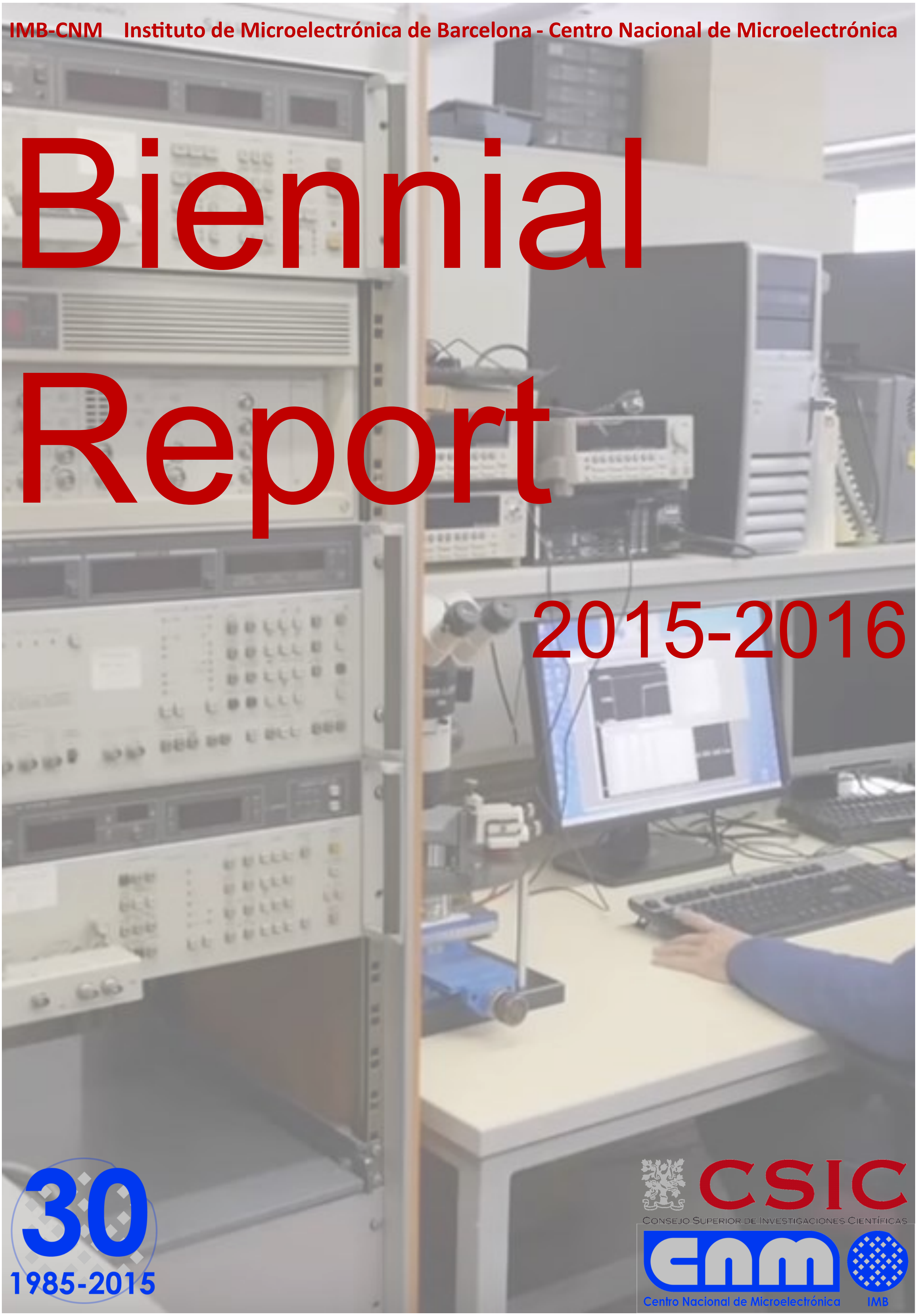


IMB-CNM Instituto de Microelectrónica de Barcelona - Centro Nacional de Microelectrónica

Biennial Report

2015-2016

30
1985-2015

CSIC
Consejo Superior de Investigaciones Científicas

CNM
Centro Nacional de Microelectrónica IMB

Contents

Research Highlights

Self powered devices

Prof. Neus Sabaté received an ERC Consolidator Grant (SUPERCELL project) in January 2016. In September 2015, together with Dr. Juan Pablo Esquivel, shefounded the spin-off Fuelium dealing with paper based disposable batteries for quick diagnosis devices among other applications. A related patent was licensed by CSIC to Fuelium for its exploitation in October 2016.

Micro energy harvesting and storage

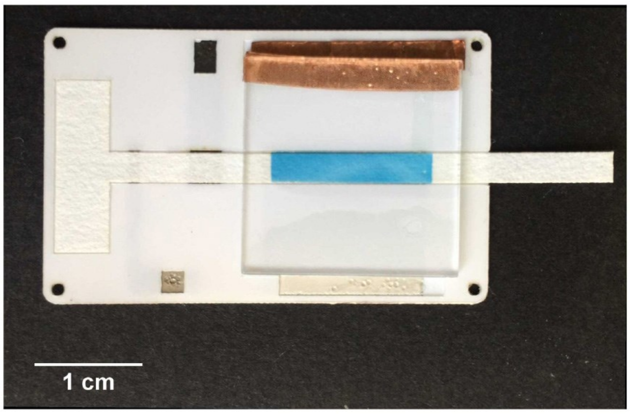
The SiNERGY Project, GA nº 604169, finished in Oct 2016. Its coordination by IMB-CNM (CSIC) was praised by the EU. It dealt with microenergy harvesting and storage based in silicon approaches. CNM itself was involved in thermoelectric and piezoelectric developments. In the frame of this project, Gonzalo Murillo was awarded Novel European Innovator of the Year under 35 at the MIT Technology Review Summit Europe. SiNERGY was also organizing the Symposium W (Materials and Systems for microenergy harvesting and storage) of the E-MRS 2016 edition, and research covered by SiNERGY as a whole received the Best Poster Award at the Industrial Technologies event (June 2016) organized during the Dutch EC Presidency.

Energy harvesting for the internet of things

Dr. Gonzalo Murillo was awarded as “Most Novel Innovator under 35 in Europe 2016” by MIT Technology Review. The project of the spin-off EnergIoT (www.energiot.com) was selected as 1st finalist of the Engega program 2016 organized by UAB, Fondo Repsol Emprendedores and KIC Innoenergy, and finalist of the KIC Innoenergy Awards 2016.

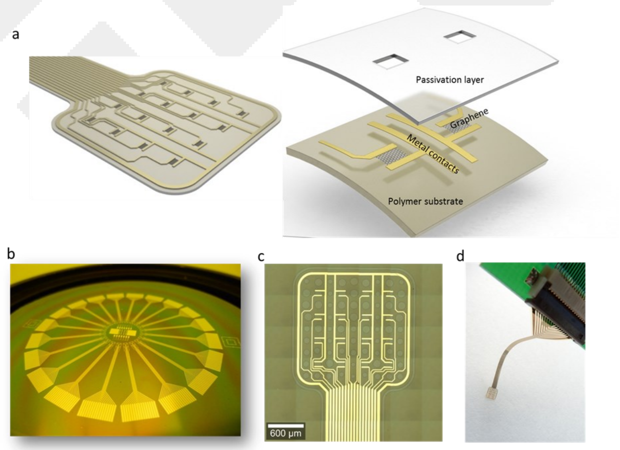
BBVA Foundation award 2016 – Self-powered electrochromic biosensors

Dr. F. Javier del Campo, from the Biomedical Applications Group, received one of the awards for researchers and cultural creators granted in 2016, for his proposal to explore unconventional applications of electrochromic materials. The research aims to apply electrochromic materials to the construction of self-powered biosensors for the non-invasive monitoring of biomarkers. Electrochromic materials change colour as a function of oxidation state. This device combines an electrochromic display and an enzymatic biosensor and provides a direct readout on the concentration of a target analyte, such as glucose. The device is easy to manufacture and requires no additional instrumentation to operate.



Graphene for biomedical applications

The Biomedical Applications Group is a partner of the Graphene Flagship project within the biomedical technologies work package. The group is responsible for the development of the technology to build solution-gated field-effect transistors (SGFET) based on graphene for recording neural electrical activity. This covers the growth of high quality CVD-graphene, its implementation in rigid (SiC, Si, Pyrex) and flexible (Polyimide) substrates using microelectronic fabrication processes for 4-inch wafers, and its final electrical characterization. For the first time, the graphene-based devices developed at the IMB-CNM have been used for µ-ECoG (electrocorticography) recordings on the visual and auditory cortices of living rats. In addition, the group is participating in the BrainCom, a FET Proactive project which aims to develop a new generation of neuroprosthetic cortical devices enabling large-scale recordings and stimulation of cortical activity to study high level cognitive functions. This research line has led to a close collaboration with the Advanced Electronic Materials and Devices Group of the ICN2.

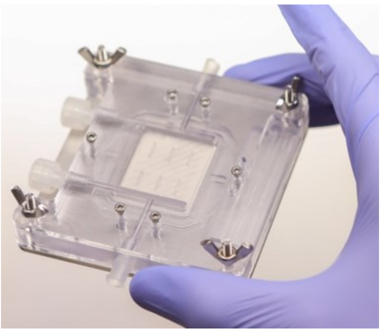


Biomimetic microfluidic devices: organ on a chip

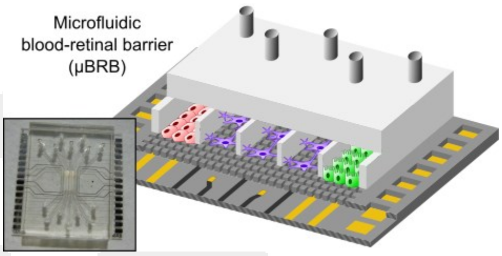
Organ on a chip has emerged as a technology to develop microfluidic cell culture devices where cells can be cultured in a controlled microenvironment that mimics aspects of the human body like its structure and flow conditions. With this technology it is possible to model physiological functions of tissues and organs, promising to accelerate drug discovery, decrease development costs and also reduce the use of animals for drug testing. In this field, the Biomedical Applications Group is collaborating with different biomedical research groups to develop different devices:

Liver on a Chip. In collaboration with the Liver Vascular Biology Research Group (IDIBAPS), a liver on a chip device has been developed and used to determine the hepatotoxicity of different drugs in primary hepatic cells. Besides the different research articles and received awards, a spin-off company (BioLiver Bioservices, BLB) has been created.

Retina on a Chip. A microfluidic chip to facilitate multicellular interaction and cell barrier function monitoring in real time by TEER measurements to study the interaction between the different cell types that are present in the retina has been developed in the IMB-CNM in collaboration with the Diabetes Research and Metabolism Unit of the Vall d'Hebron Research Institute.



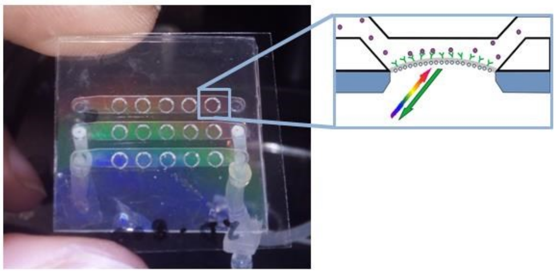
Liver on a Chip



Retina on a Chip

Colorimetric nanomechanical sensing

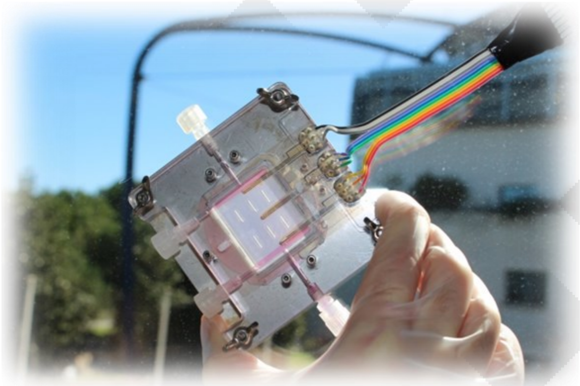
The Biomedical Applications Group (GAB) has developed a novel high-throughput and low-cost nanomechanical biosensor based on the colorimetric response of the sensors. Polymeric nanomechanical biosensors (membranes and microcantilevers) with integrated diffraction gratings based on 2D colloidal crystals were fabricated and demonstrated its suitability for pressure and surface stress sensing. The transducer bending induces a change on the angle of incident of light and a deformation of the grating (increase or decrease of the pitch for large bending). We explore and exploit the white light diffraction to achieve a power-free array of biosensors that change their reflective color depending on the surface stress change (bending) produced on each sensor.



Emergent printed sensors for Organ-On-a-Chip monitoring

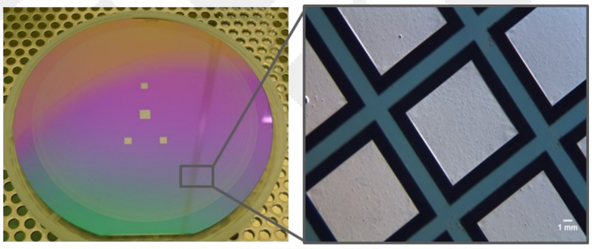
The Biomedical Applications Group (GAB) has developed a novel approach to integrate sensors in

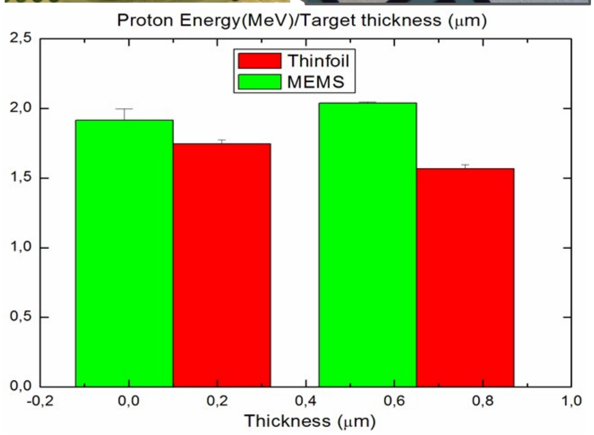
Organ-On-a-Chip (OOC) systems based on the inkjet printing technology (IJP). Electrochemical dissolved oxygen (DO) sensors were inkjet-printed on a porous and flexible cell culture membrane in order to monitor in real-time the oxygen consumption of cells. Conductive (silver and gold) and dielectric materials were deposited by IJP in a non-contact manner on the delicate membrane aiming to build up the sensor device. The manufacturing process does not require any masks and is carried out at low temperatures. Three sensors were printed and integrated on the cell culture membrane to monitor the oxygen zonation along the microfluidic channel. Experiments with cell cultures of human and rat hepatocytes were performed and oxygen consumption rate was monitored with the addition of a mitochondrial oxidative uncouplear as is FCCP molecule, that promotes an increase of respiration.



Micro-nanoengineered target for advanced laser light sources

Laser-driven particle sources are attracting notable efforts due to their ability of providing MeV ion beams over very short acceleration distances, typically few micrometers, which are almost negligible compared to standard RF based particles accelerators. This could open the route to obtain particle beams useful for a number of scientific, medical and technological applications by using a very compact source and with less radioprotection requirements. The increasing availability of extreme light infrastructures owning the promise to allow in the next years ultra-high power laser experiments at unprecedented repetition rates, between Hz and KHz, is further boosting the field and the research of smart target to improve energy and properties of laser-driven sources. The radiation detectors group participates in a National Project devoted to the development of a prototype technology able to provide a radiopharmaceutical dose through the interaction of a tabletop high power laser with primary and secondary target. Within this collaboration, the specific task of the RDG is to design and engineer by applying MEMS based manufacturing processes, target solutions capable of increasing laser-plasma coupling, and thus the efficiency of laser-particle beam energy conversion. Sub-micrometric thin layer membranes embedded in silicon wafers have been successfully fabricated, and used for laser-driven proton acceleration showing better performances with respect standard solid state targets commonly used up until now to provide laser-driven particles beam.

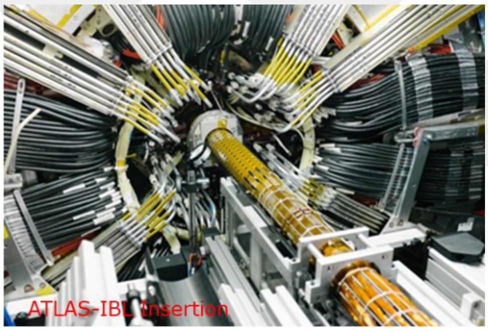


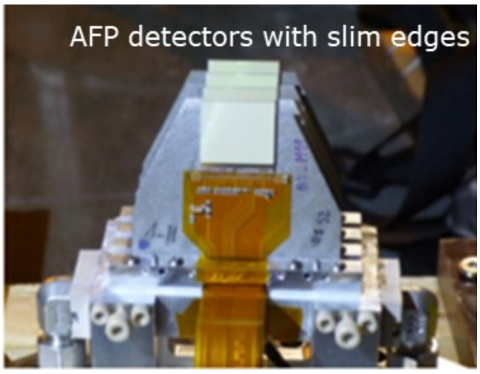


3D Detectors installed in experiments at CERN

The first upgrade of the pixel system in the ATLAS experiment has incorporated radiation-hard 3D silicon detectors designed by the radiation detector group at IMB-CNM in collaboration with an international team of physicists and engineers who worked in conjunction to move rapidly from R&D to production.

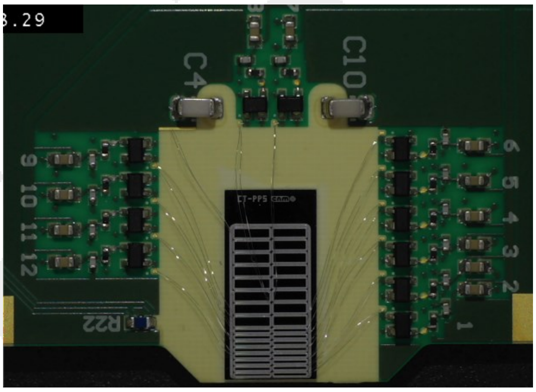
Three-dimensional silicon sensors (3D) are opening a new era in radiation imaging and radiation-hard, precise particle tracking through a revolutionary processing concept that brings the collecting electrodes close to the carriers generated by ionizing particles and that extends the sensitive volume to a few microns from the physical sensor's edge. During 2015 and 2016 3D slim edge detectors were fabricated at IMB-CNM clean room and were placed in the following experiments: Atlas IBL (Insertable b-Layer); AFP (ATLAS Forward Proton): 1st Arm assembled and installed in Roman Pots in February 2016, 2nd arm will be installed in 2017; CT-PPS (CMS-TOTEM Precision Proton Spectrometer): installed in 2016.

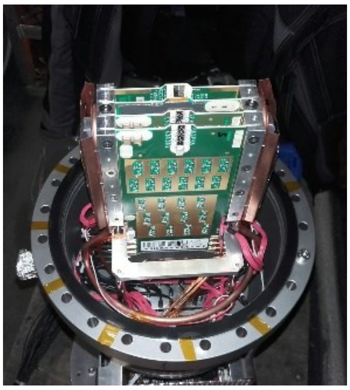




Low Gain Avalanche Detectors as Ultra-Fast Silicon Detectors

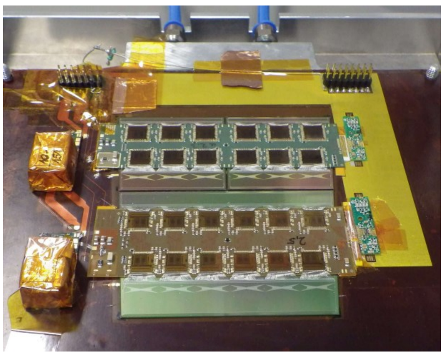
Ultra-Fast Silicon Detectors are based on the concept of Low-Gain Avalanche Detectors, which are silicon detectors with an internal multiplication mechanism so that they generate a signal a factor 10 larger than standard silicon detectors. LGAD are planar silicon detectors with internal gain under development for the last 5 years within the CERN RD50 community, which have been pioneered by the radiation detector group at IMB-CNM. This technology allows the concept of 4D tracking: high precision space (~10μm) & time (~10ps) measurements combined in one device. LGAD are the baseline technology for the High-Granularity Timing Detector for ATAS and CMS experiments that are under development at CERN. The first detectors produced at CNM were installed in the CT-PPS experiment in 2016 and are now in operation at CERN.





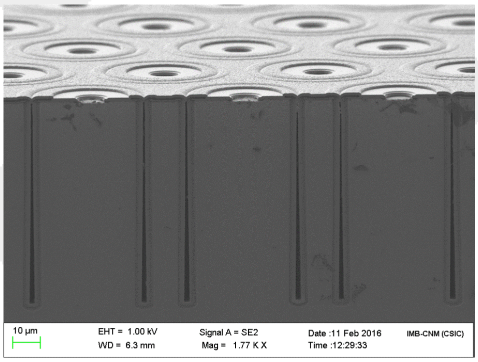
Full Sensor production for ATLAS ITk prototype

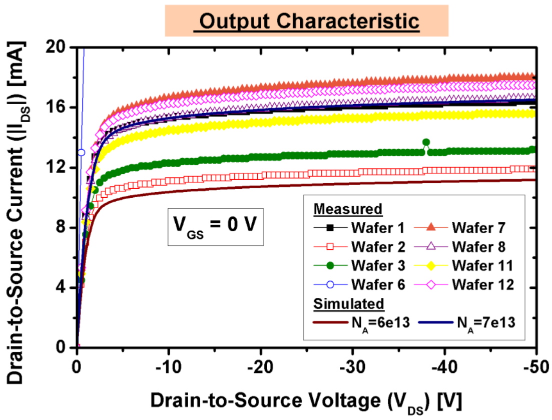
The Radiation Detectors Group has undertaken the full production of the sensors for the ATLAS ITk End -Cap prototyping, under a technology fabrication contract. The layout and technology have been improved over the production process, and many lessons have been learnt for the benefit of the sensors of the final experiment in terms of the different new solutions implemented, like the ganging of the incomplete strips and the embedded pitch adapters. More than 70 large-area sensors have been fabricated in the micro- nano- fabrication facility of CNM, fully characterized, and then supplied to the assembly sites of the End-Cap ITk Collaboration. More than 40 fully functional modules have been built and evaluated at five institutes in Spain, Germany, Sweden, and United Kingdom, and several full ITk prototypes have been built. This prototype sensor development has been fundamental in the development of the assembly tools and the expertise required to build the final ITk sensors and modules.



New rad-hard vertical JFET technology

A new Vertical JFET device, based on a 3D trenched technology, has been developed in a collaboration between the Power Devices Group and the Radiation Detectors Group. These transistors are conceived to work as rad-hard switches in the power distribution schemes of radiation environment systems like the ones encountered in Particle Physics experiments, Space applications, or Nuclear Physics. The fabricated wafers have been fully characterized and the V-JFET performance is fulfilling the expected specifications, showing also excellent agreement with simulations. The performance of the fabricated devices has been tested under harsh radiation conditions. The variation of the main figures of merit is evaluated as a function of the Total Ionising Dose (TID) and Non-Ionizing Energy Loss (NIEL). The devices have demonstrated to be radiation hard up to doses of 100 Mrad(Si) and fluences of $2{\cdot}10^{14}\ n_{eq}/cm^2$.

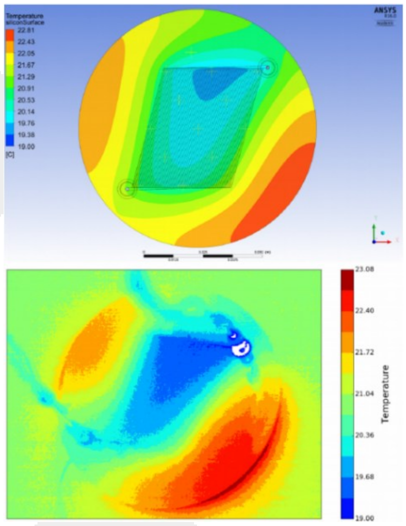


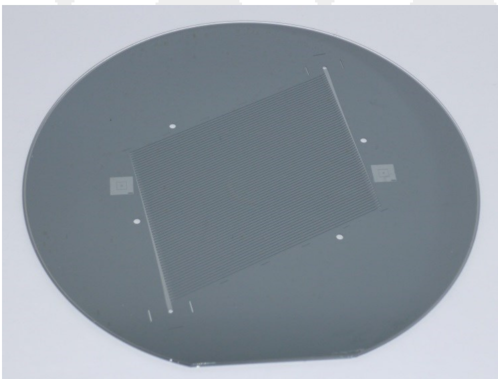


Research Highlights

Micro-channel cooling for silicon detectors

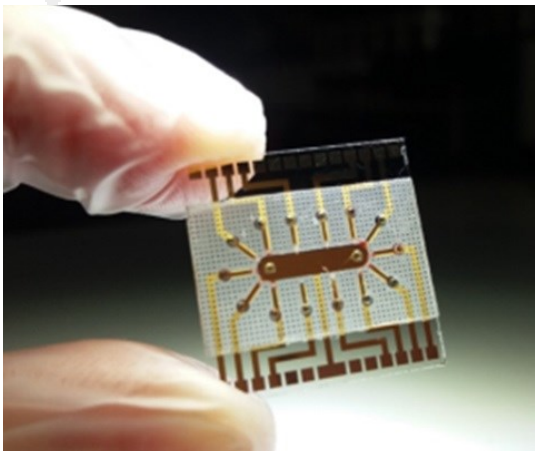
The first large-area micro-channel cooling assemblies for silicon detector applications were fabricated and evaluated in the Radiation Detectors Group in collaboration with the DESY ATLAS Group in Hamburg (Germany). Several assemblies where fabricated using DRIE technology to form the micro-channels, and different wafer bonding technologies. Micro-channel cooling, initially aimed at small-sized high-power integrated circuits, Is being transferred to the field of high energy physics. Today's prospects of micro-fabricating silicon opens a door to a more direct cooling of detector modules. The challenge in high energy physics is to save material in the full experiment construction and to cool large silicon areas more efficiently. We are developing micro-channel cooling as a candidate for the cooling system in future high energy physics experiments. The work includes the production of the assemblies and the thermal and hydrodynamic evaluation of an integrated micro-channel prototype optimized to achieve a homogeneous flow distribution and isothermal surface across the large-area sensor.





Multiple actuation wax valves

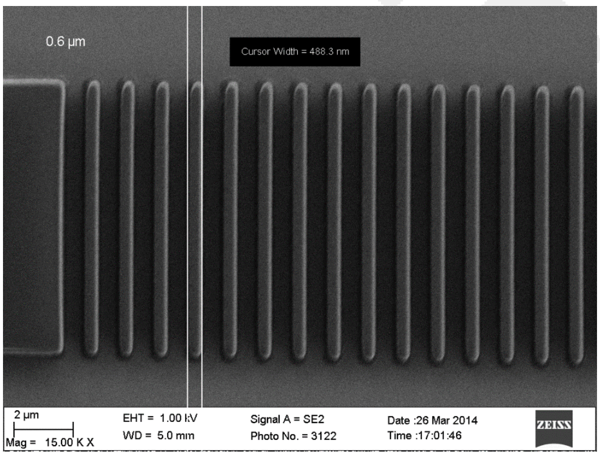
The challenge of low-cost large-scale integration of valves in portable microfluidic systems may be solved with this new valve concept. The working principle for multiple open-close actuation is simple: a small tunnel in a wax plug is created and refilled repeatedly by using a combination of micro-heaters. It allows actuation with both electrical and light (e.g. LED) pulses. Other features are low-power consumption, short response time, and very simple fabrication. Integration of these wax valves in lab-on-a-film systems are enabling the development of disposable point-of-care multiplexed biomarker analysis devices.



Liquid microsampler incorporating 14 electrically-actuated wax valves

Si_3N_4 photonic platform

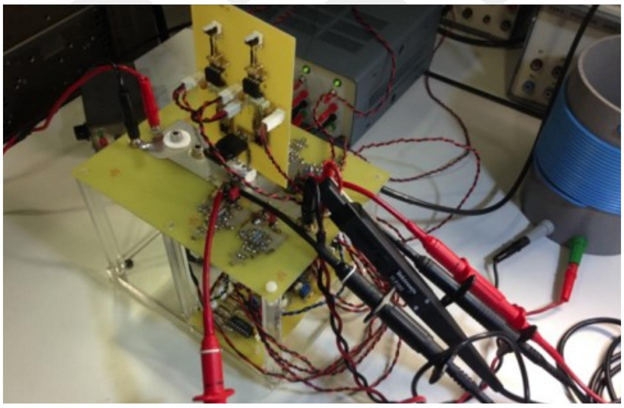
Despite many materials are amenable to produce photonic integrated circuits (PICs), only a few material systems have been mirrored the path of the semiconductors electronics industry and evolved into an eco-system of foundries, software suppliers, design houses and fabless companies. Together with the company VLC Photonics SL, a 300 nm thick Silicon Nitride (Si_3N_4) waveguide platform, amenable for biophotonics, tele/datacom and sensing applications, has been developed with low propagation losses, low autofluorescence and a high level of integration to realize compact systems at low cost targeted from the visible (400-800 nm) spectrum to the infrared (up to 4.0 µm). Passive components are introduced here with best-in-class performance, including waveguides, splitters, filters, multiplexers and couplers based on optimized loss Si_3N_4 material. In order to make efficient use of the fabrication runs and inspired by the cost sharing model that has been in use for ASICs and silicon photonics in the past, access to the fabrication platform is offered through Multi Project Wafer runs (MPW's).



Grating coupler

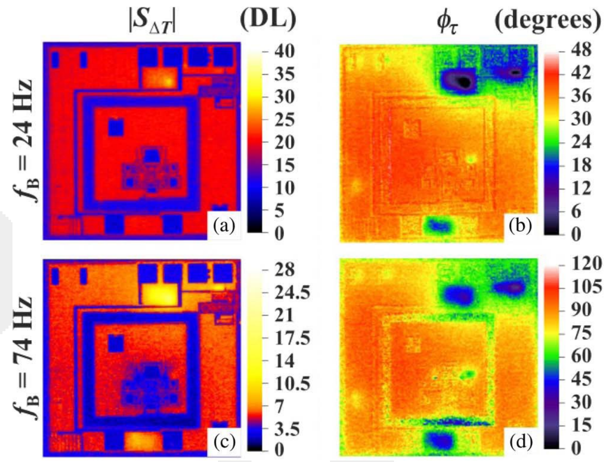
New solid-state relay concepts developed in collaboration with Bosch Siemens Home Appliances (BSH)

In the framework of a collaboration contract with the Bosch Siemens Home Appliances (BSH) company, researchers of the Power Devices & Systems Group (PDSG) have investigated the potential of last generation power devices for implementing the bidirectional switch (BDS) function to replace electro-mechanical relays in induction cookers. Emerging devices based on wide band-gap semiconductors, such as SiC and GaN, have proved their outstanding performances for this application and a patent for a BDS based on these technologies has been applied for. The impact of such studies is clear as there are millions of electro-mechanical relays in industrial and consumer electronics systems that could be potentially replaced by this new solid-state approach taking advantage of their inherent benefits, such as higher reliability, compactness and switching speed, lower acoustic noise emissions, among others.



Local, non-invasive and contactless thermal imaging approach for functional and electrical assessment of radio frequency integrated circuits

Members of the Power Devices & Systems Group (PDSG) have developed a technique based on infrared thermography, which gathers frequency-modulation and lock-in detection strategies. This enables the contactless and non-invasive assessment of any subsystem of a more complex integrated circuit, regardless of its operating frequency. Through the infrared emission ($S_{\Delta T}$), the method locally allows the chip's functional analysis, performance assessment, and energy consumption measurement. The proposed approach is adaptable to any imaging thermographic systems, very promising in production quality control, and is expected to have a strong industrial impact. Amongst the performed case studies, the analysis of wirelessly powered RFID devices (collaboration with IMB-CNM researchers, RICH project) or the assessment of thermal sensors embedded in Radio Frequency Power Amplifier Circuits (collaboration with researchers from Universitat Politècnica de Catalunya) are the most remarkable ones. Such works have provided several publications in leading peer-reviewed international journals, a PhD dissertation, and a patent for Radio Frequency integrated circuit testing (being in PCT stage).



The functional analysis of a wirelessly powered and pad-free RFID chip is performed by infrared radiation ($S_{\Delta T}$) monitoring. Its amplitude $|S_{\Delta T}|$ [(a), (c)] | and phase lag φ_τ [(b), (d)] are measured when the chip is modulated at low frequencies, i.e., [(a) and (b)] 24 Hz and [(c) and (d)] 74 Hz, highlighting the blocks activity in each working scenario. Figure extracted from "IEEE Transactions on Industrial Electronics"

HfO_2-based Resistive Switching Devices

The Advanced Thin Dielectric Films group has designed and fabricated HfO_2-based MIS and MIM capacitors as resistive switching devices for RRAM and memristor applications. Significant contributions have been made in the study of Ni/HfO_2-based structures showing unipolar resistive switching, extending the investigation from the electrical characterization of the temperature and polarity dependences, the analysis of current fluctuations and the simulation and modelling of the devices. In addition, TiN/HfO_2-based MIM devices with bipolar resistive switching behavior have been fabricated for the first time at the IMB-CNM Clean Room. The electrical characterization of these bipolar devices has shown excellent characteristics and their multi-level capability has been assessed.

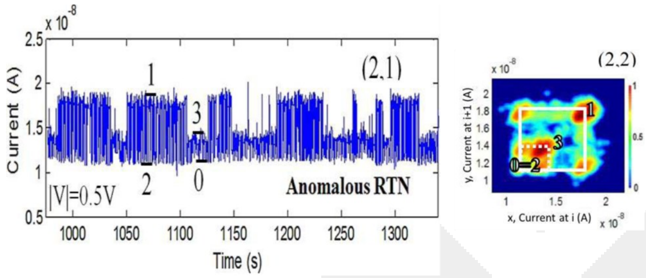
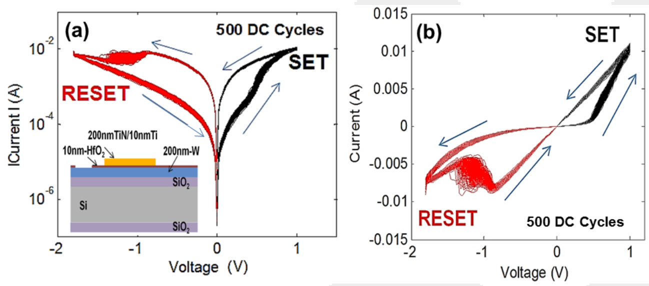


Image from M.B Gonzalez et al., Investigation of Filamentary Current Fluctuations Features in the High-Resistance State of Ni/HfO_2-Based RRAM, IEEE Trans. Electron Devices, 63 (2016) 3116.



Typical 500 DC cycles of bipolar resistive-switching in logarithmic (a) and linear (a) scale during set and reset operations.

Research Activities

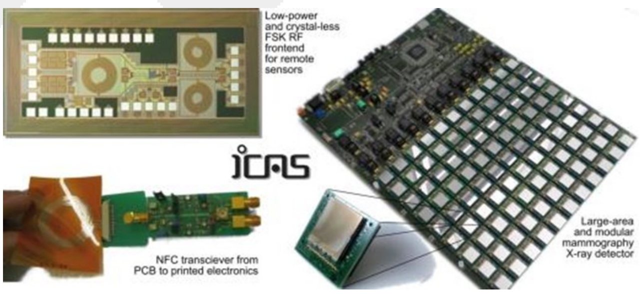
Integrated Circuits and Systems

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 and 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 and 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.



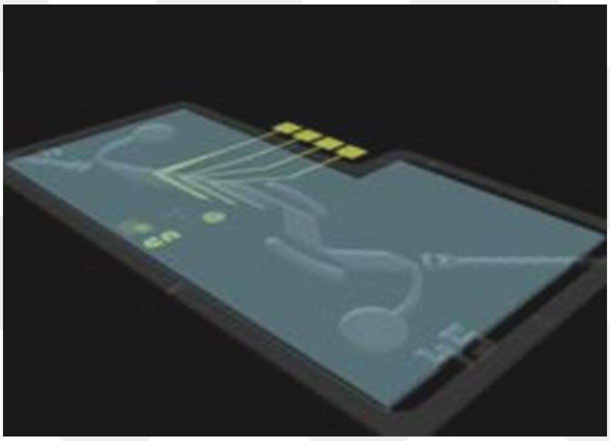
Lab on a Chip (LoCs) based on (bio)chemical transducers

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.

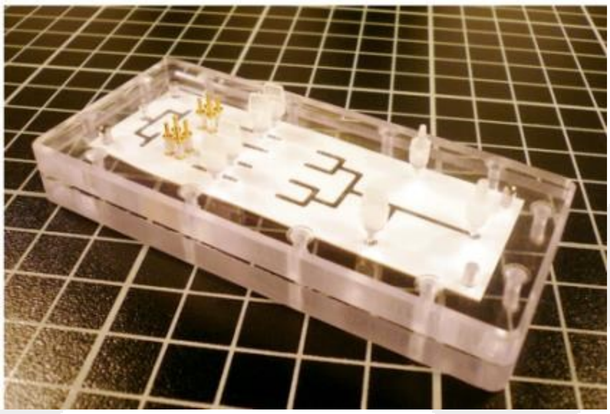


Micro-nano-bio systems

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).

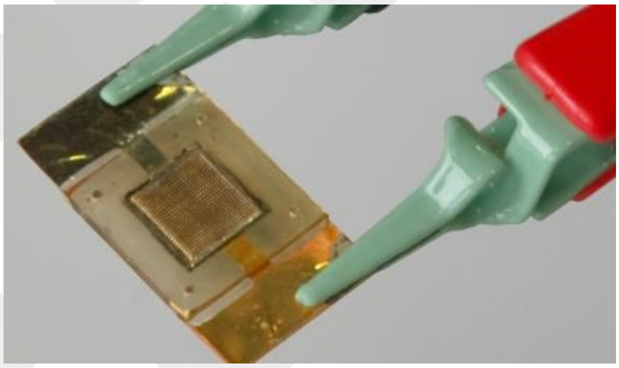
Application of ion-sensitive field effect transistors (ISFETs) for biochemical analysis. Development of a semiautomatic system for rapid determination of calcium ion level in bovine blood samples for medical diagnostic purposes.

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).

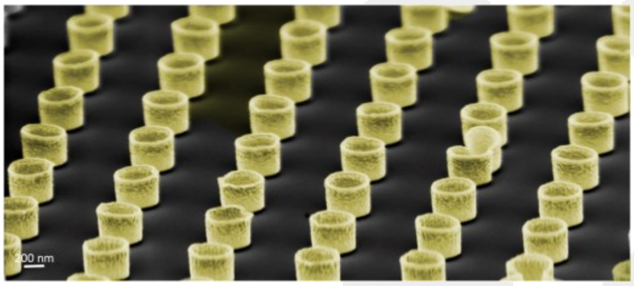


Nanofabrication and nanostructures

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

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 (CSIC): 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.

SINERGY: Silicon friendly materials and device solutions for microenergy applications

Coordinator: Luis Fonseca (IMB-CNM)

Dates: November 2013 to October 2016
Reference: 604169-1 (FP7 SEC-2011.1.5-1 IP)
Funding agency: European Union (FP7-NMP-2013-SMALL-7)
Total project funding: 3.794.913 €
IMB-CNM funding: 920.607 €

Participants
IMB-CNM: Coordinator.
- Confindustria Emilia Romagna, Italy.
- ELECTROLUX Italia S.P.A., Italy.
- Institut de Recerca en Energia de Catalunya (IREC), Spain.
- Interuniversity Microelectronics Centre (IMEC), Belgium.
- IMEC (NL), The Netherlands.
- Università di Milano Bicocca, Italy.

Summary
The project addresses the development of energy harvesting and storage materials suitable for solving energy autonomy issues of devices working in low-power and/or pulsed regimes (nano/microdevices, medical implants, smartcards, sensor networks, etc). Its focus is on the microdomain to obtain small size devices with high energy density features, and on the silicon technology friendliness of those materials (and approaches) to assure the eventual manufacturability, integratability and cost effectiveness of

the related devices/solutions. IMB-CNM contributes technologically with thermoelectric devices and mechanical energy harvesters integrating nanomaterials (Silicon nanowires and ZnO nanowires & nanosheets, respectively).

SNM: Single Nanometer Manufacturing for beyond CMOS devices

IMB-CNM IP: Francesc Pérez-Murano

Dates: January 2013 to March 2017

Reference: 318804

Funding agency: European Union (FP7-ICT-2011-8)

IMB-CNM funding: 516.8996 €

Participants

- Technische Universitaet Ilmenau, Germany: Coordinator.
- EV Group GmbH, Austria
- Interuniversitair Micro-Electronica Centrum, Belgium
- Microsystems Ltd, Bulgaria
- IBM Research GmbH, Switzerland
- Ecole Polytechnique Fédérale de Lausanne, Switzerland
- SwissLitho AG, Switzerland
- Universitaet Bayreuth, Germany
- IMB-CNM (CSIC), Spain
- VSL B.V., The Netherlands
- Technische Universiteit Delft, The Netherlands
- The Open University, United Kingdom
- Oxford Scientific Consultants Ltd, United Kingdom
- Imperial College, United Kingdom
- The University of Liverpool, United Kingdom
- Oxford Instruments Ltd, United Kingdom

Summary

To extend beyond existing limits in nanodevice fabrication, new and unconventional lithographic technologies are necessary to reach Single Nanometer Manufacturing (SNM) for novel "Beyond CMOS" devices. Two approaches are considered: scanning probe lithography (SPL) and focused electron beam induced processing (FEBIP). The project tackles this challenge by employing SPL and FEBIP with novel small molecule resist materials. The goal is to work from slow direct-write methods to high speed step-and-repeat manufacturing by Nano Imprint Lithography (NIL), developing methods for precise generation, placement, metrology and integration of functional features at 3 - 5 nm by direct write and sub-10nm into a NIL-template. The project will first produce a SPLtool prototype and will then develop and demonstrate an integrated process flow to establish proof-of-concept "Beyond CMOS devices" employing developments in industrial manufacturing processes (NIL, plasma etching) and new materials (Graphene, MoS_2). By the end of the project: (a) SNM technology will be used to demonstrate novel room temperature single electron and quantum effect devices; (b) a SNM technology platform will be demonstrated, showing an integrated process flow, based on SPL prototype tools, electron beam induced processing, and finally pattern transfer at industrial partner sites. An interdisciplinary team (7 Industry and 8 Research/University partners) from experienced scientists will be established to cover specific fields of expertise: chemical synthesis, scanning probe lithography, FEBIP-Litho, sub-3nm design and device fabrication, single nanometer etching and step-and-repeat NIL and novel alignment system.

SPEED: Silicon Carbide Power technology for Energy Efficient Devices

IMB-CNM IP: Philippe Godignon

Dates: January 2014 to December 2017

Reference: 604057

Funding agency: European Union (FP7-NMP-2013-LARGE-7)

IMB-CNM funding: 1.285.841 €

Participants

- INAEL Electrical Systems, S.A., Spain: Coordinator
- ABB Scheweiz AG, Switzerland
- IMB-CNM (CSIC)
- E-Distribuzione Spa, Italy
- Universitaet Bremen, Germany
- Universidad de Oviedo, Spain
- Norstel AB, Sweden

- Ascatron AB, Sweden
- The University of Nottingham, United kingdom
- Infineon Technologies AG, Germany
- Infineon Technologies Austria AG, Austria
- Technische Universitaet Muenchen, Germany
- Fraunhofer Gesellschaft, Germany
- Ceske Vysoke Uceni Technicke V Praze, Scheck Republic
- G.W. Leibnitz Universitaet Hannover, Germany
- Annealsys SAS, France
- Ingeteam Power Technology S.A., Spain

Summary

Highly efficient Power Electronics (PE) employed in power generation, transmission, and distribution is the prerequisite for the Europe-wide penetration of renewable energies; improves the energy efficiency; increases the power quality and enables continuous voltage regulation, reactive power compensation and automated distribution. It also facilitates the integration of distributed resources like local energy storages, photovoltaic generators, and plug-in electric vehicles.

The development of a new generation of high power semiconductor devices, able to operate above 10kV, is crucial for reducing the cost of PE in the above-mentioned applications. The material properties of SiC, clearly superior to those of Si, will lead to enhanced power devices with much better performance than conventional Si devices. However, today´s SiC PE performs rather poorly compared to the predictions and the production costs are by far too high.

Pooling world-leading manufacturers and researchers, SPEED aims at a breakthrough in SiC technology along the whole supply chain: Growth of SiC substrates and epitaxial-layers; Fabrication of power devices in the 1.7/>10kV range; Packaging and reliability testing, SiC-based highly efficient power conversion cells; Real-life applications and field-tests in close cooperation with two market-leading manufacturers of high-voltage (HV) devices.

Known and new methodologies will be adapted to SiC devices and optimized to make them a practical reality. The main targets are cost-savings and superior power quality using more efficient power converters that exploit the reduced power losses of SiC. To this end, suitable SiC substrates, epitaxial -layers, and HV devices shall be developed and eventually be implemented in two demonstrators: A cost-efficient solid-state transformer to support advanced grid smartness and power quality; A windmill power converter with improved capabilities for generating AC and DC power.

IONS4SET: Ion-irradiation-induced Si nanodot self-assembly for hybrid SET-CMOS technology

IMB-CNM IP: Francesc Pérez-Murano

Dates: February 2016 to January 2020
Reference: 688072
Funding agency: European Union (H2020-ICT-2015)
IMB-CNM funding: 612.825 €

Participants

- Helmholtz-Zentrum Dresden-Rossendorf EV, Germany: Coordinator
- CEA-LETI, France
- Fraunhofer Gesellschaft, Germany
- IMB-CNM (CSIC)
- Consiglio Nazionale delle Ricerche (CNR), Italy
- University of Helsinki, Finland

Summary

Billions of tiny computers that can sense and communicate from anywhere are coming online, creating the “Internet of Things” (IoT). As the IoT continues to expand, more and more devices need batteries and plugs. According to Gartner (www.gartner.com), there will be nearly 26 billion devices connected to the IoT by 2020. Therefore, together with improved batteries, advanced

computation and communication must be delivered at extremely low-power consumption. It is well-known that Single Electron Transistors (SET) are extremely low-energy dissipation devices. CMOS and SETs are complementary: SET is the champion of low-power consumption while CMOS advantages like high -speed, driving, etc., compensate exactly for SET's intrinsic drawbacks. Unrivalled integration with high performance is expected for hybrid SET-CMOS architectures. Manufacturability is the roadblock for large-scale use of hybrid SET-CMOS architectures. To assure room temperature (RT) operation, single dots of diameters below 5 nm have to be fabricated, exactly located between source and drain with tunnel distances of a few nm. A reliable CMOS compatible process of co-fabrication of RT-SETs and FETs is not yet available. IONS4SET will pave the way for fabrication of low-energy devices operating at RT using the discovery of a bottom-up self-assembly process. Lithography cannot deliver the feature sizes of 1…3 nm required for RT operation. IONS4SET will provide both, (i) controlled self-assembly of single ~ 2 nm Si dots and (ii) self-alignment of each nanodot with source and drain at tunneling distances of ~ 2 nm. The fabrication process of the Si nanodot involves (i) ion irradiation through a few tens of nm thin Si pillars with an embedded SiO_2 layer and (ii) thermal activation of self-assembly. Dot self-assembly works for narrow pillars only, i.e. nanopillar fabrication is crucial for IONS4SET. Finally, a power saving hybrid SET/CMOS device with a vertical gate-all-around nanowire GAA-SET will be fabricated.

SUPERCELL: Single-Use paPER-based fuel CELLs

Coordinator: Neus Sabaté

Dates: July 2015 to June 2020

Reference: 648518

Funding agency: European Union, ERC Consolidator Grant (ERC-2014-CoG)

Total funding (IMB-CNM): 1.920.738 €

Summary

The SUPERCELL project aims to develop a new generation of disposable and low environmental impact fuel cells. The approach presented will be a major breakthrough in the fuel cell field, as these devices are conceived for the first time as single-use and disposable power sources. It will also have an enormous impact in the point-of-care diagnostics domain, as it will provide simple, reliable and clean power sources to an upcoming generation of smart paper-based sensors and allow them to be energetically autonomous. Fuel will be harvested from the biological sample to be analyzed – in case of urine and blood – or tak en from hydrogen produced in situ upon the addition of any liquid in the paper platform. The project is very innovative in conception as well as in technology as these devices will be developed by means of a smart integration of paper microfluidics, printed electronics and electrocatalysis technologies. The contributions of this project are expected to promote the future creation of new commercial ventures and products, reaching applications beyond point-of-care like environmental monitoring, food safety and security.

BRAINCOM: High-density cortical implants for cognitive neuroscience and rehabilitation of speech using brain-computer interfaces

IMB-CNM IP: Lluís Terés

Dates: December 2016 to November 2021

Reference: 732032

Funding agency: European Union (H2020-FETPROACT -2016)

IMB-CNM funding: 1.069.380 €

Participants

- ICN2, Spain: Coordinator
- IMB-CNM (CSIC)
- Université Grenoble-Alpes, France
- Assoc. R&D des methodes et processus industriels, France

- Centre Hospitalier Universitaire de Grenoble, France
- Multi Channel Systems GmbH, Germany
- Université de Genève, Switzerland
- University of Oxford, United Kingdom
- Ludwig-Maximilians-Universitaet Muenchen, Germany
- Wavestone Luxembourg S.A., Luxembourg

Summary

The goal of BrainCom is to develop a new generation of neuroprosthetic devices for large-scale and high density recording and stimulation of the human cortex, suitable to explore and repair high-level cognitive functions. Since one of the most invalidating neurospychological conditions is arguably the impossibility to communicate with others, BrainCom primarily focuses on the restoration of speech and communication in aphasic patients suffering from upper spinal cord, brainstem or brain damage. To target broadly distributed neural systems as the language network, BrainCom proposes to use novel electronic technologies based on nanomaterials to design ultra-flexible cortical and intracortical implants adapted to large-scale high-density recording and stimulation. The main challenge of the project is to achieve flexible contact of broad cortical areas for stimulation and neural activity decoding with unprecedented spatial and temporal resolution. Critically, the development of such novel neuroprosthetic devices will permit significant advances to the basic understanding of the dynamics and neural information processing in cortical speech networks and the development of speech rehabilitation solutions using innovative brain-computer interfaces. Beyond this application, BrainCom innovations will enable the study and repair of other high-level cognitive functions such as learning and memory as well as other clinical applications such as epilepsy monitoring using closed-loop paradigms. BrainCom will be carried out by a consortium assembled to foster the emergence of a new community in Europe acting towards the development of neural speech prostheses. Thanks to its high interdisciplinarity involving technology, engineering, biology, clinical sciences, and ethics, BrainCom will contribute advances to all levels of the value chain: from technology and engineering to basic and language neuroscience, and from preclinical research in animals to clinical studies in humans.

Facilities

General view

Metallization and RIE area

Electron beam lithography system

The IMB-CNM facilities include a clean room for integrated micro and nanofabrication, a test and characterization service and a packaging service. The IMB-CNM Clean Room is one of the three nodes of the MICRONANOFABS Cleanroom Network dedicated to Micro and Nano Manufacturing. MICRONANOFABS is one of the large-scale scientific facilities (ICTS – Singular Scientific and Technological Facility) in Spain. Specific information can be found on the web page "www.micronanofabs.org".

The clean room (total surface 1500 m^2) 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.

The access to the IMB-CNM Clean Room is centralised through the MICRONANOFABS network. Two access modalities are available for users: application for work to be performed by the clean room personnel, and qualified self-service, which is available for specific equipment.

An external access programme (GICSERV) was 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 were funded in this way from Spain, the European Union and (since 2010) Latin-American countries.

Facilities

Ion implantation system

Advanced packaging laboratory

Electrical characterization laboratory

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.

Publications

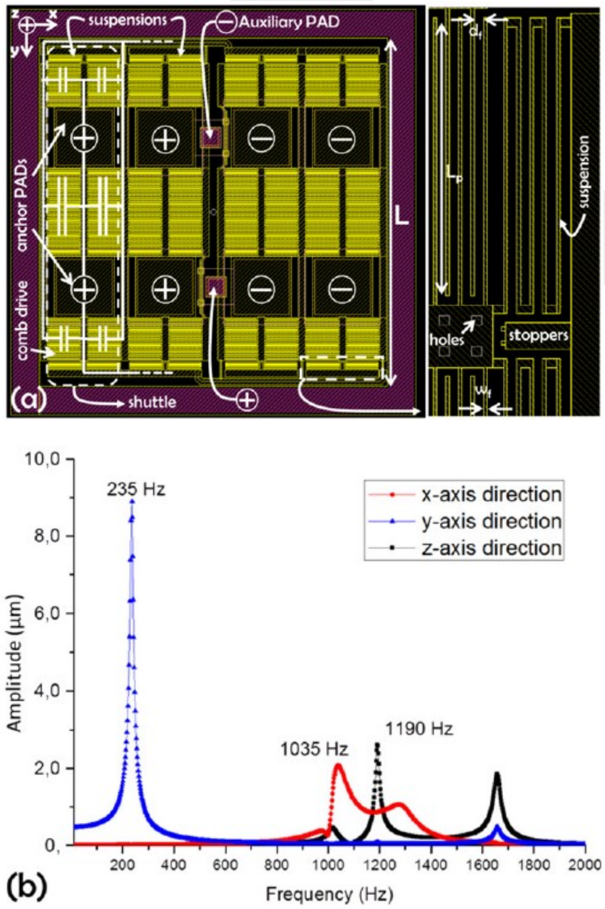
IMB-CNM has published a total of 119 scientific papers in 2015 and 111 in 2016 in journals included in the Science Citation Index. The complete list of publications in scientific journals is available at the IMB-CNM website. The specific page can be accessed through this QR code:

Some publication examples:

Self-suspended vibration-driven energy harvesting chip for power density maximization.

G. Murillo, J. Agustí, G. Abadal

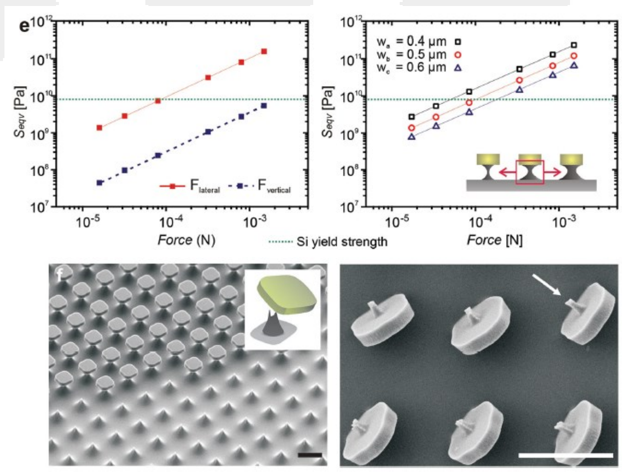
Smart Mater. Struct. 24 (2015) 115027 (10pp)



Suspended planar-array chips for molecular multiplexing at the microscale.

N. Torras, J.P. Agusil, P. Vázquez, M. Duch, A.M. Hernández-Pinto, J. Samitier, E.J. de la Rosa, J. Esteve, T. Suárez, L. Pérez-García, J.A. Plaza.

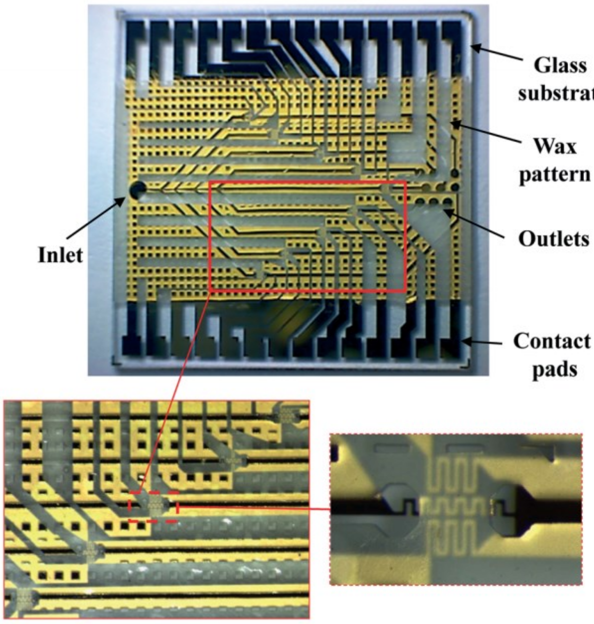
Adv. Mater. 2016, 28, 1449-1454



Multiple actuation microvalves in wax microfluidics.

M. Díaz-González, C. Fernández-Sánchez, A. Baldi.

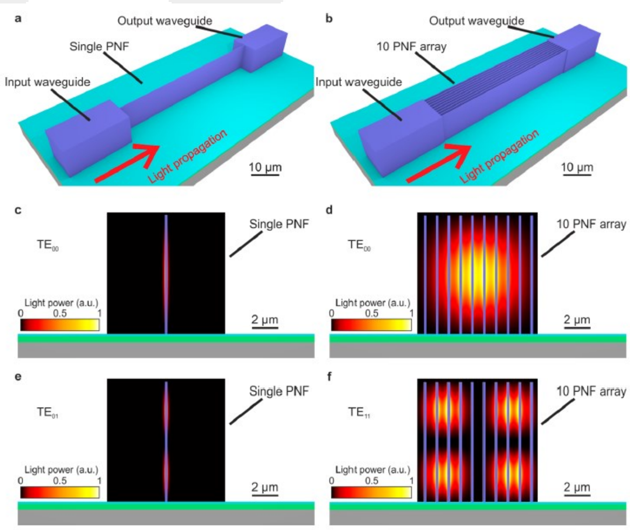
Lab Chip, 2016,16, 3969-3976.



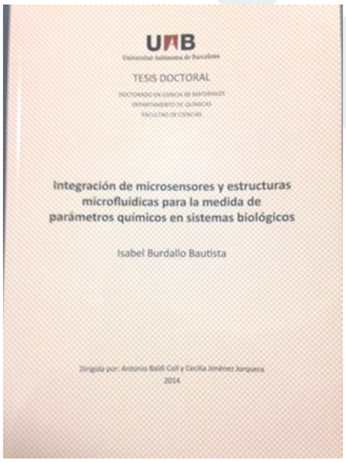
Integrated photonic nanofences: combining subwavelength waveguides with an enhanced evanescent field for sensing applications.

V.J. Cadarso, A. Llobera, M. Puyol, H. Schift.

ACS Nano, 2016, 10 (1), pp 778–785.



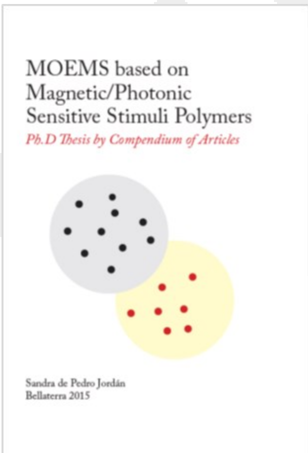
Ph.D. Thesis



Burdallo, Isabel

Integración de microsensores y estructuras microfluídicas para la medida de parámetros químicos en sistemas biológicos.

C. Jiménez-Jorquera, A. Baldi (dirs.).
Universitat Autònoma de Barcelona, Ph.D. in Materials Science, 2015.

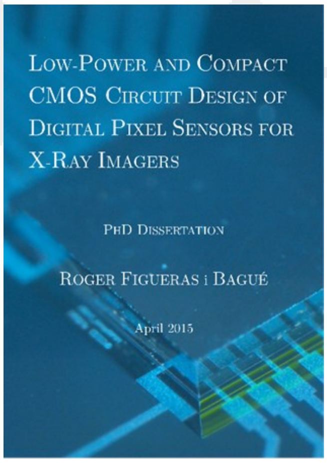


De Pedro, Sandra

MOEMS based on magnetic/ photonic sensitive stimuli polymers.

A. Llobera, V.J. Cadarso (dirs.).

Universitat Autònoma de Barcelona, Ph.D. in Physics, 2015.



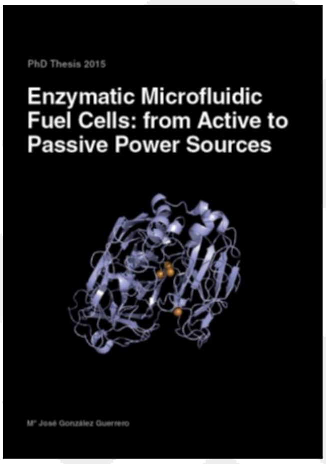
Figueras, Roger

Low-power and compact CMOS circuit design of digital pixel sensors for X-Ray imagers.

F. Serra-Graells, L. Terés (dirs.).

Universitat Autònoma de Barcelona, Ph.D. in Microelectronics and Electronic Systems, 2015.

Ph. D. Thesis

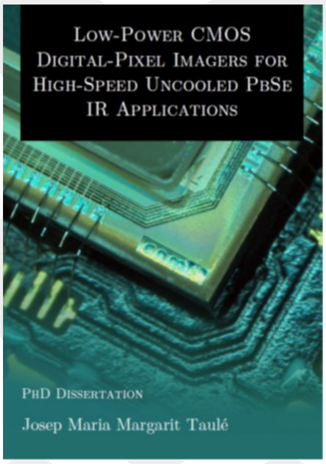


González-Guerrero, Mª José

Enzymatic microfluidic fuel cells: from active to passive power sources.

F.J. Del Campo, N. Sabaté (dirs.).

Universitat Autònoma de Barcelona, Ph.D. in Materials Science, 2015.

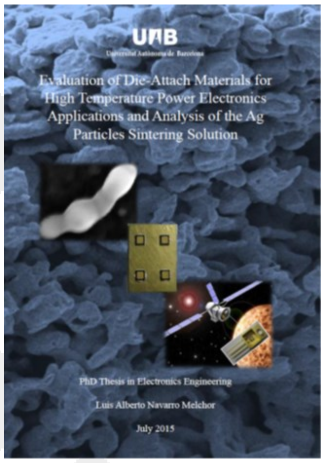


Margarit, Josep Mª

Low-power CMOS digital-pixel imagers for high-speed uncooled PbSe IR applications.

F. Serra-Graells, L. Terés (dirs.).

Universitat Politècnica de Catalunya, Ph.D. in Electronic Engineering, 2015.

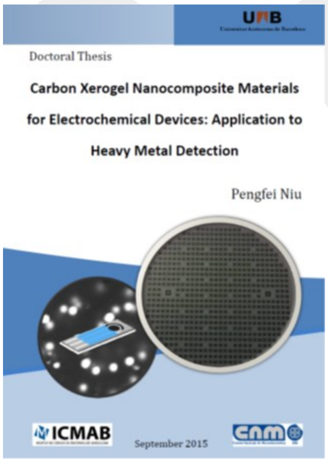


Navarro, Luis Alberto

Evaluation of die-attach materials for high temperature power electronics applications and analysis of the Ag particles sintering solution.

X. Perpiñà, F.X. Jordà (dirs.).

Universitat Autònoma de Barcelona, Ph.D. in Electronic Engineering, 2015.

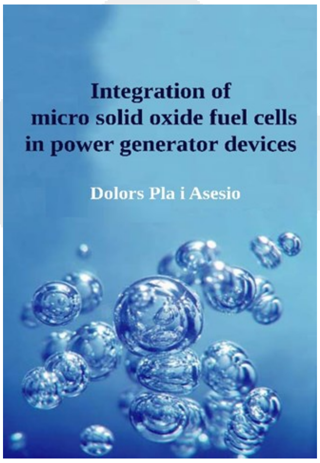


Niu, Pengfei

Carbon xerogel nanocomposite materials for electrochemical devices: application to heavy metal detection.

C. Fernández-Sánchez, M. Gich (ICMAB) (dirs.).

Universitat Autònoma de Barcelona, Ph.D. in Materials Science, 2015.

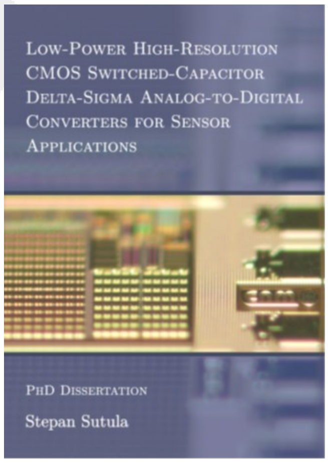


Pla, Dolors

Integration of micro solid oxide fuel cells in power generator devices.

M. Salleras (dir.).

Universitat de Barcelona, Ph.D. in Physics, 2015.

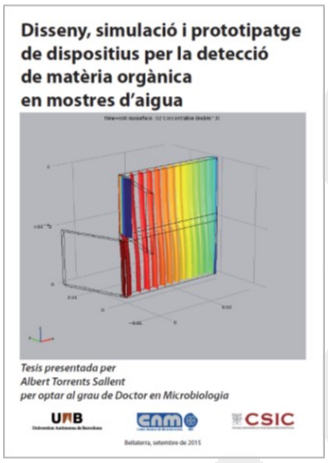


Sutula, Stepan

Low-power high-resolution CMOS switched-capacitor delta-sigma analog-to-digital converters for sensor applications.

F. Serra-Graells, M. Dei (dirs.).

Universitat Autònoma de Barcelona, Ph.D. in Microelectronics and Electronic Systems, 2015.

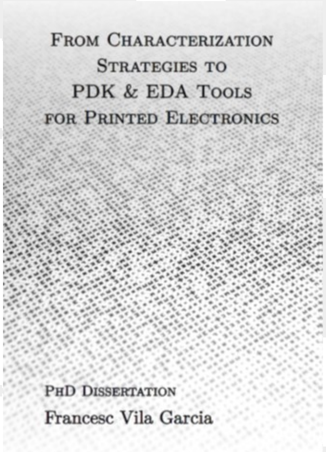


Torrents, Albert

Disseny, simulació i prototipatge de dispositius per a la detecció de matèria orgànica en mostres d'aigua.

F.J. Muñoz-Pascual, F.J. Del Campo (dirs.).

Universitat Autònoma de Barcelona, Ph.D. in Microbiology, 2015.

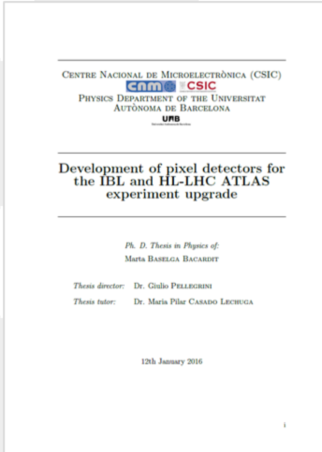


Vila, Francesc

From characterization strategies to PDK & EDA tools for printed electronics.

L. Terés (dir.).

Universitat Autònoma de Barcelona, Ph.D. in Microelectronics and Electronic Systems, 2015.

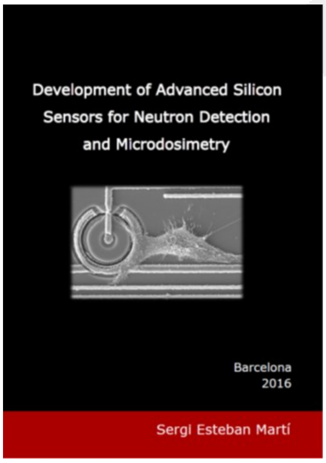


Baselga, Marta

Development of pixel detectors for the IBL and HL-LHC ATLAS experiment upgrade.

G. Pellegrini (dir.).

Universitat Autònoma de Barcelona, Ph.D. in Physics, 2016.



Esteban, Sergi

Development of advanced silicon sensors for neutron detection and microdosimetry.

C. Fleta (dir.).

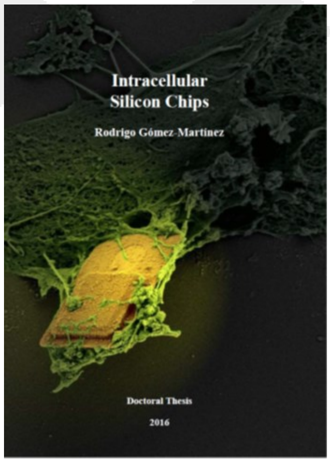
Universitat Autònoma de Barcelona, Ph.D. in Physics, 2016.

Florentin, Matthieu

Irradiation impact on optimized 4H-SiC MOSFETs.

Ph. Godignon (dir.).

Universitat Politècnica de Catalunya, Ph.D. in Electronic Engineering, 2016.



Gómez-Martínez, Rodrigo

Intracellular silicon chips.

J. Esteve, J.A. Plaza (dirs.).

Universitat Autònoma de Barcelona, Ph.D. in Electronic Engineering, 2016.

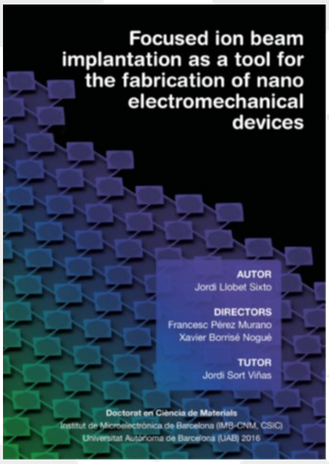
Ph. D. Thesis

León, Javier

Advanced analysis of microelectronic devices and systems by lock-in IR thermography.

M. Vellvehí, X. Perpiñà (dirs.).

Universitat Autònoma de Barcelona, Ph.D. in Electronic Engineering, 2016.

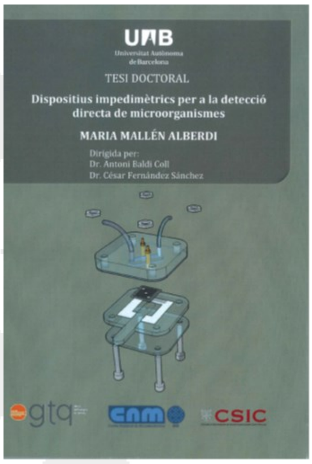


Llobet, Jordi

Focused ion beam implantation as a tool for the fabrication of nano electromechanical devices.

F. Pérez-Murano, X. Borrisé (dirs.).

Universitat Autònoma de Barcelona, Ph.D. in Materials Science, 2016.



Mallén, Maria

Dispositius impedimètrics per a la detecció directa de microorganismes.

C. Fernández-Sánchez, A. Baldi (dirs.).

Universitat Autònoma de Barcelona, Ph.D. in Biotechnology, 2016.

Mashayekhi, Mohammad

Inkjet-configurable gate arrays: towards application specific printed electronic circuits.

L. Terés (dir.).

Universitat Autònoma de Barcelona, Ph.D. in Microelectronics and Electronic Systems, 2016.

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.

Two companies have been created in 2015-2016.

Fuelium

Fuelium S.L. (www.fuelium.tech) is a spin-off from CSIC established in 2015 to commercialize the research activity on fuell cells. It offers paper batteries capable of powering a variety of single-use devices, such as portable diagnostic, and being discarded without recycling.

Fuelium batteries generate only the amount of energy required for each application and do not contain heavy metals harmful to health. They are composed mainly of paper, biodegradable carbon and metals. The Fuelium technology will enable the generation of new solutions in the field of diagnosis and other sectors which so far are not possible. The battery is capable of giving a nominal voltage of 3 V for at least 30 minutes, and a current of 5 mA in a volume smaller than of 1 cm^3.

Fuelium has been one of the seven winners of the fifth Repsol Entrepreneurs Fund awards (2016) of the Repsol Foundation, to support the best start-up.

FutureSiSens

FutureSisens S.L. (futuresisens.com) is an spin-off company from IMB-CNM and the Autonomous University of Barcelona (UAB) established in 2016 that designs, develops and manufactures thermoelectric micro-sensors that are capable of detecting very small flows and flow variations autonomously.

FutureSiSens uses nanotechnology to offer a differentiated technological solution with the level of effectiveness, sustainability and connectivity that the sensor industry will need in the future.

FutureSiSens has also been one of the seven winners of the fifth Repsol Entrepreneurs Fund awards (2016) of the Repsol Foundation, to support the best start-up.

Outreach

IMB-CNM 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

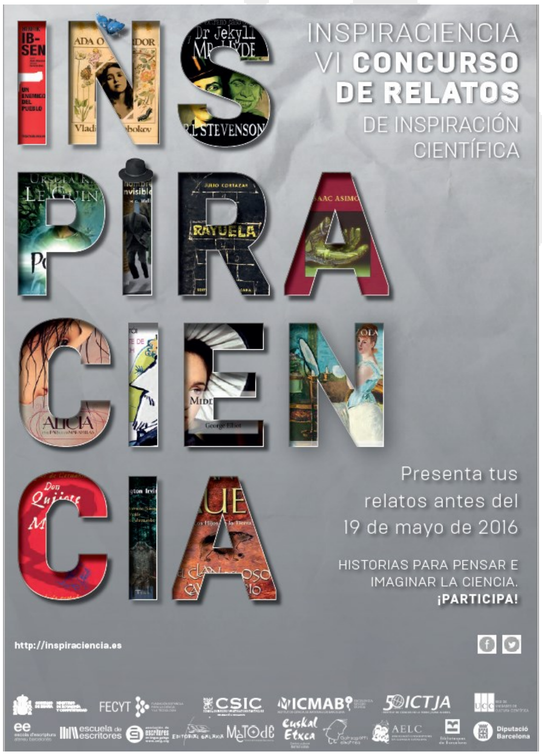
The Science and Technology Week is held annually at the Spanish and Catalan levels. IMB-CNM participates with Open Days for external visits.

Education Fair 2016

IMB-CNM participated with other CSIC institutes in the Science Space within the Education Fair in March 2016 in Barcelona.

Inspiraciencia

Participation in the organization of Inspiraciencia (2015 and 2016), a contest on science-based stories, organized by CSIC.



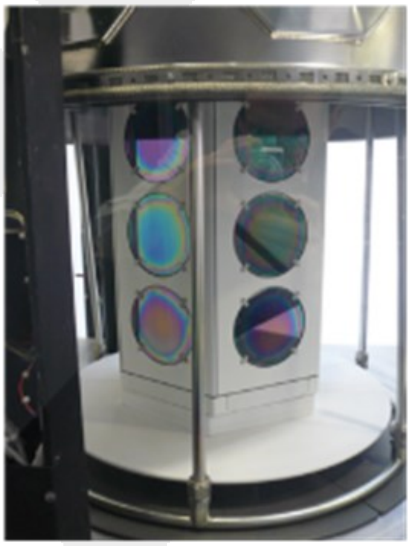
Barcelona Science Fair

IMB-CNM participated in the Festival of Science, Technology and Innovation (June 2016) in Barcelona, with a stand (*From Macro to Nano*) in which a workshop and demonstrations were presented.

Outreach

Microelectronics Museum Area

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



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

Student visits

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 more than 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 includes more than 500 researchers. Its members, excluding IMB-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
- D+T Microelectrónica, A.I.E.

http://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.

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

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

http://www.dtm.es

www.imb-cnm.csic.es

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

Campus Universitat Autònoma de Barcelona – 08193 Bellaterra (Barcelona) – Spain

Tel. (+34) 93 594 77 00

email: info@imb-cnm.csic.es