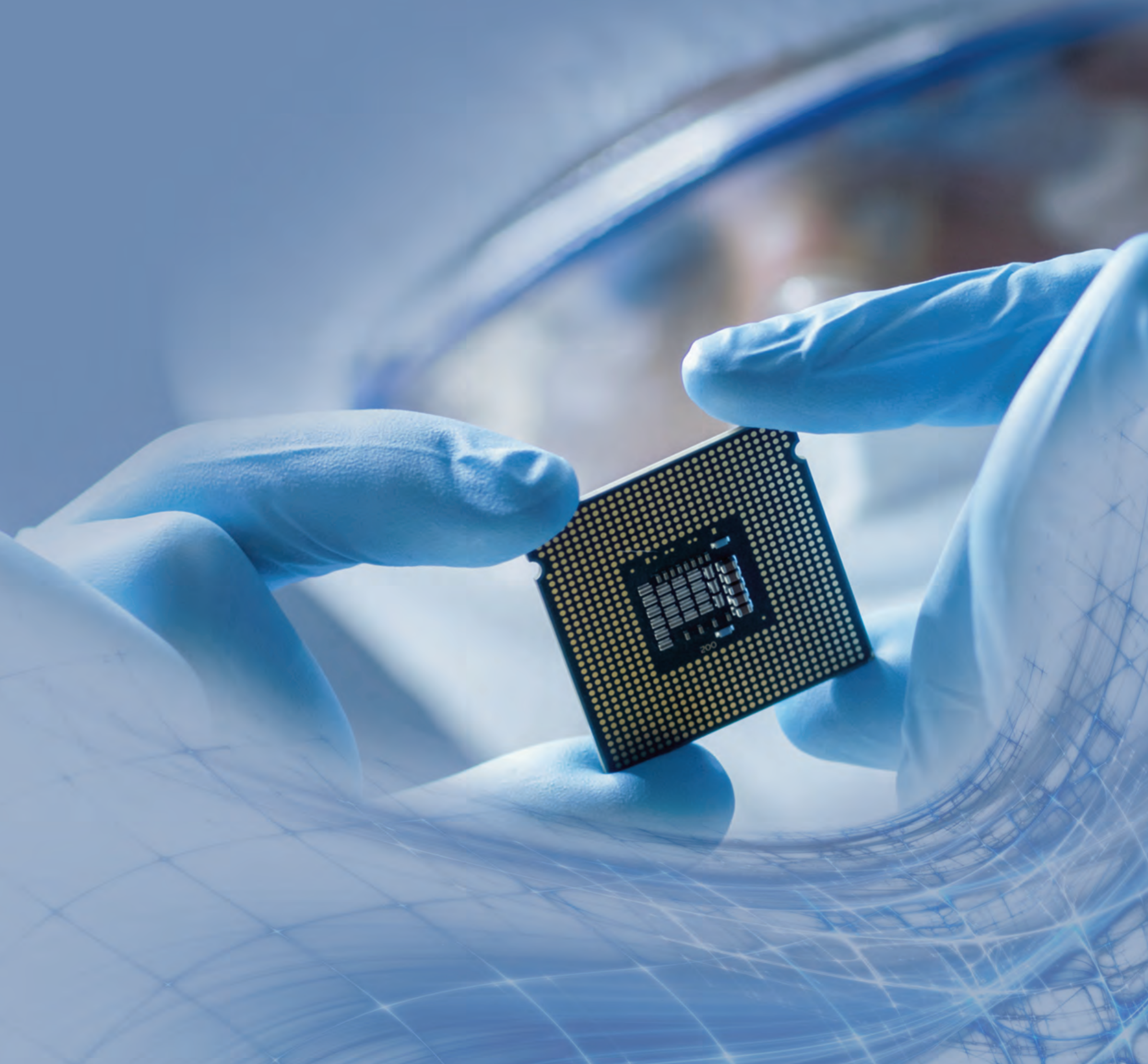
National Institute for Research and Development in Microtechnologies -
IMT Bucharest

Scientific Report 2018



From micro- to nanotechnologies,
nano-biotechnologies and nanoelectronics

Ministry of Research and Innovation

National Institute for Research and Development in Microtechnologies

IMT Bucharest

SCIENTIFIC REPORT
2018

Research, Technological development and experimental infrastructure

Design: IMT Bucharest

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Introduction

The National Institute for Research and Development in Microtechnologies – IMT Bucharest was set up at the end of 1996. The institute is the successor of the Institute for Microtechnologies-IMT, founded in 1993 which merged with Research Institute for Electronic Components, founded in 1969. In 2018 the institute was coordinated by the Ministry of Research and Innovation, acting basically as an autonomous, non-profit research company.

IMT – Bucharest is an internationally competitive organization, involved in world class research with an attractive environment for interdisciplinary research. In 2018 IMT Bucharest continued its activity in highly innovative research, developing novel technologies in the field of: micro and nanoelectronic components and systems, smart sensors, micro and nanotechnology, in education, technology transfer, offering services for industry.

IMT-Bucharest is an important actor in Romania and in Europe in micro and nanotechnologies field.
The research performed in national and international projects and/or published in ISI papers covered all range of activities from basic research to applied science and was mainly oriented, as in the previous years, to:

- micro and nanoelectronic devices
- micro and nanophotonics
- nanotechnologies
- advanced materials

At European level, IMT Bucharest in 2018 run or won as partner, **3 H2020-FETOPEN** projects: CHIRON, NANOPOLY, IQubits, being the first FET projects, ever involving Romania. The coordinators are: IMEC, Belgium, Thales RTS, France, Arhus University, Denmark. Another H2020-ICT project, won as partner, is NANOSMART (coordinated by Thales RTS, France). IMT was engaged in a H2020-ECSEL (coordinated by Infineon AG, Germany) and a H2020 Marie Skłodowska-Curie Actions- Individual Fellowship projects, M.ERANET, ESA, EUREKA and 2 FLAG–ERA projects in the field of health and robotics.

In 2018 the research activity of its 4 R&D centres, grouping 11 laboratories, was directed to the priorities of the Romanian National Strategy for Research and Innovation SNCDI (2014-2020) and of EU program Horizon 2020.

At national level, a Structural funded project "TGE-PLAT", dedicated to a Platform which offers access to IMT's infrastructure and allow transfer of knowledge to Romanian SMEs, gave the opportunity to cooperate with 6 industrial companies in the field of ICT and security.
In 2018 started a new important Romanian Project of Excellence in ICT, Space and Security (Contract 13PFE/16.10.2018), which support the development of the institute in micro and nanotechnoloies for smarts systems, consolidating its infrastructure and the competences of the staff.

Also we mansion 8 Complex Romanian projects, IMT being involved as coordinator or partner in the field of: ICT, Eco-Nanotechnoloies, Health, New and emergent Technologies, Bio-economy.

IMT's infrastructure comprises two main technological facilities: **IMT-MINAFAB** (Facility for Design, Simulation, Micro- nanofabrication of electronic devices and systems) and **CENASIC** (Research Centre for Integrated Systems, Nanotechnologies and Carbon Based Nanomaterials). In 2018 IMT continues the investments in infrastructure.

MINAFAB (www.imt.ro/MINAFAB), inaugurated in 2009, displays a broad range of experimental and computing resources for micro- and nanoelectronics, micro and nanotechnologies, from simulation and design techniques, to characterization tools, processing equipment (including a mask shop, EBL nanolitography), functional and reliability tests.

CENASIC, in use since November 2015, have state of art equipment. The main activity is oriented to research in the field of graphene based devices and other carbon based materials, as nanocrystaline diamond and SiC.

IMT organized a couple of events: The 14th edition of "Expert evaluation and Control of Compounds of Semiconductor Materials and Technologies (EXMATEC)", the 42nd Workshop on Compound Semiconductor Devices and Integrated Circuits, National Seminar on Nanoscience and Nano-technologies at its 17th edition and CAS - International Semiconductor Conference - an IEEE event, 41th edition; "Internet of Things" Workshop, in the frame of SOVAREX national project.
IMT participated at World Micrommachine Summit, held in Buenos Aires, the only country from Eastern and South Europe, 12th consecutive participation- only by invitation.

Concerning human resources, current research staff involve multidisciplinary teams (electronic engineers, chemists, physicists, materials engineers, mathematicians, biologists), young PhD students, technicians, administrative staff (in total 198), which were engaged in national and international research, advancing new knowledge and innovation.

The figures presented in the report show a relatively balanced distribution of human resources between young and senior researchers (also between male and female).

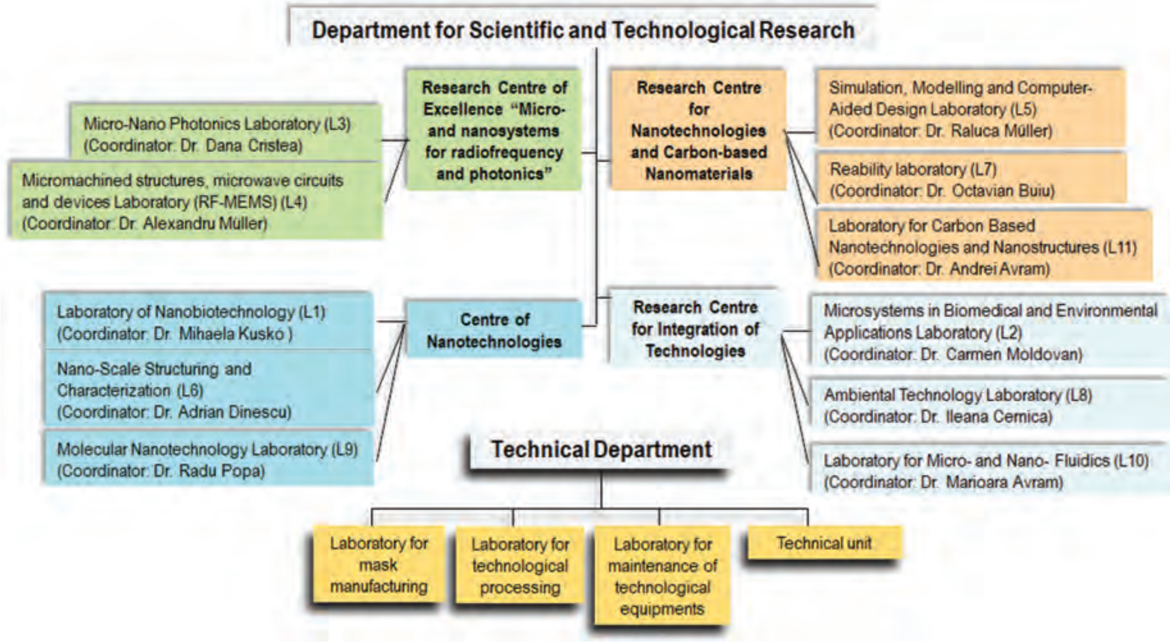
The turnover is relatively similar, compared with 2017, considering the number and value of the national and international running projects.
IMT Bucharest developed partnerships with higher education institutions (University Politechnica Bucharest and others), provided access to students for internships from Romania and all over the word, to advance their knowledge and gain new skills.

The Scientific Report 2018 presents the most important projects and the research highlights of the 11 research laboratories, grouped in 4 centers. A list of ISI scientific publications concludes the report.

I would like to thank to all the staff and their high level work and support during 2018.

Dr. Miron Adrian Dinescu
CEO and President of the Board

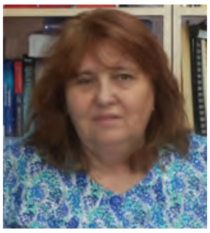
Organization: Scientific and Technical Departments



Dr. Adrian Dinescu

PhD in Physics, General Manager of IMT Bucharest.

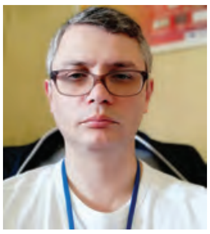
See the CV on page 20.



Dr. Raluca Müller

PhD in Electronics, Scientific Director of IMT Bucharest.

See the CV on page 24.



Dr. Dan Vasilache

PhD in Electronics, Technical Director of IMT Bucharest.

Dr. Dan Vasilache obtaine the Licence in Atomic Physics in 1995 from Bucharest Univ. and PhD degree in 2011 from Politechnica Univ. Bucharest. His career started with ICCE-Research Institute for Electronic Components, Romania (1995-1997), and starting from 1997 he is with IMT-Bucharest (1997-2009 and 2012-present), while between 2010 and 2012 he was employed at FBK-irst Trento. He was clean room head between 2006 and 2008 and 2016-2017, and starting from 2017 he is the Technical Manager of IMT-Bucharest. He is involved in technological design ang processes development for RF MEMS devices.

Ec. Domnica Geambazi

Financial Director until June 2018.

Dr. Alexandru Müller

PhD in Physics, Director 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, IMT Bucharest.

See the CV on page 9.

Dr. Radu Cristian Popa

PhD in Quantum Engineering and Systems Science, Director of Centre of Nanotechnologies CNT, IMT Bucharest.

See the CV on page 27.

Dr. Mircea Dragoman

PhD in Electronics, Director Centre for Nanotechnologies and Carbon-based Nanomaterials CENASIC, President of the IMT Bucharest Scientific Council.

See the CV on page 5.

Dr. Carmen Moldovan

PhD in Electronics, Centre for Research and Technologies Integration, IMT Bucharest.

See the CV on page 35.

Ec. Constantina Simon

Financial Director since July 2018.

Human resources, funding and investments

Human resources

IMT Bucharest is active in R&D and Innovation with a number of researchers, engineers, technicians and other support personnel. IMT has become an attraction for skilled and motivated people because of the new infrastructures and the important number of national and European projects in the field of ICT, space and security, photonics, nanotechnologies, smart sensors, and advanced materials.

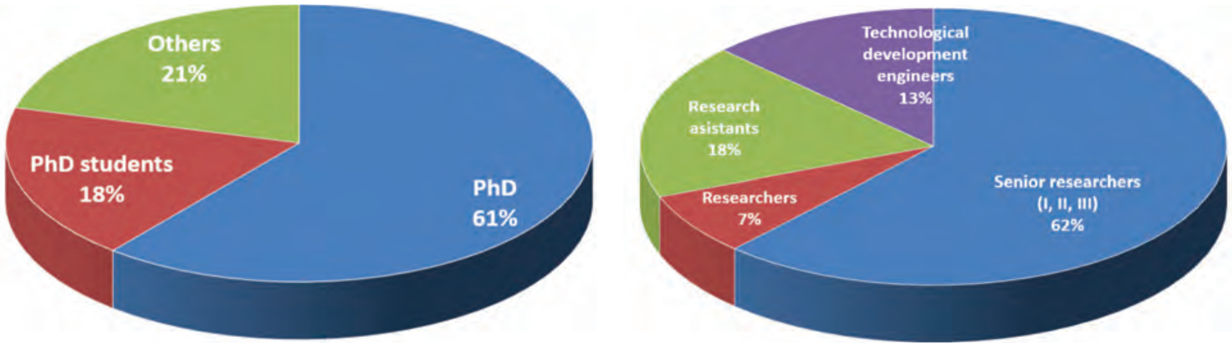


Figure 1 (a, b) provides information about the number and distribution of researchers and technological development engineers (IDT) active in IMT in 2018

Figure 1 (a, b) provides information about the number and distribution of researchers (87%), technological development engineers (IDT- 13%) and development and process engineers active in IMT in 2018 (110 persons). Considering the researchers 62% are senior researchers I, II and III, 7% researchers, 18% young assistant researchers. 32% of the employers are under 35 years. The average age of IMT researchers is around 46.

In 2018, in the frame of Complex projects, IMT hired a lot of young MS and PhD students.

Figure 2 presents information about the multidisciplinary background of researchers and IDT active in IMT in 2017. The male (52 %) - female (48 %) ratio is relatively balanced.

IMT Bucharest offer opportunities for students from Romania, especially from "Politechnica" University Bucharest, EU, Associated Counties and South Africa, to develop multidisciplinary research, to be in contact with new technologies, by providing access to practical labs, summer stages, supervising experimental/ scientific work of their diploma and PhD thesis.

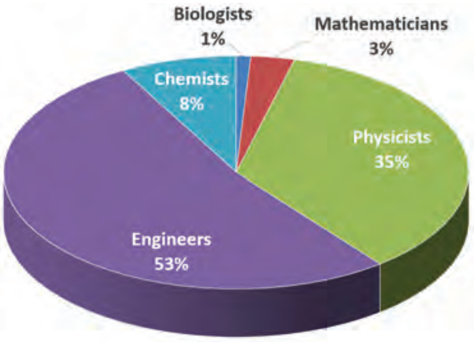


Fig. 2.

Funding sources and investments

Fig. 3 shows the distribution of funding sources in 2018: national R&D programs (competitive funding, through open calls): 28%, Structural Funds 14%, different European Projects and other sources (H2020 and related – EUREKA), ESA, SEE and bilateral) 15%.

The next figure (fig. 4) presents information about the evolution of IMT turnover during the last period and information about investments in various equipment. The financial performance in 2018 is comparable to 2017.

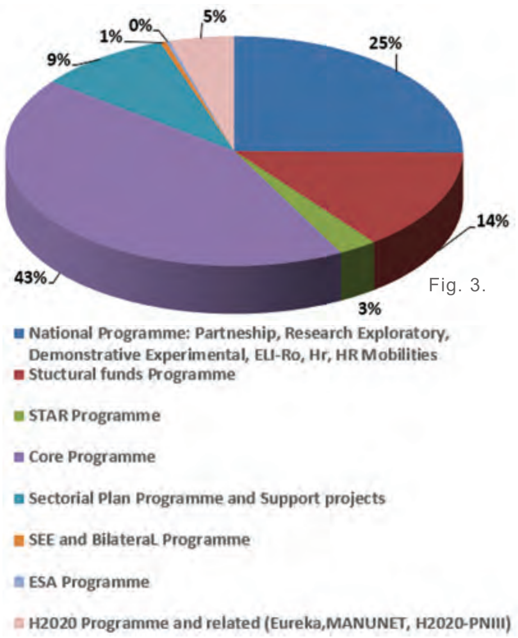


Fig. 3.

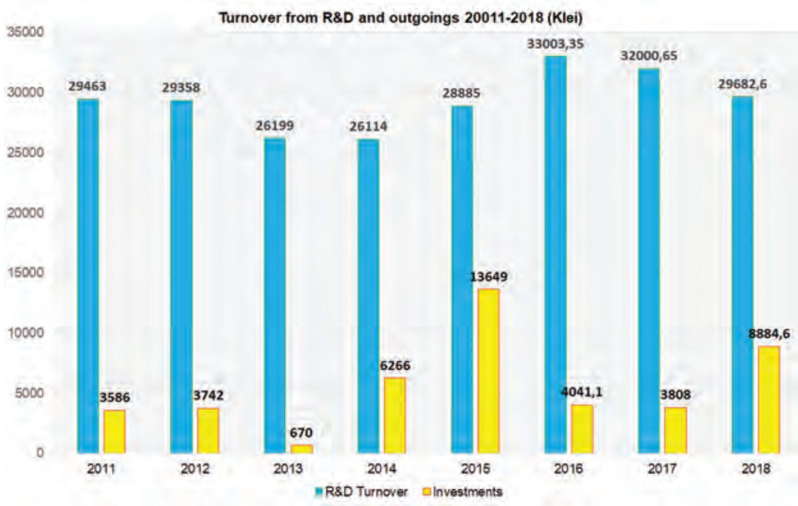


Fig. 4.

Experimental facility: IMT-MINAFAB

IMT-MINAFAB - Facility for design, simulation, micro and nanofabrication for electronic devices and systems is a modern facility, unique in Romania, competitive at European level, for research and development of micro-nanoelectronic devices, sensors and micro-systems (www.imt.ro/MINAFAB), launched in April 2009.

The facility provides "open access" to modern, state of arts equipments and is the only facility in Romania where one can fabricate electronic components and systems (including smart sensors and systems), all the manufacturing chain being available: design, modeling, CAD, technological fabrication, micro-physical characterization, functional testing and reliability examinations. The facility is a collaborative platform for research, industry and universities, similar with other EU centers and benefits of the expertise of a multidisciplinary team.

IMT-MINAFAB has several clean-room areas with specialized technological and characterization laboratories-totalizing a surface of almost 700 m^2 (including one clean room of class 1.000), and modern equipments worth more than 8 MEuro. The services and administrative activities of the center are SR EN ISO 9001:2008 certified by TÜV Thüringen e.V. This research infrastructure enabled IMT to extend its R&D capabilities.

IMT-MINAFAB infrastructure contains a key unit, the „Facility for micro-nanostructuring of devices and systems", unique in this country. This facility is responsible for mask fabrication, photo-lithography and also for micro-nanostructuring using Electron Beam Lithography-EBL. The facility acts as a platform for integrated Key Enabling Technologies (KETs), especially 4 Kets: micro-nanoelectronics, photonics, nanotechnologies and advanced materials. Since 2017, the facility has been upgraded with an area of 280 m^2 of clean room class 10,000.

IMT-MINAFAB is included in the MERIL and ERRIS databases (**https://erris.gov.ro/MINAFAB**). Short presentation of the most important components of the research infrastructure follows:

- A class 1000 clean room (220 m^2) for the mask shop and the most demanding technological processes (in use since 2008);
- A class 100,000 clean room, the so called "Grey Area"(200 m^2), mostly for the characterization equipments (in use since 2008):
- A class 10,000 clean room (105 m^2) for thin layer deposition by CVD techniques: LPCVD, PECVD; DRIE; RTP etc. (fully in use since early 2012);

• Photolithography (chrome, maskless, wafer double-side alignment and exposure)

Pattern generator-DWL 66fs Laser Lithography System (Heidelberg Instruments Mikrotechnik, De.)

Double Side Mask Aligner-MA6/BA6 (Suss MicroTec, Germany)

• Nanolithography (EBL, EBID, EBIE, Dip-pen) and SEM

Electron Beam Lithography and nanoengineering workstation-e_Line (Raith, De.)

Dip Pen Nanolithography-NSCRIPTOR (NanoInk, Inc., USA)

Field Emission Gun Scanning Electron Microscope (FEG-SEM)-Nova NanoSEM 630 (FEI Company, USA).

• Physical depositions of materials in high-vacuum

Electron Beam Evaporation-TEMESCAL FC-2000 (Temescal, USA)

Electron Beam Evaporation and DC sputtering system-AUTO 500 (BOC Edwards, UK)

• Chemical depositions, thermal processing

PECVD-LPX-CVD, with LDS module (SPTS, UK)

LPCVD-LC100 (AnnealSys, Fr.)

Rapid thermal processing/annealing AS-One (AnnealSys, Fr)

• Precision etching of materials (plasma reactive ion, humid, shallow and deep)

DRIE-Plasmalab System 100- ICP Deep Reactive Ion Etching System (Oxford Instruments, UK)

RIE Plasma Etcher-Etchlab 200 (SENTECH Instruments, De)

• X-Ray diffractometry

X-ray Diffraction System (triple axis rotating anode) - SmartLab 9kW rotating anode, in-plane arm (Rigaku Corporation, Jp)

• Scanning probe microscopy: AFM, STM, SNOM, confocal, Raman mapping

Scanning Probe Microscope-NTEGRA Aura (NT-MDT Co., Ru.)

Scanning Near-field Optical Microscope, Witec alpha 300S (Witec, De)

• Nanomechanical characterization

Nanomechanical Characterization equipment-Nano Indenter G200 - (Agilent Technologies, USA)

• Microarray spotting/scanning

Micro-Nano Plotter-OmniGrid (Genomic Solutions Ltd., UK)

Microarray Scanner-GeneTAC UC4 (Genomic Solutions Ltd., UK)

• Analytical characterization tools

Scanning Electrochemical Microscope ElProScan (HEKA, De)

Zeta Potential and Submicron Particle Size Analyzer-DelsaNano (Beckman Coulter, USA)

Fluorescence Spectrometer-FLS920P (Edinburgh Instruments, UK)

• Interferometry/profilometry; Spectroscopy

High Resolution Raman Spectrometer-LabRAM HR800 (HORIBA Jobin Yvon, Jp)

White Light Interferometer - Photomap 3D (FOGALE nanotech, Fr)

Electrochemical Impedance Spectrometer-PARSTAT 2273 (Princeton Applied Research, USA)

Fourier-Transform Infrared Spectrometer-Tensor 27 (Bruker Optics, De)

UV-Vis-NIR Thermo-Electric Cooled Fiber Optic Spectrometer - AvaSpec-2048 TEC (Avantes, The Netherlands)

Refractometer for layer thickness measurements-NanoCalc-XR (Oceanoptics, USA)

• Probers, on-wafer; electrical characterization

Semiconductor Characterization System (DC) with Wafer Probing Station - 4200-SCS/C/Keithley

Easyprobe EP6/ Suss MicroTec (Keithley Instruments, USA;

Semiconductor Characterization System - 4200-SCS, C-V 3532-50, DMM 2700-7700, 2002,6211-2182 (Keithley Instruments, USA)

Microwave network analyzer (0.1-110GHz) with Manual Probing Station (Anritsu, Japan; Suss MicroTec, De)

Frequency Synthesizer up to 110 GHz (Agilent, USA)

Spectrum Analyzer up to 110 GHz (Anritsu, Jp)

In 2018, a new thermal processes laboratory was developed, consisting of two SiO_2 thermal oxidation furnaces and four high temperature processing equipment.

Research Centre for Integrated Systems Nanotechnologies and Carbon Based Nanomaterials - CENASIC

The Research Centre for Integrated Systems Nanotechnologies and Carbon Based Nanomaterials (CENASIC) is a new asset which provides access to new equipment, laboratories and state-of-the art technologies.

The project was financed by Structural Funding Sectorial Operational Programme "Increase of economic competitiveness Project POS-CCE- (2011-2015) and represents an investment of 6 MEuro in a new building for offices, clean rooms and equipment. There are approximately 1000 m^2, including 4 levels: the clean room (ground floor), technical level, 2 levels for labs and offices. CENASIC is a unique infrastructure in Romania, competitive at regional and European level, with 8 new modern laboratories, with state of art, complex equipment, dedicated to carbon based materials and devices.

The key new technological equipment within the CENASIC are:

- Multiprocess Furnace System
- Molecular Beam Epitaxy (MBE)
- Plasma Enhanced Chemical Vapor Deposition (PE CVD)
- Atomic Layer Deposition (ALD) tool
- RF Magnetron Sputtering

The center is developing the following research topics:

► SiC technologies and functional micro-nanostructures; Processes for SiC-based micro- and nanostructures

► Technologies for graphene and hybrid MEMS/NEMS

► Technologies for nanocrystalline diamond and applications in MEMS/NEMS and precision mechanics

In 2018 the new research infrastructure CENASIC was an important support for new projects.

The young scientists, supervised by Dr. Mircea Dragoman focused their research on new technological processes for thin films of advanced materials, new technologies and nanoelectronic devices based on single layer graphene;

The center offers services and equipment of high complexity, which allow the realization of the most modern technologies for processes and analyzes dedicated to the carbon class (films and structures 0D-3D), with an advanced degree of applicability and a strong interdisciplinary character. The investments made in this research infrastructure are aimed at the creation of new technological platforms capable of supporting technologies for the synthesis and processing of nanomaterials with special properties, technologies for micro/nano processors and design of innovative systems and devices. Infrastructure direct public link in ERRIS: https://erris.gov.ro/CENASIC. Images from the new clean room (class 1000 and 100)

Director of CENASIC: Dr. Mircea Dragoman (mircea.dragoman@imt.ro)

Beneficiary: National Institute for R&D in Microtechnologies - IMT Bucharest;

Web page: www.imt.ro, 126A, Erou Iancu Nicolae Street, 077190, Voluntari, Ilfov, Romania

Dr. Mircea Dragoman graduated the "Politehnica" University of Bucharest, Electronic Faculty, in 1980. He received the doctoral degree in electronics in 1991.

Mircea Dragoman is a senior researcher at the IMT-Bucharest, he is working in the laboratory "Microsystems and micromachined circuits for microwaves- (RF MEMS)" where he designed and characterized a series of circuits in the microwave and millimeter range. He was Director of Centre for Research and Technologies Integration and currently is the president of the Scientific Council. He has published 208 scientific papers, 117 ISI papers. The papers are dedicated to the following areas: nanoelectronics, microwaves, MEMS, optoelectronics. He is co-author of several books.

Director of CENASIC:
Dr. Mircea Dragoman,
mircea.dragoman@imt.ro

TECHNOLOGICAL TRANSFER INFRASTRUCTURES

CENTRE FOR TECHNOLOGY TRANSFER IN MICROENGINEERING

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THE SCIENCE AND TECHNOLOGY PARK FOR MICRO AND NANOTECHNOLOGIES

Contact data: MINATECH-RO (www.minatech.ro); Tel: +4021269.07.67; E-mail: team@minatech.ro
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ROMANIAN-BULGARIAN SERVICES CENTRE FOR MICROSYSTEMS AND NANOTECHNOLOGY

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E-mail: office@ro-bgmicronanotech.eu

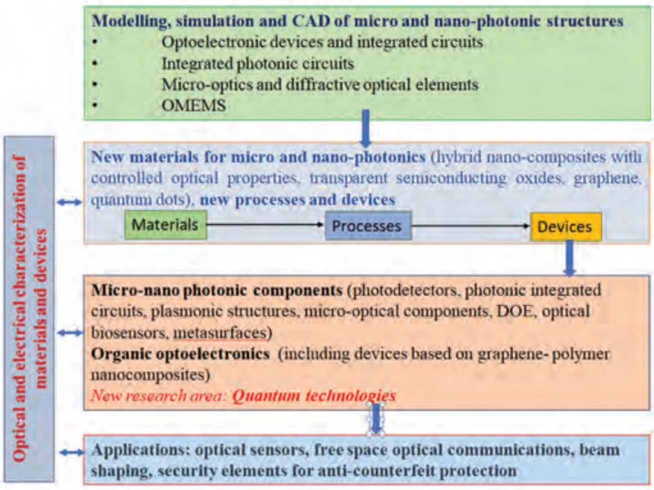
MIMOMEMS European Centre of Excellence
Laboratory of Micro/Nano Photonics

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.

Mission

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

Research activity



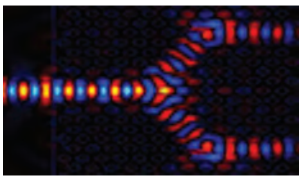
Team

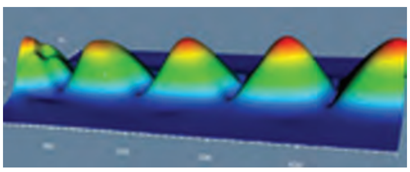
1. **Dr. Dana Cristea** senior researcher, M.Sc. in electronic engineering, Ph.D.in optoelectronics & materials for electronics;
2. **Dr. Munizer Purica** senior researcher, M.Sc. and Ph.D. in physics;
3. **Dr. Cristian Kusko** researcher, M.Sc. and Ph.D – physics;
4. **Dr. Paula Obreja** senior researcher, M.Sc. and Ph.D. in physical chemistry;
5. **Dr. Mihai Kusko** senior researcher (M.Sc. in physics and photonics, Ph.D in optoelectronics);
6. **Dr. Florin Comanescu** – researcher, M.Sc. in electronics and PhD in optoelectronics at "Politechnica" University of Bucharest;
7. **Dr. Roxana Rebigan** researcher, M.Sc. in physics and Ph.D in optoelectronics;
8. **Dr. Roxana Tomescu** – researcher, M.Sc. in electronics and PhD in optoelectronics at "Politechnica" University of Bucharest;
9. **Dr. Rebeca Tudor** – junior researcher, M.Sc. in Electronics, PhD in Physics.
10. **Ing. Ramona Călinoiu** – AC, M.Sc student in Automatic Control and Computers
11. **Ing. Ştefan Cărămizoiu** – AC, PhD student in physiscs;
12. **Ing. Costel Păun** – AC, PhD student in chemistry
13. **Fiz. George Bulzan** – AC, M.Sc student in physics.

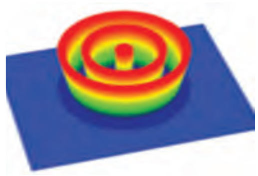
Laboratory head:
Dr. Dana Cristea,
dana.cristea@imt.ro

Dr. Dana Cristea MSc in Electronics and PhD in Optoelectronics from "Politehnica" University, Bucharest, Romania. She is the head of Microphotonics Lab and the manager of the Core program IMT. Between 2002 and 2008 she was the Scientific manager of IMT. Her main research activities are in the fields of optoelectronic devices, photonic integrated circuits, optical-MEMS, micro-optics integration technologies. She is author or co-author of more than 100 papers published in journals and Conference Proceedings and holds 5 patents. Dr. Dana Cristea coordinated more than 25 national projects, participated in several FP6, FP7 and H2020 projects (WAPITI, 4M, ASSEMIC, FlexPAET, MIMOMEMS, ENF 2019). She is currently scientific manager in two projects aiming at knowledge transfer to SMEs and in R&I projects on optoelectronic devices based on QDs and nanoplasmonic structures.

Specific facilities







Modelling and simulation:

• ***Opti FDTD 13.0.3*** – design and simulation of advanced passive and nonlinear photonic devices using FDTD (Finite-Difference Time-Domain) method.

• ***OptiBPM 13.1*** - design of complex photonic integrated circuits for guiding, coupling, switching, splitting, multiplexing and demultiplexing of optical signals using BPM (beam propagation method) method.

• ***OmniSim***-design/simulation 2D/3D of photonic components using FDTD.

• ***OptiGrating***, **LaserMod**

• **3Lit** – design of 3D micro-optical elements.

• **Zemax** – optical design.

Technology: • glove box for preparation and deposition of nanocomposites and organic layers

Characterization:

• **Spectroscopic ellipsometer**;

• **High Resolution Raman Spectrometers LabRAM HR** with module **TERS/AFM** for nanostructures based on carbon;

• **Alpha300 S System** – Scanning Near-field Optical Microscope, Confocal Microscopy and Atomic Force Microscopy, and Raman Spectrometers.

• **Optical Theta Tensiometer** (KSW Instruments)

• experimental set-up for optoelectric characterization in UV-VIS-IR spectral range.

Laboratory of Micro/Nano Photonics

National and international cooperation

• Cooperation with European research units and industry (K4-IKERLAN-Spain FhG IPMS-Germany, FundingBox Accelerator sp. z o.o.-Poland, Karlsruhe Institute of Technology-Germany, and new proposals on H2020 and COST action programs, CEA-Liten, LAAS-CNRS Toulouse, industry from Spain, Germany, Finland , Austria, France EU projects: Flexible Patterning of Complex Micro Structures using Adaptive Embossing Technology FLEXPAET (FP7/IP-NMP; European Centre of Excellence MIMOMEMS (FP7-SA-Capacities), Multifunctional Zinc-Oxide based nano-structures. (MNT EraNet)

• Cooperation with Romanian industry (Optoelectronica 2001, Pro-Optica, Apel Laser), research institutes (INFLPR, ICPE-CA) and universities (Univ. "Dunarea de jos" Galati, UAIC Iasi) on national research programs PN II and PN III.

• New national cooperation: with Optoelectronica-2001 S.A. in „Technological transfer to increase the quality and security level of holographic labels", and a new platform for a large variety cooperation with industry –TGEPLAT, Contract no. 77/08.09.2016, Cod SMIS2014+ 105623, project financed by Operational program for economic competitivity POC

New funded projects

• ***IR sensors for infrastructures' security applications***, Coordinator Dr. Ing. Roxana Tomescu, part of the Complex Project named „Sensors and integrated electronic and photonic systems for persons' and infrastructures' security", **PN-III-P1-1.2-PCCDI2017-0419**, partnership with INFLPR RA.

• ***Development of quantum information and technologies in Romania, PN-III-P1-1.2-PCCDI2017-0338***, 2018-2019, IMT Coordinator: Dr. Cristian KUSKO, Field: Emerging technologies, Consortium: Coordinator: National Institute for Research and Development in Nuclear Physics and Engineering „Horia Hulubei" – IFIN HH. Partners: National Institute for Research and Development for Lasers, Plasma and Radiation Physics – INFLPR; Politehnica University of Bucharest, National Institute for Research and Development for Molecular and Izotopic Technologies INCDTIM.

• ***Multispectral photodetector technology for surveillance and watching optical systems applications, PN-III-P2-2.1-PED-2016-0307***, project duration: 2017-2018, Coordinator: Dr. Dana Cristea (dana.cristea@imt.ro)

• **EURONANOFORUM 2019** – (ENF 2019), Nanotechnology and Advanced Materials progress Under H2020 and Beyond, call H2020-IBA-LEIT-NMBP-Romanian-Presidency-2018,

• **DNMF_net** - Network of nano research infrastructures in the Danube region (Project supported by the German Federal Ministry of Education and Research (BMBF) under the "ideas competition for the establishment and development of innovative R&D networks with partners in the Danube States", 2017-2019

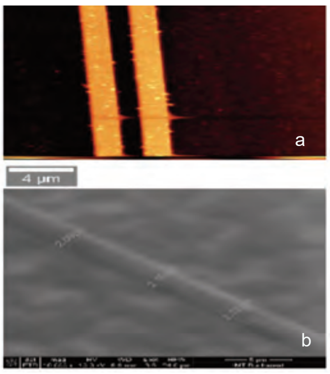
Scientific results

Developing quantum information and quantum technologies in Romania, complex project (PCCDI) PN III-P1-1.2-PCCDI-2017-0338 2018-2021 (IFIN-HH coordinator, IMT partner, ***Cristian Kusko***, cristian.kusko@imt.ro)

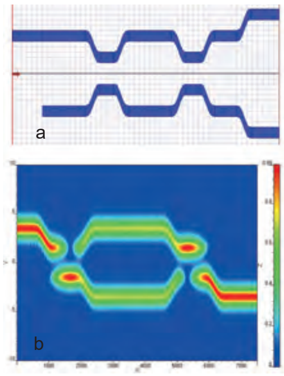
Project 2 Q-CHIP: Developing the integrated quantum photonics platform for quantum technologies fabricated with 3D lithography

We performed numerical OptiFDTD simulations for light propagation in photonic integrated circuits. We fabricated and characterized optical components based on silicon and silicon compounds. The photonic circuits were fabricated using standard silicon technology. We designed, simulated and modelled optical switches based on Mach-Zehnder which can be controlled via termo-optic effect. The waveguides are based on silicon nitride with specific geometrical parameters in order to permit the light propagation in monomod regime for λ=633 nm wavelength.

For the fabrication of the waveguides as switch or Mach-Zehnder interferometer a photolithographical process has been performed followed by a reactive ion etching.



Structural characterization for the fabricated waveguide:
a) 2D AFM image,
b) top view SEM image.



(a) Layout for switch (b) Light propagation in the switch based on Mach-Zehnder interferometer.

Project 3 Q-VORTEX: Quantum information with optical vortices (IMT)

We have been exploited a new degree of freedom for photons – orbital angular momentum (OAM) for novel quantum applications. In order to generate photons which carry OAM we designed, fabricated and characterized diffractive optical elelements such as spiral phase plates with 32 levels which operate in reflection mode at λ=633 nm wavelength. An example of these multilevel elements is illustrated in Fig. 1a). The spiral phase plate presents a high optical quality and generates OAM states of order m=-1 for quantum information processing as it can be observed in Fig. 1b).

We designed, implemented and characterized (at classical level) an optical system in order to generate and sort/detect invariant rotational states for quantum key distribution applications (QKD) Fig. 2.

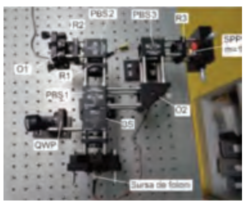


Fig. 2 Optical system which generates invariant rotational states.

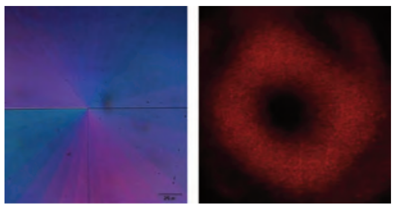


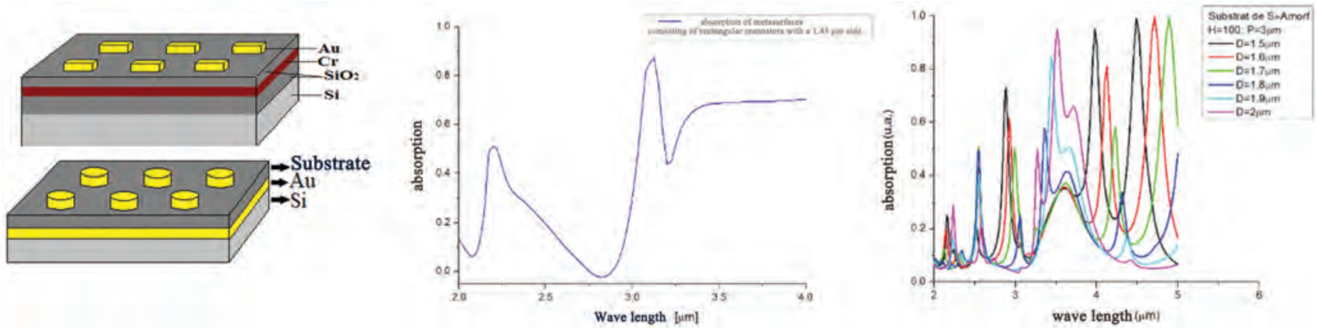
Fig. 1 a) Optical image for a spiral phase plate with order m=-1 with 32 levels operating in reflection mode b) Intensity distribution of an optical vortex which encode OAM state with m=-1

The characterization of the Q-code system has been performed at classical level by employing coherent laser beams in order to manipulate photonic states which are invariant at rotation.

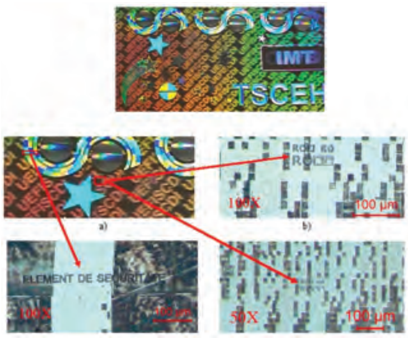
Laboratory of Micro/Nano Photonics
Scientific results

Infrared sensors with application in infrastructures security, part of the Complex Project, ***"Sensors and Electronic and Photonic Integrated Systems for the Security of People and Infrastructure"***, PN-III-P1-1.2-PCCDI2017-0419. Project Coordinatorr Dr. Roxana Tomescu (roxana.tomescu@imt.ro)

We designed, simulated and modeled metasurface structures of various geometries which have been configured to obtain improved absorptions at narrow wavelength intervals corresponding to gas molecule absorption to develop an IR source with controlled emissivity. Thus, several intervals have been obtained which provide about a maximum absorption for gases such as methane, carbon dioxide or carbon monoxide.



Schema and absorption spectra of metasurfaces consisting of rectangular resonators with a 1.45 μm side, or circular, with diameters between 1.5 μm and 2.4 μm, with a 3 μm period and a height of 100 nm.



Prototype holographic label and details of additional security elements.

Technology transfer to increase the security level and the quality of holographic labels, *PN-III-P2-2.1-PTE-2016-0072. (2016-2018) coordinator: Optoelectronca SA*

Additional security elements (alphanumeric symbols) have been designed and integrated into the structures of holographic labels to enhance the security level of protected products. The projected manufacturing process includes two consecutive stages of successive exposure (photolithography and direct laser writing) and only one development. The security elements thus added are impossible to detect and difficult to reproduce, being known only by the designer (different from the holographic structure designer) and can be identified using a 100X magnification optical microscope only knowing the coordinates to which they were placed and their number.

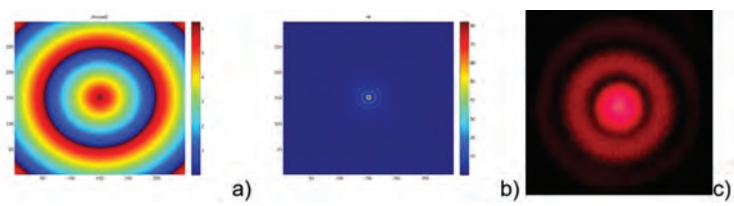
Multispectral photodetector technology for optical systems for surveillance and security application, *Project PN-III-P2-2.1-PED-2016-0307, Coordinator: Dr. Dana Cristea (dana.cristea@imt.ro)*

A technology for fabrication of photodetectors with broad spectral range, from UV to SWIR have been developed and two types of solution processed photodetectors based on PbS QDs in combination with silicon or ZnO NWs, hybrid nanocomposites and plasmonic nanoparticles have been fabricated. The ZnO NWs were grown by hydrothermal method on an RF sputtered seed layer. The PbS:P3HT:PCBM composite film was prepared by a layer-by-layer approach to obtain a uniform layer (combination drop casting+spin casting) High responsivities have been obtained – up to 1 A/W. The responsivity can be further increased by adding Ag NPs (PbS QDs : Ag NPs 100:1)

ZnO-PbS QDs heterojunction based photodetectors (left), ZnO NW- PbS QDs:P3HT:PCBM ternary blend photodetector (right)

Multilevel diffractive optical elements with advanced functionality, *Project PN 18080103/2018 from IMT Core Programme "MICRO-NANO SIS", Dr. Mihai Kusko (mihai.kusko@imt.ro), Dr. Rebeca Tudor (rebeca.tudor@imt.ro)*

We simulated, designed and fabricated multilevel asherical optical elements with high optical quality with advanced functionalities in optical communications and optical signal processing. We fabricated axicons with 32 levels which operates in transmission mode at λ=633 nm wavelength by using stantard microfabrication techniques such as photolithography and wet etching in order to generate nondiffractive Bessel beams.



a) Aspheric optical element - axicon of order 0 - simulation, b) Intensity distribution for a Bessel beam of order zero for visible light λ=633 nm b) simulation c) experiment

L4

MIMOMEMS European Centre of Excellence
Laboratory of Micromachined structures, microwave circuits and devices

Mission

Scientific research and technological development of micromachined microwave and millimetre wave devices and circuits, contributions to the developing strategy of the domain. The new RF MEMS technologies including the “membrane supported circuits” represents a solution to manufacture high performance microwave and millimeter wave devices and circuits devoted to the emerging communication systems and sensors. Lately the laboratory has also stared 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

L4 is one of the promoters of the RF – MEMS topics in Europe. It has coordinated the FP4 MEMSWAVE project (one of the first EU project in RF MEMS) nominated in 2002 for the Descatres prize and the FP 7 REGPOT MIMOMEMS (2008 – 20011). It has participated in the FP6 network of excellence “AMICOM” (2004 -2007) with new and original results obtained in cooperation with key players in the European research in this topic (LAAS–CNRS Toulouse, VTT Helsinki, FORTH Heraklion). The laboratory was partner in IP/FP7 (NANOTEC, SMARTPOWER), STREP/FP7 (NANO RF, MEMS-4-MMIC), ENIAC JU (SE2A, MERCURE, NANOCOM) and ESA.

The laboratory is now coordinator of one H2020-FETOPEN, one ESA project and one H2020/Marie Curie project (SelectX).

In 2018 the laboratory has won three European projects H2020: two FETOPEN (IQubits and NANOPOLY) and one ICT-RIA (NANOSMART). The projects will start in January 2019.

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 nano-processing materials;

• 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) based on micromachining and nanoprocessing of wide band gap semiconductors (AlN, GaN);

• UV photodetectors based on GaN/Si membrane

• Microwave devices based on carbon nanotubes;

• MEMS and NEMS technologies development;

Equipments

“On wafer” measurement system in the 0.1-110 GHz range (microwave network analyzer Anritsu and Karl SUSS Microtec Probe Station), Frequency Syntesizer Agilent up to 110 GHz; Spectrum Analyzer Anritsu up to 110 GHz; Tektronix digital serial analyzer DSA8200 with TDR module; Keithley Semiconductor characterization system, Optical profiler WLI – Photomap 3D; Millimeter wave power-meter in 0.1 – 40 GHz range, cryostat Janis Research SHI-4H-1 (5 - 500K temperature range), Network analyzer Anritsu up to 40 GHz, Büchiglasuster controlled pressure and temperature chamber, Measurement accessories, Computers and software for microwave electromagnetic simulations (IE3D, Fidelity, CST).

Team

The laboratory head is **Dr. Alexandru Müller,** PhD in Physics at Bucharest University in 1990. His competences includes Silicon, GaAs and GaN micromachining and nanomachining: manufacturing of RF MEMS components and circuits, technological process in GaAs MMICs, design, modelling and manufacturing of microwave passive membrane supported circuits, monolithically as well as hybrid integrated receiver front end modules, acoustic devices (FBARs and SAWs) based on micromachining and nano-processing of wide band gap semiconductors (AlN , GaN).

The research team has multidisciplinary expertise in physics and electronics of microsystems and is composed of 12 senior researchers (10 of them with PhD in physics and electronics) and two young researchers, PhD in electronics.

Laboratory head:
Dr. Alexandru Müller,
alexandru.muller@imt.ro

The laboratory team (from left to right):
M. Dragoman, G. Boldeiu, I. Petrini, M. Dionian,
C. Buiculescu, S. Iordanescu, A. Nicoloiu, V. Buiculescu,
A. Bunea, D. Neculoiu, A. Müller, D. Vasilache, A. Cismaru,
M. Aldrigo, C. Nastase, M Pasteanu.

Ongoing projects

International Projects

CHIRON- H2020-FETOPEN-2016-2017 No: 801055 “Spin Wave Computing for Ultimately-Scaled Hybrid Low-Power Electronics” Coordinator IMEC Belgium, 9 partners, 2018 – 2021, IMT partner

ESA - Contract No. 4000115202/15/NL/CBi “Microwave filters based on GaN/Si SAW resonators, operating at frequencies above 5 GHz” IMT coordinator, 2015 – 2017.

SelectX – H2020, Marie Curie project no.705957 “Integrated Crossbar of Microelectromechanical Selectors and Non-Volatile Memory Devices for Neuromorphic Computing”, 2016 – 2018, IMT coordinator

National projects

PN III projects: one exploratory research project (2017-2019) coordinator Dr. A. Müller, **three experimental demonstration projects** (2017-2018) coordinated by Dr. D. Neculoiu, Dr. M. Dragoman, and Dr. V. Buiculescu, **one project award for H2020 participation**, coordinated by Dr. A. Müller and **one complex research frontier project** (2018-2021) coordinator Dr. M. Dragoman.

Laboratory of Micromachined structures, microwave circuits and devices

Most important scientific results

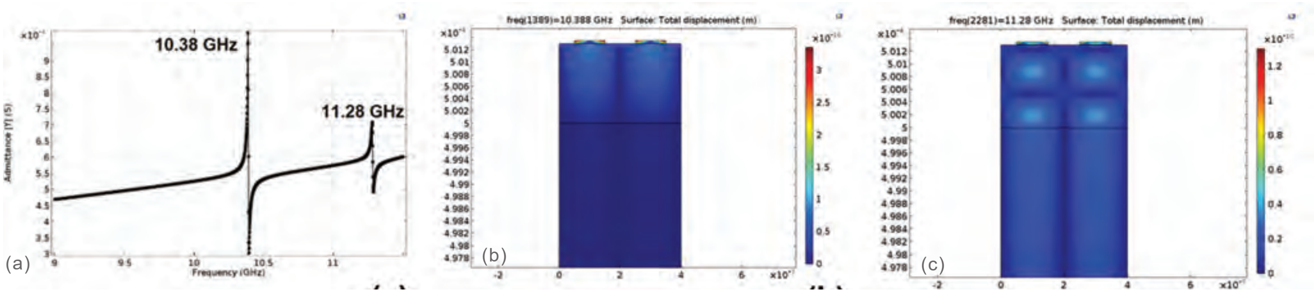
Project H2020, FETOPEN, "Spin Wave Computing for Ultimately-Scaled Hybrid Low-Power Electron-ics", CHIRON, (2018 - 2021), *Coordinated by IMEC, Belgium; IMT partner, responsible: Dr Alexandru Muller*
Other partners: TECHNISCHE UNIVERSITAET KAISERSLAUTERN Germany, Universite Paris-Sud France, Solmates BV Netherlands, CNRS France, FORTH-Heraklion Greece, THALES SA France, TECHNISCHE UNIVERSITEIT DELFT Netherlands

Objectives:

CHIRON envisions spin wave computing to complement and eventually replace CMOS in future micro-electronics. CHIRON will fabricate basic logic gates, such as inverters and majority gates, demonstrate their operation, and assess their performance.
CHIRON will develop transducers that are derived from high Q-factor acoustic devices, especially surface and bulk acoustic resonators. The targeted lateral scale (100 nm) and resonance frequency (>10 GHz) bring such resonators to the frontier of nano-electromechanical systems (NEMS). IMT is involved in the transducers development based on SAW and FBAR devices including magnetostrictive elements. The project started in May 2018 and first results connected with IMT s activity are presented bellow.

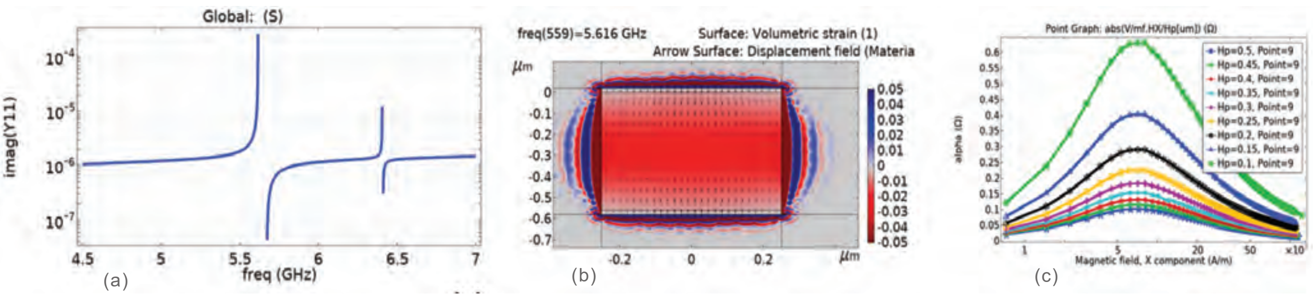
Simulation results with COMSOL Multiphysics

As one of the project objectives consists in increasing the resonance frequency to 10 GHz and beyond, we propose a design based on Surface Acoustic Wave (SAW) devices on GaN/Si for the magnetoelectric and multiferroic nanoresonators. SAW structures have the width of the electrodes, w = 100 nm and 5/45 nm thickness of the Ti/Au metallization. The simulated admittance shows a resonance frequency at 10.38 GHz, corresponding to the Rayleigh mode and a second resonance at 11.28 GHz corresponding to the Sezawa mode. The propagation modes were identified based on the mode shapes as well as on the acoustic wave velocity.



SAW structure with 100 nm wide electrodes and 5/45 nm Ti/Au thickness metallization: Simulated admittance as function of frequency (a); Simulated total displacement (zoom into the area of interest) for Rayleigh mode, resonance frequency 10.38 GHz (b); and for Sezawa mode, resonance frequency 11.28 GHz (c)

A finite-element model was developed in COMSOL to simulate the frequency response of FBAR structures. Only the active part of the transducer, surrounded by air, was included in the model. The admittance (imaginary part) for the GaN FBAR structure with Mo electrodes was simulated. The thickness of the Mo layer was 20 nm. The volumetric strain distribution and the displacement for the fundamental resonant mode was also simulated. An advanced COMSOL FEM model that couples 3 physics fields: "Solid Mechanics", "Electrostatics" and "Magnetic Fields" was developed and the magnetic field to electric field conversion was studied. The alpha coefficient (defined as the ratio between the mean value of the electric field between the FBAR electrodes and the external magnetic field intensity) was simulated with the piezoelectric layer thickness as a parameter. The FBAR structure can be used for efficient spin wave generation using a magnetostrictive layer in the top of the FBAR structure.



(a) Simulated imaginary part of the admittance of a GaN FBAR structure with Mo electrode; (b) Volumetric strain distribution and the displacement for the 5.616 GHz resonance. (c) The simulated results for the conversion coefficient with the thickness of the piezoelectric layer (Hp) as parameter.

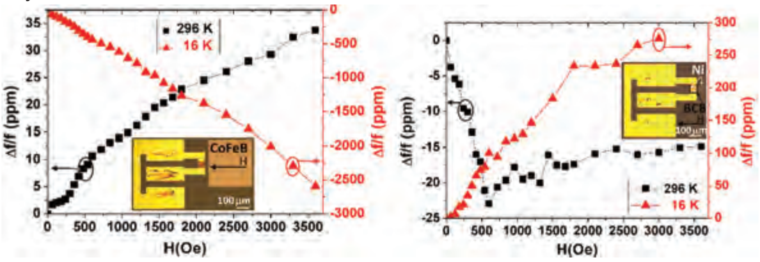
Laboratory of Micromachined structures, microwave circuits and devices

Most important scientific results

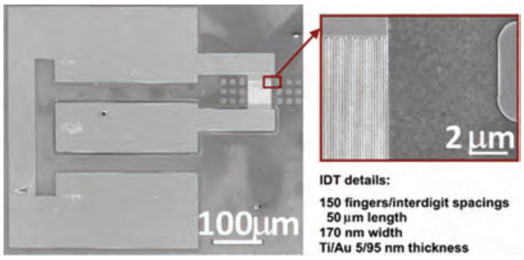
Experimental results: Magnetic sensors based on GaN/Si single SAW resonators

(cooperation IMT-IMEC and U Kaiserslautern)

The resonance frequency shift vs. the applied magnetic field strength for GaN/Si SAW single resonators operating at frequencies above 6 GHz was analysed. Magnetostrictive elements (Ni and CoFeB) were deposited in the proximity of the interdigitated transducers (IDTs) of the resonators (A-type structures) and also over the IDTs, after covering them with a BCB layer to avoid short circuits with IDTs metal (B-type structures). Magnetic sensitivity of the SAWs was analysed at room temperature (RT) and at cryogenic temperatures, for H=0....4000 Oe, obtaining high magnetic sensitivities at 16K. This work targets emerging applications of SAW resonators in driving spin wave pumping, one of the important targets of the CHIRON project.



Relative frequency shift vs. H for: (a) SAW structure A-type with CoFeB layer in the proximity of IDT and (b) for SAW structure B-type with Ni strips over and in the proximity of IDT.



SEM photo of the device.
Inset: detail of the IDT area.

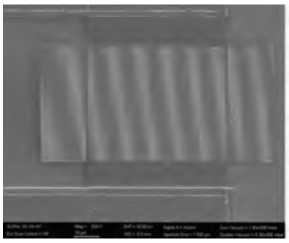
SAW temperature sensor manufactured on GaN/SiC, *PN III IDEAS PCE, Ctr 147/2017*

"Investigation of superior propagation modes in GHz operating GaN based SAW devices targeting high performance sensors and advanced communication system applications"

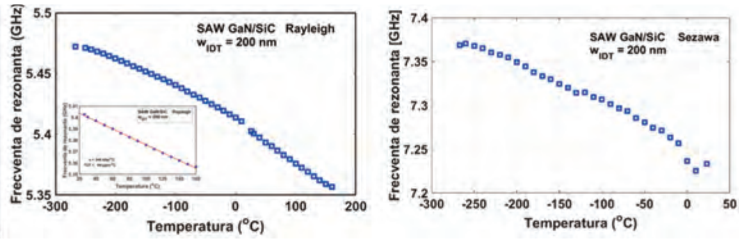
Project coordinator Dr. Alexandru Müller

The temperature dependence of the resonance frequency (Rayleigh mode) of the SAW structures on GaN/SiC (digit/interdigit of 200 nm) was measured in the -266°C to 160°C range. The sensitivity of 346 kHz/°C has been extracted.

For the Sezawa mode, the temperature measurements have been performed in two temperature intervals: -266°C to 26°C and 26°C to 160°C. For the second interval, the dependence of resonance frequency with temperature is linear. For temperatures under -250°C (23 K), the structures are insensitive with temperature, which is very interesting for some modern applications in the cryogenic temperature range. The sensitivity values obtained for the Sezawa mode are comparable to those obtained for the Rayleigh mode, representing a solution for the sensor applications targeting the increase of the resonance frequency.



SEM photo of the SAW structure manufactured on GaN/SiC



The temperature dependence of the resonance frequency for the SAW structure on GaN/SiC in the range of -266°C to 160°C: (a) Rayleigh mode, inset: 26°C to 160°C and (b) Sezawa mode

Design and realization and electrical characterization of MFS (metal-ferroelectric-semiconductor) capacitive structures using HfZrO or HfO_2 doped with Al or Cr., PN-III-PCCF **„Advanced nanoelectronic devices based on graphene/ferroelectric heterostructures", (GRAPHENEFERRO),**

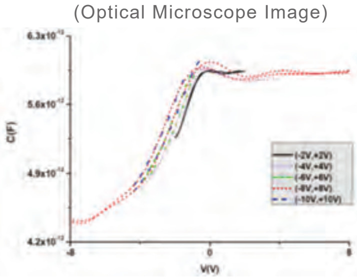
Project coordinator Dr. Mircea Dragoman

Capacitive structures MFS (metal-ferroelectric-semiconductor) type have been designed and realized in order to measure the electrical and AC properties of these structures.

MFS Structures
(Optical Microscope Image)

Measurements were performed using a Keithley SCS 4200 measuring station at room temperature inside a Faraday cage for different voltage ranges between ± 1V and ± 20V. The CVs show clearly the accumulation, drain and inversion regions for each sample in part. But the hysteresis signature in C-V curves does not fully certify ferroelectricity.

The MW-memory window is defined as the maximum capacity hysteresis at approximately C/2. If we use a dielectric instead of ferroelectric then the MW increases with the widening of the range in which the capacity is measured, but in the case of MW ferroelectrics it saturates when the critical electric field (coercive) is reached. In Phase 1 of the 2018 project (5 months), HfO_2 doped with Zr in ferroelectric state was obtained by the ALD and MS method; structural characterizations (XRD, PFM, HR-TEM) have been proven, as well as CV measurements or microstructure measurements performed on dozens of structures; PZT ferroelectric film was obtained very thin (50 nm) by the PLD method; Graphite / ferroelectric atomic studies have been initiated to discover that the HfO_2/graphene interface produces a forbidden band, which graphene does not have, a very useful result in the following research.



The C-V curve for a MFS structure at different voltage intervals at 100 kHz

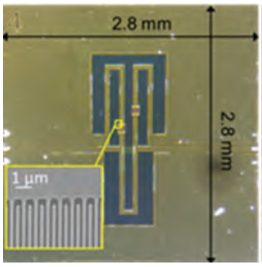
Laboratory of Micromachined structures, microwave circuits and devices

Most important scientific results

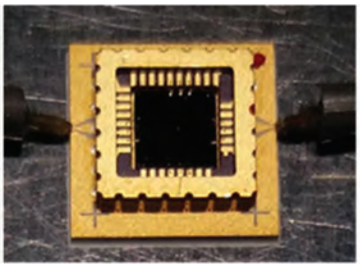
Microwave filters based on GaN/Si SAW resonators, operating at frequencies above 5 GHz

***ESA contract No. 4000115202/15/NL/Cbi „Microwave filters based on GaN/Si SAW resonators, operating at frequencies above 5 GHz"** – project coordinator Dr. Alexandru Müller*

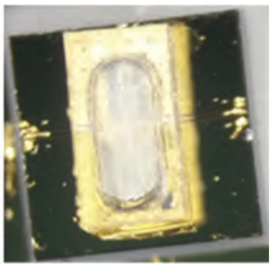
The main objectives of the project were the design, fabrication and characterization of a GaN Surface Acoustic Wave (SAW) resonator based filter, with the central operating frequency above 5 GHz. The filter developed in the frame of the project, has measured insertion losses of 12.9 dB at 5.49 GHz, reflection losses of 16 dB, a 3 dB bandwidth of 8.3 MHz and a out of band rejection of 24 dB. The filter was tested in a temperature range between -150…+150 ºC, with measured performances fulfilling the specifications formulated by the European Space Agency (ESA). The filter structures were integrated in a commercial ceramic package and using PMMA, in an on-chip packaging approach. The measured performances of the packaged devices fulfill the ESA specifications.



Band Pass Filter with 200 nm interdigital transducers



Filter structure integrated in a ceramic capsule



Filter structure integrated on chip with a PMMA cap

Design and realization and testing of cables based on graphite composites that are on average 50% lighter than copper

***PN-III-PED, ctr 91 PED/2017 "Graphite composites to improve the electric and thermal properties of cars"**- Project coordinator, Dr. Mircea Dragoman*

The project demonstrates that copper wires weighing in a Dacia 15-20 kg car can be replaced with much lighter graphite nanocomposite cables with greater mechanical strength and flexibility than copper, which reduces carbide consumption, increasing vehicle speed and reducing pollution.

Practically this project opens up the perspectives of compelling nanotechnology use in the automotive industry. Because graphene composites can be used in the construction of electric conductors used in the construction of the automobile, having the following advantages: mechanical resistance higher than the copper conductors; density much lower than copper - lighter conductors; much better flexibility than treaded copper - making it easier for cars to fit; electrical resistivity slightly decreasing with temperature.

Carbon fiber cables

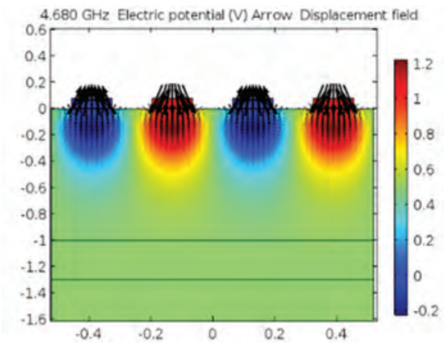
Thermal insulating elements based on graphite aerogels for Renault Dacia

Design, fabrication and characterization of surface acoustic wave (SAW) resonator band-pass filters integrated with printed lumped elements

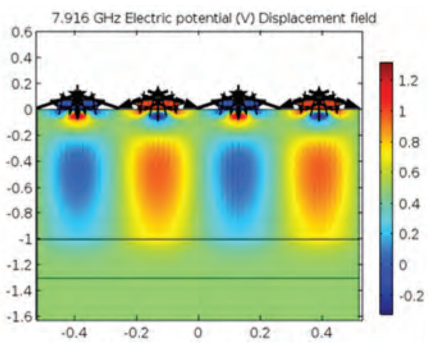
PN-III -PED "High performance Band-Pass Filters based on GaN Hybrid Acoustic Wave Lumped Element resonators for Space Applications" (HALE4SPACE),

Project manager: Prof. Dr. Dan Neculoiu

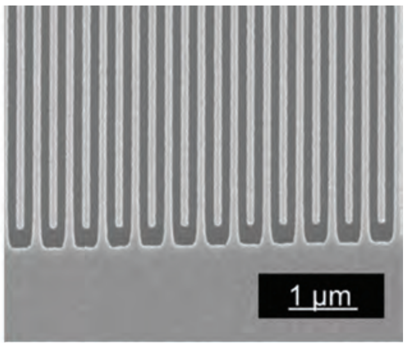
A new class of Band-Pass Filters based on Surface Acoustic Wave (SAW) resonators was developed in the frame of the project. The devices were processed on thin GaN layers grown on high resistivity silicon wafers. The high-quality factor (over 800) piezoelectric resonators were monolithically integrated with strip inductors enabling the control of the filter's selectivity characteristic. ***A Technology Readiness Level (TRL) of 4 (component and/or system validation in laboratory conditions)*** was achieved in the frame of the HALE4SPACE project. One of the main results is a filter operating at 8 GHz, with measured parameters significantly better than the current state of the art. Sezawa propagation modes were used for the surface acoustic waves, instead of the classic Rayleigh mode, together with interdigital transducers with 130 nm digits.



Electric potential distribution and mechanical displacement field for the Rayleigh propagation mode



Electric potential distribution and mechanical displacement field for the Sezawa propagation mode



SEM detail of 130 nm digits

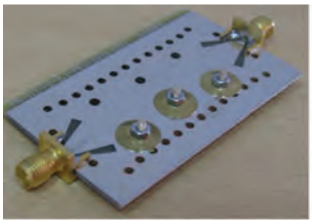
Laboratory of Micromachined structures, microwave circuits and devices

Most important scientific results

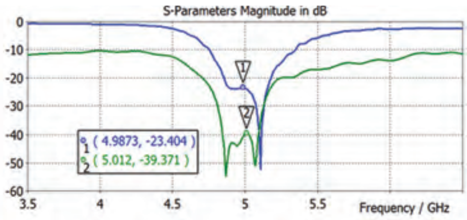
Design, manufacturing and characterization of (i) non-tunable, (ii) mechanically adjustable input matching, and (iii) mechanically adjustable center frequency substrate integrated waveguide (SIW) band-pass filters.

PN-III-P2-2.1-PED-2016-0957 (Demonstrative-experimental Project) – ctr. 215/PED/2017 „Continuous-tuning SIW band-pass filters”*, Project Director Dr. Valentin Buiculescu*

The project aimed for experimental evaluation of a recently patented mechanical tuning element (MTE) intended for SIW components. Three band-pass filters with different layout were proposed for MTEs' effectiveness assessment. The filters' design was based on regular FR-4 PCB substrate, hence poor permittivity tolerance was expected. Since the common technical and technological solutions used to cope with this drawback are quite complex and expensive, the proposed solution proved to be efficient due to its lower implementation costs. The MTEs' effectiveness regarding both impedance matching and tuning frequency ability of the SIW band-pass filter models has been fully confirmed by the experimental results.



SIW band-pass filter provided with mechanical tuning elements (MTEs).



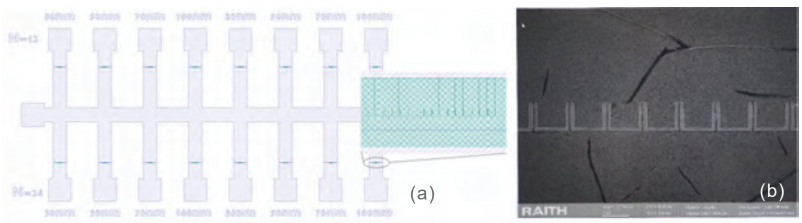
Input reflection coefficient before (blue trace) and after tuning (green trace) based on MTEs' insertion.

Design and fabrication of molybdenum disulfide-based devices

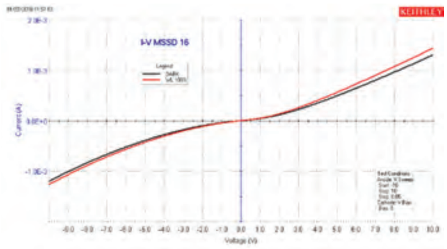
PN-III-P1-1.1-PD-2016-0535 no. 58: „Smart Radio Frequency IDentification (RFID) Technology exploiting Two-Dimensional Material-based Time-Modulated Arrays” *Project manager: Dr. Martino Aldrigo*

In this project, different topologies of molybdenum disulfide (MoS_2)-based self-switching diodes (SSD) have been designed. In detail, the technological realization of such diodes on MoS_2 thin films has been based upon the best configuration obtained from a geometrical optimization process. The designed diodes have a number of channels spanning the range 12-24, while channel's width is between 30 nm and 100 nm.

The I-V curve (see Fig. 2) shows a DC current of -1.2 mA at -10 V and of 1.31 mA at 10 V, with a leakage current of 43.2 nA at 0 V. With respect to graphene-based SSDs, MoS_2-based SSDs allow applying a larger DC bias voltage, without the risk of breakdown over 6–7 V. This phenomenon can be justified by the semiconducting nature of MoS_2 that exhibits a (direct or indirect) bandgap, which is absent in the case of graphene.



(a) Image of the designed MoS2-based SSDs for mask fabrication (via CleWin software); (b) SEM (= Scanning Electron Microscope) picture of one fabricated diode, with the channels clearly etched in the MoS2 thin film.

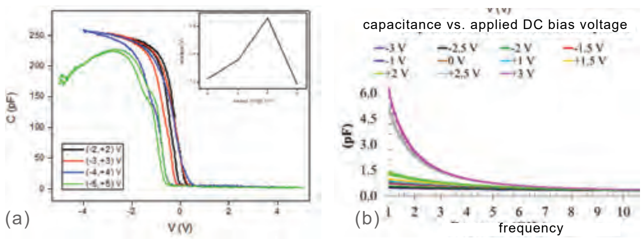


Measured I-V characteristic of a MoS2-based SSD with 16 channels.

Design, fabrication and experimental characterization of CPW-based vertical and interdigitated capacitors with hafnium-based ferroelectric thin films

FN ctr. 4N/2018: MICRO-NANO-SIS, Microstructures having piezoelectric, dielectric and ferroelectric thin films with applications in the 1-100 GHz frequency range

In this project, based on an initial electromagnetic model, MIM (metal-insulator-metal) vertical capacitors and resonators have been designed and fabricated, using CPW technology and Hf-based ferroelectric thin films. In the case of the MIM capacitors, the bulk substrate used is doped silicon and the characterization has been done in DC, by measuring I-V and C-V characteristics (in the latter case at a frequency of 100 kHz), for different ranges of the DC bias voltage. Then, interdigitated (IDT) capacitors embedded in CPW lines have been fabricated using high-resistivity silicon. In both cases (MIM and IDT capacitors), the Hf-based ferroelectric has a thickness of 6 nm. The IDT capacitors have been tested in the frequency range 1-11GHz, by applying at the same time an extremely low DC bias voltage (between -3V and 3V), which has allowed measuring the phase shift given by these components at frequencies of interest for RF applications (i.e. 2.5GHz and 10GHz). Exploiting an analytical model for the calculation of the capacitance value of an IDT capacitor designed on a double-layer substrate, it has been possible to estimate the value of the relative permittivity of the Hf-based ferroelectric thin film. Measurement for the C-V characteristic of a vertical MIM capacitor and for the capacitance vs. frequency of an IDT capacitor were performed.



(a) C-V characteristic of a vertical MIM capacitor with a 6-nm-thick Hf-based ferroelectric thin film; (b) capacitance vs. frequency (as a function of the applied DC bias voltage) of an IDT capacitor in CPW tecnology with a 6-nm-thick Hf-based ferroelectric thin film.

Centre of Nanotechnologies
Laboratory of Nanobiotechnologies

Mission

The mission of L1 is to propose and approach research directions in the field of ***nanostructures/nanomaterials/ nanocomposites***, aiming to comprehend their properties and to find novel technological solutions for integration in devices with applications in sensing, medicine and energy. Furthermore, training programmes in collaboration with universities, as well as experimental and characterization services in the field of ***nano-bio-technologies*** are carried out.

Research areas

The main areas of activity are: **(i)** fabrication of functional nanomaterials/nanostructures, investigation, control and tunning their properties for specific applications;
(ii) supporting the development of some industrial safety nanoproducts for health and enviromental protection by assessing the toxicity and risks associated with nanomaterials;
(iii) design and fabrication of nanostructures, integrated devices (optoelectronic biosensors, integrated microfluidic platforms) and development of novel biodetection schemes for medical applications;
(iv) design and fabrication of new devices based on silicon, silicon carbide, polymers and hybrid systems, as well as hybrid systems for applications in multiple fields, from gas / temperature sensors to energy (eg micro-superconductors, miniaturized combustion cells as clean energy sources).

Team

1. **Adina Boldeiu**, Chemist, PhD., Research Scientist II;
2. **Adrian Apostol**, Chemist, PhD. student, Research Assistant;
3. **Alexandra Purcarea**, Chemist, MSc student, Research Assistant
4. **Alexandru Bujor**, Chemist, MSc student, Research Assistant
5. **Alexandru Salceanu**, Physicist, Research Scientist;
6. **Cosmin Romanitan**, Physicist, PhD student, Research Scientist;
7. **Elena Constantin**, Engineer, MSc student, Research Scientist;
8. **Irina Baratosin,** Physicist, MSc student, Research Scientist;
9. **Iuliana Mihalache**, Physicist, PhD, Research Scientist III;
10. **Melania Banu**, Biologist, PhD student, Research Scientist;
11. **Mihaela Kusko**, Physicist, PhD, Research Scientist I, head of L1 laboratory;
12. **Mihai Danila**, Physicist, Research Scientist III;
13. **Mihai Mihaila**, Physics Engineer, PhD, Research Scientist I, Associate Member of Romanian Academy;
14. **Monica Simion**, Physicist, PhD, Research Scientist I;
15. **Pericle Varasteanu**, Physicist, PhD student, Research Assistant;
16. **Razvan Pascu**, Electronics Engineer, PhD, Research Scientist III.

Laboratory head:
Dr. Mihaela Kusko,
mihaela.kusko@imt.ro

Dr. Mihaela Kusko holds a PhD in physics from Univ. of Bucharest (2006). In 1998, she joined IMT Bucharest, where she currently leads the Nanobiotechnology Laboratory. In the last two decades, she was involved in new research directions, with the goal to find new applications of nanomaterials and nanostructures in optoelectronics, energy harvesting and biomedicine. She started investigating the structural and opto-electrical properties of nanoporous silicon, and continued with different metallic/semiconducting nano-assemblies. She led IMT group in FP7-IP-NMP-2010 NanoValid (2011-2016), FP7-NMP-ENV-2019 NanoSustain (2010-2013) and LIFE+ i-NanoTool (2013 – 2015), and was principal investigator in 6 National R&D projects devoted to nanomaterials exploration. Once the graphene and graphene like materials have emerged as advanced materials, she has done intensive work in the exploration of the conduction mechanisms established when they are embedded in polymeric matrices, with new results in the photodetection properties and charge storage capabilities of these nanomaterials.

Equipments

• **High Resolution SmartLab X-ray Diffraction System** (Rigaku Corporation, Japan), *contact persons: Phys. Cosmin Romanitan; Phys.Mihai Danila*

• **Micro-Nano Plotter System**–OmniGrid, UK/**Fluorescence Scanning System** GeneTAC UC4 - Genomic Solutions Ltd., UK for microarray technology, *contact persons: PhD St. Melania Banu; Biol. Alexandru Salceanu, Dr. Monica Simion*

• **Electrochemical Scanning Microscope ElProScan** (Heka, Germany), *contact persons: M St. Alexandru Bujor, Dr. Mihaela Kusko; Dr. Monica Simion*

• **Fluorescence Spectrometer** (Combined Time Resolved and Steady State Fluorescence Spectrometer - FLS920P (Edinburgh Instruments, UK),
contact person: Dr. Iuliana Mihalache

• **Impedance Spectrometer, Electrochemical analyzer/ workstation**

- Electrochemical Impedance Spectrometer - PARSTAT 2273 (Princeton Applied Research, USA)
- **Autolab PGSTAT302N / FRA32N** (Metrohm Autolab, NL), *contact persons: M St. Irina Bratosin, Dr. Mihaela Kusko; Dr. Antonio Radoi*

• **Autolab TWINGLE/SPRINGLE Surface Plasmon Resonance instrument** (Metrohm Autolab, NL),
contact persons: M St. Elena Constantin, PhD St. Pericle Varasteanu

• **Size and Zeta Potential Measurement System DelsaNanoC (Beckman Coulter, USA)**,
contact persons: Dr. Adina Boldeiu, Dr. Monica Simion

• **Noise and phonon fluctuation spectroscopy measurement system**–New measurement system (designed and realized in 2016, in the TEHNOSPEC project frame),
Contact person: Dr. Mihai Mihaila

• **Programmable Dip Coater for layer-by-layer thin film deposition** (Automated Dip Coater PTL-OV5P MTI Group, USA), *contact persons: Dr. Adina Boldeiu, Dr. Monica Simion*

National and international collaboration:

International projects (ongoing projects):

• **COST (European Cooperation in the field of Scientific *and Technical Research) Project*** - *"Raman-based applications for clinical diagnostics (Raman4clinics)"* (2014-2018) - IMT resp. Dr. Mihaela Kusko;

• **Bilateral Cooperation Project Romania - France** (Institut Polytechnique de Grenoble-INP: Grenoble-INP), Integrated Action Program Brancusi, PN-III P3-3.1-PM-EN-FR-2016 (2017-2018), *"DNA Biosensing with Silicon-on-Insulator Substrates – BIS-SOI"*, IMT resp. Dr. Monica Simion.

National projects:

• **PN-III-P1-1.2-PCCDI-2017-0820** - "New methods of pregnancy monitoring and prenatal diagnosis-MiMoSa" (2018-2020), Project director: Dr. Monica Simion

• **PN-III-P1-1.2-PCCDI-2017-0419** - „Sensors and Integrated Electronic and Photonic Systems for people and Infrastructures Security – SENSIS", **2nd component project** - "SiC-based hydrocarbons sensors for measuring the hydrogen and hydrocarbons in hostile industrial environments'', IMT responsible - Dr. Razvan Pascu

• **PN-III-P4-ID-PCE-2016-0618** „Challenges and issues in engineering nano-systems based on graphene-like materials for supercapacitors – EnGraMS" (2017-2019); Project director: Dr. Mihaela Kusko;

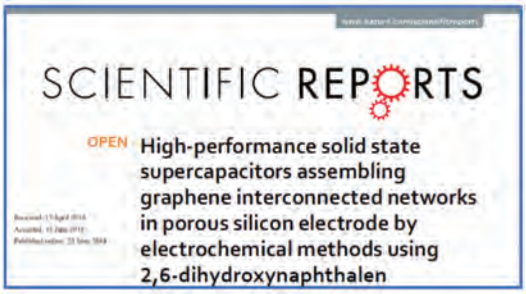
• **PN-III-P2-2.1-PED-2016-0974** „Microscale hybrid energy storage devices for integrated portable electronics - MiStorE" (2017-2019); Project director: Dr. Mihaela Kusko;

• **PN-III-P2-2.1-PED-2016-0510** - „Dye-sensitised solar cells by molecular engineering of phenoxazine- or phenotiazine-based sensitizers - EngDSSC" (2017-2019) - coordinator: Institute of Macromolecular Chemistry "Petru Poni" Iasi; Resp. IMT - Dr. Mihai Mihaila

Scientific results

I[st] Research Area – nanomaterials / thin films / physical phenomena in nanosystems

• The development of a new technology towards the fabrication of silicon based supercapacitors, using as active layer graphene nanocomposite


SCIENTIFIC REPORTS

OPEN High-performance solid state supercapacitors assembling graphene interconnected networks in porous silicon electrode by electrochemical methods using 2,6-dihydroxynaphthalen

Contract PN-III-P4-ID-PCE-2016-0618, Challenges and issues in engineering nano-systems based on graphene-like materials for supercapacitors" – Project manager Mihaela Kusko

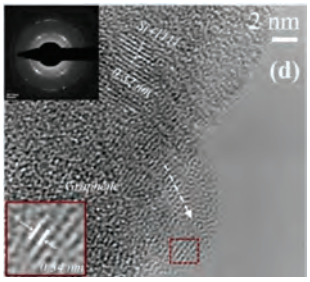
The purpose was obtaining an electro-active material to incorporate both silicon nanofibers and nanometric layers/assembly of layers with a graphenic structure.

Thus, the internal surface of the porous silicon has been modified with an electro-chemically deposited polymer, followed by a thermal treatment which resulted in a graphenic structure with local order.

For understanding the charge storage mechanisms, structural and composite analyses have been performed as such:

- The crystalline structure of the hybrid material graphene/p-Si has been examined systematically, using multiple, nondestructive X-ray techniques such as: X-ray diffraction at large angles (WAXRD) through which the existence of nano-carbon inside the porous silicon has been confirmed; Transerve scan (TS) for studying the stress of the network as well as the pores' size; X-ray reflectivity (XRR) for evaluating the density of the resulting material; Small angle X-ray scattering (SAXS) for informations regarding the morphology of pores and an estimation for the specific surface. Every X-ray measurement has been carried out using Rigaku SmartLab with a Cu spinning anode, 9 kW nominal power and monochromatic $CuK_{\alpha1}$ radiation of 1.5405 Å.

- *For investigating the surface's chemistry, both X-ray photoelectron spectroscopy and FTIR spectroscopy have been employed, which higlighted the presence of functional groups facilitating Faradaic reactions, hence indicating the presence of an additional pseudocapacitive behaviour.*



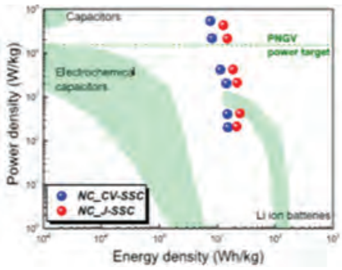
Images of the modified Si walls highlight the presence of a network of interconnected graphene sheets, randomly distributed, surrounding the Si. The graphene sheets are either isolated or arranged in stacks, where the average interplanar distance is 0.34nm, corresponding to graphite (002)

By assembling two nanostructured, hybrid electrodes, using PVA-H2SO4 gel as the electrolyte, micro-supercapacitors have been obtained, which were further put through standard performance evaluating techniques:

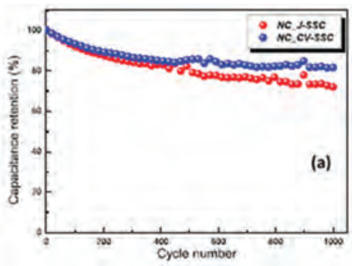
(i) cyclic voltammetry (CV) for evaluating the dynamic capacitance and the working potential window

(ii)charge-dicharge measurements at constant current for the analysis of the nature of charge storage processes

(iii) stability tests at repeated charging-discharging cycles



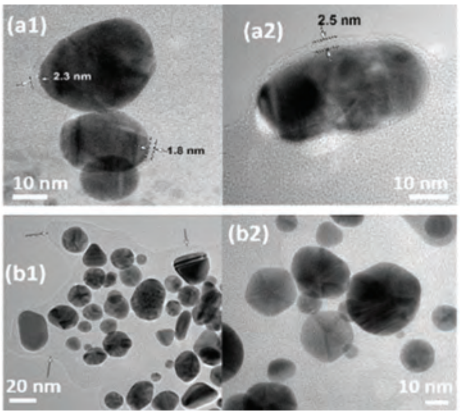
Power-energy (Ragone) curves for the obtained supercapacitors, in comparison with various charge storage devices (capacitors, electrochemical capacitors, batteries).
>>> the fabricated structure presented a significant improvement over previously recorded parameters.



Capacity retention study after 1000 cycles at the current density of 10 A/g.
>>> the structures presented show a good stability, maintaining a value of the capacity at ~80%.

Scientific results

Direction II - Physical-chemical studies for toxicity and risk assessments of nanomaterials



HR-TEM images revealing the proteins corona formed around AuNPs@citrate in DMEM (a1) and RPMI (a2) and around AuNPs@honey in DMEM (b1) and RPMI (b2). The protein corona appears like a grey shadow covering the AuNPs.

In the context of toxicity and risk assessments researches, gold nanoparticles of similar size were synthesized by the classical Turkevich method using sodium citrate reduction (AuNPs @ citrate) and by an environmentally friendly method using locally produced linden honey as a reducing agent (AuNPs @ honey). Their toxicity was investigated using two of the most widely used cell culture media - DMEM and RPMI, in order to highlight how the composition of each media type influences the stability of the nanoparticles and also to monitor the development of the protein-nanoparticle complex.

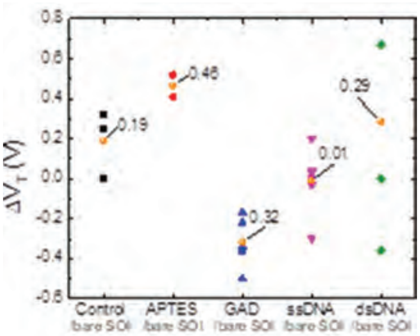
>>>>The formation of the proteins corona which individually covers the nanoparticles in RPMI like a dielectric spacer according to UV-Vis spectroscopy, was evidenced. However, DMEM promotes more abundant agglomerations, clustering together the nanoparticles, according to HR-TEM investigations.

In order to evaluate the biological impact of synthesized Au nanoparticles, cell viability assays were performed at INFIN-HH using two cell types: B16 melanoma and L929 fibroblasts, the latter proving to be more sensitive to the presence of gold nanoparticles. The obtained results showed that AuNPs@honey generates reduced toxicity trends depending on the cell type, concentration of nanoparticles and exposure time.

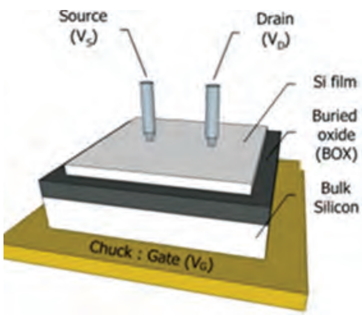
Direction III – Nanobiotechnologies / Biosensors

• Bilateral Cooperation Project Romania - France "DNA Biosensing with Silicon-on-Insulator Substrates - BIS-SOI", PN-III P3-3.1-PM-EN-FR-2016 (2017-2018), director proiect: Dr. Monica Simion

IIn this project, a biosensor test structure was designed and realized in the Ψ -MOSFET configuration for the detection of DNA hybridization processes.



Variation of the threshold voltage for different functionalization steps. Mean values represented in orange dots.



Experimental setup for the Ψ -MOSFET configuration

The variation of the threshold voltage shows that the immobilization and hybridization steps induce uniform positive shifts of +0.31V and +0.3V, respectively. A similar trend was observed for the flat-band voltage. For DNA detection, the shifts induced are considerable smaller, specifically +0.04V for the immobilization step and +0.11V for the hybridization, and they are determined by the negative charge of the DNA sugar phosphate backbone. The electrical characterizations made with this device allowed the monitoring of the steps of obtaining a functional biosensor structure including validation of DNA detection.

Ψ-MOSFET CONFIGURATION FOR DNA DETECTION, L. Benea, M. Banu, M. Bawedin, C. Delacour, M. Simion, M. Kusko, S. Cristoloveanu, I. Ionica, 41[th] Edition of the International Semiconductor Conference-CAS,October 10-12, 2018, Sinaia, Romania.

• NEW project in 2018

COMPLEX PROJECTS COMPLETED IN CONSORTIA CDI (PCCDI)

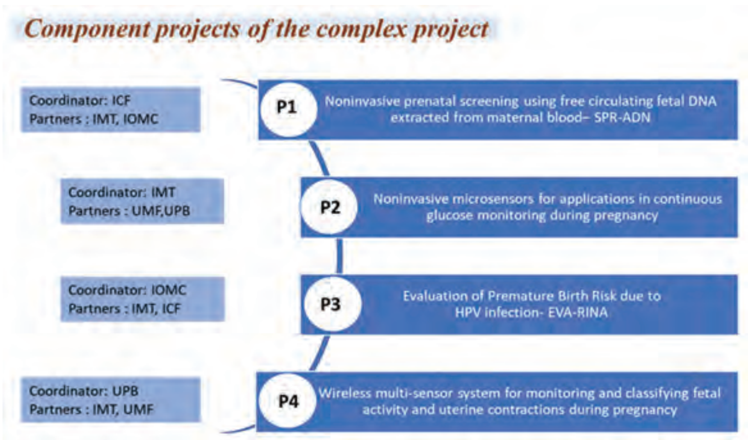
New methods of pregnancy monitoring and prenatal diagnosis – MiMoSa

Project PN-III-P1-1.2-PCCDI-2017-0820, contract nr. 67PCCDI/2018, Project Director: Dr. Monica Simion

https://www.imt.ro/mimosa/index.php

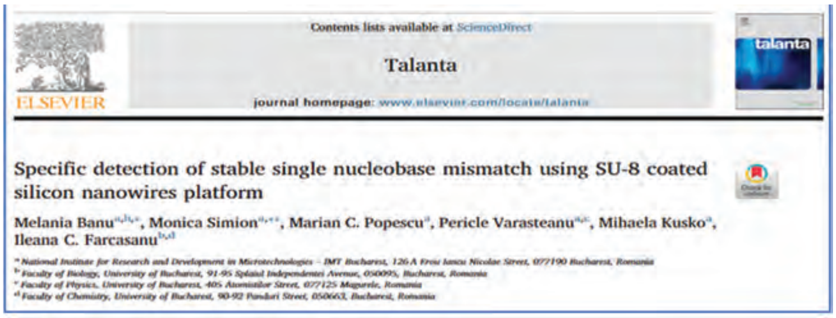
PARTNERS IN CONSORTIUM:

- **Microsystems in Biomedical and Environmental Applications Laboratory** (L2 – IMT Bucharest) - Dr. Carmen Moldovan
- **University of Medicine and Pharmacy "CAROL DAVILA"** (UMF) - Dr. Iuliana Ceausu
- **Fundeni Clinical Institute (ICF)** - Dr. Lorand Savu
- **National Institute for Mother and Child Health "Alessandrescu - Rusescu" Bucuresti (IOMC)** - Dr. Nicolae Suciu
- **Politehnica University of Bucharest (UPB)** - Dr. Irina Stanciu



Scientific results

Project 1 - Noninvasive prenatal screening using free circulating fetal DNA extracted from maternal blood – SPR-ADN, Component project manager IMT: Dr. Melania Banu


Contents lists available at ScienceDirect

Talanta

journal homepage: www.elsevier.com/locate/talanta

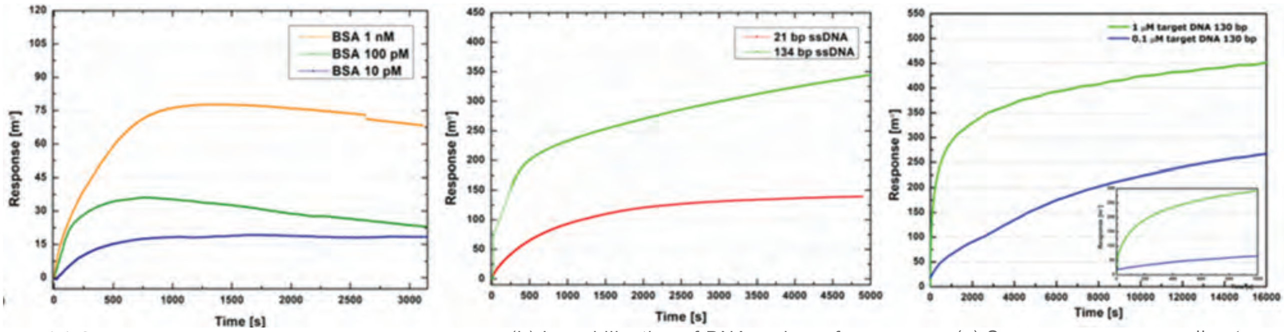
ELSEVIER

Specific detection of stable single nucleobase mismatch using SU-8 coated silicon nanowires platform

Melania Banu[a,b,*], Monica Simion[a,c,*], Marian C. Popescu[a], Pericle Varasteanu[a,c], Mihaela Kusko[a], Ileana C. Farcasanu[b,d]

[a] National Institute for Research and Development in Microtechnologies – IMT Bucharest, 126A Erou Iancu Nicolae Street, 077190 Bucharest, Romania
[b] Faculty of Biology, University of Bucharest, 91-95 Splaiul Independentei Avenue, 050095, Bucharest, Romania
[c] Faculty of Physics, University of Bucharest, 405 Atomistilor Street, 077125 Magurele, Romania
[d] Faculty of Chemistry, University of Bucharest, 90-92 Panduri Street, 050663, Bucharest, Romania

SRY fragment detection tests based on surface plasmon resonance (SPR) phenomenon. Bovine serum albumin, a protein with a mass of 68 kDa, was used at different concentrations to investigate the influence of molecular mass on detection limit. Subsequently, 21 and 134 base pair oligonucleotide sequences were used to evaluate the dependence of the detection limit on the sample size.



(a) Sensogram corresponding to the concentrations varied by BSA

(b) Immobilization of DNA probes of different sizes

(c) Sensogram corresponding to hybridization with two DNA concentrations

<u>It has proved successful detection of low concentrations of large molecules. The lower limit of detection was obtained using larger DNA fragments.</u> Based on these observations, an in-situ method will be used to increase the molecular mass of the SRY fragments in order to obtain a detectable signal.

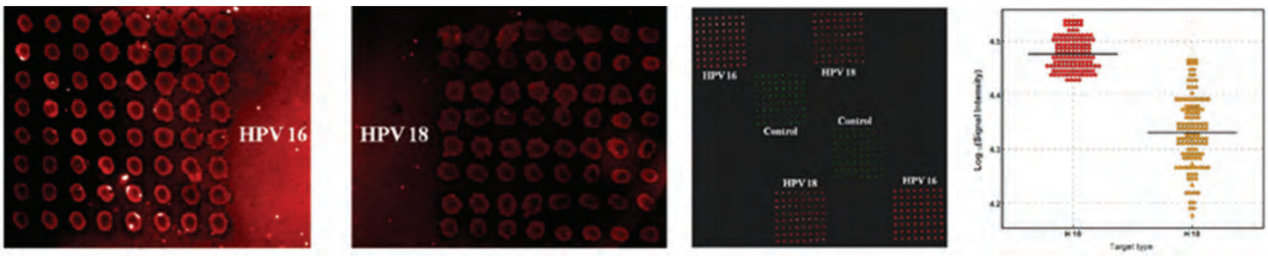
<u>Dissemination:</u> **"The influence of number of base pairs of ssDNA-SRY on SPR signal response",** Pericle Varasteanu, Melania Popescu, Monica Simion, Lorand Savu, ***International Workshop on Semi-conducting Nanomaterials for Health, Environment and Security Applications***, Grenoble, France, 6th – 7th November, 2018

Project 3: Evaluation of Premature Birth Risk due to HPV infection - EVA-RINA

Component project manager IMT: Dr. Mihaela Kusko.

Nanostructured microarray platform for HPV genotyping

A silicon nanowire support (SiNWs), the surface of which has been chemically modified using (3-glycidyloxypropyl) trimethoxysilane (GOPTMS) or the glycidyl ether of bisphenol A (SU-8), has been developed. The efficiency of hybridization was evaluated by analyzing the morphologies of the spots obtained after fluorescent scanning of the media.



(a) Hybridization results using a GOPTMS functionalized nanowires platform

(b) Hybridization results using a SU-8 functionalized nanowires platform

The size of the spots on each type of support was correlated with the type of chemical modification. Thus, the modification of the nanostructures with GOPTMS generated a hydrophilic support on 320 μm spots, while the modification with SU-8 generated a hydrophobic support on which 200 μm spots were obtained. It has been shown that functionalization conferring epoxy groups allows the successful use of chips in HPV genotyping.

<u>Dissemination:</u> • **"Specific detection of stable single nucleobase mismatch using SU-8 coated silicon nanowires platform",** Melania Banu, Monica Simion, Marian C. Popescu, Pericle Varasteanu, Mihaela Kusko, Ileana C. Farcasanu, Talanta, 185, 281-290, 2018. DOI: 10.1016/j.talanta.2018.03.095

• **"Nanostructured silicon platform for detection of specific gene sequences",** Melania Banu, Monica Simion, Marian Popescu, Lorand Savu, ATOM-N 2018 Conference, Constanta, Romania, Proceedings of the SPIE, vol. 10977 (109773F-1), 2018, DOI: 10.1117/12.2324680.

Laboratory of Nanobiotechnologies

Scientific results

Direction IV – Opto-electronic devices based on nanomaterials / thin films

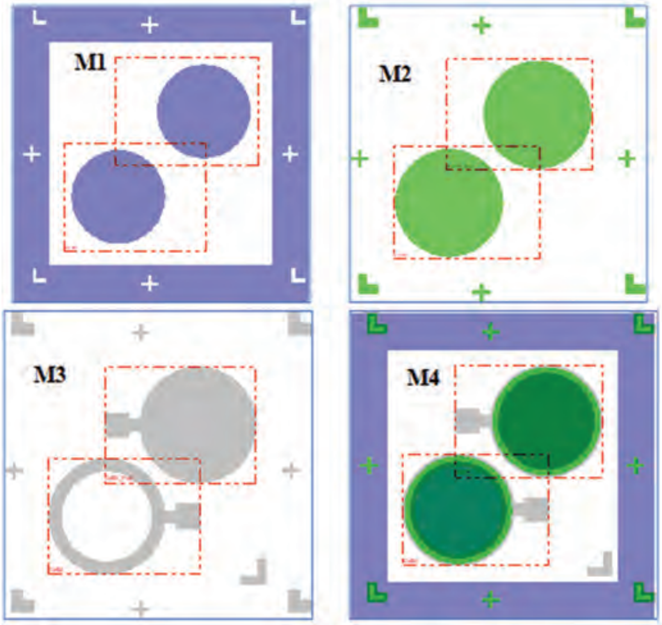
SiC based hydrocarbon sensors for security in hostile industrial environments

COMPLEX PROJECTS COMPLETED IN CONSORTIA CDI

Project PN-III-P1-1.2-PCCDI-2017, Contract nr. 71PCCDI/2018, **"Sensors and Integrated Electronic and Photonic Systems for people and Infrastructures Security – SENSIS"**.

Subproject P2-"SiC-based hydrocarbons sensors for security in hostile industrial environments", IMT Responsible: Dr. Razvan Pascu

The SiC-SENSIS component project aims, in collaboration with UPB, to manufacture devices on SiC substrate, with variable capacity working as toxic and flammable gas sensors.



In the first phase, according to the proposed technological flow, photolithographic masks were designed and manufactured in IMT, leading to the development of test structures for the detection of toxic and flammable gases by a differential measurement.

The designed structures corresponding to the set of photolithographic masks.

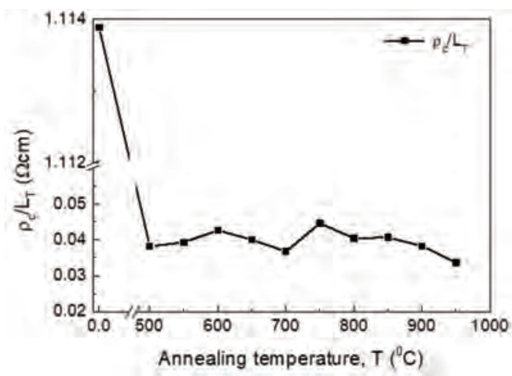
M1 – photolithographic mask for opening windows that define the active areas in the deposited oxide by the LPCVD technique. (circular windows, with a diameter of 400 μm).

M2 – photolithographic mask for the catalytic metal configuration (Ni, Pt or Pd), which will be the gate of the MOS sensor (450 μm window, 50 μm higher to allow the catalytic metal to cover the entire active area - the ramp and a part of the field oxide.

M3 – Photolithographic mask for defining the pad geometry. For design, it was considered that the geometry of the pads will allow the access of the gas to be detected. This structure represents the reference sensor during the differential measurement for the gas detection.

M4 – represents an overview of the 3 overlapped photolithographic masks.

In order to finally obtain a low series resistance, the influence of a post-metallization annealing (PMA), in N2 atmosphere, on a Ti/Pt metallic sandwich deposited on the Si substrate, was investigated using temperatures between 500-950°C. It was demonstrated that a PMA process should be included in the semiconductor devices fabrication technological flow. The best performances in terms of both the specific contact resistivity and the contact resistance were obtained at a temperature of 950°C



The ratio between the specific contact resistivity and the transfer length depending on the temperature

<u>**Dissemination:**</u> - R. Pascu, M. Danila, P. Varasteanu, M. Kusko, G. Pristavu, G. Brezeanu, F. Draghici, "Improved Ti/Pt/Au-n-Type Si Contacts by Post-Metallization Annealing in Nitrogen Atmosphere", International Semiconductor Conference-CAS, Sinaia, Romania, 2018, pp. 307-310;

- R. Pascu, C. Romanitan, M. Kusko, P. Varasteanu, G. Pristavu, F. Draghici, G. Brezeanu, "Using polyoxides as an alternative technological approach to obtain a high quality MOS oxide on SiC", European Conference on Silicon Carbide and Related Materials (ECSCRM 2018), Birmingham, UK, 2018;

- G. Pristavu, G. Brezeanu, R. Pascu, M. Badila, F.Draghici, I. Rusu, "Series Resistance Effect on Inhomogeneous SiC-Schottky Diode Forward Characteristics-An Ideal Interpretation", European Conference on Silicon Carbide and Related Materials (ECSCRM), Birmingham, UK, 2018;

- G. Pristavu, G. Brezeanu, R. Pascu, F. Draghici, M. Badila, "Characterization of non-uniform Ni-4H/SiC Schottky diodes for improved responsivity in high-temperature sensing", E-MRS Fall Meeting, Varsovia, Polonia, 2018;

- R. Pascu, C. Romanitan, P. Varasteanu, G. Brezeanu, G. Pristavu, V. Craciun, "Microstructural and electrical investigations of the interface layer between SiO2/SiC: polyoxides vs. thermally grown oxides", E-MRS Fall Meeting, Varsovia, Polonia, 2018;

- G. Pristavu, G. Brezeanu, M. Badila, F.Draghici, R. Pascu, F. Craciunoiu, I. Rusu, A. Pribeanu, "High Temperature Behavior Prediction Techniques for Non-Uniform Ni/SiC Schottky Diodes", Materials Science Forum, Vols. 924, pp. 967-970, 2018.

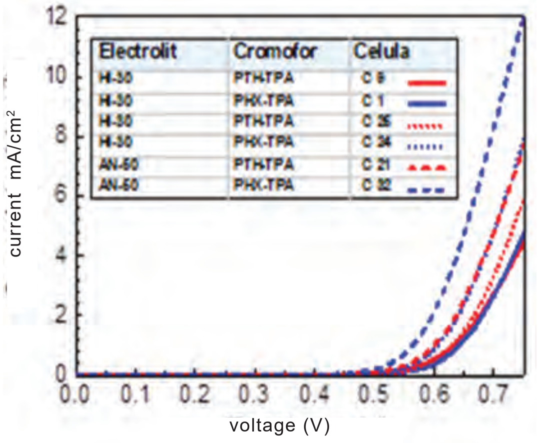
Laboratory of Nanobiotechnologies

Scientific results

Dye-sensitized solar cells by molecular engineering of phenoxazine - or phenothiazine - based sensitizers

Project PN-III-P2-2.1-PED-2016-0510, contract 59PED /2017: ***"Dye-sensitized solar cells by molecular engineering of phenoxazine - or phenothiazine - based sensitizers ",*** coordinator ICMPP Iaşi, Responsible partner IMT Bucureşti: Dr. Mihai Mihăilă

In the second phase of this project, the solar cells were manufactured with new chromophores based on phenoxazine and phenothiazine chromophores where two, three or four anchors were attached. Also, the manufacturing has been continued with the DSSC - type cells with mono-anchor chromophores (TFA-PTH, TFA-PHX and biTFA-PHX) from the first phase, in order to increase the efficiency of these cells. The electrical performances of the solar cells were evaluated performing standard dark/photo I-V characteristics, impedance spectroscopy and quantum efficiency measurements. Within the limits of the experiments, both chromophores with two anchors did not offer more than 2.5% efficiency. A similar behavior was observed for the four-anchor phenoxazine chromophore. In the case of the phenoxazine-based chromophore with three anchors, a 3.6% efficiency was obtained. It was observed that the electrolyte with higher concentration of iodine ions favors the interception of electrons in the fabricated cells with all phenoxazine-based chromophores. In the case of cells fabricated with phenothiazine-based mono-anchor chromophores, the electrolyte with higher ion concentration proved to be more favorable. These differences between the two chromophores were evinced by dark current measurements, which proved to be much larger in the case of phenoxazine-based chromophores. A fundamental factor that favors this phenomenon is the regeneration of the two chromophores, which is almost three times faster in the case of the phenothiazine-based chromophore. This is due to the presence of oxygen heteroatoms, in the case of phenoxazine, and, respectively, Sulphur, in the case of phenothiazine, which, in essence, produce different energy configurations for the two types of chromophores.



Comparison between dark I-V characteristics of the fabricated cells with **TFA-PHX** (C1, C24 and C32) and **TFA-PTH** (C9, C25 and C21) and different electrolytes; C1 and C9 fabricated with HI30; C24 and C25 fabricated with HI30 and counter electrode moved to TiO_2; C21 and C32 fabricated with AN50.

Dissemination: "Heteroatom-Mediated Performance of Dye-Sensitized Solar Cells based on T-Shaped Molecules", M.-D. Damaceanu, C.-P. Constantin, A.-E. Bejan, M. Mihaila, M. Kusko, C. Diaconu, I. Mihalache, R. Pascu, Dyes and Pigments Vol. 166, pp. 15–31, 2019.-Type Si Contacts

Planar micro-supercapacitors, on a flexible substrate, using nanocomposite assemblies based on materials with a graphenic type structure

Proiect PN-III-P2-2.1-PED-2016-0974, Contract Nr. 80/2017: Microscale hybrid energy storage devices for integrated portable electronics, Project manager: Dr. Mihaela Kusko

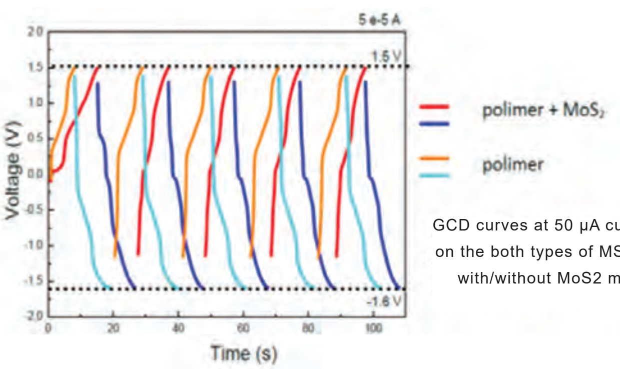
Planar micro-supercapacitors, on a flexible substrate, using nanocomposite assemblies based on materials with a graphenic type structure have been fabricated, as well as graphene dots with different functional groups or graphene monolayers, transition metals dichalcogenides. Additionally, an experimental setup has been arranged for testing the supercapacitors in laboratory conditions.

The importance of adding MoS_2 monolayers in the polymeric matrix can be observed by analyzing the comparison of GCD curves recorded at a current of 50 μA for the structures of MSC with and without monolayers of MoS_2.

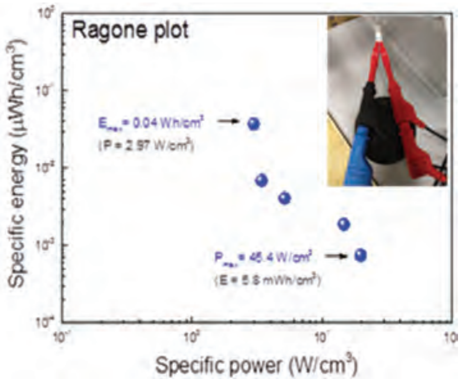
It can be observed that the charging-discharging curves present pseudocapacitive features which enhance the inner area and, as a result, the specific capacitance and the power and energy densities.

In regards to the stored energy density, a maximum of 1.7 μWh/cm² (0.04 Wh/cm³) has been obtained. The maximum power density was 0.9 mW/cm² (45.4 W/cm³).

>>>> *The resulting performances place the presented supercapacitor amongst the best highly rated in literature.*



GCD curves at 50 μA current applied on the both types of MSC structures with/without MoS2 monolayers



Centre of Nanotechnologies

Nano-scale structuring and characterization laboratory

Mission

The main mission of the lab is to support research efforts in IMT Bucharest by delivering services and innovative solutions both in characterization and in nanofabrication areas.

The lab provides advanced instrumentation and key expertise for micro and nanoscale imaging and characterization of materials, processes and structures and also for direct nanoscale patterning through Electron-Beam Lithography (EBL)–based techniques. The laboratory team is working together with other teams in IMT Bucharest in planning and developing experiments and implementing solutions in various research projects.

Areas of expertise

Characterization:

•Conventional and field emission Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray Spectroscopy (EDX);

•High-resolution surface and interface investigations by Scanning Probe Microscopy (SPM-AFM)

•Small-scale mechanical characterization using depth-sensing indentation (nano-identation) testing.

Structuring:

•Nanoscale patterning by Gaussian E-beam lithography for applications in photonics, plasmonics, MSM-UV photo-detectors, SAW components for RF/microwave circuits etc.

•Fabrication of graphene-based configurations and devices using EBL techniques.

Main equipments

L6 embeds 4 experimental laboratories clustered in the IMT-MINAFAB support centre for micro - and nanofabrication and certified to ISO 9001:2008 quality management standards: **"Laboratory for SEM characterization", "Laboratory for Electron-beam litography Raith e_Line", "Laboratory for field emission SEM characterization"** and **"Laboratory for SPM and nanomechanical testing".**

•***Electron-beam Lithography and Nanoengineering Workstation – Raith e_Line*** (RAITH GmbH, Germany). It is a versatile nanolithography system by direct patterning of electron resists, electron beam-assisted deposition and etching, with < 20 nm achievable resolution.

• ***Dip Pen Nanolitography System- NSCRIPTOR*** (NanoInk, Inc., USA). It is employed for ink-and-pen nanolithography, with applications such as: direct printing on substrates for functionalization purposes, photolithographic masks correction, stamp manufacturing for nanoimprint lithography etc.

• ***Ultra High resolution Field Emission Gun Scanning Electron Microscope*** (FEG-SEM)-Nova NanoSEM 630 (FEI Company, USA), equipped with **EDX spectrometer** (EDAX TEAM™)

• ***Scanning Electron Microscope with Thermionic Electron Gun***-(TESCAN VEGA II LMU TESCAN s.r.o, Czech Republic)

• ***Multifunctional Near-field Scanning Probe Microscope*** (SPM) - NTEGRA Aura (NT-MDT Co., Russia). It is employed for high resolution 3D imaging and complex characterization of the surfaces by advanced complementary techniques (AFM, STM, EFM, MFM, SKPM, C-AFM, etc.).

• ***Nano Indenter G200*** (Agilent Technologies, USA). It enables high resolution characterization of the mechanical properties of small-volume samples.

Team

Laboratory head:
Dr. Adrian Dinescu,
adrian.dinescu@imt.ro

• **Dr. Adrian Dinescu**, Physicist, Senior Researcher I, Head of the laboratory
• **Phys. Raluca Gavrila**, Physicist, Senior Researcher III
• **Dr. Octavian Ligor,** Physicist, Senior Researcher III
• **Dr. Marian Popescu**, Engineer, Senior Researcher III
• **Ph.D. student Bogdan Ionut Bita**, Physicist, Junior Researcher
• **Ph. D. student Stefan Iulian Enache**, Technological Development Engineer
• **Mihaela Marinescu**, Principal economist

Dr. Adrian Dinescu obtained the M.Sc. degree (1993) in Solid State Physics and the PhD degree (2010) in physics, both from the University of Bucharest. Between 1993 and 1997, Adrian Dinescu was with the National Institute for Research in Electronic Components, working in the field of optoelectronic devices fabrication.
Since 1997 he is with IMT-Bucharest, where he is currently involved in micro and nanoscale characterization using FE-SEM and in structuring at the nanoscale using Electron Beam Lithography. His expertise also includes materials processing and device fabrication.

National and international collaborations

• **Running international projects:**

- **"High photoconductive oxide films functionalized with GeSi nanoparticles for environmental applications" PhotoNanoP,** M-ERA.NET Transnational Call 2014 (IMT – Partener) (2016-2018)

- **"Nanostructured and amorphous semiconductor films for sensors application"**, JOINT RESEARCH PROJECT Romania Bulgaria (2016-2018)

• **Running national projects:**

- **"Laser targets for ultraintense laser experiments" TARGET**, PN-III- /ELI-RO (IMT – Partener) (2016-2019)

- "**Technological transfer to increase the quality and security level of holographic labels" TSCEH**, P2-2.1-PTE-2016 (IMT – Partener) (2016-2018)

- **"Technologic paradigms in synthesis and characterization of variable dimensionality systems", VARDIMTECH**, Proiect PNCDI III/PCCDI (PN-III-P1-1.2-PCCDI-2017) (IMT – Partener) (2018-2020)

- **„Techniques for storing and exploiting the results of advanced scientific research", SOVAREX**–Sector Plan MCI

Education and training

> **Master courses and laboratory activities** in collaboration with the **University "Politehnica" of Bucharest**:

The Faculty of Electronics, Telecommunications and Information Technology (ETTI):

• *"Microphysical Characterization of Micro- and Nanosystems", Master course, Microsystems MSc program*

• *"Electronic Technologies for Optoelectronic Applications"- Master course, Optoelectronics MSc program*

• *"Object-Oriented Programming" - Laboratory, Year II*

The Faculty of Entrepreneurship, Business Engineering and Management (FAIMA):

• *"Databases in Oracle environment" - Laboratory, Year III, specialization "Economical engineering in the electrical, electronic and energy fields"*

> **Lectures and laboratory activities** in collaboration with the **Faculty of Physics - University of Bucharest**.

• *„Electronics and electronic devices"* - Laboratory, Year II

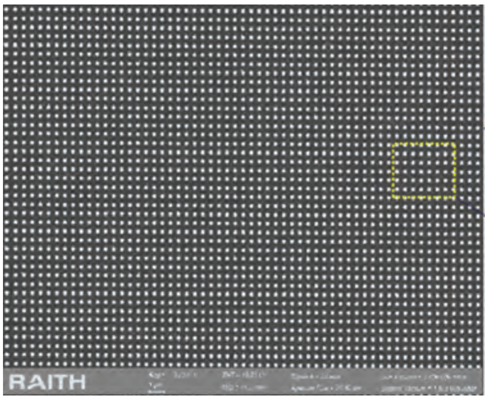
• *„Virtual Instrumentation (LabView Programming)"*- Lecture and Laboratory, Year II

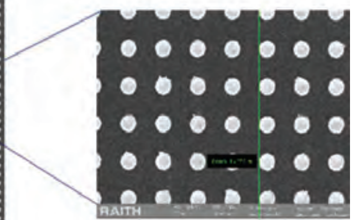
> **Lectures and laboratory activities** in collaboration with **the Faculty of Mathematics and Computer Science, University of Bucharest**

• *"Analog Electronics"* – Lecture and Laboratory, Year II

Main results - Research highlights

• Engineering two-dimensional arrangements of dots for metasurfaces with tailored IR emission





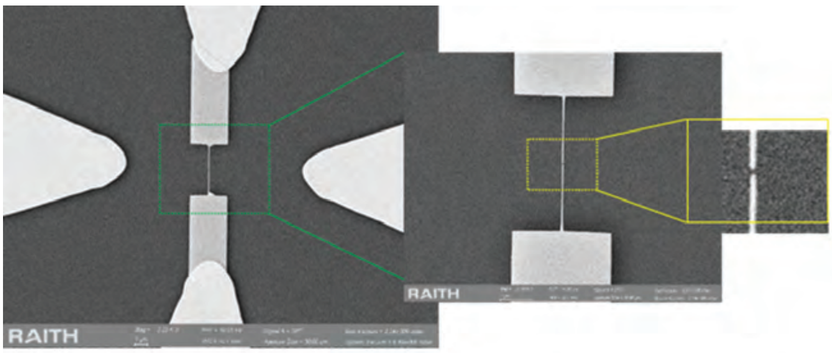
SEM images of 2D arrangements of cylindric dots with ~ 200 nm diameter and ~ 500 nm pitch, fabricated by EBL

Areas consisting of Au cylindric dots on amorphous Si have been fabricated by combining Electron-Beam Lithography (EBL) with classical microfabrication procedures (optical lithography, selective deposition and etching of thin films, lift-off technique), with the purpose of controlling and manipulation of spectral characteristics (reflexion, emission etc.) of the thus-patterned surfaces. *(Collaboration with L3 Laboratory of IMT Bucharest within the project **PN-III-P1-1.2-PCCDI2017-0419 - SENSIS-P3**)*.

• Fabrication of a <<Nothing On Insulator>> (NOI) device in the variant Metal-Air-Metal (MAM)

The device is composed of a pair of metallic nanoelectrodes (nanowires) placed on an insulating substrate at a distance of several tens of nm. The key of the device structure is the channel comprised of several air molecules located between the electrodes. Nanometre precision placement of the two metal nanowires was possible by direct application of Electron-Beam Lithography (EBL). Forcing the use of EBL technique to its physical limits, it was possible to obtain a distance of the order of 30 nm between the positions of the two electrodes in the electronoresist "mask", which was reduced to a final value of only 18 nm after the metal deposition (Cr/Au) and the lift-off process. The two Au nanowires were contacted through intermediate metal bands at the source and drain pads of the NOI-MAM device.

The device was developed in collaboration with researchers from IMT and UPB, within the project **PN-III-P4-ID-PCE-2016-0480** *(TFTNANOEL)*. **„Fabrication of the Nothing On Insulator device in the variant Metal-Air-Metal – NOI-MAM – by Electron-beam lithography",** Cristian Ravariu, Elena Manea, Adrian Dinescu et al, article under publishing)



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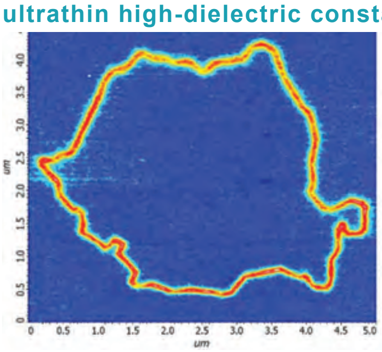
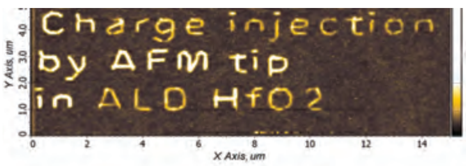
The completed NOI-MAM device. The three SEM images provide progressively enlarged details. Figure (i) shows the source and drain macroscopic pads; image (ii) reveals the intermediate contacting band; (iii) displays an enlarged detail of the area of the gap of the nanowire pair

• Controlled charge deposition ("Electrostatic writing") with nanometric resolution by an AFM tip in an ultrathin high-dielectric constant ("high k") layer



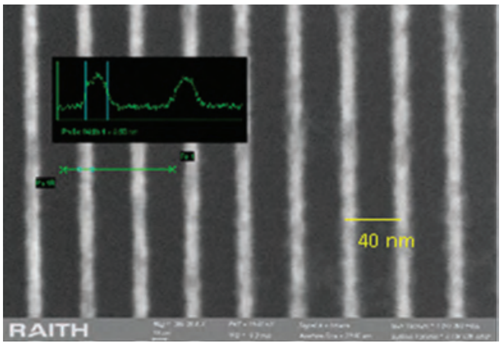
Two examples of charge injected in a controlled manner by means of a biased AFM tip on the surface of an ultrathin layer of HfO_2. The layer was prepared in the L11 Laboratory of IMT Bucharest using the Atomic Layer Deposition (ALD) technique.



Nano-scale structuring and characterization laboratory

Services

✓ Nanometric scale structuring by Electron-beam lithography

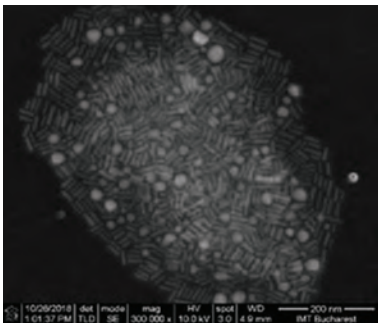


10 nm-width, 40 nm-pitch lines fabricated in a negative electronoresist (HSQ) by direct Electron-beam lithography

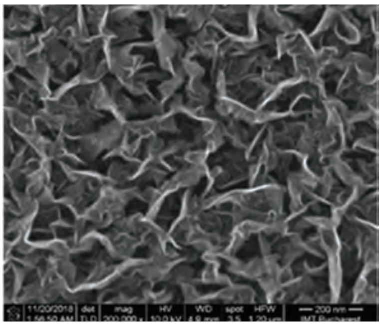
The lines are intended for further use as a mask for reactive ion etch of a platinum film, with the goal to manufacturing a “nano-wire grid polarizer” (nano-WGP) for far-UV, dedicated to UV measurements in the Solar Crown (in collaboration with Dipartimento di Fisica e Astronomia - Università degli Studi di Firenze).

✓ Characterization of various materials and structures (morphology, composition, material properties)

• **Scanning Electron Microscope (SEM) (both conventional and field emission gun)**

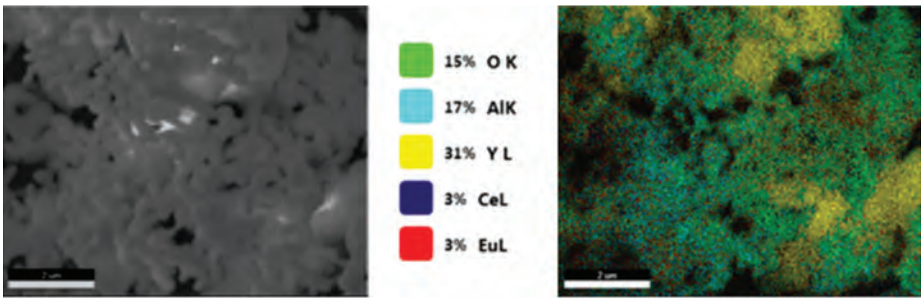


Au nanoparticles and nano-rods with typical diameters below 10 nm. Scale: 200 nm (Sample prepared by the team of L1 Laboratory of IMT Bucharest)



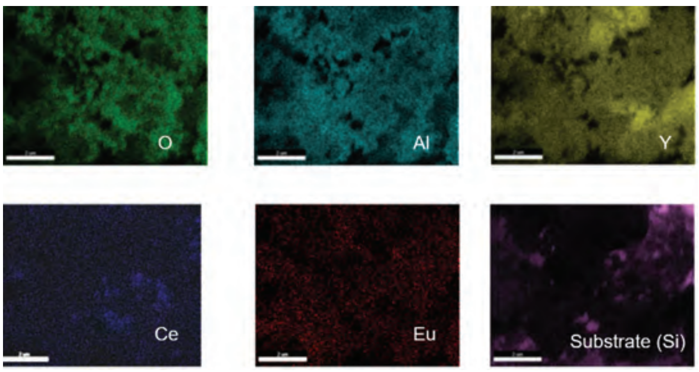
Graphene vertical "walls" obtained by PECVD technique. Scale: 200 nm (Sample prepared by the team of L1 Laboratory of IMT Bucharest)

• **Energy Dispersive X-Ray Spectroscopy (EDX)**

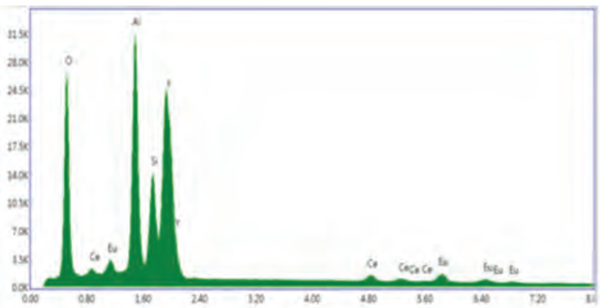


(a) (b)

SEM image (a) and elemental distribution mapping (b) on the surface of an oxidic material using EDX



Mapping of the same sample, acquired for each single element

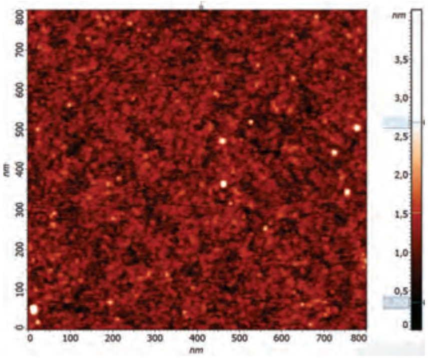


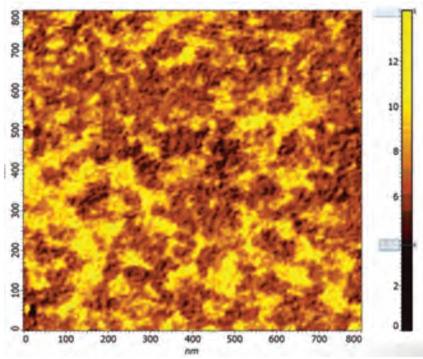
Quantitative analysis performed in the secondary electron image for the above sample

Nano-scale structuring and characterization laboratory

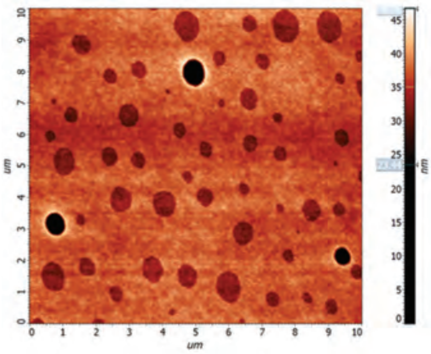
Services

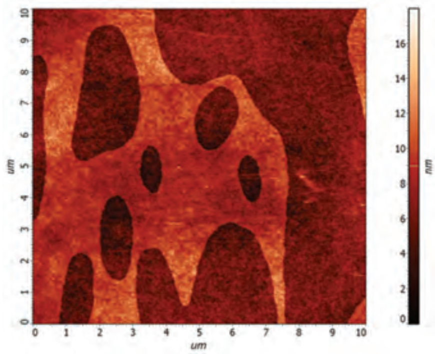
• Atomic Force Microscopy and related techniques (SPM)





AFM morphology and phase images for a ZrO_2-"doped" HfO_2 layer, obtained by ALD (Atomic Layer Deposition) - laminar method - on Si substrate. The layer was prepared within the L11 Laboratory of IMT Bucharest.
The contrast in the Phase image reflects the distribution of the two components in the analyzed area of the laminate. Scanning area: 1x1 μm^2





Treatment temperature: T1   Treatment temperature: T2

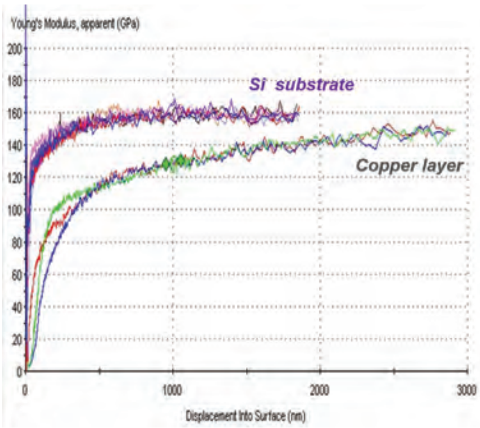
Morphology evolution for a mixture of PVA-PEG polymers subjected to heat treatment

T2 (right) > T1 (left)   Scan areas: 10 µm

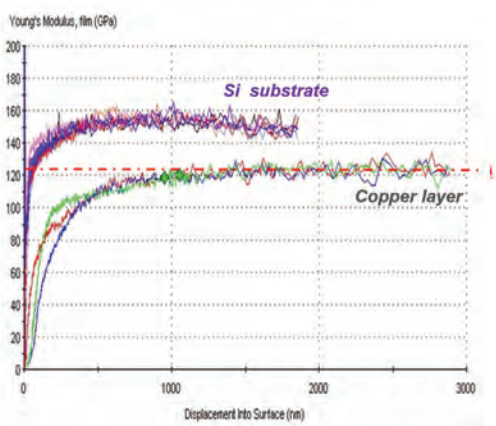
• Nano Indentation (Depth-sensing indentation techniques) for mechanical characterization at submicron scale

Example of a measurement of the mechanical properties of a electrochemically deposited copper layer.

Fig. A displays the results of measurements made using the standard Continuous Stiffness Measurement (CSM) method. Fig. B shows the same results, corrected for the substrate effect using a special analytical model. It is easy to notice that by using the optimized method it is possible to get an unambiguous value of the Young's modulus of the Cu layer, namely the plateau value reached at the depth of about 1 µm, E = 122 GPa.



A Standard Method



B Optimized Method

Young's modulus measurements versus depth for a copper layer, electrochemically deposited on monocrystalline silicon substrate (layer thickness: 10 µm). The measurements were performed dynamically by CSM[R].

Publications

In 2018, L6 team has co-authored 16 scientific papers in ISI ranked journals (3 as a first author from IMT) and 48 communications at international conferences, among which one invited paper (author Dr. A. Dinescu) and 26 published in Proceedings. L6 team has also contributed to 3 book chapters.

L9

Centre of Nanotechnologies
Molecular nanotechnology laboratory

Mission

The lab was established in 2009, based on the necessity to integrate existing practical, analytical and numerical knowledge in areas of chemistry and functional materials, molecular dynamics, and atomistic modeling / simulation.

The main areas of interest are fundamental research and development of technologies for the fabrication of functional materials and micro/nano systems and devices based on synthesis and physico-chemical modifications, structural optimization, epitaxial MBE growth etc.

The studies are directed towards understanding, and making use of, the mechanisms that provide new functions by combining the techniques of preparation and synthesis of 3D...0D structures, controlled molecular attachments, theoretical modeling and numerical analysis by ab- initio and (semi)-empirical methods.

Research areas

• Synthesis, development, characterization and mechanism studies of nanomaterials that exhibit properties suitable for applications in sensors, nanoelectronics and optoelectronics: carbon based thin films and meso/micro/nanostructures (graphene, nanographene, carbon QDs, graphene QDs), nanocomposites.

• Development and characterization of micro/nanosystems and devices that integrate functionally optimized (nano)materials: (electro) chemical/molecular sensors, mechanical sensors, solar cells, LED devices, transparent functional electrodes, MEMS. Development of dip-pen nanolithography (DPN) processing.

• Development of new materials based on MBE technology: III-N materials, epitaxial graphene etc. and related heterostructures with various applications, such as solar cells.

• Analytical-numerical investigation of essential mechanisms responsible for creating new properties and/or for offering solutions for functional optimization of the developed nanomaterials: electronic structure modeling and simulation (DFT, semi-empirical DFT, molecular dynamics, BIE), physical/chemical adsorption mechanisms, absorption/emission spectra, plasmonic resonance modes.

Team

• Dr. Lucia Monica Veca - CS I, PhD in Chemistry, Clemson Univ, USA, 2009
• Dr. Antonio Marian Radoi - CS I, PhD in Chemistry, Tor Vergata Univ., Italy, 2007.
• Dr. Titus Sandu - CS I, PhD in Physics, Texas A&M Univ., USA, 2002.
• Dr. Emil-Mihai Pavelescu - CS I, PhD in Technology, Tampere University of Technology, Finland, 2004.
• Dr. Cristina Pachiu - CS III, PhD in Physics, Univ. Le Havre, France, 2007.
• Dr. Mihaela Carp – IDT III, PhD in Engineering, Nanyang Technological Univ., Singapore, 2008.
• Dr. Steluta Carmen Ciobanu - CS III, PhD in Chemical Eng., Politehnica University of Bucharest, 2011.
• Marius Constantin Stoian - ACS, Chemistry MSc student, Faculty of Chemistry, University of Bucharest.
• Dr. Radu Cristian Popa - IDT I, PhD in Quantum Eng. and Systems Science, Univ. of Tokyo, 1998; Laboratory head.

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

Radu Cristian Popa received a MSc in Electrical Engineering (Applied Electronics) from the Polytechnic University of Bucharest (1989), and a PhD in Quantum Engineering and Systems Science at University of Tokyo (1998).

He was assistant professor in Electrical Engineering at the Polytechnic University of Bucharest (1991-1995), and senior researcher at the Science Solutions Intn. Lab., Inc., Tokyo (1998-2003), where he managed industrial research projects with leading Japanese companies and institutions, mainly in numerical modeling and analysis of complex phenomena and devices.

2003-2006, he was scientific associate at the University of Tuebingen, Germany and then became Development Director at Neurostar, GmbH, Germany, designing and developing hardware and software solutions for functional neurosurgery and neuroscience systems for brain microelectrode exploration and electrophysiological recording, and medical imaging.

Radu Popa joined IMT Bucharest in 2007. Main scientific activities include theoretical and experimental studies of micro-nano materials and structures, experiment planning.

National and international cooperation

- Clemson University, USA - Prof. Ya-Ping Sun
- Natl. Institute for R&D in Electrical Engineering ICPE-CA, Dept. of Advanced Materials, Bucharest - Dr. Cristina Banciu
- Natl. Institute for R&D in Biological Sciences, Bucharest - Dr. Sandra Eremia, Dr. Simona Litescu
- Natl. Institute for R&D in Lasers, Plasma and Radiation Physics, Bucharest-Magurele - Dr. Catalin Ticos
- Natl. Institute for R&D in Material Physics, Bucharest-Magurele - Dr. Cristian Mihail Teodorescu
- "Babes-Bolyai" University, Cluj, Romania - prof. Anamaria Elena Terec, prof. Simion Astilean
- Institutul de Chimie Fizică al Academiei Române, Bucuresti – Dr. Viorel Chihaia
- Norwegian University of Science and Technology - NTNU - prof. Turid Reenaas
- Optoelectronics Research Centre, Tampere University of Technology, Finland – Prof. M. Guina
- Wroclaw University of Science and Technology, Poland - prof. Robert Kudrawiec
- University of Kassel – Prof. J-P Reithmaier, Dr. Cyril Popov
- Université Catholique de Louvain, Belgium - prof. Sorin Melinte

Results

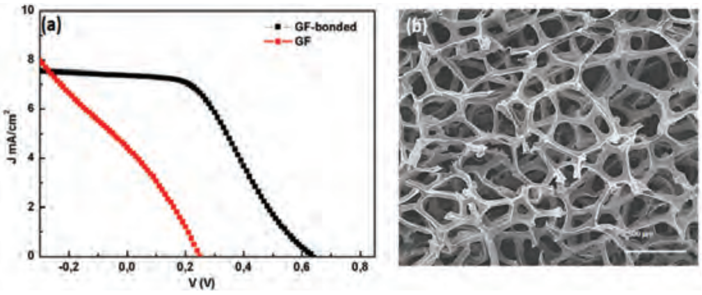
Project PN-III-P2-2.1-PED-2016-1159 “Dye sensitized solar cells with integrated 3D-graphene structures“ (2016-2018) - contact Dr. Monica Veca (partner leader) (monica.veca@imt.ro)

Project objective: Revealing the functionality of integrated 3D-graphene structures for Grätzel solar cells. The 3D-graphene layers were grown on Ni foam at ICPE-CA, the project coordinator.

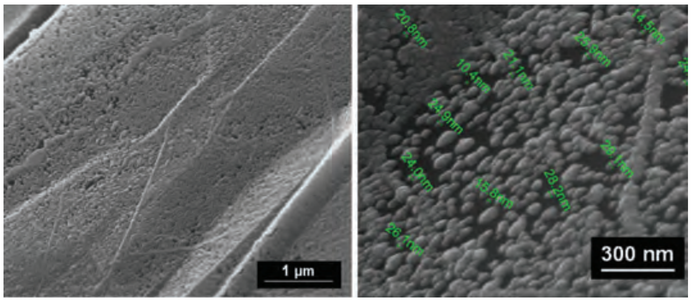
Integration of 3D-graphene in photovoltaic devices

The final stage of the project was dedicated to the fabrication and testing of DSSC structures that integrate the previously developed and characterized 3D-graphene monoliths. The 3D-graphene shells were obtained by thermal CVD growth on Ni foam at ICPE-CA. The main ensuing processing steps consisted of: etching the metallic substrate, activating the obtained self-sustained few-layers-graphene network (graphene foam - GF), and in the final deposition of ZnO films and nanowires. The integration in solar cell structures showed that the N719 sensitized DSSC devices with GF counter electrode exhibit conversion efficiencies of ~1.7%, following the optimization of the GF/FTO substrate contact.

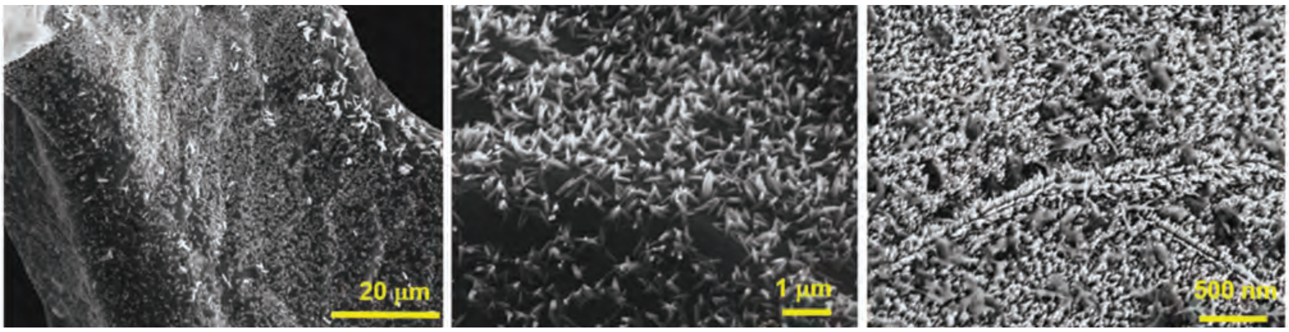
The ZnO/GF hybrids were synthetized both by controlled depositing of ZnO thin films using ALD technology, and by growing ZnO nanowires of ~350 nm length using the hydrothermal method.



a) Photocurrent density-voltage (J-V) curves for the N719-sensitized DSSC devices with GF counter electrode, under simulated AM 1.5 illumination (100 mW/cm²): before (red) and after (black) the FTO substrate bonding. b) SEM image of the GF network.



SEM images of ZnO/GF hybrid structures obtained by ALD deposition (200 cycles) of zinc oxide. The lateral electrical conductivity for the bare GF network was ~30.8 S/cm, while following the 200 cycles ALD deposition of ZnO it became ~35.4 S/cm.



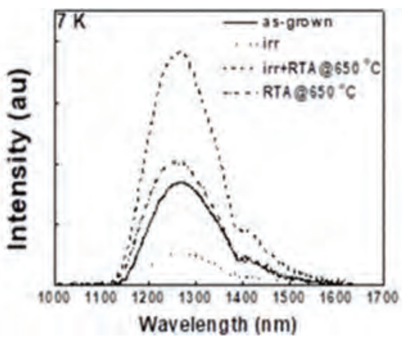
SEM images illustrating the growth of ZnO nanowires on the GF network substrate.

Project: PN-III-P1-1.2-PCCDI-2017-0152 ”Technological paradigms in the synthesis and characterization of structures with variable dimensionality (VARDIMTECH)” (2018-2020) - contact Dr. Emil-Mihai Pavelescu (partner leader) (emil.pavelescu@imt.ro)

One of the project objectives is the development of low-dimensional semiconductor materials that are lattice-matched with GaAs (used as substrate), in order to be used in tandem solar cells.

Effects of electron irradiation and of rapid thermal annealing on MBE-grown GaNAsBi/GaAs thin films

We studied the effects of modification processes caused by electron irradiation and rapid thermal annealing (RTA) on the photoluminescence properties of $GaN_{0.007}As_{0.959}Bi_{0.034}$ (MBE-grown at the University din Chicago, USA). Comparative PL measurements before and after irradiation (6 MeV, 10^{15} electrons/cm² fluence), as well as RTA treatment (650°C, 1 minute) reveal that the PL intensity significatly decays due to irradiation, while the RTA process is able to ameliorate the PL properties for both irradiated, and unirradiated, probes. Remarkably, the intensification of the PL peak caused by the thermal process is significantly enhanced in case of the pre-irradiated sample. Thus, following the same RTA process, the PL intensity of the pre-irradiated sample becomes more than double the PL intensity of the unirradiated sample. Also, in the first case the PL improvement engendered by the thermal treatment does not alter the spectral position of the PL peak (in the limit of experimental error of ≤2 nm), while for the non pre-irradiated sample an evident ~8 nm blue-shift can be measured.



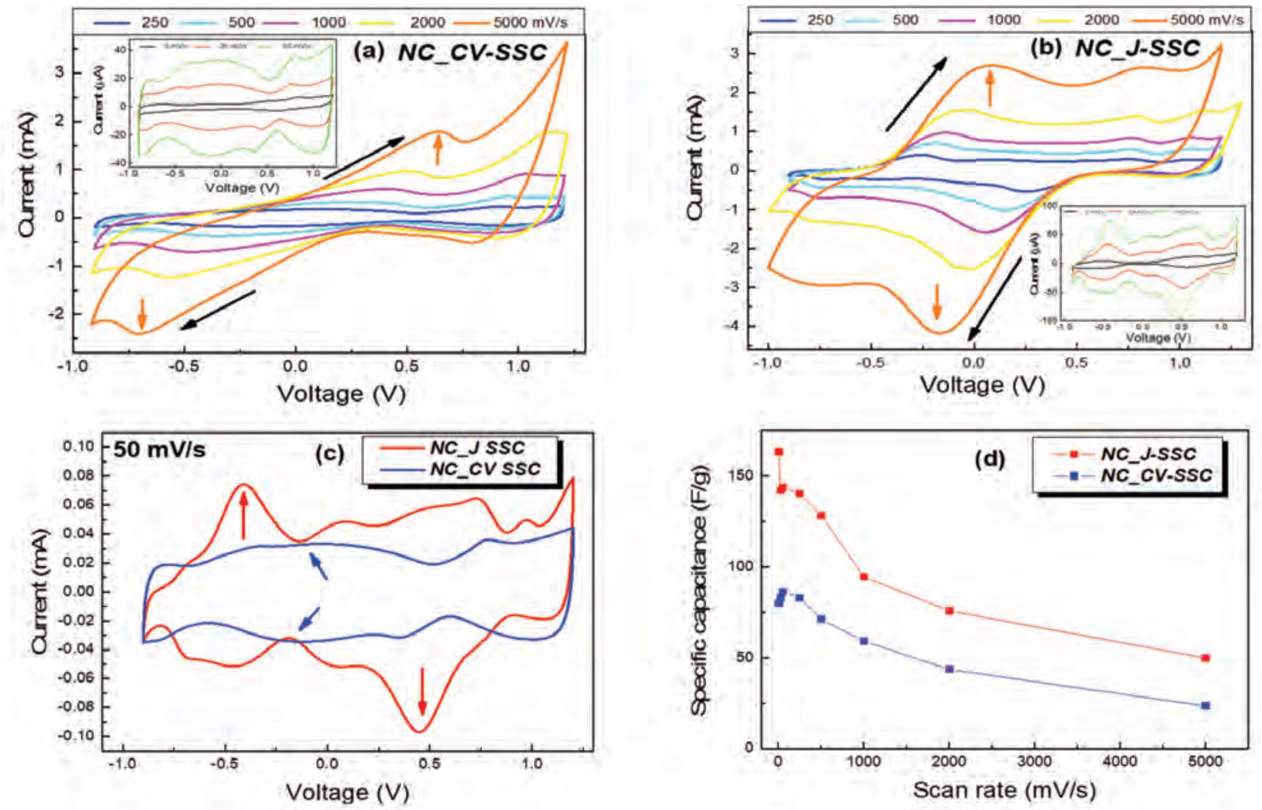
PL spectra measured at 7K for as grown GaNAsBi samples, as well as following electron irradiation / RTA modifications.

Results

Modification of nanoporous silicon surface for supercapacitor applications

- contact Dr. Antonio Radoi (antonio.radoi@imt.ro)

Silicon wafers - Si (100), p-type (boron dopant), 1-5 mΩ·cm - were porosified by anodic oxidation (10 mA/cm^2, 300 seconds) in 1/1 (v/v) electrolyte solution (40 wt. % HF and 98 wt. % ethanol). The 1.2x1.8 cm diced samples of porous silicon (p-Si) were diped in 5% (v/v) HF for 5 minutes to remove the native oxide and subsequently used as working electrode in an electrochemical cell having a saturated calomel electrode as reference electrode and a Pt wire as counter electrode. The p-Si samples were electrochemically modified using a 2 mM 2,6-dihydroxynaphthalene solution in cyclic voltammetry (at 5 mV/s, potential window between −0.45 V and +0.45 V, during 6 cycles: sample noted as NC_CV-SSC), or potentiometry (1 mA, 120 seconds: sample noted NC_J-SSC) processes and subsequently thermally treated at 800 °C, during 4 hours, under N_2 flow.



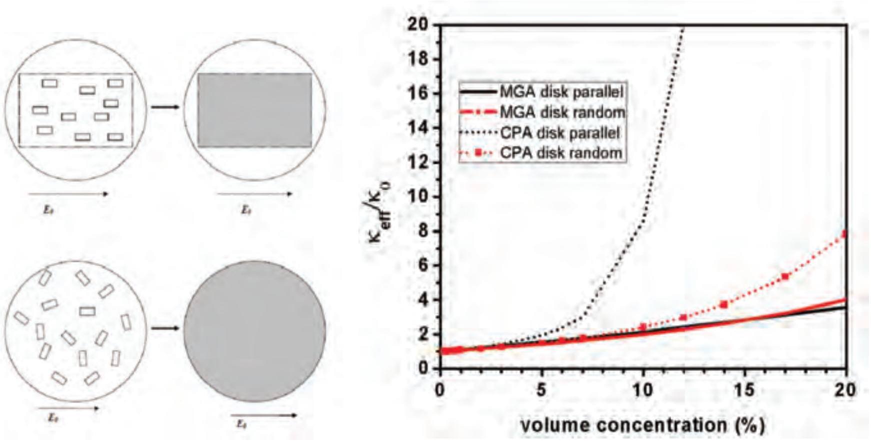
Cyclic voltammograms at different scan rates ranging from 5 to 5000 mV/s for NC_CV-SSC (a) and NC_ J-SSC (b) devices; (c) Comparative CV curves obtained at scan rates of 50 mV/s with respect to reference p-Si-SSC; (d) Variation of SSC specific capacitance with the scan rate.

Analytical/numerical methods for material modeling

contact Dr. Titus Sandu (titus.sandu@imt.ro)

Numerical models for calculations of thermal and electrical conductivities in (nano)composites with fillers of arbitrary shapes

An increasing number of applications are finding technological benefits from (nano)composite materials using filllers of various materials - e.g., carbon-based, such as graphene and nanotubes - that cause the enhancement of thermal or electrical conductivity of the initial polymer matrix. Following our theoretical investigations started in 2017, we developed a numerical method for evaluating the thermal and electrical conductivities in composites with fillers of arbitrary shapes. Furthermore, these models can predict the percolation thresholds.



Left - Schematic model for the homogenization process for arbitrary inclusions.
Right - Results of thermal conductivity modeling for a graphene-filler composite using two homogenization schemes: Maxwell-Garnett, and Coherent Potential Approximation.

Simulation, Modelling and Computer Aided Design Laboratory

Mission

Research, development and applications of simulation, modelling and design techniques of micro-electro-mechanical and microfluidic systems oriented to collaborative research projects, **education** (courses, labs), **services** (enabling access to hardware and software tools) and **consulting** (design/ optimization) in the field of micro-nano-bio/info technologies.

The lab L5 plays a key role in supporting the research activities of other laboratories of IMT Bucharest. Furthermore, L5 is developing **techniques for rapid prototyping** from micro- to macro scale, micro-sensors and **MOEMS and MEMS actuators** and investigate **new classes of advanced materials** with applications in nanodevices (thin films and nanostructures of oxide semiconductor materials).

Team

1. **Dr. Raluca Müller**, senior researcher I, PhD in electronics, laboratory head
2. **Dr. Rodica Plugaru**, senior researcher I, PhD in physics
3. **Dr. Oana Tatiana Nedelcu**, senior researcher I, MS in mathematics, PhD in electronics
4. **Dr. Gabriel Moagar-Poladian**, senior researcher II, PhD in physics
5. **Dr. Franti Eduard**, senior researcher III, PhD in electronics
6. **Phys. Constantin Tibeica**, scientific researcher, physicist
7. **Phys. Eng. Victor Moagar-Poladian**, IDT III, physicist engineer
8. **Dr. Rodica-Cristina Voicu**, senior researcher III, mathematician, PhD in mathematics
9. **Dr. Anca-Ionela Istrate**, senior researcher III, PhD in materials engineering
10. **Dr. Angela-Mihaela Baracu**, scientific researcher, PhD in electronics
11. **Dr. Mihai Gologanu**, senior researcher III, mathematician, PhD in mathematics-mechanics

Expertise

• **Design (lay-out), simulation and development/optimization of MEMS/MOEMS** devices and components (cantilevers, membranes, micro-grippers) and **microfluidic** (valves, pumps, microchannels, mixers, filters) for microelectronic and biomedical applications;

• **Modelling and simulation for multiphysics problems;** mechanical, thermal, electrical, electromagnetic, piezoelectric, **coupled field analysis** (static and transient); **microfluidic analyses: CFD, diffusion, mixing, electrokinetics, fluid-structure interaction**

• **Rapid prototyping**: 3D Printer (SLS, respectively, a single-photon-absorbed photopolymerization);

• **Design and manufacturing** of MOEMS and MEMS microsystems/actuators and microsensors;

• **Design and microfabrication of microfluidic and micro-electro-fluidic systems, electrical and contact profilometry characterization**;

• **Characterization of physical phenomena and defects related phenomena** in ultra-thin films and nanostructures, quantum dots, nanowires, core-shell nanostructures.

• **Technological processes and functional analyzes for advanced materials preparation and integration** in devices for transparent electronics, nano-optoelectronics, sensors.

• **Atomistic modelling** of the electronic structure of wide-band gap semiconductor materials in the presence of dopant impurities and point defects.

Dr. Raluca Müller received the M.Sc and PhD in Electronics and Telecommunications from "Polytehnica" University of Bucharest. From 1978-1994 she was researcher scientist with ICCE Bucharest, since 1994 she is with IMT Bucharest. Her main scientific interests include design and technological processes for sensors and actuators based on MEMS/MOEMS techniques, integrated optics, nanolithography. She was involved in teaching activities as associated professor at Univ. "Valahia Targoviste" and Master of Science courses at Univ. Politehnica Bucharest.

Raluca Müller was coordinator of an important number of national research projects and scientist in charge from IMT Bucharest in international projects as: FP6 ASSEMIC-Marie Curie Training Network (2004-2007), FP6-PATENT (Modelling and Simulation cluster), Leonardo da Vinci- Microteaching (2005-2007), IPMMAN-CA (2006-2009). She is author and co-author of more than 100 scientific papers presented at conferences and published in journals (Sensor&Actuators, J. of Micromechanics and Microengineering, Appl.Optics., Journal of Luminescence, Thin Solid Films, etc).

Laboratory head:
Dr. Raluca Müller,
raluca.muller@imt.ro

National and international colaborations

ECSEL-H2020: 3Ccar: „Integrated components for control in electrified cars“, (2015-2018) Coordinator: Infineon Technologies AG Germany, IMT Partner: Dr. Gabriel Moagăr-Poladian;

POC-G – Operational Competitivity Program 2014-2021, Axa 1: Action 1.2.3, Contract No. 77/08.09.2016, TGE-PLAT "Partnership for using Key Enabling Technologies on a platform for interaction with companies" is a project financed by **Structural Funding** dedicated to knowledge transfer from IMT to Romanian companies, in a high tech field of the Romanin Strategy (SNCDI 2016-2020): ICT, Space and Security), Coordinator: IMT

In the frame of this POC-G two collaborative projects with SME were conducted by the lab:

Sub-project C77.3D: Sensitive Platform with SAW sensor for inflammable and potentially explosive gases detection; coordinator: **Dr. Angela Baracu**, in collaboration with S.C. ROM-QUARTZ S.A.

Sub-project C77.5D: Image forming optical system by using „free-form" (FF) components and technology for the fabrication of these; coordinator: **Gabriel Moagăr-Poladian** (L5 IMT), in collaboration with S.C. ROVSOL S.R.L.

Project PN-III-P2-2.1-PED: Design and microfabrication of MEMS switch with robust metal contact, Project 33, 2017-2018, Coordinator: Technical University of Cluj-Napoca, IMT Partner: Dr. Raluca Müller

„Core" funding:MICRO-NANO-SIS: Project No.2-**PN 18080102**: Development of MEMS and microfluidic structures integrable in sensors platforms, **Coordinator: Dr. Oana Tatiana Nedelcu**.

Simulation, Modelling and Computer Aided Design Laboratory

Echipment

▪ Hardware:

- **Dual IBM 3750 Server, 8 quad-core** Intel Xeon MP 2.93 GHz, 196 GByte RAM and 1 TByte HDD + 876 GByte external storage;

Software for modelling and simulation:

COVENTORWARE 2014-software package dedicated to design, modelling and simulation for MEMS and microfluidics. It contains modules for design (2D layout, 3D models generator) and simulation modules for main physical phenomena in Microsystems functionalities and development.

SEMulator3D, 2011-Software for generating complex 3D models for thin films, structures and devices obtained by silicon technology.

COMSOL 5.3-Software package for simulation of physical phenomena such as: mechanics of solids, heat transfer, fluidics, acoustics, RF-MEMS.

ANSYS Multiphysics 19-HPC Software package for FEM simulations taking into account several physical phenomena (mechanical, thermal, electromagnetic and fluidic or coupled). Complex simulation methods: ***Sequential method*** (thermal-structural, electromagnetic-thermal-structural, electrostatic-fluidic-structural, CFX and FLOTRAN) and, respectively, ***Direct coupling*** (acoustic-structural, piezoresistive, piezoelectric, electromagnetic, electro-thermo-structural-magnetic).

MATLAB R2015b – Mathematical software: numerical computation, visualisation and programming. It can be used for mathematical calculus, algorithm development, data acquisition, visualization and analysis, scientific and engineering graphs.

SOLIDWORKS – Design software for 2D and 3D complex geometry, capable to export CAD files to other simulation software tools; it has additional modules for projects correlation and for growing the productivity of CAD and PDMWorks. It includes management solutions for design data, suited to single or group management of SolidWorks projects.

MATHEMATICA 7 – Software for numeric and symbolic calculus; suitable for solving linear and non-linear equations, integral and differential equations, statistics, optimisation, 2D and 3D graphics.

ORIGINPRO 8 – Software for data processing: graphic, interpretation/interpolation by statistical processing.

Characterization facilities:

- Semiconductor Characterization System with Manual Probe Station Model-4200 SCS/C/Keithley, EP6/ Suss MicroTec.

Tehnology:

- 3D Printer Selective Laser Sintering EOS Formiga P100
- 3D Printerbased on Single Photon Photopolymerization Mini Multi Lens system from Envision TEC

Services:

• Computer aided Modelling and Simulation (using FEM, FVM, BEM methods) for MEMS/NEMS and microfluidic structures and systems;

• Electrical characterization: I-V, C-V, C-t, C-f. Measurements in the temperature range: 77-400 K;

• Masks design, technological design and realization of microfluidic and micro-electro-fluidic systems in silicon and glass, design and fabrication of microfluidic connectors;

• Development of advanced nanomaterials and oxide semiconductor nanostructures and investigation of their functional properties for applications in nano-optoelectronic components and sensors;

• Rapid prototyping using 3D Printer Selective Laser sintering for the following applications;

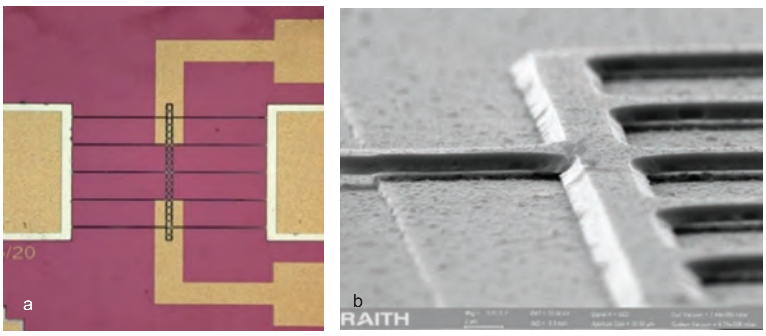
• Training for design and simulation, student laboratory work, master courses, practical stages for students;

▪ Classroom equipped with computer network for training;

Results

► **PN-III-P2-2.1-PED: Design and microfabrication of MEMS switch with robust metal contact,** Project 33, 2017- 2018, Coordinator: Technical University of Cluj-Napoca, IMT Partner: Dr. Raluca Müller

- Development of technological processes for the MEMS switch fabrication;
- Manufacture of aluminum micro-mechanical structures using photoresist as sacrificial layer;

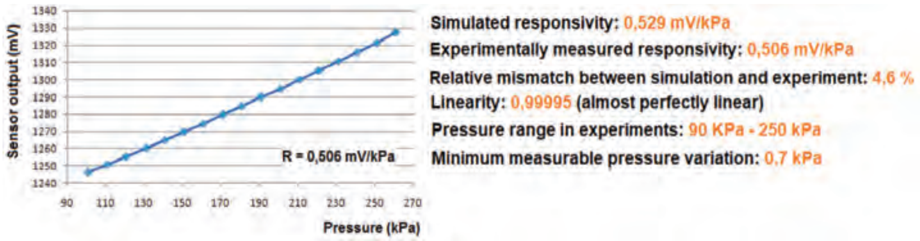


Configuration of the fabricated MEMS switch: (a) Optical image; (b) SEM characterization - detail of the central axis of the structure

Results

► ECSEL-H2020: 3Ccar: „Integrated components for control in electrified cars“, (2015-2018) Coordonator: Infineon Technologies AG Germany, Partner from L5 IMT – Dr. Gabriel Moagăr-Poladian;

- The pressure sensor was tested at various temperatures and testing cycles; testing was made at the site of Infineon Technologies Romania (IMT team: Gabriel Moagăr-Poladian, Cătălin Tibeică);



The experimental graph of the pressure sensor response.

- A preliminary model of a thermal switch for electric car's battery was made and tested by TNO team from the Netherlands (IMT team: Gabriel Moagăr-Poladian, Victor Moagăr-Poladian, the thermal electrodes were fabricated in collaboration with ISIM-Timişoara);

Table – Rexperimental results of the thermal switch characterization

State	Measured thermal conductivity W/K]	Equivalent thermal resistance [K/W]	Experimental ON/OFF ratto [-]	Simulated ON/OFF ratio [-]
ON	0.1852	5.4	45	345
OFF(*)	0.0041	244		
(*) Very difficult to measure experimentally, the thermal switch being a very good thermal insulator in the OFF state. Practically, the heat flow took place through the thermally insulating material placed around it, material that was used for thermal insulation purposes of the measurement set-up.				

- An electro-diffractive modulator with capacitive actuation was realized (IMT team: Gabriel Moagăr-in collaboration with L11- Andrei Avram)

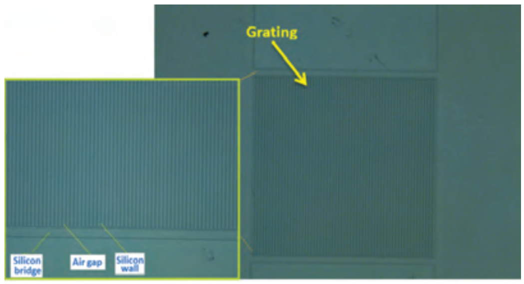
<u>Patent applications resulted from the project:</u>

• 1. C. Tibeică, G. Moagăr-Poladian – Pressure sensor for hostile media, OSIM A00238 / 02.04.2018

• 2. G. Moagăr-Poladian, V. Moagăr-Poladian, G. Boldeiu – Thermal switch for the control of the heat flux, OSIM A00575 / 09.08.2018

<u>Papers published resulting from the project (ISI journal):</u>

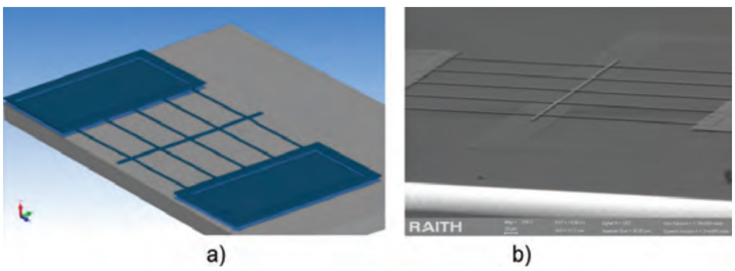
1. G. Moagăr-Poladian, C. Tibeică, V. Moagăr-Poladian – “3D Printed acceleration sensor: a case study”, Romanian Journal of Information Science and Technology, vol. 21, no. 1, p. 61-81, (2018) - open access



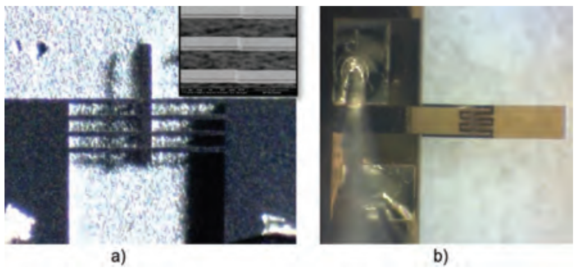
The optical microscopy image of the electro-diffractive modulator (modulator length – 1 mm); green square: a detail of the modulator.

► Contributions to PN 18080102 - Objective 2: Design and manufacture of MEMS structures, Contact: Dr. Rodica-Cristina Voicu and Dr. Angela Baracu

- Electro-thermal actuators with out-of-plane movements used in switching applications have been designed and manufactured. Different MEMS structures electro-thermally actuated with out-of-plane displacement were obtained



The configuration of out-of-plane displacement electro-thermal actuator: (a) Design-Coventor; (b) SEM image (Dr. Angela Baracu)



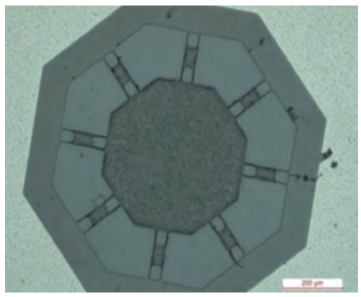
a) Optical image of the relesed device fabricated using Al with detail of the arms step; b) Microcantilever fabricated using SU-8 and Au (Dr. Rodica-Cristina Voicu)

► Contribution to project PN 18080102 - Objective 4: Design of MEMS sensors for voltage and current measurement on high voltage grid, Coordinator: Dr. Gabriel Moagăr-Poladian

Design of the miniaturised, integrated sensor for simultaneous measurement of voltage and current value. A patent request was registered at OSIM.

<u>Patent applications resulted from the project:</u>

- Gabriel Moagăr-Poladian, Victor Moagăr-Poladian – “Miniaturised system for the measurement of instantanenous values of electric current parameters on voltage grids”, OSIM A 00790 / 27.11.2018



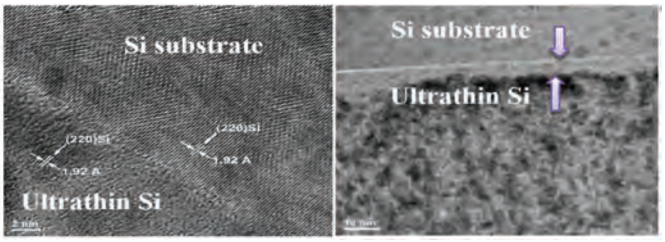
Optical microcospy image of one of the many fabricated test structures; each test structure contained 8 bridges for testing.

Simulation, Modelling and Computer Aided Design Laboratory

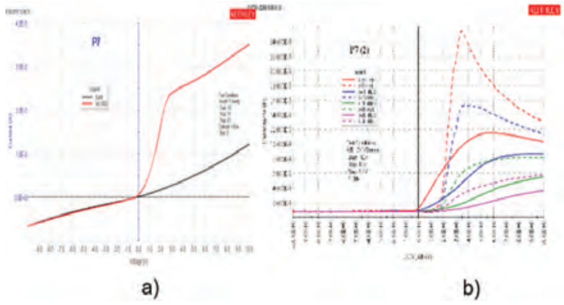
Results

► Project PN 18080102 - Objective 3: Simulation and synthesis of multilayer structures with 2D materials, Coordinator Dr. Rodica Plugaru

- Technology for synthesis of multilayer structures with ultrathin/2D Si layers, sensitive to light, for nano-optoelectronic devices and sensors used in IOT, automotive and space industry.
- Synthesis of multilayer Si:H/ultrathinSi/Au structures sensitive to light with the currents ratio $I_{illumination}/I_{dark}$ of 9.6 at 3V. The value of the photogenerated current is 2.4 mA. The C-V characteristics of the structures measured at 5 kHz demonstrate capacitances ratio $C_{illumination}$ / C_{dark} of 2.5 at 3.5V.
- Design and simulation of 2D silicon (silicene) structures on functionalized Si:H substrates.
- Computational study on the structural and electronic properties of complex silicene structures deposited on hydrogenated Si (100) substrates.



High-resolution transmission electron microscopy images (HR-TEM) of the ultrathin Si layer interface with the hydrogen functionalized Si (100) substrate.

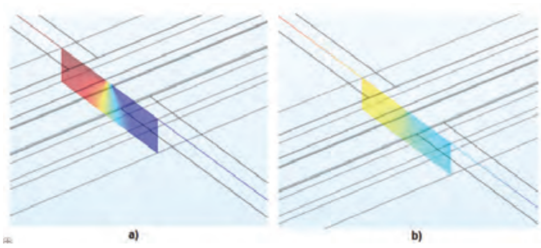


I-V (a) and C-V (b) characteristics of multilayer structures with ultrathin Si layer deposited on p-Si (100) hydrogenated substrate, p-Si:H/ultrathin Si/Au.

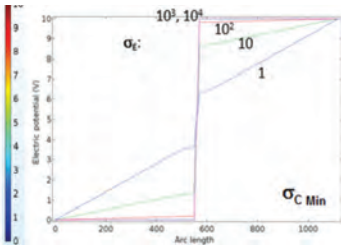
► „Core" funding: Project No.2 - PN 18080102: Development of MEMS and microfluidic structures integrable in sensors platforms, Coordinator: Dr. Oana Tatiana Nedelcu.

Contributions to project PN 18080102 - Objectiv 1: Modelling, simulation and fabrication of components and structures for microfluidic applications, Cordinator Dr. Mihai Gologanu

- Modelling and simulation of microfluidic systems with fluidic components for transport and handling, and with conductive components (electrodes) for electric control, realized from transparent conductive oxides (TCO)
- Study of lower conductivities of TCO on electro-fluidic control performances, by comparison to metals
- Characterization by simulation of system electric response as function of fluid properties, system geometry and electrodes conductivity. Simulation analysis and data postprocessing were performed using software package Comsol Multiphysics.

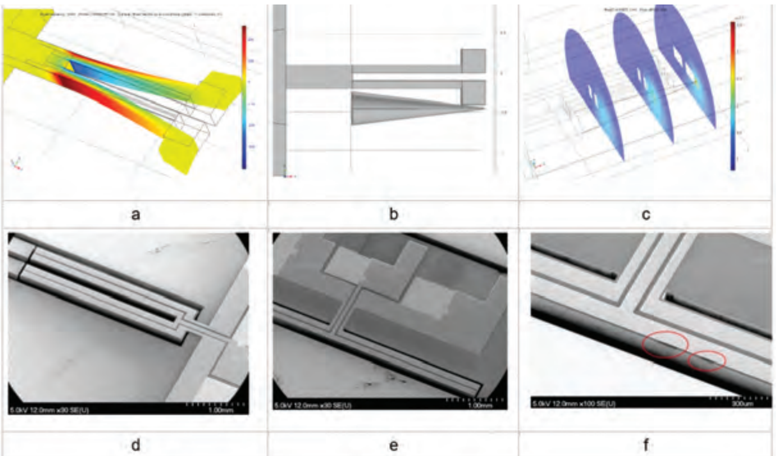


Potential distribution (V) in microfluidic channel for low buffer conductivity (σ_{CMin} =10 μS/m) and two values of TCO conductivity: a) σE=10⁴ S/m; b) σ_E=1 S/m (Comsol Multiphysics)



Potential variation (V) along electric path for variable TCO conductivity (σ_E =1-10⁴ S/m) and low buffer conductivity (σ_{CMin} =10 μS/m)

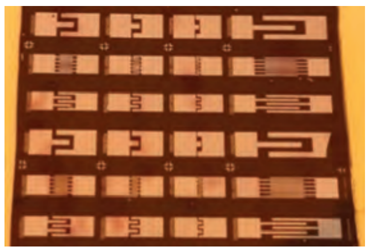
Analytical and finite element (COMSOL) simulations, design and fabrication of resonators on SOI with large quality factor (Q of 1000-2000) and electrical reading via a piezoelectric layer (ZnO).



a COMSOL model of tuning fork resonator showing displacement for the main resonance, b Lateral unfocused optical source (direct exit from an optical fiber), c Acoustic pressure due to photoacoustic effect, d-e Fabricated structure , f Under-cut of the ZnO layer and subsequent colaps of the metallization layer leading to shorted devices.)

► Contributions to M-ERA.NET "High photoconductive oxide films functionalized with GeSi nanoparticles for environmental applications" - PhotoNanoP, Project 33/2016, IMT Partner: Dr. Miron Adrian Dinescu-L6

Fabrication of Al interdigitated electrode structures using $SiGe/SiO_2$ and $SiGe/TiO_2$ substrates (Contact Dr. Angela Baracu).



Configuration of interdigitated electrode structures

Centre for Nanotechnologies and Carbon-based Nanomaterials

Reliability Laboratory

Mission

The design, development and implementation of innovative methodology, instruments and solutions for the design, testing and monitorization of normal functioning and reliability for sensors, actuators, microsystems, nanostructures, intelligent systems, and microelectronic and Opto-mechanic components. These activities have a high interdisciplinary character; their implementation is following the specific guidelines of Concurrent Engineering.

Specific activities

In pursuing his mission, the laboratory is actively involved in some specific actions, focus on: A. Research – Development – Innovation aiming to develop and demonstrate innovative solutions for sensors and intelligent sensors systems, using nanostructured carbon and metallic oxides based sensitive layers, for environmental and industrial applications; B. Testing services – design and execution of accelerated tests (one or more multiple, simultaneous, stress parameters) for micro – and nanostructures, electronic systems.

Resources

Suitable resources (human, experimental) are supporting the execution of the Lab's mission objectives; from the point of view of human resources, the L7 team is a multidisciplinary one, including seven specialists, from a variety of domains: micro- and nanoelectronics, chemistry, physics, management and engineering of technological systems, automation and computers: Dr. ing. Octavian BUIU, CSIII, head of the laboratory (Physics), Dr Ing. Cornel COBIANU, CSI (micro- and nanoelectronics), Dr Ing. Bogdan – Cătălin Şerban, CSIII (Chemistry), Dr Ing. Octavian IONESCU, CS III (electronics, automation), Ing. Niculae DUMBRAVESCU, CS III (microelectronics), Ing. Roxana Marinescu, IDT (management and engineering of technological systems), Ing. Dragoş Vârşescu, IDT III (electronics). The laboratory has several high-performance pieces of equipment (TIRA, MEMMERT, Angelatoni, Temptronic, Keithley, Rhode-Schwartz, Stanford Research Systems, Teledyne LeCroy) covering both the reliability testing (vibration combined with temperature and humidity, free fall, temperature combined with humidity and high pressure, thermal cycles), control and characterisation (data acquisition systems, thermal analysis, electrical characterisation).

Laboratory head:
Dr. Octavian Buiu,
octavian.buiu@imt.ro

Dr. Octavian Buiu is a graduate of the Faculty of Physics, University of Bucharest, with a PhD in Atomic and Molecular Physics ("Babes-Bolyai" University of Cluj). He has more than 30 years' experience in R&D, in private and public institutions: R&D Institute for Nuclear Power Reactors, R&D Institute for Electronic Components, Institute of Microtechnology Romania, and Honeywell Romania. Between 1997 and 2007, he worked in United Kingdom as research associate, fellow, and senior fellow at De Montfort University and University of Liverpool. In 2002 he has appointed as Lecturer in Electrical Eng. Dpt., University of Liverpool. Throughout his career, Octavian served as deputy scientific director at IMT Bucharest (1994-1997), Portfolio Manager and Senior Technology Manager at Honeywell Romania – Advanced Technology (2007-2014 and 2014-2017, respectively). Currently he is a scientific researcher in IMT Bucharest and head of the reliability and testing laboratory; he has more than 70 papers in ISI journals and more than 100 papers and presentations at National and International Conferences. He is author and co-author in 20 book chapters and co-author of 25 granted US and EU patents.

National and international collaborations

• Participation in the PROBA-3 ASPIICS OPSE HARDWARE – Contract No. 4000111522 / 14 / NL / GLC (ESA – European Space Agency) project (co-ordinator: laboratory L8 – IMT) ;

• Participation in the project „Parteneriat în exploatarea Tehnologiilor Generice Esenţiale (TGE), utilizând o PLATformă de interacţiune cu întreprinderile competitive (TGE-PLAT)" – cod SMIS2014+105623. The L7 laboratory prepared and presented to the interested companies its offer for reliability tests and consulting.

• NANOCARBON+ project (coordinated by Dr. O. Buiu) is focussing on the exploitation of the recently demonstrated extreme properties of a specific class of carbon nanomaterials - nanostructured graphene, used in specific morphologies and compositional categories - towards the development of innovative technologies for essential eco-industrial areas (failure monitoring, pollutant detection/decontamination in air/water, green energy). This complex, collaborative project involves Academic Research groups (Politehnica University of Bucharest, Transilvania University of Brasov) and National R&D Institutes (INOE 2000, INFLPR – Bucureşti; INECMC – Timişoara).

• Vibration reliability tests (ADT TU; AGS–WBDL) for Elettra Communications SA, Ploiesti, Romania.

• Collaboration with Peraso Technologies Inc. (Canada – Dr. Ing. Mihai Tazlauanu) for the design of a microwave sensor array.

Results

• Contribution to the development of structural models and FEM simulations for the qualification of fixing and mounting devices for the OPSE („Oculter Position Sensor Emitter" – Fig. 1a) and specific vibration testing procedures– as part of the PROBA-3 ASPIICS OPSE project. Following the approval of the procedures, vibration tests were executed and the following results reported to the external partners:

a) Development of the vibration testing procedures for OPSE;

b) Design and realisation of a mounting device for OPSE vibration testing;

c) Execution of vibration tests (Fig. 1b)

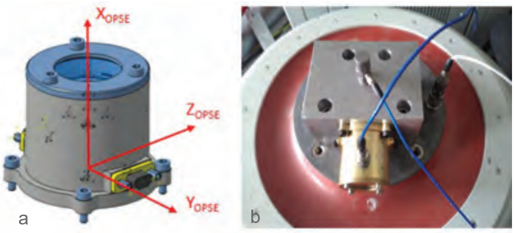
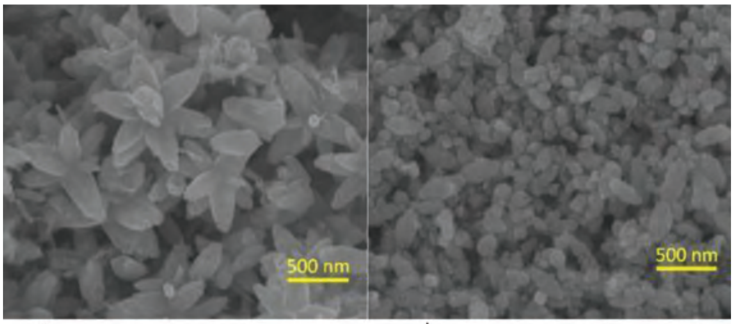


Fig. 1 – OPSE 3Ddrawing (a; vibration) and in Oy direction (b).

Results

►New, innovative technology was developed for the realisation of the binary nanocomposite powders ZnO-graphene. This technology takes advantage of the high-intensity acoustic radiation which is used for the nanostructuring of the synthesis precursors, before any thermal processes. The experiments were carried out using $Zn(NO_3)_2$ x 6 H_2O, and graphene (commercial supplier) or graphene oxide (produced in IMT). To study the role of the reducing agent (NaOH) in the realisation of the nanostructuring process, synthesis of ZnO/graphene and ZnO/GO nanocomposites was achieved at different pH values (14, 11.5, 10, 8.5) of the solutions. The synthesis of the ZnO was achieved only for a pH=14. The ZnO – commercial graphene powders were calcinated at 450^0 C, in an N_2 nitrogen atmosphere and further on analysed by SEM. The microscopy results (Fig. 2) revealed that the "nano-flower" structuring is achieved for pH=14, while decreasing the pH value will result in reducing the number of nano-petals, up to achieving a single, ZnO mono-petal.



a. b.

Fig. 2 SEM results on ZnO-commercial graphene (1.4% w/w) powders, achieved in the high-intensity acoustic field, at different pH values (a-14, b -8.5), after calcination at 450^{0}C, in N_2.

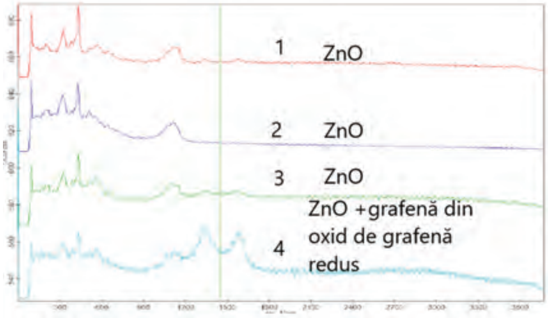


Fig. 3 Raman results for ZnO (spectra 1-3) and ZnO-graphene (from reduced graphene oxide)

►Part of the collaboration with Persao Technologies (Canada), the concept for a microwave-based gas sensing array was developed and basic architecture designed. The concept behind the smart, wireless sensing array includes - besides the hardware used for sensing and radio communication - an artificial intelligence module, which will be used for training, (periodical) calibration and interpretation of the data.

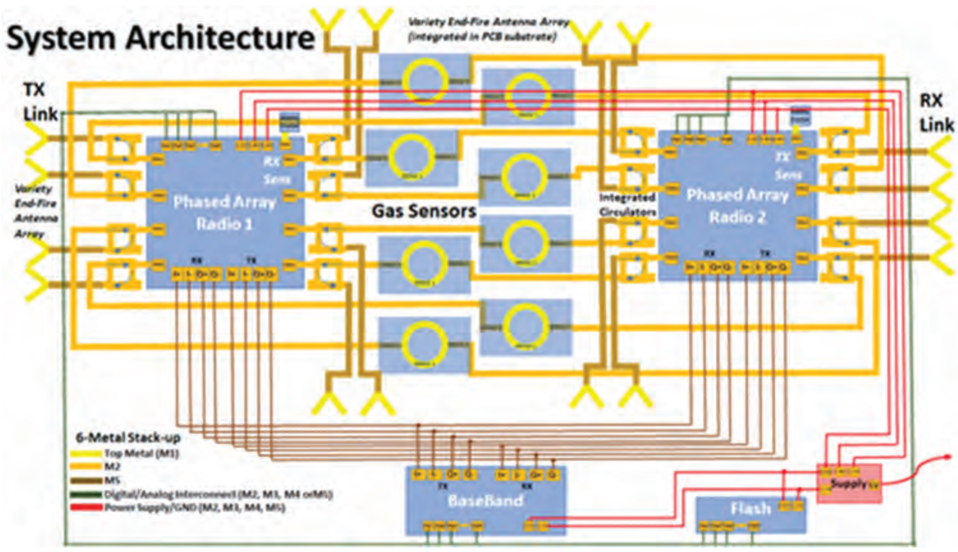


Fig. 4 – Microwave based gas sensor array

The proposed system (fig. 4) contains the following building blocks: 1. The sensing array is represented by eight integrated planar ring oscillators; resonators layout dimensions, type of sensing layer, and signal frequency may be used to design up to detect up to 8 different features of the targeted gases; 2. Two Phased Array Radios; each 8X Phased Array radio operates in 2 modes: (a) Transmit (Tx) or Receive (Rx) radio; (b) Tx or Rx sensor signal for eight independent working gas sensors; 3. The baseband (BB) and the flash memory (FM); the BB will control gas sensing, data handling and exchange as well as both radios programing, calibration and operation.

4.The antenna arrays and the power supply. Figure 5 presents a cross-section view of the sensing system.

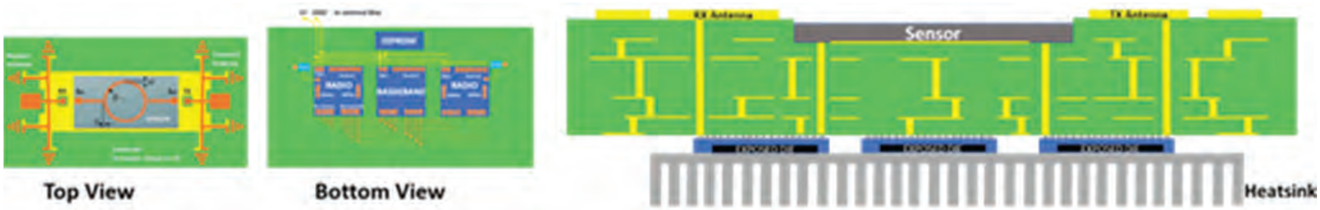


Fig. 5 – Cross-section view of the sensing system

Laboratory for Carbon Based Nanotechnologies and Nanostructures

Mission

The L11 Laboratory was founded in the **Research Centre for Nanotechnologies Dedicated to Integrated Systems and Carbon Based Advanced Materials (CENASIC)** with the main goal to assemble a team of young researchers capable to manage the newly commissioned research infrastructure in order to advance the research objectives proposed in the initial project proposal, as well as to initiate new research directions related to the mission of the centre.

Research domains

• Development, implementation, optimization of synthesis methods for carbon based advanced materials;
• Development of dedicated technologies and integration of carbon based materials in classical systems;
• Development of deposition processes for ultra-thin atomic layers with a wide range of applications, especially for nanoelectronics;
• Identification and exploitation of the special properties of integrated systems.

Equipment

• PlasmalabSystem 100, ICP-RIE dedicated to high aspect ratio etching of silicon.
• NANOFAB 1000, PECVD dedicated to plasma enhanced and thermal growth of carbon-based materials.
• PlasmaLab System 400, Rf Magnetron Sputtering for various thin films.
• OpAl, ALD for ultra-thin film deposition
• Nanocalc XR, optical reflectometer for thin film thickness measurement
• Thermal UV-Ozone Cleaner, for cleaning and surface activation

Team

• **Dr. Andrei Avram**, Physicist, Senior Researcher (CS III), Head of laboratory
• **Dr. Florin Năstase**, Physicist, Senior Researcher (CS II),
• **Dr. Cosmin Obreja**, Chemist, Senior Researcher (CS III),
• **Dr. Silviu Vulpe**, Physicist, Senior Researcher (CS III),
• **Drd. Octavian Simionescu**, Physicist,
• **Drd. Damir Mladenovic**, Physicist,
• **Drd. Elena Anghel**, Engineer, Research assistant,
• **Felicia Negreci, Engineer,** Research assistant.

Dr. Marius Andrei Avram is a full time Senior Researcher at the National Institute for R&D in Microtechnologies – IMT Bucharest, and is the head of the Laboratory for Carbon Based Nanotechnologies and Nanostructures. Dr. Avram holds a BSc in Physics (2009) and a MSc in Plasma Physics (2010) from University of Bucharest, and a PhD in Electrical Engineering (2014) from "Politehnica" University Bucharest.
He has an experience of over 10 years in developing and implementing plasma assisted process for etching and deposition of materials and process integration for the fabrication of micro- and nano- electronic devices and MEMS. Since started working as a researcher, he has been actively involved in the implementation of 15 national funded research projects, one of which he coordinated as project manager).
Currently he is working on developing and integration of carbon based materials, like graphene derivatives, into different types of sensor for industrial and research applications.
His main research interests are in developing carbon-based materials, and implementation of fabrication processes for MEMS, microfluidics, micro-nano-electronics and dedicated microstructures.

Laboratory head: :
Dr. Marius Andrei Avram,
andrei.avram@imt.ro

National and International collaborations

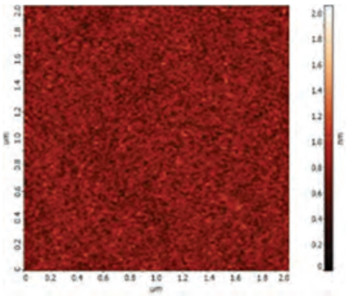
• ***Plasma & Materials Processing Group - Dept. of Applied Physics - Eindhoven Univ. of Technology*** - Prof.dr.ir. Erwin Kessels; Hybrid Solar Energy Conversion Group - Department of Physics and Astronomy - Vrije Universiteit Amsterdam - Prof. dr. Elizabeth von Hauff.
• ***Collaborations with companies, research centres and groups from national universities and institutes:***
Accent Pro 2000 SRL; DOSITRACKER SRL; Department for General Chemistry – Faculty of Applied Chemistry and Material Science – "Politehnica" University of Bucharest; Department for Metallic Materials Science, Physical Metallurgy – Faculty of Science and Materials Engineering – "Politehnica" University of Bucharest; Department of Electricity, Solid-State Physics and Biophysics – Faculty of Physics – University of Bucharest; Department of Microbiology and Immunology – Faculty of Veterinary Medicine – University of Agricultural Science and Veterinary Medicine - Bucharest; research group for "Surface and Interface Science" – National Institute for Research and Development in Material Physics; research group for „Photon Processing of Advanced Materials" – National Institute for Research and Development in Laser, Plasma and Radiation Physics; Department for "Opto-spintronics" – National Institute for Research and Development for Optoelectronics INOE 2000; Department for "Carbon-Ceramic Materials" – National Institute for Research and Development in Electrical Engineering ICPE-CA; Department for Advanced Materials – "Transilvania" University of Brașov; Laboratory for Analytical Process Technology – National Institute of Research and Development in Electrochemistry and Condensed Matter.

National Projects in 2018

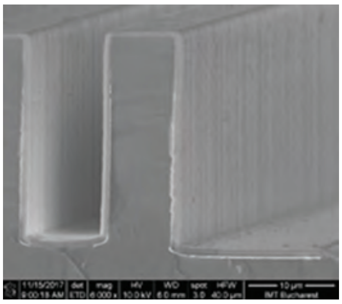
• **Graphene synthesized by thermal CVD and integrated in microfluidic devices of biomedical applications** (INTEGRAPH) - PN-III-P2-2.1-PED-2016-0123
• **Piezorezistive effects in nanocrystalline carbon films and applications in mechanical stress sensors** (PIEZOCARB), sub-project run within the complex project Nanostructured carbon based materials for advanced industrial applications (NANOCARBON+) - PN-III-P1-1.2-PCCDI-2017-0619
• Core program: **Advanced research in micro/nano-electronics, photonics and micro/nano-biosystems for development of applications in intelligent specialization areas** MICRO-NANO-SIS,
• ***Collaborations in other projects***:
- PN 18080202 - *Advanced nanoelectronic devices and circuits based on atom thick materials;*
- PN 18080201 - *Experimental processes and investigations for the fabrication of environment electrochemical sensors based on functional nanocarbon materials;*
- PN 18080103 - *Multilevel optical diffractive elements with advanced functionality*

Results

►Development of deposition processes for ultra-thin layers (atomic layer deposition - ALD) for controlled coverage of 3D (nano)structures.

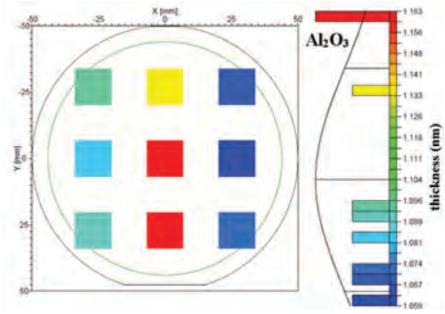


- Low roughness films (HfO_2–Ra < 0,2 nm).

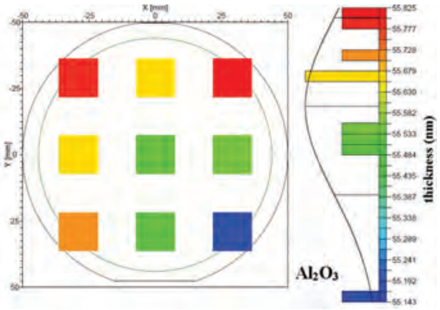


- Deposition conformity – Al_2O_3 film

ALD processes available in IMT Bucharest				
	Al	Hf	Zn	Zr
Oxides	Al_2O_3	HfO_2	ZnO	ZrO_2
Multi-compound oxides	Al_2O_3:Zn	Al:HfO_2	ZnO:Al	Zr:HfO_2
Precursors	TMA	TDMAH	DEZ	TDMAZ



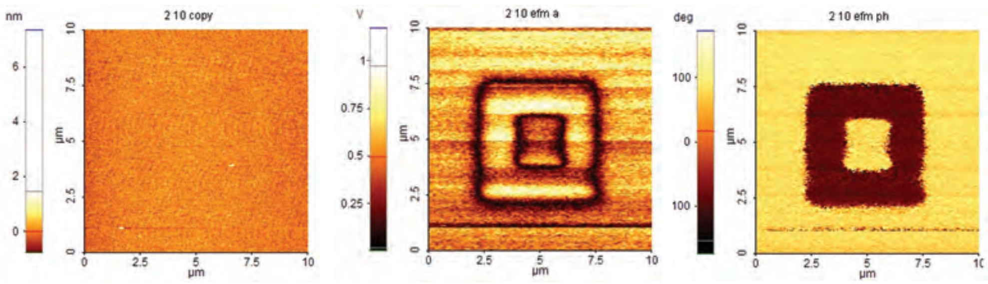
- Uniformity of a 1 nm thick Al_2O_3 film on an 100 mm Si wafer.



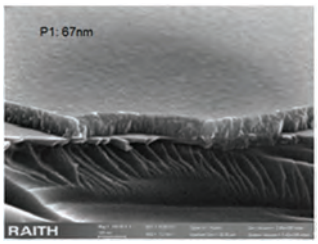
- Uniformity of a 55 nm thick Al_2O_3 film on a 100 mm Si wafer

►Development of ALD processes for ultra-thin ferroelectric films

We have developed ALD processes for deposition of HfO_2 films doped with Zr and Al. PFM (Piezoresponse Force Microscopy) characterization shows the ferroelectric nature of the material. Local manipulation of the ferro-electric domains is performed by applying CC voltage between -10 V and +10 V, while the tip is constantly maintained at 0 V. Local response of the material is performed by applying an AC voltage of 3V @17kHz on the AFM tip. For high enough applied "writing" voltage, the phase shift between areas is saturated at approximatively 180°.



PFM on HfO_2 doped with Zr



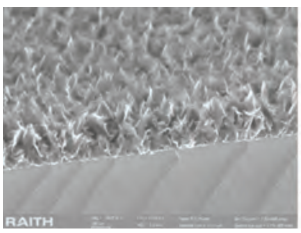
►Implementation of processes for thin films deposition by RF Magnetron Sputtering

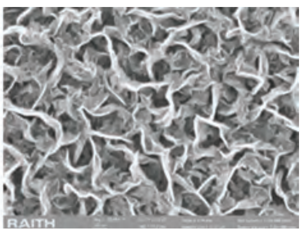
Thin stoichiometric films of TiO_2 in rutile phase have been obtained by RF sputtering at room temperature. The rutile phase is the most stable form under which TiO_2 can be found, being used for white pigments, UV absorbent coatings and interference applications.

Thin stoichiometric films of TiN have been obtained by RF sputtering at room temperature by reactive deposition from a pure Ti target. Main applications are: adherence layer, anti-diffusion barrier, conductive electrodes.

►Development of processes for growing Graphene Nanowalls (GNW) by PECVD

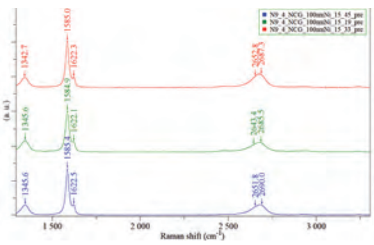
We have developed processes for growing Graphene Nanowalls using Plasma Enhanced CVD at high temperatures.

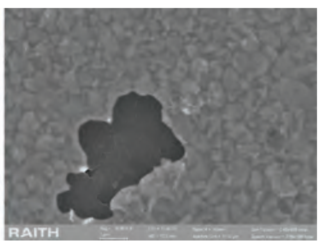




►Multilayer graphene obtained by graphitisation of nano-crystalline graphite films

Continuous films of multilayer (7 layers) graphene were obtained by high temperature annealing of a thin Ni film deposited on nanocrystalline graphite.





Laboratory for Microsystems in biomedical and environmental applications

Mission

The main mission of laboratory is **research – development**, focused on the development of microsensors (chemical sensors, biosensors, mechanical sensors), microstructures and microelectrodes, microprobes for recording of electrical activity of cells and tissues, microfluidic and integrated technologies (silicon, polymers, biomaterials), signal processing, data acquisition and graphical interfaces, development of integrated systems and platforms for food monitoring and biomedical applications, **education** in the field of micro -chemo-biosensors, and **services** in design, simulation and technology for bio - chemo and micromechanical sensors applications.

Areas of activity

Micro-Nanosensors - Microsensors development (chemorezistent, resonant gas sensors, accelerometers, micro-arrays, ISFET sensors, nanowire based sensors, electrodes for biological sensors, microprobes for recording electrical activity of cells);

Microfluidic modules and chips-Simulation, modeling and development of microfluidic platforms: microchannels, tubes, microfluidic connectors, tanks and mini-pumping systems;

Sensor platforms, Integrated systems-Platforms that integrate microsensors with microfluidic systems, with data acquisition, signal processing and graphical interfaces, operating automatically and autonomously.

Simulation and modeling - simulation / modeling using MEMS specific CAD tools (CoventorWare, COMSOL, CADENCE).

Equipment

• **Ink Jet printer** – offers the capability to deposit droplets of fluid, of the picoliter magnitude, such as liquid silver or organic inks, on all types of surfaces including flexible ones: PET (Poly-Ethylene-Terephthalate), PEN (Poly-Ethylene-Naphthalate) and Poli-Aniline (PANI).

• **VoltaLAB 10** - electrochemical laboratory, PGZ100 all-in-one potentiostat, Voltamaster 4 electro-chemical software for cyclic voltammetry, chronoamperometry and impedance spectroscopy.

• **CNC (Computer Numerical Control)** - Miniaturized machine, consisting of miniaturized system for mechanical processing and a special design and control software. CNC equipment is used to develop microfluidic components and fabricate various mechanical interfaces that connects sensors to different measuring devices.

• **Ultimaker 2+ 3D Printer** - designed and built for fused deposition modeling for various high-quality plastics like PLA, ABS, CPE. The mixture of precision and speed makes the Ultimaker 3D printer the perfect machine for concept models, functional prototypes and also the production of small series.

Team

The research team consists of 14 people, specialists in Electronics, Physics, Chemistry and Biology:

• **Dr. Carmen Moldovan**, CS I, PhD in electronics, head of laboratory;
• **Cecilia Codreanu**, CS III, engineer;
• **Bogdan Firtat**, CS III, engineer;
• **Dr. Marian Ion**, CS, PhD in Physics;
• **Silviu Dinulescu**, AC, engineer;
• **Adrian Anghelescu**, CS III, engineer;
• **Costin Brasoveanu**, IDT, engineer;
• **George Muscalu**, AC, engineer;
• **Ioana Ghinea**, technician, chemist;
• **Mihaela Savin**, CS, chemist;
• **Alina Popescu**, CS III, chemist.

Dr. Carmen Moldovan graduated on Electronics and Telecommunications and she owns a PhD in Microsensors. Her current research activity is focused on development of chemosensors and biosensors, micro-nanoelectrodes, ISFETs, nanowire transistors, MEMS, NEMS, BioMEMS, microfluidic platforms, readout design, signal processing, data acquisition for microsensor arrays and energy harvester for self-autonomous systems and Platforms and systems (e.g. Platform for pesticides detection; Portable device for early detection of acute myocardial infraction; Optical Platform for detection and monitoring of metabolic syndrome) Dr. Carmen Moldovan is / was a partner or coordinator of 15 EU Projects (FP6, FP7, ERA-NET) and 20 National Projects. She is currently coordinating two ERA-NET and three National projects. Her scientific activity was published in more than 120 papers in journals, books and Proceedings.

Laboratory head:
Dr. Carmen Moldovan
carmen.moldovan@imt.ro

International collaborations

1) International cooperation with research centers and renowned companies in the UK, Germany, France, the Netherlands, Switzerland, Hungary, Poland, in the framework of European research projects:

• **PiezoMEMS** - Piezoelectric MEMS for efficient energy harvesting – M-ERA.NET (ICF and Romelgen - Romania, Jožef Stefan Institute and HIPOT RR – Slovenia, ITE and Medbryt - Poland) - coordinated by the laboratory;

• **iBracelet** - Inteligent bracelet for blood pressure monitoring and detection of preeclampsia – EUROSTARS (InforWorld and "Politehnica" University Bucharest – Romania, Cherry Biotech and Elvesys – France);

• **RoboCom++** - Rethinking Robotics for the Robot Companion of the future – FLAG-Era.net (24 partners from Italy, Belgium, France, Switzerland, Spain, The Netherlands, Croatia, Estonia, UK, Slovakia, Greece, Romania);

• **CONVERGENCE** - Frictionless Energy Efficient Convergent Wearables For Healthcare And Lifestyle Applications – FLAG Era.net (17 partners from Switzerland, Italy, France, Belgium, Latvia, Estonia, Turkey and Romania);

• **WaterSafe** - Sustainable autonomous system for nitrites/nitrates and heavy metals monitoring of natural water sources – M-ERA.NET (ICF, Univ. Transilvania Brasov and NANOM MEMS – Romania, Institute for Technical Physics and Materials Science, Centre for Energy Research, Hungarian Academy of Sciences and University of Pannonia – Hungary).

Laboratory for Microsystems in biomedical and environmental applications

National collaborations

Cooperation with research institutes and universities (INFLPR, "Politehnica" University) and Romanian companies (ROMELGEN, Telemedica, DDS Diagnostic) within the national programs through several projects coordinated by the laboratory:

• **SENSIS** (*Sensors and Integrated Electronic and Photonic Systems for people and Infrastructures Security*): INFLPR, „Politehnica“ University Bucharest, Pitești University, Institute of Physical Chemistry I. Murgulescu, Centre of Scientific Research for Defence, CBRN and Ecology, Ministry of Defence;

• **AMI-DETECT** (*Micro Immunosensor Platform for Detection of Acute Myocardial Infarction*): DDS Diagnostic SRL, "Politehnica" University of Bucharest, Telemedica SRL, Romelgen;

• **PiezoHARV** (*Efficient Piezoelectric Energy Harvesters to Power Supply Inaccessible Sensors Networks and Low Power Devices for Aerospace Applications*): ICF „Ilie Murgulescu”, NANOM MEMS;

• **E-NOSE** (*Electronic nose for detecting small concentrations of pollutants and explosives*): ICF „Ilie Murgulescu”, Romelgen;

• **BioSIM** (*Portable analyser biochips for the assessment of insulin resistance and metabolic syndrome*), technology transfer project in partnership with DDS Diagnostic.

Results

MICROSENSORS AND MICROTRANSDUCERS

►Portable biosensors for insulin resistance and metabolic syndrome evaluation (BioSIM)

Fig. 1 The BioSIM platform: 1. Fluidic module and sensors package; 2. Electronic module; 3. Data acquisition system

Metabolic Syndrome (MS) is an independent risk factor for three of the first 10 causes of death in the world at this moment (diabetes, heart disease, cerebrovascular disease). Early identification of biomarkers of metabolic disorders in obesity and insulin resistance is the first step in the fight against this disease. The biosensors will allow the development of an accessible, fast, cost-effective and easy-to-use technology for the early identification of the patient’s insulin resistance and the presence of the metabolic syndrome.

The prototype of the clinical analysis system (for insulin resistance and Metabolic Syndrome evaluation) was developed within BioSIM. The system includes a portable reader and single-use sensing chips for the quantitative determination of 6 bio-chemical parameters (human CRP protein, human ox-LDL, Adiponectin, AFABP, Leptin and C peptide). Tests are performed on blood samples and the results are obtained in maximum 20 minutes.

►Autonomous sensors for monitoring nitrites/nitrates and heavy metals in natural water sources (WaterSafe)

The electrochemical microsensors for nitrates/nitrites and heavy metals were miniaturized, fully integrated, fabricated by micro–nano technology and they are connected to the electronic module that provides detection, data acquisition and interpretation. The sensitive layer deposited on the working electrode are metal oxides and/or polymeric membranes.

The system was integrated within a prototype that includes: the 4 sensors module for independent measurement, the microsensors themselves, the potentiostat and the computer, with hosts the dedicated command software and a LabView app for data acquisition.

The miniaturised WaterSafe portable platform measures the contaminants levels in water samples right at the sampling site. Therefore, the tests can be easily done in the field, not just in the lab. The system can detect nitrites and nitrates with sensitivities below the legal thresholds.

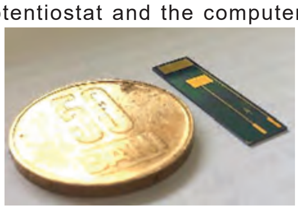


Fig. 3 The sensor’s structure

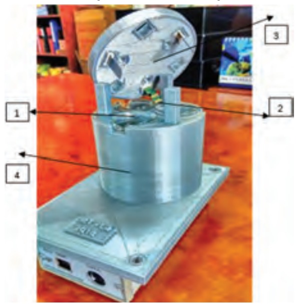


Fig. 2 The 4 sensors analysis module: 1) Eppendorf tube; 2) Sensor; 3) Cap; 4) 3D printed support-recipient

►TF BAR sensors array – based portable microsystem for multiple detection of explosive substances

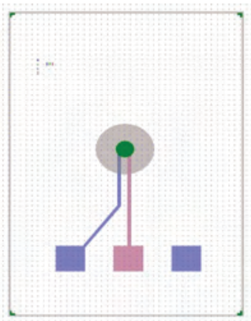


Fig. 4 The TF BAR sensor for explosive substances detection - layout

The project, a component of the SENSIS Complex Project, proposes to develop a portable microsystem based on TF BAR sensors for multiple detection of explosive substances. The system is designated to technical anti-terrorist control, critical infrastructures security (airport, subway, governmental buildings, command centres etc.) and persons / officials participating in major public events (political, sports, cultural or social events).

The risks associated with terrorist attacks in Europe are continuously rising, therefore the necessity of a portable, fully automated detection system is very present and urgent. The system will have selective and sensitive sensors, capable of detecting traces or particles of the main explosives on various objects (parcels, vehicles, clothes) or on the skin.

During 2018, the microsensors layout has been designed and the corresponding manufacturing processes were defined. These were based on the initial requirements and specifications of the system.

Results

ENERGY HARVESTING DEVICES

►Piezoelectric MEMS devices for efficient energy generation (PiezoMEMS)

The project developed an energetically efficient MEMS harvester in the form of a piezoelectric cantilever made with clean piezoelectric materials (without Pb), with high piezoelectric coefficients, deposited in thin layers on Si substrate and exhibiting low losses. The harvester included only lead-free piezoelectric materials, making it suitable for biomedical applications (e.g. powering-up implantable devices). The modelling and simulation techniques allowed an efficient optimisation of the device, suitable for the targeted applications.

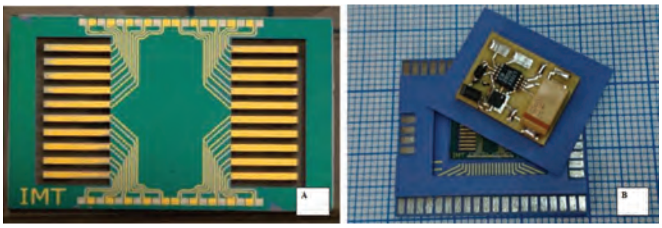


Fig 5. A: The PiezoMEMS harvester; B: The PiezoMEMS prototype


Fig. 6 The PiezoMEMS device during tests

In addition, the project built the energy storage device and the corresponding electronics. The prototype (harvester integrated with the electronic circuitry) was developed and demonstrated. The device contains 20 identical cantilevers, 2.500 μm long, 300 μm wide and 10 μm thick, manufactured on SOI wafers. During tests, the harvester generated an electrical potential of 1.8 V, sufficient to power up low power microcontrollers and devices.

►Piezoelectric Energy Harvesters for Inaccessible Sensors Networks and Low Power Devices for Aerospace Applications (PiezoHARV)

The piezoelectric harvester, based on micro-electro-mechanical system (MEMS) devices and piezoelectric material fabrication, thick film deposition and patterning (screen printing), together with storage module and power circuitry is focused on powering inaccessible sensors networks and low power devices on board of helicopters and other aircrafts.

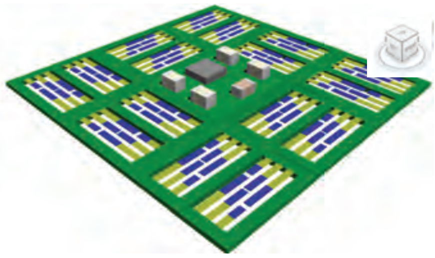


Fig. 7 Schematic of the energy harvesting device, along with the energy storage components

The harvesting cell includes several resonant micro-cantilevers, coated with a thick piezoelectric layer that converts the surrounding mechanical energy in electrical energy. The device is based on PZT as the main piezoelectric material (with several variants: PZT-5H, PZT-5A, and PMN-PZT), so that the maximum energy efficiency can be achieved. The cantilevers have variable geometries, in order to cover a wider range of resonant frequencies.

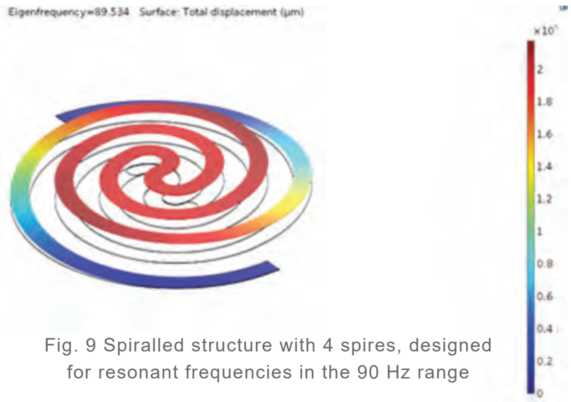


Fig. 9 Spiralled structure with 4 spires, designed for resonant frequencies in the 90 Hz range

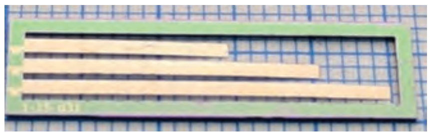


Fig. 8 The resonant structures

Alternatively, spiralled test structures were designed and optimised, in order to reduce the overall dimensions of the device. The resonant frequency of these structures is controlled by the dimensions of their proof masses.

► Energy micro-harvesters for powering up sensors and portable microsystems

The project, a component of the SENSIS Complex Project, aims at developing piezoelectric micro-harvester (a MEMS structure covered with a thin piezoelectric film with the purpose to convert the mechanical energy into electrical energy – the direct piezoelectric effect). It will contain doped PZT (with high piezoelectric coefficients) as thin films on Si substrate. The project will also provide the design and fabrication of the energy storage device and the associated circuitry. The desired targeted field is the low frequencies area (hundreds of Hertz).

Two versions of the design were designed and optimised: a rectangular silicon cantilever (2.500 μm long, 300 μm wide, 10 μm thick) with silicon proof mass and one rectangular spiralled cantilever (72 mm equivalent length and 300 μm wide).

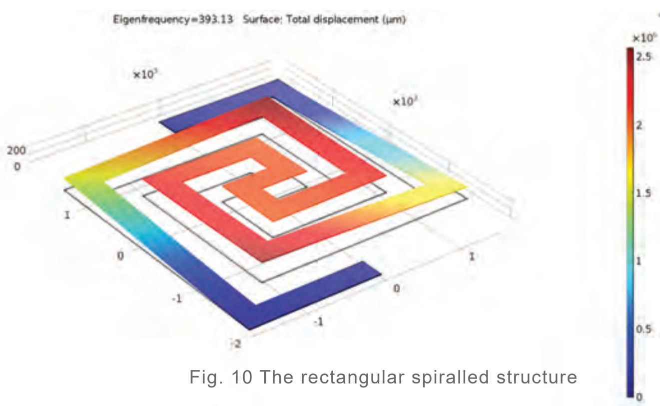


Fig. 10 The rectangular spiralled structure

Results

MICRO-NANOTECHNOLOGY-BASED DEVICES / IoT APPLICATIONS

►Intelligent bracelet for blood pressure monitoring and detection of preeclampsia (iBracelet)

A sensor system for the early detection of hypertensive disorders of pregnancy such as pre-eclampsia and other blood pressure as well. The system consists of a bracelet that incorporates a pressure sensor for continuous recording of the blood pressure waveform across the wrist artery. The sensing element consists of a resistive sensor with a microfluidic solution placed between transparent membranes (PDMS, PET).

The initial prototype was developed. It contains a pressure microsensor, a data transmission module and a data processing module. The pressure sensor contains a thin ITO film, deposited on a flexible substrate (PET).

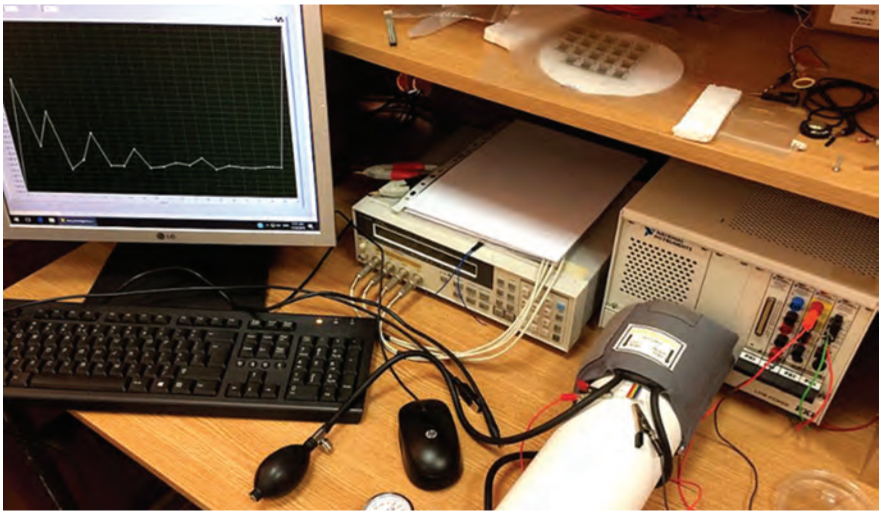


Fig. 11 The measurement setup for the sensor's functionality evaluation

►Robotic components for the Robot Companion of the future (RoboCom++)

RoboCom++ will lay the foundation for a future global interdisciplinary research programme (e.g., a FET-Flagship project) on a new science-based transformative Robotics, to be launched by the end of the H2020 Programme.

RoboCom++ will pursue a radically new design paradigm, grounded in the scientific studies of intelligence in nature. This approach will allow achieving complex functionalities in a new bodyware with limited use of computing resources, mass and energy, with the aim of exploiting compliance instead of fighting it. Simplification mechanisms will be based on the concepts of embodied intelligence, morphological computation, simplexity, and evolutionary and developmental approaches.

The IMT group is involved in "Soft technologies for wearable and mobile robots", by using soft and compliant technologies to enable the development of sensors, structures, and actuators suitable for operating in unstructured environments, in proximity to users and for tasks requiring high dexterity or conformability, such as manipulation, locomotion, rehabilitation and surgical operations.

A new method of manipulation intention identification was designed developed within the project. The method relies on using the Speech Critical Analysis for analysing written text. The results showed that the method is extremely efficient and can be implemented in intelligent interfaces of future companion robots.

► Frictionless energy efficient convergent wearables for healthcare and lifestyle applications (CONVERGENCE)

Fig 12 – Resistive measurements using the sensor device

The wearable sensor platform proposed in CONVERGENCE is centred on energy efficient wearable proof-of-concepts at system level exploiting data analytics developed in a context driven approach (in contrast with more traditional research where the device level research and the data analytics are carried out on separate path, rarely converging).

IMT is involved in the development of microelectrodes for physiological parameters measurements and sensors for Acute Myocardial Infarction diagnostic, with dedicated reader. Also, the group in IMT provides the system with gas sensors and will offer support for the signal processing from wearable human body sensors.

Education and training

Supervision of bachelor's and dissertation papers at the "Politehnica" University of Bucharest, Faculty of Electronics.

Centre for Research and Technologies Integration

Ambiental Technologies Laboratory

Mission

Research, Development, innovation of new micro/nano-sensor technologies for environmental and environmental applications (Technological design, technological development up to prototype level).

Research, development, innovation and optical alignment systems operating in a wide range of temperatures for space and security applications (Technological design, technological development up to prototype level)

Research, development, innovation of new nanostructured materials (Synthesis of new materials; Development of devices / structures based on new materials) for applications in traditional industries and agriculture.

Technological and characterization services

1.Technological assistance and consultancy (design of technological flows, control gates, etc.)

2. Analyzes Technological compatibilities and defects, on the technological flow

3. Analyzes technological compatibilities and defects, on the technological flow

4. Technological assistance in transition from prototype to zero series (technological transfer)

5. Development of individual technological processes (oxidation, dielectric and metallic depositions, photogravure, liquid and solid source doping, surface preparation processes (chemical cleaning).

6. Troubleshooting individual technological processes and technologies

7. Assistance in the synthesis of nanostructured and nanocomposite materials

8. FTIR, UV-Vis characterization

9. Electrical characterization of the device

10. RTP technological processes - rapid oxidation and nitriding processes, densification, annealing

11. Sintering, calcination at high temperatures

Education, dissemination

1.Associate teachers at University Politehnica Bucharest, Faculty of Electronics and Tc

2. Organization of workshops, presentations on the profile of the laboratory (connection with the industry)

All the activity of the Environmental Technologies Laboratory is carried out having as goal the improving of the environmental conditions and increasing the individual and social security (including health applications) and for up-grading the traditional industries in order to make them more efficient. In the last years the activity of the Laboratory has been diversified with applications in the field of space (ESA projects, STAR ROSA).

Areas of activity

Research-Development-Innovation Competences:

1. **Advanced solar cell technologies for realizing them (including for space applications)** -elena.manea@imt.ro
2. **Surface and volume microprocessing technologies** – elena.manea@imt.ro; ileana.cernica@imt.ro
3. **Technologies for integrating the electronic for signals with sensors** – ileana.cernica@imt.ro
4. **Tchnologies for micro/nanosensors** (including microsensors areas) – ileana.cernica@imt.ro; elena.manea@imt.ro; violeta.dediu@imt.ro
5. **Optoelectronic technologies (eg photodiodes, suppressor diodes, optical alignment systems)** – ileana.cernica@imt.ro; elena.manea@imt.ro
6. **Technologies for the realization of optical elements** (microlens areas, thin lenses, thin mirrors)– elena.manea@imt.ro
7. **Technologies for making advanced nanocomposite materials with antibacterial properties, self-cleaning with applications in civil constructions** – violeta.dediu@imt.ro; ileana.cernica@imt.ro

Characterization Services and Technological Processes:

- **Electrical characterization of the device** – florian.pistritu@imt.ro
- **Technological processes RTP – rapid oxidation and nitriding processes, densifications, annealing–** ileana.cernica@imt.ro
- **Technological processes specific to the applications of optical space alignment systems**– ileana.cernica@imt.ro

Dr. Ileana Cernica, received msc. on electronics and telecommunication and phd in microelectronics both from University "Politehnica" of Bucharest.

She worked as senior integration engineer in CMOS ic's technologies, CMOS RD activities and as AQ responsible in the sole romanian CMOS ic's industrial company for 10 years. Now she is senior scientific researcher, currently coordinates national and international R&D projects as responsable from IMT. She is project evaluator national RD programs (CEEX, CNCSIS) and associate professor at University "Politehnica" of Bucharest (Faculty of Electronics, OMEMS course in OPTOELECTRONICS Master Programme).

Her scientific activity was published in more than 72 papers in international journals/conferences, 110 technical reports and is author or co author of 12 romanian patents (3 of them won silver, 2 gold at international inventions exhibition in Brussels and Geneva and 2 bronze medals international exhibition "ideas-inventions-novelties"IENA, Nurnberg) and 3 books.

Laboratory head:
Dr. Ileana Cernica,
ileana.cernica@imt.ro

Team

1. **Ph.D. Ileana Viorica** CERNICA – SR I, Ph.D. in microelectronics, head of the lab
2. **Ph.D. Elena MANEA** – SR I, Ph.D. in physics
3. **Ph.D. Violeta DEDIU** – SR, Ph.D. in chemistry and physics of materials;
4. **Ph.D. Student Florian PISTRIŢU** – principal electronics engineer;
5. **Eng. Ec. Andrei GHIU** – economist engineer in Fine Mechanics;
6. **Chemist Liliana STAICU** - specialist chemist
7. **Ph.D. Student Edwin Alexandru LASZLO** – JR, Physics engineer

Ambiental Technologies Laboratory

Future directions

► Nanostructured materials and micro / nanosensors for construction applications to improve the environment and safety.
► Nanostructured materials and micro / nanosensors for agricultural applications
► Nanostructured materials and micro / nanosensors for security applications.
► Nanostructured materials and micro / nanosensors in aerospace research and industry
► Intelligent coatings for monitoring and preventing biodepositions on surfaces submerged in seawater

Focusing on the TGE-PLAT tematics:

► Applications of micro / nano technologies and nanostructured materials in security;
Microsensors and microsystems for cross-border protection (ex: explosive detection, aflatoxin detection, explosive security devices);

► Devices for the space industry (ex: areas of optical alignment devices for correlated flights and for the detection and capture of waste in space, incubators for plants growth for long-term missions or on space stations, support technologies for making areas of micro-optical elements for space applications); Applications of nanostructured materials and M / N sensors in aerospace research and industry - in both directions: aeronautics and space (ex nanocomposite coatings for space shuttles and / or fighter jets).

Equipments (selection)

Tehnologies:

- RTP Rapid Thermal Processing system for silicon, compound semiconductors, Photonics and MEMS process (ANNEALSYS, France), Manufactured in 2010. Aplications: Rapid Thermal Oxidation (RTO); Rapid Thermal Nitridation (RTN); Crystallizationd and/or annealing; Anneling of Semiconductor Compound;
- High temperature furnace, Carbolite. Manufactured in 2011. Aplications in the field of: Semiconductor field include: annealing silicon, silicon carbide and nitride samples and solid state synthesis; Ceramics fields include: desintegration, calcinations, long therm high temperature, firing and sintering of ceramic samples.

Characterization: - FTIR Spectrometer Tensor 27, Bruker Opticks, Manufactured in 2007.
- CCS-100/204 Optical cryostat system with sample in vacuum, JANIS Research Comp. Inc. Manufactured in 2017

International cooperation

Parteners : 6 Universities
University Politehnics of Bucharest (Optoelectronics Center, DCAE Department - ETTI Faculty; CEM - Science of MaterialsFaculty; Mechanics Faculty); Transilvania University of Brasov, Technical University of Timisoara, Military Technical Academy of Bucharest, University of Bucharest
3 Partners CD Institutes and the Romanian Academy:
National Institute for Electrochemistry and Condensed Matter Timişoara, ICECHIM Bucharest, ISS Bucharest
Parteners IMM - s şi IND: 1
ECONIRV
Foreign partners: 3
ESA, CSL Liege, INAF Torino

Education and training

Courses and laboratories for the masters program in Optoelectronics in collaboration with UPB
Supervision of diploma and master's works from UPB.

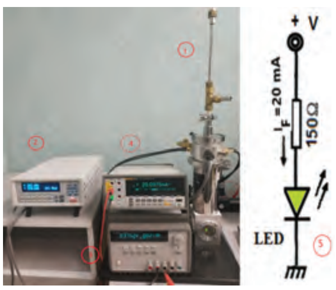
Services

Scientific services for material characterization using FTIR and technological processes using RTP and calcination furnace according to ISO 9001: 2015 for IMT and research institutions witch we are in the collaborations.

Obtained results

Project: PROBE-3 Coronagraph System Mission - OPSE (ESA)
Prime Contractor: Centre Spatial de Liège; Subcontractor for OPSE: National Institute for R&D in Microtechnologies – IMT Bucharest; Director of the IMT project Ileana Cernica (ileana.cernica@imt.ro)

Purpose: the creation of 3 Occulter Position Sensor Emitter (OPSE) systems for aligning the chronograph in the space mission PROBE 3 (launch period in space 2020)
The tests were carried out in collaboration with L7, Dr. Octavian Ionescu.



Procedure for evaluating LEDs for ESA applications - benchtest.

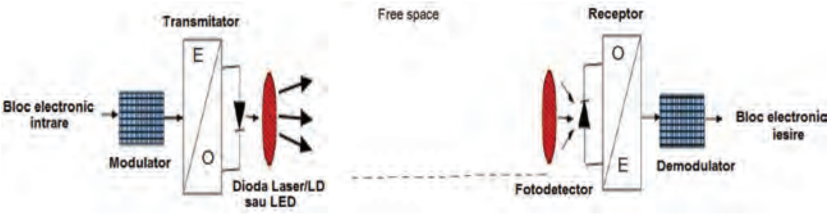
Achievement of STM OPSE

Obtained results

Project (STAR) OPTICAL ALIGNMENT SYSTEMS FOR SPACE FLIGHTS IN FORMATION AND DEBITION OF WASTE FROM SPACE - OASYS

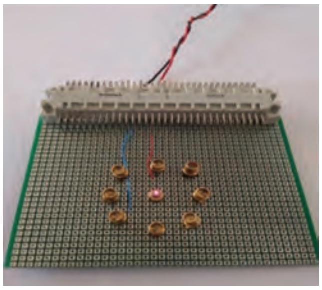
Partners: ISS Bucharest and the Military Technical Academy

IMT project manager: Ileana Cernica (ileana.cernica@imt.ro)

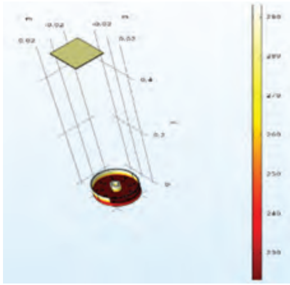


Principle diagram of an FSO system

In the research project we focused on the presentation of the methods and techniques of optical alignment that we want to implement for the two proposed applications: the realization of the flight of the spacecraft / satellites in formation and the realization of an alignment system for the removal (debiting) of the waste from around the Earth. The evolution of the human species has also led to the accelerated evolution of space technologies that have the obvious disadvantage of increasing the population of uncontrolled and non-functional residues (failed satellites or missile stages), which present a serious risk for future missions. Controlling the amount of space waste in order to maintain the long-term access to space in the coming decade, leads to the development of technologies for autonomous interception, approach and debitation missions.



OASYS DM on test-board



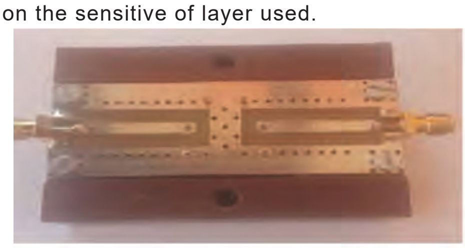
Thermal analysis of the photodetector system

Project (PED) - NEW SAW MICROSENSOR TECHNOLOGIES FOR SPACE OPERATION - SAW METEORITICS

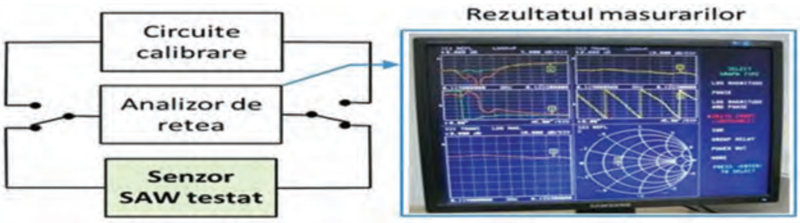
Partner: S.C.ECONIRV S.R.L.

IMT Project Director: Ileana Cernica (ileana.cernica@imt.ro)

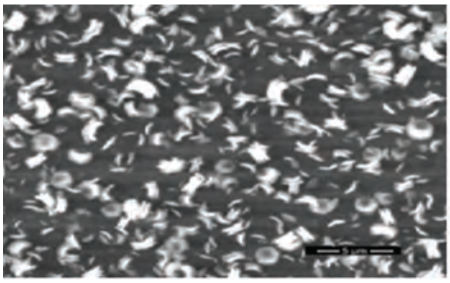
The purpose of the project is to obtain a new technology for SAW microsensors (surface acoustic waves) for working under space-specific conditions. An experimental SAW m-sensor model for hydrazine detection was chosen as the test vehicle. The strategic objective of the project is to increase the research capacity and technological expertise in the field of piezo m-sensors for space applications. The project presents innovation in: advanced piezoelectric substrates (lithium tantalate, lithium niobate, langasite), hydrazine sensitive nanostructured materials, layout, technological processes, signal electronics and assembly, designed for space applications. The SAW sensors developed within the project were tested according to the AQ procedures (vibration, temperature tests) relevant for the operation on spacecraft and / or space stations. The tests according to the procedures were performed in the MINAFAB facility of the IM, ISO 9001: 2015 certified. The procedures and tests are performed according to ESA standards. The results obtained within the project allow the development of a new family of microsensors for space applications. The technological maturity reached (TRL 4) allows the realization of such microsensors to be able to widen the area of applications with the large area of space research (mainly ESA, NASA) and terrestrial applications (mainly in security), beeing possible to develop microsensors areas and developing custom sensors for different types of gas depending on the sensitive of layer used.



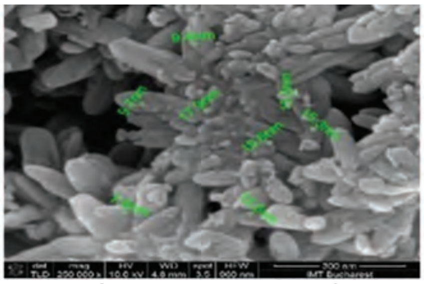
Test board assembly



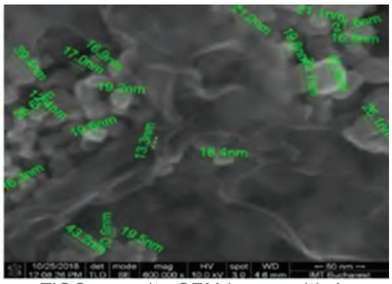
Electrical characterization assembly



SEM Image of t ZnO/TiO_2 bistrate



SEM Image nanorods of ZnO decorated with Au nanoparticles



TiOComposite SEM image with Au particles

Obtained results

(STAR) Project for SUPPORT TECHNOLOGIES FOR THE AREEA OF MICRO-OPTICAL ELEMENTS FOR SPACE APPLICATIONS - MICRO-OPTEH

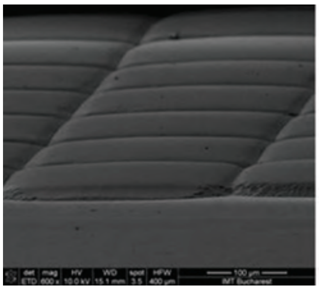
IMT project manager: Elena Manea (elena.manea@imt.ro)

The purpose of the project is the development of versatile, inexpensive and short-cycle laboratory technologies for the manufacture of micro-optical element arrays with applications in both applications for the spatial and terrestrial domain - optical devices for imaging, detection elements and different types of solar concentrators.

The technological problem we are addressing through this project it is the design, optimization and evaluation under laboratory conditions of a new technology for capturing and concentrating the light on photovoltaic areas as smaller as it is possible.

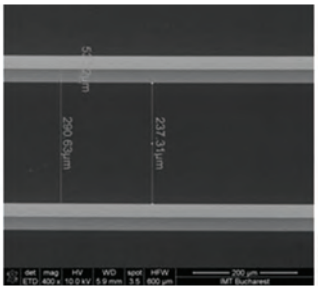
This technology will make an important contribution to reduce the mass of the solar panel, which it is a very important factor for to use in dedicated space applications (e.g. satellites), while reducing the costs associated with manufacturing of the solar panels.

The technological concept of the planar optical concentrator, based on the concentration of the light on photovoltaic areas for the smallest dimensions, developed within the project it is based on the use of three optical elements consisting of two two-dimensional arrays of micro-optical elements, one with micro-lenses and a two with micro-mirrors integrated with an optical guide and a photovoltaic cell. The networks of micro-optical elements were obtained by replication in the polymer using silicon mold.

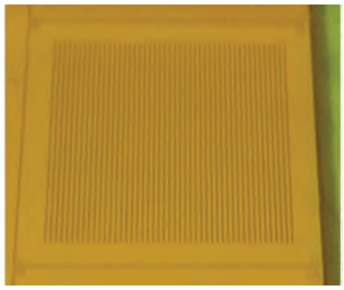


SEM image of PDMS lensses.

Optical image for microlenss matrix made of PDMS



SEM image of PDMS lensses.



Optical image matrix of micromirrors.

Project (PED)-realization of ademonstrator in planar technology of ultrathin tunneling transitors – like a promotor of a nanodevices seria and proving the utility in the industry-DEMOTUN

Project Coordinator Politehnica Bucureşti University IMT – Bucuresti – Partner 1

Director for the IMT project dr.Elena Manea (elena.manea@imt.ro)

The purpose of the project is to manufacture a prototype for an electronic device based on the tunneling of ultra-thin insulators, as the first exponent of the so-called transistor.

NOTHING on the ultra thin isolators (NOI)

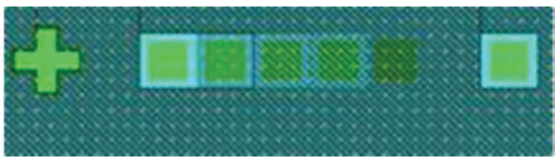
For the NOI device, the insulator may be the vacuum or the oxide, but it is important to be ultra-thin, 2 ... 10nm thickness.

Within this project a planar p-NOI architecture it was proposed, in silicon, using the oxide as insulator.

The team from IMT involved in the implementation of this project developed two technological variants for achieving thin oxides in two steps for the planar NOI: in the first variant (1)- the thick oxide was first grown, and then by successive corrosions, the thinnest oxides were obtained; In the manufacturing flow of p-NOI structures, in this variant are used different solutions of corrosion.The results is used to obtain thicknesses of the oxide from 80nm to 40nm, 20nm, 10nm, 5nm respectively 2nm.

The second variant (2) In which the thinner oxide was initially grown and then successively by thermal oxidation, the other oxides were raised on top of it.

Manufactured p-NOI transistor structures



Disposition of electrods and their eatching

Laboratory for Micro- and Nano- Fluidics

The Micro- and Nano-Fluidics laboratory was set up through the multidisciplinary project POSCCE, O.2.1.2 No. 209, ID 665, Microfluidic Factory for "Assisted Self-Assembly" of Nanosystems (MICRONANOFAB.

Mission

Research, development and education in the micro and nano-fluidics domain. The primary focus of our research is the design of microfluidic devices for applications in clinical diagnostics and regenerative medicine.

Domains of activity

► *Computational Fluid Dynamics (CFD)* modelling of Newtonian and non-Newtonian flow, e.g. single- and multiphase flows, mixing, turbulence, heat transfer, user defined function implementation for additional flow parameters setting, magnetohydrodynamics, etc.
► *Design of microfluidic devices* for applications in clinical diagnostics and regenerative medicine.
► *Experimental nano- and microtechnology*: cleanroom processes (glass silicon and polymer micromachining, plasma based processes), synthesis of nanocomposites, design, simulation, fabrication and characterization.
► *Bioengineering*: Cellular uptake of gold-coated maghemite superparamagnetic nanoparticles; studies of cells apoptosis induced by magnetic hyperthermia; tumour cells investigation spectroscopy (FTIR, Raman, Electrochemical Impedance).
► *Molecular transport in microfluidic devices*: Dielectrophoretic and Magnetophoretic systems for detection of biomolecules.
► *Visualization and flow characterization*: our experimental methods used for microscopic flow investigations are based on (i) contrast substances for the path lines distributions (ii) µ-PIV measurements for local hydrodynamic behaviour of a steady fluid flow and quantitative measurements of the velocity profiles and vortex identification.

Team

1. **Dr. Marioara Avram** - CS I, modelling, simulation, design, micro-processing and characterization of lab-on-a-chip microfluidic devices with integrated biosensors;
2. **Dr. Cătălin Valentin Marculescu** - CS III, modelling and simulation of Newtonian and Non-Newtonian fluid flow, implementation of user defined functions for setting additional flow parameters;
3. **PhD. Vasilica Tucureanu** - CS III, chemist, synthesis of nanostructured inorganic materials, study of hybrid nanocomposites, thermal processes, electrochemistry, analytical chemistry, substrate configuration;
4. **Dr. Alina Matei** - CS III, chemical engineer, synthesis of nanostructured materials and hybrid nanocomposites, thermal processes and characterization of nanomaterials;
5. **PhD Student Tiberiu Alecu Burinaru**-Research assistant, nanofluidics modelling on biomolecular interactions.
6. **PhD Student Cătălina Bianca Ţîncu**-Research assistant, experimental set-up for the characterization and testing of biosensors integrated on microfluidic platforms; synthesis and characterization of carbon nanomaterials.
7. **Dr. Petruţa Preda** - CS, graduate in Biochemistry and PhD in Biology; synthesis of polymeric biomaterials, physico-chemical analysis and their biological characterization; determination of antimicrobial activity, biocompatibility.
8. **PhD Student Eugen Chiriac** – Research assistant, modelling and numerical simulation of fluid flow in microfluidic and dielectrophoretic systems; microfluidic systems design; lithography soft; transparent micro-fabrication.

Dr. Marioara Avram is Senior Scientific Researcher at National Institute for Research and Development in Microtechnologies, Micro- and Nano- Fluidics Laboratory. She received her PhD in 2004 from the University „Politehnica" of Bucharest. Her areas of expertise include fundamental and applied research with defined innovation objectives: bionanoengineering, micro&nanofluidics, micro-biosensors and bioinspired carbon nanomaterials. She was initiator, principal investigator and manager in multiple national and international research projects. She is the author and co-author of more than 150 scientific papers with over 800 citations (between them 53 ISI indexed) and 18 patents. Awards: The WIPO Award for the Best Women Inventor in 2006; 14 Gold Medals and 14 Special Awards for her inventions to International Exhibitions of Inventions: Inventika – 2006, 2007 and 2014, Geneva- 2002, 2007, 2014, 2015, 2016, 2017 and 2019, EUREKA and Brussels 2008, ARCA in Croatia 2015, INNOVA, Barcelona 2017, Timișoara 2019.

Laboratory head:
Dr. Marioara Avram,
marioara.avram@imt.ro

Equipment

<u>**Technology:**</u>
ICP-RIE: Plasmalab System 100- ICP - Deep Reactive Ion Etching System - Etching: Bosch process for silicon and SiC, Cryogenic process for silicon
Reactive Ion Etching (RIE) Plasma Etcher, Etchlab 200
Etching: dielectrics, semiconductors, polymers, metals
Plasma-enhanced chemical vapor deposition-PECVD: LPx CVD-Deposition: silicon oxide, silicon nitride
Wafer Bonder System- SB6L- Wafer - Substrate Bonder System - Bonding: Si on Si, glass on Si, Pressure/heat assisted polymer bonding
<u>**Characterization:**</u>
Micro-PIV- PIV for Microfluidics (Particle Image Velocimetry)
Velocity fields measurements, temperature and concentration distributions in microfluidic flows
Refractometer for layer thickness measurements - NanoCalcXR
Material layer and thin films thickness measurements, refractive index measurements.

Laboratory for Micro- and Nano- Fluidics

Results

1. Nanocomposites based on transition metal oxides with applicability in aerospace (OXITRANS)

► The results obtained in the OXITRANS research:

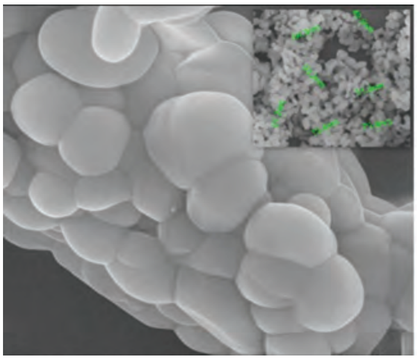
► By using the bottom-up technique and the top-down technique the nanostructured oxide materials of uncoated Y_2O_3 and doped Y_2O_3 with europium and chrome ions, respectively, doped with cerium ions YAG were developed. For each method, parameters and conditions of synthesis were optimized by the use of surfactants in the process and metal ions, which allowed the sintering temperature to decrease. The thermal treatment consisted of successive sintering steps, the final temperature varying depending on the type of material, so that the non-doped and doped Y_2O_3 powders were sintered at 900°C and the YAG powder sintered at max. 1400°C. The advantages of the developed methods have led to the improvement of the applicative properties of these oxides, which have revealed the degree of purity, crystallinity, nanostructured spherical particles with a high agglomeration tendency.

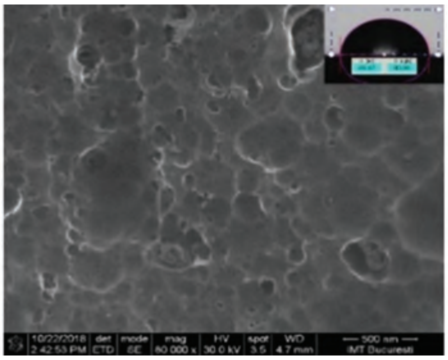
► In order to increase the efficiency, the interaction and the compatibility of the oxide nanoparticles with the selected polymeric matrices, the functionalization by the anchoring of the gold nanoparticles and the chemical interaction between the silanisation agent and the oxide particles surfaces was performed. The characterizations revealed the decrease of the agglomeration tendency and the lack of the crystalline structure of the developed oxides.

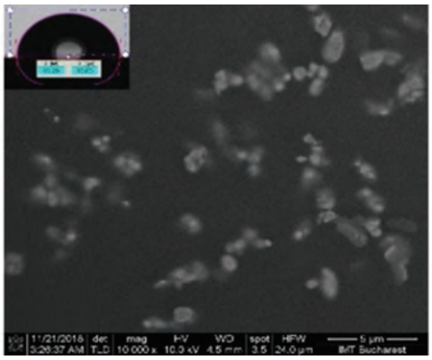
► Embedding the functionalized oxide materials into selected polymer matrices (RE and PVDF) by ex-situ synthesis, optimizing process parameters and following the morphostructural study, the incorporation of the particles into the matrix was found.

► Preparation of substrates based on aluminium alloys by stepping, chemical aspiration as a way to improve the surface characteristics of the substrates in order to prepare it by increasing the roughness and adhesion of nanocomposites synthesized to the substrate.

► Application of nanocomposite materials developed as films / protective films on pre-prepared alloy substrates. Through the morphological, compositional, topographic, and hydrophobic / hydrophilic characterization, a good interaction between the main components (nanocomposite-substrate) has been established.

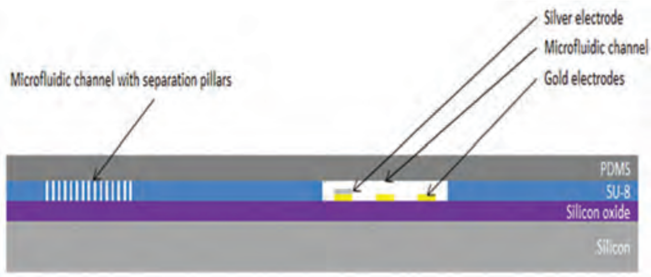

SEM of YAG: Ce


SEM of substrate

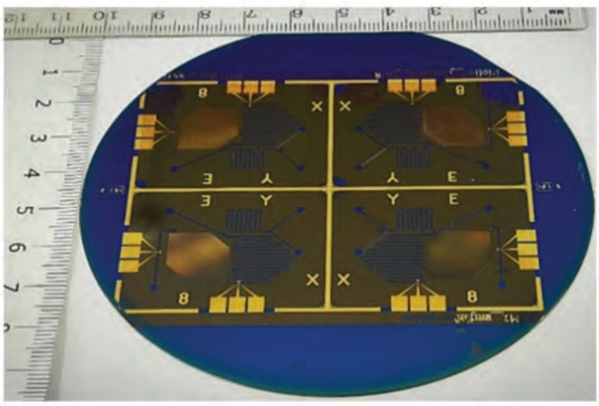

SEM of YAG: Ce-RE-substrate

2. Microfabrication and testing of the microfluidic device for determining the number of T lymphocytes - BIOLIMF

The microstructured microfluidic device has been designed to exhibit increased sensitivity and specificity to other devices. It comprises a leukocyte enrichment segment, two leukocyte counts and a capture segment thereof. The leukocyte enrichment area has the role of reducing the number of erythrocytes in the blood sample, which is of the order of 10^6 μl^{-1} of blood, which facilitates the leukocyte counting by electrochemical sensors and capture lymphocytes in the capture chamber. Electrochemical sensors have the role of counting incoming leukocytes and those coming out of the capture chamber. Based on the difference between them, the two counts determine the number of lymphocytes or their subpopulations specifically captured in the room. The capture chamber is located between the two electrochemical sensors. It has a microstructured surface designed to improve the sensitivity and specificity of the lymphocyte detection and capture rate. Also, the camera is functionalized with antibodies specific to the lymphocyte population that is wanted to be captured.



Cross section of the microfluidic device

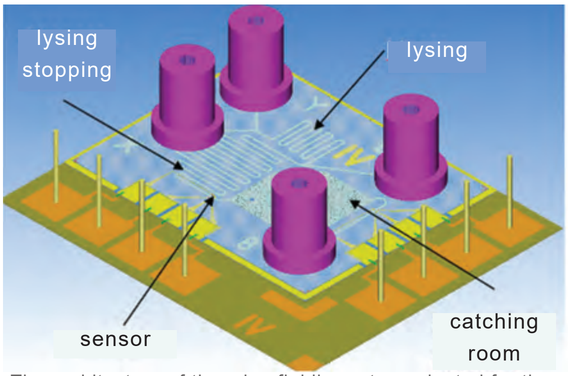

Monocrystalline silicon wafer of 4” with four microfluidic devices

Results

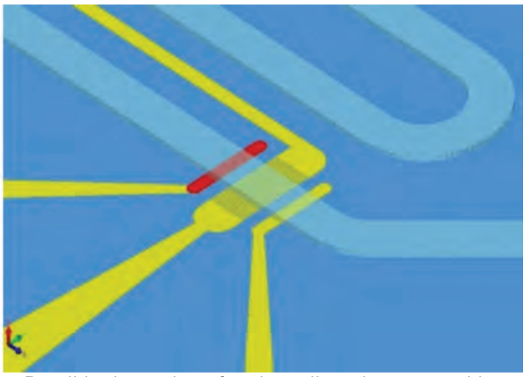
3. Design of the lab-on-a-chip microfluidic system used to determine the input parameters of numerical simulations of the dielectrophoretic system.

To determine input parameters of numerical simulations, we adapted the microfluidic system to determine the number of lymphocytes T (BIOLIMPH) previously designed and the technology transferred to DDS Diagnostic SRL. The microfluidic system designed for this project is composed of the same modules as BIOLIMPH: a erythrocyte lysis module, a erythrocyte lysate stopping module, a microstructured microstructure chamber with pylons spaced at 11 μm and two electrochemical sensors at the entrance to and exit of the room capture to determine the number of tumour cells entering the catching room and those that exit the catching room. The BIOLIMPH microfluidic device for Coulter's electrical counting of the leukocytes in suspension was obtained by integrating electrochemical sensors into narrow microchannels from 200 μm to 15 μm over a 300μm length. Each electrochemical sensor consisted of three microelectrodes: the reference electrode and the 15 μm working electrode and the counting electrode 30 μm.

In the ***uCellDetect*** project we intend to build a microfluidic platform in which the erythrocyte lysis module and lysing stopping module are replaced by a dielectrophoretic or a magnetophoretic system that will separate the tumour cells from the non-invasive blood without interfering with various chemicals.



The architecture of the microfluidic system adapted for the study of tumor cells


Detail in the region of an impedimetric sensor with interdigitated electrodes

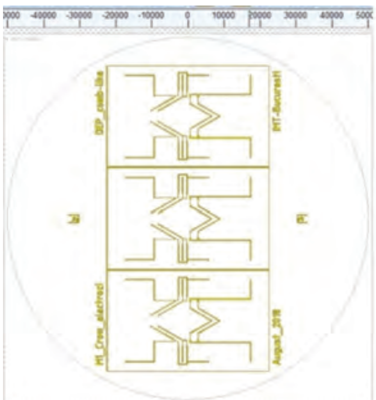
To determine input parameters of numerical simulations or experiments to characterize the electrical permeability of THP-1, SW-403 and HT-29 tumour cells, tumour lines obtained at Cantacuzino INCD. The THP-1 tumour cell line is a human monocyte cell line derived from acute monoblaste leukaemia. Tumour cell line SW-403 is a line derived from Dukes' C colorectal adenocarcinoma, and the HT-29 cell line is a tumour cell line derived from colorectal adenocarcinoma. Each known cell line was infused into the blood and injected through one of the two orifices from the entry into the erythrocyte lysis module, and the solution for lysing the erythrocytes and leukocytes was introduced through the other.

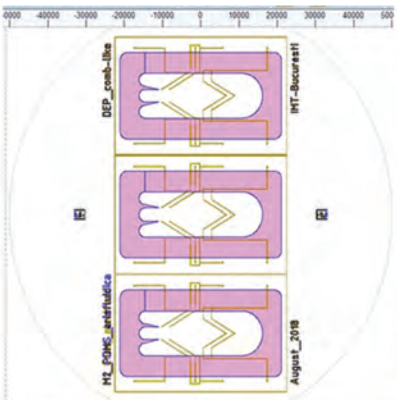
The THP-1 cell line suspension had a concentration of $1x10^6$ cells/100μl of blood, the SW-403 cell suspension had a concentration of $1x10^6$ cells/200μl of blood, and the HT-29 cell line suspension had a concentration of $0.5x10^6$ cells/150 μl of blood. Upon bringing the same suspension cell count, 20 μl of suspension from each cell line was used to determine the impedances, phase and frequency impedance and permittivity diagrams of Nyquist, Bode, Debye and Cole-Cole diagrams: electrical lines of the tumour cells belonging to these lines but also to the blood.

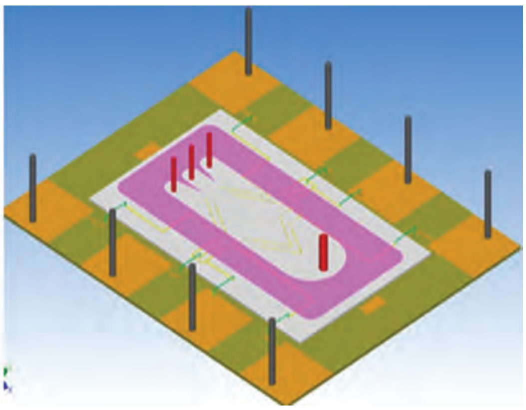
4. Design and modelling of the dielectrophoretic system

We started with the design of a simple dielectrophoretic system, then as we had the output parameters from the numerical simulations, the system was added with electrodes, or another electrodes configuration was chosen.

A more complex, but more effective and more specific dielectrophoretic system is presented below.


The first photolithographic mask for making electrodes and electrical contacts


The second photolithographic mask for making microchannels


Dielectrophoretic system with two pairs of end-to-end interdigitated electrodes mounted on the grid for electrical measurements and nano-ports for fluid access.

Scientific events and Education activities

WOCSDICE & EXMATEC 2018

IMT Bucharest organized two important international events at the Library of Romanian Academy in Bucharest, Romania, between 16-18 May 2018.
The 14th Expert evaluation and Control of Compounds of Semiconductor Materials and Technologies (EXMATEC)
The 42nd Workshop on compound semiconductor devices and integrated circuits (WOCSDICE)
The two events complement each other, covering a wide aspect of material and device considerations.

International Semiconductor Conference - CAS 2018

The International Semiconductor Conference (CAS) (www.imt.ro/cas) 41st edition was held between 12-14 October, in Sinaia, Romania. The conference is an annual event organized by IMT Bucharest. Since 1995, CAS is also an IEEE event and the Conference Proceedings is available on the IEEE Xplore Digital Library.
The main topics of CAS 2018 were: nanoscience and nanoengineering; micro- and nanophotonics and optoelectronics; microwave and millimeter wave circuits and systems; microsensors and microsystems; modelling; semiconductor devices; Integrated Circuits.
The Conference Chairman was Dr. Adrian Dinescu, the Vice-Chairs of the Program Committee were Prof. Gheorghe Brezeanu (University "Politehnica" of Bucharest) and Dr. Mircea Dragoman (IMT Bucharest).
CAS 2018 gathered 155 specialists from research institutes, universities and companies. 71 regular papers were presented at the conference, including 48 oral presentations and 23 posters. The plenary sessions comprised 12 invited talks with authors originating from France, Germany, Ireland, Italy, Japan, Romania, Serbia, The Netherlands. The awards for best student papers were sponsored by University of Cambridge, Dept. of Engineering, UK.

National Seminar for Nanoscience and Nanotechnology 2018

The 17th edition of the National Seminar for Nanoscience and Nanotechnology was organized in partnership by IMT Bucharest and Romanian Academy, combined with European Excellence in Nanotechnology (EXCELNANO), an event of the Romanian Academy, Commission for Science and Technology of Microsystems, in Bucharest, 6-7 November 2018. This edition of the Seminar consisted of different presentation focussed on European cooperation in Nanotechnology. The seminar started with a presentation related to „An European approach to Industrial Research Infrastructures: facilitating the cooperation between research and industry" by Ana-Maria Grigore, European Commission (*image right*). Horizon 2020 projects where Romanian research institutes and universities are partners have been presented. A special guest from Republic of Moldova was invited (Prof. Ion Tighineanu vice president of the Academy of Sciences of Moldova). 87 participants from academia and industry attended the event and were involved in fruitful discussions related to the nanotechnology field.

The Workshop participants visiting the new clean room from CENASIC, IMT Bucharest

SOVAREX Workshop: "IoT-Internet of Things"

IMT organized on 1st November, in cooperation with IFIN -HH (National Institute for R&D in Nuclear Physics-Horia Hulubei), in the frame of the Romanian project "Techniques for storing and capitalizing on the results of advanced scientific research" (SoVaReX) a workshop dedicated to the results of the projects. Interesting debates related to new technologies based on IoT and sensor systems have taken place during the event. The IMT Bucharest new clean room was visited by the Workshop participants.

Educational activities developed inside IMT Bucharest

Master Courses held in IMT Bucharest (teaching and laboratory classes)
M. Sc. Courses of the Faculty for Electronics, Communications and Information Technology, University "Politehnica" of Bucharest since 2009, (with access to experimental facilities) were held at IMT, by our researchers.
Specialization fields and courses are listed below:

► **Microsystems**
- Intelligent sensors and microsystems;
- Microphysical characterization of structures;

► **Micro- and Nanoelectronics**
- Advanced Technological Processes;

Laboratory classes for undergraduate and M.Sc. courses:

► **"Microsensors"**, Applications lab using MINAFAB Facility. For year IV students at Faculty of Electronics, Telecommunications and Information Technology, "Politehnica" University of Bucharest.

► **Applications lab for RF-MEMS** - M. Sc. Course.

IMT Bucharest **hosted internship** in micro and nanotechnologies for Romanian and foreign students.

ISI Papers

1. *Preparation and characterization of Ni, Co doped ZnO nanoparticles for photocatalytic applications*, Pascariu, P; Tudose, I V; **Suchea, M**; Koudoumas, E; Fifere, N; Airinei, A, APPLIED SURFACE SCIENCE Vol: 448 Pages: 481-488 Published: AUG 1 2018 IF: 4,439

2. *Correlation Between Surface Engineering and Deformation Response of Some Natural Polymer Fibrous Systems*, Vrinceanu, N; Guignard, M Iorgoaiea; Campagne, C; Giraud, S; Prepelita, R I; Coman, D; Petrescu, V D; Dumitrascu, D D; Ouerfelli, N; **Suchea, M P.** JOURNAL OF ENGINEERED FIBERS AND FABRICS Vol: 13 Issue: 2 Pages: 30-38 Published: 2018 IF: 0,678

3. *FPGA optimized cellular automaton random number generator,* **Petrica, L**, JOURNAL OF PARALLEL AND DISTRIBUTED COMPUTING Vol: 111 Pages: 251-259 Published: JAN 2018 IF: 1,815

4. *Cell therapy using an array of ultrathin hollow microneedles*, Iliescu, F S; Teo, Jeremy Choon Meng; Vrtacnik, D; Taylor, H; **Iliescu, C.**, MICROSYSTEM TECHNOLOGIES-MICRO-AND NANOSYSTEMS-INFORMATION STORAGE AND PROCESSING SYSTEMS Vol: 24 Issue: 7 Pages: 2905-2912 Published: JUL 2018 IF: 1,581

5. *In Vivo Experimental Study of Noninvasive Insulin Microinjection through Hollow Si Microneedle Array*, Resnik, D; Mozek, M; Pecar, B; Janez, A; Urbancic, V; **Iliescu, C**; Vrtacnik, D. MICROMACHINES Vol: 9 Issue: 1 Article Number: 40 Published: JAN 2018 IF: 2,222

6. *High-performance solid state supercapacitors assembling graphene interconnected networks in porous silicon electrode by electrochemical methods using 2,6-dihydroxynaphthalen*, **Romanitan, C; Varasteanu, P; Mihalache, I;** Culita, D; Somacescu, S; Pascu, R; Tanasa, E; Eremia, S A., V; **Boldeiu, A; Simion, M; Radoi, A; Kusko, M**, SCIENTIFIC REPORTS Vol: 8 Article Number: 9654 Published: Jun 25 2018 IF: 4,122

7. *Specific detection of stable single nucleobase mismatch using SU-8 coated silicon nanowires platform*, **Banu, M; Simion, M; Popescu, M C.; Varasteanu, P; Kusko, M**; Farcasanu, I C., TALANTA Vol: 185 Pages: 281-290 Published: AUG 1 2018 IF: 4,244

8. *Microarray and Surface Plasmon Resonance experiments for HPV genotyping on Au-supports*, **Banu M, Simion M, Varasteanu P**, Savu L, Farcasanu , ROMJIST IF: 0,288

9. *1D Nanostructured ZnO Layers by Microwave - Assisted Hydro-thermal Synthesis*, Musati, V; Filip, A; Tigau, N; Dinica, R; Herbei, E; **Romanitan, C; Mihalache, I; Purica, M**. REVISTA DE CHIMIE Vol: 69 Issue: 10 Pages: 2788-2793 Published: OCT 2018 IF: 1,412

10. *MWCNTs of different physicochemical properties cause similar inflammatory responses, but differences in transcriptional and histological markers of fibrosis in mouse lungs*, Poulsen, Sarah S.; Saber, Anne T.; Williams, Andrew; Andersen, Ole; Kobler, Carsten; Atluri, Rambabu; Pozzebon, Maria E.; Mucelli, Stefano P.; **Simion, M**; Rickerby, D; Mortensen, A; Jackson, P; Kyjovska, Zdenka O.; Molhave, K; Jacobsen, Nicklas R.; Jensen, Keld A.; Yauk, Carole L.; Wallin, H; Halappanavar, S; Vogel, Ulla. TOXICOLOGY AND APPLIED PHARMACOLOGY Volume: 355 Pages: 286-286 Published: SEP 15 2018 IF: 3,616

11. *Topography of the Human Ulnar Nerve for Mounting a Neuro-Prosthesis with Sensory Feedback*, Oproiu, A M; Lascar, I; Dontu, O; Florea, C; Scarlet, R; Sebe, I; Dobrescu, L; **Moldovan, C**; Niculae, C; Cergan, R; Besnea, D; Cismas, S; David, Dragomir; Muraru, D; Neagu, T; Pogarasteanu, M E; Stoica, C; Edu, A; Ifrim, Cheng Feng, REVISTA DE CHIMIE Volume: 69 Issue: 9 Pages: 2494-2497 Published: SEP 2018 IF: 1,412

12. *A quantum dot-based lateral flow immunoassay for the sensitive detection of human heart fatty acid binding protein (hFABP) in human serum,* **Savin, M; Mihailescu, C-M**; Matei, I; Stan, D; **Moldovan, C A; Ion, M;** Baciu, Ion, TALANTA Volume: 178 Pages: 910-915 Published: FEB 1 2018 IF: 4,244

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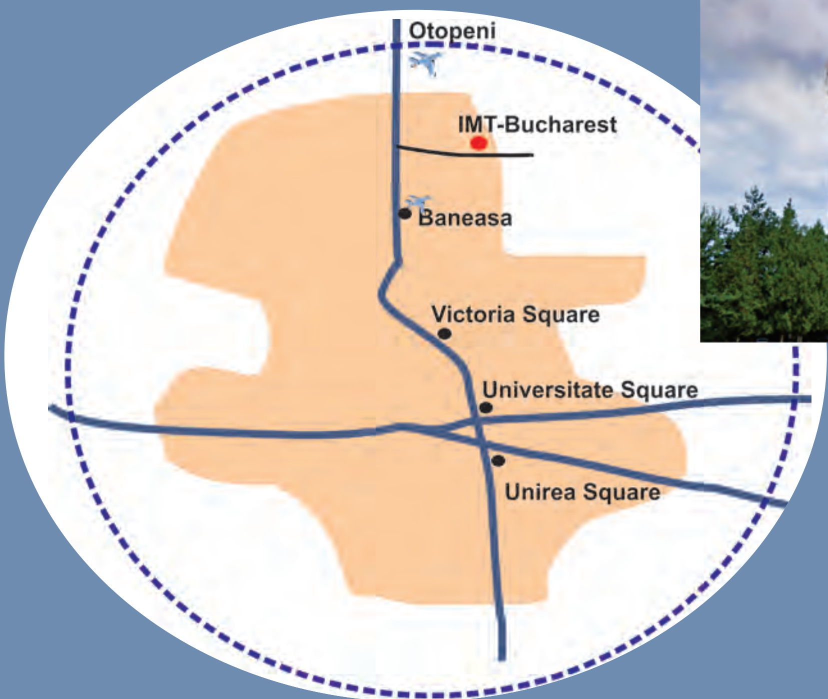

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