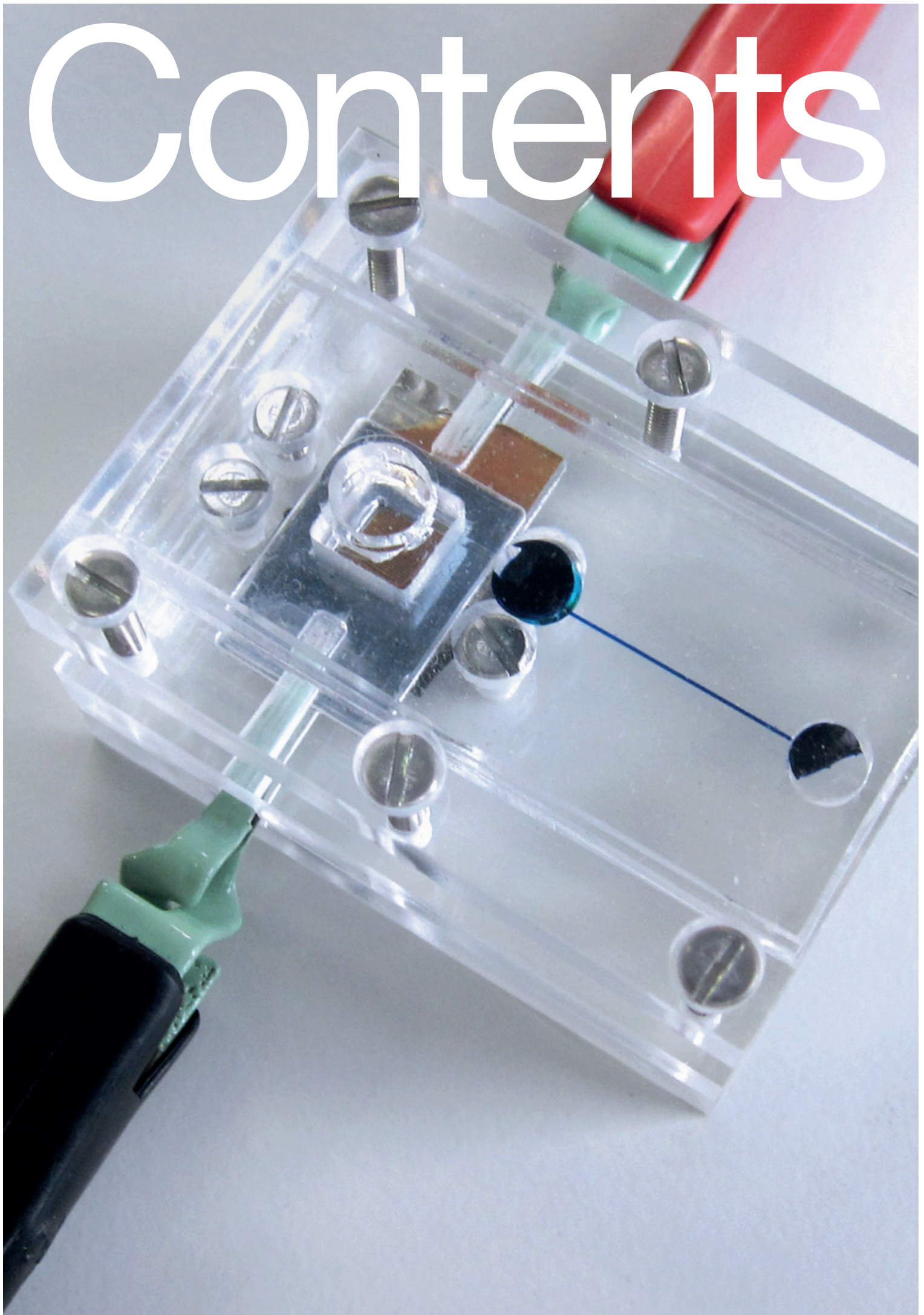


Biennial Report 2011-2012


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Foreword



It is a pleasure to present the results achieved in the biennium 2011-2012 by the researchers of Centro Nacional de Microelectrónica, CNM-CSIC, in its site of Barcelona (also known as Institute of Microelectronics of Barcelona-IMB).

In this period, we want to highlight the scientific results achieved in national and international projects, which have ended-up with a noticeable amount of high impact scientific publications, collaborations with other R&D groups and training of scientific and technical personnel. Moreover, an important effort has been put on carrying out different contracts with industrial partners from a variety of sectors and countries. CNM is also managing the Spanish Large Scale Facility (ICTS) for Micro and Nanofabrication, which gives support to the activity of internal and external R&D groups and industries working in the field. The outcome of all these activities shows that Micro and Nanotechnologies are really enabling technologies with high impact on a variety of industrial applications and on the societal challenges that the European and more specifically the Spanish citizens are now addressing.

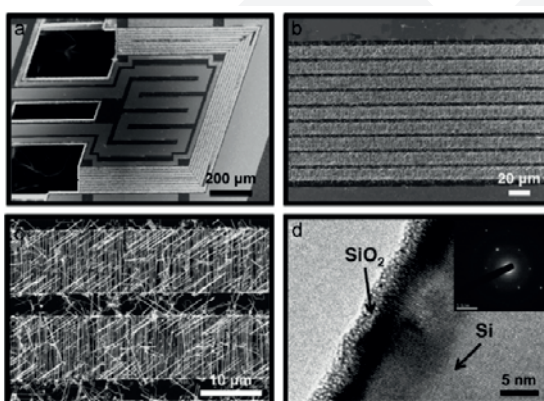
We hope that the summary that you have in your hands will be of your interest. If you wish to know more about our activities and on how micro and nanotechnologies can help you, please come and visit our laboratories in Bellaterra, an important R&D cluster set-up very close to Barcelona. My colleagues and I will be very pleased to host you.

Carles Cané
Director

Research highlights

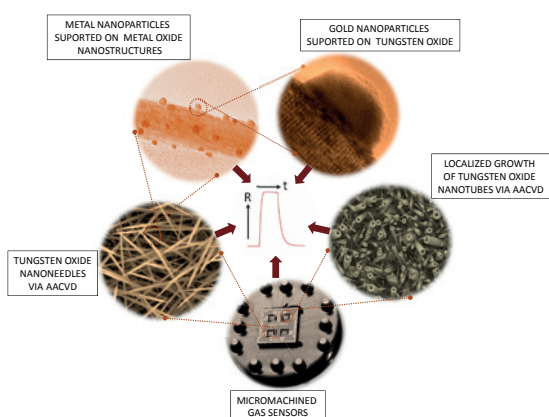
◆ Thermoelectrical devices

In the field of micro and nanotechnologies applied to thermoelectricity, multiple dense arrays of well-oriented, size-controlled and electrically connected silicon nanowires (Si NWs) have been monolithically integrated into MEMS structures as a new concept for an all-silicon planar thermogenerator. Three elements concur in this approach: (a) an appropriate starting wafer and device architecture, (b) standard silicon micromachining processes for attaining 3D-like modest/high aspect ratio structures, and (c) a bottom-up Si NWs growth mechanism that allows quasi-epitaxial growth of nanowires from silicon surfaces selectively sown with gold nanoparticles. Power densities in the order of mW/cm^2 at 200 K are achievable if such temperature difference could be conveyed directly across the nanowires ensemble. This work received the ITS Outstanding Scientific Paper Award from the International Thermoelectric Society in the 2012 ICT/ECT conference held in Aalborg.

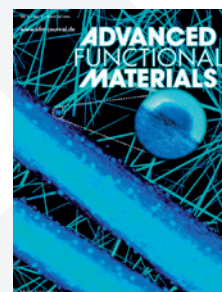


◆ Advanced metal-oxides-based gas-sensors

Nanostructured metal oxides and metal nanoparticles supported on nanostructured metal oxide have been integrated in micromachined platforms using a new one-step deposition method via aerosol assisted chemical vapor deposition (AACVD). This method has no requirement of substrate pre-treatment, and provides for direct



integration of nanostructures and co-deposited materials (i.e. metal nanoparticles supported on nanostructures) with gas sensor devices. The nanostructures deposited via this method were utilized for the fabrication of selective gas microsensor arrays based on gold and platinum decorated tungsten oxide nanoneedles, and presented in the inside cover of *Advanced Functional Materials* 23, 1313–1322. Recently this method has been extended and used for the localized synthesis of nanostructures using the self-heating capability of microsensor platforms. These results have been reported in 17th International Conference on Solid-State Sensors, Actuators and Microsystems and both new metal oxide structures and sensing platform architectures are under development.



◆ Fuel cell powered microfluidic platforms

Researchers from the Micro and Nanosystems Department have created a system that integrates microfluidics, electronics, an electrochemical sensor and a display; all powered by a single micro direct methanol fuel cell. The work, which made the front cover of *Lab on a Chip* journal, describes how a micro fuel cell can provide both electrical and hydraulic power to a microfluidic platform. The electric power generated by this fuel cell feeds the electronics module, the electrochemical sensor and the display, while offgas (CO_2) produced by the fuel cell produces a positive pressure that is used to pump a liquid sample through the microchannels and chambers of the device.

The electronics module has three functions. First, it regulates the flow rates of the solutions pumped toward the amperometric sensor. Second, it acquires the signal of the sensor using a three-electrode configuration. Last, if the concentration measured by the sensor exceeds a set threshold value, it sends a signal to an organic display to provide an immediate reading.

This approach can lead to the development of truly autonomous sensing systems, e.g. point-of-care devices. The results have been reported in *Lab on a Chip* 12 (2012) 74-79 and 4232-4235, and highlighted in several on-line journals such as *Chemistry World*, *The Engineer* and *EE Times Europe*.

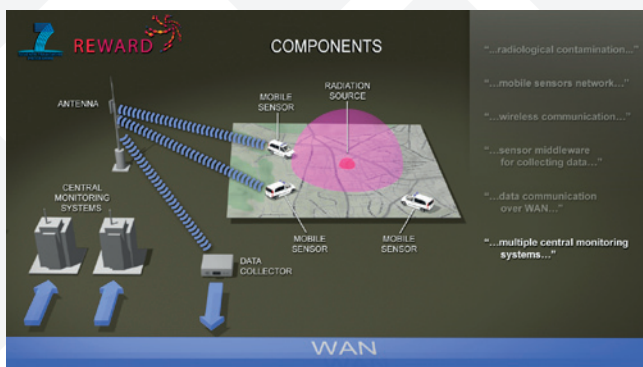


Research highlights

♦ Silicon neutron sensors for homeland security

The radiation detectors group at IMB-CNM has developed a new technology of ultra-thin silicon detectors with 3D electrodes adapted for neutron detection. The active volume of these sensors is only 10 μm thick, allowing a high gamma rejection, which is necessary to discriminate the neutron signal from the ubiquitous gamma background. Moreover, the intrinsic features of the silicon devices like robustness, small size, consumption and weight, make them the ideal response to the increasing demand of portable systems for neutron detection.

The neutron sensors fabricated at IMB-CNM are a key part of the system REWARD (Real Time Wide Area Radiation Surveillance System), a mobile system for radiation detection and monitoring. The miniaturized solid-state radiation sensors form the core of a sensing unit which also includes a wireless communication interface to send the data remotely to a monitoring base station as well as a GPS unit. The information from the sensor network is collected and processed at a control center. The REWARD project is funded within the 7th Framework Programme of the EU (FP7-SEC-2011.1.5-1/284845) and is coordinated by Prof. Manuel Lozano from IMB-CNM.

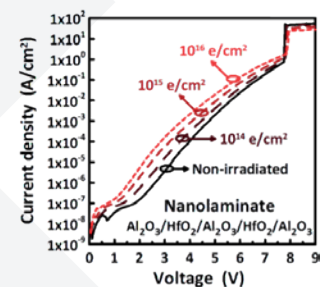
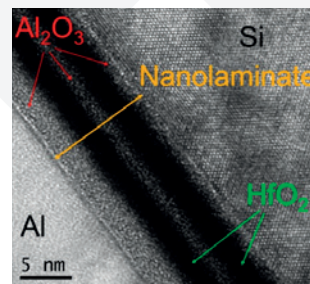


♦ High-k dielectric layers grown by Atomic Layer Deposition

Electrical stress, radiation induced degradation and defect analysis in ALD high-k dielectrics

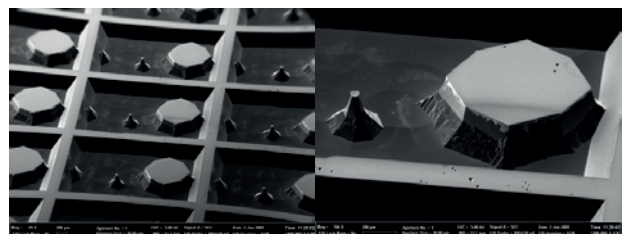
The set-up of an Atomic Layer Deposition system at IMB-CNM and the development and optimization of deposition processes on silicon substrates, made it possible to go a step further and extensively characterize thin layers of Al_2O_3 , HfO_2 and nanolaminates of them. In this biennial period, the impact of the processing conditions (oxidant precursor, annealing and deposition temperatures) on the characteristics of electrically active defects has been investigated. Moreover, a detailed analysis of the electrical degradation of the layers has been performed by measuring metal-insulator-semiconductor structures after applying electrical stress, where various phenomena, such as charge trapping related degradation and the generation of new defects induced by stress have been

evaluated, providing a deeper and fundamental insight in the underlying physics. Furthermore, the effects of electron irradiation on the electrical characteristics have also been evaluated. The results showed similar radiation-induced charge trapping and interface states generation for the high-k dielectrics under study, with an increase of the leakage current with electron irradiation fluence and no apparent impact of electron irradiation on dielectric breakdown voltage. This research has been carried out in the framework of a co-ordinated project with the University of Valladolid (ALTAKALD: TEC2008-06698-C02). The most relevant results have been published in F. Campabadal et al. J. Vac. Sci. Technol. B 29 (2011) 01AA07, J.M. Rafí et al. J. Electrochem. Soc. 158 (2011) G108 and M.B. González et al. J. Vac. Sci. Technol. B 31 (2013) 01A101.



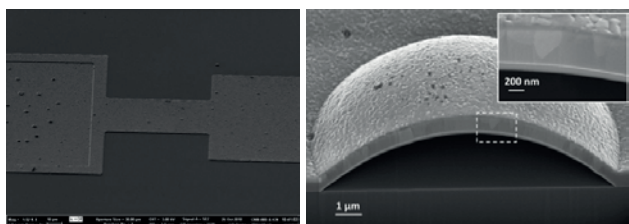
Ultra-thin atomic layer deposited layers of HfO_2 for silicon micromachining

The feasibility of using ultra-thin hafnium oxide layers grown by atomic layer deposition as a mask layer for the anisotropic wet etching of silicon has been studied. The obtained results have shown that HfO_2 layers present a high etching resistance to silicon anisotropic etchants such as KOH and TMAH and, as a consequence, act as a mask for silicon micromachining. In addition, the silicon etch rate and surface roughness are not influenced by the mask material, so ALD ultra-thin layers of HfO_2 are an excellent alternative to the $\text{SiO}_2/\text{Si}_3\text{N}_4$ stack conventionally used. The low thickness and the low deposition temperature make these films very promising for NEMS fabrication. This work has been carried out in the framework of the ALTAKALD project (TEC2008-06698-C02-01) and the results have been presented at the 37th International Conference on Micro and Nano Engineering, MNE 2011, in Berlin (Germany).



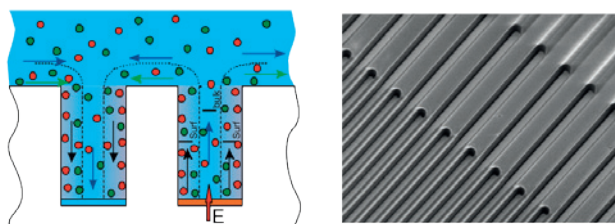
Blistering of atomic layer deposited Al_2O_3 layers on silicon

The influence of the processing conditions on the blistering of Al_2O_3 layers grown by atomic layer deposition (ALD) on silicon substrates has been investigated. The phenomenon occurs when the as-deposited layers are annealed at high temperature. The characterization of the blistering in terms of size, morphology and density indicates that the higher the annealing temperature the higher the density but also the smaller the blister diameter, while the thicker the oxide the larger the blisters. The processing of the blistered layers to obtain Al- Al_2O_3 -Si structures enhances the blistering phenomenon and at the same time affects the silicon surface underneath the blister. The latter has been evidenced by chemically etching off the deposited layers, revealing silicon voids of the size of the blister. The influence of the oxygen precursor used in the ALD process has shown that the blister



size is reduced when using O_3 instead of H_2O . Finally, the use of a thin thermally grown SiO_2 layer has been shown to avoid blistering of Al_2O_3 films. Based on the obtained results, processing rules have been defined with the purpose of avoiding or at least minimizing the blistering phenomena. This work has been carried out in the framework of the ALTAKALD project (TEC2008-06698-C02-01) and the results were presented at the 12th International Conference on ALD, ALD-2012, and published in O. Beldarrain et al. J. Vac. Sci. Technol. A 31 (2013) 01A128.

Three-dimensional interdigitated electrode array as a transducer for biosensors and chemical sensors



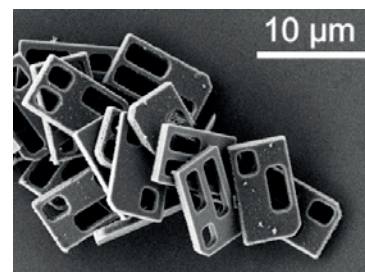
A three dimensional interdigitated electrode array (3D-IDEA) with electrode digits separated by an insulating barrier developed in the research group

finds different applications as a new transducer for chemical sensors and biosensors. Due to the presence of insulating barriers that separate the adjacent digits of the electrodes the main portion of the probing electrical current goes close to the surface of the barrier. Chemical modification of the barrier surface with the probe molecules permits to realise direct detection of subsequent target analytes in solution. The functional mechanism of the device is based on registration of changes in conductivity at the surface of the barrier provoked by electrical charge redistribution caused by surface chemical reactions. Three-dimensional sensor shows considerable improvement in sensitivity compared with a standard planar IDEA design sensor. The potential of the developed device as a sensor transducer to detect various chemical and bio chemical reactions is demonstrated. Examples include antibody immobilisation, enzyme immobilisation, polyelectrolytes layer-by-layer deposition, covalent chemical modification with molecules containing reactive groups.

Micro and Nano Tools for Cell Biology

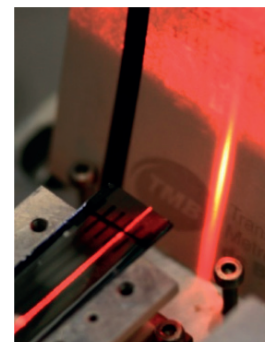
The development of Micro and Nanotools to monitor living cells is a permanent challenge. In our group we fabricate functional silicon-chips small enough to be internalized inside living cells or to be attached to the cell membrane. We anticipate this work as the first steps towards a broad range of intracellular chips that will open the possibility to study the inner of the cell. By using these chips we have fabricated silicon barcodes which have been used to tag mouse embryos.

This work was published in O. Penon et al., Bioconjugate Chemistry, 23, 12, (2012), pp. 2392-2402.



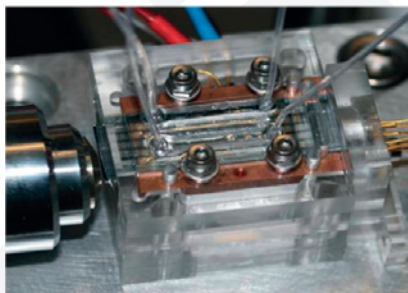
Bimodal waveguide (BiMW) interferometric device for Point-of-Care diagnosis

Most diagnostics tests are based on time-consuming, expensive, and sophisticated techniques performed by specialized technicians in laboratory environments. Last advances in micro- and nanosensing technology are offering the implementation of diagnostic tools with increased sensitivity, specificity, and reliability for in vivo and in vitro applications. Interferometric optical waveguide sensors are recognized to be one of the most sensitive evanescent wave devices which can be used for label-free analysis. But problems of stability, complex manipulation and read-out have prevented the general use of integrated interferometers biosensors for real field applications. We have developed an evanescent field sensor based on bimodal waveguide interferometer (BiMW), where the interference of two waveguide modes



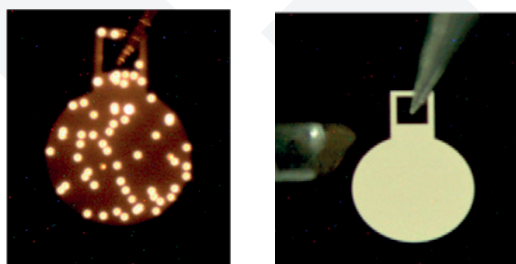
Research highlights

(fundamental and first modes) of the same polarization occurs in a straight waveguide, without the need for a reference arm. The interferometric device has been integrated with a SU8 based fluidic platform implementing a sensitive, affordable, hand-held and portable device for point-of-care diagnosis of relevant analytes. This work has been published in *J. Lightwave Technol.* 29 (2011) 1926-1930, and *Lab Chip*, 12 (2012) 1987 - 1994.



◆ Mechanism of luminescent characteristics in silicon rich Silicon Oxide (SRO)

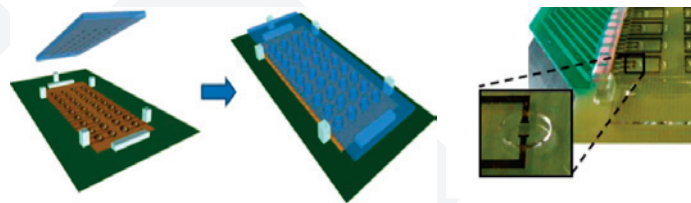
Both electrical and electro-luminescent characteristics of devices with SRO as the active layer and fabricated by PECVD and implantation of Si-ions in SiO₂ were studied. Consistently with previous results of similar materials, silicon excess variations influence the effective relative permittivity of the material, its conductivity, the quantity of trapped charge, and the electro-luminescence emission profiles. On the other hand, the choice of fabrication technique showed to have a significant effect in the electrical properties, in particular, on the type of trapped charge and in the conduction mechanisms. Differences in electrical characteristics between materials with the same Si-excess, but distinct fabrication were attributed to the different Si-nano particles size and distribution. This work has been published in *J. Appl. Phys.* 111, 053109 (2012).



◆ Electrical bioarray reader

A new approach for the electrical readout of microarrays prepared on regular glass slides, using an array of impedimetric transducers (interdigitated electrodes, IDEs) has been developed. Impedance detection relies on the use of a urease-labeled immunoassay scheme. Urease is able to produce an increase in conductivity by hydrolysis of the urea substrate, which is measured with the IDEs and directly related to the amount of target analyte. Unlike previous electrical microarrays, the assay does not take place on top of the transducers but on a regular glass slide, which may enable the development of

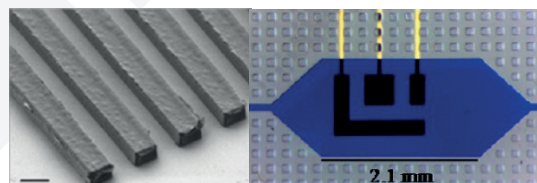
compact multiplexed analytical systems with lower cost per assay. This work has been published in *D. Bonilla, et al., Anal. Chem.* 2011, 83, 1726-1731.



Left: Standard glass slide microarrays can be read in a cheap and compact reader. Right: An IDE transducer measures the target concentration in each spot.

◆ Wax lab-on-a-chip technology

A new fabrication technology for microfluidics based on the use of wax has been developed. Microfluidic structures are assembled using wax as both a thermoplastic adhesive layer between two glass substrates and a spacer layer defining the microchannels. Wax patterns with dimensions down to 25 μm are easily produced on glass substrates using specially developed decal-transfer microlithography. On the basis of the special melting behaviour of waxes, an effective glass-wax bonding is achieved at 40 °C by applying a soft pressure and without the requirement of any glass pretreatment. Wax bonding provides an effective sealing of the fluidic networks even on nonflat glass substrates (i.e., containing metal electrodes). The mild conditions required for the bonding process enables the fabrication of lab-on-a-chip devices incorporating biomolecules. This work has been published in *M. Díaz, et al., Anal. Chem.* 2012, 84, 7838-7844.



Left: Patterning of wax down to 25 μm. Right: Microfluidic device with amperometric detection.

◆ Photonic lab on a chip for biological studies

Nowadays, there is a strong need for systems able to analyse molecular processes within cells, tissues and model organisms for early diagnosis. Here, technology mergers, such as the combination of microfluidics and photonics (obtaining the so-called photonic lab-on-a-chip, PhLoC), are called to be the next generation of analytical tools. This is grounded by the fact that using light as analytical mechanism provides with outstanding advantages, such as high

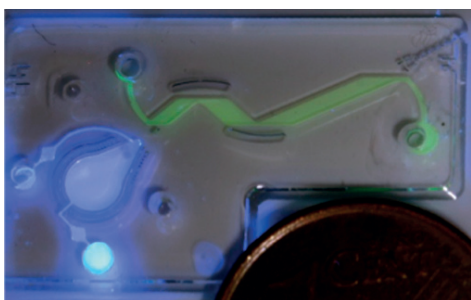
sensitivity, non-invasive analysis with very low limit of detection.

Grounded on the demonstrated experience of cutting-edge research with micro-optics of our group, polymeric PhLoC have been developed. Using a protocol that takes into account the whole spectral response, such systems are suitable for dead/live cell monitoring, germination screening of fungal spores (*A. ochraceus*), growth rate measurement of yeast cells (*S. cerevisiae*) and cytotoxicity measurements using rat aorta vascular smooth muscle cells (VSMC).

In parallel, the unspecific analyte surface absorption on the polymeric walls of the PhLoC has also been addressed and solved by developing an specific enzymatic functionalization protocol, which has proved its suitability for Horseradish peroxidase (HRP), using ABTS as mediator.

The concepts developed in this research could thus also be used to address other potential spin-off applications based on cell culture, such as drug screening and therapy monitoring.

Published works: B. Ibarlucea et al. *Analyst* 2011, 136(17), 3496-3502; S. Demming et al. *Electrophoresis* 2011, 32(3-4), 431-439; S. Demming et al. *Biomicrofluidics* 2011, 5, 014104; J. Vila-Planas et al. *Nat. Prot.* 2011, 6(10) 1642-1655; S. Demming et al. *Biomicrofluidics* 2012, 6, 034106; R. Rodríguez-Rodríguez et al. *Biomed. Microdev.* 2012, 14(6), 1129-1140

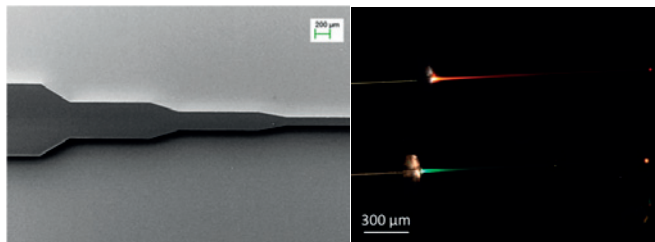


♦ Photonic components based on xerogel polymers

An approach for the fabrication of inexpensive photonic elements such as filters and emitters, which could be readily implemented in photonic lab on a chip (PhLoC) has been developed. A tailor-made organic-inorganic sol-gel polymer was doped with different dyes, and patterned using micromolding in capillaries soft lithographic technique. Absorbance microfilters covering the entire visible spectrum were fabricated and showed zero passband and sharp stopband regions with rejection levels between -6 and -55

dB. These were monolithically integrated in a PDMS Lab on a chip together with other optical components required for carrying out fluorescence-based analytical measurements. Doping a similar hybrid sol-gel polymer with fluorophores enabled the microfabrication of disposable solid-state light emitters using a similar process to the one described above. The developed structures showed the expected emitted light gain at the wavelengths of the doping agent. This work has been published in E. Carregal-Romero et al. *Optics Express* 20 (2012) 23700-23719 and in E. Carregal-Romero et al. *ACS Applied Materials and Interfaces* 4 (2012) 5029-5037.

Sol-gel polymer technology was also applied to the development of silica-based materials with superior photoluminescence behaviour, which could be easily modulated by inducing either the formation of a defective silicon oxide matrix or the segregation of silicon nanocrystals within the silicon oxide structure. This material could be applied for the fabrication of light sources. This work has been published in J. A. Rodríguez et al. *Applied Physics Letters* 101 (2012) 171908 (4pp).

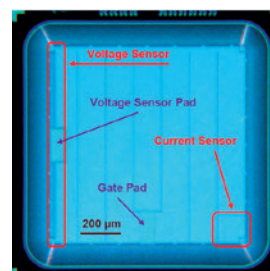


Left: SEM image of xerogel microfilters having widths between 100-1000μm.
Right: Photograph of fluorophore-doped xerogel waveguides (60-μm and 150-μm wide; 1.5-cm long) pumping light

♦ 3300 V – 50 A IGBT with Integrated Current and Voltage Sensors

A new intelligent 3300 V – 50 A rated IGBT for traction applications has been designed, optimized and fabricated at the IMB Clean Room. A conventional current sensor is used to monitor any overcurrent event to prevent the thermal destruction. A new anode voltage sensor structure based on the voltage mirror approach is monolithically integrated in the IGBT active area providing a voltage value proportional to the real anode voltage at the backside of the die. An additional pad is necessary to transfer the anode voltage sensor signal to the gate driver. Therefore, a short circuit event can be immediately detected and the IGBT can be driven to safe operating conditions until the transient overvoltage disappears.

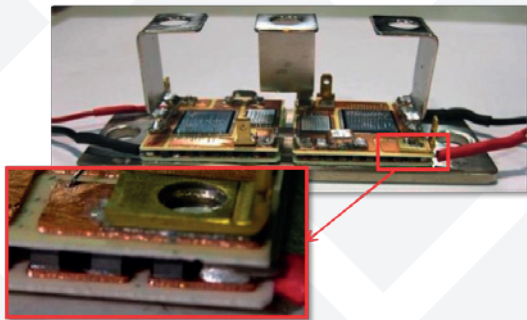
A relevant publication is: J. Urresti et al. 3.3 KV PT-IGBT with Voltage-Sensor Monolithically Integrated. 11th Int. Sem. on Power Semiconductors (ISPS'12), Prague, Czech Republic.



Research highlights

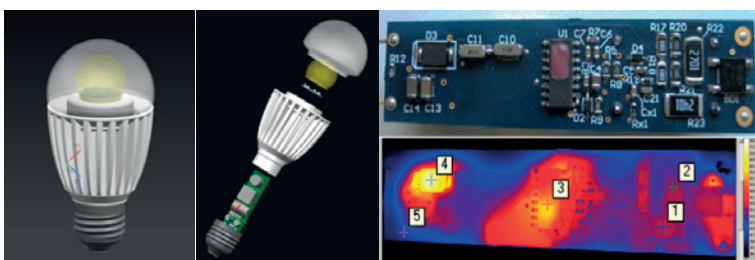
◆ Power Module with Integrated Thermoelectric Cooling System for Improved Thermal Management

In the framework of the Power Systems Integration and Reliability activities, a new thermal management solution for power modules has been developed. The proposed module integrates an inverter leg based in a classical topology with two IGBTs and two free-wheeling diodes, and it includes also an electrically-cooled stage between the power devices and the base-plate. The challenge has been to reconcile the power module fabrication technology based on ceramic substrates, with the inclusion of the BiTe pellets for the Peltier cell definition. The thermo-electrical characterisation of the first prototypes revealed not only the evident cooling performances for evacuating the dissipated heat, but also the capability for implementing more evolved solutions such as closed loop temperature regulation schemes. This work has been developed in the framework of the Spanish CENIT-VERDE project devoted to the development of Electric Vehicle solutions, in collaboration with the technological centre Leitat and LEAR Corporation. The proposed idea has been patented (US20120299375 A1).



◆ Development of Low-cost 60W Retrofit Solid State LED Lamp

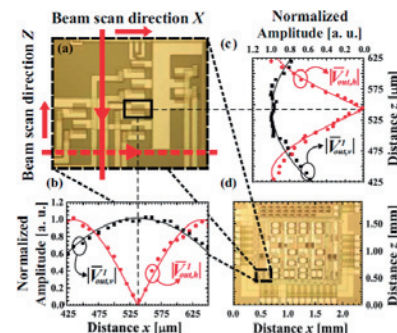
In the framework of the ENIAC JU CSSL (Consumerizing Solid State Lighting) project led by Philips Lighting, members of the Power Systems Integration and Reliability research line of the Power Devices and Systems Group have participated in the development of a low-cost 60W retrofit based LED lamp. This project aimed to develop and demonstrate affordable Smart Solid State Lightning sources for consumers via both technology and application routes. The main activities of IMB-CNM researchers have been focused on the thermal design and evaluation of the LED bulb engine, according to the guidelines or requirements of long product life expectancy, low-cost and luminous flux levels of 805 lumens (60 W). In this



context, the IMB-CNM has focused their activities on thermal parameters extraction of the different materials considered in the design of the LED lamps (thermal conductivities, thermal resistances, materials emissivity), thermal analysis of critical parts of the bulb (driver board or LEDs), proposing new solutions for reducing the thermal resistance of the LEDs, and analysing the ageing in the most critical parts of the bulb.

◆ Substrate Heat Flow Characterization in Integrated Circuits by Mirage Effect

In the framework of a research collaboration with UPC, the Power Systems Integration and Reliability members of the Power Devices and Systems Group presented a novel solution to thermally characterize active devices embedded in Integrated Circuits (IC). This work shows an analytical and experimental technique for characterizing radial heat flow. Based on lock-in detection principles, devices are activated following a periodic function of time and the deflection experienced by a laser probe beam passing through the IC substrate (mirage effect) is sensed and detected. The analytical model comes from the resolution of the Fermat equation for the trajectory of rays and supposing a spherical heat source dissipating a time-periodic power. An application example is presented; hence demonstrating how hot spots and heat transfer phenomena in the IC substrate can be characterized for reliability purposes. The developed method may become a practical alternative to usual off-chip techniques for inspecting hot spots in ICs and to experimentally characterize heat flow in the semiconductor substrate, which is a potential and promising approach for 3D stack packaging technologies. The figure 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

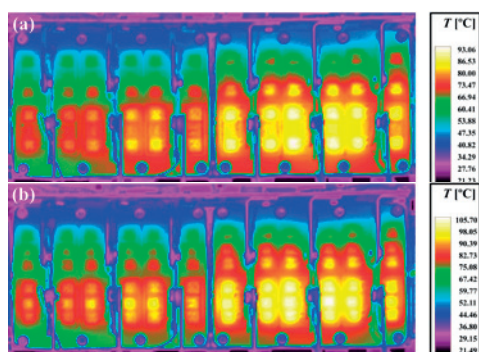


to the amplitudes (modules) of the thermal gradient corresponding to the horizontal and vertical beam deflection as a function of the lateral coordinate. From these results, it is observed that activated devices/hot spots can be located and several properties of

the heat flow inside the substrate can be inferred from the developed model. A relevant publication in this subject is X. Perpiñà et al., Applied Physics Letters, Vol. 98, 164104, 2011.

◆ Reliability Studies on Railway Power Inverters

In the framework of a research contract with Alstom Transport, members of the Power Systems Integration and Reliability of the Power Devices and Systems Group have analyzed the reliability of railway power inverters when a non-uniform temperature distribution occurs in IGBT power modules. They have analyzed the interaction between a heat-pipe-based cooling system and the power module, which is evaluated by thermal mappings using an IR camera as can be seen in the figure. The effects of the thermo-mechanical stresses on the constitutive elements of the module are pointed out under a real mission profile, as figure below shows. The obtained experimental results are linked to problems on the power inverter reliability: the thermal grease distribution is analyzed on failed IGBT modules coming from the field, and the solder delamination pattern observed in IGBT modules after endurance cycling tests is also reported. Relevant publications in this subject are X. Perpiñà et al. IEEE Transactions on Industrial Electronics, Vol. 58, pp. 2662-2672, 2011 and two free access e-books edited by one of the members of the group: Infrastructure Design, Signalling and Security in Railway (ISBN: 978-953-51-0448-3) and Reliability and Safety in Railway (ISBN:978-953-51-0451-3).



◆ Organisation of Workshops and Courses on Power Devices and Systems

Three main international events have been organized by the members of the Power Devices and Systems Group. First, in the framework of

the dissemination activities of the ENIAC-CSSL project to industry and academic institutions, the CSSL Workshop on LED based Lighting Systems took place in September 2012. This workshop was organized by IMB-CNM and Leitat Technological Center in Barcelona, with more than 60 attendees coming from the industry and academia. It included plenary talks about the hottest issues in LED lamp design, covering all fields related with this technology: LED manufacturing, packaging, driver design, dimming and design for reliability. Second, the 21st European Workshop on Heterostructure Technology (HeTech) was also organized in Barcelona by researchers of the Group in collaboration with ISOM-UPM. More than 50 scientists, engineers and graduate students working in the compound semiconductors' field and other heterogeneous technologies, attended the event on November 2012. Finally, in the framework of the dissemination activities of NetFISiC Marie Curie Network for Initial Training (FP7-PEOPLE-2010-ITN), the NetFISiC Winter School workshop was also organized by IMB-CNM in Barcelona. It took place in January 2012, with more than 30 researchers and graduate students coming from the different institutions involved in the network. The sessions covered a wide range of topics, such as specific SiC based MOSFETs, innovating GaN devices and the growth aspects of the involved wide bandgap semiconductors.

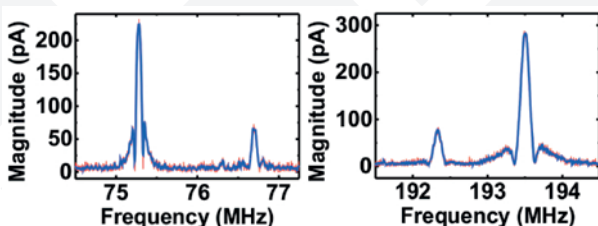
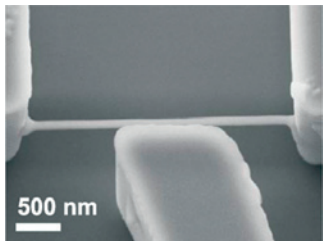


◆ Nanomechanical resonators

During the 2011-2012 period, exciting progress in nanomechanical resonators has been experienced at IMB-CNM using top-down and bottom-up silicon nanowires as building blocks. The technology to fabricate resonators based on a single silicon nanowire has been successfully completed in two different approaches: (i) growing the silicon nanowires by bottom-up methods and (ii) defining them by UV optical lithography (top-down), reactive ion etching, and subsequently performing several oxidation/etching cycles. The developed technologies allow the massive fabrication of devices, enabling the realization of extensive experimentation. Among other investigations, the electrical transduction mechanism in silicon nanowires has been studied in detail, which has allowed to discover that bottom-up silicon nanowires present the co-existence of two different transduction mechanisms. One of these mechanisms allows the implementation of an electrical read-out scheme based on frequency modulation, providing unprecedented performance in

Research highlights

terms of signal-to-noise ratio. This finding will allow exploiting the exceptional sensitivity of silicon nanowire resonators for mass sensing.



♦ Advanced nanofabrication methods

Many areas of nanotechnology need new technological methods to fabricate structures and devices with nanometer resolution. IMB-CNM is involved in a European action to develop methods that will provide single digit resolution (i.e., below 10 nm resolution). One option is the use of nanolithography methods based on Atomic Force Microscopy (AFM), an area in which IMB-CNM possesses long experience and for which high-impact publications have been achieved during this period. Other relevant results concerning the development of novel top-down nanofabrication methods have been achieved in nanostencil, nanoimprint and focused ion beam lithography.

Another approach is the use of bottom-up fabrication methods, employing molecules as building-blocks for the fabrication of nanostructures. Two different methods have been successfully demonstrated: the use of chemical surface modification to guide the self-assembly of block co-polymers (DSA lithography), achieving pattern densification that facilitates to decrease the requirements of the top-down guiding method, and the use

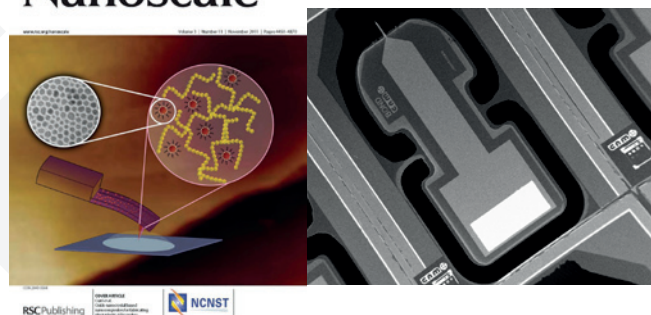
of carbon nanotube field effect transistors (CNT-FETs) for building-up chemical sensors. The activity in directed self-assembly of block co-polymers has been developed within the ENIAC awarded project LENS, in which IMB-CNM has collaborated with main European actors (Industries and academia) in nanoelectronics. In the case of CNT-FETs, the technology developed during the last years that allows massive fabrication of CNT-FETs at wafer level has been extended with the incorporation of novel passivation methods, leading to the realization of protein sensors with unprecedented sensitivity.

♦ Atomic force microscopy technology and methods

Atomic force microscopy methods and technologies are gaining more and more importance in the area of integrated micro and nanosystems. IMB-CNM is contributing to their development from different directions.

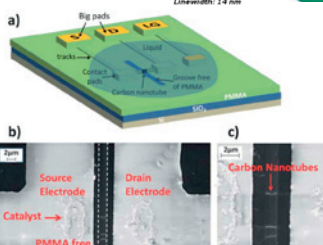
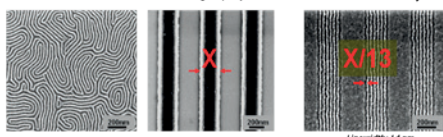
From the technological side, IMB-CNM has successfully created new technologies to provide probes with enhanced performance for the AFM community. As a result of a fruitful collaboration with CNR-Italy in the framework of the European Project Novopoly, it has been demonstrated that all-polymer probes can be reliably fabricated,

Nanoscale



Directed self assembly (DSA)

BCP property to self-assemble + Top-down Lithography = Guiding of BCP self-assembly

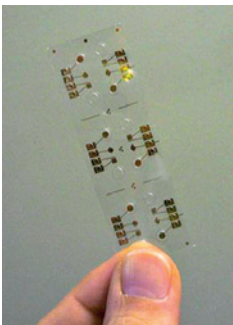


overpassing previous technological/ material issues that prevented their commercialization, by incorporating nanocrystals in the polymer material. In another European Project (BOND), IMB-CNM has developed a new technology to fabricate insulated conductive AFM probes.

With respect to applications, outstanding results have been achieved in this area, including the use of AFM as a nano-lithography method to define arrays of nanoelectrodes, and the realization of microcantilevers with integrated piezoresistive read-out to perform experiments of biomolecular recognition with pN force resolution.

◆ BioMEMS

During this period of time BioMEMS has been developing and building a single channel microfluidic chip and a diagnostic chip with multiplexed character in order to measure, at least, 4 cardiac biomarkers. The developed multiplexed system allows simultaneous operation of each sensor and, thus flexibility in carrying out to 4 independent tests.



*Single channel chips
(Arcatech3-CAJAL4EU
project)*



*Multiplexed chip (top and
bottom view)
(Arcatech4-CAJAL4EU project)*

Development of a portable microfluidic device containing a biosensing platform for determining the lactate concentration in sweat in a non-invasive manner. This parameter is of great interest to athletes, since its value gives an idea of cellular fatigue, allowing improving your fitness in a more controlled way. The final prototype is based on a communication system by Bluetooth and a recording device based on a smartphone.



Final prototype of a lactate portable monitoring device

Research activities

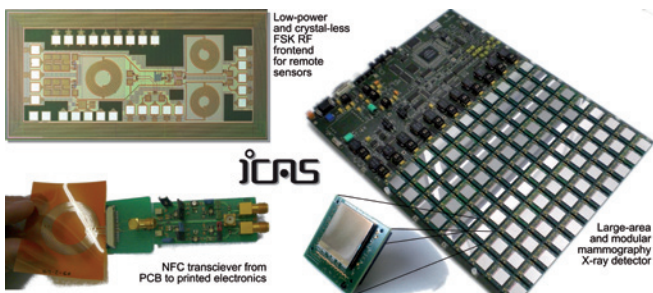
◆ Integrated circuits and systems

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.



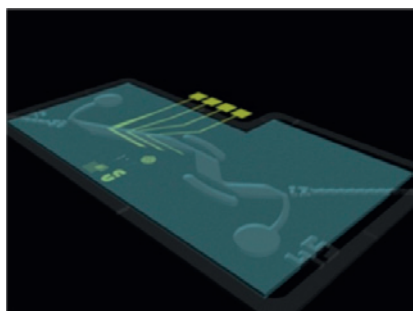
◆ Lab on a Chip (LoCs) based on (bio) chemical transducers

The activity of the Chemical Transducers Group (GTQ) is devoted to the development of new microanalytical systems and Lab on a Chip (LoCs) based on (bio)chemical transducers and new concepts of fluidic structures. Different transduction principles and/or signal propagation media are used: electrochemical devices and photonic/integrated optical devices. Electrochemical devices used are ISFET sensors, metal thin film microelectrodes for voltammetric and impedimetric detection (IDE). Besides, biosensors are developed –immunosensors and enzymatic sensors- modifying the sensing area with nanomaterials and biorecognition elements. Regarding optical systems different components (lens, filters, emitters and waveguides) are monolithically integrated to achieve photonic systems for spectral response, dispersion and phase change variation. Multisensor arrays based on several transducers are also developed for multiparametric detection.

The technology approach for LoC fabrication is adapted to the final application and integrates in a monolithic and/or hybrid way the different elements (sensors, microfluidic passive and active elements). This technology goes from silicon to micromachining, micro milling processes and soft lithography and uses materials like PDMS, SU8, hybrid xerogels, PMMA and waxes.

The main objective is to achieve the complete automation of all processes (analysis, sampling, counting, etc.) within a microsystem and the consumption of low sample and reactive volumes. For that, different technologies and designs are proposed:

- LoCs fabricated with PMMA and silicon chips for multiparametric analysis of waters and wines integrating electrochemical sensors for detection.
- LoCs based on PDMS and optofluidics including filters, waveguide structures, emitters, microreactors and channels applied to cell content.
- LoCs integrating silicon chips and microfluidic structures made of polymers for detection of metabolites in cell cultures.
- Microarray readers for DNA and protein detection.



Scheme of a dual photonic/electrochemical LoC.
O. Ordeig et al. *Anal. Chem* 2012, 84 (8), 3546–3553

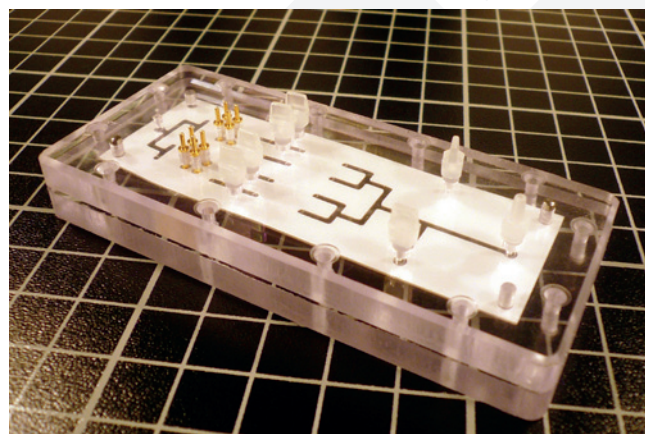
◆ Micro-nano-bio systems

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.

Application of a three dimensional interdigitated electrode array as a transducer for label free immunochemical analysis. Development of a miniaturised system for determination of 4 protein biomarkers of Alzheimer disease and biomarkers (tryptophan-kynurenine-serotonine) of other neurodegenerative diseases (Huntington disease and several mental disorders, such as the major depressive disorder, sleep disorders or schizophrenia).



Application of ion-sensitive field effect transistors (IS-FETs) for biochemical analysis. Development of a semi-automatic system for rapid determination of calcium ion level in bovine blood samples for medical diagnostic purposes.

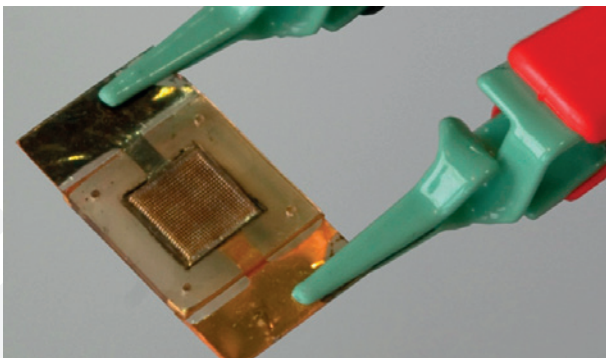
◆ Micro-nanotechnologies

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).
- Sensors and micronanosystems (More than Moore approach).
- Application-oriented smart systems and subsystems for fields such as medical, environment, food, energy, telecom, particle physics, space, etc.

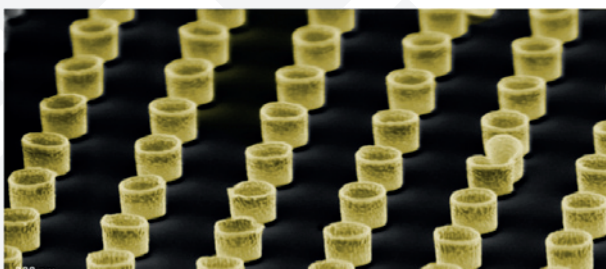
Specific topics addressed are: high-k dielectrics, reliability of devices and technologies, CMOS-MEMS, SOI-MEMS, micronanotools, MOMS/NOMS, 3-D heterogeneous integration and 3-D architectures that may be used for radiation sensors, thermally isolated micronanostructures for gas sensors, or power MEMS (microfuel cells and energy harvesting based on nano-thermoelectricity and piezoelectricity).



◆ Nanofabrication and nanostructures

This activity is dedicated to research on electronic and electromechanical properties of nanostructures, with potential to provide new or enhanced functions to nanodevices and nanosystems, as well as advanced methods for nanofabrication. The main research topics are:

- Study of the performance and applicability of nanoelectromechanical systems (NEMS); development of manufacturing methods, transduction methods, system integration and applications.



Application of NEMS as nanomechanical sensors, especially in the field of biomedicine.

- Study of the performance and applicability of nanoelectronic devices for applications in circuits and sensors.
- Development of new nanofabrication methods based on top-down techniques (AFM, e-beam, FIB, NIL) and bottom-up synthesis (nanotubes and nanowires). Nanostructure fabrication guided by self-assembled block copolymers. Combination of methods top-down and bottom-up for the future development of micro/nano electronics.
- Development of AFM methods for (i) the functional characterization of nanoelectromechanical systems and (ii) characterization of electromechanical properties of nanostructures and surfaces.

◆ 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: Design and fabrication of application oriented power devices (IGBT, VDMOS, LDMOS, Super-Junction MOSFETs). Radiation effects on power devices and their use as detectors in high energy physics.
2. Wide Band Gap Semiconductor Devices: 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 Integration and Reliability: Development of new technologies for improving power systems integration. Main activities focused on Thermal Management, Power Packaging, Electro-thermal Characterization and Reliability.



Main projects

♦ RUE: Wide band gap advanced devices for the Rational Use of Energy

Coordinator: José Millán (IMB-CNM)

Dates: December 2009 to December 2014.

Reference: CSD2009-00046

Funding Agency: MICINN-DG Investigación (Consolider-Ingenio 2010 Programme)

Total Project funding: 4.560.000 €

IMB-CNM funding: 1.112.869 €

Participants

- IMB-CNM (CSIC): Coordinator
- Universidad de Oviedo, Spain
- Universidad Politécnica de Madrid, Spain
- Universidad de Zaragoza, Spain
- Universitat Rovira i Virgili, Spain
- Fundación Robotiker (ROBOTIKER TECNALIA), Spain
- Universitat Politècnica de Catalunya, Spain
- Universidad de Valencia, Spain

Summary

The Project is focused on the development of power devices using the outstanding properties of wide band gap semiconductor materials: Silicon carbide (SiC) and Gallium Nitride (GaN). The main objective is the development of a first generation of new wide band gap power semiconductor devices. These would lead to an important improvement in the performances of existing converters and the development of new converters, achieving in both cases a more rational use of electrical energy. The improvements are due to the exceptional properties of the SiC and GaN materials, which show a very

favorable tradeoff between their theoretical electrical behavior (high capacity for voltage blocking, high temperature operation and high frequency commutation) and the commercial availability of starting substrates (wafers) added to the level of development of their technological processes.

♦ HIP-LAB: High-throughput integrated photonic lab-on-a-DVD platforms

Coordinator: Andreu Llobera (IMB-CNM)

Dates: October 2008 to September 2013

Reference: 209243

Funding agency: European Union (Support for frontier research - ERC Starting Grant)

Total project funding (IMB-CNM): 1.717.200 €

Summary

The main aim of the proposed research line is to develop high-throughput ultrasensitive photonic lab-on-a-DVD for multiple parallel analyses with an extremely high degree of integration. The already existing high-throughput platforms only use the CD platform as a substrate without any given functionality. Conversely, in this research line, the DVD platform will integrate the following elements:

- (i) Polymeric photonic components (high-sensitivity Mach-Zehnder interferometers, diffraction gratings and hollow structures).
- (ii) Polymeric microfluidics (hydrophobic valves and mixers).
- (iii) Chemical modification of the surface with functional groups prone to interact with the specific analyte and
- (iv) the necessary information storage in the DVD tracks related to the parameters required (spin speed, position and number of photonic systems, etc) for the measurement in a modified DVD reader. Additionally, a new setup will be mounted, in which a second DVD-header will be incorporated, in such a way that simultaneous high-throughput measurements could be easily performed with the different photonic elements included in the platform.

Main Projects

As compared to the existing platforms, the presented research line requires the establishment of a dynamic multidisciplinary group comprising experts of photonics, microfluidics, (bio) chemistry and electronics. The results obtained herein will allow the definition of an advanced photonic high-throughput lab-on-a-DVD platform that will definitely have a large number of application fields, ranging from molecular diagnosis to analytical chemistry or proteomics.

♦ REWARD: Real Time Wide Area Radiation Surveillance System

Coordinator: Manuel Lozano (IMB-CNM)

Dates: December 2011 to November 2014

Reference: 284845 (FP7 SEC-2011.1.5-1 IP)

Funding agency: European Union (FP7-SEC-2011-1.Collaborative Project-IP)

Total project funding: 3.020.795 €

IMB-CNM funding: 661.013 €

Participants

- IMB-CNM (CSIC): Coordinator
- Sensing & Control Systems SL, Spain
- Instituto Tecnológico Nuclear, Portugal
- Albert Ludwigs University Freiburg, Germany
- X-Ray Imaging Europe GmbH, Germany
- EDISOFT-Empresa de Servicios e Desenvolvimento de Software SA, Portugal
- Giunta Regionale della Catania, Italy

Summary

We propose a novel mobile system for real time, wide area radiation surveillance. The system is based on the integration of new miniaturized solid-state radiation sensors: a CdZnTe detector for gamma radiation and a high efficiency neutron detector based on novel silicon technologies. The sensing unit will include a wireless communication interface to send the data remotely to a monitoring base station which also uses a GPS system to calculate the position of the tag.

The system will also incorporate middleware and high level software to provide web-service interfaces for the exchange of information, and that will offer top level functionalities as management of users, mobile tags and environment data and alarms, database storage and management and a web-based graphical user interface. Effort will be spent to ensure that the software is modular and re-usable across as many architectural levels as possible. Finally, an expert system will continuously analyze the information from the radiation sensor and correlate it with historical data from the tag location in order to generate an alarm when an abnormal situation is detected. The system will be useful for many different scenarios such as nuclear terrorism, lost radioactive sources, radioactive contamination or nuclear accidents. It will be possible to deploy in emergency units and in general

in any type of mobile or static equipment, but also inside public/private buildings or infrastructures. The sensing units will be highly portable thanks to their low size and low energy consumption. The complete system will be scalable in terms of complexity and cost and will offer very high precision on both the measurement and the location of the radiation. The modularity and flexibility of the system will allow for a realistic introduction to the market. Authorities may start with a basic low cost system and increase the complexity of it based on the latest needs and also on the budget.

♦ LIPHOS: Living Photonics: Monitoring light propagation through cells

Coordinator: Andreu Llobera (IMB-CNM)

Dates: November 2012 to October 2015

Reference: 317916

Funding agency: European Union (FP7-2011-7 ICT-SME)

Total project funding: 3.200.000 €

IMB-CNM funding: 631.473 €

Participants

- IMB-CNM: Coordinator
- Rijksuniversiteit Groningen, The Netherlands
- Aarhus Universitet, Denmark
- Dublin City University, Ireland
- iXscient Limited, United Kingdom
- Cellix Ltd., Ireland
- LIONIX BV, The Netherlands

Summary

The objective of the LIPHOS project is to apply cell-based photonic systems to study cardiovascular diseases (CVD). The high incidence of CVD - responsible for around 48% of the deaths every year in EU- brings consequences not only to the health care systems of the countries, but on their global economy. Overall CVD costs are estimated to be €192 billion/year for the EU economy. LIPHOS project provides with a realistic, however disruptive possibility of reducing the CVD impact in the society and in the global economy, as well as providing with huge market possibilities to the companies involved. These objectives are assured with the cutting-edge research profile of the consortium.

♦ GreenFETs: GaN based Power Semiconductor Devices

IMB-CNM IP: Philippe Godignon

Dates: July 2009 to December 2013
Funding: ON Semiconductor Belgium BVBA
IMB-CNM contract funding: 596.800 €

Summary

The objective of this contract is to develop GaN-based power transistors for high voltage (i.e. above 650V) power switching applications. The strategy is to develop GaN-on-silicon wafers on 4 inch substrates, with a clear development roadmap to 6 inch material at the end of the project for cost-effectiveness. The main focus will be on a lateral HEMT design. Specific device developments are planned for making normally-off lateral HEMTs, as well as vertical transistors.

♦ NOMS: Nano Optical Mechanical Systems

Coordinator: Jaume Esteve (IMB-CNM)

Dates: September 2009 to August 2012
Reference: 2289
Funding agency: European Union (FP7-NMP-2008-SMALL-2)
IMB-CNM funding: 593.459 €

Participants

- IMB-CNM: Coordinator
- University of Cambridge, United Kingdom
- Polymer Institute, Slovak Academy of Sciences, Slovakia
- IQE plc, United Kingdom
- Unia Nevidiacich a Slobozrakych, Slovakia
- Universität Hamburg, Germany
- Universitat Autònoma de Barcelona, Spain
- MICROSHARP Corporation Limited, United Kingdom

Summary

Nano-optical-mechanical actuation based on nanotube-enriched polymeric materials is a much-sought-after technology. In this scheme, laser signals promote actuation of the polymeric materials producing a variety of nano-optical mechanical systems (NOMS) such as tactile displays, artificial muscles, and nano-grippers among others. The purpose of this project is to fabricate microsystems capable of light-induced actuation. In particular, this team proposes to bring NOMS into maturity by building a visualaid tablet.

Accomplishing this ambitious project requires of basic and integrating research within the field of NOMS. It also requires the contribution of expert neuropsychologists to study the effectiveness of the tablet in cooperation with end-users. A team formed by materials, photonics, neuropsychologists, end-users, tech-transfer and microsystems experts will be gathered to fabricate the first visual aid NOMS prototype. This well-balanced conglomerate poses a unique combination of talent to guarantee execution of deliverables. This approach stirs away from blue-sky research by identifying a solution (photoactuation) to a particular problem (fast refreshed portable visual-aid devices). Once past this maturity stage, NOMS will provide for tactile screens where visually impaired students can read mathematical equations and graphical representations. Everyday activities of visually impaired individuals will be greatly improved by including these devices in Automatic Teller Machines (ATMs / MAC), appliances, personal computers, and contactless brain-machine interfaces. This project is visionary with respect to some of the mainstream R&D directions, offering the EU industrial platform a competitive advantage in the assistive technology marketplace worldwide. Appropriate industrial partnership with adequate technology-transfer experience will be duly included in the consortium with the purpose of thorough product commercialization.

♦ E3CAR: Nanoelectronics for an Energy Efficient Electrical Car.

Coordinator (Spain): José Millán (IMB-CNM)

Dates: March 2009 to September 2012
Reference: PLE2009-0006
Funding agency: MICINN-DG de Cooperación Internacional + European Commission (ENIAC JTI)
IMB-CNM funding: 446.000 €

Participants

- IMB-CNM (CSIC): Coordinator
- Fundación CIDETEC - Centro de Tecnologías Electroquímicas, Spain

Summary

The Project corresponds to the National funding for the ENIAC Project E3CAR: Nanoelectronics for an Energy Efficient Electrical Car (120001). The project objective is the development of nanoelectronic technologies, devices, circuit architectures and modules for electric vehicles and the demonstration of these modules in final systems. It is a requirement to reduce future emissions of vehicles. The objective of most car manufacturers is an electric vehicle that protects the environment from emissions and noise, using renewable energy sources on board (solar) and with connection to the electrical grid. In this context, the project is oriented to the development of high electrical efficiency vehicles, battery control, high voltage components (IGBTs, high voltage FETs) and architectures and subsystems for electrical vehicle electronics.

Facilities



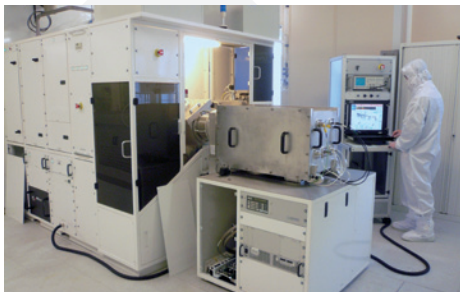
General view



Matallization and RIE area



Electron beam lithography system



Ion implantation system



Advanced packaging laboratory



Electrical characterization laboratory

The IMB-CNM large scale facility (ICTS – Singular Scientific and Technological Facility)⁽¹⁾ includes a clean room for integrated micro and nanofabrication, a test and characterization service and a packaging service.

The clean room (total surface 1500 m²) 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. The whole set of processes runs on 100 mm diameter silicon wafers, and there is a partial capability for 150 mm diameter wafers.

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 specific equipment.

An external access programme (GICSERV) has been available from 2006 to 2012, with funding from the Spanish Ministry of Science and Innovation, to allow academic external users to access the ICTS services for free, for projects of limited complexity. Up to 282 projects have been funded in this way from Spain, the European Union and (since 2010) Latin-American countries.

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

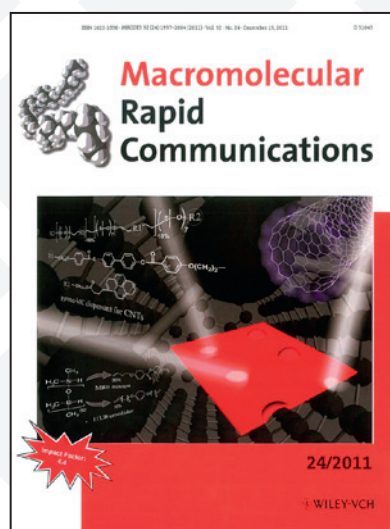
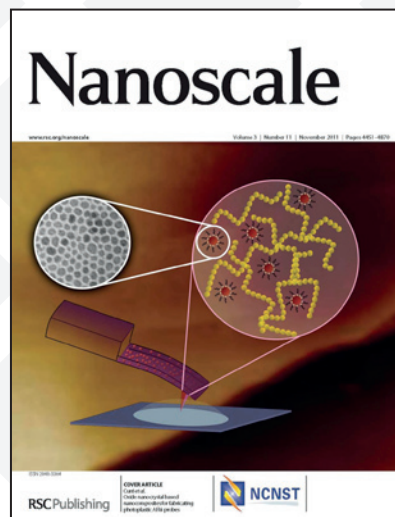
- Microsystems: electrical characterization / sensor characterization.
- Chemical transducers / general chemistry.
- Biochemical systems characterization.
- Power devices / thermal characterization.
- Engineering of electronic systems / test of integrated circuits and systems.
- Integrated optics.
-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

(1) ICTS is an official label given by the Spanish Ministry of Economy and Competitiveness to the Spanish large scale scientific facilities

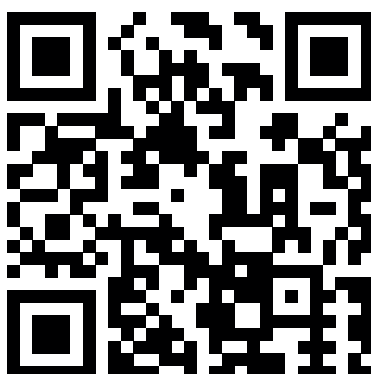
Publications

PUBLICATIONS

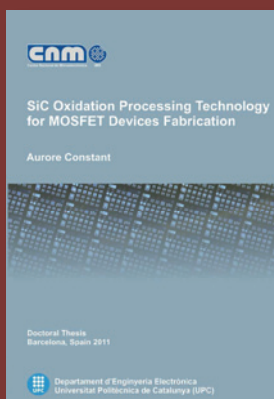
IMB-CNM has published a total of 116 scientific papers in 2011 and 112 in 2012 in journals included in the Science Citation Index.



The complete list of publications in scientific journals is available at the IMB-CNM web. The specific page can be accessed through this QR code:



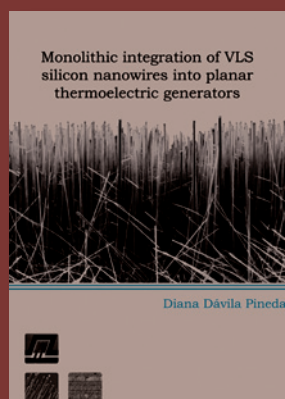
Ph.D. Thesis



Constant, Aurore

SiC oxidation processing technology for MOSFET devices fabrication.

P. Godignon, J. Camassel, (dir.), F. Guinjoan Gispert (tutor).
Universitat Politècnica de Catalunya,
Departament d'Enginyeria Electrònica,
2011.



Dávila, Diana

Monolithic integration of VLS silicon nanowires into planar thermoelectric generators.

L. Fonseca (dir.), A. Tarancón (tutor).
Universitat Autònoma de Barcelona,
Departament de Enginyeria Electrònica,
2011



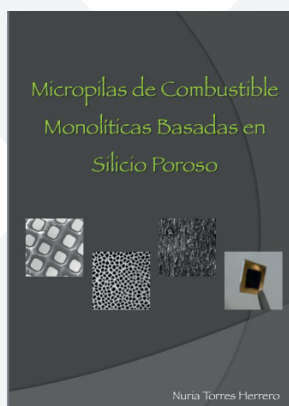
Fernández-Rosas, Elisabet

Microherramientas para el estudio de células vivas.

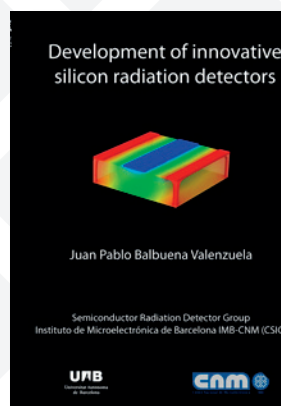
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Universitat Autònoma de Barcelona,
Departament de Bioquímica i de
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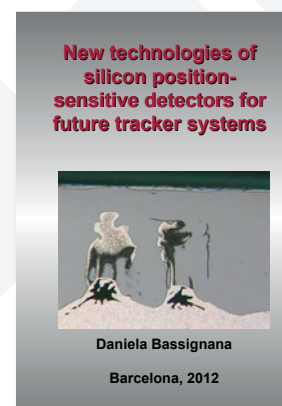
García-Cantón, Jesús
Sensors químics sense fils tipus LC basats en estructures capacitives d'efecte camp.
 A. Baldi (dir.), G. Abadal (tutor).
 Universitat Autònoma de Barcelona, Departament d'Enginyeria Electrònica, 2011.



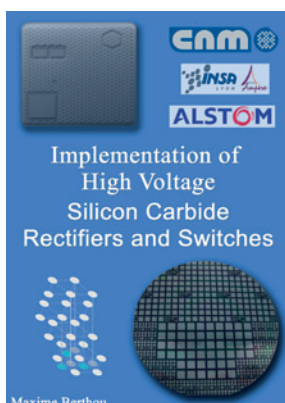
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 J. Santander (dir.), E. Brillas (tutor).
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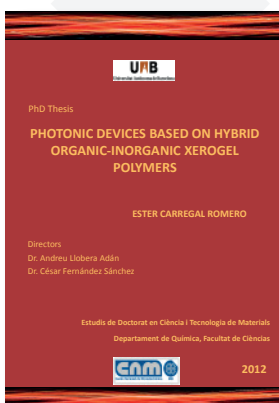
Balbuena, Juan Pablo
Development of innovative silicon radiation detectors.
 G. Pellegrini (dir.), E. Fernández-Sánchez (tutor).
 Universitat Autònoma de Barcelona, Departament de Física, 2012.



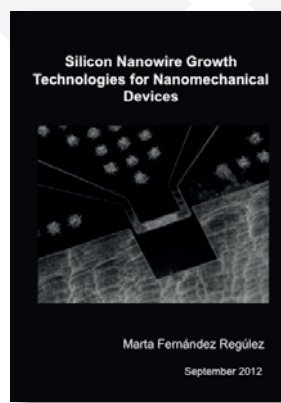
Bassignana, Daniela
New technologies of silicon position-sensitive detectors for future tracker systems.
 G. Pellegrini (dir.), E. Fernández-Sánchez (tutor).
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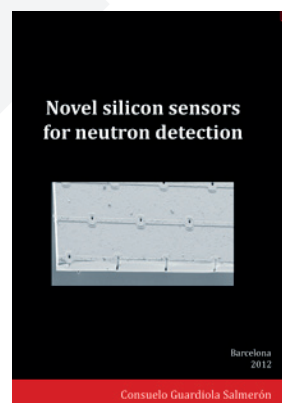
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Implementation of high voltage silicon carbide rectifiers and switches.
 F. Morancho (dir.), P. Godignon (tutor).
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Carregal-Romero, Ester
Photonic devices based on hybrid organic-inorganic xerogel polymers.
 A. Llobera, C. Fernández (dir.), J. Alonso (tutor).
 Universitat Autònoma de Barcelona, Departament de Química, 2012.



Fernández-Regúlez, Marta
Silicon nanowire growth technologies for nanomechanical devices.
 A. San Paulo (dir.), J. Bausells (tutor).
 Universitat Autònoma de Barcelona, Departament d'Enginyeria Electrònica, 2012.



Guardiola, Consuelo
Novel silicon sensors for neutron detection.
 M. Lozano, C. Fleita (dir.), E. Fernández-Sánchez (tutor).
 Universitat Autònoma de Barcelona, Departament de Física, 2012.

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.

SPIN OFFS

A number of spin-off companies have been created from the research done at IMB-CNM over the last decade. They are described in this section.

MIRAKONTA SL

www.mirakonta.es

Mirakonta SL has arisen in order to offer and market a hardware-software system universal remote water meter reading by images:

- Remote water meter reading imaging
- Optimization and traceability of waste collection
- Control System Street Cleaning Equipment
- K-Speed, control system for sporting events



X-RAY IMATEK

www.xray-imatek.com

X-Ray Imatek is a company focused on research, development and marketing of X/Gamma-Ray detectors based on Photon Counting technology. They are applied in a large number of sectors such as Medical Imaging, Non-destructive Testing (NDT) or Scientific Research.

MICRO4ENER

www.micro4ener.com

Micro4ener develops, manufactures and markets microsystems for the detection and control of microorganisms.

Fast and low cost bacterial concentration control in water treatment process, reducing the water consumption and increasing the efficiency.

Micro4Ener has been one of the seven winners of the first Repsol Entrepreneurs Fund awards (2012) of the Repsol Foundation, to support the best start-up companies providing solutions for energy saving and efficiency.



ALIBAVA SYSTEMS

www.alibavasystems.com

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.



SMALLE TECHNOLOGIES

www.smalletec.com

Energy Harvesting Company. Smalle Technologies 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.

Smalle Technologies has been one of the eighth winners of the second Repsol Entrepreneurs Fund awards (2013) of the Repsol Foundation, to support the best start-up companies providing solutions for energy saving and efficiency.

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" section. The owner of the patents is CSIC, unless otherwise specified.

Patents granted

Title: Circuito integrado para la lectura digital de sensores de imagen de alta velocidad.

Authors: Serra-Graells, F., Margarit, J.M., Terés, L.

Ref.: Spain, appl. P200801428, 2008; Granted 10/02/2011.

Title: Microagujas de SU-8 para la monitorización y la estimulación neuronal.

Authors: Villa, R., Guimerà, A., Tijero, M., Berganzo, J., Gabriel, G., Menéndez de la Prida, L., Altuna, A., Fernández Ledesma, J.L.

Ref.: Spain, appl. P200930430, 2009; Granted: 24/03/2011; PCT, appl. PCT/ES2010/070472, 2010.

Title: Lente de contacto sensora, sistema para la monitorización no invasiva de la presión intraocular y método para su medida.

Authors: Veciana, J., Rovira, C., Mas-Torrent, M., Villa, R., Aguiló, J., Pastor, J.C., Ussa, F., Laukhina, E., Laukhin, V.

Ref.: Spain, appl. P200801722, 2008; Granted 31/03/2011.

Title: Dispositivo de lectura microarrays de tipo eléctrico y reutilizable.

Authors: Fernández-Sánchez, C., Bonilla, D., Baldi, A., de la Rica, R.

Ref.: Spain, appl. P200802068, 2008; Granted 18/07/2011.

Title: Dispositivo y procedimiento para medir concentración de biomasa y uso de un elemento electrónico chip para medir dicha concentración de biomasa.

Authors: Mas, J., Del Campo, F.J., Vignes, N., Muñoz, F.J., Escudé-Pujol, R., Muñoz-Berbel, X.

Ref.: Spain, appl. P200800109, 2008; Granted 15/09/2011.

Title: Procedimiento y sistema para detectar y/o cuantificar bacteriófagos, uso de un dispositivo microelectrónico sensor para detectar dichos bacteriófagos y dispositivo microelectrónico sensor para llevar a cabo dicho procedimiento.

Authors: Blanch, A.R., García-Aljaro, C., Muñoz, F.J., Muñoz-Berbel, X.

Ref.: Spain, appl. P200801007, 2008; Granted 30/09/2011.

Title: Membrana de electrolito polimérico híbrida y sus aplicaciones.

Authors: Esquivel, J.P., Sabaté, N., Santander, J., Torres, N., Gràcia, I., Cané, C., Tarancón, A., Acero, M.C.

Ref.: Spain, appl. P200801838, 2008; Granted 17/11/2011.

Title: Biosensor para la detección de anticuerpos anti-VIH.

Authors: Laczka, O., Muñoz, F.J., Ferrer-Miralles, N., Ferraz, R.M., Villaverde, A., Del Campo, F.J.

Ref.: Spain, appl. P200802551, 2008; Granted 03/01/2012.

Patents Licensed

Title: Impedimetric sensor and applications thereof.

Authors: Bratov, A., Domínguez, C., Abramova, N., Merlos, A., Ramon, J., Sánchez, F.J., Marco, M.P.

Ref.: Spain, appl. P200701253, 2007; PCT, appl. PCT/ES2008/070084, 2008; Licenced 15/04/2011.

Title: Sensor no invasivo para determinar características funcionales de la córnea y dispositivo que incluye dicho sensor.

Authors: Guimerà, A., Villa, R., Gabriel, G., Maldonado, M.J.

Ref.: Spain, appl. P201030307, 2010; PCT, appl. PCT/ES2011/070131, 2011; Licenced 15/07/2011.

Title: Device for generating electric power from small movements.

Authors: Esteve, J., Acero, M.C., Fondevilla, N., Serre, C., Pérez-Rodríguez, A.

Ref.: Spain, appl. P200930320, 2009; PCT, appl. PCT/ES2010/070400, 2010; Licenced 17/09/2012.

International patents (PCT)

Title: Multi-analytical method and system based on impedimetric measurements.

Authors: Ramon, J., Sanchez-Baeza, F., Marco, M.P., Bratov, A., Abramova, N., Ipatov, A.

Ref.: Spain, appl. P200931164, 2009; PCT, publ. WO 2011/073481 A1, 2011; US, ref. US2012309108, 2012.

Title: Dispositivo inductivo detector de presencia bacteriana.

Authors: Baldrich, E., Muñoz, F.J., Martínez, S.

Ref.: Spain, appl. P200930031, 2010; PCT appl. PCT/ES2011/070012, 2011.

Title: Ionizing radiation detector sensitive to the 2D position.

Authors: Bassignana, D., Lozano, M., Pellegrini, G.

Ref.: Spain, appl. P201030200, 2010; PCT, appl. PCT/ES2011/070088, 2011.

Title: Microcámara y dispositivo de cultivo celular monitorizables por resonancia magnética nuclear.

Authors: Esteve, V., Sancho, F., Villa, R., Fernández Ledesma, J.L., Berganzo, J.

Ref.: Spain, appl. P201030382, 2010; PCT, appl. PCT/ES2011/070173, 2011.

Title: Dispositivo y sistema de contabilización y análisis de partículas y uso de dicho sistema.

Author: Llobera, A.

Ref.: Spain, appl. P201030015, 2010; PCT, appl. PCT/ES2011/070011, 2011.

New patents

Title: Sensor de determinación directa de la presencia de detergentes en una muestra.

Authors: Bratov, A., Ipatov, A., Abramova, N., Domínguez, C., Merlos, A.

Ref.: Spain, appl. P201131261, 2011.

Title: Dispositivo de radiofrecuencia.

Authors: Gemio, J., Parrón, J., Baldi, A., Sacristán, J.

Ref.: Spain, appl. P201101180, 2011.

Title: Circuito integrado para la sintonía digital del contraste temporal en sensores de imagen.

Authors: Serra-Graells, F., Margarit, J.M., Dei, M., Terés, L., Montojo, M.T., Vergara, G., Linares, R., Gutierrez, R.

Ref.: Spain, appl. P201130750, 2011.

Title: Detector liquido-semiconductor de neutrones.

Authors: Guardiola, C., Lozano, M., Fleta, C., Pellegrini, G., Quirion, D.

Ref.: Spain, appl. P201231769, 2012.

Title: Procedimiento para el depósito de capas gruesas de boro.

Authors: Guardiola, C., Calvo, J., Lozano, M., Fleta, C., Pellegrini, G.

Ref.: Spain, appl. P201231604, 2012.

Title: Celda de flujo, carcasa para alojar la celda de flujo y usos de la celda y carcasa.

Authors: Torrents, A., Del Campo, F.J., Baldrich, E., Sabaté, N., Mas, J.

Ref.: Spain, appl. P201231642, 2012.

Title: Aparato para la caracterización de detectores de radiación.

Authors: Bernabeu, J., García-García, C., Lozano, M., Marco-Hernández, R., Martí-García, S., Pellegrini, G., Ullán, M., Lacasta, C.

Ref.: Spain, appl. U201230590, 2012.

Outreach

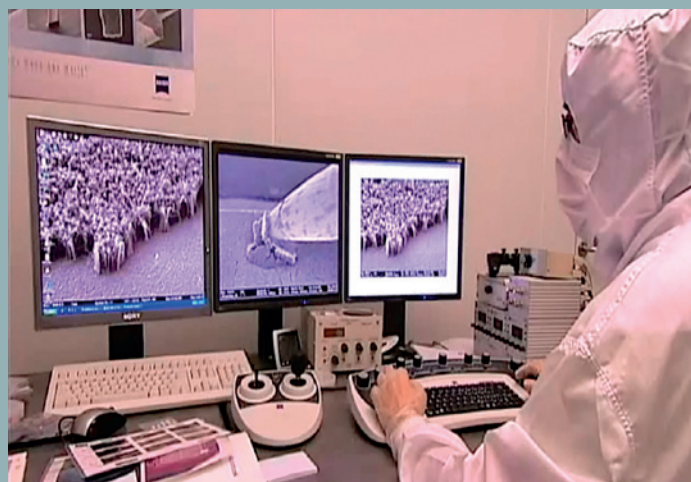
IMB has a sustained activity in outreach events aiming at promoting the social awareness of the benefits of science and technology, and the public support to them. A program of visits from high-school students is aimed at encouraging young people to follow science and technology careers. IMB participates in the annual Science and Technology Week which is organized at the Spanish and Catalan levels, and regularly presents the results of its research activities in the public media.



Science and Technology Week



Participation in the organization of Inspiraciencia (2011 and 2012), a contest on science-based stories, organized by CSIC.



IMB-CNM in TV news, October 2011

Juan Pablo Esquivel, 30

Fuentes de energía miniaturizadas para dispositivos de diagnóstico portátiles

Instituto de Microelectrónica de Barcelona



Juan Pablo Esquivel

One of the IMB-CNM researchers is highlighted in Technology Review, published by the Massachusetts Institute of Technology (2012)

◆ Microelectronics Museum Area

The “Zenon Navarro” Microelectronics Museum area has been 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.



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. The museum area is visited annually by 200 to 300 students.



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 currently includes more than 500 researchers. Its members, excluding CNM, are:



- Institut Català de Nanociència i Nanotecnologia, ICN2
- Institut de Ciència de Materials de Barcelona, ICMAB (CSIC)
- Various Departments of Universitat Autònoma de Barcelona, UAB
- MATGAS 2000, A.I.E.
- D+T Microelectrónica, A.I.E.

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 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.



parc.uab.cat

The cluster PEC4 for printed electronics was founded in 2009 by 4 research centers located in the Barcelona area to strengthen the development of this technology. The PEC4 cluster aims especially to develop printed sensors for packaging and biomedical applications, and embedded solutions in RFID and WSN domains. The main drivers are the development of body area networks and ambient intelligence.



Members: EPHIS/CAIAC (UAB), CETEMMSA Technological Center, CIMITEC (UAB), IMB-CNM.

www.pec4.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.



www.cnm.es/dt

◆ Associated Units

IMB-CNM has special collaborations with research groups from Spanish Universities and technological centres, through “Associated Unit” agreements with the Spanish Research Council (CSIC). Historically there have been agreements with various institutions, such as the University of Barcelona (UB), the Autonomous University of Barcelona (UAB), the Polytechnical University of Catalonia (UPC) or the Polytechnical University of Madrid (UPM). At the end of the reporting period the following Associate Units were active:

- Electronic Materials and Engineering Group, Department of Electronics, University of Barcelona (UB), since 1998.
- Group of Electronic Circuits and Systems, Department of Electronic Engineering, Autonomous University of Barcelona (UAB), since 2002.
- Unit of Micro-Nano Systems and Applications, Department of Microelectronics and Electronic Systems, Autonomous University of Barcelona (UAB), since 2011.



◆ Research Agreements

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

- Centre for Materials and Microsystems - Fondazione Bruno Kessler (CMM-FBK), Trento (Italy), to carry out a bilateral co-operation program in the field of “Micro and Nano Integrated Systems”.
- The Regents of the University of California, USA, as Facility Operator of Ernest Orlando Lawrence Berkeley National Laboratory (LBNL), for access of IMB-CNM researchers to the LBNL Advanced Light Source (ALS), National Center for Electron Microscopy (NCEM), and Molecular Foundry (TMF) facilities.
- Centre National de la Recherche Scientifique (CNRS), Université Claude Bernard Lyon 1, École Centrale de Lyon and Institut National des Sciences Appliquées de Lyon, all from France, to create the International Associated Laboratory (LIA) “Wide Band Gap Technologies for Integration of Energy Efficient Devices” (“W.I.D.E. - Lab.”).

◆ 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) and ARTEMIS (on Embedded Computing Systems), 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.

IMB-CNM has been a member of the Council of EURIPIDES (the EUREKA initiative for packaging and integration of microdevices and smart systems).

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 (Studies and Research Center for Space) 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, and funded by ACCIÓ, an agency of the Catalan Regional Government.



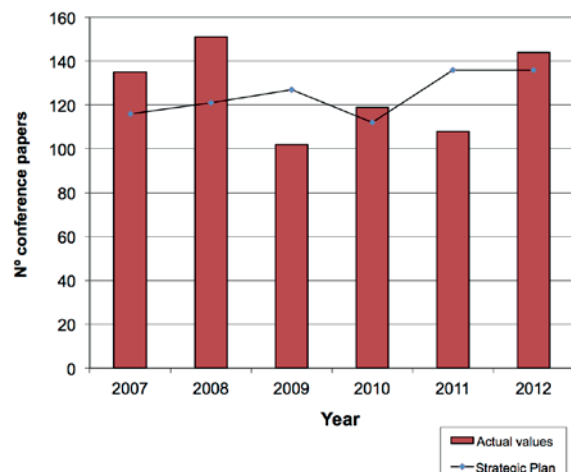
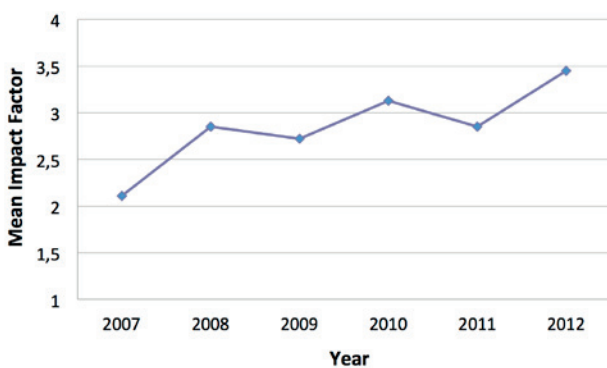
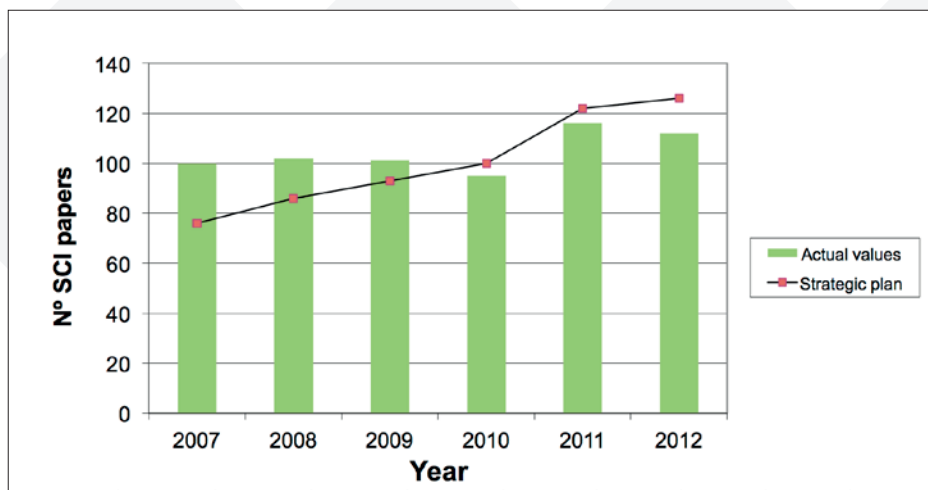
Key Figures

◆ Key figures

The time period 2011-2012 is included in the Strategic Plan 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 severe reductions in both the budget and new human resources as compared to the Strategic Plan.

◆ Publications

The graphs show the total 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 rather than their number.

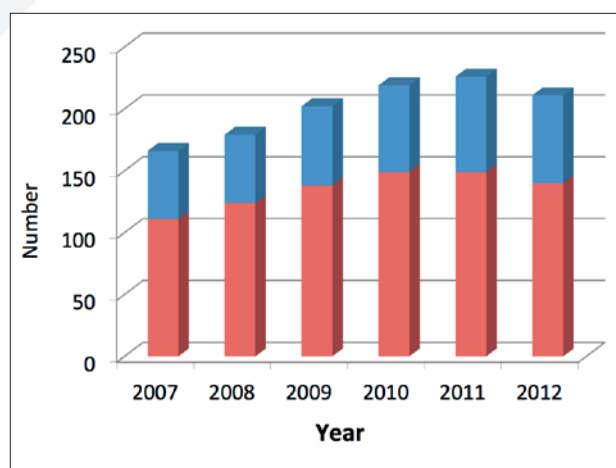


Key figures

◆ Staff

The expansion in offices, laboratories and clean room area that was completed in the period 2007-2009 resulted in a growth of human resources of 22% in the previous biennial reporting period, to a maximum of about 220-225 persons in 2010 and 2011. In 2012 and 2013 the trend is a reduction in staff due to budget limitations.

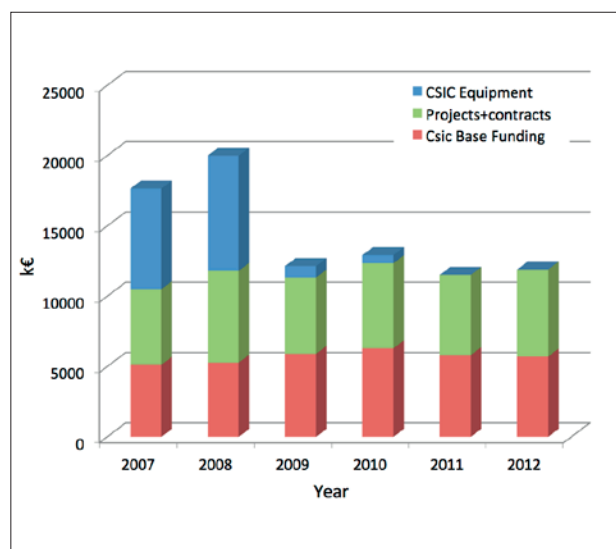
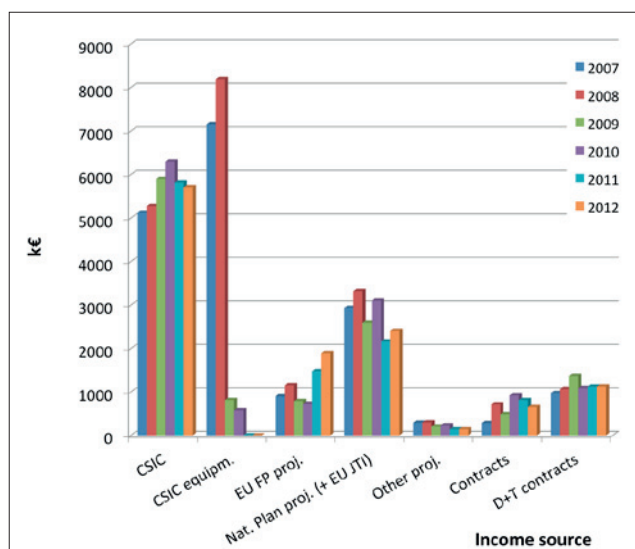
STAFF - End 2012	Female	Male	Total
Researchers	18	46	64
Ph.D. students	20	30	50
Clean room facility	18	25	43
Support services	1	31	32
Administration & general services	12	7	19
Visitors	2	1	3
TOTAL	71	140	211



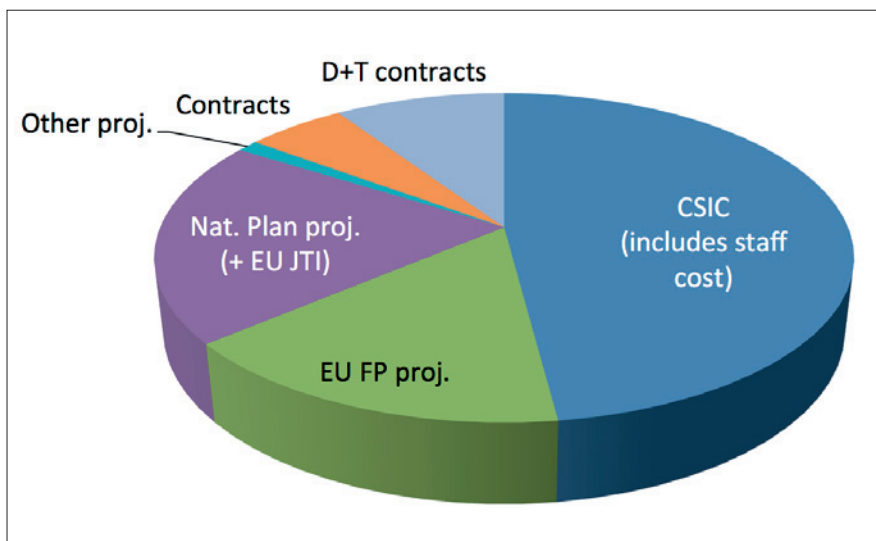
■ Female
■ Male

◆ Budget

The main income sources are CSIC, which includes base funding and the cost of permanent staff, public funded competitive research projects and industrial contracts.

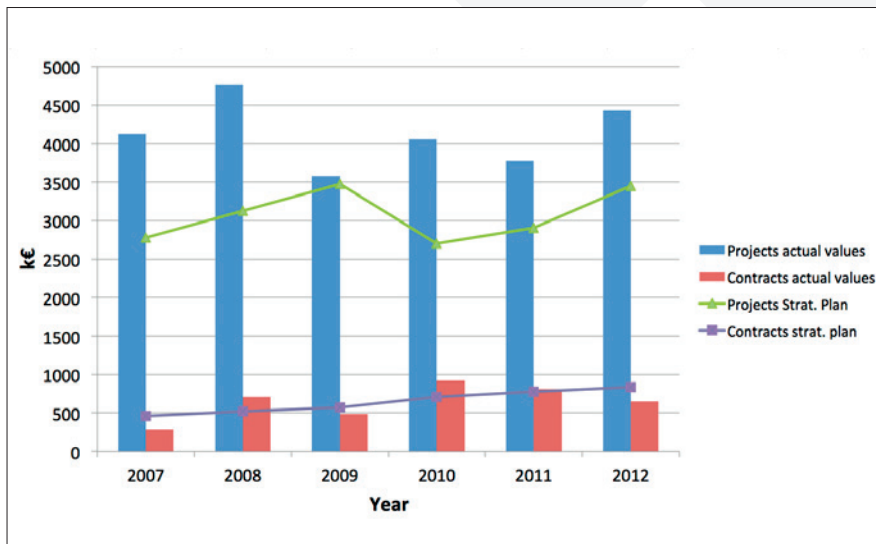


◆ Budget distribution 2012



◆ External funding

External funding from competitive public projects and industrial contracts, in the context of the 2005-2009 and 2010-2013 Strategic Plans.



www.imb-cnm.csic.es



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