ANNEX 2

IMT-MINAFAB - General description

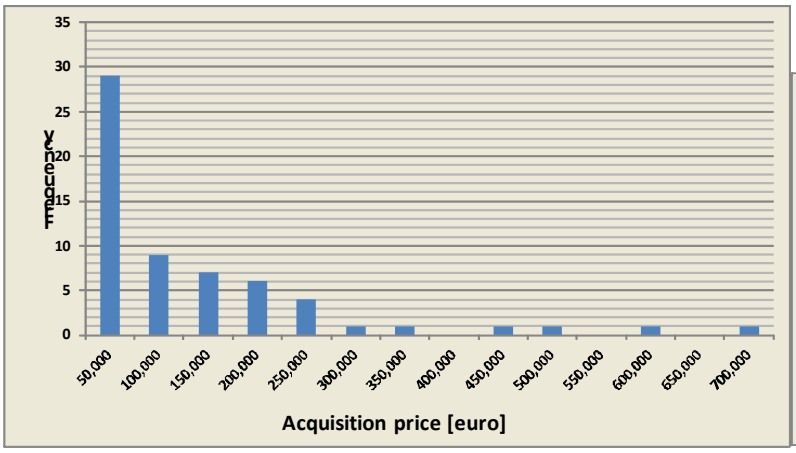
The excellent success rate in national (PN-II) and international (FP6, FP7) grants - with notable momentum during 2007-2008 - enabled IMT to pursue its strategy of creating a state-of-the-art facility for for R&D in micro/nano-technologies, that is opened for internal and external collaborations. The IMT-Center for Micro-Nanofabrication (IMT-MINAFAB, www.imt.ro/MINAFAB) was officially launched in April 2009 and consists of several clean-room areas and specialized laboratories, totaling a surface of almost 700 sqm., and modern equipments worth almost 8M euro; some of them are unique at national and regional level. The center was certified according to SR EN ISO 9001:2008 in June 2011 by TÜV Thüringen e.V.

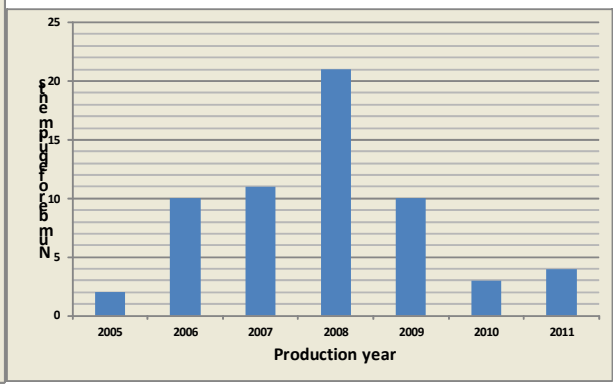
Main characteristics of the IMT-MINAFAB facility are listed below:

- Facility areas (zones):
  - **Clean room-1**: 198 sqm, 1.000/-local-100 purity class (ISO 3/2); allocated mostly to most demanding technological processes; contains the following sections: Fabrication of Lithography Masks, Microlithography, Physical Depositions, Rapid Prototyping/ Dip-Pen Nanolithography.
  - **Clean room-2**: 120 sqm, 10.000 purity class (ISO 4); allocated to chemical depositions of thin layers, reactive dry etching, thermal treatments, spectroscopy characterizations and chemical wetbenches. The room is connected to a complete system for safety gas storage, transport and sensor monitoring.
  - **"Gray" area**: 287 sqm., 100.000 purity class (ISO 5); allocated to various sets of equipments for nanolithography and complex characterization categories, such as: beam-based, scanned probe, spectrometry techniques, nano-bio spotting and combined analysis.
  - Laboratory for Tests and Reliability Aanalysis for Microtechnology Systems (called **LIMIT**): 32 sqm.
  - **High Performance Computing** (**HPC**) area - servers for intensive numerical analysis: 23 sqm.
  - **Technical support areas** - multiple zones operated by technical personnel, for ensuring the operation of necessary utilities, such as air flow and filtration, storage/transport/monitoring of process gases, neutralization of exhaust air and liquids, water demineralization, compressed air etc.

- *R&D flux*: the acquisition strategy of the experimental facilities was designed to enable the center to ensure a complete R&D flux for micro/nano-technologies: starting from design-modeling-simulation, through basic and advanced processing and fabrication, to advanced characterization, device or system integration and reliability testing.
- *Personnel and expertise*: all the R&D equipments are operated by researchers and/or technical personnel, with multidisciplinary backgrounds (physicists, engineers, chemists) and with expertise in their usage or in the operation of similar equipments of older generations.
- *Special infrastructure*: IMT-MINAFAB operates one of the three class 1.000 clean rooms currently running in Romania, and represents the sole concentration of spaces with high purity air at national level. A 2011 concluded, state-funded prospective project - "Nanotechnologies in Romania" - addressing all the national capabilities and prospects in nanotechnology R&D, showed that the experimental capabilities offered by IMT-MINAFAB were of top national level and the majority of experimental categories were of high-competitive international level.

- *General statistics:* The histograms below show the price and production-date distributions of the equipments located in IMT-MINAFAB.





- *Offer of technological and R&D services*: the center offers a large range of services (details at: http://www.imt.ro/MINAFAB/description.htm) for various categories of beneficiaries, either in the frame, or independent of, common participations in R&D projects: Romanian companies, foreign companies (operating in Romania or from abroad), universities and institutes.
- *Main categories of services offered*: technological services for development of micro/nano devices and systems; inspection and characterization of bulk materials, surfaces, micro/nano structures; design, modeling and simulation (multiphysics and quantum mechanical analysis); complex RDI services.
- *Access types*: either direct access (hands-on, assisted) or indirect access (operator services) for national and international users.
- *Education and training*: direct access and training for Master courses (3 courses initiated in October 2009), post-doc programs (including the current national POSDRU project coordinated by IMT), academic and industrial users.
- *Facility exploitation*: capitalization of the facility offer is reflected both in its intensive involvement in IMT's national and international project workpackages, and also in national and international requests for services:
  - National users: 30 companies, 15 national institutes, 15 universities.
  - Over 30 industrial partners from: Austria(1), Finlanda(1), Franta(1), Germania(8), Grecia(1), Ungaria(2), Italia(3), Polonia(1), Slovacia(2), Spania(1), Suedia(6), Olanda(3), etc.
  - Over 30 academic partners from: Belgia(2), Finlanda(1), Franta(2), Germania(11), Grecia(1), Ungaria(1), Italia(2), Irlanda(1), Israel(1), Polonia(1), Spania(1), Olanda(3), Spania(1), Marea Britanie(1), etc.
  - Main requests for direct services were/are coming from: Honeywell Romania SRL (strategic partnership), Philips (The Netherlands), Korea Electronics Technology Institute, Institute of Electronic Structure Laser (Greece), GTZ-Deutsche Gesellschaft fur Tehnische Zusammenarbeit GmbH, Plasma Antennas Electron Centre (England), University of Crete, Arcelik AS Tuzla Istanbul (Turkey), Philips Applied Technologies, DQ Energi (USA).

Operation concept

IMT-MINAFAB operates as an open infrastructure for users and collaborators, with regulated access. The access can be direct, or indirect. The main categories of external (non-IMT personnel) users are: research groups (from universities, institutes); students and post-doc researchers; companies.
Main types of collaboration with external users:

- through partnerships in RDI activities, involving IP sharing - a direct access use, with assistance from IMT personnel
- through scientific and technological activities, including design and consultancy - indirect access, through contracts for services
- through other modes of directly accessing the facility equipments through hands-on activities after proper training sessions from specialized IMT personnel - direct access, direct operation by external users.

According to the MINAFAB Regulations for Access and Collaboration, the direct access of external users is based on the issue of an access certificate and of a personal access card for the designated MINAFAB areas. Any collaboration with an external user is initiated by a proposal of a research theme that is analyzed both by the Scientific Council of IMT-Bucharest and by the Coordinating Board of IMT-MINAFAB. This is followed by the direct common analysis with the proposer of the project details and by the common signing of a project or an understanding.
The operation of the center is ensured exclusively by the personnel of IMT-Bucharest. The special technical support areas are also operated totally by IMT technical personnel.

Significance for national R&D development

The IMT-MINAFAB center is designed for enabling state-of-the-art, multidisciplinary R&D in convergent micro-nano-bio technologies, based on processing (modifying/structuring) and characterizing inorganic, organic and hybrid matter at the micro and nanoscale. The center represents a complex technological platform - based on joining the equipment capabilities in a complete technological flux with advanced knowledge and expertise - for basic and applied research, including micro production activities.

The R&D areas addressed can be grouped in the following main categories:

- Micro-nano structures, microsystems and advanced nanomaterials with applications in: medicine, transportation, energy, constructions.
- Components and devices for nanoelectronics, photonics and microwaves.
- New fabrication technologies and characterization techniques at nanometer scale.

Related to the National Plan for RDI PN-II-2007-2013, the equipments and the associated expertise offered by IMT-MINAFAB have the potential to address the following priority domains:
1-Information technology and communications
2-Energy
3-Environment
4-Health
5-Agriculture
7-Innovative materials, processes and products

The center facilities allowed IMT's researcher groups to approach increasingly complex research projects, in national and international consortia. The institute's recognition as a viable European partner for technology-intensive workpackages translated into its participation in a total of 37 FP6 + FP7 + FP-related projects, including here the MIMOMEMS Excellence Center (REGPOT-FP7).

- In brief, IMT-MINAFAB offers the Romanian research and innovation community a modern facility with international reputation, in a top science-technology area.

Management

IMT-MINAFAB is a center for scientific and technological services, and its operation is ensured based on the expertise and equipments of IMT's research teams (laboratories), together with other departments. The center is coordinated by the "Coordinating Board of IMT-MINAFAB". The Board has a president and eight members.

R&D capabilities for processing and characterization in IMT-MINAFAB
(see also http://www.imt.ro/MINAFAB/description.htm)

The research equipments installed in IMT-MINAFAB allow the following main R&D capabilities:

- Lithography for microsystems (MEMS, Bio-MEMS, MOEMS, RF-MEMS)
- Nanolithography (electron-beam, dip-pen)
- Hybrid lithography "mix-and-match"
- Nanoengineering (nanomanipulation): electron-beam-assisted deposition and etching processes
- Direct depositions of nanospots and nanopatterns (for molecules, precursors, nanodots)
- Physical depositions (10^{-7} mbar vacuum; Al, Ni, Cr, Au, Pt, Ti, W, AlSi etc.)
- Plasma-based (reactive ion) etching (dry etching - DRIE, RIE)
- Wet chemistry (e.g., wet/electrochemical etching, substrate porosification):
- Rapid prototyping (laser, 3D printing, micromolding, ink jet printing)
- Beam based characterization and imaging (scanning electron microscopy, X-ray diffractometry)
- Scanned probe characterization and imaging (atomic force, tunneling, optical near-field, electrochemical)
- Spectrometry for thin films, small concentrations, nanomaterials (Raman, fluorescence, electrochemical, ellipsometry, UV-Vis-NIR, Fourier)
- Profilometry (optical)
- Voltammetry
- Characterization of nanoparticle dispersions
- Wafer precision bonding and microfluidic flow analysis for microfluidic chips
- Electric characterization (2-3 points I/V, accelerated and multiphysics stress tests, defect analysis)
- Coupled-field numerical analysis for MEMS (modeling, simulation optimization in static, transient, harmonic regimes)
- Complex design and simulation (chemical and microfluidic systems, passive and active microphotonic components, high-frequency devices, lithography masks, simulation of technological processes)

R&D services

Based on the cumulated experience in the usage of MINAFAB equipments in national/international projects, the center offers a wide range of R&D services:

Essential technological services for micro/nano-devices and systems with electrical and/or mechanical functions

- Fabrication of photolithography masks (wafer double-side alignment, exposure, development)
- Electron-beam nanolithography "mix-and-match", nanolithography based on dip-pen depositions
- Other nanoengineering processes: electron-beam-induced depositions and etching, controlled molecular pattern depositions
- Physical depositions of materials in high-vacuum
- Precision etching of materials (humid and plasma reactive ion, shallow and deep)
- Thermal processes for Si technology (oxidations, annealing, diffusions, depositions etc.)
- Microarray-spotting of biomolecules
- Rapid prototyping (design and printing of fine 3D structures, laser micromachining, fabrication of molds)

Inspection, analysis and characterization of surfaces, bulk crystals, micro/nano-structures, thin layers, adsorbates, particles

- Scanned microscopy and analysis (SEM, AFM, STM, NSOM, SECM)
- X-ray analysis methods (crystallinity, thin-film properties, powder etc.)
- Reading of biomolecular microarrays
- Electrical probing and characterizations for microwave/mm-wave/THz wave devices and components
- Spectroscopy (Raman, ellipsometry, electrochemical impedance-EIS, fluorescence, Fourier)
- Precision analysis of nanomechanical properties of surfaces
- Evaluations and optimizations of chemical coatings, cleaning, polishing processes
- Nanometrology and defectoscopy - analysis and studies
- Testing of electronic devices and sensors against simple and combined factors (mechanical, thermal, electrical, pressure, humidity), determination of failure rates
- Analysis of surface microtopology and patterning - confocal microscopy and optical profilometry; evaluation of transparent thin layers
- Nanoparticle analysis (size distribution, properties in dispersion)

Design, modeling and simulation

- Modeling and analysis of electric/magnetic/thermal/mechanical fields for microelectromechanical systems (MEMS)
- Coupled-field analysis - electro-thermal, thermo-electro-mechanical
- Modeling and analysis of microfluidic systems: pressure-driven or thermal-gradient-driven flows, electrokinetic actuation, droplet/bubble simulations
- Design and simulation of microfluidic components for biochips
- Design of microlithography masks (for Si technology)
- 3D models for ready-to-manufacture devices: analysis of micropumps and microvalves (electrostatic/piezoelectric/pneumatic/electroosmotic); flow monitoring in microchannels, micromixers, microfilters)

Research services

- For biomedical applications - genomics, pharmaceutics, genotyping, proteomics)
  - Fabrication of nanoprocessed support surfaces for microarray chips
  - Surface chemical modifications for immobilization of biological probes - DNA, proteins, cells
  - Determinations/detections for proteins, lipids, polysaccharides, bacteria, viruses, colloidal drug delivery systems, drugs in aqueous suspensions
- Synthesis of nanoparticle colloidal suspensions - Au, Pt, Ag, Fe, Fe2O3/Fe3/O4; SiO2, TiO2, SnO2 - or of (functionalized) core-shell systems
- Fabrication of micro/nano porous silicon, with multiple applications (diagnostic chips, biochemical detections, localized therapies, energy conversion etc.)
- Modeling/simulation/CAD for micro/nanophotonic circuits with applications in integrated photonic components, optoelectronic devices, optoelectromechanical microsystems
- Design-to-development of micro-optical components for: optical instruments, microsensors, microfluidic systems
- Bio-chemical evaluations of efficiency and effects of drugs
- Electromagnetic modeling and design for filters, receiver modules and front-ends in microwaves and millimetric waves
- Functionalization technologies of surfaces for biosensor development

Development and innovation services

- Development of integrated microfluidic platforms for biochemical analysis and medical diagnostic
- Polymer processing technologies - molding-based high-throughput replication
- Development of materials and structures with controlled optical properties for sensors and for components for optical communications
- Development of photovoltaic cells using non-conventional materials
- Design, fabrication and testing of chemical sensors (pH, O2, temperature, NO2, CO)
- Fabrication of microelectrodes (for biosensors and chemical sensors) and membrane-integrated heating elements, for various substrates
- Development of microarray structures for applications in genomics, pharmaceutics, genotyping, proteomics, diagnostic

Other services

- Training courses for the operation of existing equipments and numerical analysis packages
- Theoretical and practical courses for Master academic programs
- Technological assistance and consultancy for SME's - design of technological fluxes, technological compatibilities etc.
- Internship education and training

Similar European centers

- We present a comparative table between the IMT-MINAFAB facility and a sample list of European research centers focused on micro/nanotechnologies. The listed selection is made based on similarities with the MINAFAB center in the following points: concept of open infrastructure, size of clean room spaces, sets of equipment and research instruments, research arease addressed, dimension and multidisciplinary character.

	Equipment categories, identical ST capabilities	*Identical/equivalent R&TD equipments*	*Technological /experimental surface (Clean room, class 10.000 - 1.000)*[1]
Denmark - *National Center for Micro- and Nanofabrication (DTU Danchip)* http://www.danchip.dtu.dk	♦Microlithography♦Nanolithography♦Physical depositions♦Reactive etching♦SEM-SPM♦Direct wafer measurements♦Complex spectroscopy	♦ Süss MA6/BA6 aligner♦e-beam evaporator, sputter system♦FEI SEM♦JEOL e-beam	1350sqm
Switzerland - *Center of MicroNano Technology (CMI)* http://cmi.epfl.ch	♦Microlithography♦Nanolithography♦Physical depositions♦Reactive etching♦SEM-SPM♦Direct wafer measurements♦Complex spectroscopy	♦electron beam lithography system ♦Heidelberg lithography system♦Süss MA6/BA6♦Alcatel dry etcher♦Alcatel evaporator	N/A
Finland - *Micro- and Nanotechnology Centre (Oulu)* http://www.oulu.fi/nano/index_en.html	♦ Microlithography♦ Nanolithography♦Physical depositions♦Reactive etching♦SPM♦Direct wafer measurements♦Complex spectroscopy♦Nanoparticle characterization♦Numerical analysis	♦ Süss MA8 aligner♦Torr e-beam+sputtering♦Veeco AFM/ SPM♦ Lighthouse particle analysis ♦Comsol software	550sqm
France - *Lyon Institute of Nanotechnology - NanoLyon Technological Platform* http://inl.cnrs.fr	♦ Microlithography♦ Nanolithography♦Physical depositions♦Reactive etching♦SEM-PM♦X-ray characterizations♦SNOM♦Complex spectroscopy	♦e-beam lithography♦ RIE♦SEM ♦ Ntegra AFM NT-MDT	210sqm
Germany - *Zentrum für Mikro- und Nanotechnologien (ZMN)* - http://www.tu-ilmenau.de/en/zmn	♦ Microlithography♦ Nanolithography♦Physical depositions♦Reactive etching♦SEM-PM♦X-ray characterizations♦SNOM♦ Nanoplotting♦Complex spectroscopy♦Direct wafer measurements	♦Raith e-beam lithography system♦FEI-SEM♦ integrated sputtering- and evaporation system♦ Ntegra AFM ♦Sentec ellipsometer♦ Süss MA8 aligner♦Süss wafer prober ♦RIE dry etching♦ polymer glovebox w. inert gas♦ optical profilometer	680sqm
United Kingdom - *The London Centre for Nanotechnology (LCN)* http://www.lcn.ucl.ac.uk	♦ Microlithography♦ Nanolithography♦Physical depositions♦Reactive etching♦SEM-SPM♦SNOM♦Complex spectroscopy♦Direct wafer	♦Raith e-beam lithography ♦Oxford RIE♦Laser particle measurement	325sqm (total)

[1] The listed surfaces may include also auxiliary support spaces.

	measurements♦Nanoparticle characterization		
Spain - *Centro Nacional de Microelectrónica* http://www.cnm.es	♦ Microlithography♦ Nanolithography♦Physical depositions♦Reactive etching♦ SEM-SPM	♦Double side mask aligner ♦DC/RF sputtering♦Raith e-beam lithography♦e-beam evaporator ♦mask-less lithography laser♦ Alcatel RIE♦FTIR spectrometer♦ellipsometer	1500sqm (total)