IMB-CNM Instituto de Microelectrónica de Barcelona - Centro Nacional de Microelectrónica

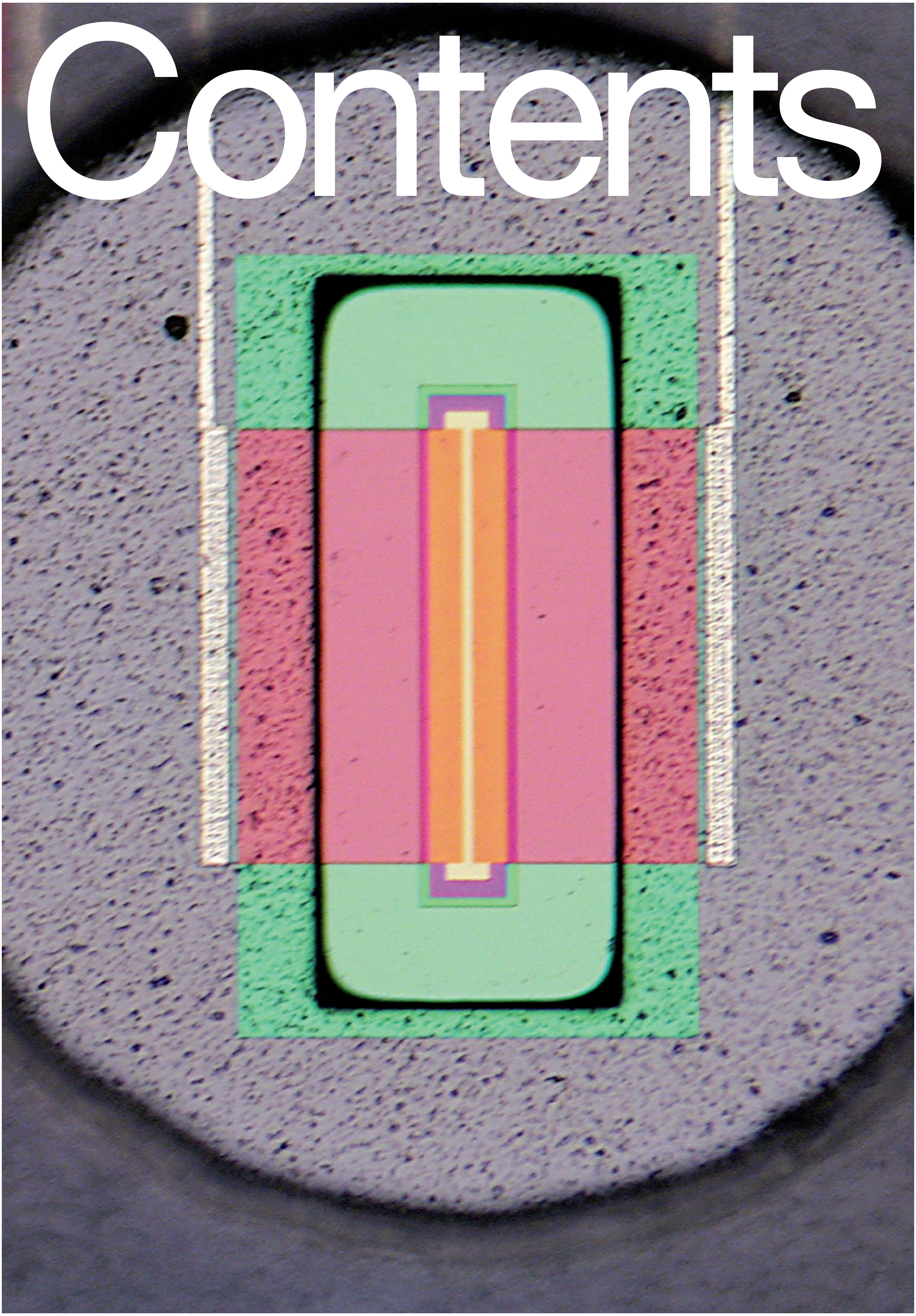
Biennial Report

2009-2010

CSIC
Consejo Superior de Investigaciones Científicas

CNM
Centro Nacional de Microelectrónica
IMB

Contents



Foreword

Emilio Lora-Tamayo
Director

The 2009-2010 biennium has been influenced by a major global economic crisis. The activity in the Centre however does not compare unfavourably with the trend defined by its history of recent years, in what refers to its positive contribution to the National and International Systems of Science and Technology. This is demonstrated by the usual numerical benchmarks and their particularization in CSIC in the form of PCO (Productivity for Achievement of Objectives), which has had comfortably positive ratings in both years. This is also confirmed by the assessment drawn up by an International Committee of Experts who evaluated the task of the Centre at the end of the Strategic Plan 2006-2009, and is guaranteed by the assessment made by the same Committee of the Strategic Plan proposed for the years 2010-2013. No doubt the capabilities of the human and technological resources of the Centre, the good work and the creativity of its staff have contributed to avoid that the crisis is reflected in the activities of the Centre, despite the real or virtual impact that it has had on the possibilities and financing capabilities of research projects and contracts.

Therefore this biennium is characterized by the transition between two quadrennial Plans, which have continuity in the conductive line of activity of the Centre: the generation of knowledge, technology and applications in the field of Micro and Nanosystems. Another feature of the activity of the Centre in this period has been the multiplicity of funding sources, from the European Framework Programme with its satellite programs (such as ENIAC, CATRENE, SUDOE, ERC, etc.), to the various National calls of MICINN, CDTI, CSIC itself or the Regional Government (Consolider, Cenit, Explora, National Plan, CSIC intramurales, INNPACTO, Avanza, Groups of Excellence, etc.) and the various forms of contracts with companies (patent licences, technical assistance, development, etc.). This somehow reflects, in addition to the interdisciplinary component of our activity, its implantation at different levels of the value chain ranging from knowledge generation to engineering and product industrialization.

For the new period which defines the Strategic Plan 2010-2013, the Centre has a significant increase in human resources (about 20% over the previous biennium), the majority of which are unfortunately of not stable nature. It also has expanded facilities, both for standard laboratories and offices and for the Micro and Nano Fabrication Clean Room of the ICTS (Spanish Large Scale Facility), as well as technological equipment significantly expanded. In addition to enhancing the capabilities of developing R&D projects and contracts, this has strengthened the ICTS role as a facility open to external access, which has consolidated the number of around one hundred projects, unrelated to those of CNM, developed in the years 2009-2010. The Minister of Science and Innovation, the President of CSIC and the Rector of UAB inaugurated these new capabilities in September 2009, marking an important date in the history of the Centre and supporting a significant leap in its potential, capabilities and visibility, which will however be conditioned by the stability of resources and by the economic climate that supports it.

It should be noted that in 2010 the National Centre of Microelectronics and its Institute of Barcelona have reached 25 years, an endeavour that started with just half a dozen people in premises temporarily borrowed from the UAB. The way appears now short to us, but the developed history shows the progress achieved at all levels, stressing and putting in value the correctness of the initial decisions, of the orientation taken and, once again, the commitment and capacity of the persons that during this time have been adding to this undertaking. At the end of December the Anniversary celebration took place, which was chaired in its closing session by the President of CSIC and the Rector of UAB.

Research highlights

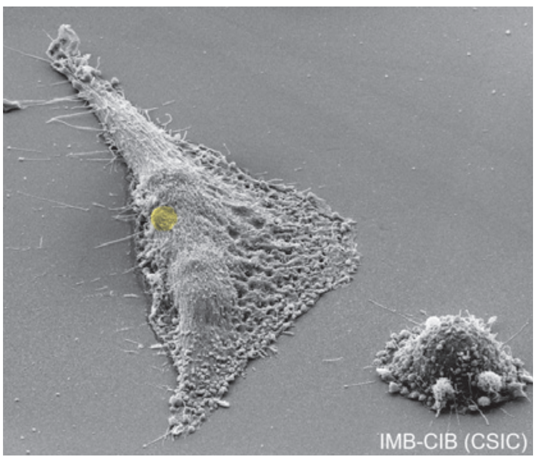
25 years of CNM

CNM was created within the National Research Council (CSIC) through an Order of the Ministry of Education and Science published on February 2nd, 1985. On 21st December 2010 the 25 anniversary was celebrated by an event in which there was a review of the history of CNM and of the current research topics and their perspectives. In addition a prize for the best research work in electronics for high schools was awarded. The one-day event was performed in the framework of a week-long celebration, which included sports activities and open doors days for the families of the IMB personnel.

Authorities during the welcome address on the 25 anniversary event.

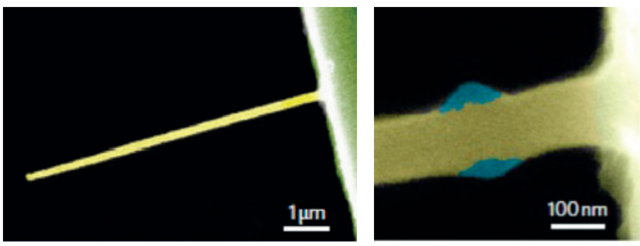
◆ Microchips in a cell

With the objective of creating an intracellular microchip sensor, IMB-CNM researchers studied how living cells internalize polysilicon devices with dimensions smaller than 3 µm. The microchips were successfully internalized by two types of cells, the social organism Dictyostelium discoideum and human HeLa cells. By using a fluorescent assay, it could be demonstrated that cells are viable over several days, which means that the microchips are not toxic. The work was published in R. Gómez-Martínez et al., Small 6 (2010) 499-502.



◆ Nanomechanical sensors

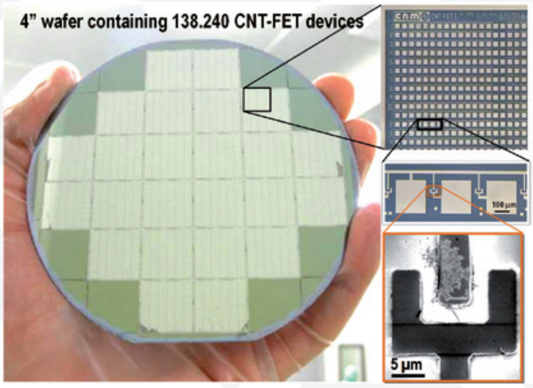
Nanomechanical resonators based on nanowires and nanotubes are promising candidates for mass sensors. However, as many biomolecules have sizes comparable to the size of the resonator, and they can land at any position along the resonator, they not only affect the resonance frequency but also the resonator stiffness. In addition, perfectly axisymmetric one-dimensional nanoresonators can support flexural vibrations with the same amplitude and frequency in two dimensions. IMB-CNM researchers participated in the research of a new approach to mass sensing and stiffness spectroscopy based on the measurement of the two orthogonal vibrations with different frequencies that result when a mass is added to the resonator. This allows the mass, stiffness and azimuthal arrival direction of the adsorbate to be determined. The work was published in Nature Nanotechnology 5 (2010) 641-645.



Research highlights

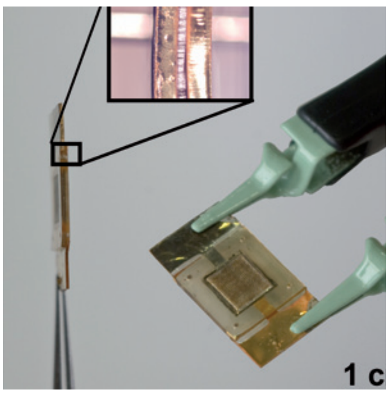
◆ Large-scale fabrication of carbon nanotube transistors

Aechnology to address massive and batch fabrication of carbon nanotube field effect transistors (CNT-FET) based systems at wafer level has been developed. In the image, a wafer composed of 24 chips and accounting for a total of 138,240 CNT-FET devices is shown. A yield of functional CNT-FET of 27% has been achieved for optimal designs. The work was published in I. Martín-Fernández et al. Microelectronic Engineering 87 (2010) 1554-1556.



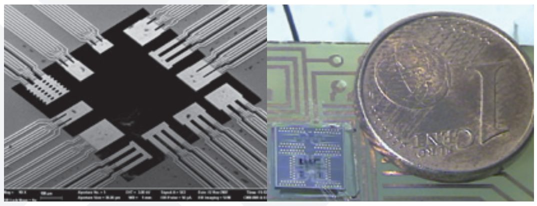
◆ Energy generating microdevices

In the PowerMEMS field, researchers of the the Micro and Nanosystems Department have developed a direct-methanol micro fuel cell that can be used as miniaturized energy source in portable applications. Its main feature is that it is completely fabricated on SU-8 photoresist. The approach takes advantage not only of the structuration and mechanical properties of this resist, but also of its capability of bonding the components by a hot pressing process to obtain a compact micro fuel cell. The membrane electrode assembly of the cell is a SU-8 porous membrane filled with a proton exchange polymer and covered by carbon-based thin film electrodes. Additional issues such as low complexity and cost have determined the design, conceived to work in passive mode (fuel transport by diffusion) with a minimum quantity of Pt catalyzer. This development has resulted in a patent application in Spain (P201031024) and has been published in Journal of Power Sources 195 (2010) 8110–8115.

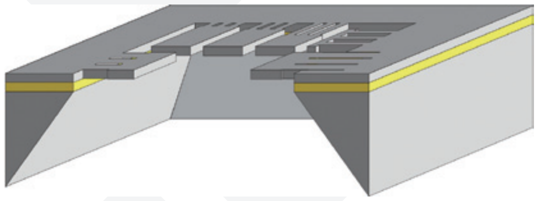


◆ Micromechanical structures

The Micro and Nanosystems group has traditionally developed various processes for the fabrication of micromechanical devices, such as accelerometers, pressure sensors, bridges and cantilevers. This has resulted in a know-how that allows the group to fabricate similar structures for their own projects and for other research groups. During 2010 the fabrication process has been improved to make it more robust and reliable.

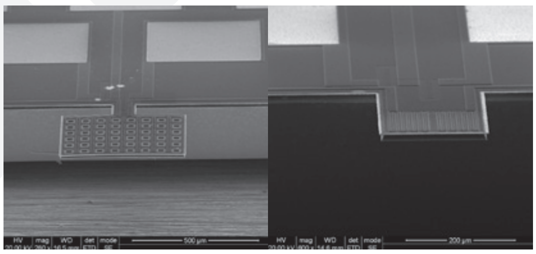


1) Chip with cantilever structures. 2) The same chip assembled to a PCB for characterization.

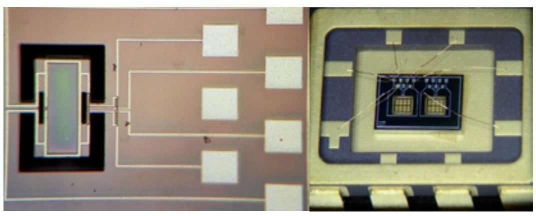


3) Schematic cross section of the chip.

These processes have allowed the fabrication of various structures for other groups, such as:



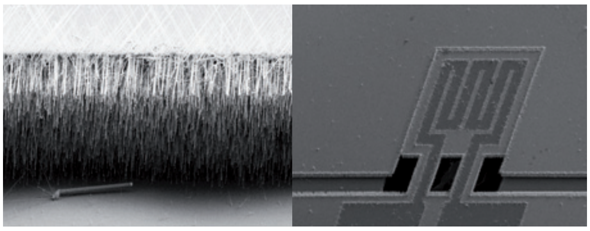
Cantilevers with various sizes and geometries for the Aragón Nanoscience Institute.



Oscillating structures for magnetic sensors for the Micro and Nanotechnology Reseacrh Center, Universidad Veracruzana (México).

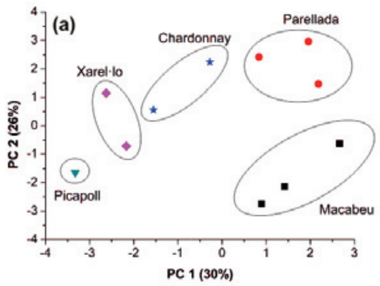
Thermoelectrical devices

In the field of micro and nanotechnologies applied to thermoelectricity the main achievement has been the integration of dense and ordered arrays of silicon nanowires on silicon microplatforms. This work has been performed in the framework of the Nanoterm project (Study of the feasibility of thermoelectrical microgenerators based on silicon nanowires (TEC2008-03255-E/TEC) of the EXPLORA programme of MICINN. The results were presented at the 29th International Conference on Thermoelectrics, ICT 2010, in Shangai (China) and have resulted in the patent application P201030486.



Multisensor systems for wine analysis

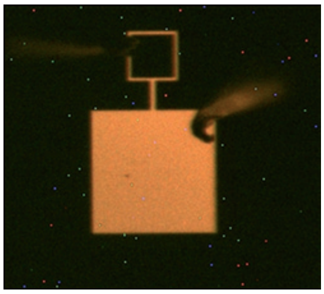
Multisensory systems based on microelectronic technology have been fabricated. Those systems are composed by electrochemical sensors -Ion Selective Field Effect Transistors (ISFETs), interdigitated platinum electrodes (IDS), amperometric thin film microelectrodes- and colorimetric optofluidic systems. These multisensors, combined with multivariate chemometric tools are applied as "Electronic Tongues" for classification and analysis of waters and wines. Later results have demonstrated the ability of these systems to classify red and white wines according to the grape varieties and even their harvest year, and for quantifying some specific parameters and the percentage of grape variety in bi and tri-varietal wines. These results have been published in M. Gutiérrez et al., The Analyst 135 (2010) 1718-1725.

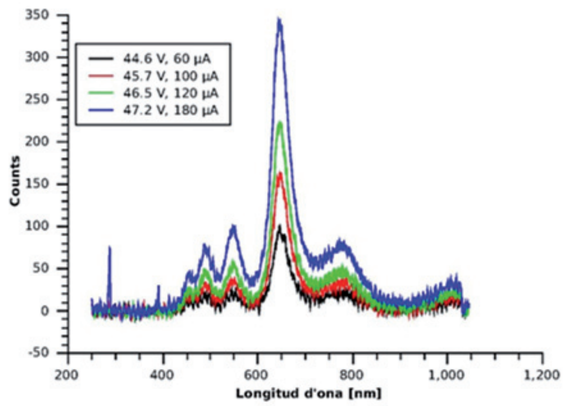


Principal Component Ananlysis plot for a set of white wines of different grape varieties with a hybrid electronic tongue

Lighting applications using silicon-rich oxide electroluminescent devices

Silicon nano-crystals (Quantum Dots), segregated from Silicon rich material, either embedded in a SiO_2 (SRO) or Si_3N_4 (SRN) matrix have been used to obtain light emitting diodes (LEDs) working at pulsed/continuous bias. Devices fabricated by chemical deposition (PECVD) techniques exhibit field-effect luminescence, whose onset decreases with the Si excess from 20 to 6 V. The measured LED power efficiency increases up to 0.1%. In addition, PECVD structures were submitted to accelerated ageing for more than 24 h of continuous operation showing an emission degradation rate of about 20%, i.e. a half life time higher than 1000h. These results have been published in M. Perálvarez et al., Nanotechnology 20 (2009) 405201 and A. Morales-Sánchez et al., Nanotechnology 21 (2010) 085710.





Label-free impedimetric measurement of cells applied to bacterial and cancer cell detection

Bacterial cells and cancer cells were selectively detected with interdigitated electrode transducers whose electric field penetration depths had been tuned to match the cell dimensions. For the bacterial cells, selectivity was achieved by modifying the transducer surface with antibodies (limit of detection down to $3 \cdot 10^{-2}$ cfu/mL). Selectivity against dead cells was also demonstrated. For the cancer cells, a specific mechanical property (swelling under hyposmotic stress) was utilized to differentiate them from non-cancer cells. This innovative approach was successfully applied to the detection of kidney and ovarian human cancer cells. This work has been published in R. de la Rica et al., Analytical Chemistry 81 (2009) 3830-3835 and 10167–10171.

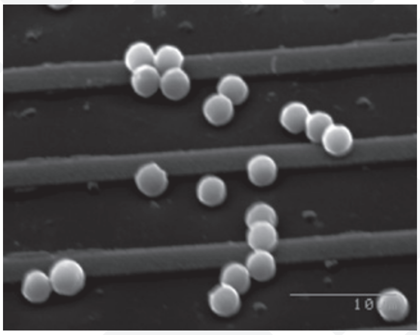
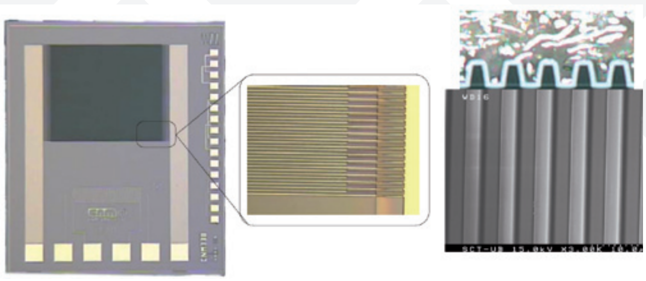


Image of a polysilicon interdigitated transducer with micron-sized dielectric beads.

Three-dimensional interdigitated electrode array as transducer for label-free biosensors

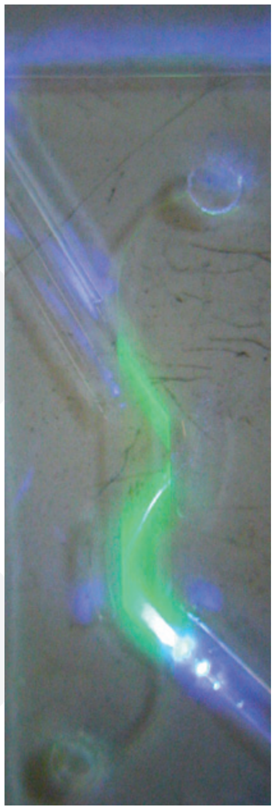
A new transducer for biosensor applications has been developed based on a three dimensional interdigitated electrode array with electrode digits separated by an insulating barrier. Binding of molecules to a chemically modified surface of the transducer induces important changes in conductivity between the electrodes. The potential of the developed device as a sensor transducer to detect immunochemical reactions, DNA hybridization events as well as enzymatic reactions is demonstrated. The sensor is also highly effective for detecting single and multilayered molecular assemblies. In a sensor array format it can be used for simultaneous multi-analyte detection in a small sample volume. This work has been published in A. Bratov et al., Electrochemistry Communications 10 (2008)



1621-1624 and Biosensors and Bioelectronics 24 (2008) 729-735, and in the book chapter “Chemical sensors and biosensors based on impedimetric interdigitated electrode array transducers” by A. Bratov, N. Abramova, in Chemical Sensors: Properties, Performance and Applications, ed. R.V. Harrison, Nova Science Publishers Inc., NY, USA, 2010, pp.93-115.

Photonic lab on a chip for absorbance, fluorescence and scattering measurements

Using light as an interrogation mechanism allows using properties that are not accessible to electrical systems, as could be changes in power, wavelength, phase or coherence. Additionally, the impossibility of having shortcuts and the remote sensing adds nothing but advantages when using light for sensing applications. When this approach is combined with microfluidics, the optofluidics concepts emerge, in which the advantages of both approaches are merged to provide with high sensitivity systems with an outstanding integration level. This work has been published in Sensors and Actuators B-Chemical 139 (2009) 166-173.



Optofluidic system comprising a hollow multiple internal reflection structure, microlenses, reservoirs, microchannels and air mirrors.

Smart Infrared and X-Ray Imagers

Digital pixel sensors (DPS) are a promising approach towards true smart integrated imagers. The embedding of complex functions inside each pixel like analog-to-digital conversion (ADC), fixed pattern noise (FPN) cancellation, crosstalk-free digital-only input-output, built-in test and even self-biasing capabilities will enable the CMOS integration of robust and high-speed miniaturized cameras. The main challenges to be faced in this hot topic

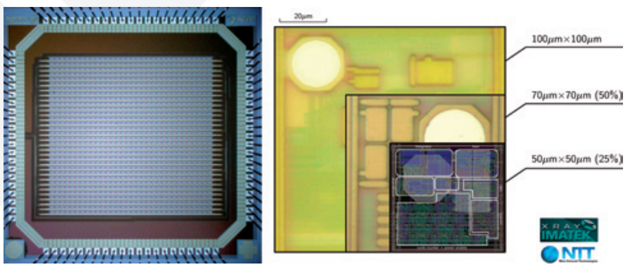


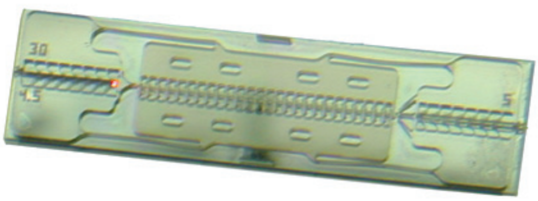
Figure: Left: a >1Kfps sub-1µW/pixel uncooled IR PbSe CMOS digital imager. Right: pitch and area comparison between three generations of 0.18µm CMOS pixel cells optimized for direct X-ray digital imagers (right). Industrial partners are NIT S.L. and X-Ray Imatek S.L. respectively.

are the research of very low-power and compact analog and mixed CMOS circuits for sub-10µW and sub-100µm pitch DPS cells, and their optimization for non-visible spectrum pixel sensors like infrared (IR) and X-ray imagers. From the industrial point of view, these IR imagers are currently driven by quality control, surveillance and strategic applications, while the X-ray counterparts are devoted to medical diagnosis and more specifically oriented to direct digital mammography systems. This work has been published in R. Figueras et al., Proc. IEEE Biomedical

Circuits and Systems Conf., Beijing, China, Nov. 2009, pp. 209-212 and in the invited paper J. Margarit et al., IEEE Transactions on Circuits and Systems-I, 56 (2009) 987-996.

Polymer-based microopto-electromechanical systems and actuators

Microoptoelectromechanical systems (MOEMS) are one of the most promising approaches in the microsystems research field. The combination of mechanization with optical readout allows defining systems with generally better performance as compared to the microelectromechanical systems (MEMS), with advantages such as the impossibility of generating spikes due to shortcuts, remote sensing and higher sensitivity. Up to date, the most significant drawback of the MOEMS field has been the excessive production costs. In this research line, this issue has been addressed and solved by defining all-polymer advanced MOEMS.This work has been published in A. Llobera et al., IEEE Photonics Technology Letters 21 (2009) 79-81, Lab on a Chip 10 (2010) 1987-1992, and V.J. Cadarso et al., Sensors and actuators A-Physical 162 (2010) 260-266.



Quad beam polymer optical accelerometer

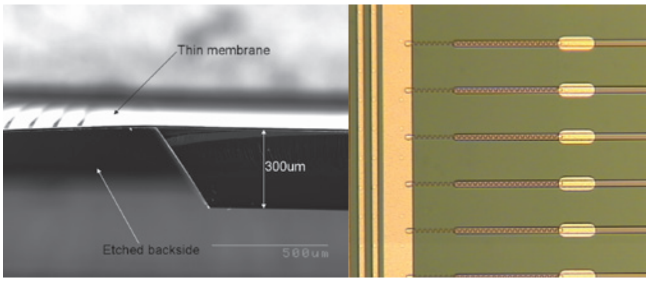
Silicon Radiation Sensors

Silicon radiation sensors fabricated at IMB-CNM are made to detect traversing charged particles or the absorption of photons. Semiconductor detectors have broad application during recent decades, in particular for gamma and X-ray spectrometry and as particle detectors.

- Silicon ultra-thin 3D detectors
- Silicon 3D radiation sensors
- Silicon micro-strip radiation sensors
- Silicon radiation sensors
- Silicon pixel sensors for imaging
- Silicon detectors for neutron dosimetry

The radiation group is involved in the fabrication of 3D detectors for the Insertable b-layer and the upgrade of ATLAS Detector for the Large Hadron Collider experiment at CERN.

The group is also member of the RD50 Collaboration at CERN that aims to develop a detector technology able to work in the harsh radiation environment foreseen in the sLHC



Hot spot location in integrated circuits by monitoring the substrate thermal phase lag with the mirage effect

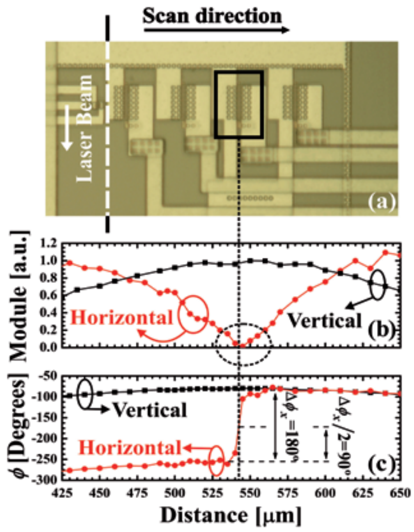
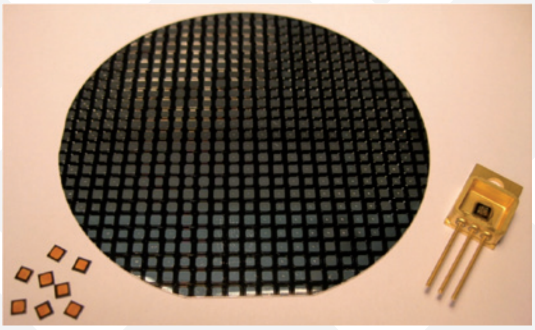


Figure extracted from: X. Perpiñà et al., Optics Letters, Vol. 35, pp. 2657-2659, 2010.

In the framework of a research collaboration with UPC, members of the Power Devices and Systems Group presented a novel solution for locating hot spots in active Integrated Circuits (IC) and devices. This method is based on sensing the phase lag between the power periodically dissipated by a device integrated in an IC (hot spot) and its corresponding thermal gradient into the chip substrate by monitoring the heat-induced refractive index gradient with a laser beam. Due to the refractive index gradient created within the IC substrate, the laser beam is deflected towards the heat source (mirage effect) and the laser beam deflection is monitored. The experimental results show a high accuracy and prove the suitability of this technique to locate and characterise devices behaving as hot spots. The figure above shows a photograph of the inspected IC indicating the activated MOS, the laser beam sense, and the scan direction (see a). Figures (b) and (c) show lock-in measurements corresponding to the amplitude (module) of the thermal gradient and the thermal phase lag corresponding to the horizontal and vertical beam deflection as a function of the lateral coordinate. From these results, it is observed that phase lag measurements show a better noise to signal ratio than module measurements, being the better choice to locate hot spots in ICs and devices.

SiC Schottky diodes for harsh environment space applications

In the framework of an ESA mission to Mercury (Bepi-Colombo), the Power Devices and Systems Group has developed a fabrication technology and packaging strategy for 300V-5A Silicon Carbide Schottky diodes with a wide temperature range operation capability (between -170ºC and 300ºC), showing a very good robustness in all performed endurance tests. These tests have been targeted to evaluate the diode behavior when working at high temperature and also under the temperature cycles corresponding to the orbits of the probe around Mercury. Radiation hardness capability has been also tested. The main conclusion outlined is that the hermeticity of the package is a key aspect to avoid electrical parameters drift. The use of gold metallization and gold wire-bonds allows reducing the diode surface and bonding degradation when compared to Al containing technology. A relevant publication in this subject is P. Godignon et al., IEEE Transactions on Industrial Electronics, vol. 58, 2582 – 2590 (2011).



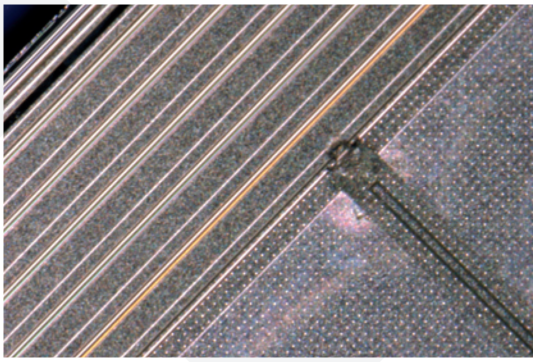
Thermal test chip for packaging and thermal transfer modelling assesment

Chips specifically conceived for thermal tests such as the assessment of packages, are of main interest in Microelectronics. Nevertheless, these test dies are required in relatively low quantities and their price is a limiting factor. The Power Devices and Systems Group has designed a low-cost thermal test chip, specifically developed for the needs of power electronics, which has been fabricated in the Clean Room facilities of the IMB-CNM. The device is based on a poly-silicon heating resistor and a

decoupled Pt temperature sensing resistor on the top, allowing to dissipate more than 60 W (170 W/cm^2) and reaching temperatures up to 200ºC. Its simple structure allows an easy simulation and modeling. These features have been taken in profit for packaging materials assessment, calibration of temperature measurement apparatus and methods, and validation of thermal models and simulations. A relevant publication in this subject is B. Allard et al., IEEE Transactions on Power Electronics, Vol. 24, pp. 2833-2846, 2009.

Reliability studies on railway power modules.

In the framework of a research contract with Alstom Transport, members of the Power Devices and Systems Group have analysed the overload turn-off failure in IGBT modules by means of experimental and simulation results. After a detailed

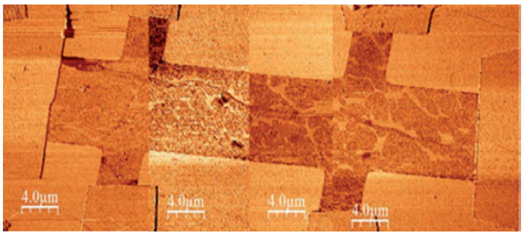


experimental analysis carried out through a dedicated test-circuit, electro-thermal simulations at device level and reverse engineering studies have been performed to determine the failure mechanism of such devices under overload conditions. The results showed that mismatches in the electro-thermal properties of the IGBT device during transient operation can lead to uneven power dissipation, significantly enhancing the risk of failure and reducing the lifetime of the railway power modules. A relevant publication in this subject is X. Perpiñá et al., IEEE Transactions on Industrial Electronics, vol. 58, 2706 – 2714 (2011).

High quality epitaxial graphene growth and processing for electronic and sensors applications

In the framework of cutting-edge research projects, members of Power Devices and Systems Group have been involved on the development of new growth strategies of single and few layer graphene (FLG) on different crystalographic faces of semi-insulating 6H-SiC substrates, improving the state of the art quality . The growth was performed in several conditions: under vacuum or argon at atmospheric pressure, as well as considering the effect of the usage of a graphite cap to cover the on-axis sample (with and without). By using high-temperature annealing conditions with a graphite cap covering,

the C-face of, both, on axis and 8° off axis 4H-SiC samples, the obtained results demonstrated large and homogeneous single epitaxial graphene layers. Raman spectroscopy showed evidence of the almost free-standing character of these monolayer graphene sheets, which was confirmed by magneto-transport measurements. On the best samples, several important characteristics have been observed: a moderate p-type doping, a high-carrier mobility, up to 12000 cm^2/Vs, and the resolution of the half-integer quantum Hall effect (typical of high-quality graphene



samples). This material is suitable for low signal and RF transistors fabrication. We also expect to use these results for the development of novel graphene based sensors. Relevant publications in this activity are B. Jouault et al., Phys. Rev. B (2010) Vol. 82, 085438 (2010), N. Camara et al., Appl. Phys. Lett. Vol. 97, 093107 (2010) and N. Camara et al., J. of Physics D, Vol. 43, 374011 (2010).

◆ Projects highlights on Power Devices and Systems

Members of the Power Devices and Systems Group are coordinating ENIAC and Consolider Ingenio projects. On the one hand, one of its researchers is the Spanish coordinator of an ENIAC project related to Consumerising Solid-State lighting (led by Philips Lighting). Light-emitting diode (LED) lamps are a rapidly-emerging technology to replace incandescent light bulbs that is gaining acceptance as an alternative to the compact fluorescent lamp. Commercial versions are already available, although there is frequently no single LED retrofit

product that meets all consumer requirements. The ENIAC JU project CSSI aims to develop and demonstrate inexpensive smart solid-state light sources through advances in technology and application opportunities. The project will also work vertically across the entire European value chain to achieve substantial cost reductions. The main actions to be undertaken by CNM will be the thermal characterisation, packaging development and reliability tests definition for this future product.

On the other hand, another researcher of this group is leading a Consolider-Ingenio project on SiC power devices, called "Advanced Wide Band Gap Semiconductor Devices for Rational Use of Energy" (RUE). The main objective of this project is to develop a real first generation of new Wide Band Gap power semiconductor devices that allow both an important improvement in the performance of existing converters and the development of new power converters; in both cases seeking a more rational use of the electric energy. Among the possible candidates to be the base materials for these new power devices, SiC and GaN present the best trade-off between theoretical performances (high-voltage blocking capability, high-temperature operation and high switching frequencies) and real commercial availability of the starting material (wafers) and maturity of their technological processes. In the framework of this project, IMB-CNM has held the first workshop on Wide Bandgap Semiconductors in Spain.

◆ Organization of the ISPSD'09 Conference

The ISPSD (International Symposium on Power Semiconductor Devices & IC's) is an IEEE international conference attracting the main academic and industrial researchers as well as decision makers in the field of power semiconductor devices and integrated circuits. The 21st ISPSD edition was organised by the IMB-CNM researchers on June 2009 in Barcelona. The number of attendants was around 200, coming from Europe, America and Asia. This conference was a great opportunity to meet a large number of researchers from different specialities such as material growth, processing, physical characterisation, electrical characterisation, devices end users and system developers.

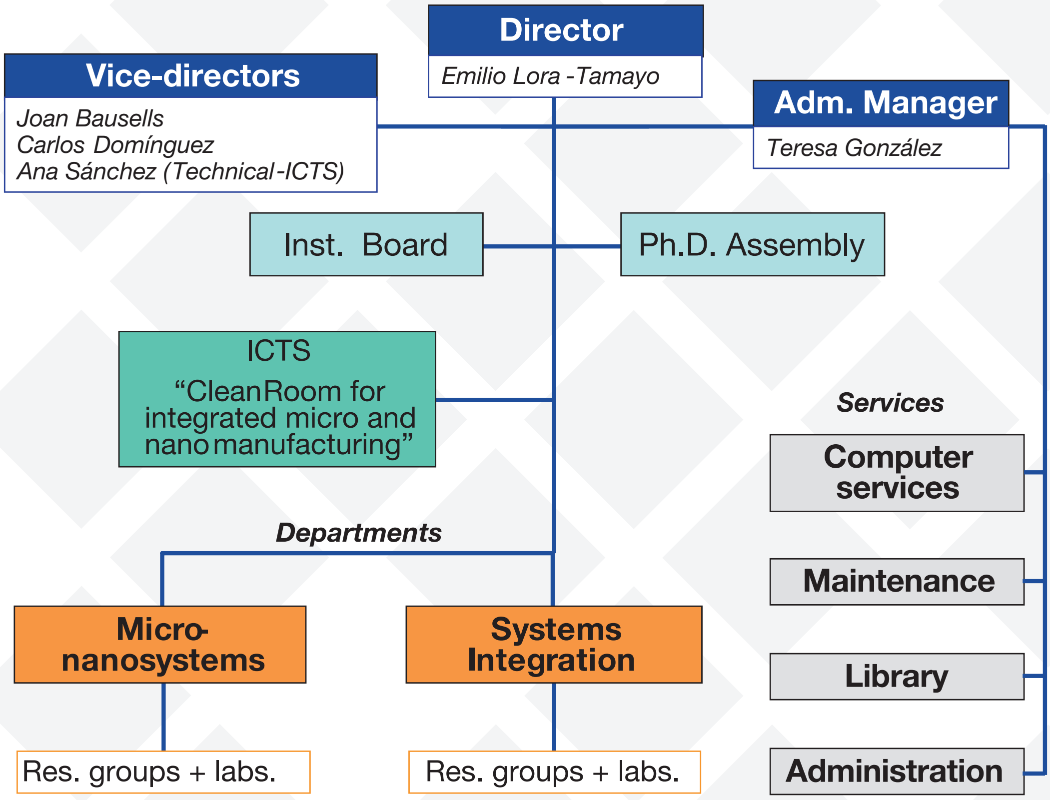
IMB structure

IMB-CNM is a research institute of the Spanish National Research Council (Consejo Superior de Investigaciones Científicas, CSIC). Its main activity is research and development primarily oriented towards applied research in the fields of silicon-based micro and nano technologies, devices and systems. The R&D activities are mainly driven by competitive research projects of the Framework Programmes of the European Union or the Spanish National R+D+i Plan. Additional activities include industrial R+D+I contracts, postgraduate and industrial training and public outreach.

The Institute has two Departments, which assemble the resources and activities related to scientific research: Micro-nanosystems and Systems Integration. Each Department is organised in various research groups. There is a dynamic internal organization within the Departments, assembling human resources according to the requirements of the research projects. The research lines touch horizontally this more or less vertical structure, gathering different skills and competences around specific scientific and technologic objectives.

The main infrastructure of the institute is the micro and nanofabrication clean room, which is organised at the Department level. It supports the research work done by the Departments and is open to external users.

IMB structure



Research groups

Micro-Nanosystems Department
Manuel Lozano

· **Bio MEMS**
F.Xavier Muñoz

· **Chemical transducers**
Electrochemical transducers
Cecília Jiménez
Silicon photonics
Carlos Domíguez

· **Micro-nanotechnologies**
Micro energy for smart systems integration
Luís Fonseca
Micro-nano tools
Jaume Esteve
Radiation detectors
Manuel Lozano
Advanced dielectric materials
Francesca Campabadal

· **Nanofabrication and functional properties of nanostructures**
Francesc Pérez-Murano

Systems Integration Department
Philippe Godignon

· **Biomedical applications**
Rosa Villa

· **Integrated circuits and systems**
Lluís Terés

· **Power devices and systems**
Silicon power devices
José Millán
Wide band gap semiconductors
Philippe Godignon
Power systems integration
Xavier Jordà

· **Reverse engineering in microelectronic devices**
Salvador Hidalgo

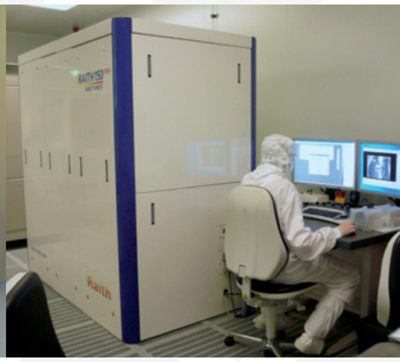
Facilities

The IMB-CNM large scale facility (ICTS – Singular Scientific and Technological Facility) includes a clean room for integrated micro and nanofabrication, a test and characterization service and a packaging service.

The clean room integrates microelectronic fabrication processes, microsystem technologies and nanofabrication equipment, such as electron beam lithography, nanoimprint lithography and focused ion beam. A complete CMOS integrated circuit fabrication line is available. In addition, microsystems-dedicated equipment allows working with materials such as metals or etching solutions that could contaminate CMOS-dedicated machines. This duplication of many of the clean room processes has been allowed by the recent extension of the clean room. The whole set of processes runs on 100 mm diameter silicon wafers, and there is a partial capability for 150 mm diameter wafers.


Metallization and RIE area


Wafer inspection


Electron beam lithography system.


Main corridor

Two access modalities are available for users: order of process runs which are performed by the clean room personnel, and qualified self-service, which is available for a limited (but growing) number of equipment.

An external access programme (GICSERV) is available from 2006, with funding from the Spanish Ministry of Science and Innovation, which allows academic external users to access the ICTS services for free, for projects of limited complexity.

Up to 256 projects have been funded in this way up to the end of the reporting period, from Spain, the European Union and (since 2010) Latin-American countries.

In the years previous to the reporting period, the clean room was expanded and increased its surface from 1000 m^2 to 1500 m^2, and the IMB-CNM main building was also expanded. The new facilities were officially inaugurated in September 2009 by the Minister of Science and Innovation, Dr. Cristina Garmendia.


Images of the inauguration of the new facilities. Left: the Minister Cristina Garmendia signs the book of Honour of IMB-CNM. In the background from left to right, IMB-CNM Director Emilio Lora-Tamayo, President of CSIC Rafael Rodrigo, General Director of Research of the Catalan Government Joan Roca, Rector of UAB Ana Ripoll, Major of Cerdanyola del Vallès Antonio Morral. Right: the Minister and the President of CSIC during the visit to the Clean Room.

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

- Microsystems: electrical characterization / sensor characterization.
- Chemical transducers / general chemistry.
- Biochemical systems characterization.
- Power devices / thermal characterization.
- Engineering of electronic systems / test of integrated circuits and systems.
- Integrated optics.
- Radiation detectors.
- Reverse engineering.
- Advanced packaging.
- 3D rapid prototyping.

Research activities

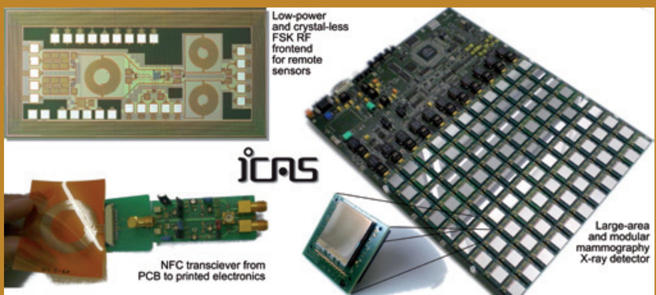
Integrated circuits and systems

The ICAS group research and development activities are in the framework of microelectronics and devoted to three main domains with different expertise key-words:

1. Integrated Circuits and Systems
   a. Very low-power analog, mixed and RF CMOS circuit design
   b. Massive multi-channel sensing systems
   c. Inductively powered systems
   d. Low-range RF transceivers
   e. Specific analog design for digital CMOS technology

2.Flexible and Organic Printed Electronics
   a. Technology characterization and design kits development
   b. Circuits and cell libraries design
   c. EDA components development and design flows/tools customization

3.Electronic Systems and Platforms
   a. Flexible platform based design
   b. Multi-technological modeling and simulation
   c. Digital SoC platform based design and IP integration



There is a close cooperation among those activity lines and expertise, as well as other R&D groups, in order to improve, apply and exploit the micro/nano-technologies for advanced applications like:

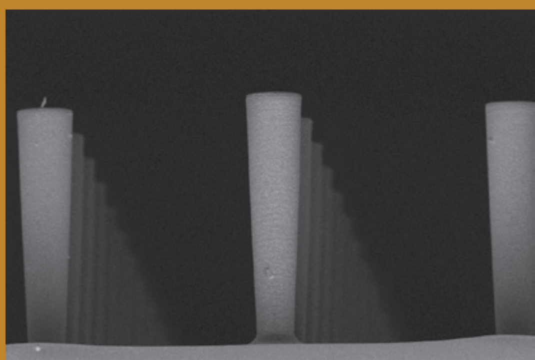
· Visible, infrared and X-ray analog & digital imagers.
· Integrated sensor and actuator N/MEMS interfaces.
· Multi-technological modeling and simulation.
· Low-power RF frontends for wireless sensors.
· Remote-powered and body-implantable systems.
· SoC & System electronics based on flexible platforms.
· NFC modules based on std. PCB or flexible/organic printed electronics.
· Library cells & design kits for Silicon or Flexible/Organic based technologies.

Micro-nano-bio systems

Design and development of novel micro and nanosensors and complex and compact miniaturized systems for biological and biomedical applications. The various steps of device design, characterization, encapsulation and packaging, as well as customized electronic instrumentation are approached from the initial conception to the final biodevice in order to generate knowledge, micro-nano devices and complete systems with high added value.

Activities include the development of new technologies and tools for the detection, identification, quantification, and monitoring of molecules, cells and tissues of clinical and biomedical relevance. Research focuses in:

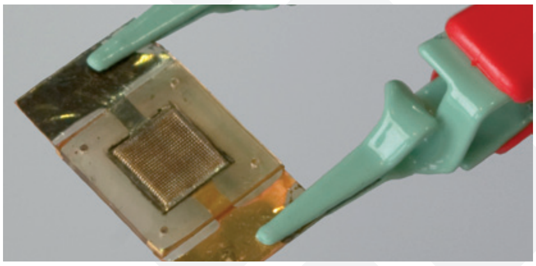
· Micro-Nano systems for diagnosis.
· On-chip environmental health monitoring.
· Nano-Bio-Electronic Interfaces.
· NanoBioFuel cells.
· Nanobioelectrochemistry.



Micro-nanotechnologies

The general objective is the advanced research and development on new processes, devices and sensors for Integrated Circuits, MEMS, NEMS and Smart Systems, mainly using silicon based micro nano technologies. More specifically, the work includes research at different levels of integration such as design, simulation, fabrication, characterization and optimization tasks for:

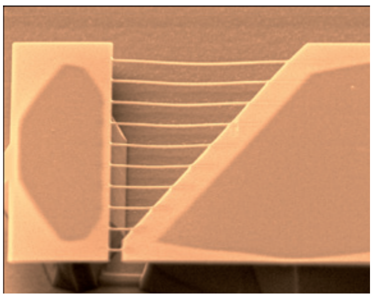
- Processes and micro-nanoelectronic technologies and their integration (More Moore approach).
- Nano-systems, sensors, NMEMS (More than Moore approach).
- Application-oriented smart systems and subsystems for fields such as medical, environment, food, energy, telecom, particle physics, space, etc.



Specific topics addressed are: high-k dielectrics, reliability of devices and technologies, CMOS-MEMS, SOI-MEMS and 3-D heterogeneous integration, micro-nanotools, MOMS/NOMS, thermally isolated micro-nano-structures, radiation sensors, radiation hardness characterization, power MEMS (nano-thermoelectrics, scavenging and microfuel cells).

Nanofabrication and nanostructures

Investigation, study and exploitation of new and exceptional electromechanical properties that arise in solid state artificial structures by the fact that their significant dimensions are in the nanometer scale. These nanostructures are obtained by using 'so called' nanotechnological methods, so that research on advanced nanofabrication methods is an essential part of the activities. Also, development of specialized electromechanical characterization methods is of great interest. The aim is to investigate on novel properties and methods with a potential to demonstrate novel functionalities and ultra-high performance of electromechanical devices and systems. The main activities are:



- Advanced nanofabrication methods.
- Novel nanometrology tools and methods.
- Singular functional properties of nanostructures.
- Ultimate performance limits of nanodevices.

Power devices and systems

The activities include research on innovative and breakthrough technologies of power devices and systems for efficiency improvements and energy consumption reduction, with special emphasis on automotive, transport, aerospace, renewable energy and energy distribution applications. Specifically:

1. Silicon based power devices and integrated circuits: Modelling, design and processing of MOS controlled devices (DMOS, IGBT), LDMOS for high frequency, superjunction devices, SOI based power switches, smart power and protection devices.

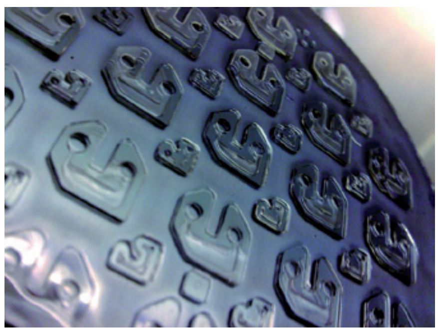
2. Wide Band Gap Semiconductors: Modelling and set up of optimized technologies for Wide Band Gap semiconductor (SiC, GaN, Diamond, Graphene on SiC) processing, design and implementation of novel power devices.

3. Power systems and heterogeneous integration: New methods for the design, modelling, simulation, development and characterization (thermal and electrical) of power integrated systems. New interconnection and packaging techniques. Reliability analysis.

Transducers for chemical and biochemical sensing

This activity is devoted to R&D of new chemical and biochemical transducers. Different transduction principles and/or signal propagation media are investigated, making use of new technologies combined with microelectronic technology, new device structures, processes and materials. This work is aimed at improving transducers performance and developing new concepts of sensors, autonomous systems, and platforms for lab-on-a-chip analytical systems.

Electrochemical devices: Barrier IDEAs, polySi impedimetric transducers, CNT sensors, voltammetric microelectrodes and UMEAs, ISFET sensors.
Photonic/Optical Devices.
Silicon based devices: Micro-optical components, optochemical sensors, interferometric devices, optomechanical components, Si nanocrystal light emitters.
Hybrid Si/polymer integration: Sol-gel based sensors, polymeric optical elements, free space components (hollow/MIR).
Advanced materials and processes: Functional organo-inorganic polymeric materials, gas phase soft-lithography, nanostructured materials for sensors.
Chemical sensor systems and arrays: Electrical protein microarray readers, multisensor systems, wireless RFID-like sensors.



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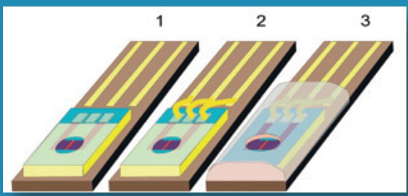

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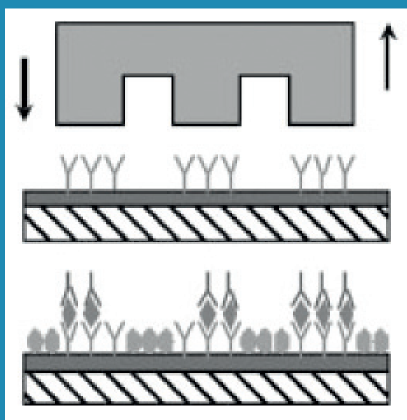

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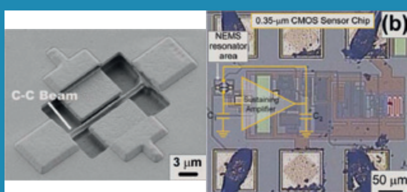

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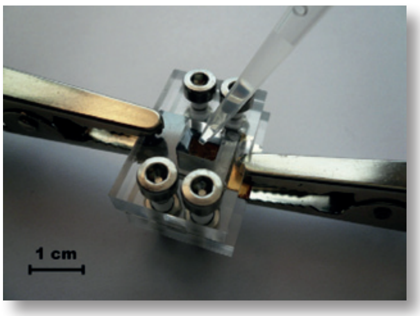

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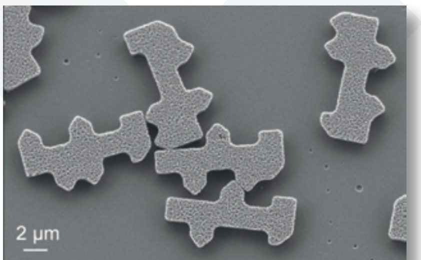

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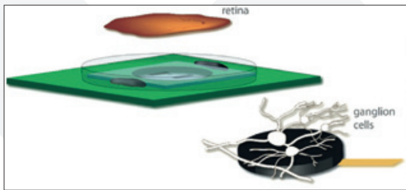

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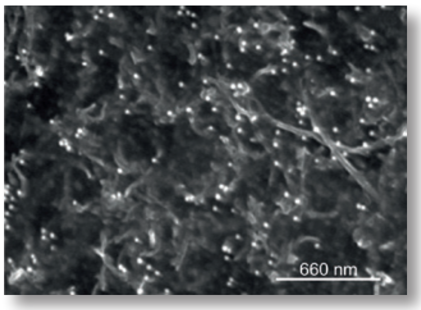

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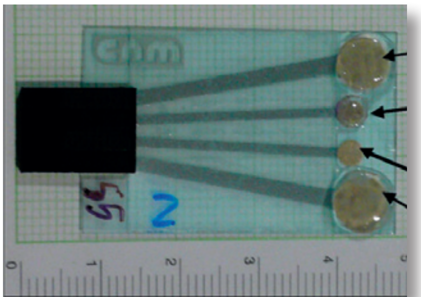

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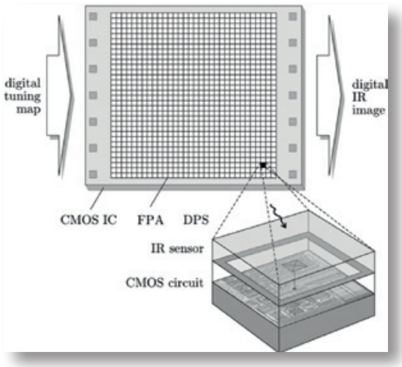

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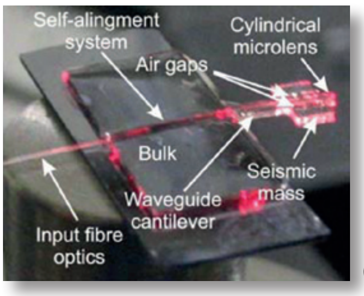

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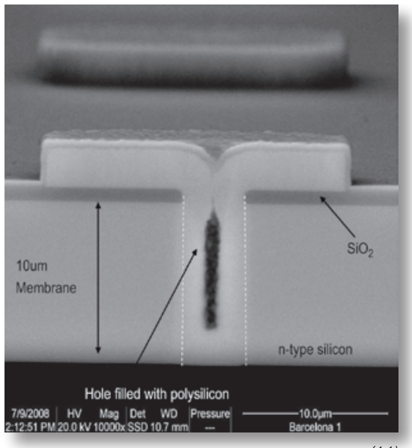

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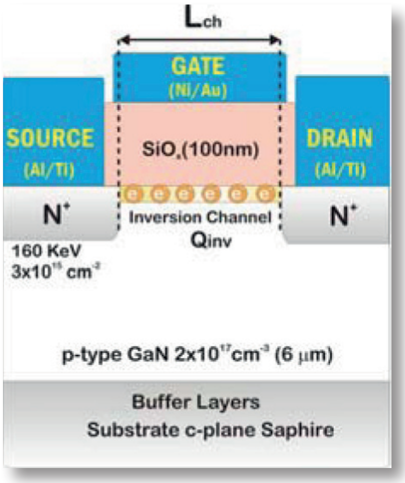

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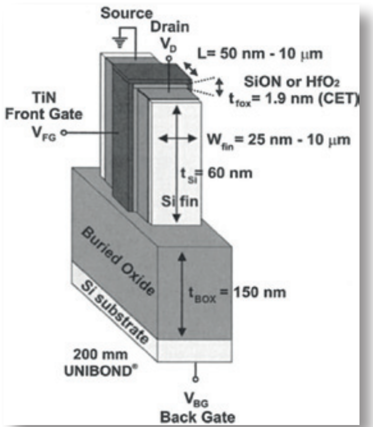

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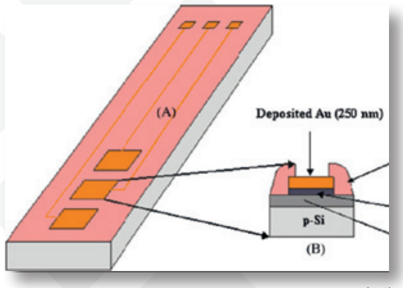

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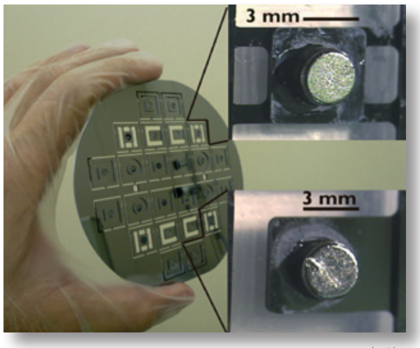

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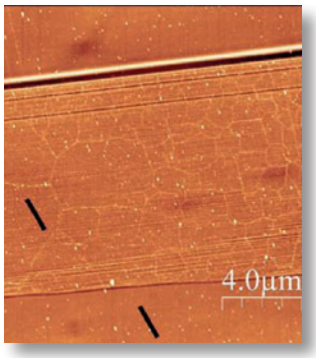

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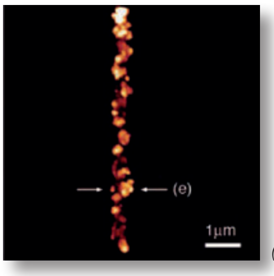

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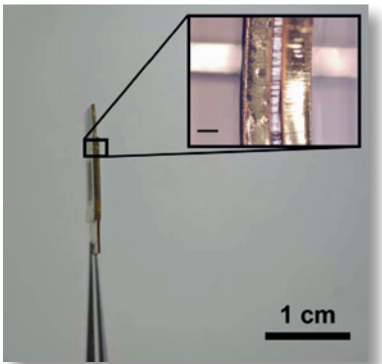

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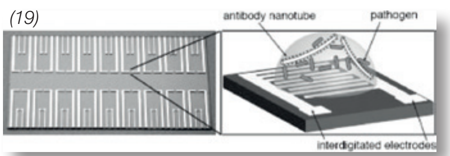

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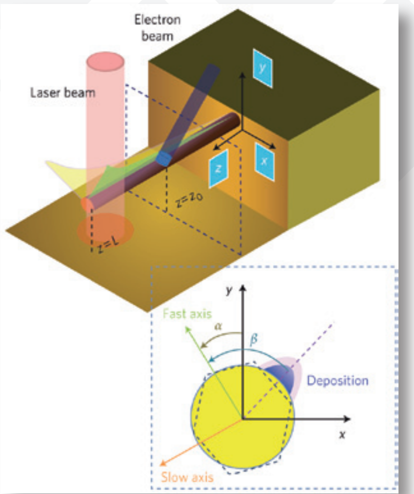

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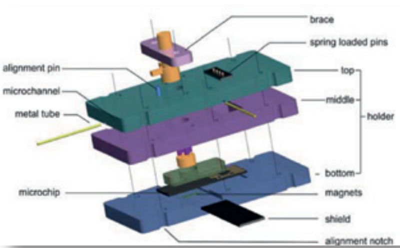

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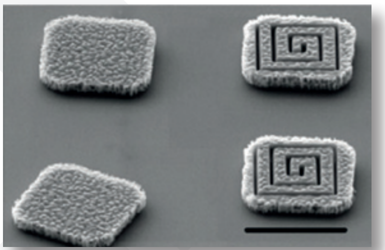

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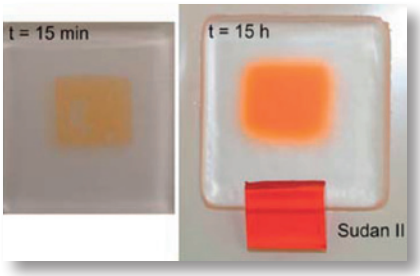

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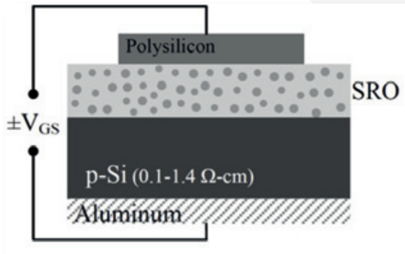

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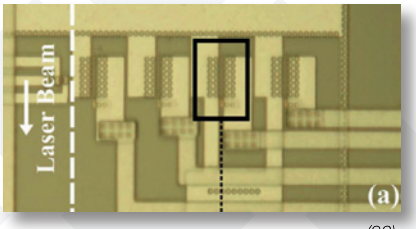

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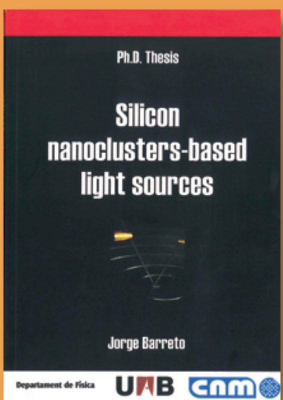

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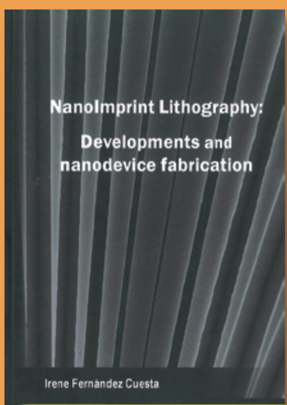

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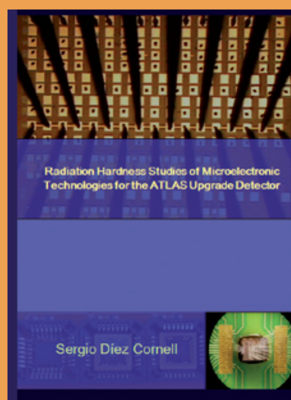

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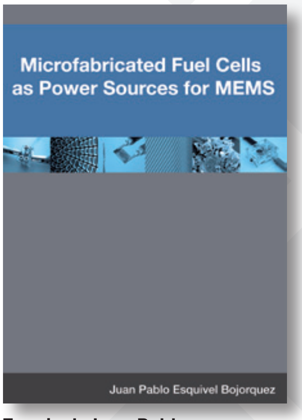

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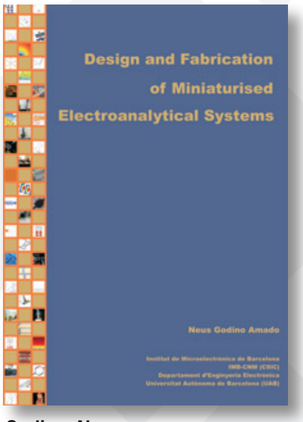

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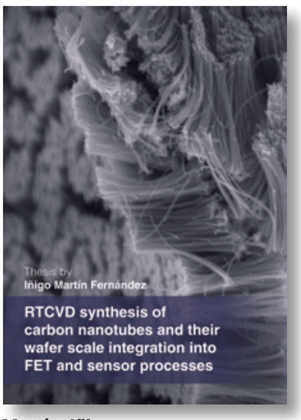

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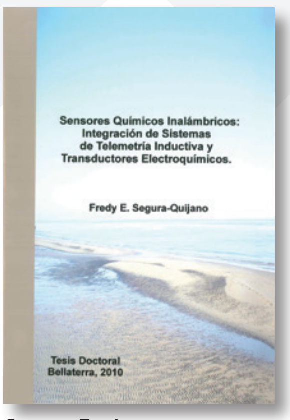

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Patents

The intellectual property rights (IPR) of the research results of IMB-CNM are managed according to the rules of CSIC. Initially a patent application is issued at the Spanish level. This corresponds to the section “New patents” below. After a period of time, the patent can be extended to other countries, typically under the PCT (Patent Cooperation Treaty) rules. The corresponding patents are listed under the “International patents” or “US Patents” sections.

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Authors: Muñoz-Berbel, X., Muñoz, F.J., Mas, J., Vigues, N., Escudé-Pujol, R., Del Campo, F.J.
Ref.: Spain, appl. P200800109, 2008; PCT, publ. WO 2009/090280 A1, 2009.

4. Title: Method for defining and producing reactive chemical nanometric surface patterns by means of gaseous-phase soft lithography, resulting patterns and devices and uses thereof.
Owner: CSIC.
Authors: de la Rica, R., Fernández-Sánchez, C., Baldi, A., Domínguez, C., Jimenez- Jorquera, C.
Ref.: Spain, appl. P200800221, 2008; PCT, publ. WO 2009/095520 A1, 2009.

5. Title: Method and system for detecting and/or quantifying bacteriophages that can infect a predetermined bacterial host strain, use of a microelectronic sensor device for detecting said bacteriophages and microelectronic sensor device for implementing said.
Owner: CSIC, UB.
Authors: García-Aljaro, C., Muñoz-Berbel, X., Muñoz Pascual, F.J., Blanch, A.R.
Ref.: Spain, appl. P200800776, 2008; PCT, publ. WO 2009/115633 A1, 2009.

6. Title: Diffraction network coupler, system and method.
Owner: CSIC.
Authors: Zinoviev, K., Domínguez, C., Lechuga, L.M.
Ref.: Spain, appl. P200801236, 2008; PCT, publ. WO 2009/133228 A1, 2009.

7. Title: Digital read-out integrated circuit for the digital reading of high-speed image sensors.
Owner: CSIC.
Authors: Serra-Graells, F., Margarit, J.M., Terés, L.
Ref.: Spain, appl. P200801428, 2008; PCT, publ. WO 2009/138545 A1, 2009.

8. Title: Hybrid polymer electrolyte membrane and use thereof.
Owner: CSIC.
Authors: Esquivel, J.P., Sabaté, N., Santander, J., Torres, N., Gràcia, I., Cané, C., Tarancón, A., Acero, M.C.
Ref.: Spain, appl. P200801838, 2008; PCT, publ. WO 2009/153380 A1, 2009.

9. Title: Electrical and reusable device for reading microarrays.
Owner: CSIC.
Authors: Baldi, A., Fernández-Sánchez, C., de la Rica, R., Bonilla, D.
Ref.: Spain, appl. P200802068, 2008; PCT, publ. WO2010/004075 A1, 2010.

10. Title: System for aligning patterns on a substrate using stencil lithography.
Owner: CSIC, UAB, EPFL.
Authors: Pérez-Murano, F., Arcamone, J., Sansa, M., Brugger, J., van den Boogaart, M.A.F, Barniol, N., Abadal, G., Uranga, A., Verd, J.
Ref.: Spain, appl. P200802208, 2008; PCT, publ. WO 2010/010224 A1, 2010.

11. Title: Microagujas de su-8 para la monitorización y la estimulación neuronal.
Owner: Ikerlan, CSIC.
Authors: Gabriel, G., Guimerà, A., Menéndez de la Prida, L., Fernandez, L.J., Tijero, M., Altuna, A., Villa, R., Berganzo, J.
Ref.: Spain, appl. P200930430, 2009; PCT, appl. PCT/ES2010/070472, 2010.

12. Title: Sistema y procedimiento multianalítico basado en mediciones impedimétricas.
Owner: CSIC.
Authors: Ramon, J., Sanchez-Baeza, F., Marco, M.P., Bratov, A., Abramova, N., Ipatov, A.
Ref.: Spain, appl. P200931164, 2009; PCT, appl. PCT/ES2010/070824, 2010.

13. Title: Procedimiento de recubrimiento de electrodos de un dispositivo electrónico por atrapamiento magnético, electrodo así obtenido, dispositivo que incorpora dicho electrodo y uso de dicho dispositivo.
Owner: CSIC.
Authors: Baldrich, E., Muñoz, F.J.
Ref.: Spain, appl. P200931261, 2009; PCT, appl. PCT/ES2010/070853, 2010.

US Patents

Title: Universal reconfigurable system and method for the remote reading of counters or equipment comprising visual indicators.
Authors: Merino, J.L., Terés, L., Rubio, L., Alvarez, G., Amuchastegui, C., Ayuso, N., Pico, J., Benitez, N.
Ref.: Spain, appl. ES20050000991, 2005; PCT, appl. PCT/ES2006/000201, 2006; US Pub. No. US2010/0013666 A1, 2010.

New Patents

1. Title: Dispositivo y método para la determinación de características eléctricas de nanocontactos entre una nanoestructura longitudinal y una pista de metal para su conexionado.
Owner: CSIC.
Authors: Santander, J., Cané, C., Fonseca, L., Figueras, E., Gràcia, I., Sabaté, N., Torres, N., Ivanov, P.
Ref.: Spain, appl. P200900370, 2009.

2. Title: Dispositivo no invasivo para la detección de metabolitos en el sudor.
Owner: CSIC.
Authors: Muñoz, F.J., Mas, R.
Ref.: Spain, appl. P200930148, 2009.

3. Title: Dispositivo para generar energía eléctrica a partir de pequeños movimientos.
Owner: CSIC.
Authors: Esteve, J., Acero, M.C., Fondevilla, N., Serre, C., Pérez-Rodríguez, A.
Ref.: Spain, appl. P200930320, 2009.

4.Title: Dispositivo y sistema de contabilización y análisis de partículas y uso de dicho sistema.
Owner: CSIC.
Author: Llobera, A.
Ref.: Spain, appl. P201030015, 2010.

5. Title: Dispositivo inductivo detector de presencia bacteriana.
Owner: CSIC.
Authors: Baldrich, E., Muñoz, F.J., Martínez, S.
Ref.: Spain, appl. P201030031, 2010.

6. Title: Materiales conductores mediante funcionalización de polímeros con nanomateriales conductores.
Owner: CSIC, ICN.
Authors: Mendoza, E., Gutiérrez, M., Llobera, A., Fernández-Sánchez, C., Jimenez-Jorquera, C.
Ref.: Spain, appl. P201030040, 2010.

7. Title : Detector de radiación ionizante sensible a la posición 2D.
Owner: CSIC.
Authors: Bassignana, D., Lozano, M., Pellegrini, G.
Ref.: Spain, appl. P201030200, 2010.

8. Title: Sensor no invasivo para determinar características funcionales de la cornea y dispositivo que incluye dicho sensor.
Owners: CSIC, Univ. Valladolid.
Authors: Guimerà, A., Villa, R., Gabriel, G., Maldonado, M.J.
Ref.: Spain, appl. P201030307, 2010.

9. Title: Microcámara y dispositivo de cultivo celular monitorizables por resonancia magnética nuclear.
Owners: CIBER-BBN, Univ. Valencia, CSIC, Ikerlan.
Authors: Celda, B., Esteve, V., Sancho, F., Villa, R., Fernández Ledesma, J.L., Berganzo, J.
Ref.: Spain, appl. P201030382, 2010.

10. Title: Aparato de agitación y caracterización de fluidos.
Owner: CSIC.
Authors: Baldi, A., Sacristán, J., García-Cantón, J.
Ref.: Spain, appl. P201030439, 2010.

11. Title: Dispositivo de generación termoeléctrica, generador termoeléctrico y método de fabricación de dicho dispositivo de generación termoeléctrica.
Owner: CSIC.
Authors: Tarancón, A., Dávila, D., Sabaté, N., San Paulo, A., Fernández-Regúlez, M., Fonseca, L.
Ref.: Spain, appl. P201030486, 2010.

12. Title: Dispositivo RFID con comunicación y alimentación remotas.
Owner: CSIC.
Authors: Baldi, A., Sacristán, J., Segura, F.
Ref.: Spain, appl. P201030609, 2010.

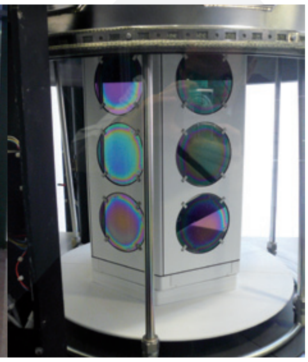
13. Title: Celda combustible polimérica.
Owner: CSIC.
Authors: Esquivel, J.P., Sabaté, N., Santander, J., Torres, N., Gràcia, I., Cané, C.
Ref.: Spain, appl. P201031024, 2010.

Outreach

IMB has an increasing activity in outreach events aiming at promoting the society awareness of the benefits of science and specifically of micro/nanoelectronics, and the public support of science and technology. A programme of visits from high school students is on-going to encourage young people to follow science and technology careers. IMB participates in the annual Science and Technology week in Spain and regularly presents the results of its research work in public media.

◆ Microelectronics Museum Area

The Zenon Navarro Microelectronics Museum area has been set up to disseminate microelectronics technology and its applications, by showing equipment used for the design, fabrication or measurement of electronic devices. The equipment on display has been used by IMB-CNM on its R&D projects. The museum includes multimedia material and device prototypes.



As part of the public outreach activities of IMB-CNM, guided visits to the institute and the museum area are organized for student groups, from high schools or universities. In 2010 the museum area was visited by around 300 students.

Partnerships

IMB-CNM has specific partnerships and collaborations with industry, universities and research centres to better address the scientific and technological challenges.

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:

· Centre d'Investigació en Nanociència i Nanotecnologia, CIN2 (CSIC-ICN)
· Institut de Ciència de Materials de Barcelona, ICMAB (CSIC)
· Various Departments of Universitat Autònoma de Barcelona, UAB
· Centre Nacional de Microelectrònica, IMB-CNM (CSIC)
· MATGAS 2000, A.I.E.
· D+T Microelectrónica, A.I.E.

BNC-b currently includes a total of more than 450 researchers.

www.bnc-b.net

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 (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 30 research centres and institutes with more than 4000 researchers.

parc.uab.cat

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 incorporation of microelectronic technologies in industrial products, by designing, developing and manufacturing chips and microsystems tailored to specific needs.

www.cnm.es/dt

Associated Units

CNM-IMB has special collaborations with five research groups from Spanish universities and technological centres, through "Associated Unit" agreements with the Spanish Research Council (CSIC):

- Electronic Materials and Engineering Group, Department of Electronics, University of Barcelona (UB), since 1998.
- Group of Semiconductor Devices, Department of Electronic Engineering, Polytechnical University of Catalonia (UPC), since 1998.
- Group of Electronic Circuits and Systems, Department of Electronic Engineering, Autonomous University of Barcelona (UAB), since 2002.
- Sensor & Biosensor group, Department of Chemistry, Autonomous University of Barcelona (UAB), since 2002.
- Institute for Systems based on Optoelectronics and Microtechnology (ISOM), Politechnical University of Madrid (UPM), since 2002.

Research Agreements

In the period covered by this report, IMB-CNM has signed several collaboration agreements with international research institutes:

- National Nano Device Laboratories, Taiwan, R.O.C. on academic exchanges between both institutions.
- International Iberian Nanotechnology Laboratory, Braga, Portugal, for the training of INL technical personnel at IMB-CNM.
- Centre de Développement des Technologies Avancées, Alger, Algeria, on personnel exchanges, research collaboration and technical assistance.

Research consortiums

IMB-CNM participates in international research consortiums and in public-private partnerships within the framework of Joint Technology Initiatives such as ENIAC (the European Nanoelectronics Initiative Advisory Council), the Framework Programmes for research and technological development of the European Union, pan-European networks such as EUREKA and other initiatives such as the European Research Council.

Within EURIPIDES (the EUREKA initiative for packaging and integration of microdevices and smart systems), IMB-CNM co-organized with FICOSA and PRUAB the 3rd Euripides Forum, held in Barcelona in October 2009. Prof. Carles Cané of CNM is a member of EURIPIDES Council since the end of 2010.

IMB-CNM is a member of EPoSS (the European Technology Platform on Smart Systems Integration), Photonics 21 (the Technology Platform for Photonics in Europe) and EPIC (the European Photonics Industry Consortium). It is one of the promoters of Génesis-Red (the Spanish Technology Platform on Nanoelectronics and Smart Systems Integration), and participates through it in the Forum of Stakeholders of ENIAC.

Researchers from IMB-CNM are members of CERES (Space Studies and Research Center) of UAB, which is a unit of IEEC (Institute for Space Studies of Catalonia).

National collaborative research projects are performed within the framework of the National Plans for R+D+I.

Two research groups (Chemical Transducers and BioMEMS) of IMB-CNM are members of the TECNIO network of applied research and technology transfer centers in Catalonia.

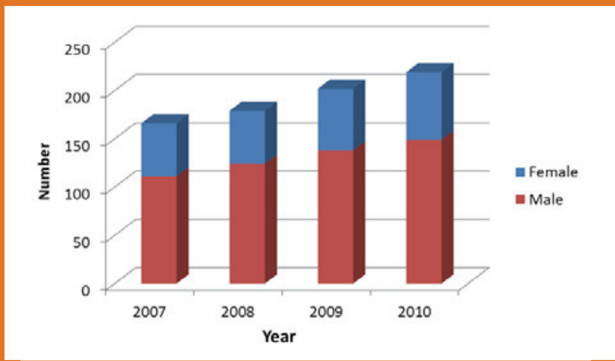
Key Figures

The time period 2009-2010 has seen the transition between the Strategic Plans of 2005-2009 and 2010-2013. The strategic plans define the institute objectives for scientific productivity, technology transfer and external funding, plus the base budget and new human resources provided by CSIC. The economic downturn started in 2009 has, in practice, resulted in reductions in both the budget and new human resources as compared to the Strategic Plan.

Staff

After the expansion in offices, laboratories and clean room area that was completed in the previous biennial period, the human resources have grown a 22% in the period covered by this report, from 179 to 219 persons. The current staff is essentially the maximum capacity of the existing premises.

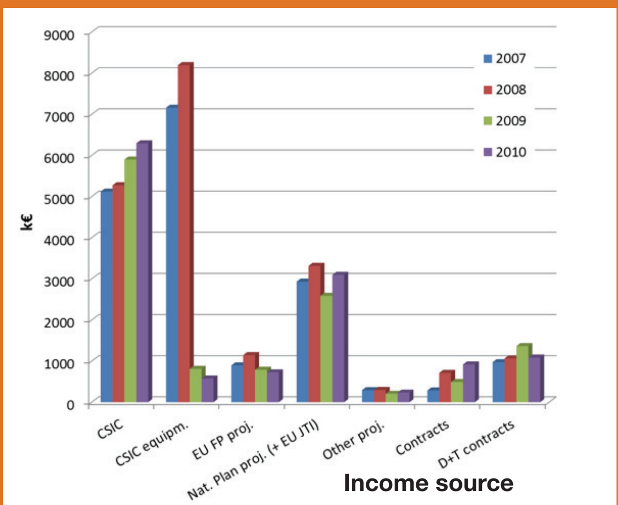
STAFF - End 2010	Female	Male	Total
Researchers	15	51	66
Ph.D. students	24	33	57
Clean room facility	16	27	43
Support services	1	27	28
Administration & general services	13	7	20
Visitors	1	4	5
TOTAL	**70**	**149**	**219**

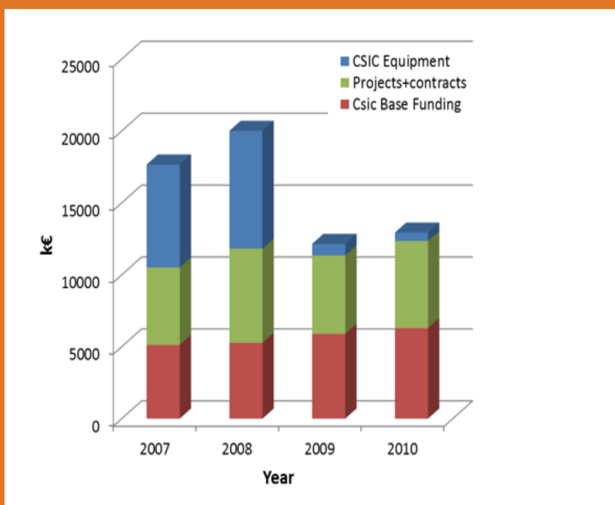


Budget

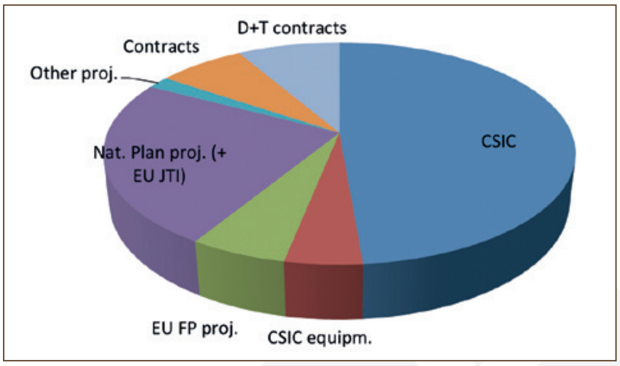
During 2007 and 2008 the budget of IMB-CNM included a special action from CSIC for clean room equipment acquisition, which was a follow-up of the clean room expansion previously completed. The income from the National Plan projects includes the national funding for projects from the European Joint Technology Initiatives such as ENIAC.

BUDGET (k€)	2007	2008	2009	2010
Equipment – CSIC action	7.158	8.194	811	576
All other income sources	10.499	11.809	11.334	12.352
TOTAL BUDGET	**17.657**	**20.003**	**12.145**	**12.928**



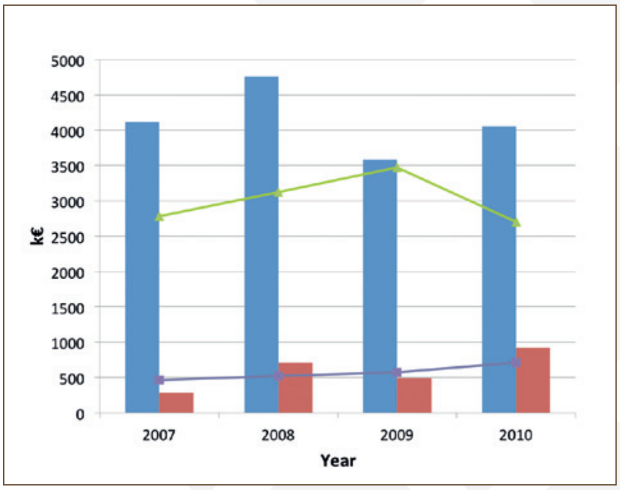


Budget distribution 2010



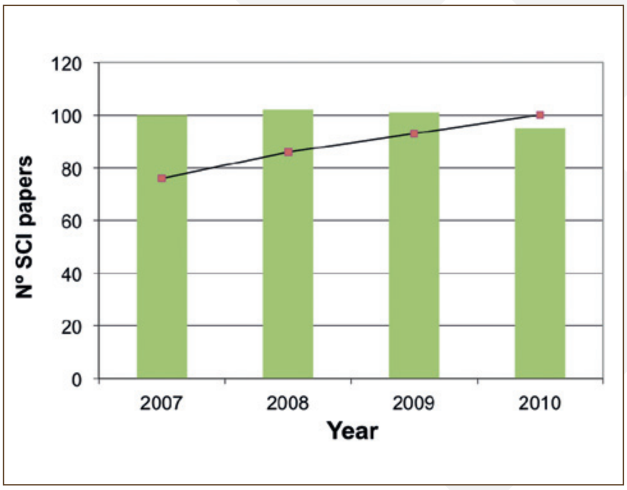
External Funding

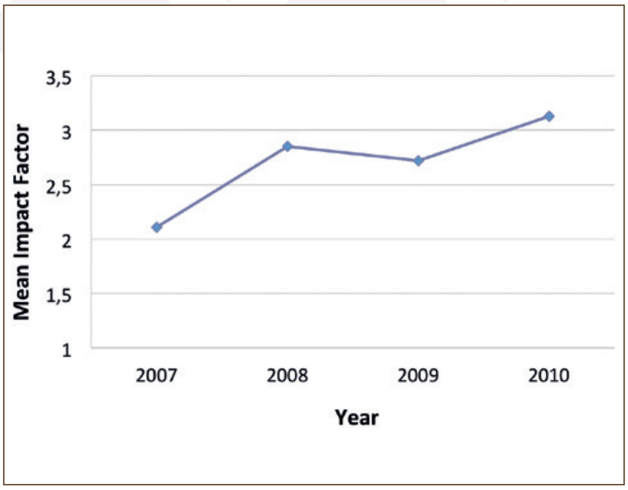
External funding from competitive public projects and industrial contracts, in the context of the 2005-2009 and 2010-1013 Strategic Plans.

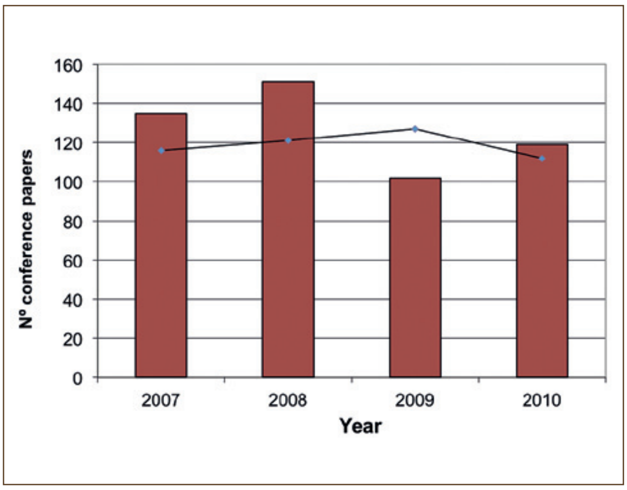


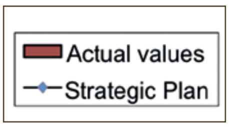
Publications

The graphs show the number of scientific papers published in SCI indexed journals, the mean impact factor per year and the number of presentations made at scientific conferences. The strategy concerning journal publications prioritizes increasing their impact, which has been achieved in the reporting period.









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CSIC
Consejo Superior de Investigaciones Científicas

Centro Nacional de Microelectrónica
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