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