipment** (*Nano Indenter G200 - Agilent Technologies*) supports the enhancement of **NanoScaleLab** characterization capabilities.



*Pt lines deposition by EBID-50nm line width*

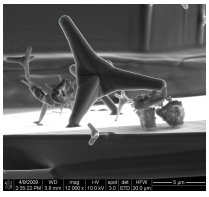


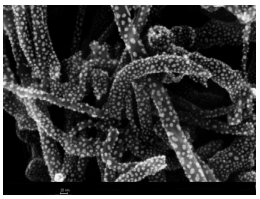
*Depth dependence of Young's modulus for a $SiO_2$ thin film on Si and morphology of the indented area*

- **Development of topographical and compositional analysis capabilities of Microphysical Characterization Laboratory - NANOSCAN** (PN II/CAPACITIES, 2007-2009)

This project had as a main goal the extension of the capabilities of Microphysical Characterization Laboratory of IMT - Bucharest in the field of topographical and compositional analysis of materials and structures for nanotechnology, nanoelectronics and biotechnology. The project provided the necessary funding for the acquisition of an ultra high resolution field emission scanning electron microscope – **FEI Nova NanoSEM 630.**



*L V SEM micrograph of uncoated ZnO Tripod deposited on glass*

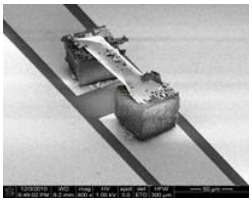


*Ag Decorated CNTs 150 k magnification*

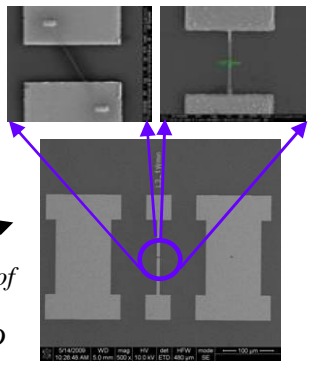
*L V SEM micrograph of Ni coated carbon fibers embedded in resin*

***FP7 projects*:**

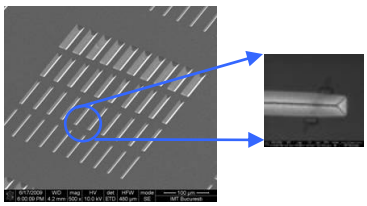
- **Carbon nAnotube Technology for High-speed nExt-geneRation nano-InterconNEcts – CATHERINE** (FP7/STREP, 2008-2010)



*SEM micrographs of test vehicle for vertical interconnects*



*Structure used for electrical characterization of CNTs at high frequencies. EBL was used for patterning the small calibration line and EBID technique for fixing the CNTs*



*Platinum deposition was used for fixing the CNTs across V-shaped trenches in order to measure their mechanical properties*

*Main results:*

- Development of cost-effective and reliable technological process for realization of high performance next-generation interconnects;
- Development of electromagnetic and multifunctional test procedures and experimental characterization methods;
- Manufacturing and testing of proof-of-concept samples of nano-interconnects at laboratory level.

**Short description of the equipments of the laboratory**

In the last five years we have equipped our lab with state-of-the-art facilities worth about two million euros, mainly through funds from research grants. We have to mention the first AFM, EBL and Nano Indenter ever installed in Romania.

- **Scanning Probe Microscope NTEGRA Aura (NT- MDT Co.)**
  Various operating modes (AFM, STM, EFM, MFM, SKPM, Conductive AFM etc); Various environments (ambient, controlled gaseous, liquid, low vacuum);. Scanning by head; scanning by sample; STM head; module for electrical measurements.
- **Nano Indenter G200 (Agilent Technologies, Inc.)**
  Nanomechanical characterization equipment, especially for small-volume samples (e.g. thin films); Methods compliant with ISO 14577 and ASTM 2546; Module for continuous stiffness and dynamic measurements (e.g. polymers).
- **Field Emission Gun Scanning Electron Microscope (FEG-SEM) –FEI Nova NanoSEM 630 (FEI)**
  *Characteristics:* Ultra-high resolution characterization at high and low voltage in high vacuum: 1.6 nm @ 1 kV; beam deceleration mode with sub-100 V and high surface sensitivity imaging; low and very low kV backscattered electron imaging for compositional characterization in high and low vacuum; 150 x 150 mm high precision and stability piezo stage.
- **Tungsten Heated Filament Scanning Electron Microscope-Tescan VEGA LMU II** and **Energy Dispersive X Ray Spectrometer with Si(Li) detector – EDAX**
- **Electron Beam Lithography and nanoengineering workstation – Raith e_Line**
  *Characteristics:* Field emission electron gun with 1.5 nm beam diameter at 1 kV accelerating voltage, laser interferometer controlled stage, writing resolution better than 20 nm, stitching accuracy better than 40nm, overlay accuracy better than 40 nm, facilities for Electron Beam Induced Deposition.

**Publications and patents:**

- 35 articles in ISI journals with a cumulated influence score of 43,8 (Thin Solid Films, Applied Surface Science, Applied Physics Letters, Journal Of Physics D-Applied Physics, Carbon)
- 65 papers in ISI- indexed proceedings of international conferences

**Collaborations :**

*Abroad:* Università degli Studi di Roma "La Sapienza" - Research Centre for Nanotechnology Applied to Engineering (SAPIENZA-CNIS) – Italy; Technische Universiteit Delft – Department of Precision and Microsystem Engineering - The Netherlands; Universite Paul Sabatier Toulouse – France; Università degli Studi di Salerno – Center NANO_MATES – Italy; Swedish Defense Research Agency, Department of Sensor Technology – Sweden; Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati (LNF) – Italy; Smoltek AB – Sweden; Institute for Solid State Physics – Latvia

*National:* University of Bucharest, Politehnica University (Bucharest), Technical University Gheorghe Asachi (Iasi), University of Craiova , INCDFM , INFLPR, ICPMPP, Zoom-Soft SRL, DDS Diagnostic

**Young scientists:** Between 2007 and 2011 a number of 5 young scientists were employed in our lab (1 physicist, 1 chemist, 3 electrical engineers).

Head of Lab: Dr. Adrian Dinescu (adrian.dinescu@imt.ro)

# Reliability Laboratory (E7)

## 1. The mission of the laboratory and main research activities

- The mission of L7 is to provide tools and expertise to improve the design & technology of sensors, actuators, microsystems, nanostructures and microelectronic components by assessing and building the quality & reliability in a Concurrent Engineering approach [1].
- The main research areas of L7 are:
  - Reliability building: Design for reliability [2] and testability - design for manufacture, Reliability monitoring & screening of micro and nanostructures, Burn-in and selection, Reliability of components used in harsh environment (nuclear, geology, automotive, aeronautics, etc.);
  - Reliability assessing: Accelerated testing of micro and nanostructures [3]; Failure analysis & physics, Data processing & Reliability prediction [4], Behaviour of electronic components in harsh environment, Virtual prototyping [5];
  - Failure analysis: Various methods for identifying the failure mechanisms [6];
  - Standardization: Certification, Qualification and periodic tests [7], Standards and other specifications;
  - Microbiosensors: Detectors of dangerous elements in environment and food [8].


[1] M. Bâzu, „Concurent Engineering - A Tool for Improving MEMS Research and Manufacturing", 24th International Conference on Microelectronics (MIEL), Nis, Serbia & Montenegro, 16-19 Mai 2004, pp.41-48

[2] M. Bazu and T, Bajenescu, Designing the Reliability of Electronic Components, *Quality Assurance*, Vol. XV, No. 59, April-June 2009.

[3] M. Bazu, L. Galateanu, V. E. Ilian, J. Loicq, S. Habraken, J.-P. Collette, Quantitative Accelerated Life Testing of MEMS Accelerometers, *Sensors,* 2007*, 7*, 2846-2859.

[4] M. Bazu, A combined fuzzy/logic & physics of failure approach to reliability prediction, *IEEE Transactions on Reliability*, Vol. 44, no. 2, 1995, pp. 237-242.

[5] M. Bâzu, C. Tibeică, L. Gălățeanu, V.Ilian, Reliability assessment by virtual prototyping of MEMS tunable Faby-Perrot optical cavity, *Proc.of International Semiconductor Conference CAS 2004*, 27th edition, Sinaia, Romania, October 4-6, 2004, pp.249-253.

[6] M. Bâzu, T. Bâjenescu, *Failure analysis. A practical guide for manufacturers of electronic components and systems*, J. Wiley & Sons, 2011, ISBN 978-0-470-74824-4.

[7] V.E. Ilian, E., Manea, M. Bazu, L. Galateanu, Solar Cells Reliability Testing Programs, *12th International Conference on Quality and Dependability*, organised by the Romanian Society on Quality Assurance and IEEE, 21-24 Sept. 2010.

[8] L. Galateanu, s.a., Building an Electrochemical Micro-Cell for Micro-Biosensors, *Proc.of International Semiconductor Conference CAS 2005*, 28th edition, Sinaia, Romania, October 3-5, 2004, pp.231-234.


## 2. Brief description of the main results of the laboratory in the international projects FP7 or others such as bilaterals and PN2 (2007-2011)

- Participant in the European project « *Design for Micro and Nano Manufacture - Patent-DfMM*" (PC6/IST, 2004-2008), a NoE with 24 partners (research institutes, universities and companies active in microsystems). Dr. M. Bazu was member of the Management Board and leader of the Reliability Cluster (14 participants). L7 obtained important scientific results in studying the typical failure mechanisms of microsystems [9-10] and in developing a new equipment for reliability testing of microsystems, starting from an original idea (see Figures 1 and 2). Two patents were obtained on this subject [11-12]). Also, L7 realized for Patent-DfMM a database containing the reliability equipment existing at network participants.


[9] T. Bajenescu, M. Bazu, *Component reliability for electronic systems*, Artech House, 2010, ISBN-10: 1-59693-436-0.

[10] P. Salomon, M.Bazu, H. Van Herren, S. Lavu, J. Bunyan, M.Desmulliez, The Reliability of Micro Nano Systems, *MST News*, No.5, 2008, pp. 20-22.

[11] L.Galateanu, V.E.Ilian, M.Bazu, V.L.M. Ilian, *Banc de incercare mecano-climatica complexa a microsistemelor*, Brevet 122964 / 28.05.2010.

[12] V.E. Ilian, L.Galateanu, M.Bazu, V.L.M.Ilian, *Procedeu de încercare mecanică a dispozitivelor MEMS*, Brevet 122963 / 28.05.2010.


- Contractor of "Micro-biosensors for pesticide detection in environment and food samples", project (2007-2010) in the National Research Programme "PARTNERSHIP" (PN2). A

micro transducer was obtained, based on metallic multilayer deposition by vacuum evaporation on a silicon substrate [13]. The achieved micro biosensors ensure efficient, rapid and cheap bio detection, allowing to monitoring the concentration of the organophosphate insecticides in samples of environment and food, at the levels required by the international legislation in the field. The developed method allows determining by a single analysis the presence of any organophosphate insecticide; it is simple to be used and could be applied in laboratories with medium level infrastructure. This allows monitoring the environment, to locate the pollution sources and to take the necessary protection methods.

[13] L. Galateanu, M. Bazu, V. Ilian, C. Tibeica, N. Cimpoca, Cecilia Podaru, I. Ardelean, Lucia Dumitru, M. Grigoras, Maria Ivanoiu, M. Totolin, D. Conduruta, *Electrochemical micro-cell for (cyano)bacteria-based biosensors*, Romanian Journal of Information Science and Technology, v.9, nr.2, 2006.

- Contractor of "Infrastructure development for reliability research in integrated micro-nano systems", project (2007-2009) in the National Research Programme "CAPACITIES" (PN2), and of "Development of a laboratory for assessing the quality of the products of micro technologies according to EU requirements - LIMIT", project (2006-2008) in the National Research Programme "National research Programme „Excellence in Research – CEEX. These two projects allow to purchase modern equipment for reliability testing, mainly at combined stresses [14-15]. Details about the equipment are given below.

[14] M. Bazu, L. Galateanu, V. E. Ilian, Reliability Accelerated Tests for Microsystems, *34th International Spring Seminar on Electronic Technology - ISSE 2011*, High Tatras, Slovakia, May 11-15, 2011.
[15] M. Bazu, L., V.E. Ilian, Typical Failure Mechanisms of Microsystem Technology, *12th International Conference on Quality and Dependability*, organised by the Romanian Society on Quality Assurance and IEEE, 21-24 Sept. 2010.

- Contractor of "Technologies at nanometer scale: time degradation phenomena", CNCSIS grant (2006-2008). Systems for evaluating the reliability of nanostructured materials, nanoelectronic structures and NEMS were elaborated. The annual project workshops, common with the CEEX project NANOCRYSTALNET (Oct 10, 2007 and Oct.17, 2008), held at the University Politehnica Bucharest, gathered Romanian specialists in nanotechnologies and invited specialists, professors at universities from Valencia (Spain) and Gauhati (India).

[16] M. Bazu, L.Galateanu, V.Ilian, About Nano-Reliability, *Quality Assurance*, No.55, July-October 2008.
[17] M. Bazu, L., V.E. Ilian, L. Galateanu, A New Challenge - the Nanoreliability, *Bulletin of Micro and Nanoelectrotechnologies*, Vol. 2, no.1, March 2011, pp. 7-11.

- Member of the "Interdisciplinary network for synthesis and studying semiconductor and conductor nanostructures for obtaining photonic and optoelectronic devices usable in biology and medicine – NANOCRYSTALNET", project (2005-2008) in the National research Programme „Excellence in Research – CEEX", 8 partners (co-ordinated by the University Politehnica Bucharest).

- Bilateral project between IMT-Bucharest and Technical University of Kosice (Slovakia) (2011-2012), focused on time and stress phenomena in lead-free solder joints.

**3. Short description of the equipments of your laboratory and nominate the personal working in MINAFAB area indicating the equipments on which they are working**

L7 is aimed to evaluate the quality of microtechnology products according to EU requirements, being provided with modern equipment (purchased in 2007-2009) for:

- Electrical characterization: *Electrical characterization: 4200SCS system (Keithley): Voltage CC<100V, Current CC<1A; Impulses: analogical signal 30V, <40MHz; Measurements: Voltage 0,5 μV, Current 1 fA.*
- Temperature conditioning: *Temptronic TP04300A-8C3-11 / Thermo Stream - Temperature variation: from - 80°C to +250°C Transition time: up 7 sec, down 20 sec; Temperature control +/- 0,1°C.*
- Environmental testing: Constant mechanical acceleration, Vibration, Storage at temperature, Hermeticity, Mechanical shock with free fall (MRAD): *Maximum acceleration 4500 g; Maximum height: 60 in; Maximum speed at impact: 200 in/sec; Minimum time duration: 0,3 ms*

- Testing at combined stresses: Damp heat, Thermal cycling, Pressure + Temperature (*49 l; +20 ... +200°C; 10 ... 1100 mbar)*, Thermal stress + Electrical stress, Electrical stress + Thermal stress + Humidity + Vibrations, Electrical stress + Thermal stress + Pressure (HAST: *Temperature range: +105 ... +142°C, Humidity range: 75%…100% RH, Pressure range: 0.02…0.196.*, Mechanical ("Tilting") + Thermal stress.
- Failure analysis: IR microscope SC 5600 + G3 L0605 / FLIR Systems.

**4. Cooperation with entities from abroad**

- The cooperation in the frame of the European project "Patent-DfMM", described above, allows to establishing close relationship with all the consortium members, which are European research institutes, universities and companies. Consequently, in December 2007, L7/IMT has initiated **"European Cluster for Microsystem Reliability - EUMIREL"**, a follow-up of "Patent-DfMM" project. IMT is member of the Management Board of EUMIREL, together with IMEC (Belgium), Politecnico di Milano (Italy) and Fraunhofer Institute IMS Duisburg (Germany). Other participants to EUMIREL are from France, UK, Poland, Germany, Italy and Spain.
- Recently (October 2011), Dr. Marc Demulliez (Herriot Watt University, UK), member of EUMIREL, solicited L7 for performing some reliability tests for the products obtained by the **FP7 project "Frequency Agile Microwave Bonding System – FAMOBS"** (a consortium of 14 European partners).
- A close cooperation was established in 2007 with the **Korea Electronics Technology Institute - KETI (R. Korea)**, which solicited the Reliability Laboratory (L7) of IMT-Bucharest to achieve a contract consisting in the elaboration of two documents describing the reliability issues and solutions for electronic components. Moreover, their satisfaction about the results of this contract was demonstrated by the Understanding signed between the Reliability Laboratory of IMT-Bucharest and the Reliability and Failure Analysis Center at Korea Electronics Technology Institute of KETI, in April 2008.
- The company Arcelik (Turkey) solicited L7 for a series of reliability tests (HAST (Highly Accelerated Stress Test) on a number of electronic modules produced by this company.

**5. Cooperation with entities from Romania**

- A demand of services was received from SC Băneasa Silicon SRL: 6 reliability tests for diodes encapsulated in DO4, performed on 30 items (5 for each test) withdrawn from the same batch of devices. The following tests were executed: storage at high temperature, thermal cycling, vibrations and functioning at high temperature.
- Several reliability tests on quantum dots were performed for the Centre for Microscopy, Microanalysis and Image processing of the University Politehnic Bucharest (UPB): 10 samples of quantum dots fabricated by PbS and TiO2/PbS, respectively was introduced in a sequence of tests: storage at high temperature, thermal cycling and combined test at temperature and humidiy (damp heat test). The properties of the quantum dots were measured initially and after the tests

**6.Other activities**

- Two books published by prestigious publishing houses from USA, in 2010 and 2011:
  - M. Bâzu, T. Bâjenescu, *Failure analysis. A practical guide for manufacturers of electronic components and systems*, J. Wiley & Sons, 2011, ISBN 978-0-470-74824-4.
  - T. Bajenescu, M. Bazu, *Component reliability for electronic systems*, Artech House, 2010, ISBN-10: 1-59693-436-0.

Head of Lab: Dr. Marius Bazu (marius.bazu@imt.ro)

# *Ambiental technologies Laboratory- E 8*

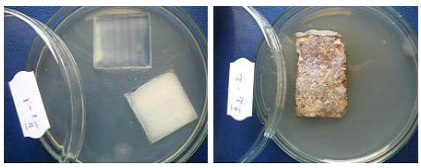
## *The mission of the laboratory:*

- New technologies developed in the areas of microsystems technologies: technological design, technological simulation and technological development up to the prototype level;
- New materials development (i.e. nanocomposites);
- New assembly techniques for microsystems (based on MCM);
- Lighting systems development (white light included);
- Technological services: technological assistance and consultancy (technological flows design, control gates, technological compatibilities) and defect analysis on technological flow;
- thermal processes (i.e. chemical synthese, RTP processes)
- Spectrometric characterization;

**Brief description of the main results of the laboratory** - PN2 (2007-2011).

***"Wood- polymer composite with components of nanostructured materials and nanosensors for improvement of indoor environment", 2007-2010.***

**Main aim:** The walls (plates) of wood-polymer structure using wastes of wood processing and PET-type wastes and plastic bags. To increase the environment protection the walls will be coated with nanomaterials protection. The main results: *"Wood-polymer" composites* were obtained in 4 variants: PAL-D, PLA-PE, (polyethylene), PLA-PE- AM (maleic anhydride) and PLA-PE-nanomaterials, which were used as chips of wood fibers of various shapes and sizes and different agents of - *compatibility*. The physical-mechanical properties analysis allowed the functionality demonstration of the different experimental models of "polymer-wood" plates. - *Polymeric matrix* with nanopowders has been obtained in 4 variants: AS–TiO2, ASAg/TiO2, AS-ZnO, AS-Ag/ZnO, where the polymeric matrix used was maleic copolymers with different coupling agents. The "wood-polymer" composites coated with polymeric matrix proved to have excellent antibacterial activity against a broad spectrum of bacteria.



Antibacterial testing of polymeric matrix containing nanopowders

"Polymer-wood" plates of dezintegrated wood type:
a) PAL – PE (polyethylene); b) PAL - PE – AM (maleic anhydride); c) PAL – PE -

***"Areas of multifunctional microtraductors based on piezoelectrical monocristaline substrate for monitoring the conditions for stocking of cereals and/or industrial plants in small silos/ farms", 2008 – 2011.***

**The aim** of this project is to monitorise the stocking conditions for the crops (grains and/or industrial plants) in small/medium farms silos. The main advantage of such Microsystems is the possibility of miniaturization, high sensibility, low detection limit, answer in short time, more easily handled and calibrated system, minimal training, small dimensions, low cost price. **The main result** is: „Microsystem for detecting humidity, temperature and contaminant in grain storage silos and/or industrial plants for small/medium sized farms"

Microsensor

Test sensors to determine sensitive substances

## Short description of the equipments of your laboratory

- **FTIR Spectrometer** (Tensor 27, Bruker Opticks): Spectral Range: 4000-400 $cm^{-1}$, Resolution: 0,5 $cm^{-1}$; Wavenumber Accuracy: 0.01 $cm^{-1}$, Scan Speed: 3 velocities, 2.2 - 20 kHz (1.4 - 12.7 mm/sec opd), Beamsplitter: KBr, Interferometer: RockSolidTM, Permanent aligned, high stability, Detector: DigiTectTM detector system, Source for MIR: Laser de HeNe, Accessories: ATR accesory (ZnSe-Cristal materials and KRS-Cristal materials), transmission accessory, manual hydraulic press; Software OPUS: automatic system for processing of dates;

Contact persons: ch. Vasilica Schiopu, ing. Alina Matei (MINAFAB)

- **UV-Vis Spectrometer** (AvaSpec-2048 TEC, Avantes): Spectral Range: 200-1100 nm; Resolution: 0,5 nm; Light source: Deuterium-Halogen light source, 215-1700 nm, incl. TTL shutter; Detector: 2048 pixel TE cooled CCD detector, DCL-UV/VIS-Detector collection lens for AvaSpec-2048 to enhance sensitivity, Quartz; Accessories: CUV-UV/VIS (Cuvette Holder, 10 mm path, includes 2 UV/VIS/NIR collimating lenses and cover); FC6-UV400-2 (6 furcated Fiber cable, 400 µm fiber, 2 m. length, SMA Terminations); FCR-22UV200/6UV400-2 (Reflection Probe, 22 illumination fibers 200 µm , 6 read fibers 400 µm fibers, common part 1 meter long, 7 legs 1 meter each, SMA Termination); Software: AvaSoft-Full Automatic system for processing of dates

Contact persons: ch. Vasilica Schiopu, ing. Alina Matei(MINAFAB)

- **Chamber furance:** maximum operating temperature 1500°C, with 8 segment pairs, each a ramp and a dwell. ***Heating elements: 4 silicon carbide*** - Powerful silicon carbide elements located on both sides of the chamber ensure good thermal uniformity. Silicon carbide elements can withstand the stress of everyday operation and provide good longevity. ***Hardwearing refractory*** brick in chamber entrance and hearth provide good resistance to abrasion Elsewhere, ***lightweight ceramic fibre*** insulation is used which ensures good energy efficiency and rapid heating Vertical counter-balanced door keeps hot door insulation away from operator. Postive break door safety switch isolates chamber from power supply, when the door is opened

Double skinned construction allows convection air flow to cool the outer case, to conform to EN61010 safety standard. Applicatipons: sintering, annealing, desintegration, etc.,

Contact persons: ch. Vasilica Schiopu, ing. Alina Matei (MINAFAB)

- **RTP** is an alternative to standard furnace processing. Its advantages include short process times (from one second to 3 minutes) and precise control of the profile (of annealing, deposition, thickness of thin films) . The following gases are available: argon, nitrogen, oxygen, $NH_3$.

Contact person: ing. Ileana Cernica, ing. Alina Matei,

- **Dicing Machines For Silicium Plates** (3M225 - Russia) with 2,3 and 4 inches, performing assignment of silicon, Si, glass substrates in chips, with diamonded dishes with thickness of 25 and 40 µm, until of maximum depth of 600 µm;

Contact person: ing. Ileana Cernica

- **Solding Thermosonic Machine With Gold Fibre** (ASM – USA): it execute operations for soldering of gold fiber of φ= 25 - 35 µm on chips at temperature of 150 - 250°C, at a frequency of 50-60 KHz

Contact person: ing. Ileana Cernica

- **Solding Ultrasounds Machine With Conexions Aluminium Fibre** (US DRATHBBONDER MDB-11-Germ): it execute operations for solder of aluminum fiber of diameter φ= 25 µm on chips, at temperature of ambiance medium, at a frequency of 50-60 kHz.

Contact person: ing. Ileana Cernica

**Internal collaborators: :**

- S.C. CEPROCIM S.A
- RESEARCH INSTITUTE FOR AUXILIARY ORGANICS PRODUCTS , ICPAO MEDIAS
- NATIONAL INSTITUTE OF RESEACH AND DEVELOPMENT FOR NON-FERROUS AND RARE METALS -IMNR BUCHAREST
- NATIONAL INSTITUTE OF WOOD - INL BUCHAREST
- NATIONAL INSTITUTE FOR ELECTROCHEMISTRY AND CONDENSED MATTER TIMISOARA
- "PETRU PONI" INSTITUTE OF MACROMOLECULAR CHEMISTRY – ICPAM IASI
- INCDO-INOE2000, RESEARCH INSTITUTE FOR ANALYTICAL INSTRUMENTATION CLUJ
- S.C. NATURA SRL – BIERTAN, SIBIU
- TRANSILVANIA UNIVERSITY OF BRASOV
- "VALAHIA" UNIVERSITY OF TARGOVISTE

**External collaborators:**

- SCIENCE UNIVERSITY BORDEAUX / INRA, FRANTA
- CONSTRUCTION TECHNOLOGY INSTITUTE / AIDICO, SPANIA

**Young scientists:**

- Ing. Ch. Alina Matei
- Ing.el. Florian Pistritu
- Ing.mec. Andrei Ghiu

Head of Lab. Dr. Ileana Cernica (ileana.cernica@imt.ro)

# Molecular nanotechnology team - E 9

*Short description of the team and its mission*

The Molecular Nanotechnology Lab ("L9" team) was established in 2008, but it gained critical mass between 2010 and 2011, when 8 researchers out of its current 11 members joined the team construction. General information about the lab personnel is presented below:

- 8 out of the 11 members have obtained their PhD's at foreign universities and had gathered rich experience and achievements in academic and industrial research projects abroad (**Mihaela Carp** - *Nanyang Technological University*, Singapore; **Victor Leca** - *University of Twente*, The Netherlands; **Octavian Ligor** - *National Institute of Applied Sciences of Lyon*, France; **Cristina Pachiu** - *University of Le Havre*, France; **Radu Popa** - *University of Tokyo*, Japan; **Antonio Radoi** - *Tor Vergata University of Rome,* Italy; **Titus Sandu** - *Texas A&M University*, USA; **Lucia Monica Veca** - *Clemson University*, USA).
- the average age of the team members is 38 years. The team includes a final year student in Computer Science, with previous studies at the University of Zaragoza, and two PhD students.
- the team presents strong interdisciplinary potential: 5 physicists (4 PhD's), 3 chemists (2 PhD's), 2 engineers (2 PhD's), 1 Master student in Computer Science. Main areas of expertise can be classified as:
  - *experimental nano- and microtechnology of organic and inorganic materials*: cleanroom processes and chemical procedures for molecular electronics; design, fabrication, characterization and simulation of MEMS and biosensors; synthesis and characterization of carbon based functional materials; synthesis and characterization of doped crystals (thin films of complex oxides and high-temperature superconductors).
  - *advanced characterization of electronic materials*: characterization of surface doping profiles with local probes; interaction of surface waves with micro-structured surfaces.
  - *modeling, simulation and analysis of quantum, microscopic and macroscopic phenomena in organic and inorganic materials and systems*: electronic structure and optical properties of crystals, molecules and low dimensional nanostructures by ab-initio and empirical methods; quantum transport in nanostructures; ab-initio molecular dynamics; dielectric response of living cells and composites; plasmonic response of metallic nanoparticles; neuronal firing detection, signal analysis and data mining for functional neurosurgery; algorithms for image guided surgery.

The Molecular Nanotechnology Laboratory belongs to the IMT's Center for Nanotechnologies (CNT, http://www.imt.ro/CNT/), under the aegis of Romanian Academy. Based on its multidisciplinary background and experience, the team aims towards major scientific achievements and recognition in the following areas:

- functional integration of biological components (peptides, proteins, antibodies, DNA or DNA-like nucleotides and fragments etc.) with micro/nano processed inorganic structures, addressing three areas:

- creating new, application oriented, properties by physical and chemical modifications (physical processes, organic or inorganic doping)
- devising microsystems and devices using controlled manipulations and bio-non-bio assembly on/with surfaces, 1D and 0D materials
- developing structures and methods for molecular detection and identification, based on optimally integrated electrical, chemical, optical effects

- investigation and control of physico-chemical properties of new nanomaterials, with the following two accents:
  - carbon-based nanomaterials (CNT's, graphene, carbon dots etc.): synthesis, assembly and development of nanocomposites with optimal properties for energy harvesting, thermal and biomedical applications
  - synthesis of new superconductor materials in bulk or thin films and novel thin films of complex oxides with controllable morphological and electrical transport properties and further coupling to molecular nanostructures (e.g. graphene)

The adopted strategy is to create a *unified* experimental-theoretical framework, by combining techniques for preparation of substrates and low-dimensional materials as well as controlled molecular depositions with methods of theoretical modeling and numerical analysis (first-principles quantum mechanics, molecular dynamics), with the final goal of uncovering the mechanisms for creating useful functional properties based on the interaction of (bio)molecules with micro/nano-objects and external fields. Current research in the lab focuses on developing innovative solutions for biosensors, functional composite nanomaterials, and molecular identification based on electronic transport phenomena in nanostructures.

*Main results*

Notwithstanding its late creation, the Molecular Nanotechnology Lab was active and successful in national project competitions. Current situation shows:

- 3 team members are coordinating (PI's) national research projects, achieved in 2010 and 2011 PN-II competitions: ♦Dr.A.Radoi: PN-II-RU-TE-2009-1 (2010-2013), *Efficient electrochemical catalysis and regeneration of nicotinamide adenine dinucleotide at layer-by-layer self-assembled doped membranes* ♦Dr.V.Leca: PN-II-ID-PCE-2011 (2011-2014), *Experimental investigation on the order parameter symmetry of the superconducting Sr1-xLaxCuO2 thin films using SQUIDs* ♦Dr.O.Ligor: PN-II-RU-PD-2011 (2011-2013), *Fabrication and characterization of micro and nano metallic structures with Dip-Pen Nanolithography*.
- 6 proposals in the 2011 PN-II framework are under evaluation (Complex Ideas-PCCE, and Partnerships-PCCA), as follows: ♦Dr. M. Veca: PN-II-ID-PCCE, *Carbon quantum dots: exploring a new concept for next generation optoelectronic devices* ♦Dr. S. Melinte: PN-II-ID-PCCE, *Molecular quantum devices for emerging thermoelectrics* ♦Dr. T. Sandu: PN-II-ID-PCCE, *Experimental and*

*computational studies of nanostructured magnetic oxides for controllable multifunctional materials* ♦Dr. A. Radoi: PN-II-PCCA, *New analytical tool based on surface-assisted laser desorption/ionization for cancer biomarkers assessment* ♦Dr. A. Radoi: PN-II-PCCA, *Microfluidic set-up for Total Antioxidant Capacity assessment of flavoured waters* ♦Dr. M. Veca: PN-II-PCCA, *Graphene based heterostructures for sustainable energy*.

Up to now, 9 research articles were published in peer review journals, with a cumulated influence score of 12.63. The papers have been published in: Bioelectrochemistry (2009), Nanotechnology (2010), Analytical Letters (2010), Romanian Journal of Information Science and Technology (2010), Journal of the Acoustical Society of America (2010), Microchimica Acta (2011), Applied Physics Letters (2011), Sensors and Actuators A (2011), Journal of Nanoscience and Nanotechnology (2011-in press). We mention also 8 ISI-indexed proceedings of international conferences, and 5 running projects in the IMT-led POSDRU post-doctoral human resources structural funds program.

The main scientific achievements are as follows: ♦ memristor effect on Au/CNT material (inter-teams collaborative work L4-L9) ♦ ultrabroadband photodetection properties for Ag/Au/graphene-ink materials (inter-teams collaborative work L4-L9-L1) ♦noble metal-decorated carbon nanotubes with special catalytic effects for NADH co-enzyme ♦synthesis of graphene nanosheets by solution phase exfoliation of graphite in organic solvents ♦electroless decoration of porous silicon with catalyst nanoparticles for growth of carbon nanotubes ♦elaboration of a theoretical framework for eigenmode-based description of dielectric relaxations in biological cells and of localized plasmon resonances in metallic nanoparticles, paving the way towards extracting electric and geometric information about biological cells ♦first-principles quantum analysis of elastic and inelastic electronic transport properties of all four DNA nucleotides sandwiched between Au electrodes, in various orientations ♦λ-phage DNA strand stretching and immobilization on molecule-functionalized substrates.

*External scientific cooperation*

While gradually aligning to the team scientific mission, the members are keeping and developing cooperation ties with international and national partners. We mention here the most important: the group of Dr. S. Melinte at Université Catholique de Louvain, Belgium; the group of Prof. G. Palleschi at Tor Vergata University of Rome, Italy; Prof. Ya-Ping Sun's laboratory at Clemson University, USA; the research group of prof. G. L. Radu from the National Institute for Biological Sciences – Bioanalysis Centre; the group of Prof. R. Kleiner and Prof. D. Koelle at the University of Tübingen, Germany; Dr. Viorel Chihaia at the Institute of Physical Chemistry, Bucharest and Forschungszentrum Jülich; group of Prof I. Stamatin at the 3Nano-SAE Research Center, Bucharest-Magurele.

Laboratory head: Dr. Radu C. Popa (radu.popa@imt.ro)

**Micro- and Nano-Fluidics Laboratory- E10**

*Short description of the team and its mission*

The Micro- and Nano- Fluidics Laboratory is a direct result of the implementation of the POS CCE 209 project, co-funded from the European Fund for Regional Development. It was formed in August 2010 and it's composed of five researchers.

General information about the lab personnel is presented below:

- the average age of the team members is 35 years. The team includes 2 Post-Docs, who recently got their PhD's in microfluidic simulation and rheological studies, and a PhD student.
- Main areas of expertise can be classified as:
  - *experimental nano- and micro- fluidics*: cleanroom processes and chemical procedures for microfluidics; design, fabrication, characterization and simulation of MEMS; micro-PIV measurements - velocity profiles in microchannels; immiscible fluid flows in microchannels; surface tension measurements; hydrodynamic characterization of vortical structure formed in microbifurcations; micro flow visualizations;
  - *modeling, simulation and analysis of nano- and micro- fluidic phenomena Newtonian and non-Newtonian flows*: Phenomenological modeling: single phase and multiphase flows, mixing, turbulence, heat transfer, diffusion process in microchannels, reactions for industrial applications, user defined function implementation for additional flow parameters setting, shear thinning behavior of non-Newtonian fluid flows (with different generalized Newtonian models); complex geometry and mesh generation: 2D and 3D models with structured grids (quadratic and hexahedral finite elements) and unstructured meshes (triangular and tetrahedral, prismatic and polyhedral finite elements), automated scripts for the geometry and mesh generation; post-processing data in specialized software: 2D and 3D physical characterization (e.g. pressure, velocity distributions, streamtraces representations, vectors distributions, etc), particle tracking, 2D and 3D plots, histograms, fluxes and forces reports, automated script generation for all the post-processing data;

Based on its multidisciplinary background and experience, the team aims towards major scientific achievements and recognition in the following areas:

- Creation of a lab-on-a-chip systems with extensive applicative potential;
- Modelling of the molecular transport in biological fluids and the physico-chemical modelling of the biological material / substrate interface used for the realization of microfluidic devices;
- Studies and preliminary experiments on superparamagnetic nanoparticles integration in microfluidic systems;
- Design and simulation of the micro-nanotechnologies needed to realize integrated lab-on-a-chip system;

- The development of a magnetophoretic platforms which can be easily integrated into lab-on-a-chips with other subcomponents;
- The development and characterization of the microfluidics which can deliver multiple solutions for magnetic nanoparticles based immunoassays;

*Main results*

Notwithstanding its late creation, the Molecular Nanotechnology Lab was active and successful in national project competitions. Current situation shows:

- 1 project co-founded by the European Fund for Regional Development (POS-CCE 209 - Microfluidic factory for assisted self-assembly of nanosystems, "MICRONANOFAB").
- 2 Partnerships national projects (Microfluidic biochip for rheological characterization of non-Newtonian biological fluids with applications in medical diagnosis and treatment, "MELANOCHIP"; Micro- electro- mechanical system with applications in reconstructive microsurgery of peripheral nerves, "RECONECT")
- 1 Ideas national project (Development of A Conceptual Model of a Lab-On-A-Chip for Continuous Particles Separation Through Magnetophoresis And Dielectrophoresis)
- 4 proposals (both as coordinators and partners) in the 2011 PN-II framework are under evaluation (Partnerships-PCCA), as follows: ♦Dr. M. Avram: PN-II-ID-PCCE, *Immunoassay Lab-on-a-chip for cellular apoptosis study*♦Dr. M. Avram: PN-II-ID-PCCE, *Multi Purpose High Sensitivity Spintronic Planar Hall Effect Sensors with Tunable Properties (coordinated by Transilvania University of Brasov)* ♦ Dr. C. Balan: PN-II-ID-PCCE, *Patterned surfaces for applications in rheometry and microfludics (coordinated by Politehnica University of Bucharest)*♦ A. Avram: PN-II-ID-PCCE, *Soft and hard magnetic micro and nanostructure arrays for flux concentrators and actuators MEMS (Coordinated by the Institute for Technical Physics, Iasi).*

During the past years, 9 research articles were published in peer review journals, with a cumulated influence score of 6.7. The papers have been published in: *Journal of Optoelectronics & Advanced Materials*, *Journal of Magnetism and Magnetic Materials*, *Microsystem technologies-micro-and nanosystems-information storage and processing systems*, *Materials Science & Engineering B*, *Reviews on advanced materials science*, *Diamond & Related Materials*.

## 2.4 Representative project

## 2.4. Representative project

# European Centre of Excellence in Microwave, Millimetre Wave and Optical Devices, based on Micro-Electro-Mechanical Systems for Advanced Communication Systems and Sensors-"MIMOMEMS" (www.imt.ro/mimomems)

## FP7 Project No 202897 financed (2008-2011) through the "Regional potential" part REGPOT call 2007-1

**Coordinator Dr. Alexandru Muller (alexandru.muller@imt.ro)**

The overall aim of the **MIMOMEMS project** was to bring research activity in Radio Frequency (RF) and Optical Micro-Electro-Mechanical Systems (MEMS) at the National Institute for Research and Development in Microtechnologies - IMT-Bucharest, Romania, to the highest European level, and create a European Centre of Excellence in microwave, millimetre wave and optical devices, based on Micro-Electro-Mechanical Systems for Advanced Communication Systems and Sensors.

Two laboratories from IMT Bucharest, the RF MEMS Laboratory and the Micro and nano-photonics Laboratory, have joint their efforts to create this European Center of Excellence.

The inspiration for this initiative came from previous successes, including involvement in FP4, FP6 and FP7 EU projects. The two labs have been involved in STREPs (Specific Targeted Research Projects) and IPs (Integrated Projects) and NoE (Network of Excellence):

***-The Laboratory of RF-MEMS*** (lab head Dr Alexandru Muller) has coordinated one of the first European projects in RF-MEMS: Micromachined Circuits for Microwave and Millimetre Wave Applications (***MEMSWAVE***, 1998-2001, FP4-INCO), nominated in 2002 among the top ten European projects for the Descartes Prize. Also, the RF-MEMS Laboratory was a key partner in the FP6 NoE: "Advanced MEMS for RF and Millimetre Wave Communications" (***AMICOM***, 2004-2007 FP6 NoE), and is also partner in the FP7 STREP (call ICT-2007-2) ***MEMS 4 MMIC*** Strep (2008-2011). The group was involved in the ENIAC proposals: "SE2A" where it participated at the design and manufacturing of a ground speed sensor based on a 77 GHz transceiver for SUV cars.

***-The Laboratory of Micro and nano-photonics*** (laboratory head Dr. Dana Cristea – dana.cristea@imt.ro) has participated in several FP6 projects: ***WAPITI***, STREP, 2004-2007, FP6-IST; ***4M***, NoE, 2004-2008, FP6-NMP); ***ASSEMIC***, RTN Marie Curie Trainning Network, 2004-2007 FP6- Mobility , FP 7 IP call NMP-2007-1 ***FlexPAET*** (2008-2010).

**The main objectives** of the MIMOMEMS project were:

(i) Exchange of know-how and experience with **twining partners, LAAS-CNRS Toulouse** (which has strong expertise in silicon based RF and millimetre wave microsystems, photonic devices, circuits manufacturing and characterization) **and FORTH Heraklion** (which has excellent knowledge of IIIVs (GaAs and related semiconductors) and wideband gap semiconductor processing (GaN, AlN),

(ii) Recruitment of incoming experienced researchers,

(iii) Acquisition, development/upgrading of research equipment,

(iv) Organisation of workshops and conferences,

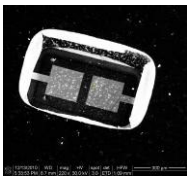
(v) Dissemination and promotional activities.

MIMOMES represents a support action for the developing of microwave, millimetre wave devices and circuits, optical devices and sensors based on MEMS technologies, with applications in modern communication systems. The MIMOMEMS project targeted to support development of:

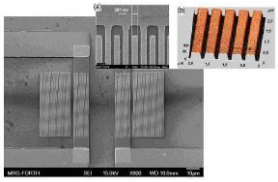
- Millimeter wave reconfigurable filters for millimeter wave applications
- Micro-machined receiving modules based on silicon and GaAs micromachining
- Acoustic devices for GHz applications based on micromachining and nano-processing of Wide band-gap semiconductors
- Polymer-based micro-photonic devices
- Sub-wavelength photonic structures

**(i)** Together with the twinning partners we have developed state-of-the-art research in each of these fields. Collaborative scientific work and state-of-the-art devices and technologies have been developed in collaboration with the twining partners. Papers in high-ranked journals have been published. In addition, a common European laboratory including IMT-BUCHAREST, LAAS Toulouse and FORTH Heraklion has been created (LEA SMART MEMS). Strong cooperation has also been harnessed with other important European research centers in the field, including VTT Helsinki, Finland, as well as with a number of European industrial partners like Thales TRT (France) and NXP (Netherlands).

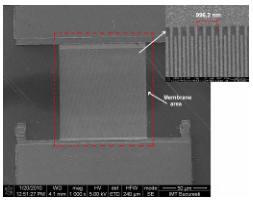
## Highlights of the state of the art results obtained in cooperation with twining partners with the support of the MIMOMEMS project



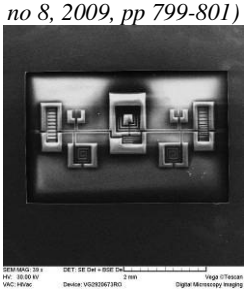
*FBAR structure on 0.5µm GaN membrane resonating at 6.3 GHz (A Muller, D. Neculoiu, G Konstantinidis et al., **IEEE Electron Devices Lett.**, vol 30, no 8, 2009, pp 799-801)*



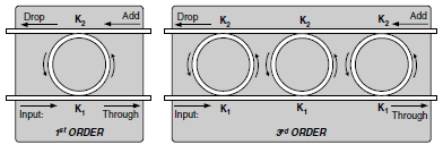
*GaN based 5.3 GHz SAW structure (A Muller,D.Neculoiu G Konstantinidis G. Deligeorgis, A. Dinescu, A. Stavrinidis, A. Cismaru, M. Dragoman, A. Stefanescu, **IEEE Electron Devices Lett.**, vol 31, no. 12, 2010, pp 1398-1400)*



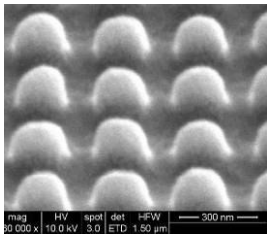
*GaN membrane supported UV photodetector (A Muller, G. Konstantinidis, A. Dinescu et all, **Thin Solid Films** in press doi:10.1016/j.tsf.2011.09.045)*



*SEM photos of the WLAN 5200 filter bottom view (Andrei A. Muller, D. Neculoiu, A. Cismaru, P. Pons, R. Plana, D. Dascalu **Int. J. Electron Commun. AEU (Elsevier)** 65, 2011, 1050-1053)*




*Add–drop filters realized with a single microring resonator (left) and three parallel coupled microrings resonator (right) (D. Alexandropoulos, H. Simos, M. Kusko, D. Cristea, D. Syvridis, N. A Vainos, J. Opt. A: Pure Appl. Opt. 11, 2009, 125401)*




*Structured obtained PMMA double- Lenses-with $\phi$ <150 nm (P. Obreja, D. Cristea, A.Dinescu and R. Gavrila, Symposium on Design, Test, Integration & Packaging MEMS/MOEMS, Rome, Italy, 2009, p.349*

**(ii)** Three experienced scientists (post-docs) have been employed using the project budget. Six applications have been received. Following the interviews with the applicants three of them were hired. The researchers were initially hired for 18 months. At the end of the period, the researchers became full time IMT employees.

| | | |
|---|---|---|
|  |  |  |
| *Dr. Mihai Pavelescu (38), Univ. Kassel* | *Dr. Alexandra Stefanescu, (28) "Politehnica" Univ. Bucharest* | *Dr. Mihaela Carp (42), Nanyang Technical Univ. Singapore* |

**(iii)** MIMOMEMS has contributed to increasing the competitiveness of IMT-BUCHAREST as a reliable European partner in micro and nanotechnologies. One of the important tasks was to upgrade the research equipment.

- Near field scanning optical microscope (SNOM) (Co-financed by a national project)
- Upgrade to 110GHz the 1-65 GHz set-up for on wafer characterization - upgrade of the VNA up to 110 GHz, (Co-financed by a national project) and upgrade the on wafer measurements set-up up to 110 GHz,
- Frequency synthesiser up to 110 GHz
- Au plating facility for semiconductor wafers
- Digital Serial Analyzer Sampling Oscilloscope with the Time Domain Reflectometry function, up to 50 GHz and the dedicated software and measuring accessories
- Experimental set-up for UV photodetector responsivity characterization (lock-in amplifier, optical chopper, monochromator, optical source, accessories)

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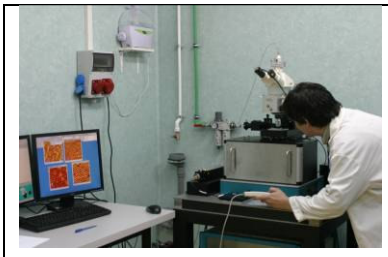
|  |  |  |
| *The Scanning Near Field Optical Microscope* | *The millimetre wave characterization equipment up to 110 GHz* | *The Au plating facility for semiconductor wafers* |

**(iv)** The MIMOMEMS project has funded the organization of two scientific and one strategic workshop in RF and optical MEMS. Reaching key players in the field, these took place alongside the IEEE organized International Semiconductor Conference (CAS) in Sinaia (2008 and 2010), Romania. The **scientific workshops** have evidenced the main technical results obtained by IMT-BUCHAREST and its partners supported by the MIMOMEMS project, together with results obtained by other teams in RF and Optical MEMS. The **strategic workshop** had many invited lecturers from industry and could give some important directions in the topics. The papers presented at the strategic and scientific workshops are available on the project webpage (www.imt.ro/mimomems). The strategic workshop was organized to define a road-map and to contribute to the improving of national co-operation to facilitate knowledge transfer in the field of RF MEMS/NEMS and Optical-MEMS, for promoting a better response of the research activities to the socio-economic need, for improving the centre research strategy and for contributing to national research strategy in the field of MEMS/NEMS/MOEMS/NOEMS

**(v)** The objective is to maximize the transfer and promotion of project results and activities of the MIMOMEMS project in Romania and across the EU. The MIMOMEMS group has achieved the publication of research results in peer reviewed journal and presentation at international conferences; organization of workshops to make research proposal submissions to relevant calls from the FP7 ICT program.

Publication and participation at scientific conferences with papers having the topics in the scientific objectives supported by the MIMOMEMS project:

- 11 ISI ranked papers published in cooperation with twining partners in prestigious journals like IEEE Electron Device Lett., Electronic Letters, Appl. Optics, Microelectronics Journal, J. Opt. A: Pure Appl. Opt, Thin Solid Films, etc.
- 25 papers submitted and accepted to prestigious conferences (European Microwave Conference, Asia Pacific Microwave Conference, EMRS, NATO

Workshop, MEMSWAVE, CAS, Micromechanics Europe Workshop, EOS Topical Meeting on Optical Microsystems, etc.)

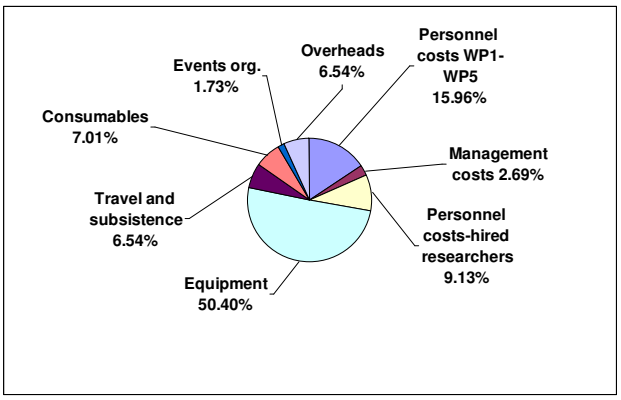
- One chapter in a book (Springer)
- 20 projects in FP7 and FP7 related calls have been proposed during the MIMOMEMS project. Six *of these proposals have been successful:*

➢ ***Four* projects in related to FP7 calls (ENIAC JU and MNT ERANET) were financed and are in progress**

➢ ***Two IP proposals* in the *FP7-ICT-2011-7* call *were wining projects: "SMARTPOWER" and "NANOTEC", both coordinated by Thales TRT France, and started in September 2011.***

## The project costs

The project claimed for 1,042,757 EUR and the breakdown of the costs is presented below. Six months after the end of the project costs have been already approved by the EC. It is clear that the most important amount of funds was devoted to equipment acquisition which was a major target of the project.




***Cost breakdown for the MIMOMEMS project (post-calculation)***

An important contribution was devoted to hire the three Post Doc scientists (two of them from abroad) for 1.5 years during project running. All of them are now included in the permanent staff of the Institute. Research mobilities (18 stages coming to Romania from abroad for common work in the labs, training stages and participation at the two workshops and 41 stages abroad of Romanian scientists (to work in twining partners labs, to disseminate at Conferences the scientific results of the work) have been granted by the MIMOMEMS project. Personnel costs have been partially used to participate at the preparation of 20 project proposals.

## Impact of the project after its end

Even though some of them are already widely used in communications systems, radio frequency micro-electro-mechanical systems (RF MEMS) and Optical-MEMS are still considered emerging technologies. Developments in such systems and their application are continually evolving, and constitute a significant field in both research and industry. Under FP7 REGPOT funding, a research facility in Bucharest, Romania, has been established as a Centre of Excellence in MEMS research. The success of the MIMOMEMS team in European cooperation is almost unique in Romania. It is not just pure chance that MIMOMEMS was the first Centre of Excellence to be financed from European Programs after Romania acceded to EU.

As an illustration of the extensive funding from which the Centre has benefited, the new infrastructures of IMT- Bucharest (including the new nanolithographic equipment, the new Low-pressure chemical vapor deposition (LPCVD) and Plasma-enhanced chemical vapor deposition (PECVD) equipment, the nano-identer, the new MA6 mask aligner, the mask fabrication equipment

from Heidelberg, equipment, the new scanning electron microscope (SEM,) the new clean room, etc.) represent investments of around 3 million Euros. The about 0.5 million Euros for investment coming form the MIMOMEMS were now devoted to the microwave, millimeter wave and optical MEMS devices.

Whilst IMT-Bucharest is the lead organisation in the MIMOMEMS Centre of Excellence, the role played by twinning partners LAAS-CNRS and FORTH-IESL-MRG cannot be underplayed: collaborative scientific work and state-of-the-art devices and technologies have been developed in collaboration with these partners, and co-authored papers in high-ranked journals have been published. The published results represent the state of the art in the scientific targets of the project. In addition, a common European laboratory including IMT-BUCHAREST, LAAS and FORTH has been created (LEA SMART MEMS). Strong cooperation has also been harnessed with other important European research centers in the field, including VTT Helsinki, Finland, as well as with a number of European industrial partners (Thales TRT-Fr, NXP-Nl)

MIMOMEMS has brought the level of RF and MEMS research at IMT-BUCHAREST on a par with its partners and collaborators.

Bringing together a number of research bodies at the forefront of this field, MIMOMEMS has demonstrated the importance of working with innovative and influential partners. Benefits of this have included:

- *The creation of a strong multidisciplinary research team with complementary competences and facilities*
- *The creation of opportunities to participate collaboratively in FP7 proposals*
- *The sharing with partners of contacts with industry*
- *The facilitation of knowledge transfer*
- *Opportunities for sharing access to facilities*
- *The collaborative development of research work*

MIMOMEMS has contributed to increasing the competitiveness of IMT-BUCHAREST as a reliable European partner in the entire topics of micro and nanotechnologies. The presence of the MIMOMEMS Centre of Excellence will have a major impact on creating cooperation activities with the new high-tech industry that is now emerging in Romania. In the last years IMT-BUCHAREST has developed also relations with high-tech companies established in Romania, like Honeywell Ro, Infineon Ro, Renault TRT.

The MIMOMEMS Centre has already been made a permanent Department of IMT-BUCHAREST, proof not only of the strength of the MIMOMEMS project, but of its sustainability in the future. It also symbolises the importance of MEMS research for the institute. The new structure of the institute also marks a clear shift in strategy: *from microtechnologies to micro- nano – biotechnologies* (or convergent technologies)

Although in the past, the absence of industrial partners in Romania prohibited productive cooperation, European projects like MIMOMEMS have provided valuable opportunities for IMT-Buxharest to connect with European industrial partners. Today, IMT-Bucharest is involved in four **ENIAC JU projects**, working together with industrial partners (NXP, the Netherlands; Thales, France; and Volvo, Sweden) to research emerging solutions for true ground speed measurements at 77 GHz, and sensors for poisonous gases based on GHz GaN/Si acoustic devices.

The MIMOMEMS IMT team is one of the partners in the **SMARTPOWER and NANOTEC wining Integrated Projects (call FP7 ICT 2011-7)**. Both projects are coordinated by Thales TRT France. The result became public in the last month of the MIMOMEMS project (April 2011). The two integrated projects have started in September 2011. This is a certain sign that the **MIMOMEMS project** was a real success.