IMB-CNM Annual Report 2020

Centro Nacional de Microelectrónica IMB

CSIC
Consejo Superior de Investigaciones Científicas

Contents

About IMB-CNM

The Institute of Microelectronics of Barcelona (IMB-CNM) is the largest institute in Spain dedicated to the research and development of Micro and Nano Technology (MNTs) and microsystems and with unique capacities of silicon technology. It belongs to the Spanish National Research Council (CSIC) since its foundation in 1985.

IMB-CNM is located in Bellaterra (Cerdanyola del Vallès), on the Campus of the Autonomous University of Barcelona (UAB), which is a privileged environment for both basic and applied/industrial research. It is a member of the Barcelona Nanotecnology Cluster-Bellaterra. The IMB-CNM as part of CSIC is also a member of the UAB Research Park.

IMB-CNM mission is to perform applied research based on micro and nanotechnologies, mainly focused towards the development of components and micro and nano systems. IMB-CNM aims to contribute to the advancement of knowledge and to the economic and social development of society, as well as to the training of researchers and engineers and to the advice to public and private entities.

Intelligent miniaturized systems, eventually with integrated electronic, photonic, mechanical components and circuits, play an important role in society. Research, development and application of miniaturized components and systems will improve the health and well-being of people, help control environmental conditions, save and improve efficient management of energy. IMB-CNM aims to be a recognized contributor in exploring and developing micro and nanotechnologies for the realization of miniaturized components and systems. Its experience in micro and nanotechnologies enables IMB-CNM to lead projects ranging from academic research to industrial contracts, in an international environment.

The R&D activities of IMB-CNM are complemented with training of students, researchers and engineers and with technology transfer to companies.

IMB-CNM also participates in Spanish and International Technology Platforms and Networks of Excellence and has established collaborative agreements with various universities and research centres, to which it offers cooperation in their R&D activities and also access to manufacturing technologies through the "Integrated Micro and Nanofabrication Clean Room". This infrastructure has been recognized by the Ministry of Science and Innovation with the National label of large-scale infrastructure (Unique Science and Technology Infrastructures - ICTS).

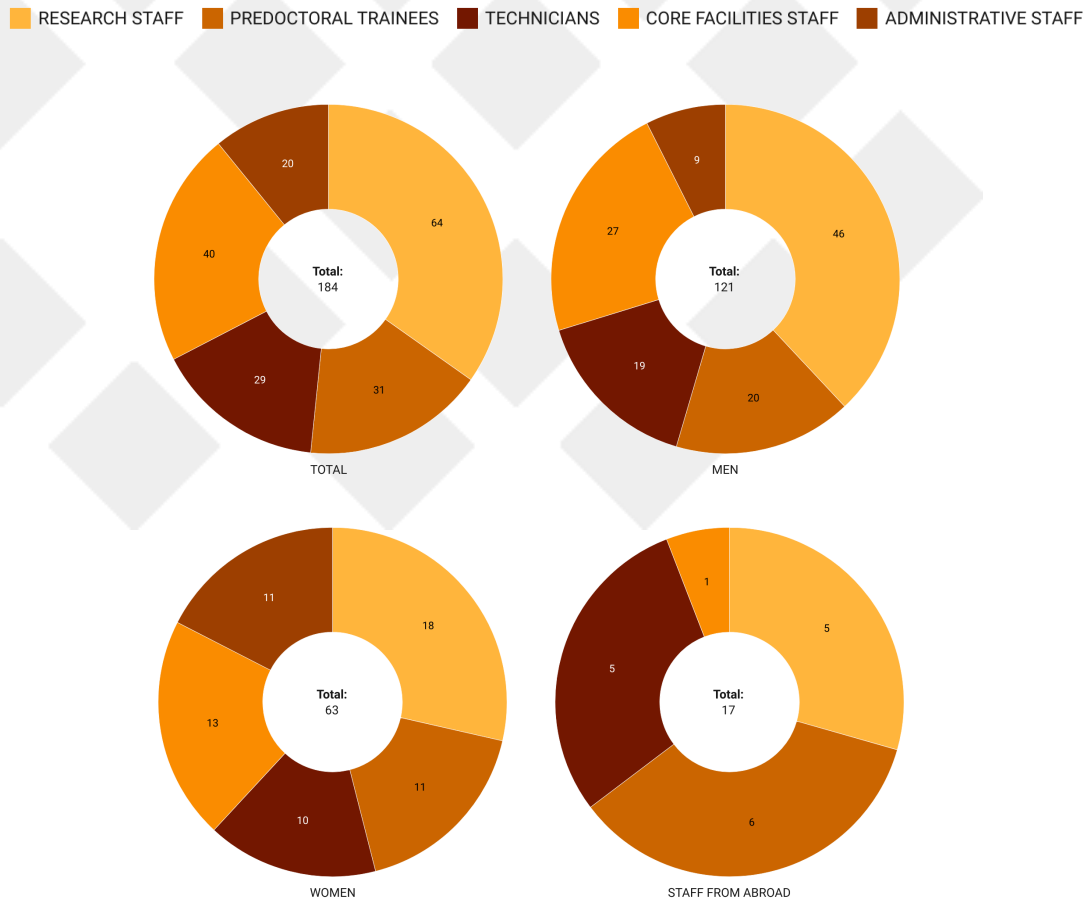
About IMB-CNM

IMB-CNM receives many students throughout the year, as well as researchers doing stages from all over the world. The average staff is a changing number, though it moves along the lines of 200 people. At the end of 2020, there were 184 people working at the institute.

The total staff of IMB-CNM is 184 people, composed of 63 women and 121 men (so women are a third part of the whole institution). The staff is mainly composed of researchers (scientific professors and postdoctoral researchers), 64 people; predoctoral trainees, coming mainly from Catalonia and Spain, 31 people; technicians and core facilities staff, the IMB-CNM is one of the research centers with the highest number of technicians, 29 and 40 (the latter belonging to the ICTS), due to the nature of our research; and Administrative Staff, 20 people, mainly women.

The Direction team during 2020 was composed of:

- **Manuel Lozano Fantoba**, research professor acting as Director.
- **Cecilia Jiménez Jorquera**, research scientist acting as Deputy Director.
- **Francesc Pérez-Murano**, research scientist acting as Deputy Director.
- **Miguel Zabala**, acting as Technical Deputy Director in charge of the Clean Room.

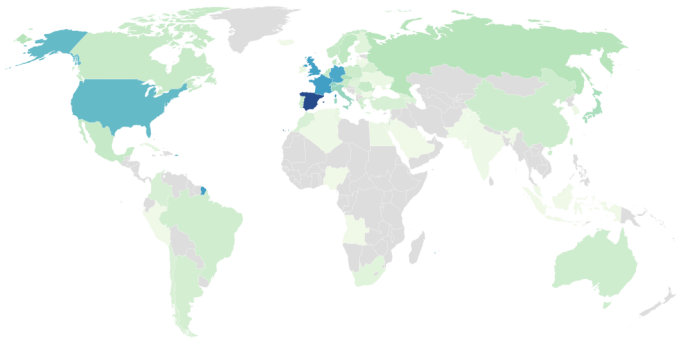


Key Figures

The 2020 was a year marked by the Covid-19 pandemics and uncertainty. The institute closed its doors during the lockdown and it remained that way, though the Clean Room gradually reopened its doors during that time. The number of publications and collaboration did not decline with the remote working and the doubt that accompanied the year. The publications in the Q1 journals were 60, accounting for almost 62% of the total publications. The institute and its people carried out more than 100 projects throughout the year, between the projects that started, the ones that ended and the ones in development. The funding was mainly public and coming from national sources, with an average funding of 11.1 million Euros.

The Key Figures section is a summary of these numbers.

Collaboration



Worldwide collaboration with institutions through the years shows that the institute is expanding its colleagues and collaborations:

This is a summary of the IMB-CNM collaborations since the decade of 1990. The countries with the most collaboration are mainly European, though collaboration with US institutions and Japan is currently increasing.

The international institutions with the most signed papers are the following: CNRS (the French homologue of the National Spanish Research Council (CSIC), University of California SYSTEM and Helmholtz Association.

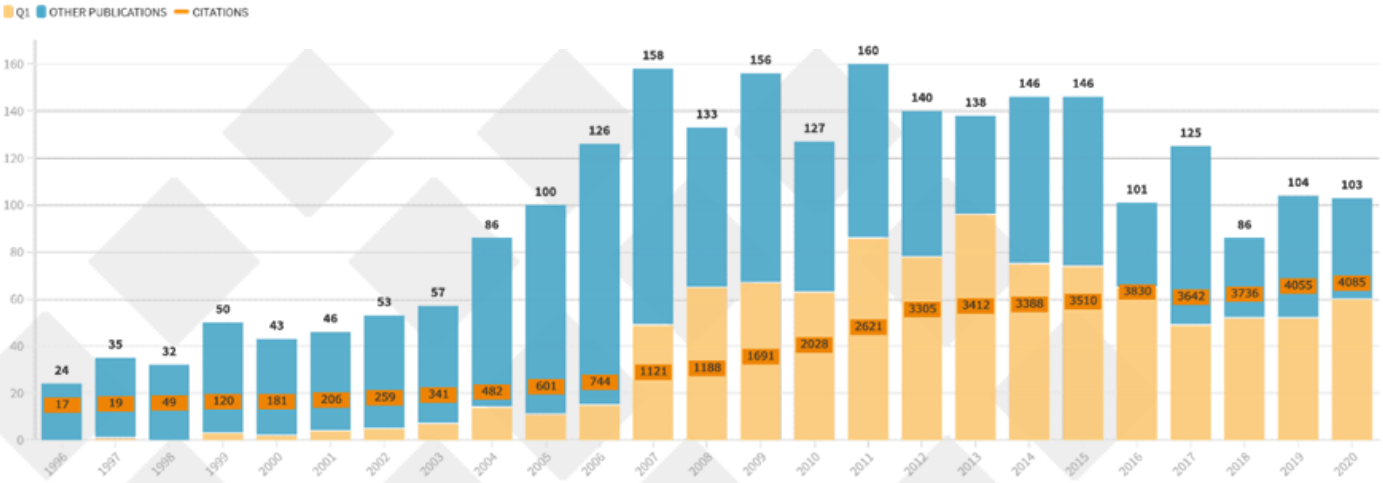
The signed collaborations within Spain show that we maintain strong ties with our environment, with the

UAB, UB and the BIST in the top three. The IMB-CNM mostly collaborates with high research institutions surrounding the institute. ICMAB, next to IMB-CNM, and IFIC, in Valencia, are some of the CSIC centers with the most collaboration.

Publications

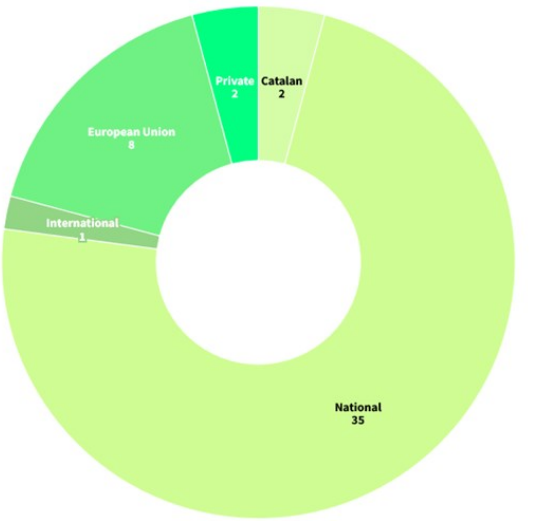
In the following graphic there is a chronology of the last 25 years regarding publications. A peak can be found in the first years of the 2000 era, though the researchers efforts to have more publications in the Q1 area made that number to decline in order to have more efficiency. The citations of our activity are increasing year after year. The total publications in 2020 were 103, 60 in the Q1 and 43 as other publications.

Key Figures

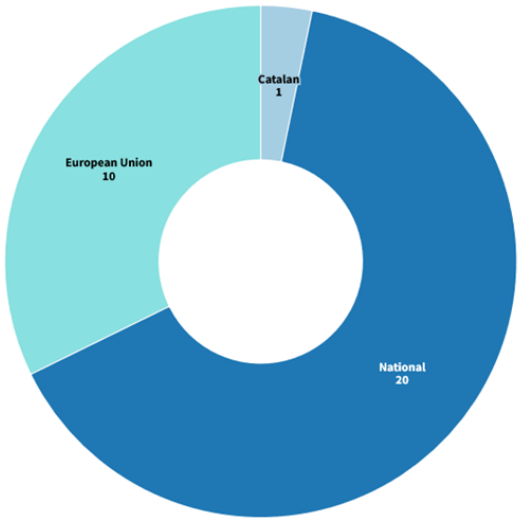


Projects

In 2020, 48 new projects started, with the national funding accounting for 73% of the total. The distribution of the sources is the following:



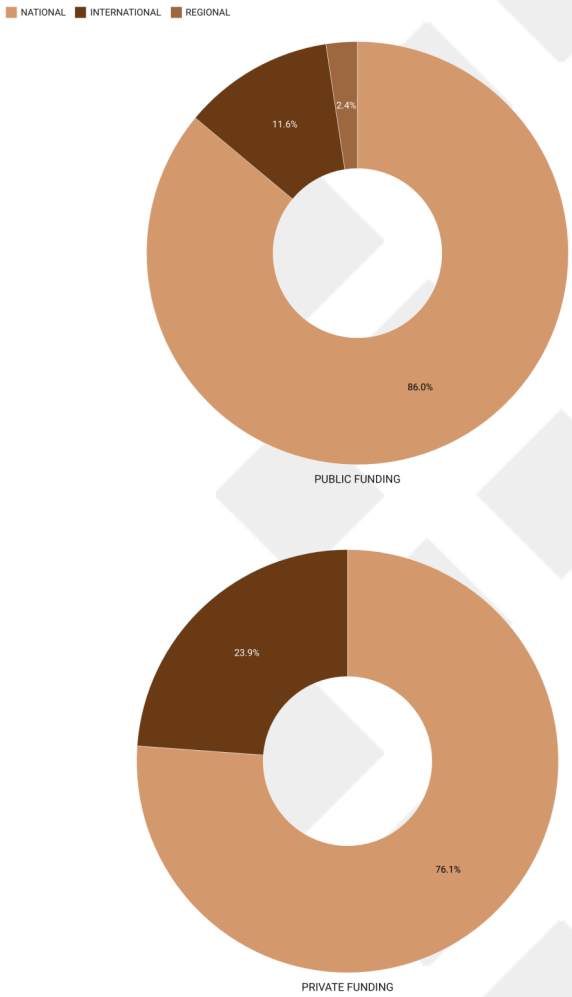
The ended projects were 31, putting an end to a good streak of several European projects funded in the Horizon 2020 calls. The biggest projects in terms of funding ending in 2020 have been ION4SET, GreenDiamond, ENSO and P-SPHERE.



Key Figures

Budget

The total budget of IMB-CNM has been 11.1 million €. The funding is mainly public and comes from the CSIC.



Covid-19 Impact

The Micro and Nanofabrication Clean Room closed on 16th March, Monday, due to global pandemics. It gradually reopened at the end of April, Monday 27th, when Spain was still in total lockdown, in order to fabricate devices related to the treatment of Covid-19.

The CSIC authorities and the General Secretariat for Research declared that the Clean Room was an essential facility for the development of research projects related to the detection of Covid and, as such, they were urged to keep it active and continue providing service to the scientific community.

The IMB-CNM became involved in two projects regarding the coronavirus disease: CONVAT, led by CSIC researcher at ICN2 Laura Lechuga with Carlos Domínguez acting as PI of the IMB-CNM contribution, and POC4COV, led by CSIC researcher Pilar Marco at IQAC with César Fernández acting as PI of the IMB-CNM contribution. In both cases, the Group of Chemical Transducers was involved in the development. CONVAT aimed the creation of a rapid test device to detect de Covid-19 infection and the development was carried out in the Clean Room, from the early stages of the pandemics.

The Clean Room staff (processes and maintenance) came to work in controlled shifts in the midst of a pandemic with effort and dedication. A special protocol of measures to contain the infection was created before their reinstatement with special hours, limited capacities and control of the environment.

A shift work plan was established for the maintenance staff, who accessed the Institute daily, even during the first days of confinement, to keep everything running, mainly the air conditioning and services of the Clean Room. The team also carried out management/ logistics tasks together with the members of the Direction.

Subsequently, on the last week of April and first week of May, the staff began to access the Room in shifts and with restricted hours, with only between 6 and 8 people accessing simultaneously on the morning shift and with staggered access. In the following weeks and until the full re-opening on June 22nd, this access was kept restricted and in shifts.

Throughout this period, a very strict weekly planning of the runs that could be processed was made, based on prioritized and justified requests from the research groups.

In the beginning, the institute also contributed with donations of masks to two hospitals (due to the great shortage of supply of surgical masks) and plastic rolls, and with the initial manufacture of a prototype of masks by 3D printing (formiga), according to SEAT plans.

Highlights

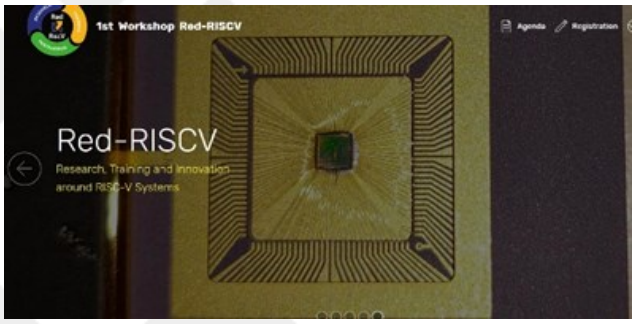
News

Anton Guimerà-Brunet, finalist of the Vanguardia de la Ciència award

The IMB-CNM researcher, together with José Garrido from Institut Català de Nanociència i Nanotecnologia/ICREA, were candidates to the award for the development of graphene implants for the measurement of the hidden cerebral activity. The award is jointly promoted by La Vanguardia and the Fundació Catalunya La Pedrera to give visibility to the research of excellence carried out in Spain.

Some of the brain's electrical activity occurs in the form of very slow impulses that the usual electrodes cannot detect. These low frequency currents participate in the modulation of signals that coordinate different parts of the brain, which occurs during sleep, and are related with pathologies such as epilepsy, migraine or brain damage. Anton Guimerà-Brunet and José Garrido have shown that this brain activity can be detected by implanted electrodes containing graphene, a material flexible, biocompatible and very stable. The new devices can contribute to improve the diagnosis of epilepsy.

The network Red-RISCV is created to promote the development of open source hardware



Formed by 14 research groups from all over Spain, and coordinated by IMB-CNM, it was born as a research network around open hardware architectures based on the ISA RISC-V (the language open source machine), but it aims to go further and generate collaborative synergies between the fields of research, training and innovation.

ISA's open RISC-V architecture began to be created in 2010 at UC Berkeley to reduce the enormous and growing complexity of microprocessor instruction sets, and to limit the heavy dependence on third countries and business oligopolies. The RISCV Network will promote collaboration and the joint evolution of research, training and innovation. “The new RISC-V architectures of open ISA offer an opportunity to gain technological independence, increase the guarantees of a more robust and secure hardware, reduce monopoly risks and facilitate market competition, something that Europe cannot miss”, says Lluís Terés, IMB-CNM researcher and coordinator of the RISCV network.

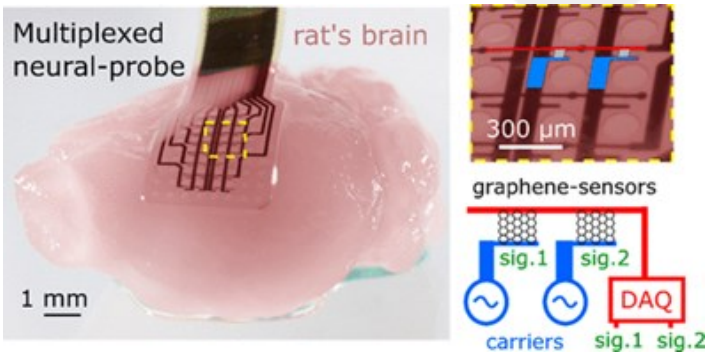
The silicon carbide components of IMB-CNM are back in space

The components are protection diodes, located in the solar panels of the Solar Orbiter joint NASA-ESA mis-

sion. They will be exposed to extreme temperatures of up to 350 degrees Celsius.

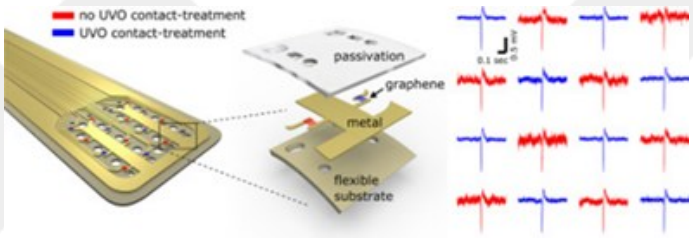
The protection diodes are essential to guarantee the supply of energy in the ship. Located next to the solar panels to protect them in case of failure of one of the cells, they are prepared to withstand very high temperatures. These components use the same technology that the scientists, the members of the IMB-CNM Power Devices and Systems Group, had already developed for a previous mission, the BepiColombo. Some parameters in the device design have been adapted to meet the environmental conditions of this new mission. Solar Orbiter is a scientific solar observation satellite that aims to make detailed measurements of the magnetic field on the solar surface, radiation levels in the inner heliosphere and the solar wind.

Experimental validation of multiplexing concepts with switchless GFETs arrays



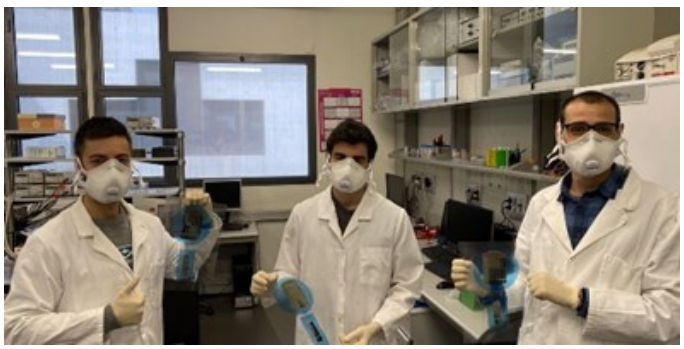
The connectivity is one of the major limiting factors in the development of high density neural interfaces. The use of graphene graphene transistors arranged in addressable arrays enable the use of multiplexed read -out strategies to reduce the connectivity footprint. Recent developments demonstrated the capability of GFETs based arrays for implementing Time Domain Multiplex(TDM) or Frequency Domain Multiplex (FDM), paving the way for future developments of high channel count neural interfaces.

Advances towards clinical/ preclinical translation of GFET technology: Increasing the technology maturity



Graphene transistors provides unique capabilities for recording high fidelity DC-coupled neural recordings, this capability enable the study of the role of the infra-slow activity in the brain behavior and its pathologies. Recent research has provided better knowledge on electrical modeling and fabrication process, increasing the maturity of this novel technology.

The IMB-CNM Clean Room develops photonic devices for a European project to develop a sensor for the fast diagnosis of SARS-CoV-2



The photonic devices are developed and fabricated for the European project CONVAT, coordinated by Prof. Laura M. Lechuga, CSIC researcher at the Catalan Institute of Nanoscience and Nanotechnology (ICN2). The objective of the project is to develop a new device

based on an optical biosensor, to detect the SARS-CoV -2 coronavirus in 30 minutes, without the need of centralised clinical laboratories.

The new technology would also identify if the infection is a coronavirus or a common flu. The biosensor device will also be used for the analysis of coronaviruses in reservoir animals, such as bats, for the observation of possible evolutions of these viruses and to prevent future infectious outbreaks in humans. Prof. Carlos Dominguez of IMB-CNM manages the development of the transducing devices required by the project, which are fabricated in the Photonic Integration Platform operated by the IMB-CNM Clean Room.

CONVAT is a cooperation project between Spain, Italy and France.

The IMB-CNM participates in the project POC4CoV to develop technologies for the fast and reliable diagnosis of SARS-CoV-2

The project Point-of-care tests for the rapid detection of SARS-CoV-2 (POC4CoV) will be funded by CSIC. Three CSIC institutes participate in the project: IMB-CNM, the Institute of Advanced Chemistry of Catalonia (IQAC) and the Institute of Materials Science of Aragon (ICMA).

The objective of the Project is to develop Point-of-Care devices for the fast and reliable in vitro diagnosis of the SARS-CoV-2 infection, by using multiplexed systems and specific biomolecular probes. The POC technological platforms will be used in combination with specific capture biomolecules and nanobiotechnologic probes (enzymatic bioconjugates and plasmonic/ magnetic biofunctionalised nanoparticles). These will allow the simultaneous detection of different biomarkers (viral RNA and antigens, IgM and IgG) related to the Covid-19 disease. The biomolecular complexes will be attached to specific places on the devices, where the electrochemical or optical signals will be measured. The POC platforms will be analytically and clinically validated in a clinical environment.

Improving zinc-air rechargeable batteries with nanoparticles

CSIC scientists at the IMB-CNM and ICMAB are working to achieve an efficient zinc-air battery recharging. These batteries have more capacity than the lithium-ion ones, and are made of cheap materials, which are widely available in nature as well as safe.

The scientists Dino Tonti, Eulàlia Pujades-Otero, Nieves Casal Pastor, the three from the ICMAB, and Libertad Abad Muñoz, from the IMB-CNM.

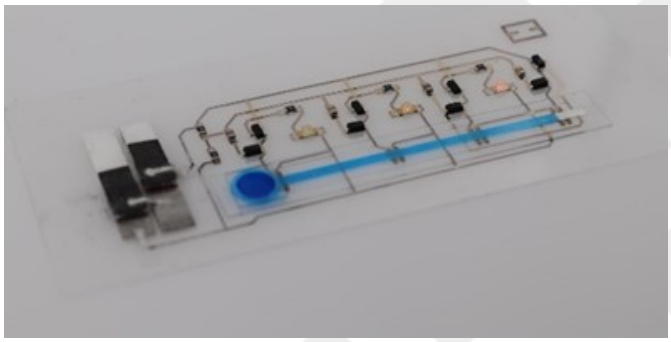
Environmental crisis is boosting emerging markets in large-scale electromobility and energy storage for an efficient use of clean energy. The current lithium-ion battery technology has limitations in terms of energy density, safety, sustainability, as well as a high cost in terms of € per kWh, which makes it an inefficient proposal for large-scale applications.

Fuelium, spin-off of IMB-CNM, receives a 240000 euro grant from the Bill & Melinda Gates Foundation

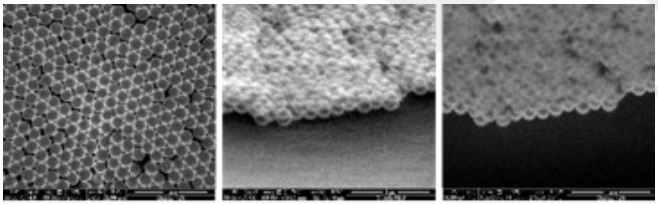
The company develops ecological paper-based batteries that power portable diagnosis devices. The company will use the grant to design autonomous paper batteries for molecular diagnosis assays.

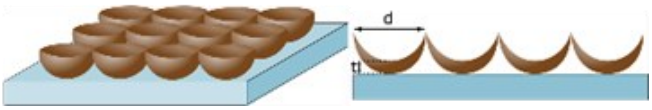
The company, founded by the researchers Juan Pablo Esquivel and Neus Sabaté, develops ecological paper-based batteries that are activated when they come in contact with a liquid. The batteries only generate the energy required for each application and do not contain heavy or toxic metals. They are mainly made of paper, carbon and biodegradable metals.

The development, integration and validation of the new modules will be made in collaboration with the company Pragmatic Dagnostics and the SPEED research group of IMB-CNM. The group develops autonomous devices by combining engineering, paper microfluidics, flexible electronics and electrochemistry.



Ultrabroadband absorbing material for soft opto-mechanical devices



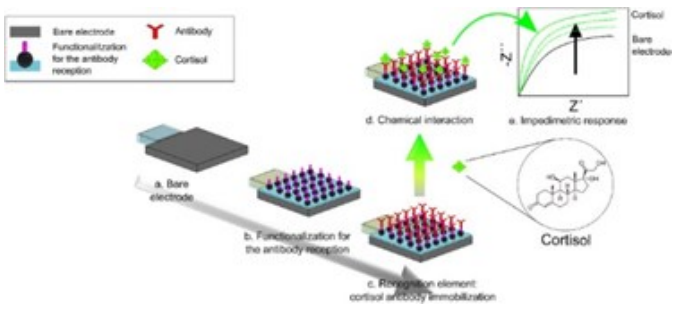


Development, in collaboration with the ICN2, of a novel metamaterial showing an angle-independent and efficient ultrabroadband optical absorption range (average 84% within 300 to18000 nm), which results in an excellent photothermal conversion efficiency. The developed material exploits the unexplored optical properties of highly-damped plasmonic materials combined with the infrared absorption of thin polymer films, in particular, the material is composed of a nanostructured Fe layer mechanically coupled to a thin poly- dimethylsiloxane (PDMS) film. The material has potential applications in solar thermal energy, energy harvesting, or mechanical actuators. The ferromagnetic properties of the material allow a combination of the photothermal and magnetic actuation to tune the actuation strength in mechanical systems. At IMB-CNM, it is being developed as the subject of Pau Guell's thesis, directed by researcher Mar Álvarez.

IV Training Course on Introduction to Microelectronics

The fourth edition of the training course on Introduction to Microelectronics started as an in-person course in March 2020 and then continued online during the COVID-19 lockdown period, until May. The course is intended to provide an introductory training on microelectronics technology and devices to new staff. It was coordinated by Josep Maria Cirera.

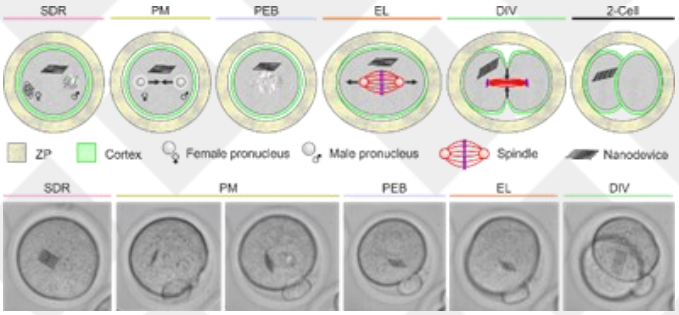
Building new sensors using inkjet printing technology



The concept of Personalized Medicine has entered with force, with the main objective being the continu-

ous improvement of patient care; and research in the area of technology for the manufacture of PoCs is considered essential to provide personalized medical care. The development of a miniaturized platforms that integrates a sensor as well as a hybrid printed circuit that allows transducer measurements to be carried out will further push future PoC devices. The technology used will be additive digital manufacturing on flexible plastic substrates, emphasizing Inkjet Printing (IJP) technology, which will allow for a complete platform that will be autonomous, portable and low cost. Sensors for cortisol sensing, as well as sensors for dissolved oxygen for microbial activity monitoring within a biofilm are being developed.

Discovering the intracellular forces at the origin of life



A team led by researcher José Antonio Plaza at IMB-CNM has designed and fabricated sophisticated nanochips microinjected in living cells to detect the mechanical properties changes and intracellular forces that occur in the early stages development. This work, as part of an international collaboration with the team headed by Anthony C. F. Perry from the Molecular Embryology of Mammals of the University of Bath (United Kingdom), was financed with Spanish public funding from the National R+D+i Plan, Feder funding and UK Research Councils.

The chip is extremely tiny, 3-times thinner than the diameter of a virus as SARS-CoV-2, and works as a mechanical sensor being able to identify a program of forces and changes to the cytoplasmic mechanical properties required for mouse embryo development from fertilization to the first cell division.

Awards

Neus Sabaté awarded at the Royal Spanish Physical Society Awards

The IMB-CNM researcher has been awarded in the Physics, Innovation and Technology category. The jury highlighted “her pioneering vision of it and her great creativity in the field of biodegradable batteries. This innovative work has the potential to generate a significant social and environmental impact. It represents an inspiring example for young researchers in an area where the presence of women is still a minority”.

Neus Sabaté is CSIC and ICREA researcher at IMB-CNM. She is co-founder of the Fuelium spin-off, which develops paper-based batteries.

This eco-friendly paper-based batteries, to be used in portable diagnosis devices, are activated when they come in contact with a liquid and can power single-use devices. The technology allows the development of diagnosis kits more affordable and environmentally friendly, by avoiding the use of standard batteries. These kits could be used in rural or developing countries without access to electricity. A recent result of the technology is a device for the fast diagnosis of cystic fibrosis.

The Physics Awards of the Royal Spanish Physical Society (RSEF) – BBVA Foundation recognize every year since 2008 the creativity, the effort and the achievements in the field of physics, to encourage professionals working in research, teaching, innovation, technology and outreach.

CSIC researcher Neus Sabaté, candidate for the Women Innovators 2020 award

Twenty-one of the most talented and inspiring women entrepreneurs in Europe and beyond are in the shortlist for the EU Prize for Women Innovators 2020. The prize celebrates the outstanding achievements of female entrepreneurs running innovative companies and is funded by the EU's Horizon 2020 programme for research and innovation.

ENERGIOT finalist in the EDF Pulse Awards 2020

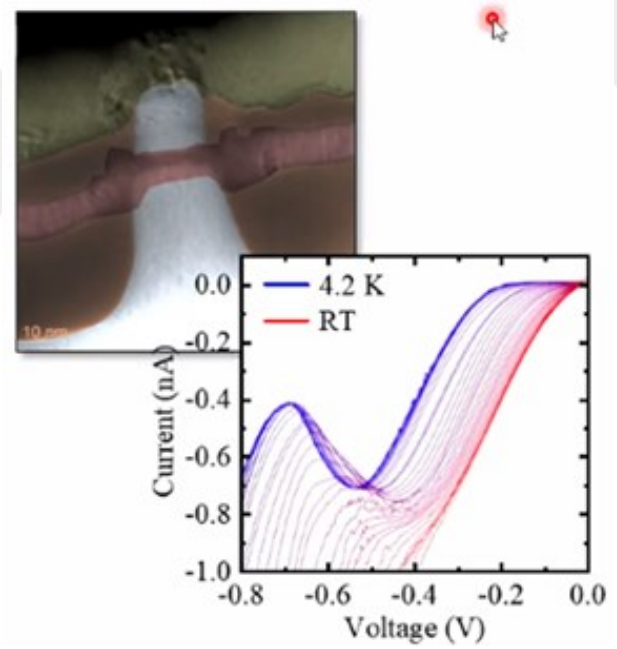
The IMB-CNM's technology-based company, Energiot, is one of the 12 finalists in the seventh edition of the EDF Pulse start-up Awards, organized by the largest French energy company.

With a patented technology based on piezoelectricity (the electric charge that accumulates in certain solid materials as a result of mechanical pressure), the start-up Energiot has developed autonomous IoT sensors that recharge themselves from the magnetic field around overhead power lines, and collect an impressive amount of data from the power transmission grid. More specifically, they can be used to predict unexpected events and produce detailed maps of power transmission lines. Grid operators can then use this data to limit losses of electricity and reduce their operating costs by around 20%. Unlike other sensors available in the market, these generate no toxic waste whatsoever and are also between 5 and 10 times cheaper than other sensors. The company was founded by the IMB-CNM researcher Gonzalo Murillo.

Since 2014, the EDF Pulse Start-up Awards have given a helping hand to European startups to develop new technological solutions for the electric field with solutions to improve environmental efficiency and connectivity. The award involves the development of a marketing and commercialization campaign and an aid of up to € 80,000.

Projects

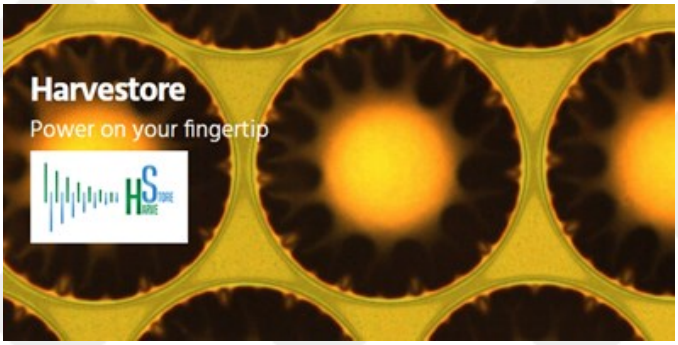
The IONS4SET project is completed



The aim of the IONS4SET project (Ion-irradiation-induced Si nanodot Self-Assembly for Hybrid SET-CMOS Technology) was to create single electron transistors for ultra-low power electronics so that the component using these optimized transistors delivers good performance at very low energy consumption. This

type of transistor requires fabrication of nanopillars well beyond the state of the art. The IMB-CNM activity demonstrated that the nanopillar devices can be integrated with CMOS transistors in the same chip. The project has been funded by the Horizon 2020 European programme.

IMB-CNM participates in the EU HARVESTORE project



It is a five years FET-PROACTIVE project aiming at miniaturised mixed energy harvesting and storage devices using disruptive concepts from the emerging Nanoionics and Iontronics disciplines. These nano-enabled micro-energy systems with a footprint below 1 cm3 should power autonomous wireless sensor nodes for the future Internet of Things from ubiquitous heat and light sources. IMB-CNM is providing the technological resources and knowhow to integrate those devices in silicon technology allowing the highly dense features and scalability required for real miniaturization and massive deployment that will show their viability as a new technological paradigm of embedded energy.

New European projects on Power devices and Systems

The project “Intelligent Reliability 4.0” (iRel40), funded by the EU ECSEL Joint Undertaking and MCIN/AEI, is led Xavier Perpiñà. The project has the ultimate goal of improving reliability for electronic components and systems by reducing failure rates along the entire value chain, i.e., chip-package-board/system. In iRel40, 79 partners from 14 countries collaborate in 6 technical work packages along the value chain. By collaboration between academy, industry and knowledge institutes on this challenging topic of reliability, the project secures more than 25.000 jobs in the 25 participating production and testing sites in Europe. The project supports new applications and reliable chips push applications in energy efficiency, e-mobility, autonomous driving and IoT.

The project “Extract Forensic Information for LEAs from Encrypted SmartPhones” (EXFILES), funded by the European Union through the Horizon 2020 programme, is led by Salvador Hidalgo. Mobile phones are often a key factor in criminal cases, intrusions, intellectual property theft, security threats, and more. The data stored in these devices may contain critical evidence associated with the above-mentioned crimes. The latest generation of devices incorporate new security features and encryption schemes to "protect" the device and its associated user data. The EXFILES project aims to provide law enforcement agencies (LEAs) with new tools to extract data and associated evidence from these devices in strict legal contexts. A unique consortium of five LEAs, universities and cyber security companies from the EU have joined forces to address these challenges. The main objective is to improve LEAs techniques and methods, to extract digital evidence from modern encrypted smartphones used by criminals based on holistic approach (both software and hardware).

Memberships

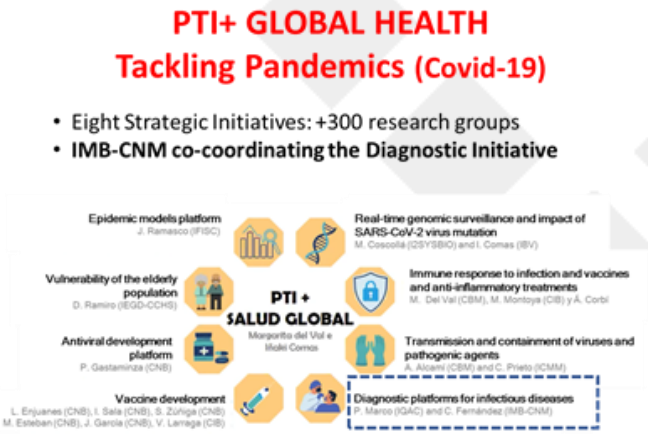
IMB-CNM becomes member of the FutuRed Platform

FutuRed, the Spanish Electrical Grid Platform, was created to foster the technological evolution of Spanish electricity transmission and distribution systems in order to promote the technological leadership, the sus-

tainable development and an increased competitiveness. The IMB-CNM has become member through the Power Devices and Systems (PDS) group.

FutuRed is a Spanish Technological Platform of Electrical Grids created for integrating all the agents involved in the electricity sector, to define and promote strategies at national level allowing the consolidation of a more advanced network capable of responding to future challenges. FutuRed tries to develop the main objectives of the Spanish energy policy, increasing the independence from foreign energy and consistently reducing the environmental impact caused by electrical system infrastructures. The primary strategies to achieve these objectives consist of saving and using energy rationally, via the most effective electrical systems, and taking greater advantage of domestic resources.

IMB-CNM coordinates the Diagnostic Initiative of the CSIC PTI+ on Global Health



The Interdisciplinary Thematic Platforms (PTIs) of CSIC are collaborative frameworks for research groups to address relevant scientific challenges together. The PTI+ on Global Health: Tackling Pandemics was created to address the COVID-19 disease. IMB-CNM (Dr. César fernández) is coordinating the specific strategic initiative on Diagnostic Platforms, jointly with Dr. Pilar Marco from IQAC. One of the main activities is the project POC4COV that is also presented as a highlight.

The IMB-CNM new member of the SECPHO cluster

SECPHO is a cluster of technological innovation that brings together companies, technology centers and research groups, experts in deep tech, who firmly believe in collaboration. It is focused on promoting technological innovation through the application of deep technologies, mainly photonics or technologies based on light, to all types of sectors of our economy.

Open access platform for Photonic Integrated Circuits

The Open Access platform for the fabrication of Photonic Integrated Circuits based on silicon nitride technology has been in operation. The platform uses the Multi Project Wafer (MPW) approach by means of a Process Design Kit developed with VLC Photonics. During 2020 the MPW#4 has been manufactured, and the figure shows an example of MPW user. The S2QUIP project is developing a hybrid quantum photonic platform using 2D materials to generate flying qubits on scalable silicon-based photonic integrated circuits.

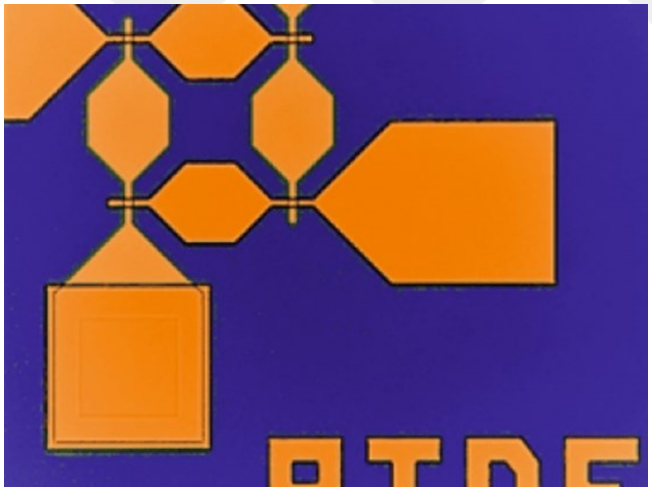
Research

The research activities of IMB-CNM are dedicated to Micro/Nano Integrated Systems: miniaturized electronic systems which include sensing and/or actuating capabilities in addition to electronic information processing, power management and external interfaces.

The core of the IMB-CNM research can be included into the *More than Moore* and the *Heterogeneous integration* internationally established technology domains, although some of the activities can be integrated into the *Beyond CMOS* and *More Moore* areas.

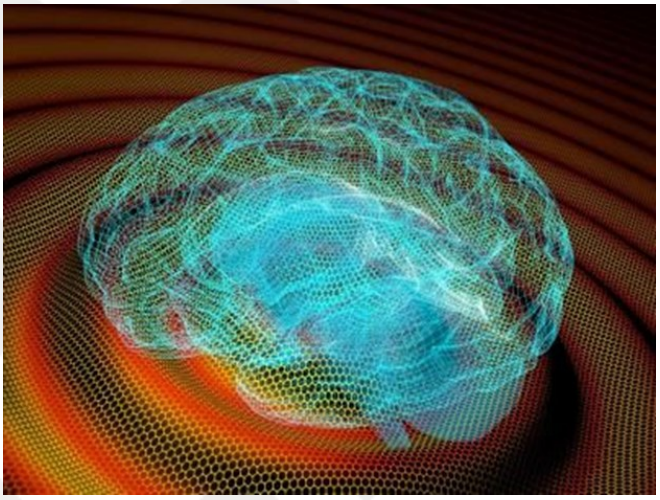
Advanced Thin Dielectric Films Group (ATDF)

The aim of the group is the investigation of the properties of thin dielectric films for silicon-based micro / nanoelectronic applications. Within this general framework, the group is currently working in the field of memristor devices based on the resistive switching-phenomenon in high-k dielectrics deposited by Atomic Layer Deposition. Research activities cover from the development of memristor fabrication technologies, the electrical characterization of resistive switching devices and their study as electronic synapses for neuromorphic applications.



Biomedical Applications Group (GAB)

The Biomedical Applications Group (GAB) mission is to provide clinicians with advanced tools, based on micro and nano-technologies, to tackle the medical challenges of the future.

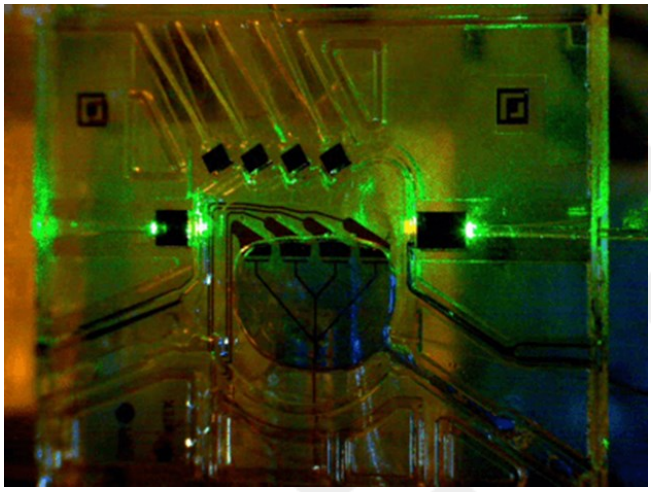


BioMEMs Group

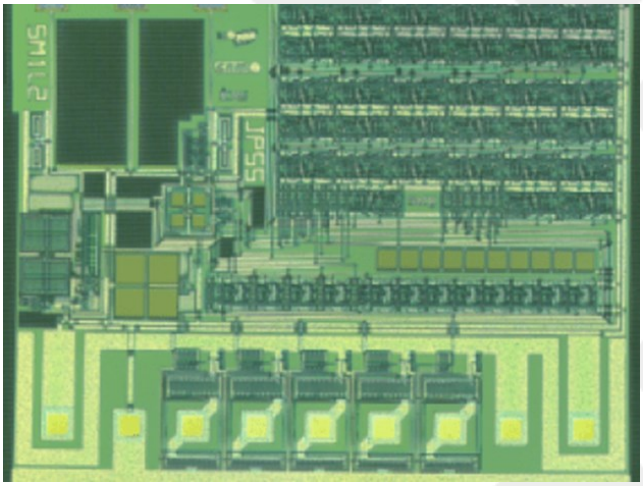
The main activity of the group addresses the design and development of novel micro and nanosensors and complex and compact miniaturized systems for biological and biomedical applications.

Chemical Transducers Group (GTQ)

The group activities are focused on applied research on the development of application-specific analytical systems (ASAS): Ad-hoc analytical tools for the measurement of chemical parameters in (biological) liquid fluids. We aim at offering market solutions to analytical needs in the environment, health and food fields and contributing to some of the sustainable development goals set by the UN to address the social, environmental and economic challenges of our time.



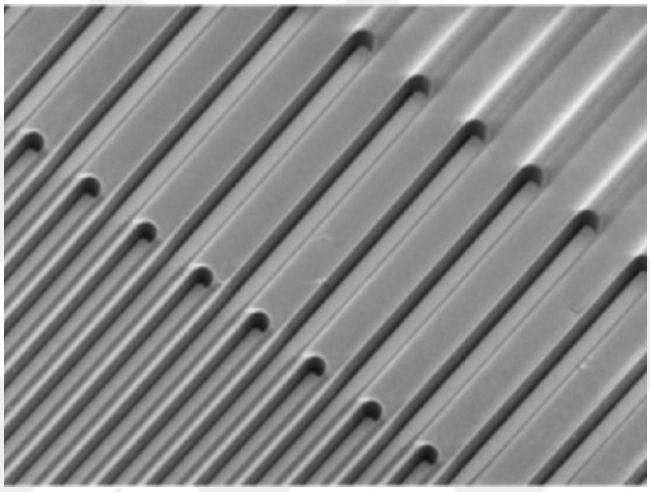
Integrated Circuits and Systems Group (ICAS)



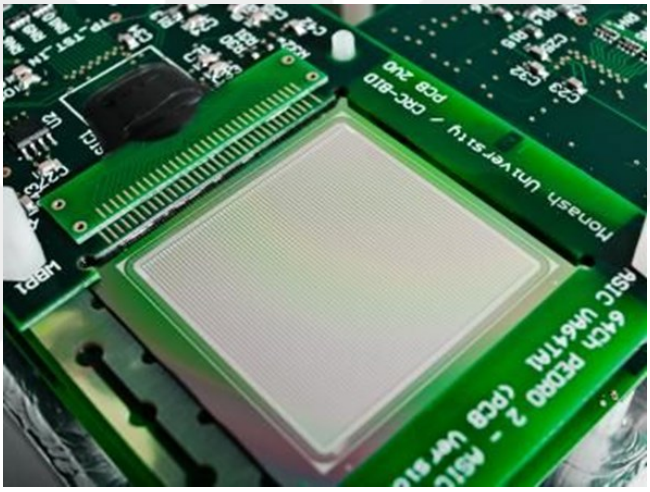
The essence of this group has been always the design of application specific integrated circuits (ASICs). Currently, ICAS R&D is focused on ultra low-power analog, mixed and RF integrated circuits, organic/printed microelectronics, short range RF communications with remote power systems, digital integrated circuits in nanoelectronics and multi-technological HDL-AMS modeling. The group also supports electronic system design for the ICAS itself as well as for other R&D groups of IMB.

Micro and Nanotools Group (MNTL)

“Contributing to lay the foundations of micro- and nanosystems of the future". The research line of the group is focused on the development of new Micro- and NanoTools to explore new applications or functionalities for MEMS and NEMS.

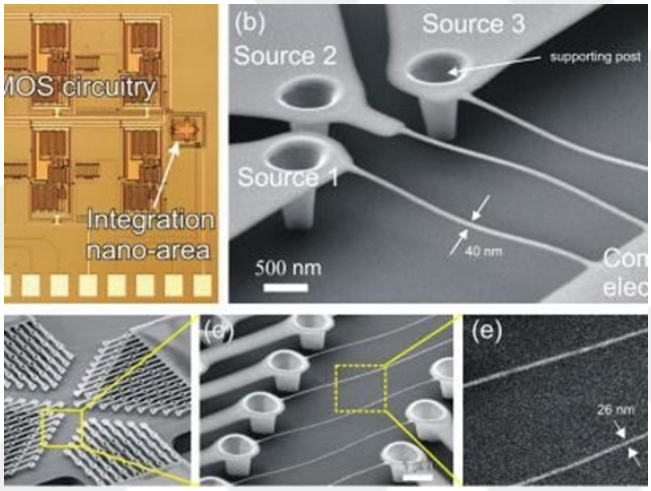


MicroEnergy Sources and Sensor Integration Group (MESSI)



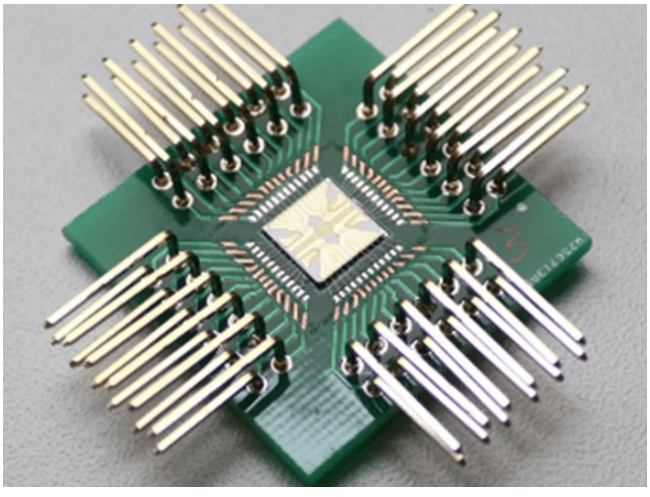
The aim of the group is to contribute with new microenergy and smart sensing devices to important long-term challenges such as “Healthier Citizens” and “Net Zero Human Impact”. Within this general framework, different lines of research are addressed: In the microenergy field, we cover harvesting (thermoelectricity) and generation/storage (micro-fuel cells / biodegradable batteries) activities. In the sensing field, we focus on systems that allow identifying gases or biomarkers. The microintegration feasibility of both sensors and energy sources to achieve autonomous systems is another interest of the group, using standard silicon technologies and rapid prototyping and additive manufacturing.

Nanofabricacion and Nanomechanical Systems Group (NANONEMS)



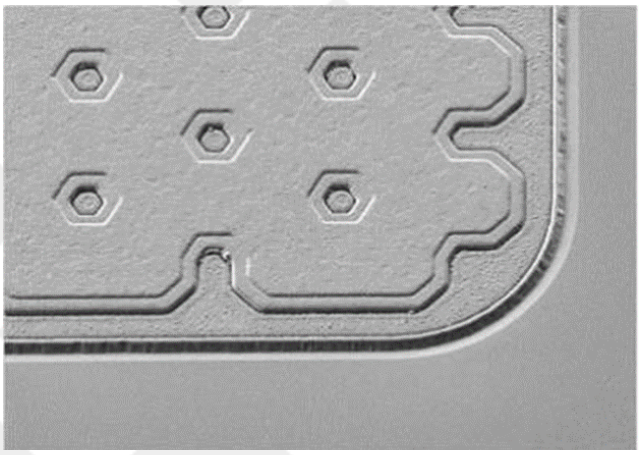
The group explores the electronic and electromechanical properties of nanostructures that can provide new or improved features to nanodevices and nanosystems. It also performs research and development of advanced nanofabrication methods, preferably those that can be applied to devices used in miniaturized integrated systems. These activities cover two of the Key Enabling technologies (KETS): nanotechnology and micro-nanoelectronics.

Power Devices and Systems Group (PDS)



The Power Devices and Systems Group focuses on the design, fabrication, characterization and integration of power semiconductor devices, optimized for developing reliable and energy efficient converters and electronic systems, operating even in harsh environments (high temperature, radioactive environments, etc.).

Radiation Detectors Group (RDG)



The aim of the RDG is to contribute to the research and development of advanced technologies and applications of radiation detectors. The R&D activity of the group rest on the expertise of its members in layout design, simulation, fabrication and characterization of semiconductor radiation sensors; microelectronics devices; interconnections; implementation of complete systems and study of the radiation effects on components and systems. The fields of application of the RDG activity are: particle physics, nuclear physics, medical imaging and dosimetry, synchrotron and nuclear fusion facilities, space applications, instrumentation for civil security and societal challenges.

Facilities

Micro and Nanofabrication Clean Room

The Micro and Nanofabrication Clean Room (SBCNM) is a Unique Scientific and Technological Infrastructure (ICTS) dedicated to the development and application of innovative technologies in the field of Microelectronics together with other emerging Micro/Nanotechnologies.

SBCNM is an open access facility that aims at helping national and international research groups to carry out R&D activities thanks to the availability of a set of complete micro and nanotechnologies and processes housed in a highly specialised Clean Room environment devoted to R&D&i of excellence, and driven by an expert team. Such support ranges from technology awareness to the development of basic demonstrators, or small series of prototypes.

Since 2014, the ICTS-SBCNM it is one of the three nodes of the MICRONANOFABS ICTS Network, the Large Scale Facility supported by the Spanish Ministry of Science and Innovation (MICINN), together with the Clean-Room from ISOM-UPM and the one from NTC-UPV.

MICRO nano FABS

Red Española de Salas Blancas de Micro y Nano Fabricación

Facilities

Clean Room features

- **Work area**: 1,500 m^2
- **Auxiliary services**: 3 x 600 m^2
- **Class**: 100 - 10,000 (ISO 5-7)

  It has < 10,000 particles, whereas a normal environment contains 1,000,000 particles
- **Temperature**: 21º ± 1ºC
- **Humidity**: 45% ± 5%
- **Deionized water**: 18MΩ - 20,000 l / d
- **Equipment**: > 150
- **Wafer sizes**: 100 mm / 150 mm

IMB-CNM's Clean Room is one of the 31 Unique Science and Technology Infrastructures (ICTS)

Infraestructuras Científicas y Técnicas Singulares

Within the MICRONANOFABS structure, the CSIC's Clean -Room at IMB-CNM offers its know-how on:

- Fabrication of devices and electronic circuits.
- Physical and electrical characterisation of electronic components, MEMS/NEMS, sensors, actuators, Lab-on-Chip, integrated circuits and smart systems.
- Packaging of electronic components.
- Training activities on micro and nanoelectronics.
- Dissemination and outreach on micro and nanoelectronics.

The IMB-CNM Integrated Clean Room includes equipment for micro and nanofabrication processes mainly based on silicon technologies for wafers of 100 mm and 150 mm, but can also operate with substrates of different materials and sizes on demand. Its structure allows flexible operation, which makes it especially suitable for R+D+i.

In addition to the ICTS facilities, IMB-CNM has a number of research laboratories dedicated to specific fields:

- Advanced Packaging Laboratory
- Biosensors Laboratory
- Characterisation of Microsystems Laboratory
- Chemical Transducers Laboratory
- Design & CAD Service
- Electronic Systems Laboratory
- General Chemistry Laboratory
- Integrated Circuits and Systems Testing
- Integrated Optics Laboratory
- Micro/nano systems Laboratory
- Packaging Service
- Power Devices Laboratory
- Printed Electronics Laboratory
- Prototyping Laboratory
- Radiation Detectors Laboratory
- Reverse Engineering Laboratory
- SAM/SEM Laboratory
- Thermal Characterisation
- Wafer Electrical Characterisation Service

Publications

IMB-CNM has published a total of 108 scientific papers in 2020 in journals included in the Science Citation Index. The complete list of publications in scientific journals is available at the IMB-CNM website. Fins all of the publications through this QR code:

Some of the scientific highlights of 2020:

Multidimensional Anisotropic Architectures on Polymeric Microparticles

Juan Pablo Agusil, **María Isabel Arjona**, **Marta Duch**, **Naüm Fusté**, **José A. Plaza**.

Next generation technologies will require Multidimensional Anisotropic Architectures with tunable physical and chemical intraparticle building blocks combination to meet the demands of high throughput and multiplexing. Here, we report a strategy to integrate a vast number of anisotropic dimensions combining polymer photolithography with (bio) chemical modifications via soft lithography. Our work allows a combination of microparticle traits in a 15-dimensional anisotropic space at the micrometric scale. No current technology provides these degrees of physical, chemical, surface coverage, and surface pattern anisotropies, which can be used interchangeably or in combination; obtaining an innumerable number of engineering microparticles with barcoding capabilities.

Small 2020, 16(46), 2004691, 2004691, DOI: 10.1002/smll.202004691

A self-calibrating and multiplexed electrochemical lab-on-a-chip for cell culture analysis and high-resolution imaging

Pablo Giménez-Gómez, Rosalía Rodríguez-Rodríguez, Juan Manuel Ríos, Marta Pérez-Montero, Estrella González, **Manuel Gutiérrez-Capitán**, **Jose Antonio Plaza**, **Xavier Muñoz-Berbel** and **Cecilia Jiménez-Jorquera**.

This paper presents a new tool that allows a self-calibrating and multiplexed electrochemical lab-on-a-chip (ME-LoC) for cell culture analysis and high-resolution imaging. The ME-LoC contains a complex network of micro-channels and micro-chambers that allow compartmentalization of the reference electrode; cell seeding and proliferation without biofouling; electrode reactivation and recalibration; and multiple

analyte detection, namely glucose and hydrogen peroxide concentrations, conductivity and ORP, as a way to monitor cell metabolism. For its simplicity, integration, automation, compartmentalisation and microfluidic control, thist technology is a promising alternative for in vitro testing and organ-on-a-chip development in the near future.

Lab on a Chip 2020, 20, 823-833, DOI: 10.1039/C9LC01051C

Lanthanide Luminescence to Mimic Molecular Logic and Computing through Physical Inputs

Miguel A. Hernández-Rodríguez, Carlos D. S. Brites, Guillermo Antorrena, Rafael Piñol, Rafael Cases, Lluïsa Pérez-García, Mafalda Rodrigues, **José António Plaza**, **Nuria Torras**, Isabel Díez, Angel Millán, Luís D. Carlos.

The remarkable advances in molecular logic reported in the last decade demonstrate the potential of luminescent molecules for logical operations, a paradigm -changing concerning silicon-based electronics. Here, the use of monolithic silicon-based structures incorporating Ln3+ complexes for performing logical functions is reported.

Advanced Optical Materials 2020, 8(12), 2000312, DOI: 10.1002/adom.202000312

Tracking intracellular forces and mechanical property changes in mouse one-cell embryo development

Marta Duch, **Núria Torras**, Maki Asami, Toru Suzuki, **María Isabel Arjona**, Rodrigo Gómez-Martínez, Matthew D. VerMilyea, Robert Castilla, **José Antonio Plaza** & Anthony C. F. Perry.

We identify a program of forces and changes to the cytoplasmic mechanical properties required for mouse embryo development from fertilization to the first cell division. Injected, fully internalized chips responded to sperm decondensation and recondensation, and subsequent device behavior suggested a model for pronuclear convergence based on a gradient of effective cytoplasmic stiffness. Forces greater than those inside muscle cells were detected. The results suggest that intracellular forces are part of a concerted program that is necessary for development at the origin of a new embryonic life.

Nature Materials 2020, 19, 1114-1123, DOI: 10.1038/s41563-020-0685-9

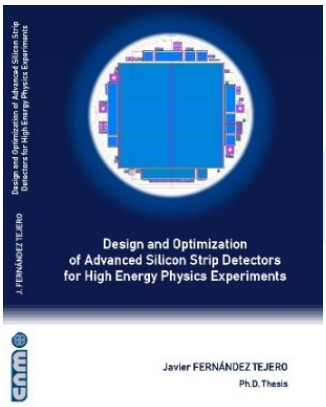
Internalization and Viability Studies of Suspended Nanowire Silicon Chips in HeLa Cells

Sara Durán, **Marta Duch**, Rodrigo Gómez-Martínez, **Marta Fernández-Regúlez**, **Juan Pablo Agusil**, Manuel Reina, Claudia Müller, Álvaro San Paulo, **Jaume Esteve**, Susana Castel and **José A. Plaza**.

We propose the integration of silicon nanowires on cell internalizable chips in order to combine the functional features of both approaches. The first stage of cell internalization was favored by silicon nanowire interfaces with respect to bulk silicon. In addition, chips were found inside membrane vesicles, and some nanowires seemed to penetrate the cytosol, which opens the door to the development of silicon nanowire chips as future intracellular sensors and drug delivery systems.

Nanomaterials 2020, 10(5), 893, DOI: 10.3390/nano10050893

Ph.D. Thesis



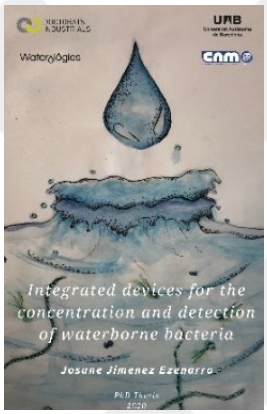
Fernández Tejero, Xavier

Thesis: ***Design and Optimization of Advanced Silicon Strip Detectors for High Energy Physics Experiments***

University: UAB

Directors: **Miguel Ullan Comes** and **Celeste Fleta**

Defense Date: 24/07/2020



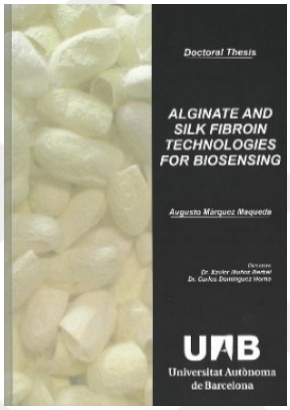
Jiménez Ezenarro, Josune

Thesis: ***Integrated devices for the concentration and detection of waterborne bacteria***

University: UAB

Directors: **Francesc Xavier Muñoz Pascual**

Defense Date: 04/09/2020



Márquez Maqueda, Augusto

Thesis: ***Alginate and Silk Fibroin based Technologies for Biosensing***

University: UAB

Directors: **Francesc Xavier Muñoz Berbel** and **Carlos Domínguez**

Defense Date: 28/02/2020

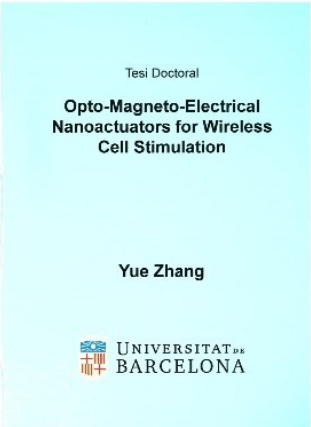
Setka, Milena

Thesis: ***Nanoscaled polypyrrole for sensing gaseous analytes and volatile organic compounds***

University: Brno TU

Directors: **Stella Vallejos Vargas**

Defense Date: 28/02/2020



Zhang, Yue

Thesis: ***Opto-Magneto-Electrical Nanoactuators for Wireless Cell Stimulation***

University: UB

Directors: **Borja Sepulveda** and **Jaume Esteve**

Defense Date: 30/11/2020

Technology Transfer

Micro and nano electronics, photonics and smart systems have been identified as a fundamental part of the Key Enabling Technologies, which are the basis for the development and the improvement of the innovation capability of the European industry. These technologies have a high economic potential and the capability to contribute to solve the current societal challenges. The mission of IMB-CNM is, in addition to improve the knowledge in the micro and nano electronics fields, to contribute to the implementation of solutions based in these technologies in industrial products. It has therefore a strong focus on technology transfer activities, which mainly include the creation of spin-off companies and the development of patents.

Researchers of IMB-CNM have collaborated in the recent years to create Spin-Offs for the valorisation of ideas and products partially or fully developed within the research groups of the institute. Along the years, the institute has been involved in the creation of 12 spin-offs. At the end of 2020, the IMB-CNM had 31 technological offers in commercialization. The active spin-offs are the 7 that follows:

Alibava Systems

Compact System for Radiation Sensor Characterisation. The Alibava system is conceived to measure ionising radiation with semiconductor detectors, providing high sensitivity to low signals, high position resolution and high speed.

A4CELLS (Arrays for Cell Nanodevices)

A4CELL develops New technology named SPAchip (Suspended Planar-Array Chips) offering a perfect way to monitorize single cell alive. SPAchips are intracellular silicom microchips for monitoring extraordinarily small volumes as a single cell.

BLB (Barcelona Liver Bioservices)

Design and development of pre-clinical studies in the field of liver diseases and hepatotoxicity. The system allows human liver cells to be kept in culture for long periods of time and in better conditions than conventional culture methods, much as if they were in the liver. This allows in vitro studies of drug efficacy and toxicity in a microenvironment very similar to that of the human liver.

CALY Technologies

CALY Technologies' SiC products offer unrivaled protection and superior performance than silicon devices in Transportation & EV applications. Our protection products are used in battery packs and power converters to limit the inrush or short-circuit current.

EnergIoT Devices

EnergIoT develops microgenerators to harvest ambient energy for smart wireless sensors, making possible a self-powered Internet of Things (IoT). EnergIoT can also create customized monitoring solutions to enable predictive maintenance for applications in other utility services such as water and gas distribution.

FUELIUM

Spin-off from CSIC established in 2015 to commercialize the research activity on fuell cells. It offers paper batteries capable of powering a variety of single-use devices, such as portable diagnostic, and being discarded without recycling. Fundación Repsol Entrepreneurs Fund Award (2016).

Smalle Technologies

Energy Harvesting Company. Has developed an electromagnetic harvester device for scavenging ambient mechanical energy with slow, variable and randomness nature. It has applications in sailboats, oceanographic and navigation buoys. Fundación Repsol Entrepreneurs Fund Award (2013).

Outreach

The IMB-CNM research and technician staff is actively involved in outreach activities to society. In 2020 many efforts had to be cancelled or repurposed in an online format. These are some of the activities the staff engaged in:

- **Exporecerca Jove**: IMB-CNM participated in the 2020 edition of Exporecerca Jove, a contest evaluation scientific and social projects carried out by preuniversitary students in Catalonia and Spain. The institute has been involved in the jury since the creation of the CSIC jury in 2018.
- **Inspiraciencia**: IMB-CNM participated in the organization of Inspiraciencia 2020, a contest on science-based stories organized by CSIC.
- **Escolab**: activity organized by Barcelona City Council to bring research laboratories closer to students. The IMB-CNM has participated in the 2019 and 2020 editions offering interactive workshops on sensors.

"Zenon Navarro" Microelectronics Museum

The "Zenon Navarro" Microelectronics Museum area was created to make micro and nanoelectronics technology and applications known to the general public. The museum displays equipment used for the design, fabrication and measurement of electronic devices. It describes what the silicon chips are and how they are made, by using static displays, multimedia material and device prototypes.

The Museum is dedicated to Zenon Navarro Garriga (1947-2007), physicist, who in the early 1980s built the UAB clean room that was used by CNM during its initial years. He later managed the construction and installation of the IMB-CNM clean room and during many years he was the photolithography process manager.

Partnerships

The scientific and technological challenges of today's society are complex and interdisciplinary, and cannot be addressed by a single institution. Cooperative innovation is therefore a key issue, and for this reason IMB-CNM has specific partnerships and collaborations with industry, universities and research centres.

IMB-CNM is a member of the **Barcelona Nanotechnology Cluster-Bellaterra (BNC-b)**. BNC-b is a scientific and industrially oriented virtual entity, grouping the capabilities and expertise in nanoscience and nanotechnology of a number of research centres and companies located in the Research Park of Universitat Autònoma de Barcelona (UAB) at Bellaterra. It includes more than 500 researchers.

http://www.bnc-b.net/

D+T Microelectrónica A.I.E. is an Association of Economic Interest which provides access for industry (especially SMEs) to the micro and nanotechnologies of IMB-CNM. It is located in the IMB-CNM building, and its mission is to facilitate the inclusion of microelectronic technologies in industrial products, by designing, developing and manufacturing chips and microsystems tailored to specific needs.

http://www.dtm.es

The **UAB Research Park** is a non-profit private foundation, created in 2007 by three research institutions, the Autonomous University of Barcelona (UAB), the Spanish Research Council (CSIC) and the Agrofood Research and Technology Institute of Catalonia (IRTA), as a basic tool to promote the transfer of knowledge and technology between the academic community and the industry. It gathers the research capabilities located at the UAB campus, and it currently includes more than 30 research centres and institutes with more than 4000 researchers.

https://www.uab.cat/parc-recerca/

In addition, IMB-CNM is member of more than 20 national and international clusters, technological platforms, industrial associations and research networks.

www.imb-cnm.csic.es

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