National Institute for Research and Development in Microtechnologies –

IMT Bucharest

Scientific Report 2020-2021

From micro - to nanotechnologies, nano-biotechnologies and nanoelectronics

Ministry of Research, Innovation and Digitalization

IMT Bucharest

Scientific Report
2020-2021

Research, technological development and experimental infrastructure

CONTENT

Introduction – CEO message

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**. IMT Bucharest is coordinated by the Ministry of Research, Innovation and Digitalization, acting basically as an autonomous, non-profit research company.

Our institute is an internationally competitive organization, involved in world class research with an attractive environment for interdisciplinary research.

During the period of 2020-2021 IMT continued its activity in highly innovative research, developing novel technologies in the field of: micro and nano- electronic components and systems, smart sensors, micro and nanotechnology, education, technology transfer and offering services for industry.

The research activity performed in national and international projects is published in ISI ranked papers, covering all range of activities from basic research to applied science and is mainly oriented to:

- micro and nanoelectronic devices
- micro and nanophotonics
- nanotechnologies
- advanced materials
- devices and circuits devoted to quantum computing
- digital platform for health, societal security and environment

IMT- Bucharest is one of the most successful institutes in Romania related to EU funding. In this period, our institute was involved as partner in **8 H2020 projects**: **4** H2020-FETOPEN projects: NANO-EH, CHIRON, NANOPOLY, IQubits, **2** NMBP: BIONANOPOLYS, FIT-4-NMP, **1** H2020-ICT: NANOSMART, **1** ECSEL project: Moore4Medical (projects coordinated by: IMEC, Belgium; Thales RTS, France; Arhus, University, Denmark; Thales RTS, France, Instituto Tecnologico del EMBALAJE, TRANSPORTE Y LOGISTICA, Spain; INTELLIGENTSIA CONSULTANTS SARL, Luxemburg; Tyndall-University College Cork, Ireland; PHILIPS ELECTRONICS NEDERLAND BV, The Netherland;). Other types of European projects as: M.ERANET, ESA, EEA & Norway Grants were also implemented by IMT Bucharest in this period.

As in previous years, the research collaborative activity of its **4 departments**, grouping **11 laboratories**, was focussed to the priorities of the Romanian National Strategy for Research and Innovation SNCDI and of EU program Horizon 2020 and Horizon Europe.

At national level, a **Structural Funded project ”TGE-PLAT”** (https://www.imt.ro/TGE-PLAT/) is a dedicated platform offering access to IMT's infrastructure and allowing knowledge transfer to Romanian small and medium-size enterprises, offering the opportunity of cooperation with 12 industrial companies in the fields like ICT and Security and Health .

We must mention the PCCDI **7 Complex Romanian projects** in the field of: ICT, Eco-Nano-technologies, Health, New and emergent Technologies, Bio-economy Solution. In all these projects IMT being involved as coordinator or partner.

IMT's infrastructure (https://eertis.eu/erio-2200-000u-4306) 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).

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 and e-beam nanolitography) and functional and reliability tests.

CENASIC, in use since November 2015, is oriented to research in the field of graphene-based devices and other carbon-based nano materials, as nanocrystaline diamond and SiC.

Two editions (43th and 44th) of the annual international conference, **CAS - International Semiconductor Conference** (www.imt.ro/cas) - an IEEE event - were organised by IMT Bucharest, online due the pandemic related restrictions.

Current research activities involve multidisciplinary teams, composed of: physicists, electronic engineers, chemists, material engineers, mathematicians, biologists, PhD students, technicians and administrative staff, who are engaged in national and international research projects.

IMT Bucharest is involved in partnerships with higher education institutions, providing access to Romanian and international students for internships, to advance their knowledge and gain new skills.

The Scientific Report 2020-2021 presents the most important projects and the research highlights of the 11 research laboratories. A list of ISI scientific publications concludes the report.

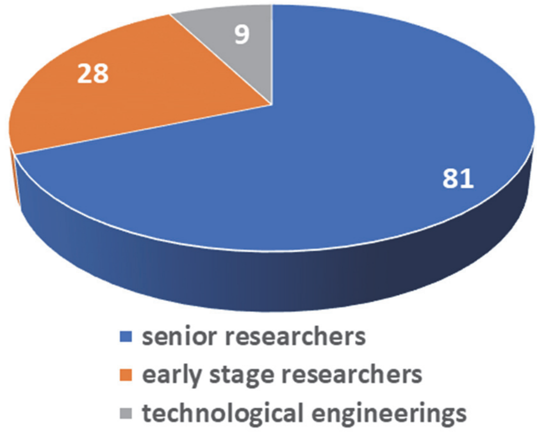
I would like to thank my colleagues for their great work and support during this period.

Dr. Miron Adrian Dinescu
CEO and President of the Board

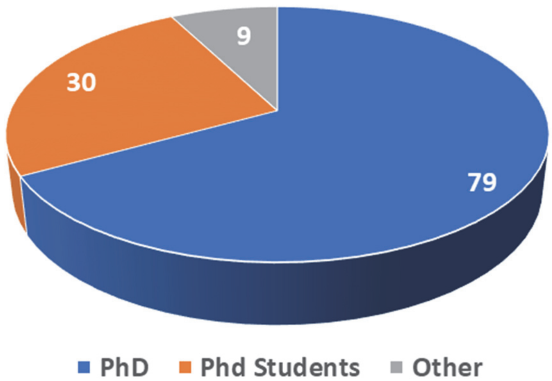
IMT Bucharest - key facts and figures

People and Culture

Researchers



PhD's and PhD students



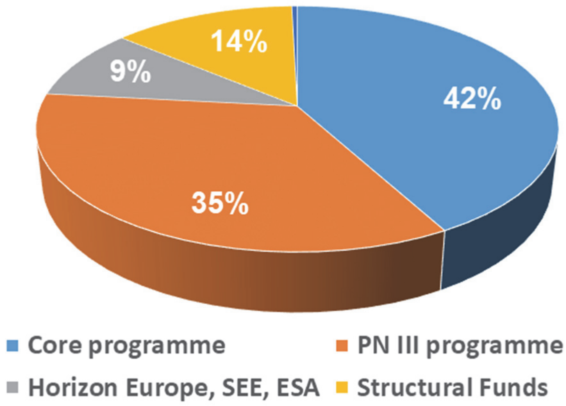
International Reach

Research activities of IMT Bucharest during this period - participation in 16 international projects and 46 national projects:

8 funded through H2020 (3 FET-OPEN, 2 NMBP, 1 ICT, 1 FETPROACT EIC, 1 ECSEL);
5 funded through ERA.NET and MANUNET
2 funded through EEA & Norway Grants
1 funded through ESA programme;

36 funded through National Plan (PNIII);
8 funded through Core Programme;
3 funded through Structural funds programme;

Source of funding:



Output of research and services 2020-2021

Prototypes: 97

Products: 9

Technologies: 74

Services: 46

Prospective and technological studies: 64

Technical plans, procedures and technical-economic documentation: 34

Patent request: 34

Patent granted: 4

Papers on conferences: 128

Papers on conferences published in proceedings: 92

ISI articles: 154

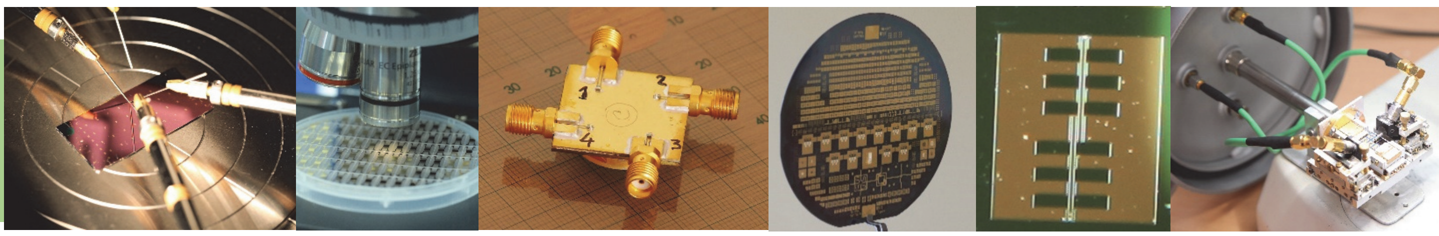
Impact factor cumulated: 519

Articles publishes in Journals indexed by Scientific International Databases: 12

Books and chapter in Books: 8

Number of citations of IMT Bucharest ISI article: 2978

Scientific national and international event organized by IMT Bucharest: 7



IMT Bucharest Infrastructure

IMT-MINAFAB infrastructure, ISO 9001 certified, contains a key unit, the „Facility for micro-nanostructuring of devices and systems", unique in Romania. 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.

- **Clean Room - 200 sqm: Class 1.000/100 (ISO 6/5);**
- **Clean Room – 120 sqm: Class 10.000 (ISO 7);**
- **Clean Room – 180 sqm: Class 10.000 (ISO 7);**
- **Clean Room – 85 sqm: Class 1.000 (ISO 6);**
- **Clean Room "Gray Area" - 287 sqm: Class 100.000 (ISO 8);**

Services:

- Photolithography (chrome, maskless, wafer double-side alignment and exposure);
- Nanolithography (EBL, EBID, EBIE, Dip-pen) and SEM;
- Physical depositions of materials in high-vacuum;
- Chemical depositions, thermal processing (PECVD-LPX-CVD; LPCVD; RTP);
- Precision etching of materials (plasma reactive ion, humid, shallow and deep);
- X-Ray diffractometry;
- Scanning probe microscopy: AFM, STM, SNOM, confocal, Raman mapping;
- Nanomechanical characterization;
- Microarray spotting/scanning;
- Analytical characterization tools;
- Interferometry/profilometry; Spectroscopy;
- Probers, on-wafer; electrical characterization (Semiconductor Characterization System & Microwave network analyser).

The CENASIC 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;

The key technological equipment within the CENASIC: Multiprocess Furnace System; Molecular Beam Epitaxy (MBE); Plasma Enhanced Chemical Vapor Deposition (PE CVD); Atomic Layer Deposition (ALD) tool; RF Magnetron Sputtering.

This research infrastructure provides an opportunity of new technological platforms able of supporting technologies as: synthesis and processing of nanomaterials with special properties, technologies for micro/nano processors and design of innovative systems and devices.

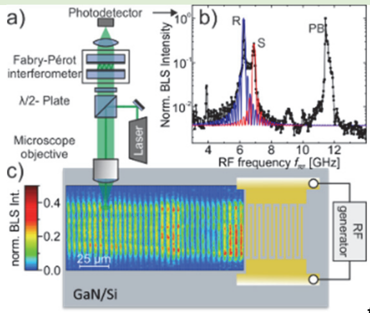
- **CENASIC Clean Room - 200 sqm: Class 1.000/100 (ISO 6/5);**

Relevant projects in Horizon 2020

CHIRON project (https://www.chiron-h2020.eu/)

Within H2020 CHIRON project, single and two-port SAW type structures having resonance frequency > 6 GHz and CoFeB (thickness 18 nm) as magnetostrictive layer, were developed and manufactured on GaN/Si by IMT and IMEC. Single-port SAW structures with IDTs of 170 nm width were analyzed at Kaiserslautern University by micro-focused Brillouin light scattering (μBLS) technique to directly and locally probe the Spin Waves excited by SAW. Using the high sensitivity of μBLS, we were able to study this phenomenon in a wide frequency range from 4 to 12 GHz, hance Rayleigh and Sezawa waves could be excited simultaneously.

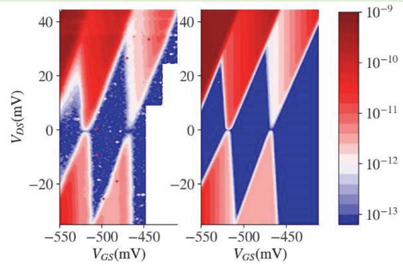
M. Geilen, et al., Appl. Phys. Lett. 117.21 (2020): 213501



(a) Schematic BLS setup. (b) Normalized BLS intensity (log scale) for different excitation frequencies f_{RF} applied to the IDT. The square of the calculated excitation efficiency for the Rayleigh mode (blue) and Sezawa mode (red). (c) Two dimensional time-averaged BLS intensity map of a SAW emitted from an IDT with f_{RF} = 6.25 GHz. The SAWs form a confined beam with a periodic interference pattern.

iQubits project (https://www.iqubits.eu/)

In H2020 iQubits project, cryogenic measurements of 1x18nmx70nm pMOSFET fabricated in a FDSOI CMOS process were used to demonstrate a compact DC I-V characteristic model which adds a tunnelling component on top of the classical MOSFET foundry model to capture quantum and Coulomb Blockade effects. The measurements were performed on-die at 6.2 K. The measured (performed in IMT) and simulated (by UofT) stability diagram, with the Coulomb Blockade, shows a good accuracy across V_{GS} and V_{DS} values relevant for operation as a single-hole transistor (SHT).



Measured at IMT (left) and simulated at UofT (right) stability diagram for 1x18nmx70nm p-MOSFET at 6.2K

S. P. Tripathi et al., ESSCIRC 2021 - IEEE 47th European Solid State Circuits Conference, pp. 43-46

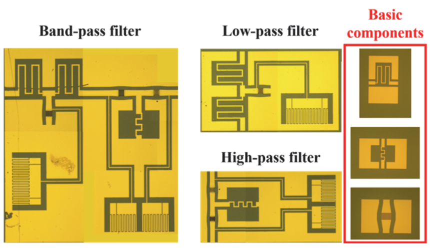
NANOSMART (https://project-nanosmart.com/) and NANOPOLY (https://project-nanopoly.com/)

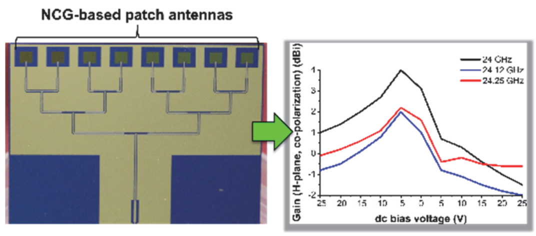
IMT has successfully demonstrated the first proof-of-concept of:

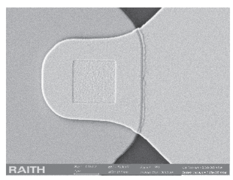
a microwave filter, working in the X-band (i.e., 8-12 GHz), based on dense matrices of vertically aligned carbon nanotubes (VACNTs) to create low-voltage variable capacitors able to tune the filtering frequency with more than 1 GHz;

a MIM diode based on few-nm-thick layer of hafnium oxide for microwave/millimetre-wave detection of RF interference, with cutoff frequency of hundreds of GHz.

an array of patch antennas made of nanocrystalline graphene (NCG), working in the ISM band at 24 GHz (i.e., 24-24.25 GHz), with reconfigurable frequency and gain by applying a DC voltage onto the NCG layer;



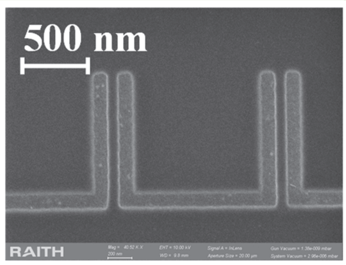




M. Aldrigo et al., IEEE Access, Vol. 9, pp. 122443–122456, Aug. 2021; M. Dragoman et al. Physica E Low Dimens. Syst. Nanostruct., 126.114451 (2021); M. Aldrigo et al., Proc. of the 51st European Microwave Week Conference (EuMW 2021), 2-7 Apr. 2022, London, UK; A. Cismaru et al., Proc. of 2021 IEEE 16th Nanotechnology Materials and Devices Conference (NMDC), 12-15 Dec. 2021, Vancouver, Canada;

NANO-EH project (https://www.nano-eh.eu/)

In this project IMT has successfully designed, fabricated, and experimentally characterized geometrical planar diodes with few-nm-wide channels etched from a two-dimensional heterojunction made of graphene and molybdenum disulphide. These diodes have demonstrated beyond-the-state-of-the-art performance in terms of both responsivity and noise equivalent power, with excellent performance as microwave detectors up to the X-band.



M. Dragoman et al., Phys. Status Solidi RRL, Art. No. 2000521, 2021; M. Dragoman, et al., IEEE Nanotechnol. Mag., Vol. 15, No. 5, pp. 8–19, Oct. 2021; M. Aldrigo et al., Proc. of IMS2021, pp. 315–318, 7-25 Jun. 2021, Atlanta, USA; N. Pelagalli et al., Proc. of PIERS 2021, Virtual PIERS (25-29 Apr. 2022), Hangzhou, China;

“Partnership for using Key Enabling Technologies on a platform for interaction with competitive companies”

Structural Funding Project

In the framework of the Action 1.2.3 - "Partnerships for knowledge transfer" through the Competitiveness Operational Program (POC), Priority Axis 1 "Research, technological development and innovation (CDI) in the field of economic competitiveness and business development", **IMT Bucharest** implemented as coordinator the Project ***“Partnership for using Key Enabling Technologies on a platform for interaction with competitive companies”, acronym “TGE-PLAT“*** (8.09.2016 and 7.09.2021). The project was co-financed from the European Regional Development Fund through the Competitiveness Operational Program 2014-2020 (POC). The total value of the project was around 3 millions Euro.

The **TGE-PLAT project** realised a platform for interaction between research and industry, at national level, developing 3 KET (Key Enabling Technologies- in Romanian TGE: Tehnologii Generice Esentiale): micro-nanoelectronics, photonics, nanotechnologies, two of them being considered also in KDT (Key Digital Technologies), which are today priorities of the European Union (and Romania).

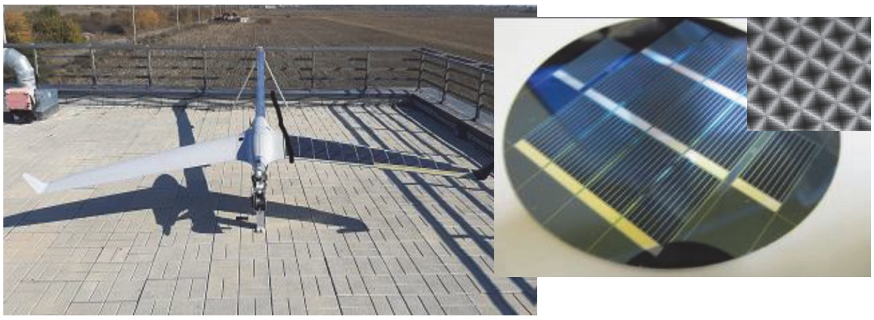
The **TGE-PLAT project**, based on the long experienced in the field of semiconductor, microelectronics of IMT researchers and the fact that it is possible to address the whole value chain of a device/sensor/microsystem manufacturing, starting with design and simulation to micro-nanofabrication, microphysical characterization and reliability tests, developed three main directions: **microsensors, photonic components and systems for security applications** and **devices and systems for millimetre and sub-millimetre waves** . Innovative companies that wanted to benefit from the new technologies had a unique opportunity through this project, thanks to the multidisciplinary expertise of the institute's team, their experience in European collaboration in high-tech fields, the extremely high-performance infrastructure (which ensures a virtual micro-nanomanufacturing pilot line) and the open collaboration environment at the institutional level. In the frame of TGE-PLAT project IMT- Bucharest offered transfer of knowledge to Romanian enterprises, through a variety of activities, from information and consultancy, to scientific or technological services and dedicated CD activities. It was established a Platform for interaction with the companies, which provide information about access to IMT infrastructure/equipment, services available for SMEs, support for implementation of their projects, according to their needs.

A main action of the project was industrial research and experimental development in partnership with SMEs (D type subprojects). The interest of different companies, active in this advanced field, for implementation in partnership a high technical level projects, oriented to market demand, was high, exceeded the financing possibilities through the TGE-PLAT project, so that the requests were selected on a competitive basis and two such competitions were organized.

The first R&D direction was that of **Microsensors**. These are microsensors for the detection/identification of people, scattered areas of micro/nano sensors for the detection of dangerous substances/materials such as explosives, drugs, sensors based on microarray technology for the detection of bacteria or viruses with the potential to be used as biological weapons, results that falls under subfield 2.3.1 – cross-border combating of terrorism, organized crime, illegal trafficking of goods and persons. It is also aimed at obtaining microsensors for the detection of toxins, smart sensors for the rapid and selective detection of dangerous substances in liquid environments (including surface waters) with applications in the development of monitoring techniques for the assessment and reduction of disaster risk (subfield 2.3 .2).

A second R&D direction was that of **photonic components and systems** relevant to subdomain 2.3.1: components for optical systems used for state border guarding and for some particularly important objectives - micro-optical components (for example diffractive optical elements with 3D profile, variable lenses) and for optical surveillance systems with a large visual field; photodetectors optimized for various spectral domains for daytime and night-time image acquisition systems; miniaturized, integrated sources in the far infrared range.

A third R&D direction was related to **millimeter wave imaging systems and diffraction networks for phase contrast X-ray imaging systems** for baggage and passenger control for the detection of prohibited substances, such as drugs, explosive substances and their precursors.



Photovoltaic cells with increased textured area and higher efficiency, fabricated by IMT; Prototype of a ultralight aircraft wing (UAV) manufactured by composite material, with integrated photovoltaic cells (IMT and AFT) - Market Watch No. 239, November 2021, page 22 and 23.

In the framework of the project, apart from the activities of assistance granted to businesses, by advisers, several types of subsidiary contracts took place (14):

- Type B (Enterprise access to facilities, installations, equipment) with the companies: SC EQUILIBRIUM MEDICAL SYSTEM SRL; SC PRO OPTICA SA; SC Tehnopro Engineering SRL.
- Type C (Activities to transfer CD skills/competencies and to support innovation) with the companies: SC EQUILIBRIUM MEDICAL SYSTEM SRL; SC LAIF COMPUTATION SRL.
- Type D (Research-development activities in effective collaboration) with the enterprises: S.C. ACCENT PRO 2000 S.R.L.; SC PRO OPTI- CA SA.; SC ROM-QUARTZ SA.; SC OPTOE- LECTRONICA-2001 SA.; SC ROVSOL SRL; SC AUTONOMOUS FLIGHT TECHNOLOGY R&D SRL; SC SITEX 45 SRL; DDS Diagnostic SRL.

An important component of the project's financed activities was industrial research and/or experimental development in effective collaboration between the research organization and the enterprise.

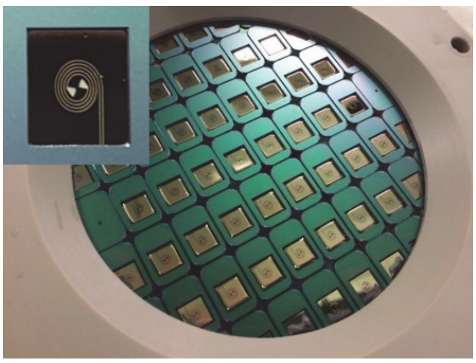
Microscopy determination of optical parameters for Diffractive Optic Elements, fabricated by IMT.
SOFID System with aspherical lenses and Diffractive Optic Elements realized by PROOPTICA SA together with a Long Wave Infrared Detector without cooling. (Market Watch N0. 230, December 2020, page 30)

IMT developed together with the companies 9 type D projects:

- Millimeter wave passive imaging system for rapid scanning of people, with application in the field of security (ACCENT PRO 2000 SRL).
- High-quality image forming optical system, with diffractive optical elements, in the LWIR spectral range, intended for multisensor systems (PRO OPTICA SA)
- Development of a technology for the production of security metallic holographic microparticles (SC OPTOELECTRONICA-2001 SA).
- Image forming optical system using "Free-Form" (FF) components and their production technology (ROVSOL SRL)
- Sensitive platform with SAW sensor for the detection of flammable, potentially explosive gases (SC ROM-QUARTZ SA).
- Electrochemical microsensors for rapid and selective detection of pesticides (SC DDS DIAGNOSTIC SRL).
- System of micro-textured photovoltaic cells of increased efficiency integrated into the wing of an unmanned aerial vehicle (UAV) with applications in societal security (SC AUTONOMOUS FLIGHT TECHNOLOGY R&D SRL - IMT)
- Development of technology for making sensors for combustion gases with nanocomposite hybrid materials based on titanium dioxide nanotubes and graphene (SC SITEX 45 SRL – IMT)
- Electrochemical microsensors for the detection of some narcotics: codeine and morphine (SC DDS DIAGNOSTIC SRL - IMT)

The results of the "TGE-PLAT" project allowed the growth of the research - development and innovation capacity of the companies with which the institute collaborated, through the transfer of knowledge between the academic and industrial environments, through the development of new, innovative products and services. The "TGE-PLAT" project allowed IMT-Bucharest to develop sustainable cooperation with economic partners, by capitalizing on research and within new national projects, especially through "Transfer to the economic operator" projects, as and through joint European project proposals.

Details about the event are available at the address: https://www.imt.ro/TGE-PLAT/



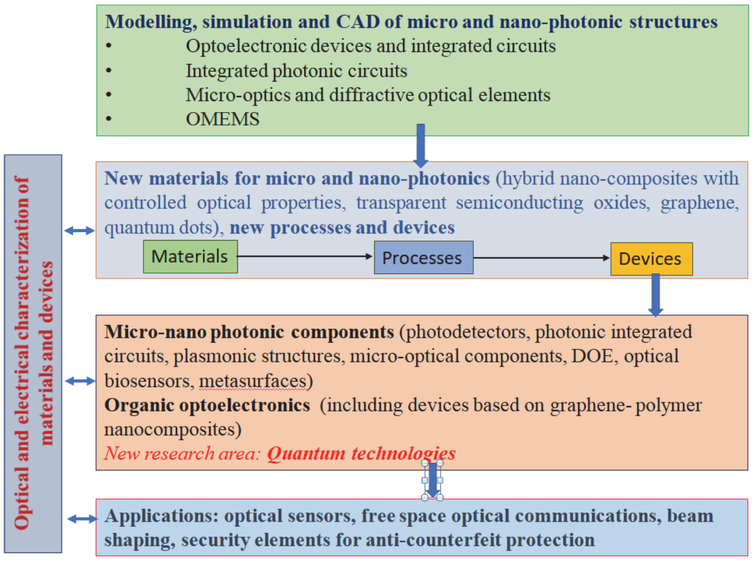
Thin membrane supported antenna used as a component in a millimeter wave (30 - 300 GHz) passive imaging system for security applications (hidden object detection made from metallic and nonmetallic materials, explosives, drugs, etc). (Market Watch Nr. 230, December 2020, page 31)

Laboratory of Micro/Nano Photonics – L3

Mission

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

Research domains



Team: Dr. Dana Cristea laboratory head, senior researcher, M.Sc. in electronic engineering, Ph.D.in optoelectronics & materials for electronics; **Dr. Munizer Purica** senior researcher, M.Sc. and Ph.D. in physics; **Dr. Cristian Kusko** researcher, M.Sc. and Ph.D in physics; **Dr. Mihai Kusko** senior researcher (M.Sc. in physics and photonics, Ph.D in optoelectronics); **Dr. Florin Comanescu** – researcher, M.Sc. in electronics and PhD in optoelectronics at "Politechnica" University of Bucharest; **Dr. Roxana Rebigan** researcher, M.Sc. in physics and Ph.D in optoelectronics; **Dr. Roxana Tomescu** – researcher, M.Sc. in electronics and PhD in optoelectronics at "Politechnica" University of Bucharest; **Dr. Rebeca Tudor** – junior researcher, M.Sc. in Electronics, PhD in Physics; **Ştefan Cărămizoiu** – AC, PhD student in physics; **George Bulzan** – AC, M.Sc student in physics. **Veronica Anastasoaie** – MSc in Food Chemistry and PhD Student in Chemical Engineering.

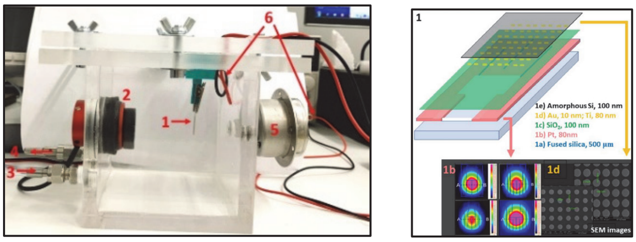
R&D Projects

- ***IR sensors for infrastructures' security applications***, Coordinator Dr. Ing. Roxana Tomescu, part of the Complex Project ***„Sensors and integrated electronic and photonic systems for persons' and infrastructures' security"*– PN-III-P1-1.2-PCCDI2017-0419 2019-2021**, partnership with INFLPR RA.
- ***Development of quantum information and technologies in Romania, PN-III-P1-1.2-PCCDI2017-0338,* 2018-2021**, IMT Coordinator: Dr. *2014-2021*Cristian KUSKO, with the ***Sub-projects:***
  - ✓ **Q-INFO:** Developing theoretical and computational methods for quantum information and quantum technologies **(coordinator IFIN-HH);**
  - ✓ **Q-CHIP:** Developing the integrated quantum photonics platform (coordinator INFLPR);
  - ✓ **Q-VORTEX:** Quantum information with optical vortices (coordinator IMT)
  - ✓ **Q-LAB:** Developing two research laboratories and a quantum source (coordinator UPB)
- ***Partnership for using Key Enabling Technologies on a platform for interaction with companies***" TGE-PLAT POC-G – Operational Competitivity Program, , Action 1.2.3, Contract No. 77/08.09.2016, a project found by Structural Funding dedicated to knowledge transfer from IMT to Romanian companies, in a high tech field of the Romanian Strategy (SNCDI 2016-2020): ICT, Space and Security), *subprojects in partnership with SMEs*:
  - ✓ ***C77.2D High quality forming image optical system with diffractive optical elements in LWIR spectral range for multisensory systems – SOFID*** – Project manager Dr. Cristian Kusko; cooperation with ProOptica SA
  - ✓ ***C 77.4 DTechnology for anti- counterfeit metal microparticles***- Project Manager Dr. Catalin Parvulescu; cooperation with OPTOELECTRONICA 2001 SA.
  - ✓ **C77.8D:** ***Development of the technology for combustion gas sensors based on titanium dioxide nanotubes and graphene,*** *cooperation with* SC SITEX 45 SRL*, Project manager Dr. Roxana Tomescu*
- ***Plamonic and dielectric metasurfaces as platforms for fluorescence enhancement* -** PN-III-P2-2.1-PED-2019-1300, **2019-2021** IMT- DDS Diagnostic S.R.L, coordinator Dr. Roxana Tomescu
- ***Adaptive mobile mixing and dispersing system using nanoparticles into innovative colloidal solutions for chemical, biological and radiological agents' mitigation* NANODEC ,** PN-III-P2-2.1-PED- **2020-2022,** coordinator Dr. Munizer Purica
- **Zoom optical imaging systems for MWIR spectral domain, with applications in the security field - MWIRO PN-III-P2-2-1-PTE**-2019-0465, **2019-2021**, coordinator PRO Optica SA, IMT manager: Dr. Mihai Kusko
- **Combined technologies for the development of multi-layer smart holograms with a high level of security, PN-III-P2-2.1-PTE-**2019-0578, **2020-2022*:*** Coordinator: Optoelectronica 2001, IMT manager: Dr. Catalin Parvulescu
- ***MICRO-NANO SIS PLUS* IMT Core Programme 2019-2021** - *PN 19.16, Coordinator Dr. Dana Cristea*
  - ✓ **Project PN 19160103** Technologies for photonic and optoelectronic components with applications in optical information processing at classic and quantum level **2019-2002,** coordinator Dr. Cristian Kusko

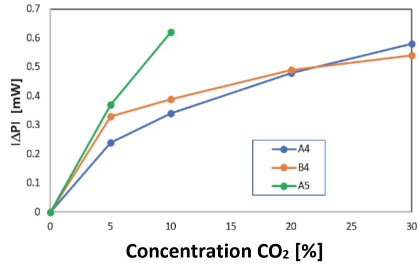
Scientific highlights

► ***IR sensors for infrastructures' security applications*** Coordinator: Dr. Roxana Tomescu (roxana.tomescu@imt.ro).
Aim: development of a gas detection system ***based on a highly selective IR sources***

A highly selective and efficient gas detection system based on a narrow-band IR metasurface emitter integrated with a resistive heater has been designed and fabricated. In order to develop the sensor for the detection of specific gases, both the microheater and metasurface structures have been optimized in terms of geometry and materials. Our prototype showed that the modification of the spectral response of metasurface-based structures is easily achieved by adapting the geometrical parameters of the plasmonic micro-/nanostructures in the metasurface. The advantage of this system is the on-chip integration of a thermal source with broad IR radiation with the metasurface structure, obtaining a compact selective radiation source. From the experimental data, narrow emission peaks (FWHM as low as 0.15 µm), corresponding to the CO_2, CH_4, and CO absorption bands, with a radiant power of a few mW were obtained.



The sensor assembly is composed of: a (1) micro-IR source based on a metamaterial "perfect" absorber integrated with a microheater for selective gas sensing, which has the property to change the broadband emission of the microheater into a narrow and high intensity emission band with the center wavelength overlapping the absorption peak of test gases; (2) thermopile detector; (3) gas inlet; (4) gas outlet; (5) manometer; and (6) connection wires for thermal source. The narrow-band IR source (1) is composed of 5 layers: (1a) substrate, (1b) Pt heater (inset—thermal images obtained with an IR camera), (1c) SiO_2 insulator, (1d) metasurface based on Au nanodisks (inset—SEM image), and (1e) amorphous Si.

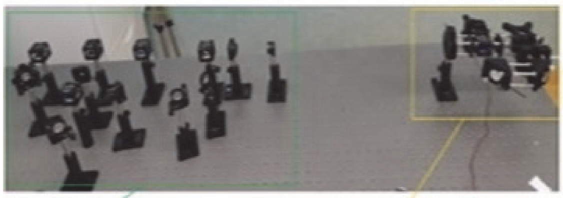


Detected power function on the CO_2 concentration measured with three different highly selective IR sources

► **Developing quantum information and quantum technologies in Romania**, complex project (PCCDI), coordinator: Cristian Kusko, cristian.kusko@imt.ro)

Aim: development of microtechnologies for the fabrication of photonic circuits, optical and optoelectronic components for quantum technologies, quantum processing information and quantum cryptography.

We developed an experimental setup for BB84 quantum cryptographic key distribution (QKD) and a system generating photonic states showing rotational invariance. This system consists in a polarization sensitive Sagnac interferometer using light configurations with orbital angular momentum. When this system is attached to a BB84 it encodes the polarization states generated by BB84 into rotational in variant states such that the alignment for relative rotation between transmission and reception block it is no longer required. This system can be used in scenarios where emitting (Alice) and receiving (Bob) blocks as a BB84 QKD system are in relative motion.

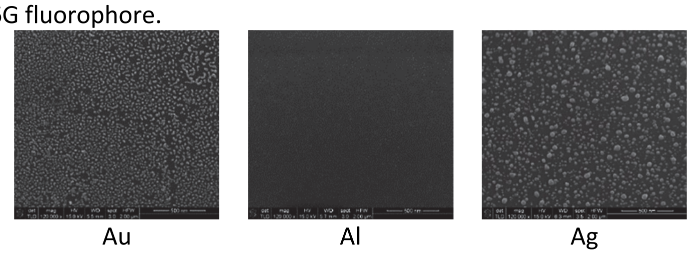


Functional model of BB84 QKD system using rotational invariant photonic states.

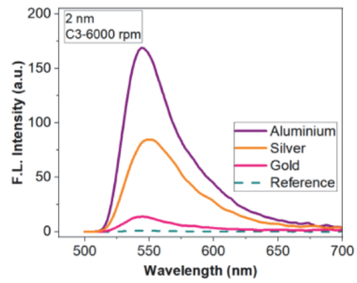
►**Project *Plamonic and dielectric metasurfaces as platforms for fluorescence enhancement***, coordinator: Dr. Roxana Tomescu (roxana.tomescu@imt.ro).

Aim: obtaining plasmonic metasurfaces for fluorescent enhancement

Metasurface structures composed of elements (meta-atoms) randomly arranged on both silicon and glass substrates were made to improve the fluorescent emission of the Rhodamine 6G fluorophore.



SEM micrographs of the morphology obtained for 2 nm metallic film



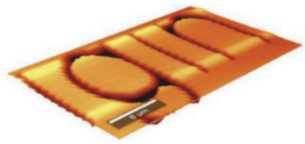
Fluorescence enhancement for three types of metasurfaces

►***Project* "Combined technologies for the development of multi-layer smart holograms with a high level of security",** coordinator: Dr. Catalin Parvulescu (catalin.parvulescu@imt.ro)

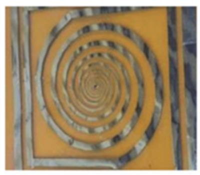
Aim: development of multilayer holographic labels with a high degree of security

Security elements that contain nano/microtext elements using low-cost lithography technology processes and RFID (Radio Frequency Identification) elements operating in the 860-960 MHz band have beed designed and fabricated

Alphanumeric security element



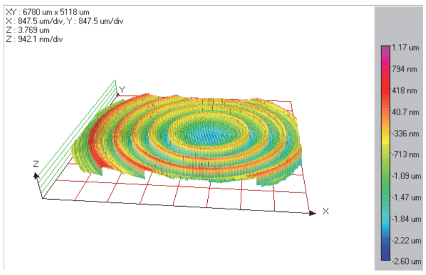
AFM image of security element type nano-text on the surface of the smart hologram



RFID element (antenna and symmetric attenuation network)

►Project: Zoom image forming optical systems for MWIR spectral range with applications in security field – MWIRO, coordinator: Dr. Mihai Kusko, (mihai.kusko@imt.ro)

Aim: development of medium IR optical systems operating in mid IR spectral range, using silicon diffractive optical elements fabricated in IMT Bucharest. Diffractive optical components were simulated using "zone plate" surface in ZEMAZ software. Based on the simulations a 16-level profile, correcting diffractive element has been fabricated using 4 photolitographic masks and RIE dry etching processes. Fabricated Fresnel lens were characterized using an experimental setup where the intensity of the IR diffracted beam generated by the optical element is measured as a function of the angular coordinate.



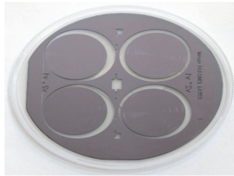
WLI image of fabricated optical element

► POC-G – Operational Competitivity Program 2014-2021, TGE-PLAT "Partnership for using Key Enabling Technologies on a platform for interaction with companies"

In the frame of this POG three collaborative (public-private) projects with SME were conducted by the lab:

- Sub-project C77.2D: High quality forming image optical system with diffractive optical elements in LWIR spectral range for multisensory systems – SOFID – coordinator: Dr. Cristian Kusko

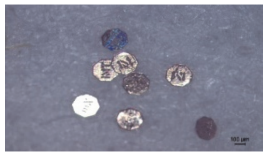
Optical components were fabricated for the general correction of the image generated by an optical system operating in the thermal IR range. The optical components illustrated in the figure bellow are Fresnel lens fabricated on silicon substrate by photolithography and plasma etching techniques.



Individual Fresnel lens diced from the wafer by a DRIE process

- Sub-project C77.4D: *Technology for anti-counterfeiting metal microparticles* (in collaboration with OPTOELECTRONICA 2001 SA), coordinator: **Dr. Catalin Parvulescu** (catalin.parvulescu@imt.ro)

- Metal security microparticles with holographic information and alphanumeric code were developed and made to protect products against counterfeiting .



Security metal microparticles

- Sub-project C77.8D: *Development of the technology for combustion gas sensors based on titanium dioxide nanotubes and graphene* (in cooperation with SC SITEX 45 SRL), coordinator: **Dr. Roxana Tomescu**

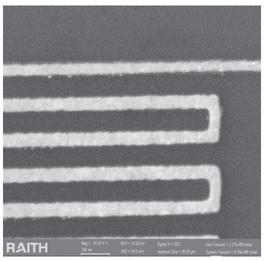
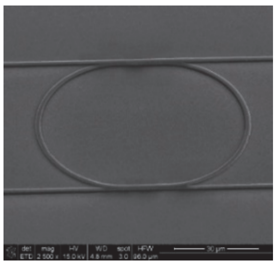
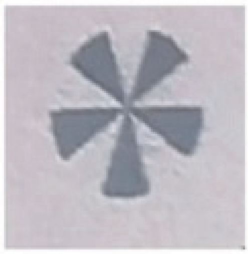
Sensitive structures based on TiO_2 nanotubes were designed and fabricated for a high-sensitivity combustion gas detection system for low CO concentrations.

Image of a sensor structure in the TO39 case.

►Project: Technologies for photonic and optoelectronic components with applications in optical information processing at classic and quantum level, Dr. Cristian Kusko (cristian.kusko@imt.ro).

Aim: to develop microtechnologies for the fabrication of photonic circuits, optical and optoelectronic components for quantum technologies.

Using microfabrication techniques we realized (i) micro-nanometric superconducting structures for TES detectors (transition edge sensors) and nanowire detectors from low temperature NbTiN with a transition temperature of 18 K and high temperature YBCO with a transition temperature of 92 K; (ii) integrated optical components such as circular micro-resonator (with applications in wavelength multiplexing/demultiplexing) and wavelength filters, long distance waveguides in meanders form used as delay lines or non-linear optical effects enhancement; (iii) diffractive optic elements realized by maskless photolithography using space light modulator.

(a)  (b)  (c) 

(a) SEM image of a detector realized by the superconducting material NbTiN, (b) SEM image of microring resonator realized from silicon nitride, (c) optical image of a diffractive optic element realized by maskless photolithography.

R&D Services: Active pharmaceutical ingredient/ API investigated by micro-Raman spectroscopy (contract with contract with SARA PHARM SOLUTIONS SRL, Bucharest, Romania); Cryogenic measurements of the spectral characteristics of selected LEDs for space applications transfer characteristics project PROBA-3 Coronagraph System/Subcontractor Occulter Position Sensor Emitters OPSE 3. Contact: munizer.purica@imt.ro.

Micromachined structures, microwave circuits and devices Laboratory (RF-MEMS) - L4

Laboratory head: Dr. Alexandru Müller

Mission

L4 laboratory, was the first European team that has developed microwave and millimeter wave circuits supported on thin dielectric and semiconductor membranes. The FP4 MEMSWAVE project was among the first European Commission projects in this field coordinated by IMT (L4 laboratory). In 2002, this project was nominated in the top ten European projects from all fields for the Descartes prize competition. Starting from 2008 the laboratory is also involved in the develop of acoustic devices for GHz applications using micromachining and nano-processing of wide bandgap semiconductors (GaN/Si, AlN/Si and ScAlN/Si) and also on experimental devices based on graphene, two-dimensional materials, carbon nanotubes, ferroelectric materials and metamaterials. The L4 laboratory has coordinated also the FP 7 REGPOT call 2007-1 MIMOMEMS project and participated in the Network of Excellence/FP6 "AMICOM. The laboratory has participated in IP/FP7 (NANOTEC, SMARTPOWER), STREP/FP7 (NANO RF, MEMS-4-MMIC), ENIAC JU (SE2A, MERCURE, NANOCOM), and ESA project. Recently the laboratory was involved in first H2020-FETOPEN projects with Romanian participation (CHIRON, IQubits, NANOPOLY, NANO-EH). The laboratory was also involved in a lot of projects won in the competitions organized by national authorities.

Expertise

• **Development of millimeter wave circuits** based on microprocessing/nanoprocessing of Si, GaAs, GaN;
• **SAW and FBAR devices** (resonators, filters, sensors) in GHz frequency range, based on microprocessing and nanoprocessing of WBG semiconductors (GaN, AlN and ScAlN);
• **Coupling of SAWs with spin waves**, using a magnetostrictive layer placed between the IDTs of a SAW manufactured on III-Nitrides materials, with resonance frequency in GHz domain
• **Characterization** of semiconductor devices at **cryogenic temperatures (up to 4 K and respectively 2 K)**, directly on the wafer, in the range of microwaves and millimeter waves and in a magnetic field, for **quantum computing** application
• **Field effect diodes and transistors** based on **monoatomic layers** (two-dimensional/"2D") made of **graphene** or other **2D materials** (molybdenum disulphide);
• Resonant sensors manufactured in the **substrate integrated waveguides (SIW)** technique;
• **Devices and components for microwave applications** (up to 30 GHz) integrated with thin layers (≤ 6 nm) based on ferroelectric doped hafnium oxide: **phase shifters, transmission lines, filters and antennas**;
• **Passive antennas based on nanocrystalline graphite** with gain reconfiguration characteristics by applying a bias voltage;
• **Reconfigurable filters and switches in the X band** (8-12 GHz) and ISM 24 GHz based on vertical carbon nanotubes.

Team: **Dr. Alexandru Müller** (PhD in Physics, Habilitated) - laboratory head, senior researcher I; **Dr. Mircea Dragoman** (PhD in Electronics) senior researcher; **Dr. Dan Neculoiu** (PhD in Physics) senior researcher I; **Dr. Sergiu Iordanescu** (PhD in Electronics) senior researcher II; **Dr. Valentin Buiculescu** (PhD in Electronics) senior researcher II; **Dr. Dan Vasilache** (PhD in Electronics) senior researcher II; **Eng. Cristina Buiculescu** (MSc in Electronics) scientific researcher III; **Dr. Alina Cismaru** (PhD in Physics) senior researcher I; **Dr. Alexandra Nicoloiu** (PhD in Electrical Engineering) senior researcher II; **Dr. Alina Cristina Bunea** (PhD in Electronics) senior researcher II; **Dr. Martino Aldrigo** (PhD in Electronics) senior researcher II; **Dr. Ioana Zdru** (PhD in Electronics) senior researcher III; **Dr. Caudia Nastase** (PhD in Physics) senior researcher II; **Dr. Cristina Ciornei** (PhD in Electronics) senior researcher III; **Eng. George Boldeiu** (PhD student in Physics) researcher; **Mircea Pasteanu**, technician; **Maria Dionian**, technician.

International collaborations – R&D Projects

- **CHIRON - H2020-FETOPEN** No: 801055 *Spin Wave Computing for Ultimately-Scaled Hybrid Low-Power Electronics*, Coordinator IMEC Belgium, 9 partners (2018-2022) IMT partner (https://www.chiron-h2020.eu/)
- **Qubits - H2020 FETOPEN** No. 829005, *Integrated Qubits Towards Future High-Temperature Silicon Quantum Computing Hardware Technologies*, Coordinator: Aarhus Univ. (DK), 6 partners (2019–2023) IMT partner (https://www.iqubits.eu/)
- **NANOPOLY - H2020 FETOPEN** No. 82906, *Artificial permittivity and permeability engineering for future generation sub wavelength analogue integrated circuits and systems, Coordinator: Thales TRT, France; 8 partners (2019-2021) IMT partner (*https://project-nanopoly.com/*)*
- ***NANOSMART - H2020* ICT RIA*,*** No. 825430, *NANO components for electronic SMART wireless systems, Coordinator: Thales TRT, France; 10 partners (2019-2021) IMT partner, (*https://project-nanosmart.com/*)*
- **NANO EH** - **H2020 FETOPEN,** No. 951761, *Nanomaterials enabling smart energy harvesting for next generation Internet of Things, Coordinator:* Tyndall-University College Cork (2020- 2023) 9 partners, *IMT partner (*https://www.nano-eh.eu/*)*

National collaborations

- ***PCCF - B*****asic Research and Frontier, Project: GRAPHENEFERRO-***Advanced nanoelectronic devices based on graphene/ ferroelectric heterostructures (2018-2021)* Coordinator: Dr. Mircea Dragoman, http://www.imt.ro/grapheneferro/
- ***PD – Postdoctoral research project*: *MoMiCom*** *- Monolithic Millimeter wave Front-End for Advanced Communications* (2020 -2022) Coordinator: Dr. Alina Bunea, https://www.imt.ro/momicom/
- **PED – Demonstration experimental project: (i) dualSAW** - *Dual pressure and temperature sensors based on GaN membrane supported Surface Acoustic Wave (SAW) devices* (2020 – 2022) https://www.imt.ro/dualSAW/, Coordinator: Dr. Alexandra Nicoloiu; **(ii) SAWSAT** - *GaN/Si Lumped-Element SAW Duplexers for Satellite Telecommunications above 7 GHz* (2020 - 2022) https://www.imt.ro/sawsat/, Coordinator: Dr. Alina Bunea; **(iii) ResoSens** - *Tuneable RESOnant SENSors based on multi-layer substrate integrated waveguide technology* (2020 - 2022) https://www.imt.ro/resosens/, Coordinator: Dr. Valentin

Buiculescu; **(iv) NANOFERRO-RF** - *NANOelectronics based on a new generation of hafnium oxide FERROelectrics for future RF devices and circuits* (2020 – 2022) https://www.imt.ro/NANOFERRO-RF, Coordinator: Dr. Martino Aldrigo

- **Support H2020** : **(i)** *Integrated Qubits towards Future High-Temperature Silicon Quantum Computing Hardware Technologies (2020-2022)* https://www.imt.ro/Iqubits/index.html Coordinator: Dr. Alexandru Müller; **(ii)** *Nanomaterials Enabling Smart Energy Harvesting for Next Generation Internet-of-Things* (2021 – 2023) https://www.imt.ro/NANO-EH_24.2021/, Coordinator: Dr. Martino Aldrigo; **(iii)** *NANO components for electronic SMART wireless systems*, (2021) https://www.imt.ro/NANOSMART_suport/ Coordinator: Dr. Mircea Dragoman; **(iv)** *Artificial permittivity and permeability engineering for future generation sub wavelength analogue integrated circuits and systems* (2021) https://www.imt.ro/NANOPOLY/, Coordinator: Dr. Mircea Dragoman.

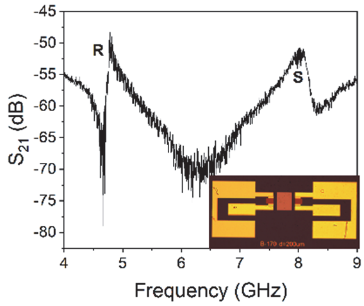
Scientific highlights

- ***H2020, FETOPEN Project** CHIRON* https://www.chiron-h2020.eu/; ***IMT responsible: Dr. Alexandru Müller***

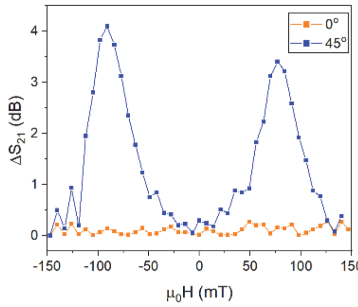
Main objective of IMT team is to manufacture of acoustic devices (SAW and FBAR) with resonance frequencies in the GHz range, capable of coupling SAWs and FBARs with spin waves.

• Two port SAW structures with resonance frequency > 4.5 GHz were manufactured on ScAlN/Si having Ni/Au (12/3 nm) magnetostrictive layer placed between the two interdigitated transducers (IDTs) of the SAW. Participants: A. Nicoloiu, A. Dinescu, I. Zdru, C. Nastase, G. Boldeiu, A. *Müller*

The digit interdigitated space width was 170 nm.The SAW structures were placed on a metal holder and the S parameters were analyzed at room temperature, for different applied magnetic fields at an angle of 45° to the direction of propagation of the SAW waves. S_{21} parameter was measured from -147 mT to +147 mT and two maximum values of absorption (at ± 91 mT) were determined. The preliminary results aim at emerging applications of SAW resonators in spin wave pumping, one of the main objectives of the CHIRON project.

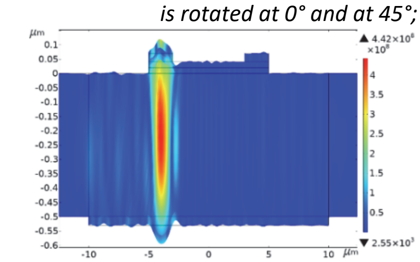


S_{21} of SAW structure with Ni layer between the IDTs, fabricated on ScAlN/Si; inset: optical photo of structure



The absorption on the entire magnetic field range, when the probe is rotated at 0° and at 45°;

• A concept for magneto-electric bulk acoustic wave resonators integrated with magnetic waveguides on piezoelectric membranes was developed together with FORTH Heraklion. The magnetic waveguides are 100 nm wide and the piezoelectric membranes (ScAlN) have thicknesses in the range of 100...500 nm. The model proposes a through membrane metallized via for the connection to the backside electrode. Test structures will be fabricated using advanced nanolithographic and silicon micromachining technologies. Spin wave generation and propagation efficiencies will be tested. (A. Bunea. D. Neculoiu)



Von Misses stress for a 500 nm ScAlN membrane

- ***H2020, FETOPEN Project** iQubit* https://www.chiron-h2020.eu/; ***IMT responsible: Dr. Alexandru Müller***

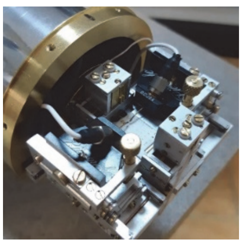
The objectives of IMT team are: (i) to design and fabricate an on-wafer cryogenic measurement set-up for device and circuit characterization up to 110 GHz and at temperatures down to 4 K; (ii) to measure the transfer characteristics of qubit transistors designed and manufactured in 22 nm FDSOI technology from SiGe by the University of Toronto (UofT) at cryogenic temperatures; (iii) fabrication of transistor test structures by developing of nanolithographic processes below 20 nm.

Participants: A. Dinescu, S. Iordanescu, M. Pasteanu, C. Nastase, A. Nicoloiu, G. Boldeiu, I. Zdru, A. *Müller.*

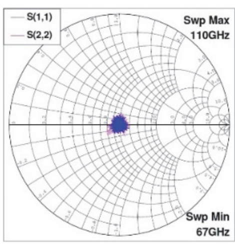
• For on-wafer measurements up to 110 GHz at temperatures from 300 K down to 4 K, a dedicated mechanical fixture was designed and manufactured in-house in L4 Laboratory. The calibration of the system was performed with the 37397D Anritsu VNA in the frequency range 67-110 GHz. After calibration, the shorter CPW test line on the calibration kit was measured.

• The transfer characteristics were measured for pMOS transistors (single hole test transistors – SHTs) with dimensions of 1x18nmx70nm, for back gate voltage values between +/-0.5V and - /+3.02V, at cryogenic temperatures (2K) for drain voltage values of -/+1V.

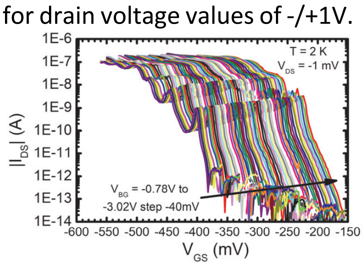
• In the manufacturing process SOI wafers were used and spectacular structures with 50 nm pitch, 15 nm gates and 19 nm wide Si channels have been obtained by using Ti masks for channels and HSQ masks for gates.



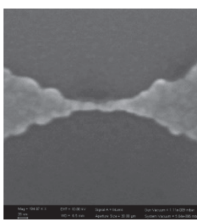
Calibration of the dedicated mechanical



S-parameter results for a short 50 Ohm CPW through-line

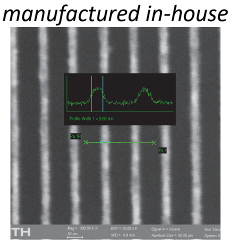


Transfer characteristics for pMOS transistor at 2 K vs. different backgate voltage values



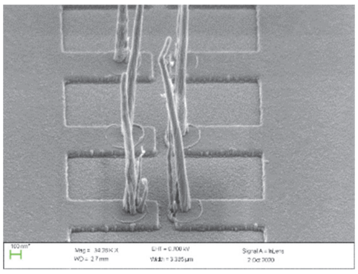
Cr metallization, 20 nm wide and 20 nm thick

SEM micrograph of 10 nm wide HSQ lines fixture manufactured in-house



- **H2020, ICT RIA** Project **NANOSMART,** ***IMT responsible: Dr. Mircea Dragoman***
https://project-nanosmart.com/

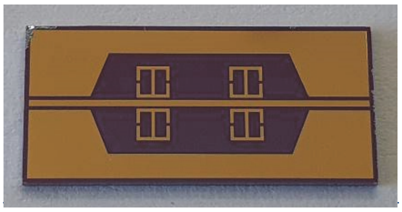
• Switches based on vertically grown carbon nanotubes (VACNTs) were characterized in DC and in microwaves, for applications in the X band (i.e., 8-12 GHz) and ISM 24 GHz (i.e., 24-24.25 GHz). A very detailed equivalent circuit was also developed, the results of this modeling being very close to the experimental results.



SEM picture with the area of interest of the switch with CNTs

- **H2020, FETOPEN** Project ***NANOPOLY, IMT responsible: Dr. Mircea Dragoman***
https://project-nanopoly.com/

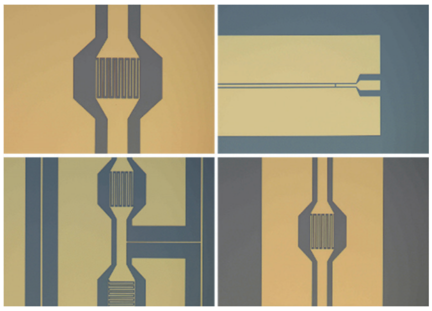
• Band-stop filters in the Ku band (i.e., 12-18 GHz) were designed, simulated, manufactured and measured, using a high-resistivity silicon oxide/silicon substrate. They are based on coplanar waveguides integrated with so-called "electric-type LC resonators", for their exploitation in transmission/ reception systems based on metamaterials.



Fabricated prototype of the metamaterial-based band-stop filter

- **H2020, FETPROACT** Project ***NANO-EH, IMT responsible: Dr. Martino Aldrigo***
https://www.nano-eh.eu/

• Test structures were designed, manufactured and characterized in microwaves for verifying the ferroelectric characteristics of thin films based on doped hafnium oxide. In detail, some planar phase shifters were measured in coplanar waveguides and made up of 12 interdigitated capacitors in series and connected alternatively to a DC polarization source. The value of the phase shift is excellent in the X-band (i.e., 8-12 GHz), with a maximum value of over 90 degrees at 11.74 GHz.

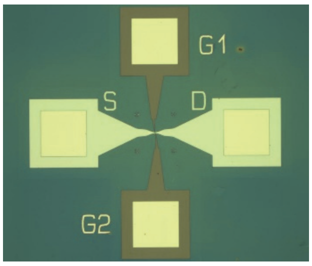


Phase shifters manufactured on a HfZrO/HRSi wafer

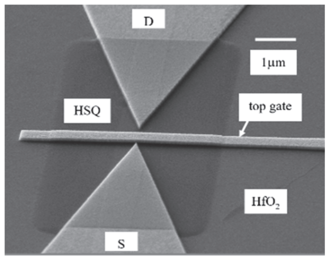
- **PCCF** project **GRAPHENEFERRO** http://www.imt.ro/grapheneferro/, **Coordinator: Dr. Mircea Dragoman**

• Microtransistors, i.e. FETs with two gates above the graphene channel (top gates) and one formed by the doped Si substrate (bottom gate) were manufactured and experimentally characterized. Using the HfGeO ferroelectric we made a 15×15 area of graphene/HfGeO FET transistors.

The HfGeO graphene-based memtransistor works at low drain voltages (-2 V to +2 V), specific to digital circuit applications, while the MoS_2-based transistors have much higher working voltages. A memtransistor that works as an artificial synapse was manufactured, being the demonstrator that illustrates a neuromorphic circuit with the role of imitating operations done by the human brain. This memtransistor is capable of elementary non-associative learning operations



Optical image of a three-gate graphene/ HfGeO memtransistor for logic circuits



FET graphene/HfGeO – artificial synapse

- **Subsidiary contract C77/1D TGE-PLAT (Code SMIS2014+ 105623) BODYSCAN (2018-2021)**
"Millimeter wave passive imaging system for rapid person scanning for security applications",
Coordinator: Dr. Alina-Cristina Bunea

W band (75 – 110 GHz) passive imaging modules were designed, fabricated and tested. The modules consisted of hybrid integrated millimeter wave sensors, encased in a functionalized 3D printed package, connected to a biasing circuit and low frequency signal amplifier for the detected signal. The modules were tested individually using a single pixel x-y scanning system. The functionality was proven in relevant conditions, by scanning biological elements, crystalized substances, liquids, non-magnetic metals and electronic devices.

14 functional modules consisting of passive imaging sensors and low signal amplifier circuits

Single pixel testing: scene with temperature gun

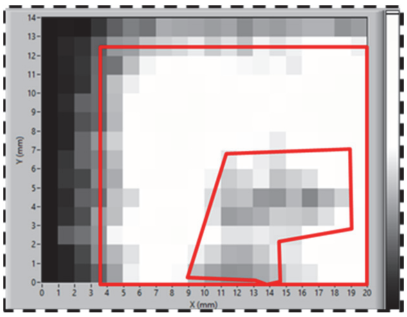


Image scanned with the W band passive sensor

Laboratory of Nanobiotechnology– L1

Laboratory head: Dr. Mihaela Kusko

Mission

The mission of L1 is to propose and address **research directions in the field of nanostructures / nanomaterials / nanocomposites**, with the aim of understanding their properties and finding **new technological solutions** for integration into devices with **applications in sensing, medicine and energy**, including **offering experimental and characterization services** in the field of nano-bio-technologies based on existing expertise. Furthermore, **training programs** in collaboration with universities, through the participation of collective members in **doctoral programs** as well as through the involvement of researchers with experience in the coordination committees of doctoral training programs.

Expertise

• **Fabrication of functional nanomaterials / nanostructures,** investigation, control and tuning their properties for **biomedical applications,** like highly sensitive layer for biosensors or substrate for **protein and DNA microarray technology,** novel substrates for **SERS / SEIRS biodetection, cold electron emitters and electrocatalytic**;

• **Supporting the development** of some industrial **safety nanoproducts for health and environmental** protection by assessing the **toxicity and risks associated with nanomaterials;**

• **Design and fabrication of nanostructures, integrated devices (**optoelectronic biosensors, integrated microfluidic platforms**) and development of novel biodetection schemes for medical applications;**

• **Design and fabrication** of new devices based **on silicon, silicon carbide, polymers,** as well as hybrid systems **for applications in multiple fields, from gas / temperature sensors to energy (**e.g. micro-supercapacitors, solar cells or miniaturized fuel cells as clean energy source

Team: Dr. Mihaela Kusko (PhD in Physics) - laboratory head, senior researcher I; **Adrian Apostol,** (PhD. student in Chemistry), Research Scientist; **Adina Boldeiu**, (PhD. in Chemistry), Research Scientist II**; Alexandru Bujor,** (PhD. student in Chemistry), Research Scientist, **Alexandru Salceanu,** (PhD. student in Biology), Research Assistant; **Cosmin Romanitan,** (PhD in Physics), Research Scientist III; **Irina Bratosin** (PhD. student in Physics), Research Scientist; **Iuliana Mihalache,** Physicist, PhD, Research Scientist II; **Larisa Gogianu** (PhD. student in Biology), Research Assistant; **Melania Popescu,** (PhD. in Biology), Research Scientist III; **Mihai Mihaila**, (PhD in Electronics), Research Scientist I, Associate Member of Romanian Academy; **Monica Simion**, (PhD in Electronics), Research Scientist I; **Pericle Varasteanu**, (PhD in Physics), Research Scientist; **Razvan Pascu**, (PhD in Electronics), Research Scientist II

National collaborations

► **PN PN-III-**P4-ID-PCE2020-1712(PCE 88 - 09/02/2021) ***„ Engineering low dimensional heterostructures for boosting the performances of on-chip 3D energy storage / power delivery device - EgiDe"*** **(2021-2023); Project director: Dr. Mihaela Kusko,** http://www.imt.ro/egide/

► **PN-III-**P1-1.2-PCCDI-2017-0820 (***67PCCDI***) ***„New methods of pregnancy monitoring and prenatal diagnosis – MiMoSa"*** **(2018-2020)** https://www.imt.ro/mimosa/index_en.php**, Project manager: Dr. Monica Simion**

►**PN-III-**P1-1.2-PCCDI-2017- 0419 (87PCCCDI-) ***„Sensors and Integrated Electronic and Photonic Systems for people and Infrastructures Security"*** **(2018-2020)** https://sensis-ict.ro/?lang=en**, Project manager: Dr. Carmen Moldovan 2nd constituent Project: „SiC-based hydrocarbons sensors for security in hostile industrial environments"** https://sensis-ict.ro/sic-based-hydrocarbons-sensors-for-security-in-hostile-industrial-environments/?lang=en

IMT team leader: Dr. Razvan Pascu

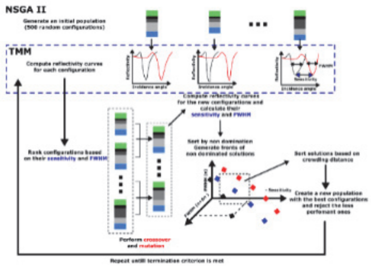
► **PN-III-**P1-1.1-PD-2019-1081, (PD 74 -12/08/2020) - **"Innovative flexible systems based on vertical silicon nanowires for multi-wavelength photodetection - FlexSiNoW" (2020-2022);** Project director: **Dr. Iuliana Mihalache,** https://www.imt.ro/flexsinow/

► **PN-III-**P1-1.1-PD-2019-0924, (PD 75 - 12/08/2020) - **"Advanced processing for stability improvement in SiC-MOS devices - SiC-MOS" (2020-2022);** Project director: **Dr. Razvan Pascu,** http://www.imt.ro/sic-mos/

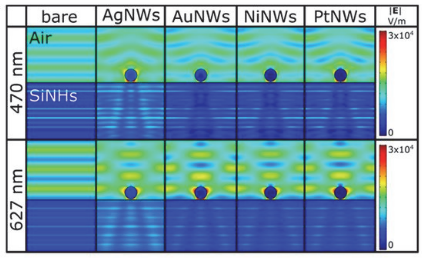
► **PN-III-**P2-2.1-PED-2019-4339 (275PED - 03.08.2020) –"**High Temperature Ptat Sensor, Based On Silicon Carbide Devices For Monitoring And Security In Hostile Industrial Environments - SiC-HITs", (2020-2022)** *Coordinating institution: UNIVERSITATEA POLITEHNICA DIN BUCURESTI (RO),* Project partners: **Partner (P1) - INSTITUTUL NATIONAL DE CERCETARE- DEZVOLTARE PENTRU MICROTEHNOLOGIE - IMT BUCURESTI INCD (RO)** -Partner team leader - **Dr. Razvan Pascu** , Partner (P2) - CEPROCIM S.A. (RO), Partner (P3) - HEIDELBERGCEMENT ROMÂNIA S.A. (RO)

A. The results of researchers in doctoral programs during 2020-2022

➢ **Pericle Varasteanu- "*Plasmonic Heterostructures for Applications in Opto-Electronics: Theoretical and Experimental Studies*"-** was successfully defended on 16/06/2022. The thesis was focused on three main objectives: i) exploration of parameter space of Surface Plasmon Resonance (SPR) based sensors by employing optimization algorithms, ii) fabrication of plasmonic structures through alternative methods, and iii) improving the performances of biosensors and photodetectors by harnessing the plasmonic resonances on metallic nanowires.



Schemnatics of the implementation of the NSGA II algorithm alongside TMM

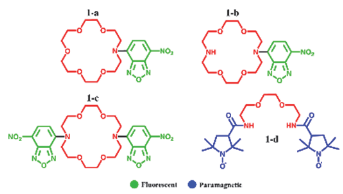


Simulation of electric field distribution around metallic nanowires on the nanostructured silicon

ISI article: *Pericle Varasteanu, Mihaela Kusko*, (2021)**,** Applied Sciences**, 11, 4353; *Pericle Varasteanu,*** Antonio Radoi, Oana Tutunaru, Anton Ficai, ***Razvan Pascu, Mihaela Kusko, Iuliana Mihalache,*** (2021), Nanomaterials, 11(9), 2460

➢ **Alezandru Bujor- „Synthesis and characterization of new fluorescent and paramagnetic ionophores"**

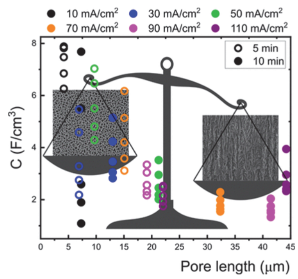
A preliminary study on the synthesis, characterization and complexation ability of old and new paramagnetic or fluorescent crown-ethers derivatives was made. Synthesis was started off with the use of crown-ethers, cyclic polyethyleneglycols, as the cation binding site of the final synthesized molecule and for the fluorescent moiety we chose nitrobenzofurazan derivatives (NBD, 7-nitro-1,2,3-benzoxadiazole), as they were frequently employed in analytical procedures and shown good cell membrane permeability. Furthermore, the paramagnetic unit employed in this preliminary study was Proxyl (2,2,5,5-tetramethyl-1-pyrrolidinyloxyl) which is a stable paramagnetic compound used as paramagnetic probe or for spin-labelling.



Poster presentation on 45th edition of the International Summer School on Organic Synthesis «A. Corbella»- ISOS-2021

➢ **Irina Bratosin- „New hybrid nanostructures for energy storage applications"**

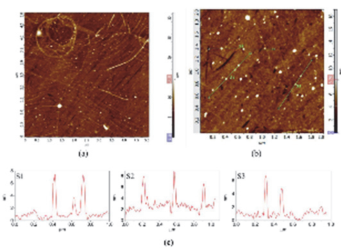
We performed a study on the effects the porosification of Si electrodes on their electrical performance, correlating the influence with the optimal exposure time and current density applied for maximum results. We have discovered that in order to obtain the best supercapacitor performance, a balance must be found between the degree of porosity and pore length. While a high current density will generate very wide diameter pores and ultimately a lower porosity, a too long exposure time leads to losses and an unsatisfactory capacitive behaviour.



ISI article: Irina-Nicoleta Bratosin*, Pericle Varasteanu, Cosmin Romanitan, Alexandru Bujor,** Oana Tutunaru, Antonio Radoi, **Mihaela Kusko*, <u>The Journal of Physical Chemistry C</u> 125, 11, 6043–6054, 2021

➢ **Adrian Apostol - "Coordinative compounds attached to the graphene support"**

Two [ZnLn] heterobinuclear complexes decorated with pyrene groups, [ZnEu(valpn)(hfac)2(pb)], have been obtained, in order to be deposited on graphene (LnIII⍰EuIII 2a; TbIII 2b); H2valpn is the Schiff base compartmental ligand resulted from the condensation reaction between o-vanillin and propylenediamine (Hpb = 1-pyrenebutiric acid; Hhfac = hexafluoroacetylacetone). The two complexes have been obtained by replacing the acetato ligand in [ZnEu(valpn)(hfac)2(CH3COO)] (EuIII: 1a; TbIII: 1b) by pb− anions. The two hybrid materials have been characterized by Raman spectroscopy, atomic force microscopy (AFM), and scanning electron microscopy (SEM) measurements, which confirm the presence of the complexes on graphene.



Isi article: *A. Apostol, I. Mihalache*, T. Mocanu, O. Tutunaru, C. Pachiu, R. Gavrilă, C. Maxim, M. Andruh, Applied Organometallic Chemistry, 2021, 35, e6126.

➢ **Larisa Gogianu - „ New insights into inositol polyphosphate mediated signalling** " (PhD thesis - start in 2020)

Aims of theses is to ***develop a living-yeast cell microarray biochip for colorimetric/fluorimetric detection of microbial pathogens*** by deposition of **modified yeast cells** on a **nanostructured surface.** The yeast cells will be armed with receptors for pathogen-specific proteins and with a reporter element that will allow for colorimetric and fluorimetric detection.

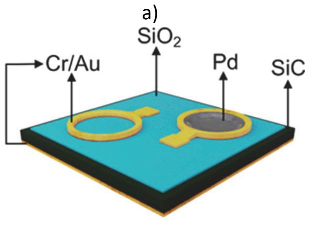
➢ **Alexandru Salceanu - "Bioinformatics Data Analysis in Tumour Sequencing"** (PhD thesis - start in 2020)

Tissues samples will be prelevated together with blood samples and total genomic DNA will be extracted. Both tumour DNA and blood (healthy) will be sequenced and a comparative analysis will be performed.

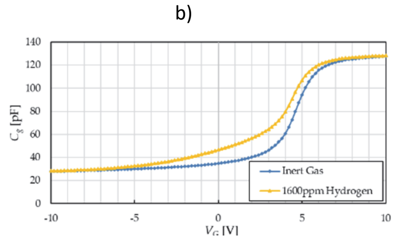
B. Projects results

- ***PN-III-P1-1.1-PD-2019-0924 (PD75/2020 - 01.09.2020), "Advanced processing for stability improvement in SiC-MOS devices", SiC-MOS (2020-2022)***, Project coordinator: ***Dr. Razvan Pascu***, Coordinator: ***IMT BUCURESTI INCD*** (RO)

SiC MOS capacitors were designed, fabricated and successfully tested. An improved SiO_2/SiC interface was obtained, leading to a better stability of the MOS devices both at different temperatures and high bias voltages. The first batch of the SiC MOS capacitors used a standard technology (dry oxidation) for the MOS oxide fabrication. The fabricated devices were both microphysical and electrical characterized at different temperatures in order to identity the interface traps (D_{it}) distributed on different energy levels in SiC band gap. In order to decrease the D_{it} and to improve the stability of the MOS devices, different post-oxidation annealing treatments were performed in phosphorous and boron atmosphere. Moreover, high k dielectrics were used in order to improve the breakdown voltage, leakage currents and density of the effective oxide charges. They were deposited onto a thin film of a grown SiO_2 by using Atomic Layer Deposition technique.



SiC MOS hydrogen sensor



MOS sensor C-V experimental characteristics (in inert gas and with 1600 ppm H2)

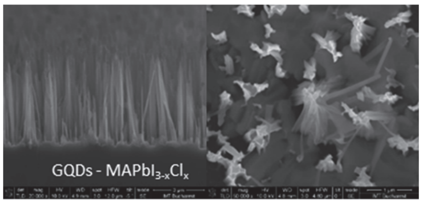
ISI Articles:
Enache, F. Draghici, F. Mitu, **R. Pascu*** , G. Pristavu* , M. Pantazica, G. Brezeanu*,, Sensors, Vol. 22(4), pp 1462, 2022;*
***R. Pascu*, C. Romanitan**, Journal of Materials Science: Materials in Electronics, 2021, 32, 16811–16823.*

- **PN-III-P1-1.1-PD-2019-1081 *(PD74/2020 - 01.09.2020) – "Innovative flexible systems based on vertical silicon nanowires for multi-wavelength photodetection", FlexSiNoW* (2020-2022)**

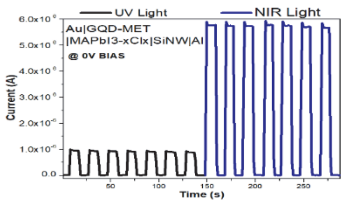
Project coordinator: ***Dr. Iuliana Mihalache***, Coordinator ***IMT BUCURESTI*** INCD (RO)

The FlexSiNoW project is focused on the development of PVKT/GQDs and silicon nanowires flexible structures designed for multi-wavelength photodetection with cost and performance competitive over current employed technologies, which represents a valuable approach towards autonomous and sustainable wearable devices. A new type of photodetector was proposed with the fallowing structure Au/GQDs-MET/MAPbI3-xClx/SiNWs/Al which showed broadband photoresponse from UV to Vis and NIR. The I-V measurements at 0V polarization (autonomous mode) show a reduced dark current of ~ 4-7 nA and photocurrent of ~ 0.9 ⍰A in UV and ~ 5 ⍰A in NIR so that the structure enables high performance in terms of the photocurrent to dark current ratio of ~ 2.2 x 10^2 (UV) and ~ 1.4 x 10^3 (NIR). Compared to the reference, the signal-to-noise ratio of the triple heterostructure increased by two orders of magnitude for UV light and by three orders of magnitude for NIR. Moreover, the photodetector exhibits the maximum responsivity of ~ 65 ⍰A/W in NIR (868 nm) and demonstrates capability for weak light detection. The hybrid photodetection concept developed in this project can also be extended to applications such as optoelectrical switches and photovoltaic devices.

ISI article: Varasteanu, P., Radoi, A., Tutunaru, O., Ficai, A., ***Pascu, R., Kusko, M. and Mihalache, I.*** Nanomaterials, 11(9), p.2460, 2021.



a)
SEM images of GQDs-MET/MAPbI3-xClx heterojunction

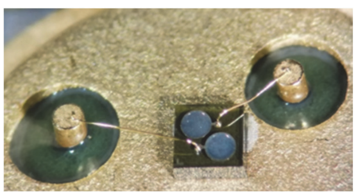


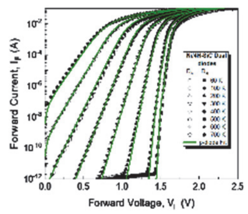
b)
The transient photocurrents at 0V obtained for 368 nm and 868 nm on/off illumination of 150 mW/cm²

- **PN-III-P2-2.1-PED-2019-4339 (275PED/2020 - 03.08.2020) – "High temperature PTAT sensor, based on silicon carbide devices for monitoring and security in hostile industrial environments"**, **SiCHITs (2020-2022),** Partner team leader - Dr. Razvan Pascu. **IMT BUCURESTI** Partner (P1); Coordinator: University "Politehnica" Bucharest.

An experimental model (product) for a high temperature proportional-to-absolute-temperature (PTAT) sensor, with silicon carbide (SiC) devices (Schottky diodes) as sensing elements, to be used in hostile environment critical industrial applications (the cement industry), was developed. The sensor was able to operate up to 400°C, in various points of a cement production line (different detection ranges) and offered full electrical (4mA – 20mA current mode industrial output) and mechanical compatibility with existing industrial monitoring equipment. Key projected performances included high reliability (exceeding current solutions by at least 50%) and accuracy (sensing resolution better than 0.2°C), in order to ensure personnel and industrial equipment security. The following novel results were obtained: SiC Schottky diode structure fabrication technology that facilitates differential measurement, robust packaging technique for devices working at high temperatures (up to 400°C), yield improvement method by identifying optimum classification of SiC Schottky diodes in respect to temperature range and bias levels.

ISI article: R. Pascu*, G. Pristavu, G. Brezeanu, F. Draghici, P. Godignon, ***C. Romanitan***, M. Serbanescu, A. Tulbure, Sensors, Vol. 21, pp. 942, 2021.


a) Dual-diode sensing element: Encapsulated structure

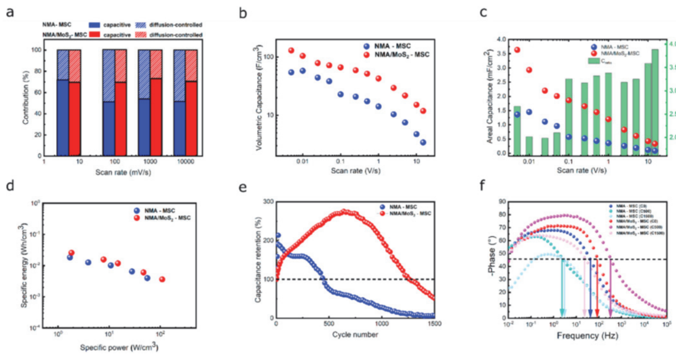


b) Forward I-V characteristic for the dual SiC Schottky diodes.)

Measurement data (symbols) and their p-diode model-fitted counterparts (lines).

• **PN PN-III-P4-ID-PCE2020-1712(PCE88-2021)** ***"Engineering low dimensional heterostructures for boosting the performances of on-chip 3D energy storage/power delivery device - EgiDe"*** (2021-2023); Project director: Dr. Mihaela Kusko, http://www.imt.ro/EgiDe/

Our supercapacitors possess ultrafast charging and discharging capability, and could be operated at high scan rates up to 15 V/s, one order of magnitude higher than that of conventional supercapacitors, maintaining the large operational voltage range of 3.1 V. Neither device shows an ideal capacitive response, which can partially be attributed to the complementary contribution of pseudo capacitance that can have different causes: it can arise as result of surface controlled electrochemical processes such as monolayer adsorption of ions at the electrode surface or surface redox reactions or as ions' intercalation in electrode bulk material.



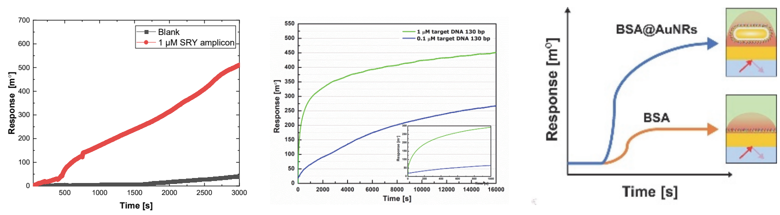
(a) Contribution ratio of the capacitive and diffusion-controlled charge at different scan rates; specific volumetric (b) and areal (c) capacitance of NMA and NMA-MoS2 based supercapacitors calculated from CV curves at different scan rates ranging from 0.005 to 15 V/s; (d) Ragone plots for NMA- and NMA/MoS2- micro-supercapacitors; (e) capacitance retention at current density of 0.67 mA/cm2; (f) EIS measurements (Bode phase angle plots as function of frequency; arrows indicating the frequency at phase angle of -45◦) recorded before cycling (C0), after 500 cycles (C500), and after 1500 cycles (C1500), respectively.

ISI articles: **Irina Bratosin*, Pericle Varasteanu, Cosmin Romanitan, Alexandru Bujor,** Oana Tutunaru, Antonio Radoi, **Mihaela Kusko***, *The Journal of Physical Chemistry C*(2021) 125, 11, 6043–6054.

Cosmin Romanitan*, Pericle Varasteanu, Dana C. Culita, **Alexandru Bujor,** Oana Tutunaru, Journal *of Applied Crystallography* (2021) 54, 847-855.

► **PN-III-**P1-1.2-PCCDI-2017-0820 (*67PCCDI -2019*), ***„New methods of pregnancy monitoring and prenatal diagnosis – MiMoSa"*** **(2018-2020)** https://www.imt.ro/mimosa/index_en.php, **Project manager: Dr. Monica Simion**

Prenatal non-invasive screening, using cell free fetal DNA, extracted from the mother's blood, protocol and detection limit using SPR technology. We prepared monodispersed gold nanorods with an AR of ~4.57, and a longitudinal LSPR near the infrared region of 836 nm, using a seedless synthesis technique. SPR-based detection limit of the molecules with high molecular weight can be enhanced ~10 times, leading to a limit of detection of 1.081 × 10−8 M (0.713 µg/mL); Finite element method was employed to support the potential enhancement of the SPR. signal by adding AuNRs on the SPR sensor's metallic layer.

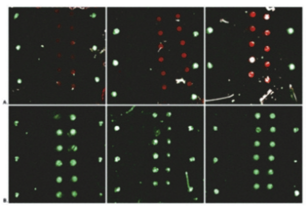


Comparative SPR response between blank solution consisting of H1 and H2 diluted in hybridization solution and sample consisting of 1 µM amplicon and 0.5 µM H1 and H2, diluted in hybridization solution

SPR response for 1 µM and 0.1 µM target sequence

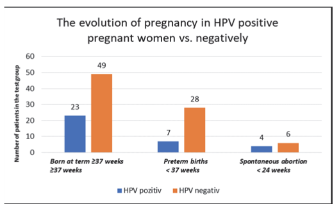
ISI article: Elena Constantin, **Pericle Varasteanu**, **Iuliana Mihalache**, Gabriel Craciun, Raul-Augustin Mitran, **Melania Popescu***, **Adina Boldeiu***, **Monica Simion***, ***Biophysical Chemistry*** 279, 106691, 2021

Evaluation of premature birth risks due to the HPV-EVA-RINA infection. A protocol for fluorescent marking of samples from patients for detection based on the microarray system was develop base on asymmetric PCR amplification.



(A)Results of hybridization of fluorescently labelled single-stranded DNA (Cy5 - red) obtained by asymmetric PCR.

(B) Fluorescent labelled single-stranded DNA (Cy3 - green) hybridization results obtained by digestion with Lambda exonuclease. The green-marked marginal columns represent the positive control of the probe immobilization on the microarray chip. Negative hybridization control shows no fluorescent signal.

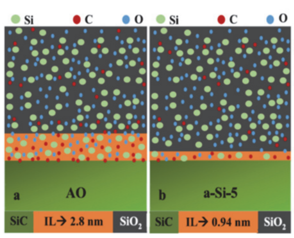


The evolution of pregnancy in HPV positive patients vs. negatively

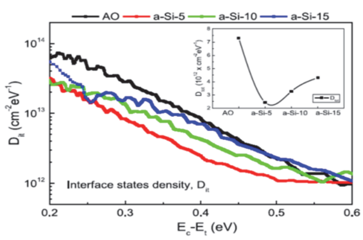
►**PN-III-**P1-1.2-PCCDI-2017- 0419 (87PCCCDI-2019) ***„Sensors and Integrated Electronic and Photonic Systems for people and Infrastructures Security"*** **(2018-2020)** https://sensis-ict.ro/?lang=en, *Project manager: Dr. Carmen Moldovan, 2nd constituent Project: „SiC-based hydrocarbons sensors for security in hostile industrial environments"* **IMT team leader: Dr. Razvan Pascu**

An alternative technological approach is proposed to obtain a SiO_2 film on SiC using processes that finally reduce the effective fabrication costs.

We demonstrated that using a two-step process, consisting in depositing of an a-Si thin film by room temperature sputtering followed by oxidation, represents a valuable technological approach for fabrication of an oxide layer for SiC-MOS type devices, in terms of both technological steadiness and structure quality. The improvement of the oxide/semiconductor interface was further validated by



Schematic cross-section view for the SiO2/SiC interface layer in the case of: a) AO sample; b) a-Si-5 sample.



Distribution of interface trap densities (Dit) evaluated with Terman method.

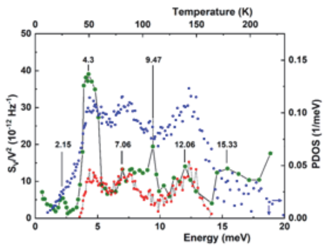
the electrical investigation of the fabricated MOS structures, where a significant diminishing of the effective oxide charge density, interface traps density, and near interface oxide traps density was assessed.

ISI article: Razvan Pascu, **Cosmin Romanitan**, **Pericle Varasteanu**, **Mihaela Kusko**, ***IEEE Journal of the Electron Devices Society***, 7 , 158 – 167, 2019

C. Other results - *Core funding: MICRO-NANO-SIS PLUS - no. 14N/2019, „Signal amplification nanosystems in sensors based on optically, electronically and electrochemically active markers on Si and SiC nanostructured substrate"*

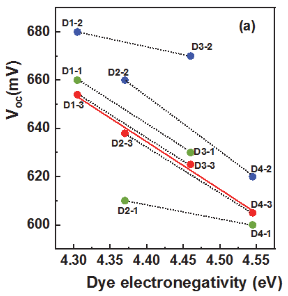
➢ ***Image of the phonon spectrum in the 1/f noise of topological insulators*** *(M. Mihaila, S. Dinulescu, P. Varasteanu, arXiv:2111.03525, 5 Nov. 2021)*

Islam *et al.* [Appl. Phys. Lett. 111, 062107 (2017)] and Biswas *et al.* [Appl. Phys. Lett. 115, 131601 (2019)] reported that 1/f noise intensity in both $(Bi,Sb)_2Te_3$ and $BiSbTeSe_{1.6}$ features noise peaks which develop at some specific temperatures. We compared this noise structure with either phonon density of states or Raman spectrum of each topological insulator (TI), respectively. In $(BiSb)_2Te_3$, the comparison revealed that the noise peaks track the van Hove singularities in the phonon density of states. In the case of $BiSbTeSe_{1.6}$, we found that all noise singularities are mirrored in the Raman spectrum of a structurally close TI ($BiSbTeSe_2$). This indicates that the carrier-phonon interaction is the source of 1/f fluctuations in TIs. These results prove that thermal motion of the atoms is the microscopic source of 1/f noise in solid.



Comparison between $S_V/V^2(T)$ in $(Bi,Sb)_2Te_3$ (green dots, from Islam et al.(Appl. Phys. Lett. 111, 062107 (2017)) and PDOS of $(Bi_{0.26}Sb_{0.74})_2Te_3$ (blue and red dots, - reproduced (adapted) with permission from B. Klobes et al. (Phys. Stat. Sol. 9, 57, 2015; copyright 2015 John Wiley and Sons); the numbers denote noise peak energies (meV); dotted line is guide to the eyes.

➢ **Open-Circuit Voltage Degradation by Dye Mulliken Electronegativity in Multi-Anchor Organic Dye-Based Dye-Sensitized Solar Cells (C.P. Constantin, M.-D. Damaceanu, M. Mihaila, M. Kusko)**

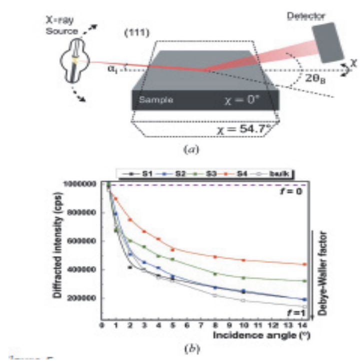


Four dyes consisting of a double-donor assembly, on which one to four cyanoacrylic acid acceptor groups were grafted, have been synthesized and characterized at "Petru Poni" Institute of Macromolecular Chemistry, Iasi). Dye-sensitized solar cells were fabricated with these dyes in IMT. Their open-circuit voltage (Voc) was found to decrease with the increase in the anchor number. The Mulliken dye electronegativity, which increases as more anchors are attached to the donor core, was identified as the cause of the open-circuit voltage degradation observed experimentally.

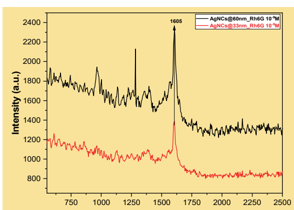
Dependence of Voc on the dye absolute electronegativity for Dn-1 (green dots, HI30), Dn-2 (blue dots, HI30) and Dn-3 (red dots, AN50) cells; dotted lines connect cells realized with the dyes having LUMO on the same moiety.

➢ **Development of a new, non-destructive laboratory method for X-ray diffraction investigation of the porosity gradient in porous Si - Cosmin Romanitan, Pericle Varasteanu**, Daniela C. Culita, **Alexandru Bujor**, Oana Tutunaru, ***X-ray scattering profiles: revealing the porosity gradient in porous silicon***, **Journal of Applied Crystallography**, 54, 847-855, 2021.

The method consists in the variation of the angle of incidence of the X-ray source, which leads to different penetration depths of the X-rays in the material. In this way, the variation of the static Debye-Waller factor in porous Si along the z-axis was obtained. Finally, the porosity profile was also obtained. Unlike standard diffraction methods, this method allows us to study the porosity gradient in porous Si, a central element in the context of physical properties. The proposed method allowed the scattering profile to be obtained, taking into account the finite nature of the X-ray penetration depth. It was shown that a higher anodization current leads to a larger pore diameter, which can be further assigned with a profile of different scattering. Precisely, the inelastic scattering, reflected in the static Debye-Waller factor, decreased with increasing porosity. Starting from the scattering profiles, the porosity profile was obtained in each sample. X-ray diffraction results were correlated with BET isotherms and scanning electron microscopy. Accurate determinations of the stress in the porous Si samples were made by reciprocal space maps (X-ray RSMs) in ultra-high resolution configuration (triple-axis).

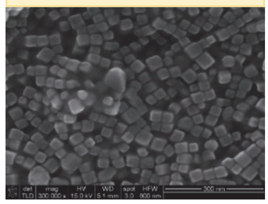


➢ **Shape controlled metallic nanoparticles synthesis -** Localized surface plasmon resonance (LSPR) is specific for the noble metallic nanoparticles, given by the free electrons oscillations from the metal surface, under the influence of the electromagnetic field. Among the noble metals, silver is one of the best choices to prepare SERS substrates. In this regard, the anisotropic shapes, like nanocubes, triangles and nanorods are able to enhance the highly intensify a Raman signal due to the so-called 'hot-spots'. Following this idea, we synthesized well defined AgNCs of 33 and 60 nm, using the polyol method, based on poly (vinyl pirrolidone) – PVP, ethylene glycol (EG), sodium sulphide (NaHS) and silver trifluoroacetate (CF_3COOAg). Ag nanocubes were then, used as active SERS substrates for Rhodamine 6G (Rh6G) detection, known as an important organic pollutant, being thus demonstrated the ability of using our SERS substrates for future sensing applications.

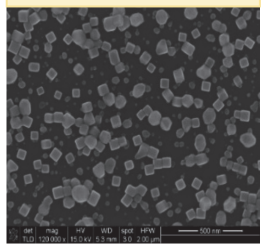


Raman spectra of AgNCs with Rh6G 10^{-9} M

AgNCs of 33 nm



AgNCs of 60 nm



Nano-Scale Structuring and Characterization Laboratory - L6

Laboratory head: Dr. Adrian Dinescu

Mission

The core 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.

Expertise

• **Structuring:** Nanoscale patterning by Gaussian e-beam lithography for applications in photonics, plasmonics, MSM-UV photodetectors, SAW components for RF/ microwave circuits etc.; Fabrication of graphene-based configurations and devices using EBL techniques.

• **Characterization:** Field emission Scanning Electron Microscopy (FEG-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-indentation) testing.

Team

Dr. Adrian Dinescu, physicist, senior researcher I, Head of the laboratory; **Phys. Gabriel Crăciun,** physicist, senior researcher III; **Dr. Livia Alexandra Dinu,** senior researcher II; **Ing. Stefan Iulian Enache,** technological development eng.; **Phys. Raluca Gavrilă,** physicist, senior researcher III; **Dr. Octavian Ligor,** physicist, senior researcher III; **Mihaela Marinescu,** principal economist; **Dr. Mirela Petruta Suchea,** physicist, senior researcher I; **Dr. Oana Tutunaru (Brîncoveanu),** physicist, senior researcher III;

Main equipment

Electron Beam Lithography and Nanoengineering Workstation – Raith e_Line (RAITH GmbH, Germany) - versatile nanolithography system by direct patterning of electron resists, electron beam-assisted deposition and etching, with < 20 nm achievable resolution; ***Ultra High resolution Field Emission Gun Scanning Electron Microscope (FEG-SEM) - Nova NanoSEM 630 (FEI Company, USA)***, equipped with ***EDX spectrometer (EDAX TEAM Multifunctional Near-field Scanning Probe Microscope (SPM) - NTEGRA Aura (NT-MDT Co., Russia)*** - 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 (KLA*** - *former* ***Agilent Technologies, USA)*** - used for high resolution characterization of the mechanical properties of small-volume samples.

L6 comprises four 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**".

International collaborations – R&D Projects

- Elastomeric tuneable metasurfaces for efficient spectroscopic sensors for plastic detection (ELASTOMETA)", **EEA Grants,** EEA-RO-NO-2018-0438 (*IMT – Partner*) (2019-2023)
- "Formation of spatially ordered matrices based on nanostructured metal oxides and transition metal sulphates for advanced sensory and photovoltaic devices" **– Bilateral project within the Romania-Belarus inter-academic exchange**
- "Reliable roadmap for certification of bonded primary structures", **COST Action** CA18120 (2019-2023)

Education and training

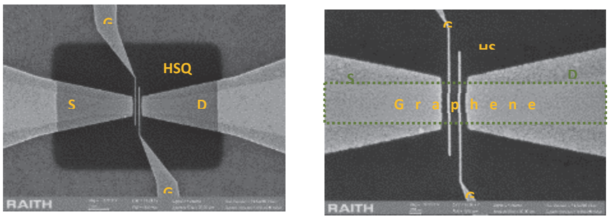
Master courses **and laboratory activities** in collaboration with the ***University "Politehnica" of Bucharest***:
"*Advanced nanotechnological processes*" - Master course, <<Microsystems>> MSc program, Faculty of Electronics, Telecommunications and Information Technology - **ETTI,** "*Object-Oriented Programming*" - Laboratory, Year II, **ETTI,** "*Databases in Oracle environment*" - Laboratory, Year III, "Economical engineering in the electrical, electronic and energy fields", specialization, The Faculty of Entrepreneurship, Business Engineering and Management - ***FAIMA***

Scientific highlights

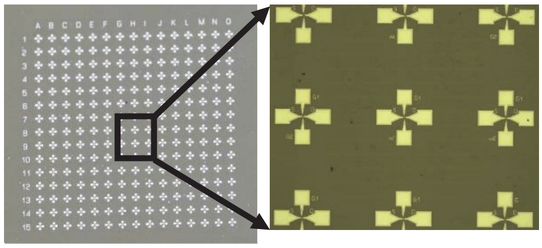
• **Fabrication of an array of graphene/ferroelectric (Ge-dopped HfO_2) adaptive transistors with reconfigurable logic gate function** *(Collaboration with L4 Laboratory of IMT Bucharest, published in* ***Nanomaterials,*** *M. Dragoman, A. Dinescu et. al.,* ***"Graphene/Ferroelectric (Ge-Doped HfO_2) Adaptable Transistors Acting as Reconfigurable Logic Gates")****.*

Contact: Dr. A. Dinescu, adrian.dinescu@imt.ro.

Using Electron Beam Lithography (EBL) and processing steps based on Si fabrication technology, we have produced an array of 225 FETs, with dual upper gate and the p Si substrate acting as the lower gate. The channel of each FET consists of a monolayer graphene configured by EBL, deposited on a triple layer: control HfO2 (22 nm)/ Ge-HfO2 (5 nm)/ tunnelling HfO2 (8 nm). The ferroelectric intermediate layer operates as a floating gate. The FETs act like as memristors, operating as two-input reconfigurable logic gates with memory, the gate type depending only on the selected gate voltage and threshold current values.



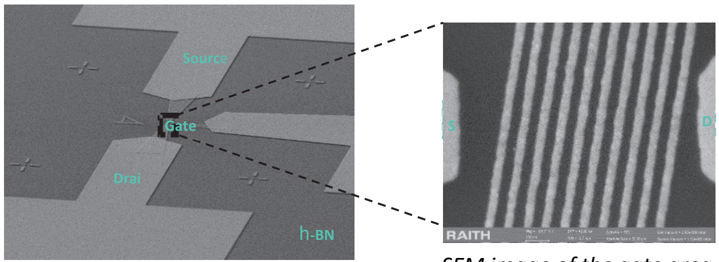
SEM images of one device, at two successive magnifications. The graphene channel and dual upper gates are clearly visible



Optical images of the array of 225 graphene-ferroelectric FETs – chip overview (left) and detail (right)

- **Electrostatic Superlattice of Graphene-on-BN FETs with Grating Gate** *(Collaboration with L4 Laboratory of IMT Bucharest, Project UEFiSCDI* ***PN-III-P4-ID-PCCF-2016-0033 „GrapheneFerro****" and Core Project* ***MICRO-NANO-SIS PLUS****, 2019-2022, published in* ***Nanotechnology,*** *M. Dragoman, A Dinescu, et. al.,* ***"[Bloch oscillations at room temperature in graphene/h-BN electrostatic superlattices](#)")****.*

The device consists of an array of metal electrodes forming the tilted grating gate of a FET transistor, in which the channel is the graphene monolayer transferred on h-BN grown on Si/SiO2. Fabrication of the device involved a series of steps including: metal deposition, EBL lithography and lift-off processes for the source (S), drain (D) and gate electrodes, EBL patterning and dry etching (RIE) to configure the graphene channel, HSQ deposition and EBL patterning for the gate insulator. Room temperature measurements, supported by numerical modelling, revealed the formation of minibands, a negative differential resistance and the presence of Bloch oscillations with a period of 55 meV, corresponding to a frequency of 13 THz. **Contact: Dr. A. Dinescu,** adrian.dinescu@imt.ro



Overview of the graphene/h-BN FET

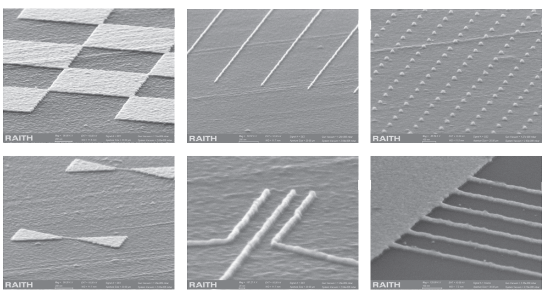
SEM image of the gate area of the FET

- **Process development aimed at gate and channel width reduction for the manufacturing of 10 nm qubits on SOI wafers**

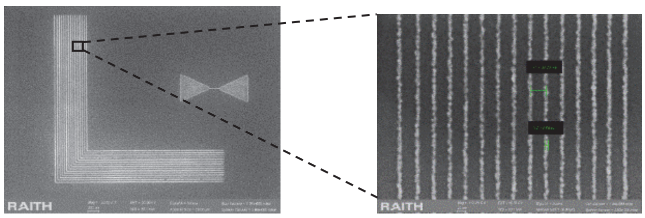
Contact: Dr. A. Dinescu, adrian.dinescu@imt.ro

(*Collaboration with L4 Laboratory of IMT Bucharest, project* ***H2020 FET OPEN****,* ***Research and Innovation Actions- RIA, 2018-2019-2020-01*** *"Integrated Qubits Towards Future High-Temperature Silicon Quantum Computing Hardware Technologies"*- **IQubits** ***https://www.iqubits.eu/)*.**

To this goal, three new types of electronoresists were tested and multiple SPL (Single Pixel Line) resolution tests were carried out, targeting the thickness of the electronoresist layer, exposure doses, acceleration voltage, temperature and development time and the configuration transfer technique (lift-off or RIE corrosion). Several types of geometries were also tested (see the figure). By testing new electronoresists, implementing new ideas for masking layers and perfecting the etching processes, the progress achieved compared to the previous year of the project consists in reducing the critical dimensions of the device as follows: the pitch of the gate lines from 50 nm to 30 nm and their width from 15 nm to 9 nm, with a very good edge roughness.



SEM images of some geometries tested in experiments: a - 1x1 µm areas; b - isolated SPL lines; c - points; d - Si channel geometry; e - gate geometry; f - test structures

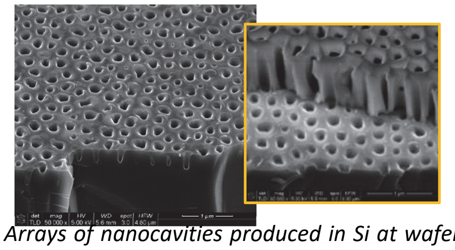


Lines with 40 nm pitch and 9 nm width configured in HSQ on Si substrate, using EBL patterning

- **Fabrication of arrays (spatially ordered structures) of nanocavities on Si substrates, using thin anodized Al films as a mask**

(***Bilateral project within the Romania-Belarus inter-academic exchange*** *"Formation of spatially ordered matrices based on nanostructured metal oxides and transition metal sulphates for advanced sensory and photovoltaic devices"***)**

Regularly spaced nanocavities were fabricated on Si substrates at wafer level by dry etching (RIE - Reactive Ion Etching) techniques, using anodized Al (AAO) thin layers as masks. As such, we have proved the possibility of manufacturing ordered systems of nanocavities in Si through a relatively cheap process, easy to integrate into standard microfabrication technologies. With the role of compensating the mechanical stress due to the crystal lattices mismatch and different thermal coefficients, they can be used as a "template" buffer layer for the growth of high quality, low internal stress AIIIBV epitaxial films for new generations of optoelectronic and microwave devices.



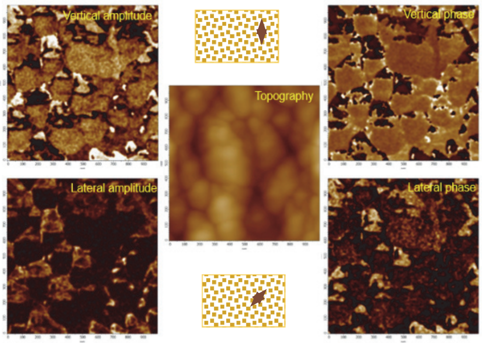
Arrays of nanocavities produced in Si at wafer level. The nanocavities have quasi-uniform, 500 nm pitch spatial arrangement, 150-200 nm lateral size and depth in the range of 200-300 nm. Inset: Detail with visible remnant anodic oxide (SEM images).

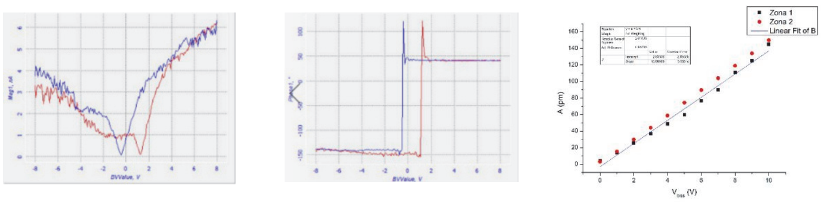
- **PFM (Piezoresponse Force Microscopy) studies on CoFe2O4/BNT–BT0.08 thin ferroelectric film**

(Collaboration with National Institute of Materials Physics, published in ***Materials Science and Engineering B.*** *Marin Cernea, Roxana Radu, et. al., „**Dielectric, piezoelectric and magnetic behavior of $CoFe_2O_4$/BNT–$BT_{0.08}$ composites thin films**”.*

The ferrimagnetic-ferroelectric film combines a perovskite structure with a ferritic phase. PFM measurements provide the "out-of-plane" and "in-plane" components of the local polarization for the active piezoelectric domains of the film. Local spectroscopy enables tracing the hysteresis and "butterfly" loops for the phase and amplitude and estimating the d33 piezoelectric coefficients of the composite films.

Contact: Phys. R. Gavrilă, raluca.gavrila@imt.ro

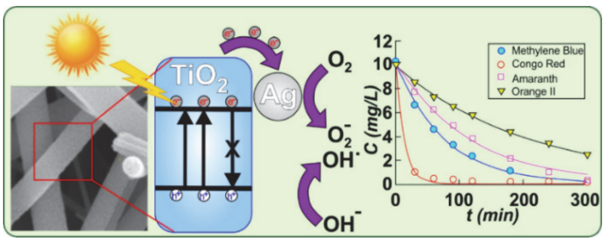




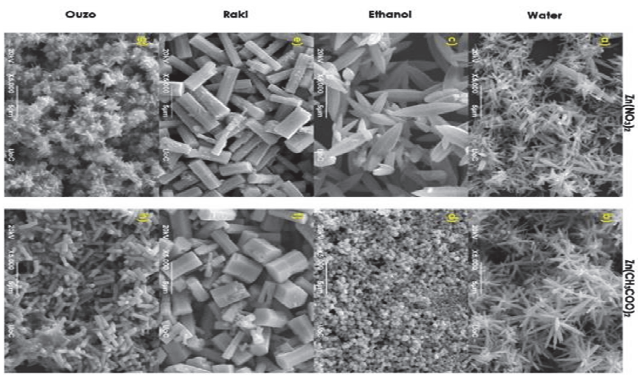
Left: Local polarization of piezoelectric domains visualized via the vertical and lateral components of the piezoelectric response in amplitude and phase.
Up: Hysteresis loops for a) amplitude and b) phase acquired in PFM "Switching spectroscopy" mode; c) measurement of the d33 coefficient averaged in two different areas of the film. The averaged slope of the linear regression fit gives a d33 value of 14 pm/V.

- **Growth/fabrication and characterization of multifunctional metal oxides for optoelectronic and photocatalytic applications**

(*Collaboration with Petru Poni Institute - Iași, SFMG-CEMATEP group - Hellenic Mediterranean University, Greece and Dr. G Kenanakis group - IESL FORTH Greece*). **Contact: Dr. Mirela Suchea**, mirela.suchea@imt.ro



Ref: ***Catalysts,*** *Petronela Pascariu et. al.,* ***"Innovative Ag–TiO_2 Nanofibers with Excellent Photocatalytic and Antibacterial Actions. Catalysts",*** *2021;11(10):1234.*



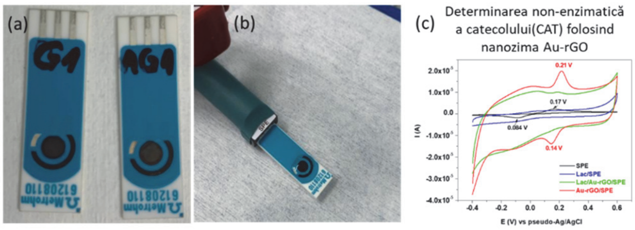
Morphologies of ZnO obtained by 4 different synthesis routes, at 195 C – SEM images at X 5000. *Ref:* ***Nanomaterials,****M. Suchea et. al.,* ***"Obtaining Nanostructured ZnO onto Si Coatings for Optoelectronic Applications via Eco-Friendly Chemical Preparation Routes"***

- **Manufacturing and characterization of carbon screen-printed microsensors, functionalized with an artificial enzyme nanomaterial (nanozyme) for detecting pollutants in water samples** („Core" funding: MICRO-NANO-SIS PLUS, Project *"Development of components and microsystems for sensors and smart control with applications in IoT and bio-engineering".*

The artificial enzyme (graphene doped with Au nanoparticles) was deposited on screen-printed electrodes, electrochemically characterized and subsequently used for the determination of catechol in water samples. Its sensitivity and selectivity proved to be greater than for the standard, well-established enzyme used for catechol detection (laccase). ***(Journal of The Electrochemical Society,*** *L.A.D. Gugoașă et. al.,* ***"Graphene-Gold Nanoparticles Nanozyme-Based Electrochemical Sensor with Enhanced Laccase-Like Activity for Determination of Phenolic Substrates")****.*

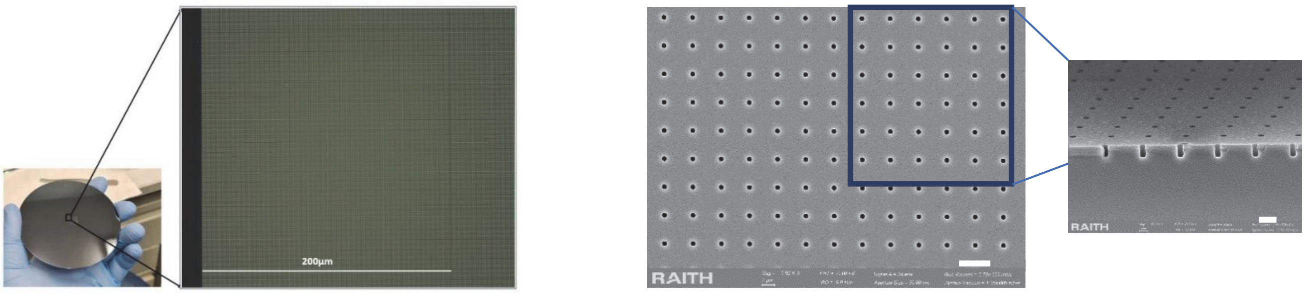
Contact: Dr. Livia Dinu Gugoașă, livia.dinu@imt.ro

(a) Carbon screen-printed electrodes functionalized with Au nanoparticles-dopped graphene in the working electrode area.
(b) Electrochemical sensor connected to the equipment during a measurement
(c) Cyclic voltammetry for the determination of catechol using Au-rGO nanozyme



Scientific services

❖ **Nanometric scale structuring by Electron Beam Lithography (EBL).** **Contact: Dr. A. Dinescu,** adrian.dinescu@imt.ro

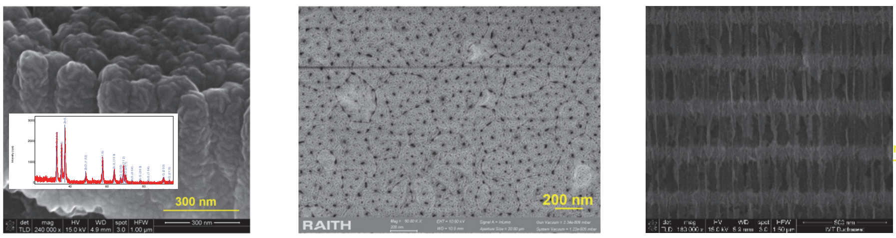


Array of regular cavities, 750 nm diameter and 4.5 µm pitch, patterned by EBL on 1 cm x 1 cm area.
Left: Optical images of the wafer with detail the processed area. Right: SEM images of the structured surface, tilted at 45^0
The pattern was transferred on Si by RIE etching, in cooperation with L11 of IMT Bucharest. Applications in photovoltaic devices with CdTe/CdS heterojunctions (Collaboration with the Faculty of Physics, University of Bucharest.

❖ Characterization (morphology, composition, material properties)

- ***Scanning Electron Microscopy (FEG-SEM) with Energy Dispersive X-Ray Spectroscopy (EDX).***

Contact: Dr. Oana Brîncoveanu, oana.brincoveanu@imt.ro, **Phys. G. Crăciun**, gabriel.craciun@imt.ro, **Dr. A. Dinescu,** adrian.dinescu@imt.ro

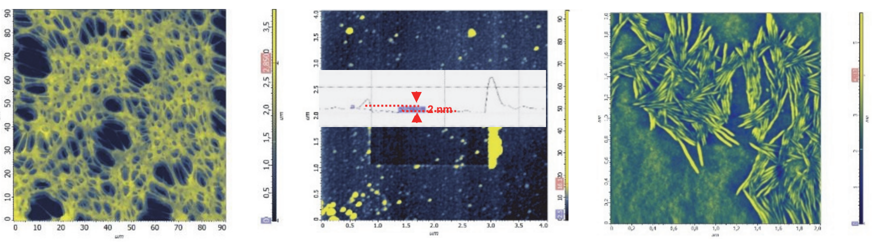


Left: SEM and EDX analysis of ZnO (50 nm thickness) deposited by ALD on anodized Nb film with EDX analysis

Middle: Nanostructured TiO2 on anodic alumina matrix

Right: Cross-section of porous silicon structures produced by pulsed electrochemical etching. Sample prepared by the team of L1 laboratory of IMT Bucharest

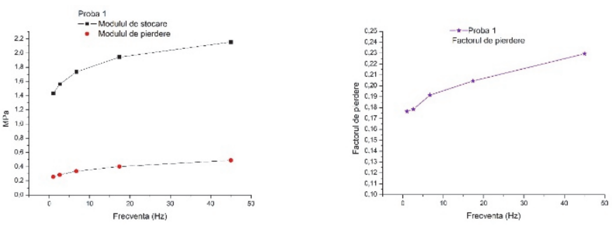
- ***Atomic Force Microscopy and related techniques (SPM).*** **Contact: Phys. R. Gavrilă**, raluca.gavrila@imt.ro



Left: PVDF layer on Si/SiO2 substrate, for applications in antifouling coatings. Sample prepared by the team of L8 laboratory.
Middle: Thickness (1.9 nm) of G proteins layer deposited on SAMS/Au substrate, measured by 'scraping' with the AFM tip. Sample from L8 laboratory.
Right: Standard commercial oligonucleotides, 6-140 bases in length. Sample prepared by C. Obreja.

- ***Nano Indentation (Depth-sensing indentation techniques) for submicron scale mechanical characterization.***

Contact: Phys. R. Gavrilă, raluca .gavrila@imt.ro



Elastic and loss modulus (*left*) and loss factor (*right*) measurements for a viscoelastic bio-nanocomposite used in biomedical coatings. The measured values were obtained by nanoindentation in dynamic mode, with a technique analogous to DMA, using the Nanoindenter® G200 (KLA -Tencor). Sample prepared by L10 - IMT Bucharest

- ## Publications

In 2021, L6 team has authored or co-authored 41 scientific papers in ISI ranked journals (10 as a first author from IMT) and two book chapters.

Molecular Nanotechnology Laboratory – L9

Laboratory head: Dr. Radu Popa

Mission

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; integration of experimental, analytical and numerical methods in areas of chemistry and functional materials, molecular dynamics, and atomistic modelling / simulation. 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 modelling and numerical analysis by ab- initio and (semi)-empirical methods.

Expertise

- 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, medical probes;
- Development of direct-writing processes on 2D and 3D substrates (inkjet, dip-pen nanolithography-DPN);
- 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 modelling and simulation (DFT, semi-empirical DFT, molecular dynamics, BIE), physical/chemical adsorption mechanisms, absorption/ emission spectra, plasmonic resonance modes.

Team: **Dr. Radu C. Popa** (PhD in Quantum Eng. and Systems Science, U. Tokyo) - laboratory head, IDI I; **Dr. Lucia Monica Veca** (PhD in Chemistry, Clemson U.), senior researcher I; **Dr. Antonio M. Radoi** (PhD in Chemistry, Tor Vergata U.), senior researcher I; **Dr. Titus Sandu** (PhD in Physics, Texas A&M U.), senior researcher I; **Dr. Emil-Mihai Pavelescu** (PhD in Technology, Tampere U. of Technology), senior researcher I; **Dr. Cristina I. Pachiu** (PhD in Physics, U. Le Havre), senior researcher III; **Dr. Mihaela Carp** (PhD in Engineering, Nanyang Tech. U.), IDT III; **Dr. Liviu Luca Bîlteanu** (PhD in Physics, U. Paris XI Sud Orsay; MD-Radiotherapy), senior researcher III; **Marius C. Stoian** (MS in Chemistry, U. Bucharest), research assistant.

International collaborations – R&D Projects

- **ATTRACT Third Party Project** - Carbon quantum dots/graphene hybrids with broad photoresponsivity – BANDPASS, 2019-2020. Coordinator: IMT, *Dr. Monica Veca*. In collaboration with: the Faculty of Chemistry and Chemical Engineering, Babes-Bolyai University; National Institute of R&D for Isotopic and Molecular Technologies (INCDTIM, Cluj), National Institute for R&D in Electrical Engineering (ICPE-CA, Bucharest).
- Image analysis by machine learning techniques: semantic labeling in medical imaging according to a model used for geospatial images. *Dr. Liviu Bîlteanu*, in collaboration with Deutsches Zentrum fur Luft- und Raumfahrt.

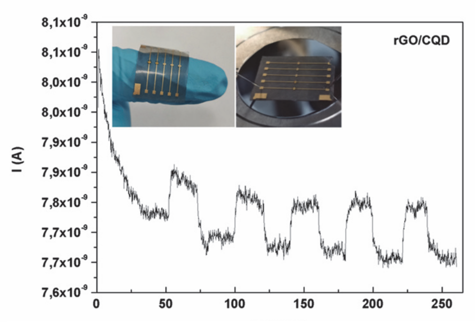
National collaborations

- **PCCDI** - Carbon based nanostructured materials for environmental gas and PAHs sensors, RDI collaborative complex project, sub-project no. 3 of PN-III-P1-1.2-PCCDI-2017- 0619, 2018-2020. Coordinator: IMT, *Dr. Antonio Radoi*. In collaboration with the National Institute of R&D for Electrochemistry and Condensed Matter (INCEMC, Timisoara).
- **PED** – Modular electrochemical device for charge storage, experimental-demonstrative project PN-III-P2-2.1-PED2019-4146, 2020-2022. Coordinator: IMT, *Dr. Antonio Radoi*. In collaboration with “Politehnica” Univ. Bucharest.
- **PED** - Innovative probe system for electrophysiological guidance in functional neurosurgery – BRAIN-GUIDE, experimental-demonstrative project PN-III-P2-2.1-PED-2019-3775, 2020-2022. Coordinator: IMT, *Dr. Radu Popa*. In collaboration with: Termobit Prod srl, Bucharest; University of Medicine and Pharmacy "Carol Davila", Bucharest.
- **PED** - Laboratory validation of white electroluminescent carbon dot-based light emitting diodes – SHINE, experimental-demonstrative project PN-III-P2-2.1-PED2019-0841, 2020-2022. Coordinator: IMT, *Dr. Monica Veca*. In collaboration with: the Faculty of Chemistry and Chemical Engineering, Babes-Bolyai University; “Politehnica” Univ. Bucharest.

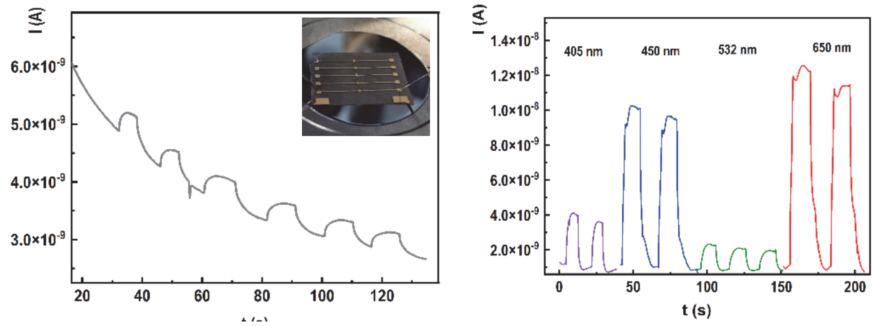
Scientific highlights

Carbon quantum dots/graphene hybrids with broad photoresponsivity–BANDPASS - ATTRACT Third Party Project **- contact Dr. Monica Veca (monica.veca@imt.ro)**

The project aims to develop photodetection devices based on carbon materials (graphene and CQD - carbon quantum dots), which would allow obtaining a flexible photodetector with wide spectral response. The thin films obtained on flexible substrate by solution technology using graphene derivatives and CQDs present reproducible transient photocurrent at successive cycles of exposure to white light of 40 mW/100 mW incident power and 5 V/1 V polarization voltage, respectively. The responsivity of the structures under these conditions is 5.8 µA/W / 2.2 µA/W, respectively. The responsivity varies with the wavelength of the source (e.g., 8.4 mA/W, for 650 nm wavelength and 1 V polarization).



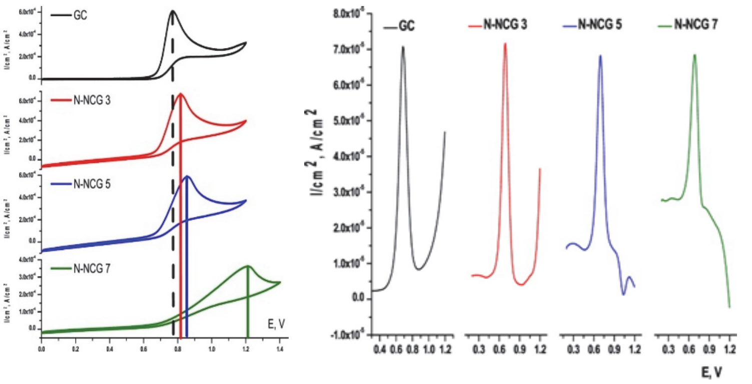
Transient photocurrent response for CQD/graphene derivative film on flexible substrate, at 5 V bias voltage and 40 mW incident illumination power.



Transient photocurrent response at 1 V bias voltage and exposure to 100 mW solar simulator (Left), and to different wavelengths (Right).

Carbon based nanostructured materials for environmental gas and PAHs sensors - RDI collaborative complex project **- contact Dr. Antonio Radoi (antonio.radoi@imt.ro)**

The stage focus was on nitrogen-doped nanocrystalline graphene (N-NCG), that was used to develop an electrochemical sensor for the detection of polycyclic aromatic hydrocarbons (PAH), such as anthracene. The electrode developed was capable to detect anthracene in various concentrations.

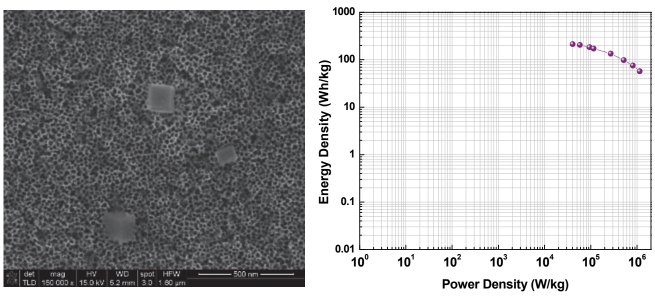


Response of the N-NCG electrodes compared to that of a glassy carbon (GC) electrode in the presence of: (Left) 1 mM anthracene (cyclic voltammetry, 50 mVs^{-1}, acetonitrile/H_2O, 80/20 v/v + 0.1 M $LiClO_4$); and (Right) 50 µM anthracene (differential pulse voltammetry, acetonitrile/H_2O, 80/20 v/v + 0.1 M $LiClO_4$) [Journal of the Electrochemical Society, 2020, 167(12), 126510].

Modular electrochemical device for charge storage - Experimental-demonstrative project **- contact Dr. Antonio Radoi (antonio.radoi@imt.ro)**

The project aims to develop electrochemical charge storage devices - multicell supercapacitors (SC) – based on double-porosified silicon wafers covered with graphene layers, for simultaneous, storage and delivery, energy management by integrating batteries and supercapacitors to realize hybrid energy storage systems.

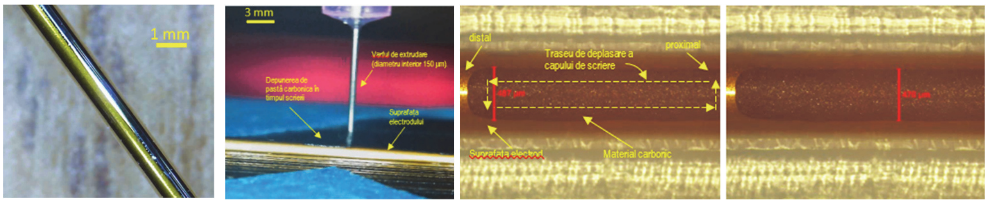
Hybrid CoHCF/C/Si electrodes were obtained by depositing metallic hexacyanoferrate species on graphitized porous silicon. The cobalt hexacyanoferrate increases the energy storage capacity, aiming at energy densities > 20 Wh kg^{-1} and a power density > 15 kW kg^{-1}, thus leading the working potential window towards 2.3 V. The supercapacitor obtained by this strategy reaches a maximum energy density of 213 Wh kg^{-1} at a power density of 40.63 kW kg^{-1}, and also an energy density of 57.3 Wh kg^{-1} even at a power density of 1142.2 kW kg^{-1}, thus exceeding the established targets.



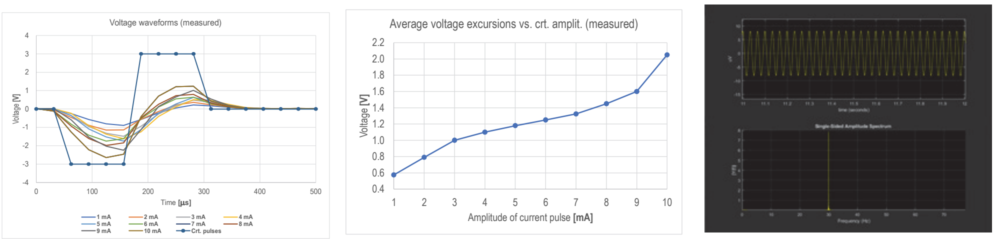
Left: SEM image of the CoHCF/C/Si hybrid electrode in which CoHCF nanocubes can be observed dispersed on the surface of the graphitized porous silicon. Right: Ragone diagram of the symmetric supercapacitor based on CoHCF/C/Si hybrid electrodes.

Innovative probe system for electrophysiological guidance in functional neurosurgery - Experimental-demonstrative project **- contact Dr. Radu Popa (radu.popa@imt.ro)**

The project aims reaching TRL-4 for an innovative electrophysiological mapping system, with: (1) a mapping probe with circumferentially-segmented carbon electrodes; (2) an electronic head stage for multichannel recording and stimulation realized in wireless technology (objective of the industrial partner Termobit Prod SRL). To achieve the 1st objective, the previously patented technology was followed, which is based on the realization of a stack of functional materials on a cylindrical (diameter: 550/770 µm) and long (10-20 cm) hypodermic steel substrate. To obtain the stimulation/recording channels, proximal-distal conductive paths are fabricated along the entire length of the electrode by direct writing via ink-jet printing using Ag NP inks, obtaining up to 3 parallel and equidistant tracks, 250 µm wide, thickness=1-2 µm, electrical resistance=2-3 Ω/cm. The circumferentially segmented distal carbonic macro-contacts (exposed dimensions: 1.5x0.5 mm, thickness 13 µm) are fabricated by pressure extrusion via micro-syringe (bioprinting) of a graphitic paste. The electrochemical characterizations and the functional evaluations for the stimulation and recording functions led to clinically relevant and high-performance results: the charge transfer is purely capacitive, the impedance at 1 kHz is below 1000 Ω, the average voltage excursion required at maximum pulse amplitudes (10 mA) is only 2-3 V, while the *in-vitro* recording tests indicate a good quality recording (low baseline noise and undistorted signal).



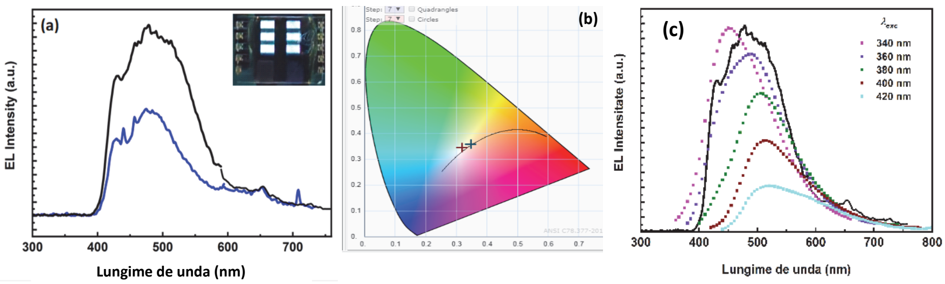
Left: Electrically conductive path deposited on the surface of the polyimide-covered electrode. Center: Pressure extrusion deposition of carbonic paste. Right: Distal carbonic macro-contacts fabricated on the electrode surface.



Left: voltage waveforms during the generation of biphasic 1...10 mA current pulses. Center: average voltage vs. current amplitude. Right: in-vitro recording of a 30 Hz floating signal, and its spectral composition.

Laboratory validation of white electroluminescent carbon dot-based light emitting diodes - Experimental-demonstrative project **- contact Dr. Monica Veca (monica.veca@imt.ro)**

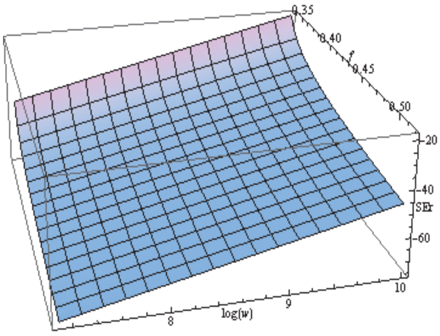
The project aims to demonstrate and validate at TRL-4 level a CQD-WLED device: white light emission LED using carbon quantum dots (CQD) as active material. The electroluminescence spectra exhibit a broad emission band between 400 and 800 nm, corresponding to the CIE coordinates (0.35,0.36) and (0.32,0.34), and CRI indices of 84 and 91, at 100 and 50 mA, respectively. The comparison of the electroluminescence spectrum with the photoluminescence spectra of the CQD solution, obtained at different excitation wavelengths, suggests that the emission is produced by the same excitation states, regardless of the excitation mode, being characteristic to the carbon dots.

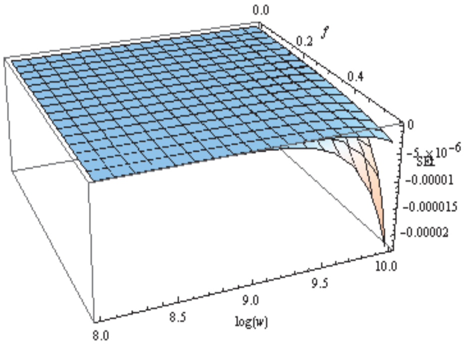


a) Electroluminescence for 50 mA and 100 mA current (inset: 3x2 CQD-LED matrix emission); b) CIE coordinates corresponding to the electroluminescence spectra; c) the electroluminescence spectrum (continuous line), and the photoluminescence spectra in solution at different excitation wavelengths (dotted line).

Analysis of homogenization models for composite materials, for describing or predicting the properties of composites used in electromagnetic shielding applications - contact Dr. Titus Sandu (titus.sandu@imt.ro)

The properties of composite materials are usually described using real-valued material properties; however, for specific applications (such as for dielectric materials with either ohmic, or dielectric, losses), complex physical properties are involved. We analyzed formulae that provide the complex effective permittivity of a composite material in which the material added to a polymer matrix has spherical shapes and the targeted application is electromagnetic shielding. The models used are: Maxwell-Garnett, Lewis-Nielsen, Bruggeman, and Rayleigh. Some numerical results are shown in the figures below. [T. Sandu et al., "Electromagnetic Interference Shielding Assessment From Mixing Formulae", IEEE-2020, International Semiconductor Conference (CAS)].

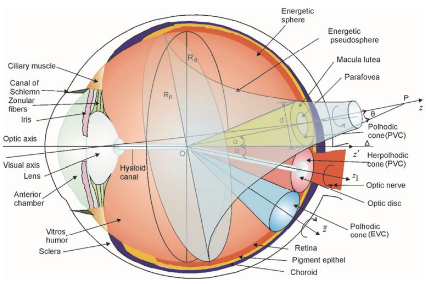


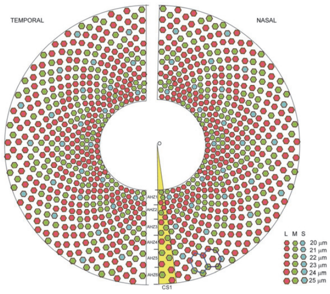


Left: The shielding coefficient due to reflection (SER) based on the Bruggeman model, for a composite containing Al nanospheres with a concentration starting from the percolation limit (>32%) and having a conductivity of 10^6 S/m and a relative permittivity of 1, immersed in a polymer matrix with zero conductivity and relative permittivity of 5.
Right: Total shielding coefficient (SE_{total}) based on Maxwell-Garnett, and Lewis-Nielsen, models for Al nanospheres (conductivity 10^6 S/m and relative permittivity 1) with concentration between 0 and 50%, dispersed in a polymer matrix with zero conductivity and relative permittivity of 5.

Optics of the visual apparatus in the hyperbolic geometry formalism and implications in the design of visual prostheses - contact Dr. Liviu Bilteanu (liviu.bilteanu@imt.ro)

Addressing the need to increase the efficiency of visual prosthetic devices used in artificial human vision, we developed a method to optimize the arrangement of photodiodes in subretinal implants. Starting from an analogy with an original theory regarding the ionospheric auroral gyroscope, and using the hyperbolic geometry formalism we obtained a new perspective in the optics of the human eye. Based on the actual distribution (obtained from cadaver studies) of photosensitive cone cells on the human retina, we modelled the macula of the human eye as a pseudospherical surface. This allows the rigorous description of photoreceptor cell density in parafoveal areas by a model based on an optimized coverage method. Due to the close morphological similarities with a normal human retina, the performance of the visual prosthesis in camera-less systems could be significantly improved in the following aspects: colour perception by high pixel density individualized polarized light perception, efficient power supply and thermal energy management, etc. Rigorous theoretical foundations for the next-generation microelectrode array have been established, with the next step being the implementation and testing of models. [L. Bîlteanu et al., "Human Eye Optics within a Non-Euclidean Geometrical Approach and Some Implications in Vision Prosthetics Design", Biomolecules 2021, 11(2), 215].





Left: The hyperbolic model of energy pseudosurfaces corresponding to polhodic and herpolhodic vortices superimposed on the anatomical structures of the human eye.
Right: Pixel organization in the first avascular zone of the fovea. In the artificial human macula this area is composed of two hemipseudospheres. Each of these hemipseudospheres contains 486 pixels so the entire prosthesis contains 972 pixels (artificial photodiodes). S-, L-, and M-type photosensitive cone cells are represented by the corresponding colors.

Simulation, Modelling and Computer Aided Design Laboratory – L5

Laboratory head: Dr. Raluca Müller

Mission

Research, development, and applications of simulation, modelling and design techniques of micro-electro-mechanical and microfluidic systems focused to collaborative research projects, **education** (labs,), services (specific design solution, models, enabling access to hardware and software tools) and **consultancy** (design/ optimization) in the field of micro-nanobio/info technologies. **The L5 lab 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).

Expertise

• **Design, simulation and development/ optimization of MEMS/MOEMS** and **microfluidics** devices and components (cantilevers, membranes, micro-grippers; micro-channels, mixers, filters, handling and monitoring systems) for microelectronics, environmental, security, biomedical and biological applications);

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

• **Rapid manufacturing**: 3D Printing (SLS, single-photon-photopolymerization), development of novel additive manufacturing technologies;

• **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**;

• **Realization of heterostructures** with (ultra)thin layers by advanced technological processes for devices with controlled functionality;

• **Complex characterization of response functions of junctions** with ultra-thin films and nano-object arrays by electrical measurements**;**

• **Analysis of the physical phenomena at surfaces and interfaces** in metal-oxide-semiconductor heterostructures. **Modelling** their properties for multifunctional devices.

Team: **Dr. Raluca Müller** (PhD in Electronics) - laboratory head, senior researcher I; **Dr. Rodica Plugaru** (PhD in Physics), senior researcher I; **Dr. Oana Tatiana Nedelcu** (MSc in Mathematics, PhD in Electronics), senior researcher I; **Dr. Neculai Pugaru** (PhD in Physics**)**, senior researcher I; **Dr. Gabriel Moagar-Poladian** (PhD in Physics), senior researcher II; **Dr. Franti Eduard** (PhD in Electronics), senior researcher II; **Phys. Constantin Tibeica (MSc in Physics)**, scientific researcher; **Phys. Eng. Victor Moagar-Poladian (MSc Physical Engineering)**, IDT III, physicist engineer; **Dr. Rodica-Cristina Voicu** (PhD in Mathematics), senior researcher III; **Dr. Angela-Mihaela Baracu** (PhD in Electronics) senior researcher III; **Dr. Mihai Gologanu (**PhD in Mathematics-Mechanics) senior researcher III; **Phys. Nicolae Filipoiu** (PhD student in Physics), researcher.

International collaborations – R&D Projects

- **H2020: BIONANOPOLYS -**Open Innovation Test Bed for Developing Safe Nano-Enabled Bio-Based Materials and Polymer Bionanocomposites for Multifunctional and New Advanced Applications, H2020-NMBP-TO-IND-2020project (Contract nr. 953206, 2021–2024), Coordinator: ITENE, Spain; IMT responsible: *Dr. Oana Tatiana Nedelcu*
- **MANUNET Project -** *Tool Kit for Robotics for Manufacturing Electronic components and Nodes using Digital Fabrication Technologies*, coordinator Fraunhofer Institute (Germany)*,* IMT responsible: *Dr. Gabriel Moagăr-Poladian*; 2021-2023

***International collaborations – Scientific services contracts*:**

- **For CEA Saclay, France**, March-August 2019: *Design and fabrication of microfluidic chips, consultancy for experimental set-up for microscopy without lenses*, IMT PM: Dr. Oana Tatiana Nedelcu.
- **For City Technology Ltd., Great Britain, 2019**: *Development of environmental compensation methods for gas electrochemical sensors*; IMT PM: Dr. Mihai Gologanu
- **For Garrett Transportation Inc., USA,** 2020-2021: *Experimental and modelling support for gas sensors based on solid electrolytes*; IMT PM: Viorel Avramescu, Dr. Mihai Gologanu.

National collaborations

► **POC-G – Operational Competitivity Program 2014-2021, 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"*** project financed by **Structural Funding** dedicated to knowledge transfer from IMT to Romanian companies, in a high-tech field of the Romanian Strategy (SNCDI 2016-2021): ICT, Space, and Security. Coordinator: IMT

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

- **Sub-project C77.3D:** ***Sensitive Platform with SAW sensor for inflammable and potentially explosive gases detection*** (in collaboration with S.C. ROM-QUARTZ S.A.)**;** coordinator: **Dr. Angela Baracu**,
- **Sub-project C77.5D:** ***Image forming optical system by using „free-form" (FF) components and technology for the fabrication of these (***in collaboration with S.C. ROVSOL S.R.L.); coordinator: **Dr. Gabriel Moagăr-Poladian**,

► **Project PN-III-**P1-1.2-PCCDI-2017-0871, contract 47PCCDI/2018***: „ New directions of technological development and use of advanced nanocomposite materials"***, Coordinator INCD-FM;2018-2020; IMT Partner, Coordinator **Dr. Raluca Müller**.

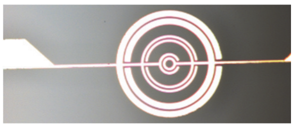
R&D Services: ● Contract with Alfarom SRL: ***FEM simulation and optimization for an 'angular rate sensor' gyroscope***, **Contact: Dr. Rodica Voicu**.

Scientific highlights

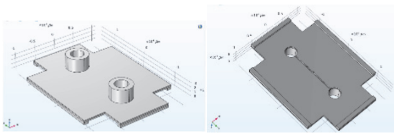
►„Core" funding: MICRO-NANO-SIS PLUS, Project ***"Development of components and microsystems for sensors and smart control with applications in IoT and bio-engineering",*** **2019-2022 Coordinator: Dr. Oana Tatiana Nedelcu (**oana.nedelcu@imt.ro)

Objective 1: Modelling, simulation and fabrication of microsystems for detection applications in microfluidics

- Fabrication of electro-fluidic microsystem components: microchip with Au-Cr electrodes on a glass plate and microchip with microchannels, chambers, and visualization area made in transparent polymer by 3D printing for transport, dielectrophoretic handling and optical analysis of biological cells;
  Contact: Dr. Oana Tatiana Nedelcu, oana.nedelcu@imt.ro, **Phys. Catalin Tibeica**, catalin.tibeica@imt.ro



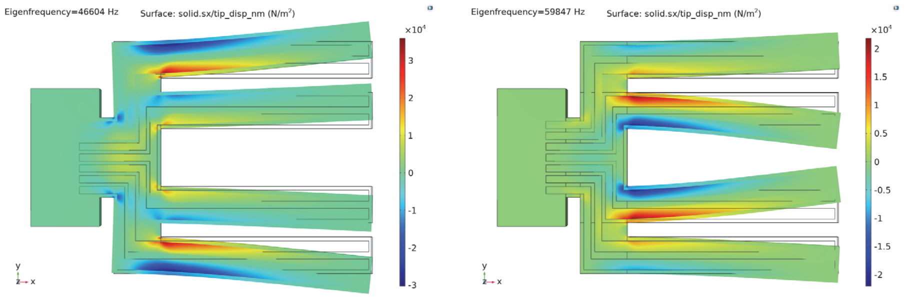
Optical image of the central area of the electrodes



Design of the test model (Comsol Multiphysics)

The fluidic component and the support are made of transparent resin

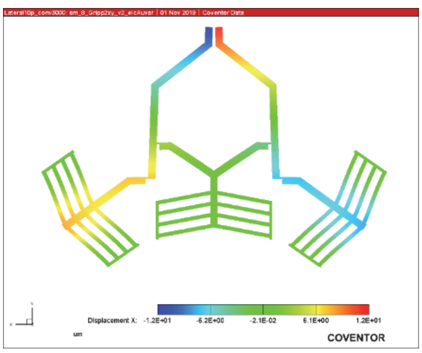
- **Using coded sequencer to interrogate the silicon photoacoustic gas sensor to improve the signal-noise ratio**
  The photoacoustic gas sensor uses a resonator on silicon (MEMS) with piezoelectric readout to capture the acoustic waves generated by the photoacoustic effect. In order to increase the signal-to-noise ratio, we designed a double tuning fork, with two resonances; a new interrogation method that gives better results than the classic PLL (Phase Locked Loop) interrogation of a resonator with a single resonance is proposed. The figures below show the simulated tuning fork in COMSOL, a coded LED interrogation sequence (with values 0 = closed, 1 = open), and the resulting signal after applying a matched FIR filter. Finally, the results of a white noise simulation show that the new method leads to a 40% error reduction compared to PLL, a reduction due to the use of the 2 resonators simultaneously. **Contact Dr. Mihai Gologanu**, mihai.gologanu@imt.ro



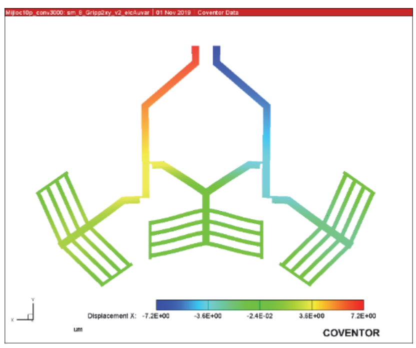
Double range with resonances at 47kHz and 60kHz excited by an acoustic source located on the axis of symmetry.

Objective 2: Design, simulation and fabrication of MEMS structures with multidirectional displacements (in-plan and out-of-plane) and with integrated sensors

- **Design and simulation of MEMS** structures that integrate electro-thermal actuators in order to obtain in-plane multidirectional movements (2D). Coupled electro-thermo-mechanical simulations realized with CoventorWare® 2014 software to analyze the structural behaviour when it is actuated. **Contact Dr. Rodica Voicu** *(rodica.voicu@imt.ro)*

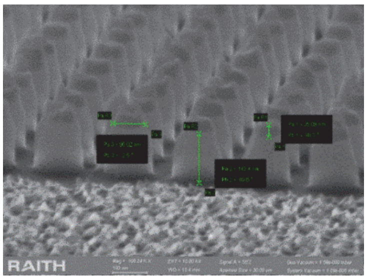


Displacements simulation (closing the tips, in-plane) when the lateral actuator pairs are actuated

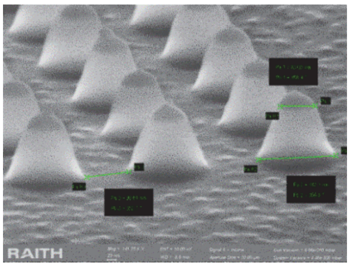


Displacements simulation (opening the tips, in-plane) when the middle actuator is used

- **Preliminary experiments for technological processes for MEMS actuators**



Etching profile of Si O_2 test structures

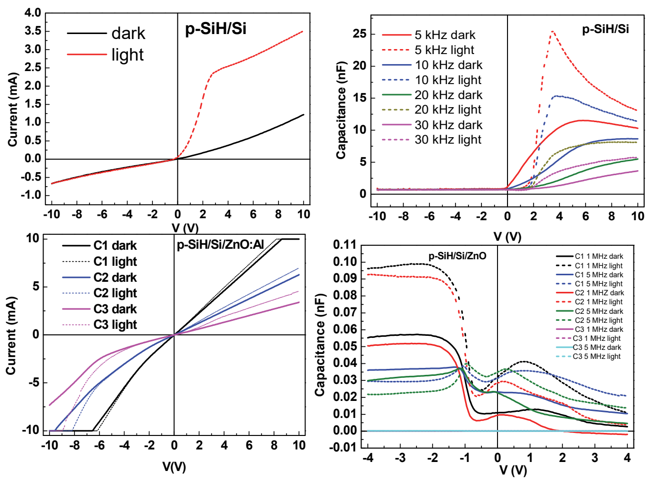


Etching profile of SiO_2 after process optimization

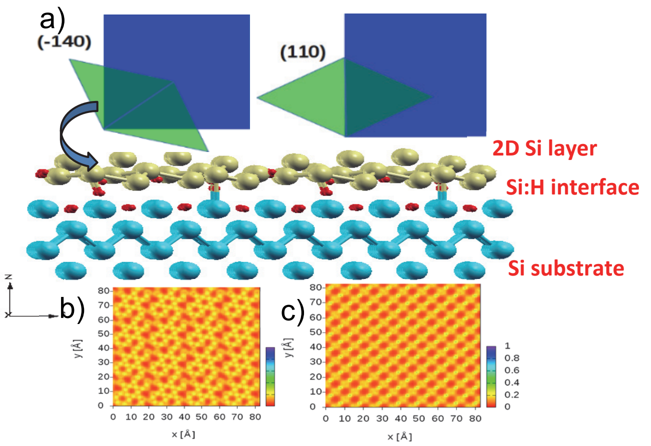
Technological tests were performed for dry etching of thermal 100 nm SiO2 layer used as sacrificial layer for structures fabrication. The tests were done using RIE (Reactive Ion Etching), SI220 in order to have a precise control for the gap, for high performance RF- MEMS switches. The follow key attributes of etch processes were investigated: a) the aspect of the etched surface; b) etching isotropic grade; c) etching rate. **Contact Dr. Angela Baracu**, angela.baracu@imt.ro.

Objective 3: Characterization of response functions to various perturbation factors of interfaces with intercalated nanomaterials and ultrathin layers. Contact: Dr. Rodica Plugaru *(rodica.plugaru@imt.ro)*

- Electrical characterization of the electronic properties of interfaces in heterostructures with ultrathin films, Si:H/Si and Si:H/Si/ZnO:Al, obtained by deposition of ultrathin films of Si or ZnO:Al on hydragenated p/n-type Si;
- Analysis of physical phenomena at oxide/semiconductor interface, related to the formation of the 2D electron gas with high density and mobility and Analysis of interface states contribution to carriers photogeneration, transfer and accumulation.



I-V and C-V characteristics of heterostructures with ultrathin films of Si and ZnO:Al deposited on p-Si:H substrates.

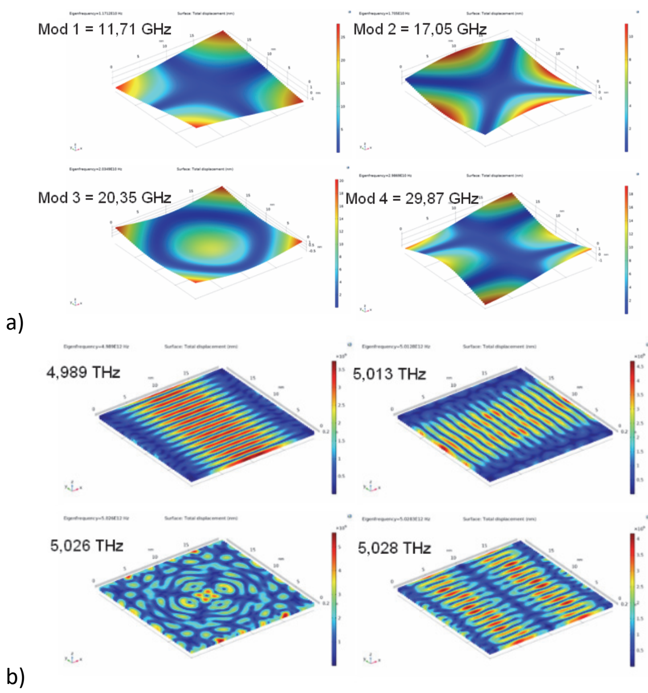


Atomistic models of 2D Si layer interface with a hydragenated Si substrate, Si:H (100) (a); Charge distribution: in 2D Si layer (b); at the interface with the Si:H substrate. Atomistic simulation (DFT).

Technological processes for the production of nanopatterned electronic components: anodic oxidation of two substrate types by using DPN Nscriptor system - *Preliminary experiments for sub-micron structure made of carbonic compounds*

Contact: Dr. Gabriel Moagăr-Poladian (gabriel.moagar@imt.ro)

We have studied a way to directly produce already-patterned graphene layers and the possibility of detaching the graphene films from their catalytic copper substrate followed by their subsequent deposition onto the desired substrate. The concept includes the growth of already-patterned (configured) graphene and its transfer, by electrostatic means, onto the desired substrate. The growth of an already-patterned graphene film is made by employing local oxidation of the copper substrate. The oxidation is achieved in two ways: by using e-DPN system and local anodic oxidation that allows highly precise configuration on a small area and, respectively, chemical oxidation through a photoresist mask (less precise, but able to cover large area).



The first four eigenmodes of the graphene film. a) free-standing graphene; b) graphene onto copper substrate (ANSYS)

For the detachment of the patterned graphene from its copper substrate and deposition onto the desired substrate, we have considered capacitive (electrostatic) detachment under a sinusoidal regime. In order to evaluate the feasibility of the method, we have determined through simulations (using finite element analysis) the eigenmodes and eigenfrequencies of the graphene films residing onto the copper substrate. For this purpose, we have considered the van der Waals forces acting between each copper atom and the corresponding carbon atom.

Reliability Laboratory – L7

Laboratory head: Dr. Octavian Buiu

Mission

The design, development, and implementation of innovative solutions for the testing and monitoring of the functionality and reliability of sensors, actuators, microsystems, nanostructures, intelligent systems, and microelectronic and optomechanical components. These actions, with a strong interdisciplinary character, take place in the spirit of Concurrent Engineering, starting with the design and definition phase of the project and then throughout the entire development of the device, including real-life use.

Expertise

• Activity areas

Research-development-innovation

Development of innovative solutions for sensors and intelligent sensor systems using nanocarbonic sensitive layers and metal oxides, with applicability in environmental monitoring. Reliability building: Design for Reliability (DfR), Design for Manufacture (DfM), Monitoring and selection of micro and nanostructures and devices, Reliability of components in Harsh environments (extreme temperatures, aerospace, radiation field, etc.); Customized Robust Design (environmental quality monitoring biosensors, for example).

Testing and trials services for internal and external partners

- Accelerated testing of micro and nanostructures (using single or combined tests);
- Accelerated testing of electro-optomechanical components used in pieces of equipment that work in hostile environments or with special requirements (space, automotive, security).

Team: **Octavian Buiu** (PhD, Physics) - laboratory head, senior researcher I; **Bogdan-Cătălin Șerban** (PhD, Chemistry), senior researcher III; **Octavian Ionescu** (PhD, Electr. Eng.), senior researcher III; **Niculae Dumbrăvescu** (MSc, Electronics), senior researcher III; **Maria-Roxana Marinescu** (PhD, Eng. Ec.) scientific researcher.

International collaborations – R&D Projects

- Participants in the project coordinated by the Laboratory L8, project with the European Space Agency (ESA) the project entitled PROBA-3 ASPIICS OPSE HARDWARE - Contract No. 4000111522/14 / NL / GLC;
- Collaboration with CSEM (Switzerland) and ESA for the development of gyro sensor testing methodology and implementation on industrial-grade gyroscopes;
- System of microtextured photovoltaic cells of increased efficiency integrated in the wing of unmanned aerial vehicle (UAV) with applications in societal security - UAVPHOTO.

National collaborations

- Collaboration with national institutes (INOE 2000, INFLPR – Bucharest, INECMC - Timişoara) and research groups from Universities (UPB, "Transilvania" University of Braşov) for the execution of activities within the Nanocarbon + complex project. Within the activity of exploiting the results, a collaboration agreement was concluded with S.C. Termobit SRL, regarding the development, in common, of some industrial applications that would use the results obtained within Nanocarbon +.
- Performing testing/reliability services: ADT TU Testing (AGS–WBDL) for Elettra Communications, Romania; RF antenna testing for INFLPR Bucharest.
- Services for the development and characterization of sensors and materials developed within IMT Bucharest (graphene-based aerogels, electronics for accelerometer testing) and used by the Romanian automotive industry.
- The project "Controlled atmosphere for fruit and vegetable storage: solution multidisciplinary and low cost (CASTOL)". Contract No. 364 (PN-III-P2-2.1-PED-2019-5248).
- The Project "Platform of Sensors Based on Ecological Materials for Monitoring City Environment (SPSMCITY)". Contract No. 475 /2020 (PN-III-P2-2.1-PED2019-4734).
- Contract no. 14N/2019 "Advanced research in micro/nanoelectronics, photonics and micro/nano-bio systems for the development of applications in the fields of specialization intelligence - MICRO-NANO-SIS PLUS". Code: PN 19 16.

Scientific highlights

1. Within the **contract no. 14N/2019 "New advanced research in micro/nanoelectronics, photonics and micro/nano-bio systems for the development of applications in the fields of intelligent specialization - MICRO-NANO-SIS PLUS". Code: PN 19 16, Project no. 5:** ***Nanocarbon materials - unconventional processes and technologies, test applications,*** the following results were obtained, as follows.

In **phase 5.4a,** the research and development activities were focused on two directions: <u>I) the development of the synthesis methodology</u> of the four compositions of quaternary nanohybrids, organic-inorganic, in which the mass concentration of nanocarbon materials is in the range (33-50) wt % C and <u>II) structural, morphological and compositional characterization</u> using SEM/EDS, XRD, and Micro-Raman instrumentation. When designing the chemical syntheses of quaternary materials, we took into account the very good detection results of relative humidity (RH) and ethanol obtained at room temperature on the ternary nanocomposites based on Ox-SWCNH/SnO_2/PVP, previously studied and reported, performances that were possible for concentrations of carbonaceous material well above the percolation threshold (0.1 wt% C on rigid substrate). The design of the quaternary nanocomposites was carried out keeping approximately the same mass concentrations of carbonaceous material (wt% C) in the total nano-hybrid mass; thus, two types of quaternary nanocomposites were made (Ox-SWCNH/SnO_2/ZnO/PVP and Ox-SWCNH/GO/SnO_2/PVP), each of them having two concentrations of carbonaceous material, in the range (33-50) wt% C, in the total mass. Thus, it will be possible to compare the detection results in the chemiresistive sensors made with ternary and quaternary sensitive layers, in order to select the best composition from the perspective of the sensors' response. The GIXRD spectra (Fig. 1) performed on each of the four components revealed features specified in the literature, with a single exception related to graphene oxide (GO) whose spectrum was characteristic of graphite, which could be explained by the high degree of structural defects in the commercial graphene oxide we used.

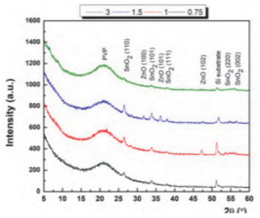


Fig. 1. GIXRD analysis results of the quaternary thin sensitive layers deposited on silicon

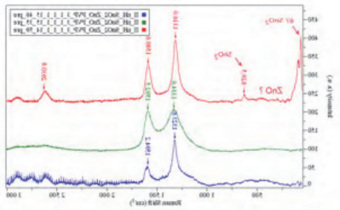


Fig. 2. Micro-Raman spectra of the quaternary layer Ox SWCNH/SnO_2/ZnO/PVP=3/1/1/1.

The result is also supported by the Micro-Raman spectra (Fig. 2) of the quaternary composites based on Ox-SWCNH, GO, SnO_2 and PVP, which highlighted new characteristics of the nanohybrid due to the interaction of the two nanocarbon materials both between them and with SnO_2, respectively the PVP matrix, and on the other hand due to the structural defects of the graphene oxide used.

2. Within the research **phase 5.4b,** quaternary organic-inorganic hybrid layers based on ox-SWCNH-SnO_2-ZnO-PVP and respectively ox-SWCNH-GO-SnO_2-PVP were developed, synthesized and characterized.

Using these materials, chemiresistive structures were developed, using interdigitated structures made on silicon, and their sensing properties, to water vapor (RH(%): 0...100) and ethanol vapor (0-100 mg/L in dry air) were experimentally determined. In these experiments, chemical compositions were used in which the mass concentration (wt% C) of the nanocarbon material (ox-SWCNH and GO) in the total mass of the nanocomposite is in the range (33-50) wt% C. Fig. 3 shows the response as a function of time (during 0-10000 seconds) of the chemiresistive sensor „0.75" compared to the response of the commercial capacitive sensor that directly indicates the RH value in percent. It can be noted that although our research is still at an early stage (TRL 3), yet our sensor tracks in time the commercial sensor with a quite well response. In addition, as qualitatively can be seen from Fig. 3, the recovery time of our sensor to the sudden change of relative humidity from RH=100% to RH=0% is even shorter than that of the commercial sensor. At this stage, we can still see the existence of a small drift of our sensor when it returns to the "baseline" characterized by RH=0%, but in Fig. 3 its evolution was in the beneficial direction of reducing electrical resistance, which means that the desorption of water vapor performed better and better with the passage of operating time.

Similar characteristics were obtained for all the developed sensors. Fig. 4 shows the transfer functions (R=R(%RH)) of the four chemiresistive sensors developed by our group which show a linear behaviour according to the relative humidity variation over the whole range (0-100%) RH.

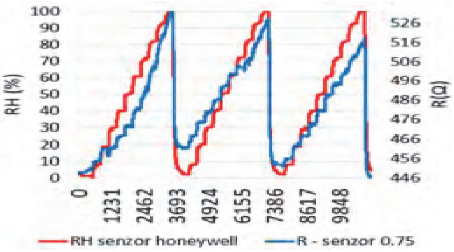


Fig. 3. The response of the humidity sensor developed in L7 (blue curve), compared to a commercial sensor (red curve)

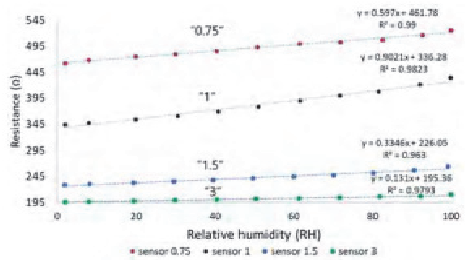


Fig. 4. The linearity of the response for the developed chemiresistive sensors (RH variation between 0 and 100%)

By automatically processing the data of the four chemiresistive sensors in Fig. 4 the sensitivity of each was determined, which will allow us to do a comparative performance analysis in order to select the most promising concept for a possible further development.

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3. Chemiresistive structures, using sensitive layers based on oxidized carbon nanohorns and PVP (mass ratio 1:1), for RH determination, were mechano-thermally tested, in order to identify possible changes functionality (i.e., anomalous variations in resistance) generated after the tests. 8 samples were prepared and analyzed, with the thicknesses of the sensitive layer reaching approximately 200 nm (see Fig. 5, result obtained using the Nova NanoSEM 630 equipment). For each sample, the electrical resistances were measured under normal temperature conditions (23 ºC), at RH=35%; later they were tested using the Mecmesin Multitest equipment (Fig. 6), at values of 2N, 5N, 10N and 20N. A correlation was established between the value of the applied mechanical stress and the electrical resistance, for different thicknesses of the sensitive layer.

At the same time, the values of Young's modulus of elasticity (E) were determined for the samples with 1 layer and for the sample with 8 layers, respectively 8.33 MPa and 3.99 MPa. To investigate potential temperature induced changes two samples (1 and 8 layers respectively) were tested to see the reaction of the sensitive layer. A Cryogenics 8200 compressor (model CCS-450) was used for testing at temperatures below 50 ºC and a Memmert oven for tests at +50 ºC. The samples were observed using an optical microscope. No major changes of the layer were observed. The results were published in the UPB/B Series magazine.

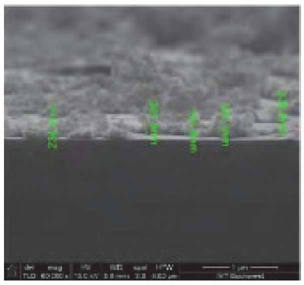

Fig. 5. - SEM image of the sample with 8 layers

Fig. 6. - Testing the sample on Mecmesin Multitest

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4. Chemiresistive humidity sensors based on carbon composites on flexible substrate.

The research was focused on three directions: a) design and electrical characterization of some IDT type structures on a flexible substrate; b) synthesis and characterization of two sensitive materials for the development of RH sensors on a flexible substrate; c) functional characterization of RH chemiresistive sensors, using IDTs on a flexible substrate. Thus, the CorelDraw 11 program was used for the design of the IDT and the creation of the photoplot type masks, software supported by the photo-plotter with a resolution of 3000 dpi, where the masks were made on film; two types of IDTs were designed and made, with digit/space of 25.4 microns and 50.8 microns, respectively.

• ***Synthesis and characterization of sensitive materials*: **Two composite materials were synthesized and characterized, later tested as sensitive materials for monitoring relative humidity. Both composite materials are based on oxidized carbon nanohorns (oxCNH) and polyvinylpyrrolidone (PVP), together with TiO_2 (solution 1) and KCl (solution 2). For each solution, materials with various concentrations of oxCNH were prepared (2 mg; 4 mg; 6 mg for solution 1, referred to as samples P1, P2, P3; for solution 2, the following concentrations were used - 6 mg, 6.5 mg and 7 mg referred to as samples K1, K2 and K3). The sensitive composite materials were deposited by the "drop-casting" method both on the IDTs on a flexible substrate (for functional characterization) and on glass and silicon substrates (for structural characterization).

• ***Structural characterization:***

→ The **AFM investigations** (performed in tapping mode - Fig. 7-8) focused on the determination of surface texture parameters (defined according to ISO25178); thus, for the "K" samples, all the parameters characterizing the texture (SDR, SDQ, SA) have much higher values, indicating a much more disordered and rougher surface. For the "P" samples, it was found that the average roughness (Sa) decreases proportionally with the increase in the concentration of oxCNH.

→ **Raman spectroscopy results.** For the "P" samples, the Raman measurements highlighted the vibration modes associated with the presence of carbon nanohorns and the other components of the composite. It is worth noting that the presence - in greater quantity - of carbon nanohorns led to a better highlighting of the specific modes of TiO_2 (see Fig 9. for P3- 6/2/2). For both sets of samples (P and K), the Raman measurements clearly highlighted the vibration bands specific to the nanocarbon material and PVP, as well as those specific to the nanocarbon material.

→ **Functional characterization of chemiresistive sensors on flexible substrate.** Relative humidity measurements were made both for the sensors using the "P" type sensitive material, as well as for the "K" type. The PICOLOG measuring system was used, whose architecture and mode of use were presented in a previous report. Characteristic results (the blue curve) can be found in figures 10 (for three measurement cycles) and 11 (for 5 measurement cycles); in red is represented the response of the capacitive reference sensor.

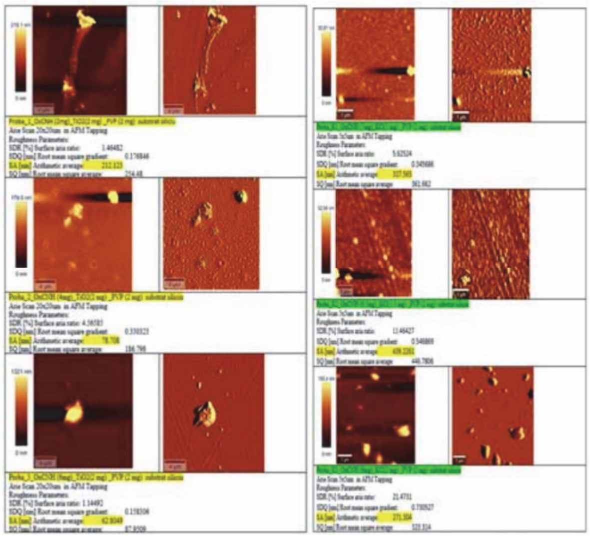

Fig. 7. AFM results for "P" samples; Fig. 8. AFM results for "K" samples

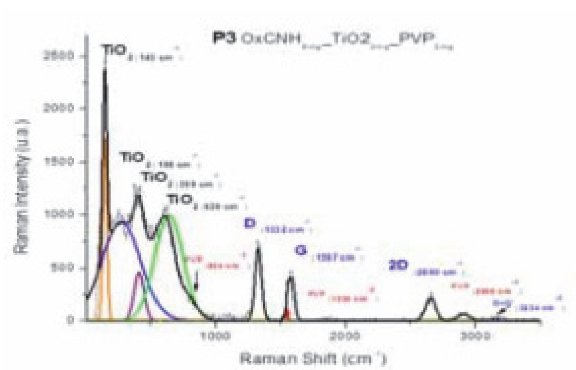

Fig. 9. Raman spectrum for sample P3

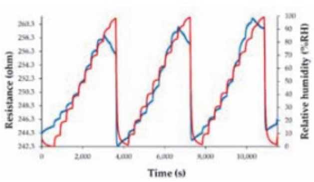

Fig. 10. The response to H (0-100%) for sensor P1

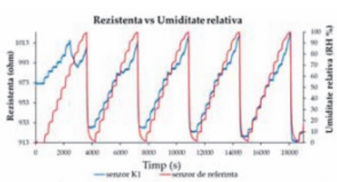

Fig. 11. Humidity response for the K2 sensor

5. Within the **contract c77.2B/ 08.07.2020 (Knowledge Transfer Partnership)**, reliability testing services were performed for the CONDOR VLRD 660 and RAVEN thermal cameras, made for export. The following tests were performed: free fall (Fig. 12a), vibrations (Fig. 12b) and climate tests, temperature-humidity (Fig. 12c).

Fig. 12a. - MRAD 0707-20 – Free Fall Sock Machine / Cambridge with Thermal Camera – CONDOR VLRD 660 installed for testing;

Fig. 12b. - Vibration system with camera climate (Frequency band: 2000 Hz. Maximum mass of the device tested 50kg)

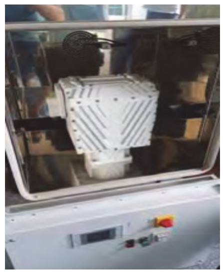

Fig. 12c. – Climate room for environmental testing (temperature: -40 °C/+180 °C; humidity: 10-95% RH)

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6. Within the **ESA contract no 4000116436/16/NL/CBi.** the design, execution and testing of an extension module (Fig. 13a and 13b), developed for testing, up to 50g accelerations, prototypes for MEMS-Gyro was completed. The module testing was done successfully (Fig. 13c), and the device tests will be performed.

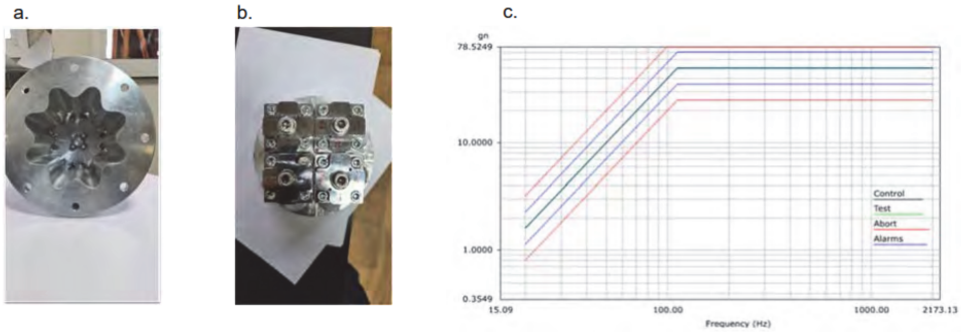

Fig. 13: a, b: extension mode view (a- from below; b – from above); c – vibration test profile, at 50g.

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7. CASTOL project - "Controlled atmosphere for fruit and vegetable storage: solution multidisciplinary and low cost (CASTOL)". Contract No. 364 (PN-III-P2-2.1-PED-2019-5248)

Within the project, the group from L7 synthesized, characterized and tested sensitive layers for measuring relative humidity (RH); they are constituted by a ternary nanocomposite matrix of oxidized carbon nanohorns (CNHox), graphene oxide (GO), polyvinylpyrrolidone (PVP). Three different compositions were synthesized and characterized (in mass ratio 1/1/1, 2/1/1, 3/1/1) in order to maximize the response of the humidity sensor and decrease the response time. The deposited sensitive layers were characterized by scanning electron microscopy (Fig. 14-15) and RAMAN spectroscopy (Fig. 17).

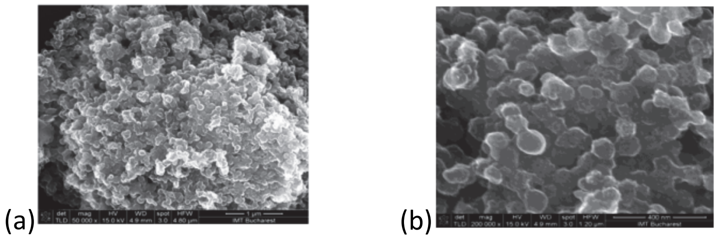

Fig. 14. SEM for a sensitive layer consisting of a ternary nanocomposite matrix of the type /CNHox/ GO/PVP in 1:1:1 mass ratio: (a) ×50,000 & (b) ×200,000 magnification.

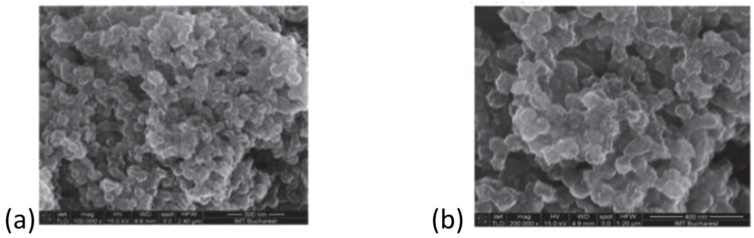

Fig. 15. SEM for a sensitive layer consisting of a ternary nanocomposite matrix of the type /CNHox/ GO/PVP in mass ratio 2:1:1: (a) ×100,000 & (b) ×200,000 magnification.

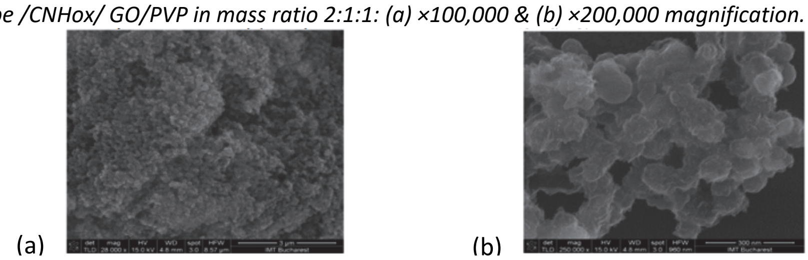

Fig. 16. SEM for a sensitive layer consisting of a ternary nanocomposite matrix of the type /CNHox/ GO/PVP in mass ratio 3:1:1: (a) ×28,000 & (b) ×250,000 magnification.

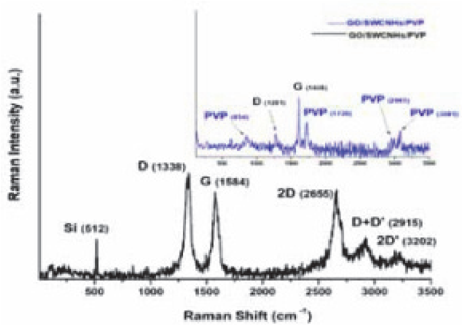

Fig.17. Raman spectra recorded on silicon (black color) for CNHox/GO/PVP nanocomposite in mass ratio 1/1/1)

The recorded Raman spectra show the typical D (~1338.8 cm^{-1}), G (~1584.1 cm^{-1}), D' (1601 cm^{-1}) and second-order bands of the localized 2D and D + D' band at 2655.5 and 2915.9 cm^{-1} which are characteristic to carbon nanomaterials. The Raman band at about 3202.7 cm^{-1} can be associated with the so-called 2D' band, and this may originate from the vibrational spectrum of graphite, the most important impurity in oxidized carbon nanotubes. The peak located at ≅ 520 cm^{-1} is associated with the silicon substrate. Moreover, the well-known peaks belonging to PVP (854, 1429, 1665, 2925 and 2997 cm^{-1}) overlapped with the bands of nanocarbon components. The Raman band at about 920 cm^{-1}, which is not assigned in the carbon nanocomposite spectrum, may originate from the overlap of the Raman bands of the silicon substrate and PVP. Some of the small Raman peak shifts associated with the carbon nanocomposites are most likely a consequence of multiple chemical interactions, between oxidized carbon nanohorns, graphene oxide and polyvinylpyrrolidone.

Relative humidity detection measurements were performed in a special test bench (Fig. 18), where to vary the relative humidity in the test chamber from 0% to 100% RH, dry nitrogen was purged through two bubblers in series containing deionized water. The humidity in the test chamber (the chamber size is 10 x 8 x 4 cm^3) was changed by mixing dry nitrogen passing through the containers with deionized water in different ratios.

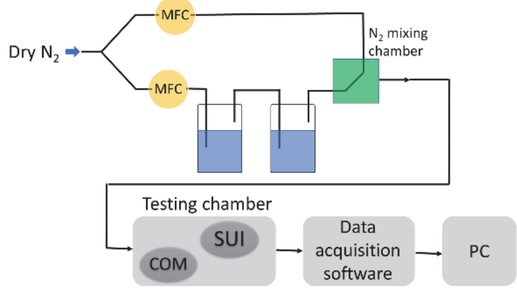

Fig. 18. Experimental device: MFC – mass flow controller, REF – reference sensor; SI – investigation sensor; PC – computer.

The relative humidity monitoring capability of each carbon nanocomposite-based substrate was explored by applying a current between the two electrodes and measuring the voltage difference when varying the RH from 0% to 100%. An important feature of these devices is the low power consumption, below 2 mW.

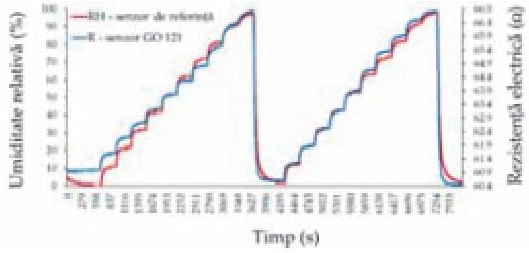

Fig. 19. Response comparison of reference sensors and GO/CNHox/PVP sensors: 1/2/1.

After analyzing the data of the tested sensors, the best results for the field of higher relative humidity in the fruit and vegetable storage spaces are presented by the GO 111 and GO 121 sensors that qualify for the work procedure described in figure 20. The procedure involves obtaining 16 experimental datasets (four fruits/vegetables stored at two different temperatures and two storage modalities) for one of the newly designed sensors.

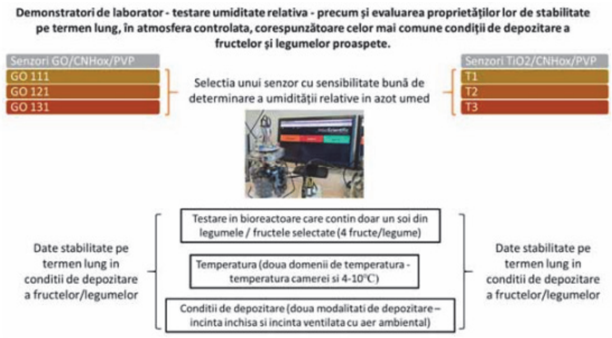

Fig. 20. Schematic of experimental demonstrators aimed at testing relative humidity of new sensors in fruit/vegetable storage condition

Also, within the CASTOL project, the specialists from L7 participated in the design and realization of a hardware platform, which integrates sensitive elements and a communication system for data acquisition and processing (Fig. 21).

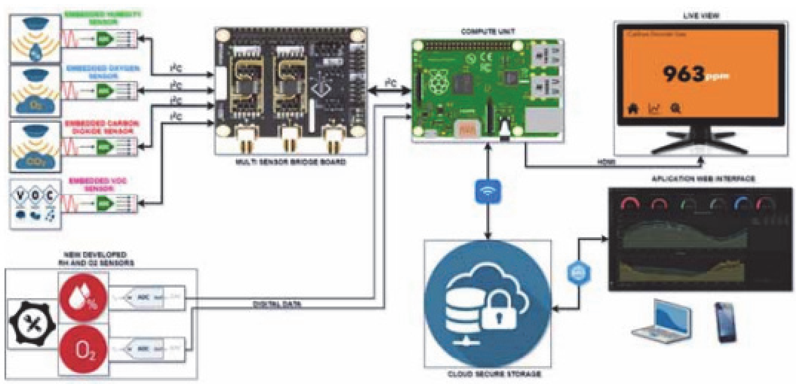

Fig. 21. The hardware platform for the acquisition and processing of storage medium data

- **Results obtained in the projects mentioned above were disseminated in 24 ISI indexed journals and 22 patent applications (20 national and 2 EPO).**

Laboratory for Carbon Based Nanotechnologies and Nanostructures – L11

Laboratory head: Dr. Andrei Avram

Mission

Research, development, and implementation of micro- and nano- fabrication processes for carbon-based structures and devices. The L11 laboratory manages the experimental laboratories for etching and deposition of various materials, aiming to integrate carbon nanostructures (i.e., graphene, CNTs, nanocrystalline graphite) in classical microfabrication workflows for developing new functional devices and systems.

Expertise

• **Plasma assisted etching:** Reactive Ion Etching for etching and surface modification of various substrates, Deep Reactive Ion Etching of silicon substrates (Bosch and Cryogenic processes);
• **Plasma Enhanced Chemical Vapor Deposition:** carbonaceous materials (CNTs, graphene, nanocrystalline graphite), silicon oxide, and silicon nitride;
• **Metal deposition by RF-Sputtering:** reactive deposition of oxides and nitrides with various stoichiometries including Ti, TiN, TiO_2, Ni, HfO_2, VO_2;
• **Deposition and characterization of thin films by the LPCVD** technique based on silicon nitride, polysilicon and thermal growth of silicon dioxide;
• **Atomic Layer Deposition** of Al2O3 and HfO2, including doping with various elements, such as Zr, and Yt, for tailoring ultra-thin ferroelectric films;
• **Synthesis and functionalization of carbon-based materials** including graphene and carbon dots with applications in optoelectronics, energy storage, EMI shielding and photocatalytic applications;
• **Synthesis and characterization of graphene/carbon dots nanocomposite materials**, development techniques of thin films, aerogels and polymer nanocomposites;
• **Synthesis and characterization of polymers, water-based and solvent-based resins** for coating applications.

Team: **Dr. Andrei Avram** (MSc in Physics, PhD in Electrical Engineering) - laboratory head, senior researcher II; **Dr. Cosmin Obreja** (PhD in Chemical Engineering), senior researcher II; **Dr. Florin Năstase** (PhD in Physics), senior researcher II; **Dr. Vulpe Silviu** (PhD in Physics), senior researcher III; **Dr. Anca-Ionela Istrate** (PhD in Materials Engineering), senior researcher III; **Phys. Octavian Simionescu** (PhD student in Physics), researcher; **Eng. Elena Mădălina Mihai** (PhD student in Materials Engineering), researcher.

International collaborations – R&D Projects

- **EURONANOLAB: Dry etch expert group**, joint cooperation of the main Nanofabrication Facilities across Europe to standardise plasma etching processes and share expertise (2017-ongoing). Coordinator: Meint De Boer, MESA+, Netherlands; IMT responsible: *Dr. Andrei Avram*
- **Athena: Diamond Like Coating Device**, ESA Contract No. 4000134244/21/NL/GP (2021 – 2024). Coordinator: INFLPR, Romania; IMT responsible: *Dr. Andrei Avram*
- **Elastomeric tuneable metasurfaces for efficient spectroscopic sensors for plastic detection - ElastoMeta**, EEA-RO-NO-2018-0438 (2019-2023); IMT Responsible: Dr. Adrian Dinescu

National collaborations

► ”**Atom thick materials (2D) and their applications at the limit of Moore's law**”, ”Core” funding: MICRO-NANO-SIS PLUS, 2019-2022 Coordinator: Dr. Andrei Avram

► ”**Nanostructured carbon based materials for advanced industrial applications**” PN-III-P1-1.2-PCCDI-2017- 0619 (2018-2021). Coordinator: Dr. Octavian Buiu;

Sub-project 1: "**Piezoresistive effects in nanocrystalline carbonic films and their application as foil strain gauges**"; IMT Responsible: Dr. Andrei Avram

Sub-project 2: "**Oxidic nanocomposites using nanocarbon based materials for the development of lasers and photovoltaic systems**"; Dr. Cosmin Obreja.

Sub-Project 4: "**Photocatalytic composite coatings based on metallic oxides and nanocarbon based materials for the development of environmental technologies (self-cleaning and organic pollutants treatment)**"; Dr. Cosmin Obreja

R&D Services: • **INCDFM**: ***Cryogenic etching of silicon nanostructures***, **Contact: Dr. Andrei Avram**, 8-28 June, 2021.

Scientific highlights

► **Elastomeric tuneable metasurfaces for efficient spectroscopic sensors for plastic detection** - ElastoMeta, EEA-RO-NO-2018-0438 (2019-2023)

Development of cryogenic etching processes for surface nanostructuring

- Fabrication of silicon nanopillars with vertical sidewalls and low roughness with high aspect ratio.

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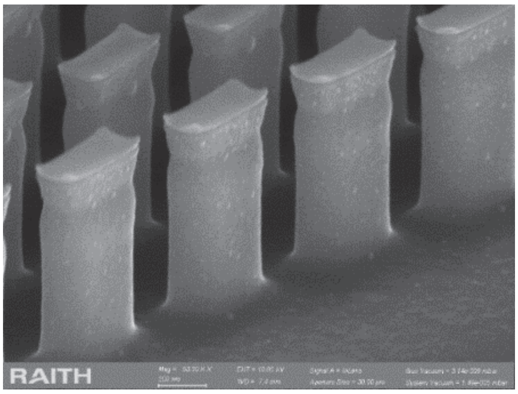
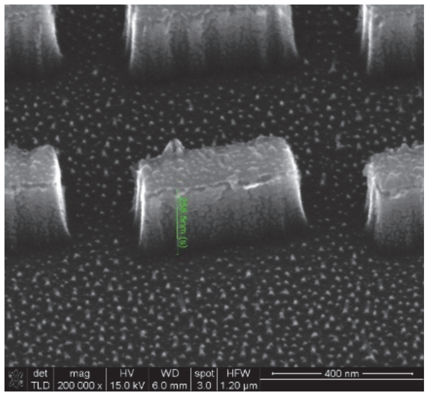


SEM image of etched nanopillars using a 30 nm Ti masking layer



SEM image of etched structures using a 30 nm Ti masking layer

Development of room temperature anisotropic etching process for surface nanostructuring

- Fabrication of silicon nanostructures with vertical sidewalls at room temperatures using fluorine- based plasma chemistries.

Contact: Dr. Andrei Avram (andrei.avram@imt.ro)

►"**Atom thick materials (2D) and their applications at the limit of Moore's law**", MICRO-NANO-SIS PLUS, Core project, 2019-2022

- Fabrication of graphene devices with non-linear I-V characteristics.

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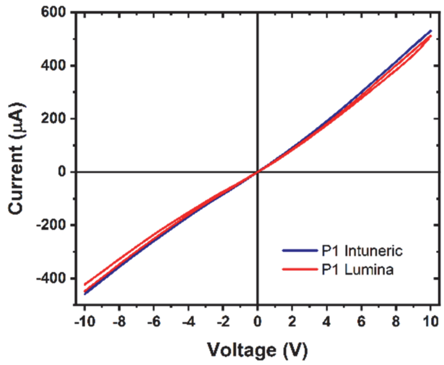
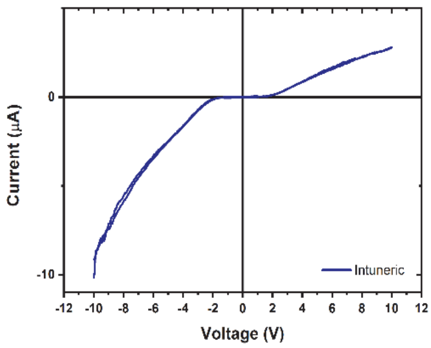
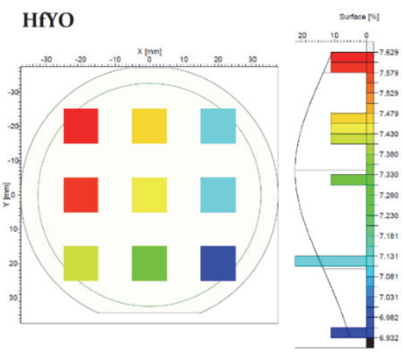


I-V characteristic of graphene on planar surface

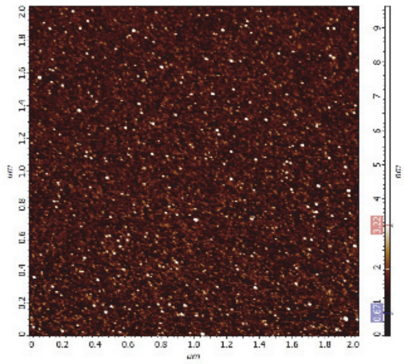


I-V characteristic of graphene on non-planar (sloped) surface

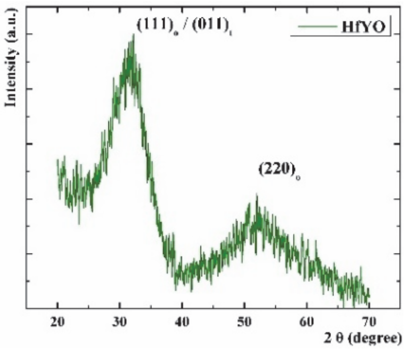
- ALD deposited HfYO ultrathin ferroelectric films. **Contact:** Dr. Florin Năstase (florin.nastase@imt.ro)



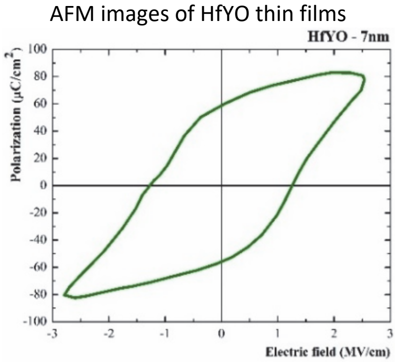
Ellipsometry thickness characterization of HfYO thin films



AFM images of HfYO thin films



GI-XRD diffractogram of HfYO thin films



Hysterezis characteristics for HfYO

Microsystems in Biomedical and Environmental Applications Laboratory- L2

Laboratory head: Dr. Carmen Aura Moldovan

Mission

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

Expertise

• **Micro-Nanosensors–Microsensors** development (chemo-resistant, resonant gas sensors, accelerometers, micro- arrays, ISFET sensors, nanowire-based sensors, implantable electrodes for peripheral nerves stimulation and detection, CNT and graphene-based devices)

• **Microfluidic modules and chips – Simulation, modelling and development of microfluidic platforms for organ on chip development.**

• **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 modelling-simulation/modelling using MEMS specific CAD tools (CoventorWare, COMSOL, CADENCE).**

Team:

The research team consists of 13 people, specialists in Electronics, Physics, Chemistry and Biology: Dr. Carmen Moldovan - CS I, PhD in Electronics, head of laboratory; **Dr. Bogdan Firtat** - CS II, PhD in Electronics; **Dr. Marian Ion –** CS III, PhD in Physics**; Silviu Dinulescu –** CS, engineer**; Adrian Anghelescu -** CS III, engineer**; Costin Brasoveanu –** IDT, engineer**; George Muscalu –** CS, engineer**; Dr. Carmen Mihailescu,** CS III, PhD, chemist; **David Dragomir**, CS, engineer; **Mihaela Savin** – CS, chemist; **Alexandru Grigoroiu** CS, engineer; **Ioana Ghinea –** technician, chemist; **Alina Popescu** – CS III, chemist.

International collaborations – R&D Projects

Horizon 2020

• **FIT-4-NMP** "Strategic and targeted support to incentivise talented newcomers to NMP projects under Horizon Europe", Project number: 958255, 2021- 2023**.**

M-ERA.NET

• **SmartEnergy –** Piezoelectric Energy Source for Smart Factory Applications – (IMT-Bucharest, Renault Technologie Roumanie, Łukasiewicz Instytut Technologii Elektronowej, Medbryt sp. z o.o. – Poland, École polytechnique fédérale de Lausanne, Center for Corporate Responsibility and Sustainability @ University of Zürich – Switzeerland).

•**VOC-DETECT -** Smart Portable System for VOCs detection - (partners: ICF and NANOM MEMS SRL – Romania, Institute for Technical Physics and Materials Science (MFA), Hungarian Academy of Sciences) – coordinated by UPB

FLAG-Era.net

• **RoboCom++ -** Rethinking Robotics for the Robot Companion of the future;

• **CONVERGENCE-**Frictionless Energy Efficient Convergent Wearables for Healthcare and Lifestyle Applications

EUROSTARS

• **iBracelet -** Inteligent bracelet for blood pressure monitoring and detection of preeclampsia– (InfoWorld and "Politehnica" Univ. Bucharest, Romania, Cherry Biotech and Elvesys, France); 2017-2020, IMT Responsible- Dr. Carmen Moldovan

SEE Norway Grants

• **ARMIN-**Arm neuroprosthesis equipped with artificial skin and sensorial feedback– („Politehnica" Univ. Bucharest, Univ. of South-Eastern Norway, Areus Technology, Romanian Academy of Medical Sciences, Emergency Hospital Bucharest);

H2020-ECSEL

• **Moore4Medical -** Accelerating Innovation in Microfabricated Medical Devices, ECSEL-JU project (Contract no. 876190, 2020–2023), Coordinator: Philips Electronics, Netherlands; IMT responsible: *Dr. Bogdan Firtat*

National collaborations

• ► **Complex Projects: SENSIS** - Sensors and Integrated Electronic and Photonic Systems for people and Infrastructures Security, Contract no. 71PCCDI, 2018-2021. Coordinator: IMT-Bucharest (Dr. Carmen Moldovan); Partners: INFLPR, „Politehnica" University Bucharest, Pitești University, Institute of Physical Chemistry I. Murgulescu, Centre of Scientific Research for Defence, CBRN and Ecology, Ministry of Defence.

• **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"*** project financed by **Structural Funding** dedicated to knowledge transfer from IMT to Romanian companies, in a high-tech field of the Romanian Strategy (SNCDI 2016-2021): ICT, Space, and Security. Coordinator: IMT

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

- **Sub-project C77.6D:** *Electrochemical microsensors for rapid and selective detection of pesticides - ORGANOPEST* 2018-2020; Coordinator: DDS Diagnostic; IMT responsible: Bogdan Firtat

•**MiMoSa** Project financed by PNIII, Institutional performance Complex projects implemented in consortia CDI (PCCDI) PN-III-P1-1.2-PCCDI-2017-0820, Contract No. 67PCCDI/ 2018.

•**uCARDIOFRET** (*Förster rapid resonance microbiosensor (FRET) prototype manufacturing technology for early diagnosis of acute myocardial infarction (AMI)*), Program PN III: Program 2-Increasing the competitiveness of the Romanian economy through research, development and innovation, Subprogram 2.1 - Competitiveness through research, development and innovation
Project type: Transfer project to the economic operator, Project financed from the state budget and co-financed by DDS Diagnostic, Contract No. 37PTE / 2020, Period: 2020-2022, Coordinator: DDS DIAGNOSTIC S.R.L Bucharest;

•**VigiAIR** (*Smart system for indoor air quality monitoring*), Romelgen SRL, PTE project, contract 50PTE, 2020-2022;

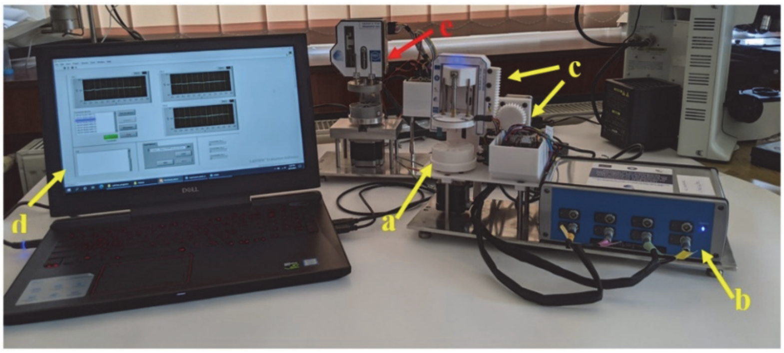
•**Tech4Green** (*Micronanotechnologies for greenhouse gases monitoring*), Institutul de Chimie Fizică I. Murgulescu, PED project 2020-2022.

•**CESMIN** "Support Centre for European Cooperation in Micro- and Nanotechnologies" , Cod SMIS 2014+ 107894, contract POC/ 234/16.04.2020, 16.04.2020 - 15.06.2023; IMT Responsible: Dr. Carmen Moldovan.

Scientific highlights

► TGE-PLAT, Sub-Project C77.6D ***"Electrochemical microsensors for rapid and selective detection of pesticides - ORGANOPEST",*** **2018-2020. Coordinator:** DDS Diagnostic; IMT responsible: Bogdan Firtat

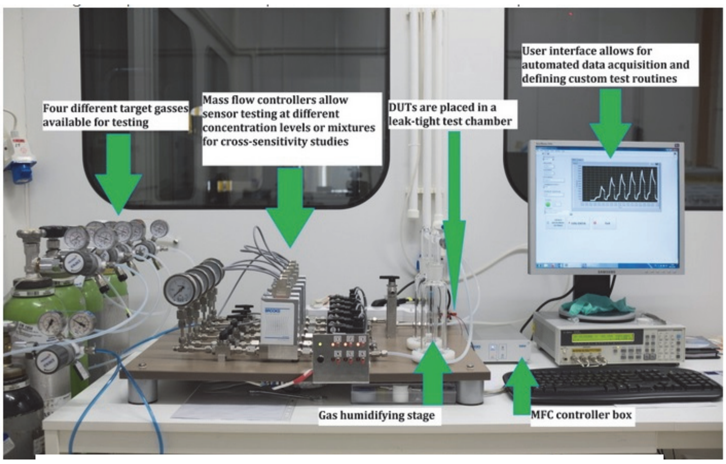
ORGANOPEST is an integrated system for the detection of pesticides. The electrochemical microsensors were designed and fabricated at IMT-Bucharest, as well as the mechanical and electrical components for the detecting platform. The result consists in the testing and validation of the integrated system for detection of organophosphorus and organochlorine pesticides. The integrated platform for pesticide detection is an automated platform which was designed accordingly with the measurement protocol for the project microsensors. The platform is shown in the figure below, together with its main components.



Pesticide detection platform: a – divided beaker and microsensor support for detection; b – electronic module for electrochemical measurements; c – control module for beaker position and sensors immersion; d – graphical user interface for control and data acquisition; e – previous version of the platform

► **National Project:** ***Smart system for indoor air quality monitoring (VigiAIR),*** **PTE project, 2020-2022**; Coordinator: ROMELGEN; IMT responsible: Dr. Carmen Moldovan

The VigiAIR project developed and manufactured an intelligent system for indoor air quality monitoring, based on microsensors with sensitive graphene oxide/polyaniline layers for the quantification of target gases (CO, NH3, NO2, formaldehyde) in gas mixtures.Within the project, the design and processing part of the work masks was carried out with the help of which, based on a predefined technological process, the test structures were obtained, on a ceramic substrate, structures sensitive to the detection of the gases of interest (CO, NH3, NO2, formaldehyde). The test structures were made, on a ceramic substrate, obtained for the detection of the gases of interest.

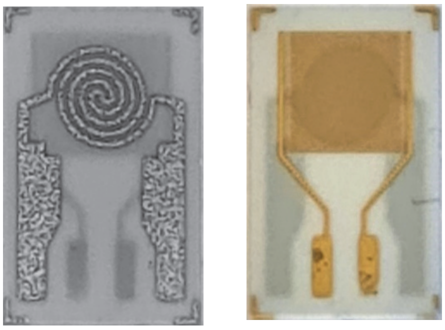


Gas sensor test platform

► **National Project:** ***Micronanotechnologies for greenhouse gases monitoring (TECH4GREEN),*** **PED project, 2020-2022**
Coordinator: Dr. Carmen Moldovan

The project developed a new technology for monitoring greenhouse gases using a series of newly designed sensors. For this purpose, a series of microsensors using miniaturized, alumina-based transducers were used. The target gases in this project, considered to be the main contributors to the greenhouse effect, were methane (CH4), ozone (O3), carbon dioxide (CO2), as well as humidity (water vapor). The micro-transducers consist of alumina µ-chips with interdigitated gold electrodes on top (front of the transducer) and platinum microheater on the back of the transducer.

At the end, the sensors will be connected to a portable electronic module for data acquisition, display and subsequent Wi-Fi data transmission. For the moment, the set of masks necessary for the development of sensitive structures was manufactured. At the same time, the technological flow for obtaining sensors for the detection of greenhouse gases was defined. The test structures, on a ceramic substrate, for the detection of the gases of interest are presented in the following figure.



Test structures on ceramic

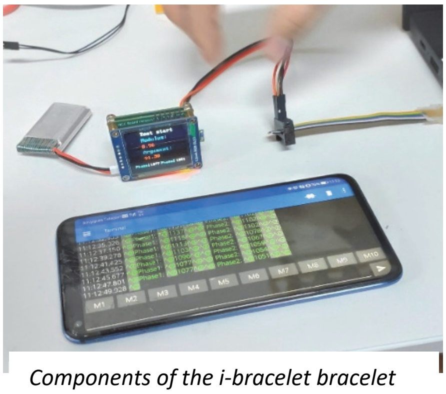
► **Eurostars Project** ***iBracelet - Inteligent bracelet for blood pressure monitoring and detection of preeclampsia*** – (InfoWorld and "Politehnica" Univ. Bucharest, Romania, Cherry Biotech and Elvesys, France); 2017-2020, IMT Responsible- Dr. Carmen Moldovan

The i-bracelet project "Smart bracelet for monitoring blood pressure and detecting preeclampsia" aims to develop a portable medical device for continuous monitoring of blood pressure and detection of blood pressure problems (such as hypertension).

The project consists of an intelligent sensor system for continuous management and outpatient monitoring of blood pressure. The system contains a sensor module, an electronic module and a wireless transmission module, these being the components of the smart bracelet created. A software application controls the operation of the system and provides data transmission and processing. The pressure sensor that detects the blood pressure waveform is based on a carrier micro fluidic sensor located in the wrist area. It works based on the technique of arterial tonometry. The electronic module ensures the conditioning and processing of the sensor signal, and the data is transmitted wirelessly to a smartphone or tablet.

A dedicated algorithm processes data and provides relevant physiological parameters that are displayed in numerical and graphical format on a graphical interface. An alarm signal is issued when the blood pressure value exceeds the normal level.

The smart bracelet for conditions caused by high blood pressure allows 1) early detection of preeclampsia, and 2) other conditions caused by high blood pressure.



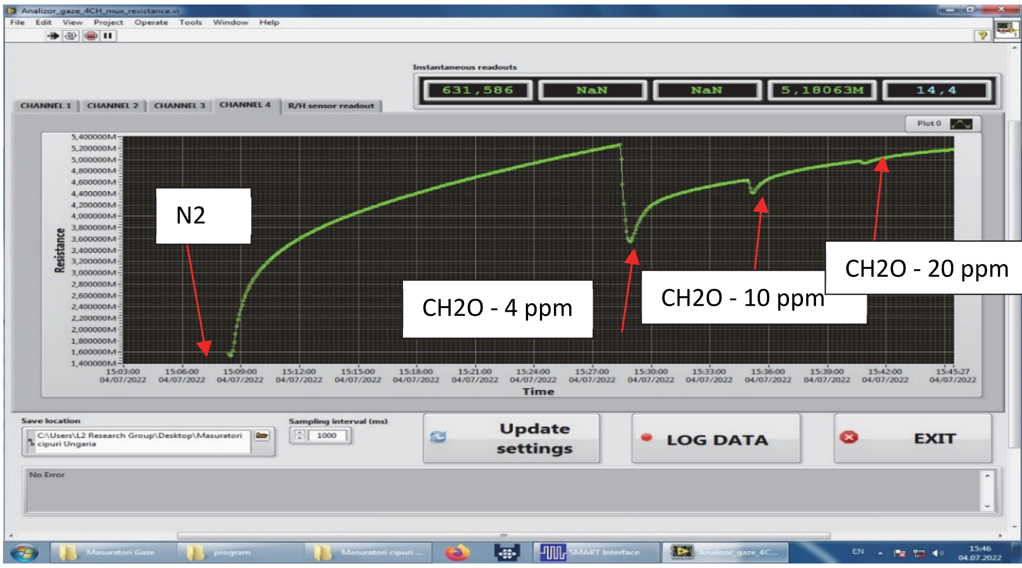
Components of the i-bracelet bracelet

Graphical interfaces of the i-bracelet application

► **m-ERA.NET, Project** ***VOC-DETECT - Smart Portable System for VOCs detection*** - (partners: ICF and NANOM MEMS SRL – Romania, Institute for Technical Physics and Materials Science (MFA), Hungarian Academy of Sciences) **– coordinated by UPB**

The focus of the project was on the development of new sensors, highly sensitive, and selective, for detection of the most dangerous VOCs affecting the human health at low concentration exposure and with a high probability to be found in houses and working environments: Formaldehyde and Benzene. Sensitive materials (CuO and CoO films) with detection properties of volatile organic compounds (formaldehyde and benzene) were tested by depositing them on alumina transducers with different thicknesses. The target gas concentrations were established in the range of 0.5-4.0 ppm. The selectivity of the sensors for the two VOC gases was measured. It can be concluded that the sensors with sensitive film of CuO are partially selective for formaldehyde and have a lower working temperature by 800C than the sensors with sensitive

The portable system for real-time data film of CoO, which are also partially selective to formaldehyde, but at higher working temperatures. From the experimental point of view, the sensors have a good response (110-230 seconds), reproducible, and a complete recovery for the tested VOC gases. At the end, a Smart portable system to be used in houses or working environment was provided. The measurement data can be received and read with the help of an application developed on the phone through a bluetooth connection.

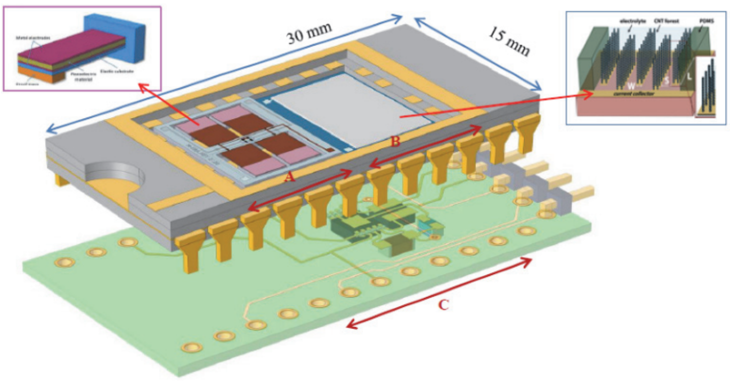


Response of the sample No. 9 for Formaldehyde (CH_2O*)*

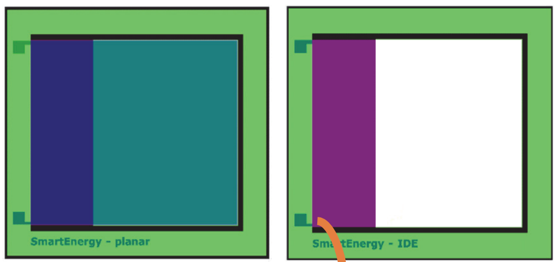
► **m-ERA.NET, Project** ***"Piezoelectric Energy Source for Smart Factory Applications (SmartEnergy)",*** **2021-2024.**
Coordinator: Dr. Carmen Moldovan

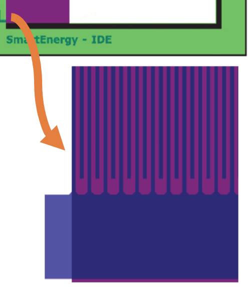
SmartEnergy project will develop a high-efficiency, scalable and reconfigurable energy source through the integration of a piezoelectric energy harvester (a MEMS device which will harvest the ambient mechanical vibrations and transform them into electrical energy using a cantilever structure), an electronic circuit for signal rectifier from the energy harvester and a supercapacitor for energy storage. The new energy source is dedicated for ultra-low-power sensors and it could replace conventional energy sources (batteries) and significantly reduce the impact on the environment.

Within the project, different parameters for car vibrations were measured and the initial specifications were defined. Targeting a resonant frequency of down to 200Hz and accelerations up to 3g, 3D structures were designed and simulated in COMSOL Multiphysics 5.6 and the processing masks and technological processes were designed for two different versions of the harvester, one with planar electrodes and one with inter-digits electrodes (IDE).



Energy harvesting device: (A) piezoelelctric energy harvester; (B) Supercapacitor; (C) Electronic module



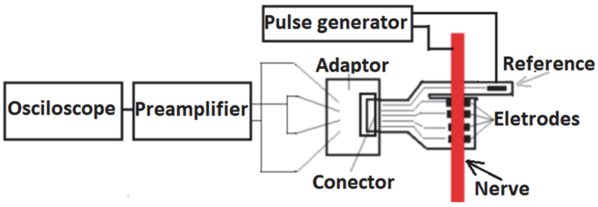


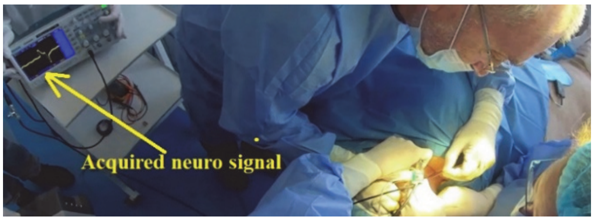
Processing masks design for two versions of the energy harvester (overlapped masks): planar electrodes – left; inter-digits electrodes (IDE) with detailed view – right

► ***ARMIN project (Arm neuroprosthesis equipped with artificial skin and sensorial feedback) EEA Grant, EEA-RO-NO-2018-0390, nr. 8/2019; Coordinator: "Politehnica" University of Bucharest; IMT responsible: Carmen Moldovan***

The overall aim of the project is to develop a new, functional and performing neuroprosthesis, providing the amputee with the possibility to recover the lost arm functions. The results obtained so far in the project include a prototype of the mechanical structure, the design of the implantable electrodes and several experiments regarding the functionality and biocompatibility of electrodes. The implantable electrodes were made of gold and were fabricated on Kapton substrate (50 microns thick) using metal deposition by sputtering, gold patterning by lift-off and clean room facilities and equipment. They have been designed to be wrapped around specific branches of the median /ulnar nerves from the patient's stump.

Two types of neural interfaces for bidirectional connection of the prosthesis to the peripheral nervous system in the patient's bladder have been designed and fabricated at IMT. Motor neural interfaces have been designed and fabricated to process signals acquired from the patient's motor nerves and transmit them to the neuroprosthesis control system. Tactile feedback neural interfaces were designed and fabricated for the transmission of tactile signals from the neuroprosthesis to the sensory nerves in the patient's fob. The functioning of motor neural interfaces was achieved with the help of doctors at Floreasca Clinical Hospital in a clinical study on 2 pigs.





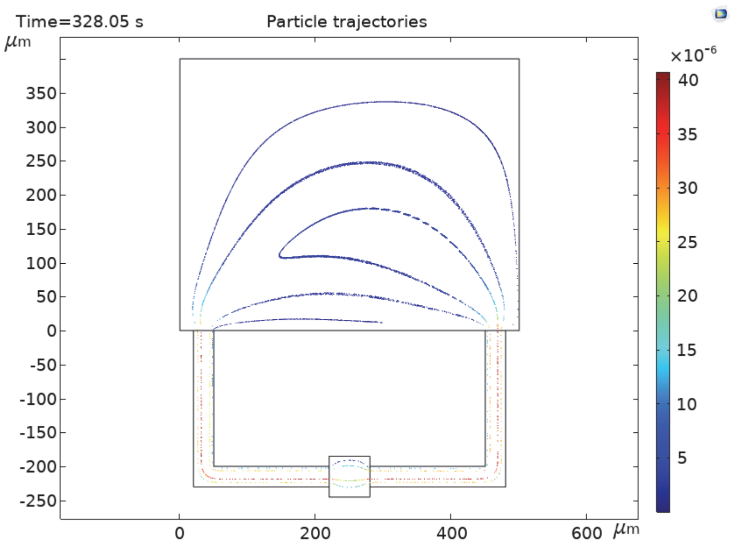
Acquisition of neural signals from the motor nerve of a pig during clinical study

► ***ECSEL-JU: Moore4Medical - Accelerating Innovation in Microfabricated Medical Devices, 2020 – 2023; Coordinator: Philips Electronics; IMT responsible: Bogdan Firtat***

Design and optimisation for Organ-on-Chip devices

The Moore4Medical project aims to take an important and essential step towards the standardization of Organ-on-Chip technologies, through the development of open technological platforms. The proposed smart multi well plate system is an example of such an open technological platform, which will perfectly suit the biological and pharmaceutical flows, and will be able to define the necessary standards for the implementation of Organ-on-Chip technologies.

The smart multi well plate (SMWP) system will be designed to cover the widest possible range of Organ-on-Chip applications where active perfusion, physiological stimulation and electrical sensing are needed. The SMWP system will need to accommodate various Organ-on-Chip applications that meet the interface requirements between the board and the electronic chips.



The simulated particles behaviour within the fluidic system

For Organ-on-Chip systems, one of the main elements is the ability to ensure the correct and continuous flow of fluids and cells in the reaction zone. The system consists of the organ-on-chip device located in a microfluidic path that contains a pump to ensure the continuous flow of fluids and a reservoir, located in its upper part. The initial stage of using the system consists in placing living cells inside the organ-on-chip device, by inserting them into the microfluidic path. After this stage, the reservoir is filled with the working medium and the pump is started, which will ensure the recirculation of the fluid along the reservoir - organ-on-chip device and return route. To avoid these phenomena, it is very useful to design the system in such a way as to minimize the number of cells that are taken over by the microfluidic system and that reach the micropump area. For this purpose, we used the CFD simulation techniques offered by COMSOL Multiphysics to optimize the design and smooth operation of the system.

AMBIENTAL TECHNOLOGIES Laboratory – L8

Laboratory head: Dr. eng. Ileana CERNICA

Mission

RDI of new micro/nanosensor technologies for societal, security and environmental applications (Technological design, technological development up to prototype level) including the IoT part**/ RDI for applications in space and security** - special operating conditions and reliability (Technological design, technological development up to prototype level)/ **RDI 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: Technological assistance and consultancy (design of technological flows, control gates, etc.)/ **Analyze technological compatibilities and defects, on the technological flow/Technological assistance** when moving from prototype to zero series (technology transfer)/**Development of individual technological processes**

All the activities of the Ambiental Technologies Laboratory is carried out with the aim of improving environmental conditions and increasing individual and societal security and for upgrading traditional industries in order to make them more efficient. In recent years, the Laboratory's activity has diversified with applications in the space field (ESA, STAR ROSA projects) and the hard part for AI projects. Specific for L8 is the increased number of projects with completion in TRL greater than TRL 5 and collaboration with SMEs (up to technology transfer)

Expertise

Research-Development-Innovation Competences:

- ✓ Advanced technologies for making solar cells (including for space applications);
- ✓ Surface and volume microprocessing technologies;
- ✓ Integration technologies of signal electronics with sensors;
- ✓ Micro/nano sensor technologies (including sensor arrays);
- ✓ Optoelectronic technologies (e.g.: photodiodes, suppressor diodes, optical alignment systems);
- ✓ Technologies for optical elements (microlens arrays, thin lenses, thin mirrors);
- ✓ Technologies for advanced nanocomposite materials with antibacterial, antifungal properties with applications in civil construction, agriculture, health;
- ✓ Technologies for optical alignment systems with operation in special working conditions (e.g.: applications in space);

Services Characterization and Technological Processes Competences

- ✓ Microsystem electrical characterization;
- ✓ Individual technological processes & technological flows design;
- ✓ Realization of test benches and signal electronics;
- ✓ IoT enabling technologies

Team

Dr.eng. Ileana CERNICA – Senior Researcher I, PhD. in microelectronics, head of laboratory; **Dr. Elena MANEA**, Senior Researcher I, PhD in physics; **Dr.eng. Ciprian ILIESCU**, Senior Researcher I, PhD in mechanical engineering; **Dr.eng. Octavian Narcis IONESCU**, Senior Researcher II, PhD in Systems Theory-*collaborator*; **Dr. Florina Silvia ILIESCU**, Senior Researcher II, PhD in medicine; **Dr. Violeta DEDIU**, Senior Researcher III, PhD in materials engineering; **PhD student Florian PISTRITU** – senior electronics engineer; PhD student in electronics (Politehnica University-Bucharest); **PhD student Edwin Alexandru LASZLO**, Researcher, physical engineer, PhD student in Physics (Bucharest University); **PhD student Andreea Gabriela Marina POPESCU**, Assistant Researcher, physical engineer, PhD student in Electronics (Politehnica University-Bucharest); **PhD student Costel PAUN**, Assistant Researcher, Electrical Engineering, Master: Technical and Applied Magnetism, PhD student in Electronics (Politehnica University-Bucharest).

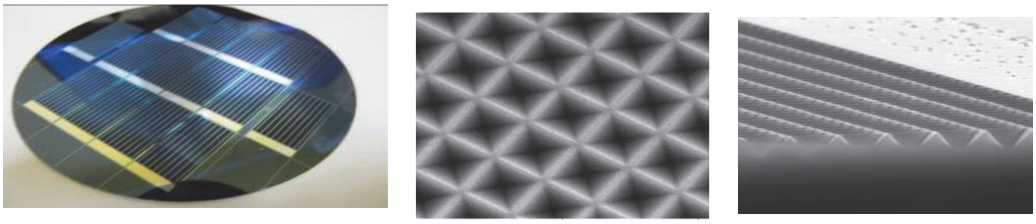
Scientific highlights

Project: TGE-PLAT 77.7D High efficiency microtextured photovoltaic cell system integrated in the wing of an unmanned aircraft (UAV) with applications in social security – UAVPHOTO, IMT project manager Dr. eng. Octavian Narcis Ionescu, onionescu@gmail.com

TRL 2-TRL 6 (flying prototype)

The UAV is adapted for data collection from sensors and satellites and benchmarking for streamlined monitoring in agriculture or CBRN surveillance. Highly efficient micro-structured solar cells can also be used in space applications. Two samples made of the same material as the prototype were made and covered with photovoltaic cells, for testing using the small size equipment from IMT-Bucharest. Based on the regulations used for UAVs, they were mechano-climatically tested (vibrations, repeated bends, temperatures +/-). The results showed that the technology used to make them meets the requirements of using the prototype made for UAVs.

The prototype allows the increase of the flight autonomy by approximately 20 minutes, the increase depending on the meteorological conditions. The initial autonomy of the model is 180 minutes.



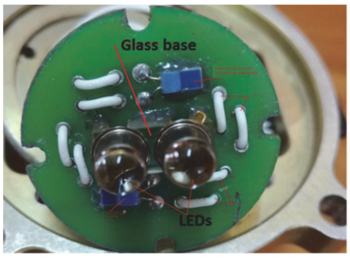
High efficiency microtextured solar cell structures (structure on wafer and SEM details)

Ultralight wing with solar cell area built-in.
Hirrus UAV with cell area solar wing landed (improving flight time by 20 min.)

Project ESA FQ/3-13899/13/NL/GLC PROBA 3 Coronograph System ESA Space Mission
Prime contractor: Centre Spatial de Liege; Subcontractor for OPSE" Occulter Position Sensor Emitters Heada"
IMT project manager Ileana Cernica, ileana.cernica@imt.ro

TRL 2- TRL 9 (space mission)
The PROBA 3 mission aims to create 2 satellites that fly in formation for the space study of the solar corona. The first is equipped with a shutter of the solar corona. The second satellite carries a telescope studying the solar corona. In order to be able to do the study, it is necessary for the formation flight of the 2 satellites to be synchronized so that the telescope can only "see" the crown and not the sun. An important element of alignment are the 3 Occulter Position Sensor Emitter (OPSE) systems developed by the IMT-Bucharest PARTNER.

OPSE Flying model



OPSE Flying model detail

OPSE Flying model detail

TECHNOLOGICAL achievements – The realization required special conditions (for space applications). Starts with optimized redesign. Then DM, STM, EM, QEM models and finally with Flying Model was the first device of this type made and was made in Romania. DEMONSTRATION\ VALIDATION - The launch of the PROBA 3 Mission will take place in the 3/2023 quarter in the French Guyana polygon.

Project: PN-III-P4-ID-PCE-2020-1886 Microfluidic platform on paper for the concentration and amplification of nucleic acids
IMT project manager: Dr. Ciprian Iliescu cipi_sil@yahoo.com

TRL 2-TRL5
Paper-based microfluidic devices are attractive, low-cost, and easy-to-use diagnostic platforms for nucleic acid (NA) amplification and testing. However, they have limited clinical applications due to their relatively low sensitivity and the substantial amount of AN required for detection. Therefore, sensitive and specific detection of AN using paper-based microfluidic devices requires the incorporation and development of both sample preparation and amplification steps at the same time. The project aims to design, fabricate and test a 3D, modular microfluidic platform for molecular diagnostics - probe-response type (HEAD-NAs) that aims to work with low concentrations of AN. The platform integrates four different original modules: filtration, lysis, preconcentration and amplification. The original elements are related to: sample preconcentration method, electrochemical lysis module, thermophoretic convective valve, AN amplification design structure. A pathogen detection test kit will be developed with 5 independent detection points (one for control) for the simultaneous detection of: Enteropathogenic / Enterohemorrhagic E. coli, Campylobacterspp., Salmonella spp., Rotavirus. The HEAD-NA platform has great potential for further commercialization of national and EU collaborations.

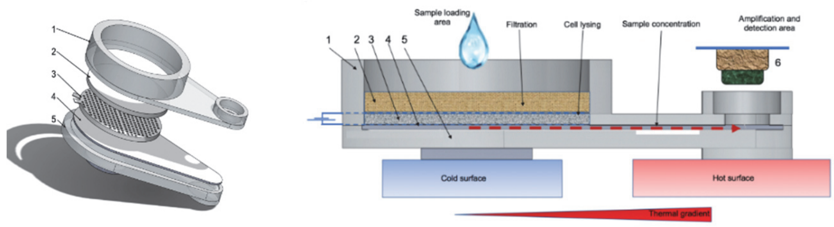


Figure 1: 3D image of the microfluidic device on paper and the principle of operation

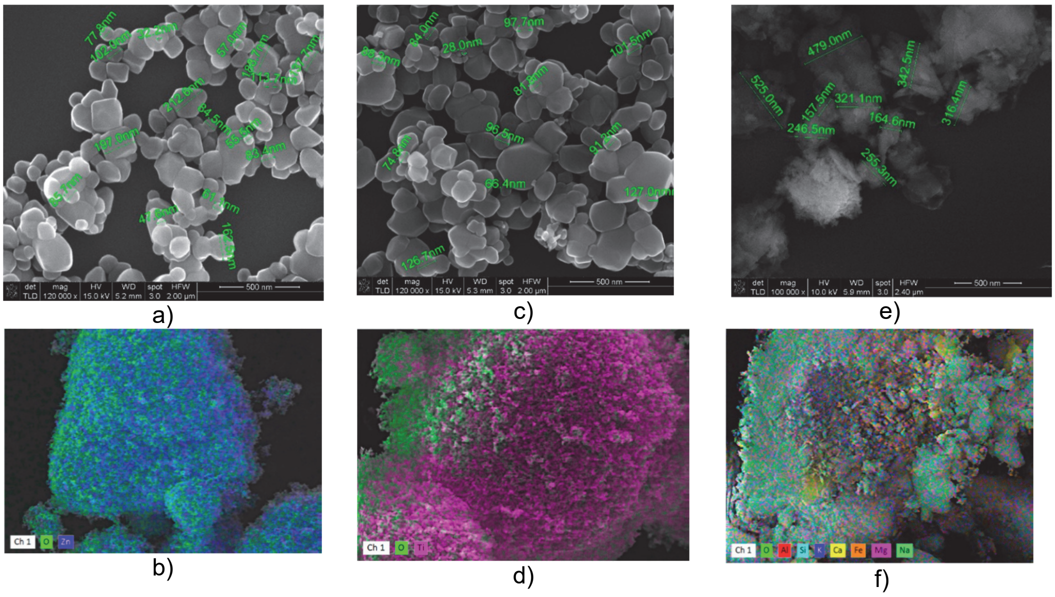
Project:* Adaptive mobile mixing and dispersing system using nanoparticles into innovative colloidal solutions for chemical, biological and radiological agents' mitigation/ *NANODEC, *PN-III-P2-2.1-PED- 2020-2022*, project manager Dr. Munizer Purica (munizer.purica@imt.ro).

TRL 2-TRL4

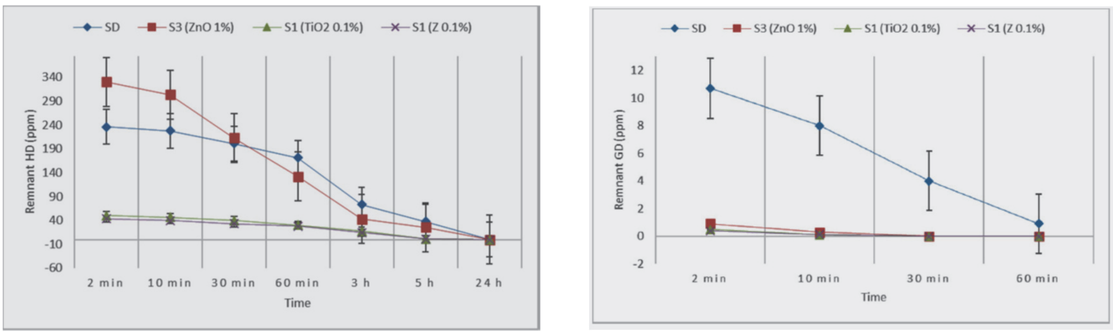
The NANODEC project aims to obtain a new innovative colloidal solution, based on an organic decontamination matrix combined with several types of nanoparticles and a new adaptive system for dispersing the prepared solution. The components of the proposed organic solution are: 1) ethylene glycol mono-ethyl ether; 2) mono-ethanolamine; 3) sodium hydroxide solution; 4) isopropyl alcohol; 5) sodium lauryl sulphate. The selected nanomaterials that will be added to the organic solution for the decontamination experiments are: zinc oxide nanoparticles that have proven antibacterial; titanium dioxide nanoparticles that present photocatalytic properties; micro/nano-crystalline zeolites extracted from Transylvania, with a porous structure and with adsorbent and catalytic properties.

Results:

- Organic decontamination solution as a dispersive medium for adsorbents for nanoparticles, Fig. 1. The concentrations of ZnO, TiO2 anatase and zeolite were (wt. %) – 0.1; 0.5; 1; 2 zinc oxide, titanium dioxide and zeolites;
- The testing and evaluation of the decontamination efficiency for two chemical agents (toxic mustard gas/HD and soman/GD) and a biological agent (Bacillus anthracis), Fig. 2, was carried out on the specific equipment and procedures by the project partners – CCIACBRNE /P1 and TM/P2.



SEM images and EDX mapping of nanoparticle clusters: (a,b) ZnO, (c,d) TiO2, and (e,f) zeolites/Z.



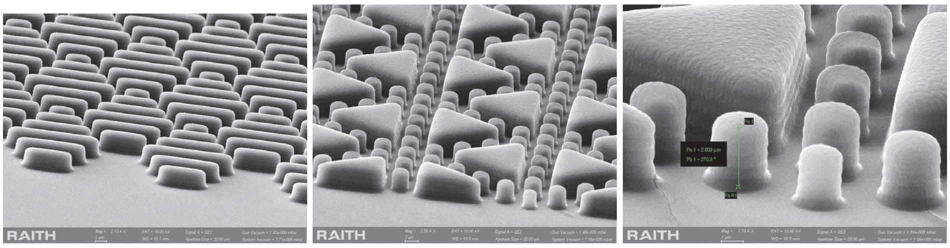
Residual contamination with HD and GD after decontamination with the prepared solution.

Core funding 14N/2019-2022: MICRO-NANO-SIS PLUS, Project: Integrated technologies using smart multilayer coatings based on nanocomposite materials for monitoring and preventing bio-deposits on marine-immersed surfaces without affecting local eco-systems*;* *Acronym ECO-SAFE* Project manager: Dr. Eng. Ileana Cernica, Ileana.cernica@imt.ro

TRL 2-TRL 5

Core Project/Phase 3/2020: Design and technological experiments of microfluidic topography in nanocomposite films,
contact person Dr. Elena Manea, elena.manea@imt.ro

Anti-fouling (AF) coatings have been developed to prevent surface contamination with bio-deposits. Currently, one of the nontoxic AF strategies is to physically disrupt the adhesion of marine micro-organisms by using microtopographic surfaces, as used by natural marine organisms – such as shark skin, mollusc shells which discourages the deposition of biofouling on them. We present non-toxic microtopographic surfaces made by the technique of casting in Si moulds and replication in PDMS.

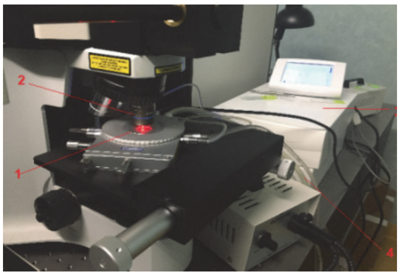


The SEM images of micro-topographies made in PDMS: a) imitation of shark skin made of ribs of combined lengths of 2, 4, 8, 12 μm and separation widths of 2 μm and heights of 3 μm; b) equilateral triangles with a side of 10 μm surrounded by circular pillars with a diameter of 2 μm and a height of 3 μm; c) detail of the component element

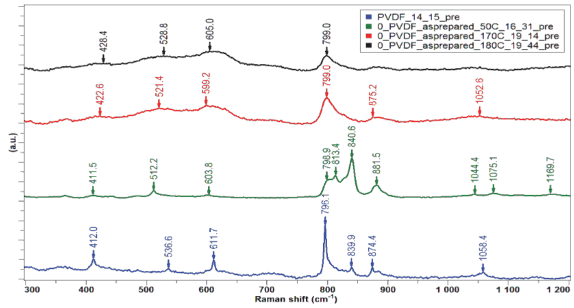
Obtained AF micro-topographies are useful for reducing the settlement of marine micro-organisms with sizes from a few microns to a hundred (algal spores (5−10, diatoms (3−15 μm))), considered to be the major microfouling organisms.

Core Project/Phase 4/2020: Development of characterization methods for evaluating the structure and behaviour of nanocomposite multilayers in order to optimize technological processes,
contact person Dr. Munizer Purica, munizer.purica@imt.ro.

A method for the investigation of thermally induced phase changes transition in thin polymer layers using Raman spectroscopy has been developed. An experimental platform for in situ Raman analyses with temperature was configured and realized by coupling the LabRAM HR spectrometer with a thermo-electric cell with a rigorous temperature control over a wide range of temperatures, from -150 °C to + 600 °C. The developed method was tested and validated on samples of polyvinylidene fluoride (PVDF), a polymer that presents a pronounced polymorphism, 4 phases - α, β, γ, δ, and shows an evolution of the structure depending on the temperature.



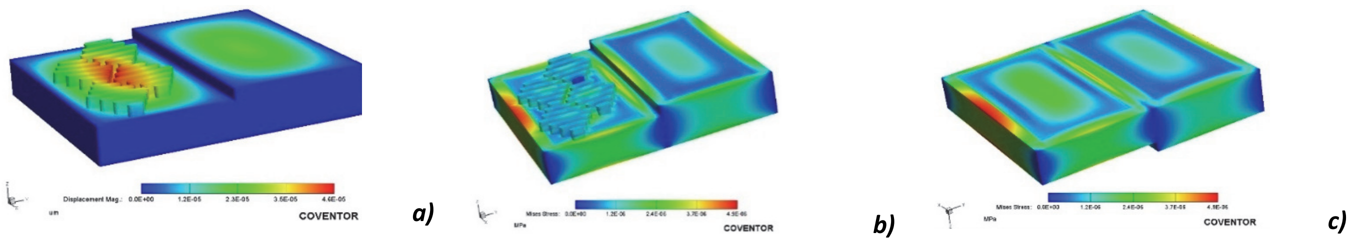
The test platform connected to the micro-Raman spectrometer, LabRAM HR 800. 1- thermoelectric cell with optical access; 2- the objective of the confocal microscope, with a focal distance of 4.5 mm; 3- temperature controller; 4- connection to the water recirculation pump.



The evolution of the structure of the PVDF polymer sample depending on the temperature. The α phase (~799 cm^{-1}) predominates up to 25 °C and, at 50 °C there is a transition to the β phase(513 cm^{-1}, 840 cm^{-1}) which predominates up to close to 150 °C.

Core Project/Phase 5/2021: Simulation and modelling of integrated multilayers - functional simulations,
contact person: Dr. Oana Nedelcu oana.nedelcu@imt.ro

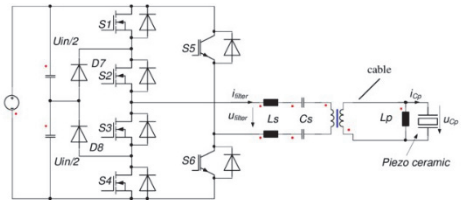
Models and simulations were made to determine the mechanical and thermal properties for two types of nanocomposite materials depending on the component materials: CP1-rasina epoxydic si nP de ZnO si CP2- PVDF- nanorods de ZnO . Functional numerical models were built for multilayer nanocomposite test structures and thermo-mechanical simulations were performed using the calculated properties of nanocomposites to evaluate the mechanical and thermal behaviour of the representative elements of multilayer structures (CP1 - anticorrosive / CP2 piezoelectric / AF layer, respectively CP1 - anticorrosive / AF Maritime). The figure below shows the results of the mechanical response analysis for structures with AF topography configured on the PDMS layer and without topography for the two volumes that were joined for comparison but physically disjoint



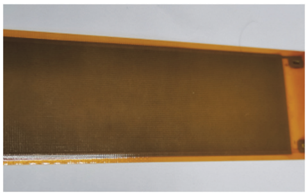
Comparative results of mechanical simulation for the structure with and without topography:
(a) displacement (μm); Mises voltage in view of the top (b) and bottom (c)

Core Project/Phase 6/2021: Design and realization of the control/command signal analysis electronics of the intelligent multilayers, contact person Dr. Eng. Octavian Narcis Ionescu onionescu@gmail.com
The piezoelectric layer made of PVDF can be considered from the point of view of electrical signal supply as being similar to a piezo actuator. In order to control the large areas, the electrical diagram of the control assembly was designed. Based on the measurements made with the test module, a resonance frequency of 35 KHz and a voltage amplitude of 270 Vpp. Inverter topology consists of a hybrid inverter with three PWM levels was chosen. The left branch of the inverter is composed of four MOSFETs (S1

- S4), operated on the pulse width. The modulation frequency is three times higher than the fundamental one, that is, 105 kHz. The right branch of the inverter consists of S5 and S6 that operate only at the fundamental frequency.



Inverter PWM plus LLCC-filter



Experimental module of the layer for the prevention of bio-deposits on the submerged surfaces without affecting the local eco-systems

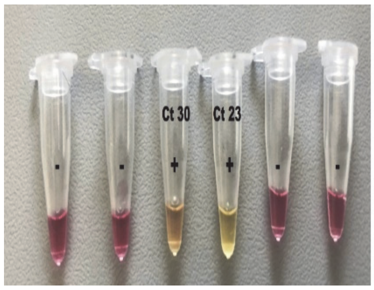
The image of the matrix of elements from the piezoelectric material and of the conductive routes through which the supply is made

PN-III-P2-2.1-SOL-2020-0090 Solutions Project 2020-2021 Project: Advanced techniques and performance enhancement in early virus detection SARS-CoV-2 Project manager: Dr. eng. Ciprian Iliescu cipi_sil@yahoo.com
Partners: Bucharest University and Bucharest University Emergency Hospital

TRL 2- TRL 6

The project proposes the RT-LAMP reaction as an alternative for the development of molecular tests for the detection of SARS-CoV-2 viral RNA. Our research shows that the RT-LAMP reaction with certain primer sets for viral genes can have a lower limit of detection of 300 viral RNA copies /µl for the colorimetric variant, with visible reading, and even as low as 0.5 viral RNA copies / µl for the fluorometric version with real-time reading. It was noted that the specificity of the RT-LAMP test, which did not generate any false positive results, so that a person can be considered almost certainly infected with the SARS-CoV-2 virus if the RT-LAMP test result is positive.

Within this project, prototypes of devices capable of supporting the rapid detection reaction of SARS-CoV-2 RNA were developed and evaluated. Optimizing the incorporation of rapid detection reactions in such devices opens up the possibility of performing molecular tests for the detection of SARS-CoV-2 outside specialized molecular biology laboratories, thus facilitating the early diagnosis of patients with COVID-19.



Validation of the LAMP protocol on clinical samples (yellow-positive, red-negative)

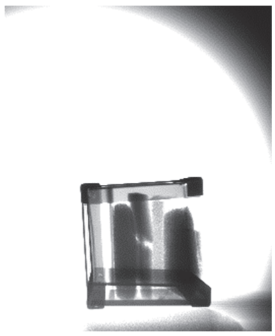
Project (won at the SEAP auction): 221993/18.09.2020, research services - Development of a mobile system of anti-ballistic panels for the protection of personnel and strategic infrastructure against small and medium-sized artisanal bombs
Contractor: ROMANIAN INFORMATION SERVICE through Military Unit 0466
IMT project director: Dr. eng. Octavian Narcis Ionescu onionescu@gmail.com

TRL2- TRL 7

The project aimed to develop a "mobile system of anti-ballistic panels for the protection of personnel and strategic infrastructure against small and medium-sized artisanal bombs". The created system is composed of three interconnected mobile frames that can be positioned so as to frame the improvised explosive device on three sides in a "U" configuration or on two sides in a "V" configuration. The anti-ballistic devices are mounted on these frames. The proposed modular solution ensures the quick installation by a small number of personnel (maximum of two operators) of the entire system in a short period of time and under maximum security conditions.

The central and innovative element is represented by the creation of a panel with a structure multilayer, which uses innovative materials with increased efficiency, having superior physical-mechanical capabilities. The realization of these materials as well as their integration into a structure capable of resisting the cumulative effect of shrapnel and the shock wave also represents an exceptional technological achievement. The panel system was made in IMT and successfully tested in the Mihai Bravu training ground.

Panel prototype



X-ray characterization of the Experimental Model penetrated by an Φ 3mm steel ball accelerated to 1200 m/sec

The Micro- and Nano-Fluidics laboratory – L10

Laboratory head: Dr. Marioara Avram

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**. **The Micro- and Nano-Fluidics laboratory** is the result of the **multidisciplinary project** POSCCE, O.2.1.2 Nr. 209, ID 665, Microfluidic Factory for "Assisted Self-Assembly" of Nanosystems (MICRONANOFAB), which gathered experts from micro- nanotechnology and chemistry, and had the fundamental objective the realization of a prototype of an integrated microfluidic system able to dose, encapsulate and deliver different chemicals for medical treatment.

Expertise

- **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**.**
- **Investigation of fluid flow and rheology at the microscale,** and its application to optimize lab-on-a-chip devices. Experimental nano- and microtechnology: cleanroom processes (e.g.: glass silicon and polymer micromachining, plasma-based processes), design, simulation, fabrication and characterization of MEMS and biosensors.
- **Development of micron-resolution particle image velocimetry (µ-PIV), micro**-mixing devices and protocols, particle manipulation using dielectrophoresis and magnetophoresis and analysis of boundary conditions at the microscale.
- **Bioengineering:** Cellular uptake of gold-coated maghemite superparamagnetic nanoparticles; studies of cells apoptosis induced by magnetic hyperthermia; tumour cells investigation using UV fluorescence, microscopy (SEM, SNOM) and spectroscopy (FTIR, Raman, Impedance).
- **Microchannel Flow Physics:** Hydrodynamic focusing of liposomes (e.g.: a three-inlet and one outlet design) has been studied from experimental & numerical viewpoints.
- **Molecular transport in microfluidic devices:** Magneto-phoretic system for detection of magnetic marked biomolecules; active magnetophoretic systems for cell separation through magnetic fields; filters for separation of microparticles with different morphological, electrical and magnetic properties; nanoparticles separation microfluidic devices.
- **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: **Dr. Marioara Avram** (PhD in Physics) - laboratory head, senior researcher I; **Dr. Cătălin Valentin Mărculescu** (PhD in Fluid Mechanics), senior researcher III; **Dr. Petruta Preda** (PhD in Biology), senior researcher III; **Dr. Vasilica Tucureanu** (PhD in Material Science)**,** senior researcher II; **Dr. Alina Matei** (PhD in Material Science), senior researcher II; **Dr. Cătălina Bianca Adiaconiță** (PhD in Chemistry), scientific researcher; **Drd. Tiberiu Alecu Burinaru** scientific researcher; **Drd. Eugen Chiriac**, scientific researcher.

International collaborations

- **European university research centres and companies from England, Spain, Germany, France, Austria, Norway.**

National collaborations

- **National cooperation with research institutes, universities and Romanian companies (SUUB, DDS, Spital LOTUS, SANIMED, UPB, UTBv).**

Scientific highlights

► „***Innovative approaches for control and treatment of SARS-CoV-2 virus infected patients SARS-CoV-2***" (Project code: PN-III-P2-2.1-SOL-2020-0061, contract nr.15SOL/2020) – (CoV-Control), 2020-2021 **Coordinator: Dr. Marioara Avram (**marioara.avram@imt.ro)

Microfluidic systems fabrication for DNA amplification: LAMP and NANO-PCR

- LAMP and NANO-PCR systems for DNA amplification are composed of: i) Fused Silica wafer – which contains the electric circuit, the interdigitated electrodes and the pads; ii) the PDMS (polidimetilsiloxan) microfluidic channel; and iii) textolite sheet with SATA II interface. 5 photolithographic masks have been used, 4 for the Fused Silica wafer and one for creating the PDMS microchannel matrix. The 4 masks have been: M1 – CIG Nanopillers, M2 – Gold electrodes CIC, M3 – CIG Passivation and M4

CIC Ag/AgCl. The differences between the 2 systems consist on the microfluidic channel design and the textolite sheet design (Fig. 1 and 2).

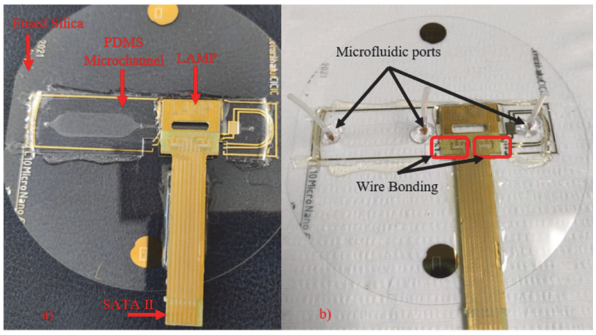


Fig. 1. a) LAMP system formed of PDMS channel bonded on the Fused Silica wafer and the textolite sheet bonded on the PDMS; b) Complete LAMP system with microfluidic ports and electrical connection between the LAMP board and the Fused Silica wafer.

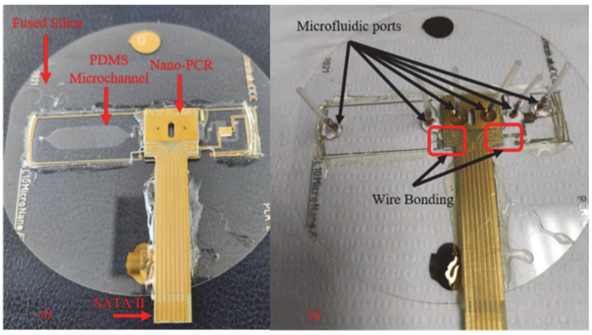


Fig. 2. a) Nano-PCR system formed of PDMS channel bonded on the Fused Silica wafer and the textolite sheet bonded on the PDMS; b) Complete Nano-PCR system with microfluidic ports and electrical connection between the LAMP board and the Fused Silica wafer

Microfabrication, characterization and testing of the vertical graphene based electrochemical sensor, for the detection of the SARS-CoV-2 nucleocapsid protein

- To test the electrochemical sensor functionalization several electrochemical measurements have been performed: impedance and cyclic voltammetry, to highlight the Nyquist diagram, performed using the electrochemical impedance spectroscopy method on PGSTAT204 equipment, with FRA32M module (electrochemical impedance spectroscopy – EIS module). The cyclic voltammetry was recorded using an electrolyte solution containing $[Fe(CN)6]3-/4-$ redox mediator, sensitive to functional groups from the surface of the vertical graphene modified electrodes. The Nyquist graph reveals the impedance change for different N protein concentration (1 nM to 1aM). The Randles circuit fits the experimental curve. In the equivalent Randles circuit we identified the electrochemical behaviour for high and low frequencies. At high frequencies, we can identify the solution resistance – Rs, the polarization resistance – Rp, and double layer capacitance – Cdl. The double layer capacitance is identified through the constant phase element (CPE) due to the porosity of the working electrode. CPE is a lossy capacitor. The behaviour at low frequencies is described by the Warburg impedance (W). The detection limit of the SARS-CoV-2 N protein is in at aM level.

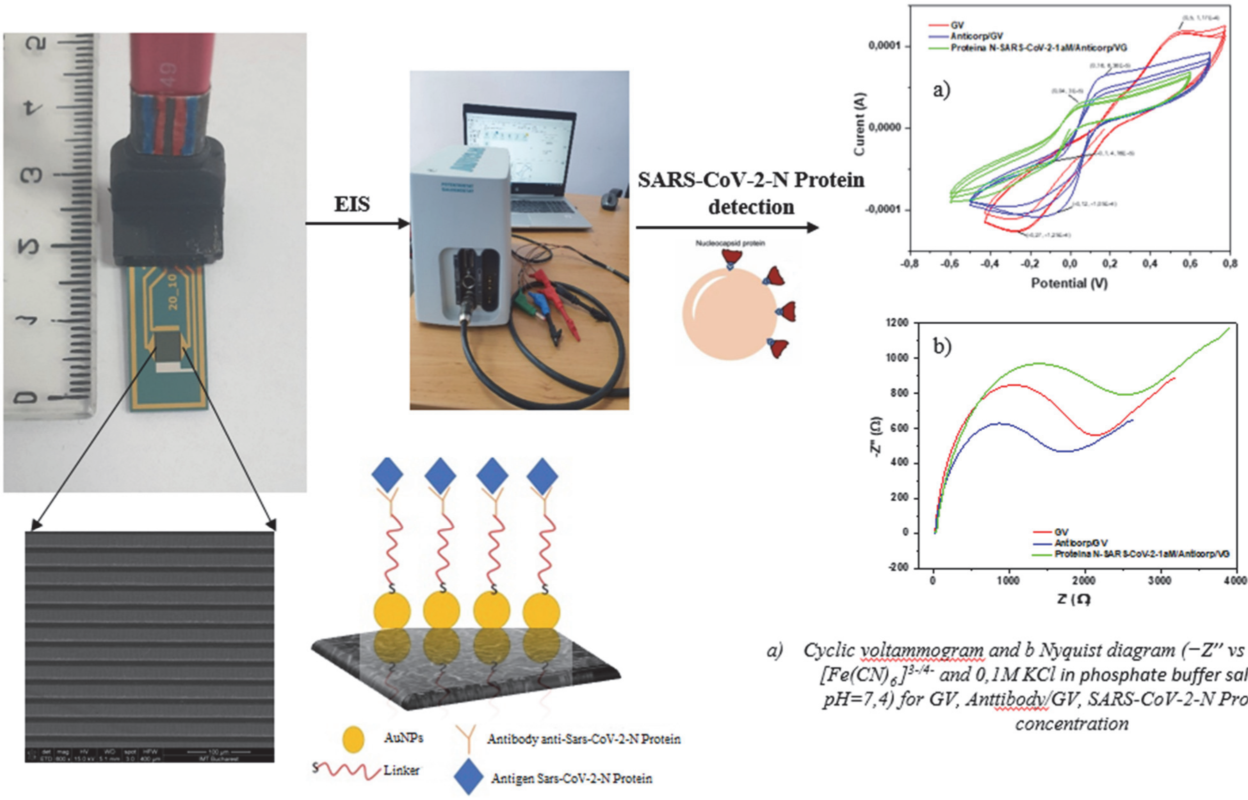


Fig. 3. Functioning layout of the vertical graphene based electrochemical sensor with interdigitated microelectrodes.

Microfabrication, characterization and testing of the nanocrystalline graphite-based field effect transistor for the detection of the SARS-CoV-2 nucleocapsid protein

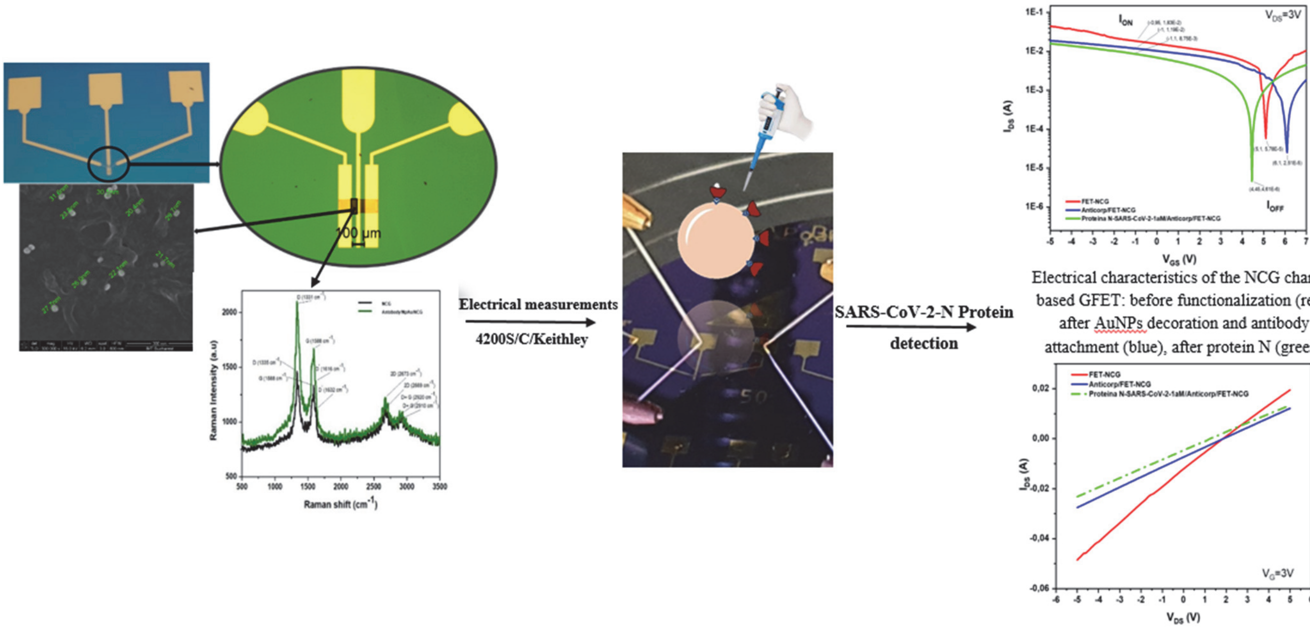


Fig. 4. Functioning layout of the nanocrystalline graphite-based field effect transistor.

► "***Microfluidic platform for circulating tumour cells (CTCs) concentration through dielectrophoresis-magnetophoresis and analysed via broadband dielectric spectroscopy and electrochemical impedance***" (Project code: PN-III-P1-1.2-PCCDI-2017-0214, contract 3PCCDI) – (uCellDetect). Project responsible: **Dr. Marioara Avram (**marioara.avram@imt.ro)

- The microfluidic platform is composed of tree substrates: the first substrate is a textolite sheet, with the electric pads for the clamps connection from the alternating current generator, the second substrate being the Pyrex wafer with the interdigitated electrodes and the electrical routes, and the third one, the PDMS microfluidic channel with the microfluidic ports.

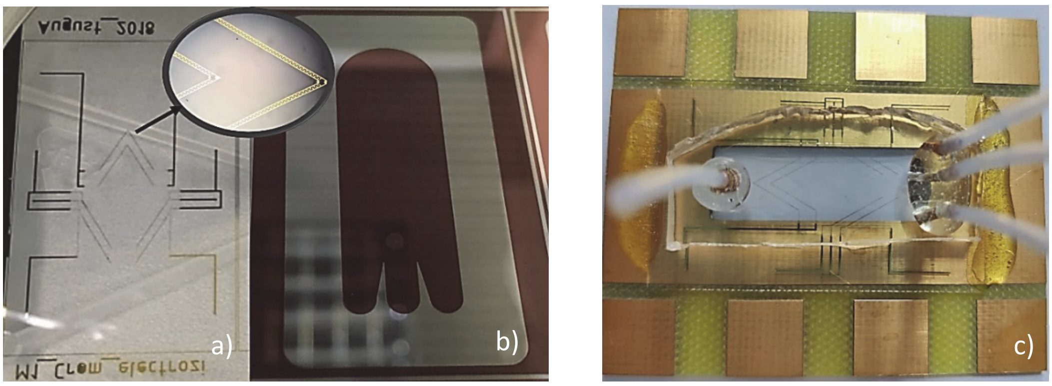


Fig. 5. a) Pyrex wafer with the interdigitated electrodes and the electrical routes; b) PDMS matrix; c) Final microfluidic platform composed of the textolite sheet Pyrex wafer, and the PDMS microfluidic channel with the microfluidic.

► "***Microfluidic platforms for biochemical sensors with applications in societal security"*** (P_40_283, code SMIS2014+ 105623, Contract No.: 77/1C). Project responsible: **Dr. Marioara Avram (**marioara.avram@imt.ro)

Experimental model for matrices fabrication using 3D microfabrication additive techniques

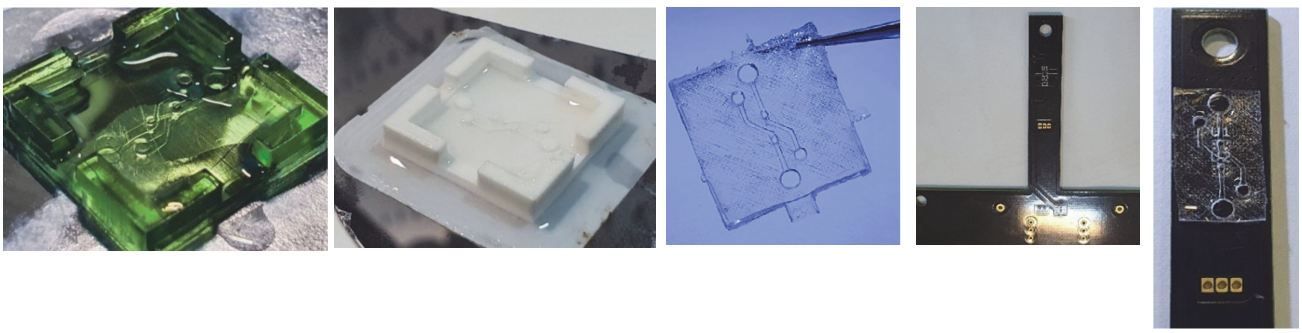


Fig. 6. Sequence of technologic stages to obtain and assemble the microfluidic system with integrated sensors on a PCB platform

► "*Electrochemical microsensors for the detection of drugs: codeine and morphine.*" **(P_40_283, code SMIS2014+ 105623, Contract no.: 77 / 08.09.2016). Project responsible:** Dr. Marioara Avram (marioara.avram@imt.ro)

Microfabrication of electrochemical sensors with nanocomposites modified sensors for codeine detection

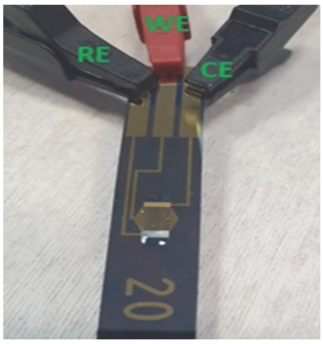


Fig. 7. Sensor with interdigitated microelectrodes fabricated on silicon substrate for codeine detection

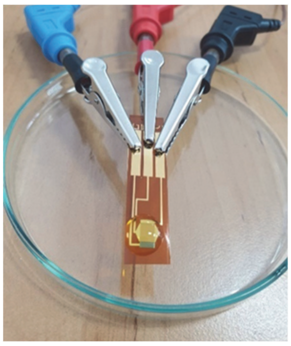


Fig. 8. Sensor with interdigitated microelectrodes fabricated on Kapton substrate for codeine detection

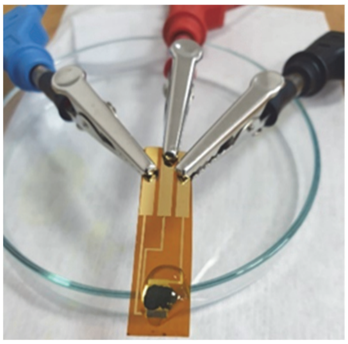


Fig. 9 Sensor with interdigitated microelectrodes modified with PVDF-RGO-NiO/Au paste, 3% composite filling material fabricated on Kapton substrate for codeine detection

► "***Technology based on anti-CD36 functionalized and nanostructured substrate for metastatic circulating tumour cells intake - CTCnanoSCAN.***" (PN-III-P2-2.1-PED-2019-3141, Contract 382/2020) Project responsible: **Dr. Marioara Avram (**marioara.avram@imt.ro)

Characterization and evaluation of the functionalized nanostructures biocompatibility

- Scope: Nanostructured substrates capacity evaluation to bind tumour cells. Because in the next phase we aim for a complex biologic product (blood mixed with tumour cells), in the current phase, we included for testing a new type of circulating blood cells (monocytes), that might interfere with the tumour cells binding. Moreover, we genetic edited the tested cells with CrisprCas9, silencing the CD36 receptor gene (CD 36KO cells). These cells will be used to evaluate the CD36 impact on the CTC intake efficiency in the next phase (2022).

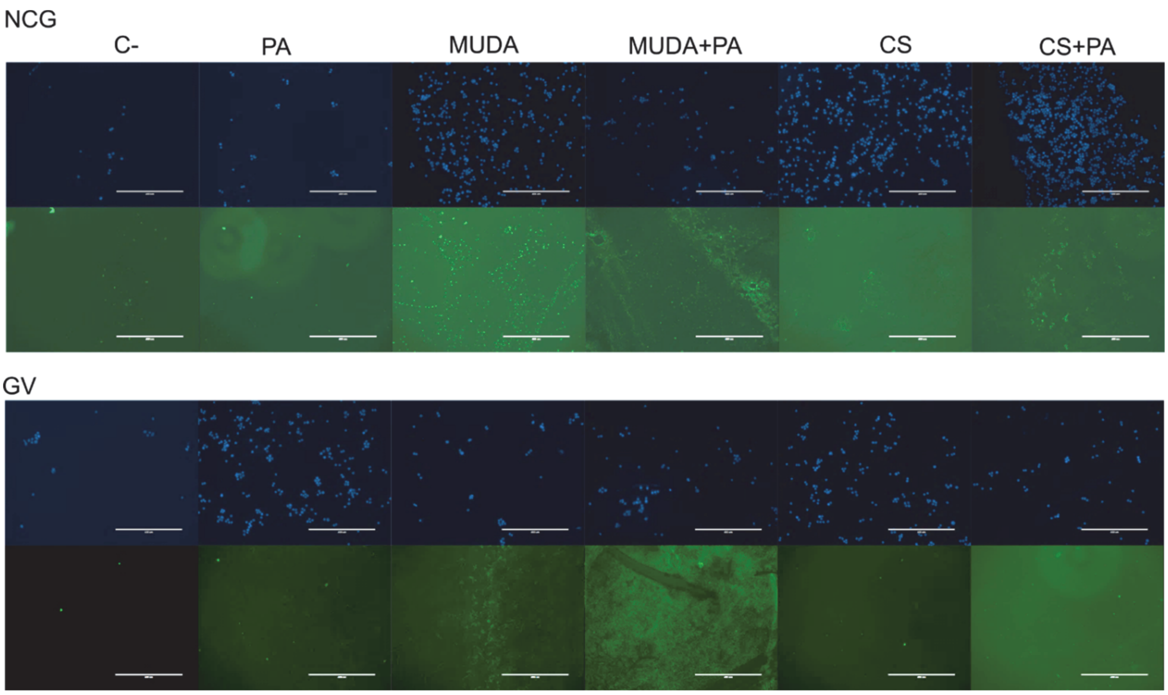


Fig 10. Parallel evaluation of the CTC capture and functionalization of the nanocrystalline graphite (NCG) and vertical graphene (VG) substrates.

► “***Magnetoresistive sensors optimized for on-chip magnetic nanoparticles – MagSensOnChip”*** - (PN-III-P2-2.1-PED-2019-3514, Contract 510/2020) **Project responsible:** Dr. Marioara Avram (marioara.avram@imt.ro)

- The microfluidic devices have been created using standard photolithography on silicon substrate, using positive photoresist AZ4562. The silicon substrate has been etched using a Bosch process in DRIE (Deep Reactive Ion Etching) on the microchannel mask (Fig. 11). The microchannel is 70 µm deep.
- Three types of carbon-based materials have been integrated in the microfluidic devices: SLG (single layer graphene), NCG (nanocrystalline graphite) and VG (vertical graphene), using different methods. SLG has been transferred from the copper catalysing substrate to the working substrate, while NCG and VG have been grown directly in the microchannel.

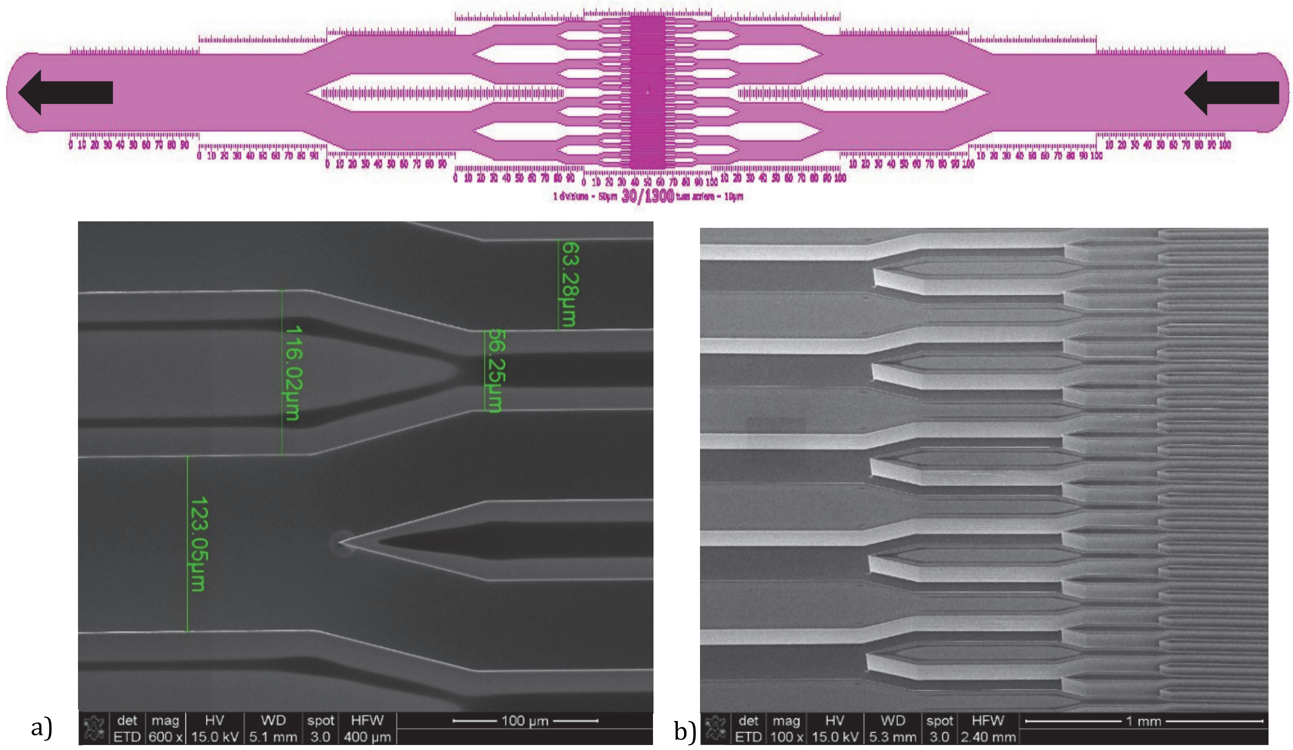


Fig. 11. a) Microchannel design; b) SEM micrographs of the silicon microchannel

- The SLG presence is confirmed by Raman spectre in Fig. 12. a). Graphene vibration mods are present in the spectre through the graphene specific G (1581 cm-1) and 2D (2686.23 cm-1) bands. IG/I2D~1.38 ratio reveals the graphene folding in the microchannel as a result of graphene domains overlaying. ID/IG~0.88 ratio reveals the increasing of the defects degree as a result of the etching process.
- The NCG presence is confirmed by Raman spectre, both in the microchannel and the walls, in Fig. 12. b). The presence of D (1350.63 cm-1), 2D (2689 cm-1) and D+D’ (2947.89 cm-1) bands, IG/I2D~1.25 and ID/IG~1.25 ratios reveal a stable presence of the NCG after etching and photoresist removal processes.
- The VG presence is confirmed by Raman spectre, both in the microchannel and the walls, in Fig. 12. c). The presence of D (1346.82 cm-1), G (1587.45 cm-1), 2D (2691.31 cm-1) and D+D’ (2940.57 cm-1) bands, and ID/IG~1.47 ratio reveal a stable presence of the VG. IG/I2D~0.85 ratio supports the VG microchannel integration.

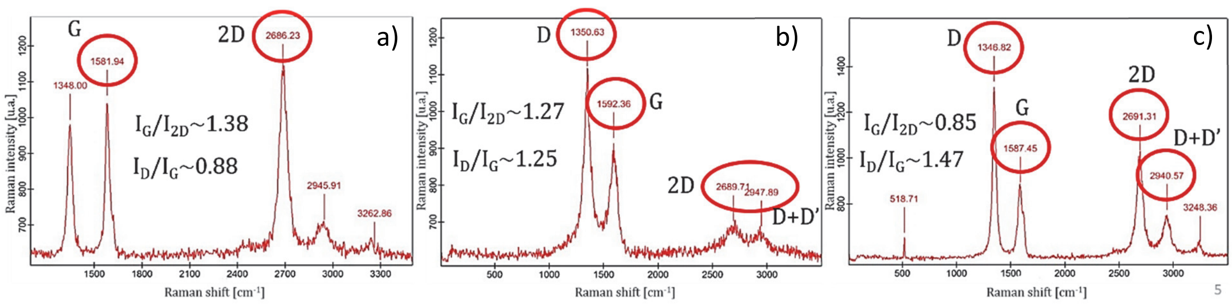


Fig. 12. Raman spectre a) SLG; b) NCG; c) VG.

ISI Papers 2021-2020

1. 60-700 K CTAT and PTAT Temperature Sensors with 4H-SiC Schottky Diodes, R Pascu, G Pristavu, G Brezeanu, F Draghici, P Godignon, C Romanitan, M Serbanescu, A Tulbure, SENSORS, Vol 21, Issue3, DOI10.3390/s21030942, FEB 2021;
2. A Multi-Objective Optimization of 2D Materials Modified Surface Plasmon Resonance (SPR) Based Sensors: An NSGA II Approach, P Varasteanu, M Kusko, 2021, APPLIED SCIENCES-BASEL 11 (10)
3. A New Hybrid Sensitive PANI/SWCNT/Ferrocene-Based Layer for a Wearable CO Sensor, M Savin, CM Mihailescu, V Avramescu, S Dinulescu, B Firtat, G Craciun, C Brasoveanu, C Pachiu, C Romanitan, AB Serban, AC Ion, C Moldovan, 2021, SENSORS 21 (5), DOI10.3390/s21051801
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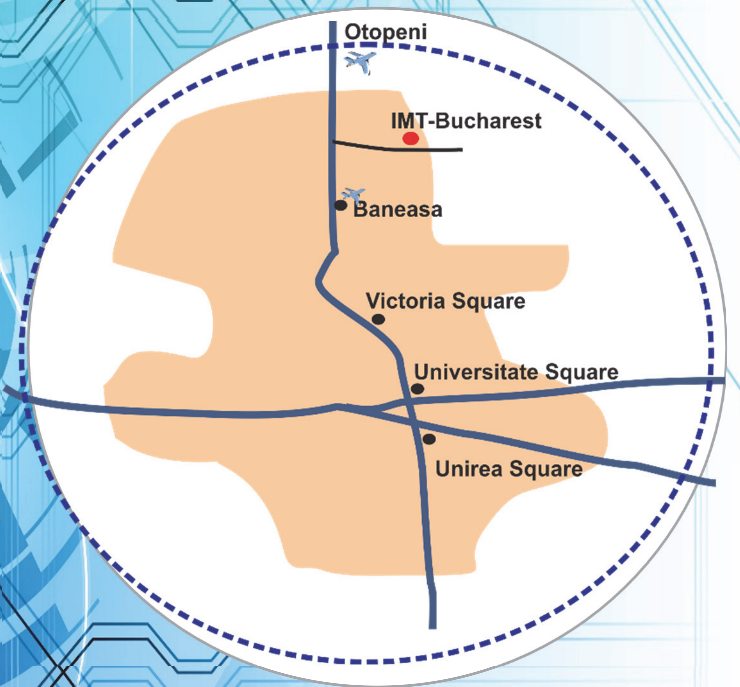

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