2015

2016

# Activity Report

CIC nanoGUNE

NANOSCIENCE COOPERATIVE RESEARCH CENTER

2015

2016

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CIC nanoGUNE

nanoscience cooperative research center

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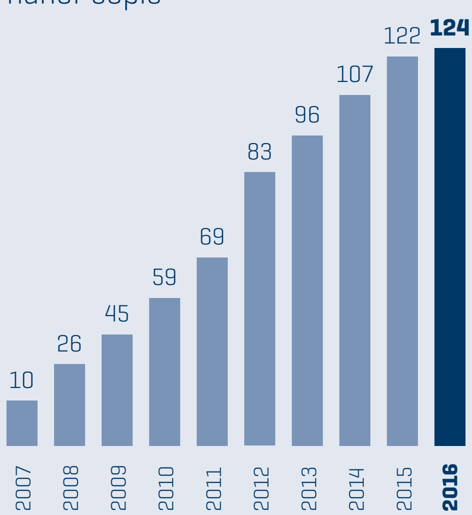
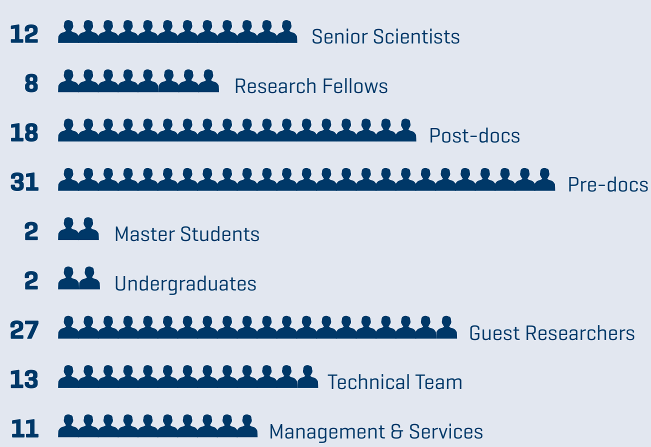
# Our mission is to perform world-class nanoscience research for the competitive growth of the Basque Country

## Researchers from **21** countries

Argentina **2**
Belarus **1**
Canada **1**
China **5**
Croatia **1**
Czech Republic **1**
France **3**
Germany **10**
India **2**
Italy **8**
Japan **1**
Pakistan **1**
Portugal **1**
Russia **2**
Slovenia **1**
South Korea **1**
Spain **77**
Thailand **1**
Ukraine **1**
United Kingdom **3**
USA **1**

## nanoPeople




nanoGUNE personnel on 31 December 2016

**187**
ISI publications

**4 430**
Citations

**7.1**
Average impact factor

**69**
Researchers

**82**
Seminars

**121**
Invited talks

**10**
Research groups

**96**
Guest researchers

**8**
Phd theses accomplished

**13**
Industrial collaboration agreements in place

**3**
Submitted patents

**1**
Granted patents

**9**
Conferences and workshops organized

**41**
Phd theses ongoing

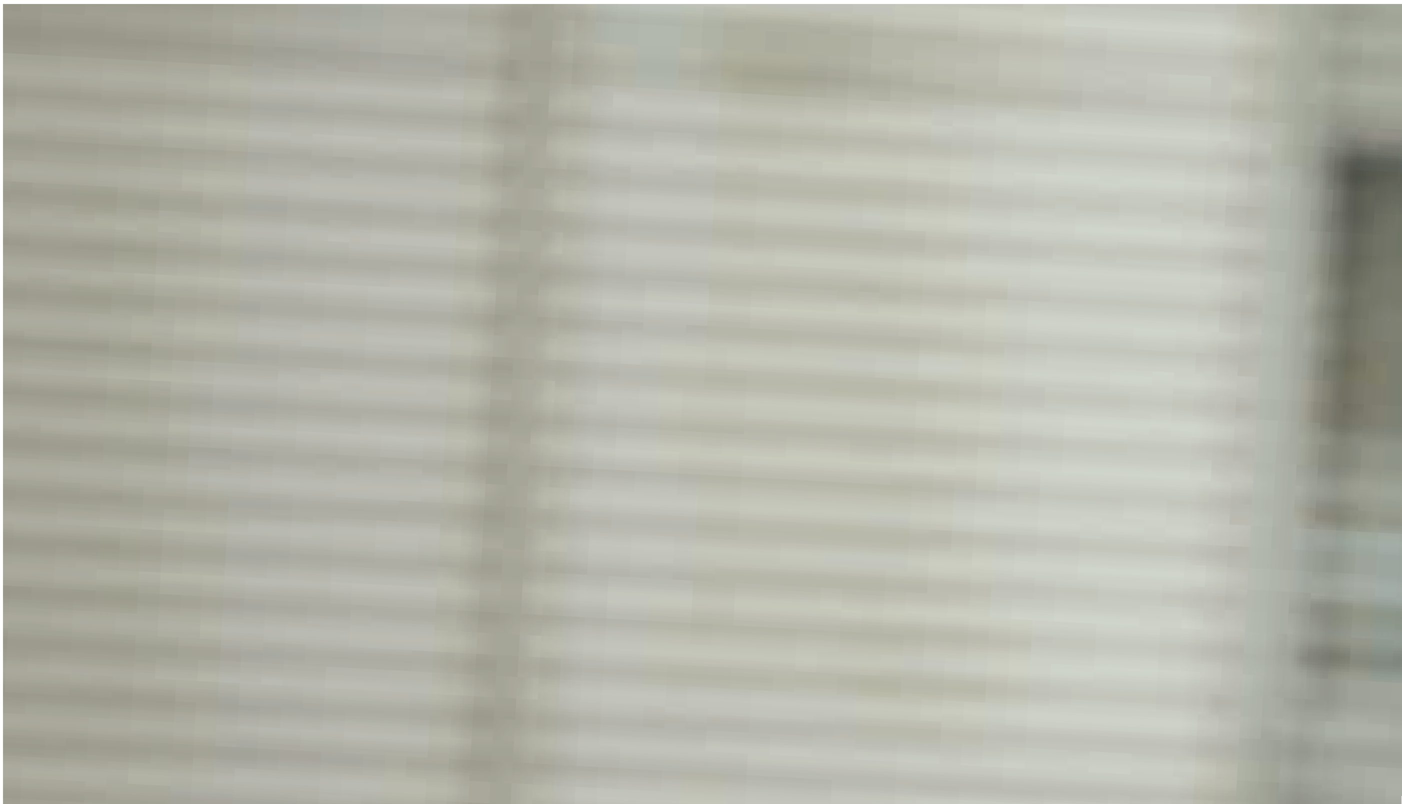
**256**
Visitors from high schools and universities

**98**
Grants in place

**493**
Times in the media

**1**
New spin-off

In the 2015-2016 time frame



# "We are intensifying our efforts towards knowledge and technology transfer"

The period 2015-2016 has been scientifically fruitful and strategically challenging. Since the opening of nanoGUNE in 2009, we have been working hard with the aim of building up a research center and infrastructure that combine state-of-the-art research with a focus to industry. Now we have an international team of outstanding scientists and a number of spin-off companies that we have been launching for the development of nanotechnology in the Basque Country and worldwide. During the last two years, our structure has been reinforced in order to intensify our efforts towards the transfer of knowledge and technology, specifically in the three areas (manufacturing, energy, and health) that have been taken by the Basque Government to be strategic in the framework of the research and innovation smart specialization strategy (RIS3) of the European Comission.

In line with our latest efforts to strengthen our connection to industry, in the period 2015-2016 we have opened a new research group on nanoengineering, led by Ikerbasque Research Professor Andreas Seifert. This new group focuses on research at the interface between fundamental research and applied engineering, in particular in the area of biomedical applications. Our team is now composed of more than 80 researchers (including graduate students and post-docs) and technicians, coming from 21 different countries worldwide, in addition to a few undergraduate and master students and a good number of guest researchers. This team has been making outstanding contributions to the fields of nanomagnetism, nanooptics, self-assembly, nanobiomechanics, nanodevices, electron microscopy, theory, nanomaterials, nanoimaging, and nanoengineering.


As for our connection to Basque industry we have participated actively in a so-called nanotransfer project led by the Basque Institute of Competitiveness Orkestra, which has shed some light on how to overcome the main barriers that are encountered in the penetration of nanotechnology into local companies. And we are in the process of moving from the external-services department that we launched recently to a true platform for industrial research and experimental development, which is expected to serve as a basis to strengthen our ties with companies in the Basque Country and worlwide. Last, but not least, we have founded our 5th spin-off company (Prospero Biosciences) in the area of mass spectrometry, and we have launched (jointly with Hasten Ventures) a new tool (NanoInnovations) that should facilitate the transfer of knowledge and technology both locally and internationally.

World-class nanoscience research in close collaboration with other research laboratories and with industry, and a commitment to the society define the way we understand our activity.

In this exciting journey, we have benefited from the continuous support of a good number of individuals, public institutions, especially the Basque Government, and our International Advisory Committee. Being a small center in a small country we will keep doing our best in the search for innovation, with the expectation that we will always find a niche for us to offer something different. This is the big challenge of the small.

José M. Pitarke
Director

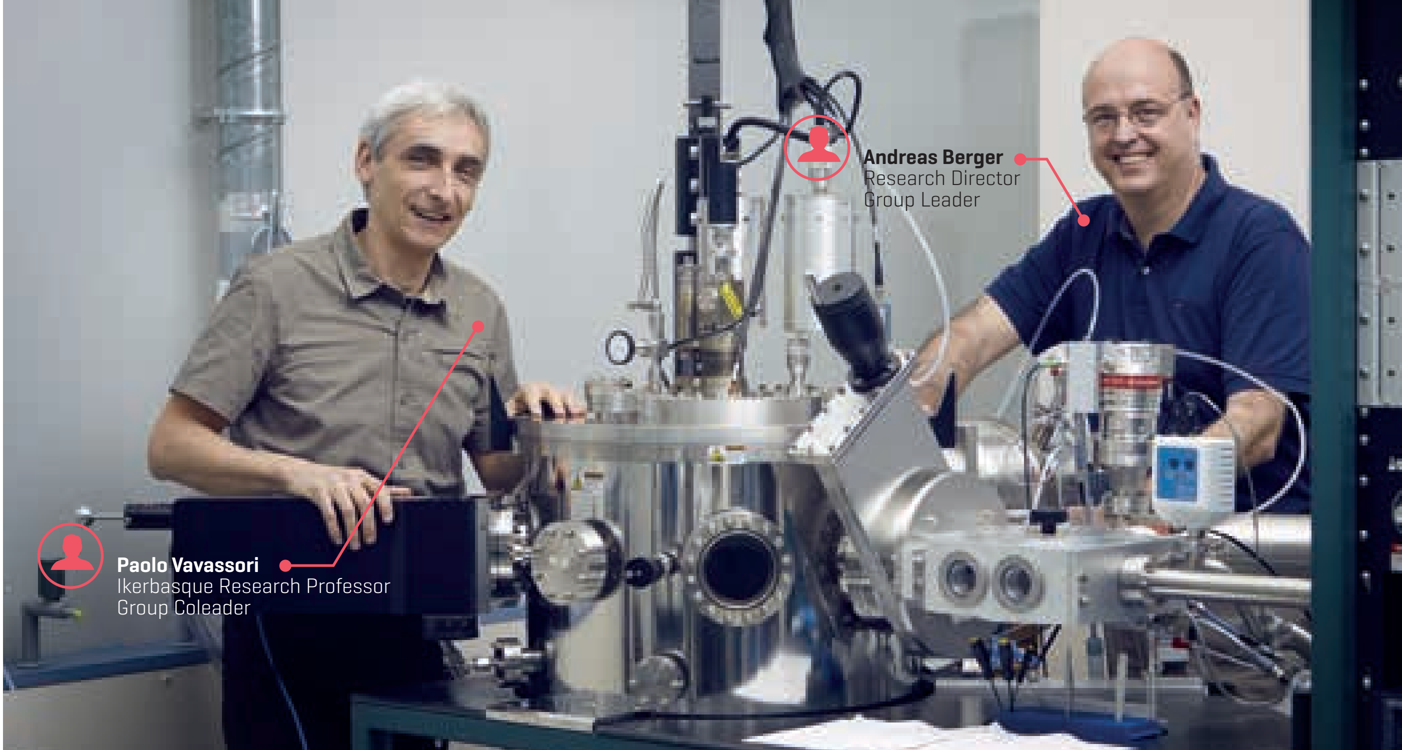
Donostia - San Sebastian, December 2016

# 1

# Researchers in Action

**10** Research Groups

**69** Researchers



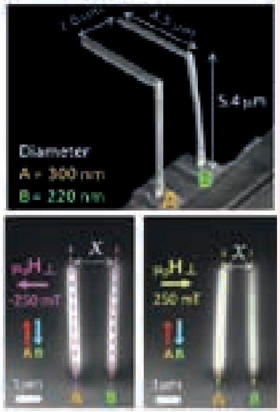

# Nanomagnetism

The Nanomagnetism Group conducts world-class fundamental and applied research in nanomagnetism and related characterization techniques. The group is hereby playing a leading role in the investigation of advanced magneto-plasmonic and magneto-optical effects and their utilization for fundamental and applied purposes, including tool and device design. The group also has a long-standing expertise in the fields of thin-film and multilayer growth, nanostructure fabrication, and magnetic-materials characterization. Key activities furthermore include the development of theoretical and computational models for quantitative descriptions of magnetic and optical properties at the nanoscale.

The main scientific topics currently pursued by the Nanomagnetism Group encompass several key scientific themes that are at the very forefront of research worldwide. The group's members are working on understanding magnetism and magnetic phenomena on very small length scales and in the presence of thermal or other excitation sources by means of experiments, theory, and modeling, with the long term goal of aiding and enabling novel nanomagnetic device concepts. The group is also developing advanced methodologies and tooling for magnetic-materials characterization to assist materials development for fundamental investigations as well as for possible industrial applications. Moreover, the Nanomagnetism Group is focused on the design, fabrication, and characterization of novel nanometer-scale magnetic structures, metamaterials, thin films, and multilayers to achieve improved or novel materials properties. Finally, the group studies novel concepts for designing magnetic nanoscale materials to achieve utilization in novel devices.

In the 2015-2016 time frame, the work of the Nanomagnetism Group has led to numerous key achievements, of which some were realized in collaboration with other research groups from around the globe. In particular, the magneto-optics work led to several important developments and achievements. For instance, the group discovered very substantial enhancements of magneto-optical responses for nanostructured samples and identified extremely localized edge enhancement effects as its origin, which led to an up-to-10-fold enhancement of the magneto-optical response. Another achievement was the study, classification, and exact quantification of magneto-optical responses in materials exhibiting anisotropy, which are crucially important for an accurate interpretation of measurements. An additional key activity in this field was the investigation of magneto-optics in the presence of surface-plasmon modes: in particular, the demonstration of how a resonant enhancement of magneto-optical effects can be obtained at desired radiation wavelengths by plasmonic band engineering through the proper lattice design in nanostructured magnetic films.

In terms of more application-oriented work, the Nanomagnetism Group demonstrated a novel readout method for molecular diagnostic assays based on optical measurements of field-induced rotational dynamics of magnetic nanoparticles in liquid solutions. Another technologically most relevant work addressed the question of what is the minimum energy that is required to change the information content of nanomagnetic switches. This limit, which is also known as "Landauer erasure principle", is a crucial topic and fundamental challenge of current technology, in terms of power dissipation and scalability. Also, the materials research topics studied by the Nanomagnetism Group were related to long-term technological applications, including, for instance, the demonstration of boundary magnetization robustness towards alloying or the exploration of collective magnetic behavior in artificially graded materials.




## Remote magneto-mechanical nanoactuation

Three-dimensional (3D) magnetic cantilever pairs were grown by means of Focused-Electron-Beam Induced Deposition (FEBID), and their remote magneto-mechanical actuation was demonstrated, achieving nanoscale precision. The top panel shows a scanning-electron-microscopy image of a FEBID double-cantilever device made of two suspended Co magnetic nanorods of different diameter. The two bottom panels show the change of their relative orientation upon applying a uniform and remotely controlled magnetic field. Furthermore, the relative motion and orientation of the cantilevers can be controlled by the preselected magnetization states in A and B (red and blue arrows indicate the orientation of the magnetic moments in the two nanorods for the case shown in the figure), for which four different combinations are easily accessible.

*P. Vavassori et al., Small **12**, 1013 (2016)*

## Team

**Andreas Berger**
Research Director
Group Leader
**PhD** in Physics in 1993
RWTH Aachen University (Germany)

**Paolo Vavassori**
Ikerbasque Research Professor
Group Coleader
**PhD** in Physics in 1994
Politecnico di Milano (Italy)

### Technician

**César Rufo**

### Guest Researchers

**Moufida Mansouri,** University of Sfax (Tunisia)
**Tomita Satoshi,** NAIST (Japan)

One-month stay minimum

### Master Students

**Xabier Inchausti,** UPV/EHU (until 15/09/16)
**Alba Pascual,** UPV/EHU (until 31/07/15)

### Pre-doctoral Researchers

**Jon Ander Arregi,** FPI Fellow, *Multi-layers and nanostructures with competing electronic order states*
**Adrián Crespo,** DE Fellow, *Study and control of spatial correlation and dynamics of magnetization in nanoestructured metamaterials with magnetic frustration*
**Lorenzo Fallarino,** PFPI Fellow, *Fabrication and magnetic characterization of Co-based magnetic alloy films, multilayers, and nanostructures*
**Nicolò Maccaferri,** PFPI Fellow, *Designer magneto-optics with plasmonic magnetic nanostructures (until 01/09/2016)*
**Matteo Pancaldi,** FPI Fellow, *Magnetization reversal in magnetic films, multilayers, and nanostructures*
**Patricia Riego,** La Caixa Fellow, *Study of magnetic order dynamics in epitaxial thin films*

FPI, predoctoral grant of the Spanish Government
PFPI, predoctoral grant of the Basque Government
DE, Basque Department of Education

### Post-doctoral Researchers

**Alberto López-Ortega,** Juan de la Cierva Fellow
**Eva Oblak,** Elkartek Fellow

### Undergraduate Students

**Beñat Alberdi,** UPV/EHU (until 17/07/15)
**Irene Azaceta,** UPV/EHU (until 30/06/16)
**Cristina Martínez,** UAB (until 02/09/16)


# Nanooptics

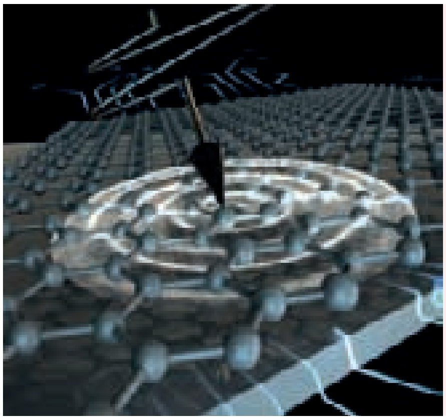
The Nanooptics Group performs experimental and theoretical research in nanooptics and nanophotonics, covering both fundamental and applied aspects. Essentially, we develop near-field nanoscopy (scattering-type scanning near-field optical microscopy, s-SNOM) and infrared nanospectroscopy (Fourier transform infrared nanospectroscopy, nano-FTIR), and we apply these novel analytical tools in different areas of science and technology.

Near-field nanoscopy and nanospectroscopy achieve a wavelength-independent spatial resolution of about 10 to 30 nm at visible, infrared, and terahertz frequencies, thus beating the conventional resolution (diffraction) limit by a factor of up to 1 000. During the last two years, we have continued working on novel instrumental developments, with the goal to push the spatial resolution towards the single-molecule level and to enable depth-resolved and hyperspectral infrared nanoimaging.

Further, s-SNOM and nano-FTIR spectroscopy have been applied to study plasmon polaritons in metal and graphene nanostructures, as well as phonon polaritons in boron nitride, for the development of ultracompact nanophotonic devices and their application, e.g. in optoelectronics and sensing. We also introduced infrared and terahertz photocurrent nanoscopy for studying plasmons and optoelectronic properties of devices based on graphene and other two-dimensional (2D) materials. s-SNOM and nano-FTIR spectroscopy have been also used for the nanoscale mapping of the chemical composition of nanocomposite materials.

We have also been developing and applying theory for the propagation and scattering of surface waves in natural, artificial, and 2D materials, for modeling near-field spectroscopy, and for reconstruction of materials properties from near-field data.

Our activities involve manifold and widely interdisciplinary collaborations, internationally and within the Basque Country.



## Graphene plasmonics

Artistic representation of near-field excited acoustic graphene plasmons producing a thermoelectric current.

## Team

**Technician**
Carlos Crespo

**Guest Researchers**
**Vladimir Biolek,** Brno University (Czech Republic)
**Shu Chen,** Xiamen University (China)
**Andrea Konecna,** CFM (Spain)
**Patryk Kusch,** Freie University Berlin (Germany)
**Jian Li,** Nanjing University (China)
**Matthias Wiecha,** Goethe University (Germany)

One-month stay minimum

**Research Fellow**
**Alexey Nikitin,**
Ikerbasque Research Fellow

**Rainer Hillenbrand**
Ikerbasque Research Professor
Group Leader

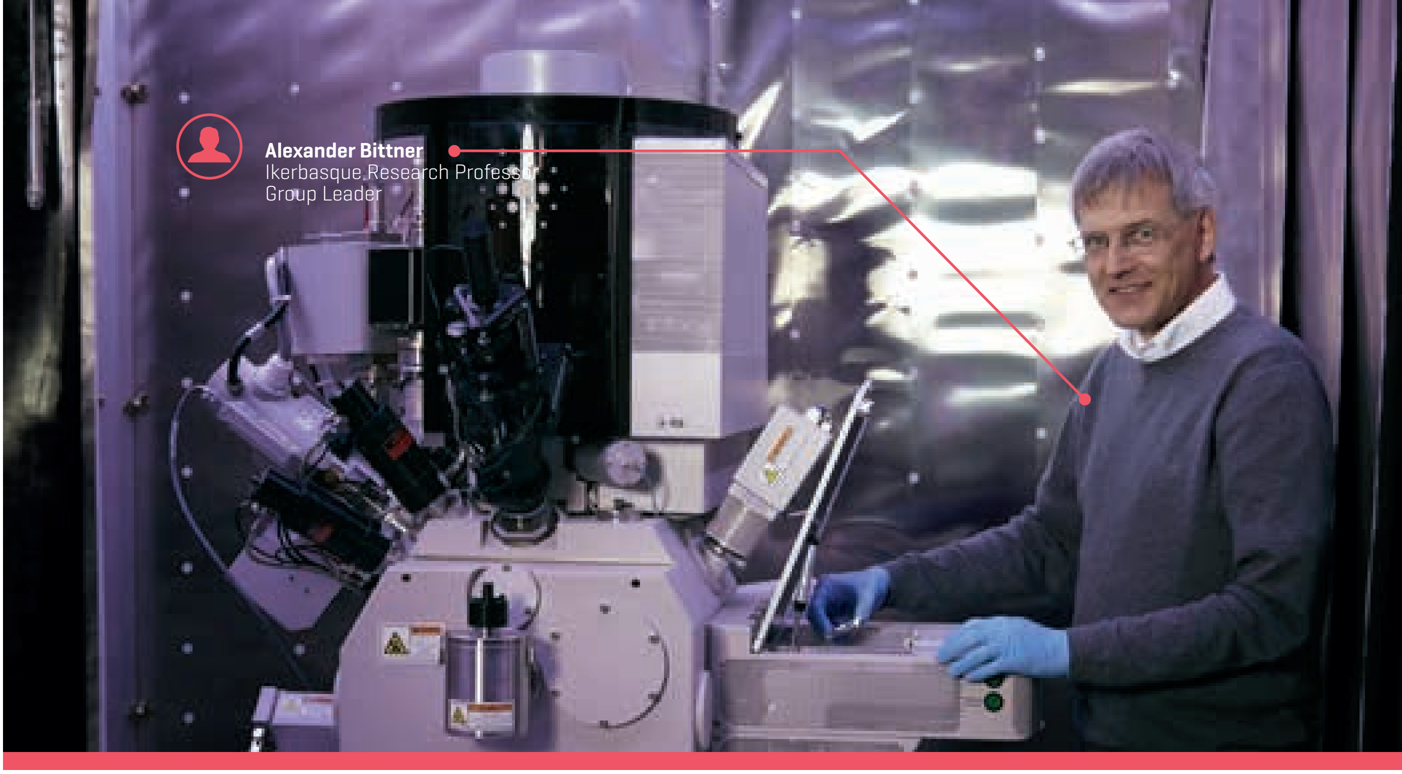
**PhD** in Physics in 2001
Technical University of Munich (Germany)

**Pre-doctoral Researchers**
**Francisco Javier Alfaro,** Flagship Fellow, *Low-dimensional nanophotonics with hyperbolic polaritons*
**Iban Amenabar,** FPI Fellow, *Infrared near-field imaging and near-field spectroscopy of biological nanostructures*
**Irene Dolado**, PFPI Fellow, *Optoelectronic nanosensors based on hyperbolic polaritons in two-dimensional materials*
**Florian Huth,** ERC Fellow (until 31/05/15), *Nanoscale infrared near-field spectroscopy*
**Stefan Mastel,** Flagship Fellow, *Near-field spectral contrast and enhanced sensitivity in s-SNOM*
**Paulo Sarriugarte,** PFPI Fellow (until 31/12/2015), *Development of novel infrared near-field probes based on antenna and waveguide structures*

FPI, predoctoral grant of the Spanish Government
PFPI, predoctoral grant of the Basque Government

**Undergraduate Students**
**Unai Aseguinolaza,** UPV/EHU (until 31/12/15)
**Marina Fontaiña,** TECNUN (05/08/16)

**Post-doctoral Researchers**
**Pablo Alonso-González,** Flagship Fellow (until 29/10/15)
**Marta Autore,** Flagship Fellow
**Monika Goikoetxea,** Etortek Fellow (until 30/09/15)
**Alexander Govyadinov,** ERC Fellow (until 30/09/16)
**Peining Li,** Flagship Fellow
**Simon Poly,** ERC Fellow (until 01/12/15)
**Martin Schnell,** Marie Curie Fellow
**Edward Yoxall,** ERC Fellow (until 31/07/15)




# Self-Assembly

The self-assembly of molecules is a natural and synthetic method to create complex nanoscale structures. We use it specifically for proteins, in a combined biochemistry, chemistry, and physics approach. Our research group is interested in one-dimensional structures built from proteins, such as the tobacco mosaic virus, the textbook example for self-assembly. We have confirmed its known structure now also for the surface, on the single-molecule level, and we have found that its apparently simple structure features subtle and complex non-periodic elements.

In our electrospinning projects, we shape pure proteins into extremely thin wires. We also test foodstuff electrospinning on the microscale. The main activity has been, however, to build a new combination of an electrospinning device with a three-dimensional (3D) printer, which is now marketed under the brand Novaspider.

Our structures are useful as scaffolds to assemble and to confine extremely small amounts of liquids. Specifically for water on protein surfaces, nanoscale experiments are still rare. We found that virus capsids can be nanoscale substrates for wetting by water. Our study can have wide-ranging consequences because humidity influences virus transmission, for plant and for human viruses.

In a project related to bionano self-assembly, we have constructed a new type of DNA/protein hybrids. For the already well-developed activities on biomineralization, the encapsulation of metals and alloys in virus capsids now opens the route to new magnetic nanodevices.

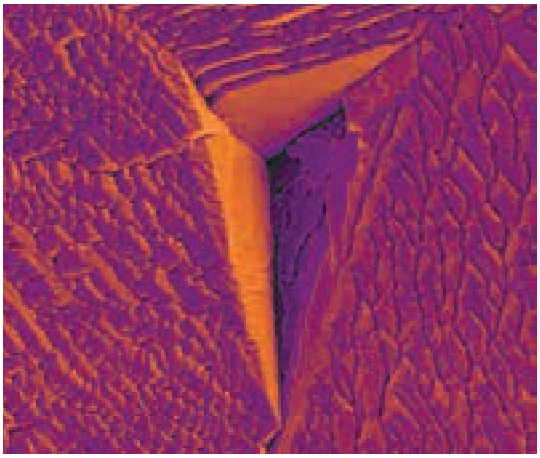
Our energy research is focused on the aging of supercapacitor real devices. We had discussed the polymerization of the solvent acetonitrile as one of the possible mechanisms for performance loss, but we have now found that this assumption was wrong. Generally, supercapacitors are much safer than batteries, based on exactly this lack of chemical reactivity.

Some of our projects require patience. It is great to see some results that are finally surfacing:

- The movement of particles on ice surfaces can only be recorded during growth or sublimation of ice in an electron-microscopy chamber. Catching a dynamically changing ice crystal with a suitable surface, covered by particles, has an element of chance. Finally, we have recorded a sufficient amount of videos to analyze the motion in detail.

- DNA origami folding is a straightforward process, which can be optimized by software. If the final structure is very large, assembly and analysis ask for trial and error.

- Recording AFM data with vertical resolution below 0.1 nm and with lateral resolution below 5 nm requires careful planning, optimal tools, clean conditions, and the chance of hitting on a super tip.



## Environmental electron microscopy of ice

This 315 μm scan shows polycrystalline ice growing at -20.8 °C in 1 mbar water vapor (above saturation) and filling up a triangular hole in the center. Under these conditions, the growth and coalescence of microcrystals is so rapid that grain boundaries, the dark meandering lines, dominate.

## Team

**Alexander Bittner**
Ikerbasque Research Professor
Group Leader

**PhD** in Chemistry in 1996
Free University of Berlin (Germany)

**Research Fellow**
**Mitsuhiro Okuda,** Ikerbasque Research Fellow

**Technician**
**Aitziber Eleta**

**Master Student**
**Nasim Tavakoli,** UPV/EHU (until 31/07/15)

**Pre-doctoral Researcher**
**María Cascajo,** nanoGUNE Fellow,
*Nanofluidics at single-molecule scale*

**Guest Researchers**
**Sylvie Morin,** York University Toronto (Canada)
**Chloé Rodríguez,** UAM (Spain)
**Kornelius Zeth,** Roskilde University (Denmark)

One-month stay minimum

**Undergraduate Students**
**Sara Arietaleaniz,** TECNUN (until 21/08/15)
**Elena Esteban,** Don Bosco (until 28/05/15)
**Franziska Günl,** University of Rostock (until 15/07/16)
**Larraitz Sansinenea,** TECNUN (until 16/12/16)

**Post-doctoral Researchers**
**José M. Alonso,** Aspargi Fellow (until 15/03/16)
**Annalisa Calò,** DFG Fellow (until 31/12/15)
**Wiwat Nuansing,** nanoGUNE Fellow

DFG, Regional Council of Gipuzkoa

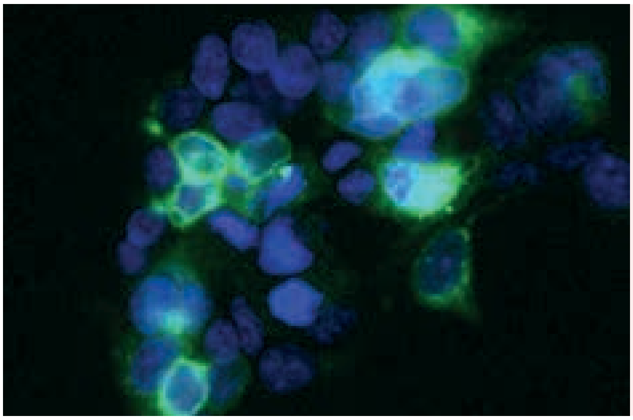

# Nanobiomechanics

All living organisms feel and react to mechanical forces. Our skin, our muscles, and our bones are all designed to resist and function under force. We are able to walk because our muscles are capable of generating mechanical forces; our heart pumps blood creating a shear stress in vessels and arteries. Almost any biological process is related somehow to the existence of mechanical interactions. Unfortunately, this also includes diseases and disorders such as inflammation, tumor spread, heart failure, injuries, arthritis, etc. In addition, bacterial and viral infections occur with the interplay of mechanical forces at the molecular level, at the nanoscale.

The Nanobiomechanics Group employs state-of-the-art techniques to investigate how mechanical forces impact the molecules that form living cells. From a multidisciplinary point of view, we are focused on proteins that are captured individually and studied in detail. From bacteria to animals and viruses, our group investigates biological processes that occur under force and that are crucial for life, using single-molecule force spectroscopy. This allows us to observe how the conformation of proteins changes under force and how forces can also trigger biochemical reactions.

We believe that studying the mechanics of proteins is essential to understand the development of many diseases. In particular, we investigate proteins involved in viral and bacterial infections. We also use imaging techniques such as confocal microscopy to investigate the dynamic interaction of viruses and bacteria with their target under mechanical stress. Our research provides new information that no other technique can reveal. We are discovering new aspects of microbial infections that could lead to new methodologies for treatment and prevention of microbial diseases. Over the last four years, the group has investigated the implication of mechanical forces on HIV-1 infection. We have demonstrated how forces can affect the molecules involved in the interaction between the HIV virus and human cells, which prompted us to search for novel molecules that interfere with the attachment process.

Another successful research line in our group focuses on the improvement of enzymes that can be used for biotechnological applications. We use novel techniques based on molecular evolution to make better enzymes with improved capabilities. We cover a wide range of enzymatic functions from cellular oxidation processes to the industrial generation of nanocellulose, a biomaterial with numerous potential applications.



## A molecular force sensor for cells

T cells expressing a GFP-based fluorescence force sensor in their outer membrane. Alterations in the GFP fluorescence reports the existence of mechanical forces in the picoNewton range. Interactions between cells and microbes will be now monitored as a mechanical perturbation.

## Team

**Raúl Pérez-Jiménez**
Ikerbasque Research Professor
Group Leader

**PhD** in Physical Chemistry in 2005
University of Granada (Spain)

### Research Fellow

**David De Sancho,**
Ikerbasque Research Fellow

### Technician

**Marie Fertin**

### Master Students

**Anne Aguirre,** UPV/EHU
**Leire Aldazabal,** UPV/EHU

### Guest Researchers

**Abel A. Rodrigues,**
Abel Rodrigues & Asociados (Argentina)
**Leyre Barandiaran,** Ceit (Spain)

One-month stay minimum

### Pre-doctoral Researchers

**Álvaro Alonso,** PFPI Fellow,
*Nanomechanics of cell-surface proteins*
**Borja Alonso,** Elkartek Fellow
*Ancestral cellulases for degradation of lignocellulosic materials*
**Nerea Barruetabeña,** nanoGUNE Fellow,
*Ancestral cellulases for bioenergy*
**Aitor Manteca,** nanoGUNE Fellow,
*Molecular evolution: nanomechanic and biotechnological aspects*
**Susana Revilla,** FP7 Fellow, *Design of molecular force sensors based on fluorescence to reveal the nanomechanics of viral infections at the cellular level*
**Bárbara Rodríguez**, UPV/EHU Fellow,
*Search and design of mechanoactive compounds for the control of the mechanics of cell surface proteins in microbial infections*

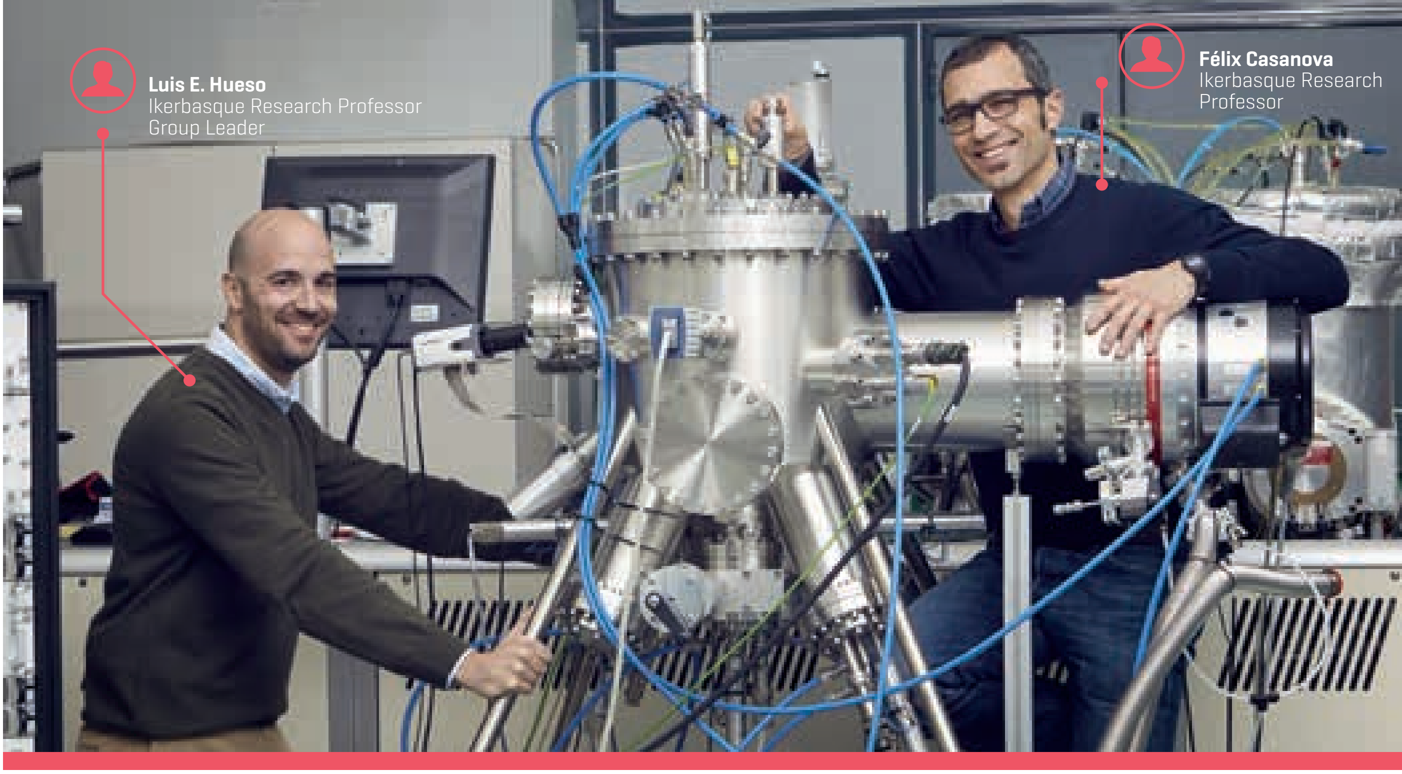
PFPI, predoctoral grant of the Basque Government

### Post-doctoral Researchers

**Patricia García,** Elkartek Fellow
**Simon Poly,** nanoGUNE Fellow (until 28/02/15)
**Jörg Schönfelder,** nanoGUNE Fellow

### Undergraduate Students

**Jean Karla Escalier,** Don Bosco (until 28/05/16)
**Amalia Miranda,** Don Bosco (until 28/05/16)
**Estibaliz Martin,** Don Bosco (until 27/05/16)



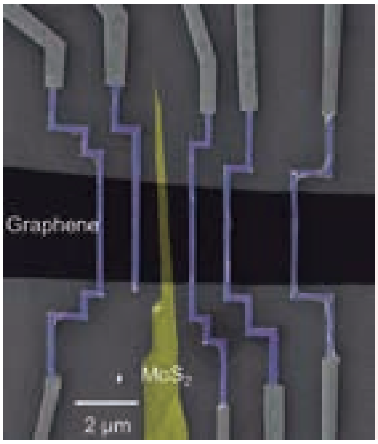

# Nanodevices

A major challenge faced nowadays by the electronics industry is to find suitable materials to continue with the progressive size reduction of transistors. In this context, the aim of the Nanodevices Group is to study the electronic properties of materials at the nanoscale. Some of these materials are potential candidates for future transistors, but they are also interesting for electronic memories, light-emitting or photovoltaic devices, and many other gadgets. For this we use advanced nanofabrication methods and measure the electron transport of the materials in extreme conditions, such as low temperatures and high magnetic fields.

We are currently working in three main lines of research connected with possible applications in several industry fields. In the first place, we are working on spintronics and electronics with organic molecules, two-dimensional (2D) materials, and metals. Spintronics is a field based on the use of the electron spin, a purely quantum mechanical entity, to transmit information. It works as a substitute of the role of the electron charge in standard electronics, aiming at reaching lower power consumptions in devices. We can create, transport, and manipulate pure spin currents, both as an alternative and as a complement to conventional electronics. In the standard electronics front, we use organic and 2D materials as building blocks for novel (opto-)electronic devices.

In the second place, we are studying neuromorphic devices. The underlying idea here is to build electronic devices that mimic how the brain works. Our brain is capable of amazing computing tasks while working at very low speeds and using very limited power. Some of the novel electronic devices we fabricate, such as memristors, can mimic how the neurons compute and transfer information.

In the third place, we are interested in magnetism and superconductivity in correlated materials. This type of materials, for example some rare-earth oxides, have an indicated interplay among different degrees of freedom such as the electronic carriers, the lattice vibrations, and the magnetic interactions. Understanding these materials provide useful knowledge for the understanding of how matter works at the nanoscale and how to manipulate it for creating, for example, supercurrents flow without heat dissipation.




## A two-dimensional spin field-effect switch

Future development in spintronic devices requires an advanced control of spin currents by an electric field. The Nanodevices Group has demonstrated a novel approach based on a van der Waals heterostructure of atomically thin graphene and semiconducting $MoS_2$, shown in this false-colored scanning-electron-microscopy image. Our device combines the superior spin transport properties of graphene with the strong spin-orbit coupling of $MoS_2$, and it allows switching the spin current in the graphene channel ON and OFF by tuning the spin absorption into the $MoS_2$ with a gate electrode.

*W. Yan et al., Nat. Commun.* **7,** *13372 (2016)*

## Team

**Luis E. Hueso**
Ikerbasque Research Professor
Group Leader
**PhD** in Physics in 2002
University of Santiago de Compostela (Spain)

**Félix Casanova**
Ikerbasque Research Professor
**PhD** in Physics in 2003
University of Barcelona (Spain)

### Pre-doctoral Researchers

**Coline Adda,** ANR Fellow, *Neuromorphic devices with Mott insulators*
**Libe Arzubiaga,** PFPI Fellow, *Nanostructuring of devices for nanoscience applications* (until 30/03/15)
**Ainhoa Atxabal,** PFPI Fellow, *Hot-electron devices*
**Miren Isasa,** PFPI Fellow, *Spin orbitronics in metals (until 31/12/15)*
**Josu López,** H2020 Fellow, *Noncollinear magnets for spintronics*
**Juan Manuel Gómez,** H2020 Fellow, *Spin-dependent transport in metallic/ferromagnetic insulator hybrid devices*
**Emmanouil Masourakis,** ITN Fellow, *Electronic transport in single molecular devices* (until 31/12/15)
**Luca Pietrobon,** ITN Fellow , *Charge and spin transport in graphene devices (until 30/06/15)*
**Mário Ribeiro,** ITN Fellow, *Control of spin injection and spin transport in graphene and other 2D crystals by molecular decoration*
**Edurne Sagasta,** FPU Fellow, *Spin-dependent transport in complex systems using lateral nanostructures*
**Oihana Txoperena,** FPI Fellow, *Spin injection in two-dimensional layered materials and local magnetoresistance side effects (until 08/04/16)*
**Elisabetta Zuccatti,** nanoGUNE Fellow, *Design and optimization of organic field-effect transistors*

FPI, predoctoral grant of the Spanish Government
PFPI, predoctoral grant of the Basque Government
FPU, predoctoral grant of the Spanish Government
ANR, Agence National de la Recherche (France)
DFG, Regional Council of Gipuzkoa

### Research Fellows

**Santiago Blanco-Canosa,** Ikerbasque Research Fellow
**Pablo Stoliar,** Ramón y Cajal Fellow

### Technician

**Roger Llopis**

### Guest Researchers

**David Etayo,** DAS-NANO (Spain)
**Federico Golmar,** CONICET (Argentina)
**Yasutomo Omori,** The University of Tokyo (Japan)

One-month stay minimum

### Post-doctoral Researchers

**Amilcar Bedoya-Pinto,** FP7 Fellow (until 31/07/15)
**Néstor F. Ghenzi,** ERC Fellow (until 30/06/15)
**Subir Parui,** DFG Fellow
**Xiangnan Sun,** ERC Fellow (until 31/12/15)
**Saül Vélez,** DFG Fellow
**Wenjing Yan,** ITN Fellow

### Master Students

**Eneko Lopez,** UPV/EHU (until 14/02/16)

### Undergraduate Students

**Asier Álvarez,** UPV/EHU (until 14/08/15)
**Julen Echavarri,** TECNUN (until 15/09/15)
**Beñat García,** UPV/EHU
**Iñigo Losada,** UPV/EHU (until 12/08/16)
**Markel Pardo,** UPV/EHU (until 12/08/16)
**Eduardo Rodríguez,** University of Oxford (until 31/08/15)
**Leire Urreta,** UPV/EHU (until 14/08/15)


# Electron Microscopy

Information about the structure and composition of materials is of key importance for the basic understanding of their properties and of the functioning of nanodevices. Moreover, our ability to characterize and understand these structures is critical for revealing the quality issues of existing products, providing answers for problems currently faced by industry. The Electron-Microscopy Group provides a high-level electron-microscopy support to the local scientific community in order to face these challenges.

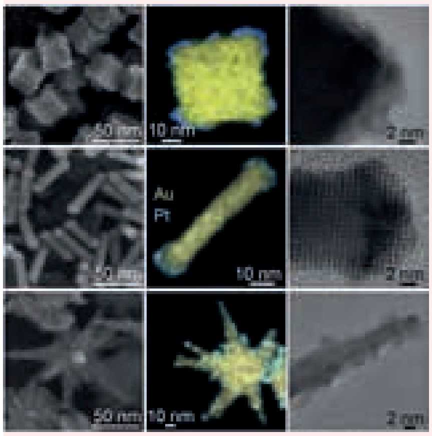
Our laboratory is specialized in high-resolution Transmission-Electron Microscopy (TEM) imaging and structure analysis, local analysis of the composition of materials, prototyping of metal plasmonic structures and the study of plasmonic resonances by electron energy-loss spectroscopy (EELS), the visualization of magnetic fields by electron holography and Lorentz microscopy, nanofabrication using focused ion and electron beams, as well as electron microscopy of wet and liquid materials.

During the last years, we have developed a methodology for characterizing the dynamics of individual defects in graphene, giving access to kinetic data on a single-atom level. We have demonstrated a principal possibility to quantify reversible atomic processes with cross-sections of up to 3 500 barn by direct imaging; the formalism of classical chemical kinetics has been adopted and applied for the treatment of data based on stochastic events; a principal possibility for the estimation of kinetics of thermally activated reactions by direct imaging has been shown; and a superefficient energy transfer pathway to defects in graphene has been discovered, yet not explained.

We have systematically studied a novel and technologically valuable method for the fabrication of functional nanostructures, and we have proposed a number of new approaches for the fabrication of magnetic nanodevices.

We maintain a broad collaboration with many other institutes in the Basque Country and worldwide.

## Plasmonic photocatalysis – efficiency by complexity




The light harvesting capacity of plasmonic nanoparticles is a fundamental feature for catalyzing chemical reactions close to their surface. The efficiency of the photochemical processes depends not only on the geometrical aspects on a single particle level but also on the complexity of the multiparticle architectures. Here in collaboration with biomaGUNE we study composite platinum/gold nanoparticles of complex shape in respect to plasmon enhanced photo-catalytic reaction of photoregeneration of cofactor molecules. The figure demonstrates the variety of shapes studied: cubes, rods and 3D stars, as well as targeted location of an ultra-dispersed active component (Pt) on the ends, edges, and spikes of a plasmonically active component (Au) – at the positions where the maximum light field enhancement is expected due to plasmon excitations. In photochemical and photoelectrochemical measurements, we found that branched nanoparticles are better photocatalysts as compared to the rod or cube-like particles, which is explained by the geometrical features of gold nanostars that efficiently harvest the light improving photoelectrocatalytic effect.

*J. Mater. Chem. A* **4,** 7045 (2016)

## Team

**Andrey Chuvilin**
Ikerbasque Research Professor

**PhD** in Physics and Mathematics in 1998
Siberian Branch of the Russian Academy of Sciences, Novosibirsk (Russia)

**Technician**
Christopher Tollan

**Pre-doctoral Researcher**
**Bentejui Medina,** DE Fellow, *Influence of the microstructure of steels on workpiece machinability*

DE, Basque Department of Education

**Post-doctoral Researcher**
**María Jesús Pérez,** FEI Fellow (until 31/08/15)

**Guest Researchers**
**Olga Antonova,** NIIC (Russia)
**Alexander Fedoseev,** Institute of Inorganic Chemistry, SB RAS (Russia)
**Yuliya Fedoseeva,** NIIC (Russia)
**Evgeny Gerasimov,** Novosibirsk State University (Russia)
**Dmitriy Gorodetskiy,** NIIC (Russia)
**Iurii Ivanov,** KAUST (Russia)
**Victor Koroteev,** NIIC (Russia)
**Dmitry Melnikau,** CFM (Spain)
**Evgeny Modin,** Kurchatov Institute (Russia)
**Alexei V. Nashchekin,** Ioffe Institute (Russia)
**Yuliya A. Nashchekina,** Ioffe Institute (Russia)
**Ekaterina Obraztsova,** Russian Academy of Sciences (Russia)
**Andrey Orekhov,** AV Shubnikov Institute of Crystallography (Russia)
**Eugenii Pustovalov,** Far Easter State University (Russia)
**Feruza Tuyakova,** University of Eastern Finland (Finland)
**Oksana Yurkevich,** I. Kant Baltic Federal University (Russia)
**Vladimir Vdovin,** Russian Academy of Sciences (Russia)

One-month stay minimum

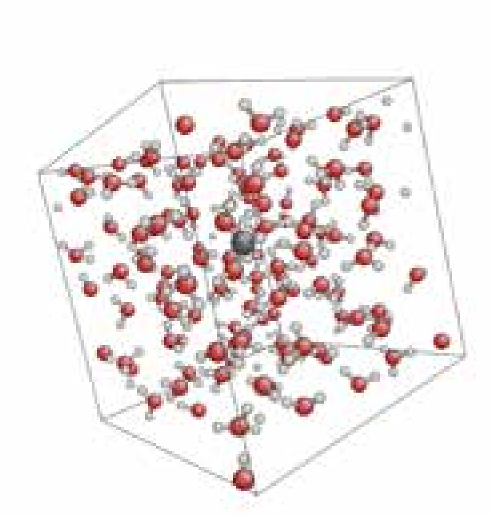

# Theory

In the Theory Group we do theoretical simulations of matter at the nanoscale. Starting from the fundamental equations of quantum physics, which are the ones describing the behavior of electrons and nuclei, we do "virtual reality" simulations of materials, nanoparticles, liquids, and their interfaces at the atomic scale, thereby gaining a very detailed view of their structure and dynamics, as well as predicting properties of interest for such systems.

Part of our work is in the development and improvement of simulation methods allowing a more effective simulation of systems of increasing complexity. Such developments are based on progress in the theoretical physics of solids and liquids, in a project called SIESTA that involves scientists in Spain (Barcelona, Madrid, San Sebastian, Santander), the USA (Stanford), and Australia (Perth). The Siesta method is used by thousands of scientists worldwide. In its 20th anniversary, SIESTA has been recently converted to a free open-source license (GPL) after years of open source for academics only. The article describing the method was within the twelve papers recently selected as most prominent of the fifty years of life of the *Journal of Physics Condensed Matter* of the Institute of Physics of the UK.

A prominent line of research in our group explores the behavior of water and wet systems at the atomic scale, including nanoscale wetting and nanoconfined water and biomolecules in water. We collaborate in this with scientists at the University of Stony Brook (USA) and the Autonomous University of Madrid (Spain). Understanding water confined at the nanoscale is extremely important for understanding the inner workings of cells. We recently found that in narrow confinement (around 1 nm) water transits from a very complex behavior related to its molecular structure to suddenly behaving as a simple ideal two-dimensional (2D) liquid of spherical particles. Completely unexpected. It ends up being a consequence of the oxygen atoms in water slowing in their motion within the liquid, while the hydrogen atoms keep moving rather quickly.

Another important line of research is the study of radiation damage in materials, relevant to the treatment of cancer by ion therapy, for instance. When a charged particle shoots through a material or biological tissue, electronic excitation processes take place, which we try to understand with time-dependent (non-equilibrium) theories. This we do in collaboration with top players in the field: DIPC and CFM, both at the same campus as nanoGUNE, Helsinki, and several USA National Laboratories (Argonne, Los Alamos, and Livermore). We have recently joined a European initiative in the search for dark matter. The building of suitable detectors demands an understanding of how materials would react to dark-matter projectiles, which connects with our radiation damage expertise and could be optimized in nanostructured detectors, of relevance to the ultra-high-precision tool industry in the Basque Country.



## Water radiolysis by low-energy carbon projectiles from first-principles molecular dynamics

Water is central to many processes in chemistry, biology, and environmental science. Of particular interest is water under ion irradiation. Ions can be produced in accelerators and used as radio-therapeutic and materials processing tools. In particular, carbon ions are promising in cancer treatment due to reduced side effects. Here we study the irradiation process by real-time computer simulations whereby slow carbon ions are launched at different velocities towards a few nanometers thick water film. Ions colliding with water molecules eventually produce dissociation and lead to the formation of other molecules. We find that, due to the more frequent dissociative collisions, slow ions produce very significant damage in a low-velocity regime previously considered safe.

*J. Kohanoff and E. Artacho, PLoS One* ***12 (3),*** *e0171820 (2017)*

## Team

**Emilio Artacho**
Ikerbasque Research Professor
Group Leader

**PhD** in Physics in 1990
Autonomous University of Madrid (Spain)

### Undergraduate Students

**Adiran Garaizar,** UPV/EHU (until 31/07/16)

**Maitane Muñoz,** UPV/EHU

### Guest Researchers

**José Alfredo Caro,** Los Alamos National Laboratory (USA)

**Paul D. Bristowe,** University of Cambridge (UK)

**Giovanni Cistaro,** University of Calabria (Italy)

**Matthew Dawber,** Stony Brook University (USA)

**Mario Gravina,** University of Calabria (Italy)

**Eleanor Green,** ETH Zurich (Switzerland)

**Ander K. Gray,** Belfast University (UK)

**Hanen Hamdi,** University of Liege (Belgium)

**Andrea M. Schiaffino,** University of Milano (Italy)

**José M. Soler,** Autonomous University of Madrid (Spain)

**Etienne Plésiat,** ECAM (France)

**Joas S. Grossi,** Universidad Nacional de Cuyo (Argentina)

**Magdalena Serrano,** Los Alamos National Laboratory (USA)

**Oliver Strickson,** University of Cambridge (UK)

**Aleksandr V. Terentjev,** DIPC (Spain)

One-month stay minimum

### Pre-doctoral Researchers

**Rafi Ullah,** FPI Fellow, *Non-adiabatic processes in the radiation damage of materials from first principles*

**Jon Zubeltzu,** FPI Fellow, *Theoretical simulation of nanconfined water from first principles*

FPI, predoctoral grant of the Spanish Government

### Post-doctoral Researchers

**Pablo Aguado,** FP7 Fellow (until 31/01/16)

**Fabiano Corsetti,** FP7 Fellow (until 31/12/15)

**David López-Durán,** MEIC Fellow

MEIC, Ministry of Economy, Industry and Competitiveness


# Nanomaterials

Working with materials at the nanoscale allows for enhancing functionalities or even introducing completely new properties that are not present at the macroscopic shape of the materials. The Nanomaterials Group aims at developing functional materials and ways to fabricate functional materials for emerging applications. We target a variety of research directions, including energy, biomedicine, and further emerging technologies.

To achieve our objectives, we follow two distinct research lines. One is focused on thin-film coatings by atomic layer deposition or molecular layer deposition, which should serve as a fundamental strategy to add functionalities (corrosion protection, flexible electronics, sensing, or energy applications) to existing materials by nanoscale coatings. The other research line involves the development of bioactive materials by encapsulating drugs, catalysts, or further functional materials into natural protein spheres, which can be transported into cells, for particular applications in nanomedicine. Application fields include molecular biomimetics, drug delivery, and screening.

We had a European project that ended in November 2015 (TREASORES) and was dedicated to the development of organic electronics in a roll-to-roll process. Our task was to develop barrier foils for enhancing the lifetime of organic LEDs. Within this work, we hold a joint patent with the company OSRAM in Germany.

A further work of interest is the delivery of siRNA into cells using our natural protein sphere ferritin. The transport of the RNA through the cell membrane without being recognized by the cell allowed to silence (shut down) some genes of the cells and may serve as an interesting novel approach for gene therapy. This work was published in the journal *Biomaterials* in 2016 *(Li et al., Biomaterials* ***98,*** *143 (2016)).*


## Multilayer Fresnel zone plates

Nanoscale multilayer structure of aluminum oxide and titanium oxide for its use in X-ray microscopy. This structure allows to focus radiation on one spot and in this way image features down to about 20 nm in size by X-rays.

## Team

**Mato Knez**
Ikerbasque Research Professor
Group Leader

**PhD** in Physical Chemistry in 2003
Max Planck Institute of Solid State Research, Stuttgart (Germany)

### Technician

**Mikel Beltrán**

### Research Fellow

**Ana Beloqui,** Gipuzkoa Fellow

### Guest Researchers

**Iva Saric,** University of Rijeka (Croatia)
**Chiara Tullio,**
University of Milano-Bicocca (Italy)
**Oksana Yurkevich,**
Immanuel Kant University (Russia)

One-month stay minimum

### Post-doctoral Researchers

**Chaoqiu Chen,** Elkartek Fellow (until 27/09/16)
**Nagore Ibarra,** H2020 Fellow
**Le Li,** nanoGUNE Fellow (until 31/05/16)
**Fan Yang,** nanoGUNE Fellow
**Lianbing Zhang,** FP7 Fellow (until 31/05/16)
**Ana Zuzuarregui,** FP7 Fellow (until 31/12/15)

### Pre-doctoral Researchers

**Itxasne Azpitarte,** PFPI Fellow, *Modifications of polymers through vapor phase infiltration*
**Unai Carmona,** PFPI Fellow, *Bio-inorganic nanoparticles for catalysis*
**Sarai García,** nanoGUNE Fellow, *Functionalization of nanoparticles for energy storage*
**Weike Wang,** ITN Fellow, *Vapor phase doping and infiltration of conducting polymers*
***Fan Yang***, nanoGUNE Fellow (until 30/06/16), *Functionalization of nanomaterials by atomic layer deposition*

PFPI, predoctoral grant of the Basque Government

### Undergraduate Students

**Amaia Benavente,** TECNUN (until 31/07/15)
**Orhi Esarte,** UPV/EHU (until 14/08/15)
**Jan Mees,** UPV/EHU (until 31/07/15)


# Nanoimaging

Nature behaves differently at the scale of atoms. The Nanoimaging Group studies the quantum behavior of small objects, just formed by a small number of atoms or molecules, using scanning probe microscopies. We search for effects related to their optical, magnetic, or electronic properties, which could help us to understand the fundamentals of quantum processes and to construct models explaining their peculiar behavior. The guideline of our research is to turn quantum phenomena relevant for novel materials.

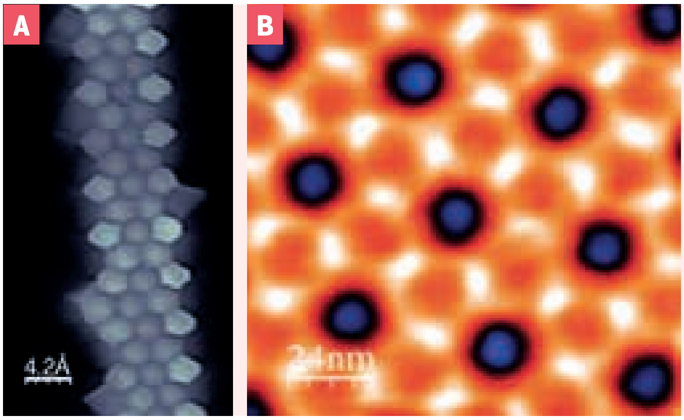
Our experiments use different kinds of probe microscopies to study materials down to the scale of atoms and molecules. But beyond "seeing", our group is fundamentally experienced in spectroscopy. Scanning Probe Spectroscopies "measure" forces, electrons, photons, and spins at the nanometer-length scale.

A major field of research in our group is the physics and chemistry of hybrid molecular nanostructures, studied one by one. We study how a molecule can transport electricity, emit light, or behave as a nanomagnet. Coupling molecules together through chemical reactions extend a single-molecule playground into larger entities. An example of this "molecular LEGO" is the creation of graphene nanoribbons of different sizes and structures by inducing reactions of organic precursors on a metal surface.

We are also interested in correlated phenomena of quantum materials, such as superconductivity and magnetism. Superconductivity is a quantum phenomenon in macroscopic length scales. Little is known about its behaviour when the dimensions of the material are reduced below its characteristic coherence length scale. We study how superconductivity evolves in the limit of two dimensions and the effect of local magnetic fields and distortions at interfaces and atomic impurities.

Within the field of novel materials we are particularly interested in investigating the growth and atomic-scale properties of transition metal dichalcogenides, a family of two-dimensional (layered) materials that can behave as a semiconductor, metal, or superconductor simply by modifying its composition. The two-dimensional (2D) character of these materials favors the creation of very clean and atomically perfect interfaces, facilitating charge transport. Our goal is to create ideal optoelectronic devices performing efficiently in comparison with current heterostructures.

Our research fields are established in collaboration with various groups at nanoGUNE and with university groups in Berlin, Zaragoza, Santiago de Compostela, and the Basque Country, as well as with research institutes such as ICN2 in Barcelona.




### Visualizing the interior of materials

A. STM image with a CO-functionlized tip of a narrow graphene nanoribbon, only three phenyl rings wide, functionalized with CN groups at the edges.

B. Constant heigth current image (V = 1 mV) of the vortex structure of an exfoliated $NbSe_2$ crystal in the superconducting state under a 1 T magnetic field.

## Team

**José Ignacio Pascual**
Ikerbasque Research Professor
Group Leader

**PhD** in Physics in 1998
Autonomous University of Madrid (Spain)

**Technician**
David Arias

**Research Fellows**
**Richard Balog,** Ikerbasque Research Fellow (until 31/07/15)
**M. Reyes Calvo,** Ikerbaque Research Fellow
**Miguel M. Ugeda,** Ikerbasque Research Fellow

**Guest Researchers**
**Ana I. Barragán,** CFM (Spain)
**Joeri de Bruijkere,** Delft University (The Netherlands)
**Martina Corso,** CFM (Spain)
**René Ebeling,** Forschungszentrum Jülich GmbH (Germany)
**Dimas García de Oteyza,** DIPC (Spain)
**Alexander D. Hughes,** Stanford University (USA)
**Wolfgang Kuch,** Freie University Berlin (Germany)
**Jingcheng Li,** CFM (Spain)
**Samuel Mañas,** ICMol (Spain)
**Maciej M. Topyla,** Ilmenau University of Technology (Germany)
**Néstor Merino,** DIPC (Spain)

One-month stay minimum

**Pre-doctoral Researchers**
**Eduard Carbonell,** nanoGUNE Fellow, *Light emission from quantum systems induced by tunneling electrons*
**Nieves Morquillas,** FP7 Fellow, *Quantum effects in the interaction of light with metallic nanostructures*
**Carmen Rubio,** nanoGUNE Fellow, *Ultra-low temperature study of the atomic limits of magnetism*
**Javier Zaldivar,** nanoGUNE Fellow, *Local probe studies on superconducting nanomaterials*

**Undergraduate Students**
**Mikel Álvarez,** UPV/EHU (until 14/08/15)
**Mikel Iraola,** UPV/EHU (until 12/08/16)

**Post-doctoral Researchers**
**Deung J. Choi,** Marie Curie Fellow
**Jeremy G. Hieulle,** DFG Fellow (until 30/09/16)
**Zsolt Majzik,** nanoGUNE Fellow (until 30/06/15)

**DFG**, Regional Council of Gipuzkoa

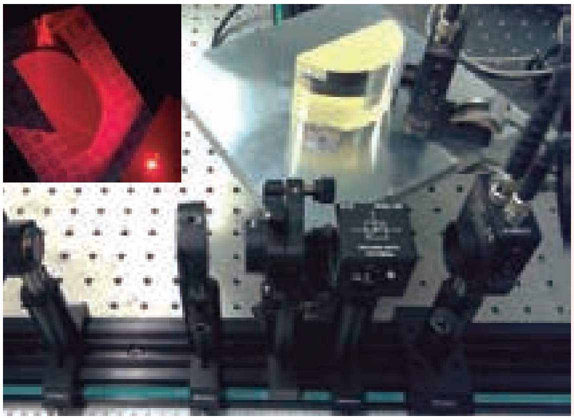

# Nanoengineering

The Nanoengineering Group focuses on research at the interface between fundamental nanoscience and applied engineering, in particular in the area of biomedical microsystems. In collaboration with clinical partners, new diagnostic tools are to be developed, particularly for widespread diseases as for example cardiovascular diseases, cancer, or neurodegenerative diseases. We are currently working in three main research lines in order to open new diagnostic and therapeutic opportunities.

One research line focuses on plasmonic sensing of exosomes and other biological nanoparticles. Exosomes are cell-derived vesicles with dimensions of some tens of nanometers. Since exosomes carry a signature of the cell of their origin and they migrate through the body and can be found in any body liquid, reliable detection of exosomes exhibits a huge potential to improve the diagnosis of cancer, infectious diseases, and neurodegenerative diseases. In other words, the detection of exosomes provides a 'liquid biopsy'. In collaboration with clinical partners and biomedical research centers, new optical detection methods for exosomes are aimed to be developed.

In a second research line, we are developing a new platform that combines Raman and MIR (mid infrared) spectroscopy to be applied for early diagnosis of Alzheimer's disease (AD). This research is carried out in collaboration with Fundación CITA Alzheimer (San Sebastian) and the University of the Basque Country (Department of Biochemistry and Molecular Biology). Our major diagnostic challenge is to develop a unique prototype that is able to identify a reliable biomarker (protein) with high predictive power to be applied in healthy middle-age subjects in order to know their risk to eventually develop dementia after some years. For this challenge to be solved, it is of utmost relevance to determine the dynamics of these proteins in blood and CSF (cerebrospinal fluid) samples of individuals with such characteristics by using new technological approaches capable to identify them at nanomolar concentrations.

Continuous monitoring of vital signs using photonic methods is subject of the third research line. Over one billion people worldwide suffer from hypertension and further cardiovascular diseases. Reliable blood-pressure management is the key to avoid cardiac events resulting from hypertension. The regular measurement of blood pressure, outside the clinical environment, can optimize the necessary drug treatment. Furthermore, continuous monitoring of cardiovascular parameters can immediately detect an emergency case that can be life threatening if not treated within one hour. Within this research line a multi-parametric cardiovascular sensing strategy and technology is developed that is comfortable for the patient, to finally provide miniaturized long-term monitoring systems with telemetric technology.



## Customized SPR setup for highest sensitivity

A customized SPR (surface plasmon resonance) measurement system was set up to measure extremely low changes of the refractive index of analytes. The system is optimized by physical optics modeling using ray tracing, such that highest sensitivity is achieved. This will allow to detect low concentrations of bio-nanoparticles that are related to specific widespread diseases.

## Team

**Technicians**

**Monika Goikoetxea** (until 23/12/15)

**Eneko López**

**Guest Researcher**

**Odei Vegas,** BTI (Spain)

One-month stay minimum

**Andreas Seifert**
Ikerbasque Research Professor
Group Leader

**PhD** in Physics in 1998
University of
Freiburg (Germany)

**Post-doctoral Researchers**

**María C. Morant,** nanoGUNE Fellow

**Gajendra Singh,** Elkartek Fellow

**Ana Valero,** nanoGUNE Fellow

**Undergraduate Students**

**Amaia Benavente,** TECNUN (until 09/09/16)

**Irene Mendizabal,** TECNUN (until 12/08/16)

**Jon Zabalo,** TECNUN (until 12/08/16)

# 2

# Research Outputs

**187** ISI Publications

**4 430** Citations

**121** Invited Talks

# Highlighted publications

1

## Gate-controlled energy barrier at a graphene/molecular semiconductor junction

Advanced Functional Materials **25**, 2972-2979 (2015)

2

## Ultrasensitive and label-free molecular-level detection enabled by light phase control in magnetoplasmonic nanoantennas

Nature Communications **6**, 6150 (2015)

3

## Charge redistribution and transport in molecular contacts

Physical Review Letters **115**, 136101 (2015)

4

## Direct observation of ultraslow hyperbolic polariton propagation with negative phase velocity

Nature Photonics **9**, 674-678 (2015)

5

## Enhanced magneto-optical edge excitation in nanoscale magnetic disks

Physical Review Letters **115**, 187403 (2015)

6

## Characterization of collective ground states in single-layer $NbSe_2$

Nature Physics **12**, 92-97 (2016)

7

## Enhanced configurational entropy in high-density nanoconfined bilayer ice

Physical Review Letters **116**, 085901 (2016)

8

## Real-space mapping of tailored sheet and edge plasmons in graphene nanoresonators

Nature Photonics **10**, 239-243 (2016)

9

## Nanopatterning reconfigurable magnetic landscapes via thermally assisted scanning probe lithography

Nature Nanotechnology **11**, 545-551 (2016)

10

## A simple two-state protein unfolds mechanically via multiple heterogeneous pathways at single-molecule resolution

Nature Communications **7**, 11777 (2016)

1

# Gate-controlled energy barrier at a graphene/molecular semiconductor junction

Advanced Functional Materials **25**, 2972-2979 (2015)

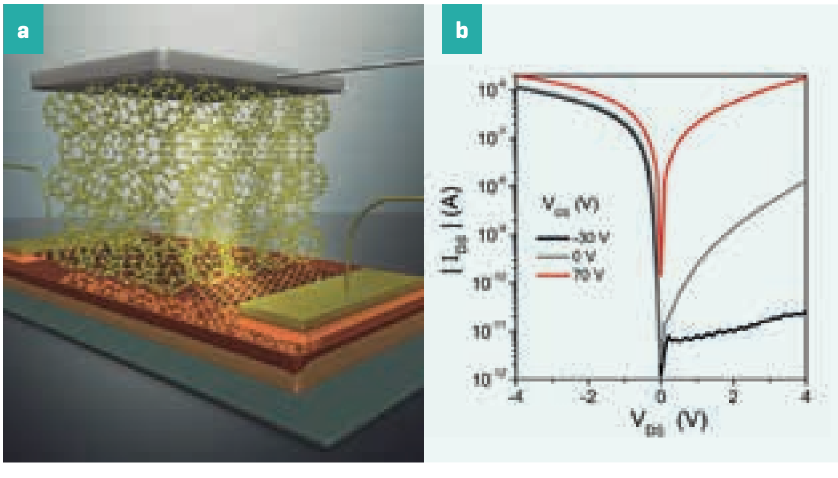
**S. Parui, L. Pietrobon, D. Ciudad, S. Vélez, X. Sun, F. Casanova, P. Stoliar, and L. E. Hueso**

Field-effect transistors with vertical configuration are groundbreaking electronic devices, principally since they reduce energy consumption and occupy much less space when compared to their traditional lateral counterparts. In particular, vertical molecular field-effect transistors are very much sought after as power elements for fully flexible organic displays in mobile applications. In this work, we demonstrate for the first time a vertical graphene/molecular transistor. By taking the best of two related carbon nanomaterials, we open a promising route toward molecular-semiconductor based devices.

A molecular transistor is a fundamental building block for any complex organic circuit, such as organic photovoltaics or bendable displays with organic light-emitting diodes. A key parameter that determines the performance of such devices is the energy barrier at the metal/molecular semiconductor junction. Typically, a specific metal/molecular semiconductor combination leads to a fixed energy barrier, but the possibility of a gate-controlled energy barrier is very appealing from the point of view of possible advanced applications.

In this article, we have addressed the problem of the fixed interfacial energy barrier by performing experiments on a vertical molecular-based device. We present a graphene/fullerene based device in which we demonstrate control of the interfacial energy barrier such that the junction switches from a highly-rectifying diode at negative gate voltages to a nearly-ohmic behavior of no rectification at positive gate voltages and at room temperature. We further demonstrate the operation of a vertical transistor that also allows us to obtain a gate-modulated photocurrent. Most importantly, the vertical device architecture that relies on the thickness of the organic layer provides great advantage to miniaturize electronic components for future industrial products.

Currently we are expanding this concept by using graphene electrodes for solution-processed organic transistors, which will expand the portfolio of materials we can explore and will move us closer to commercial organic transistors based on graphene electrodes.




**(a)** Schematic diagram of our device, which acts as a graphene lateral field-effect transistor as well as a graphene/$C_{60}$-based vertical field-effect transistor.

**(b)** A controllable switch of the energy barrier of a graphene/$C_{60}$ junction from a highly rectifying diode (gate voltage = -30 V) to a nearly-ohmic junction (gate voltage = 70 V) operating at room temperature.

2

# Ultrasensitive and label-free molecular-level detection enabled by light phase control in magnetoplasmonic nanoantennas

Nature Communications **6**, 6150 (2015)

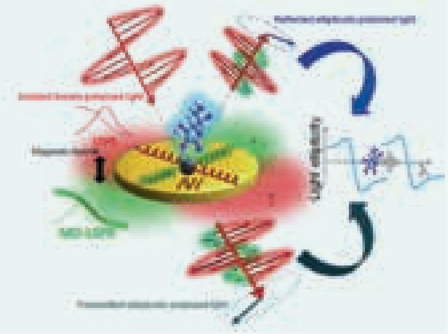
**N. Maccaferri, K. E. Gregorczyk, T. V. A. G. De Oliveira,** M. Kataja, S. van Dijken,
Z. Pirzadeh, A. Dmitriev, J. Akerman, **M. Knez, and P. Vavassori**

Systems allowing label-free molecular-level detection are expected to have enormous impact on biochemical sciences. Research focuses on materials and technologies based on exploiting the coupling of light with electronic charge oscillations, the so-called localized surface-plasmon resonances, in metallic nanostructured antennas. The reason for this focused attention is their suitability for single-molecule sensing, arising from the intrinsically nanoscopic sensing volume and the high sensitivity to the local environment. Usually the metals used to build such nanoantennas are gold or silver. The coupling of light with localized plasmons of ferromagnetic metals like nickel or cobalt was for a long time considered inefficient and thus of no practical relevance.

A few years ago we demonstrated that ferromagnetic nanoantennas support localized plasmons and, at the same time, show a sizeable magneto-optical activity under the application of external magnetic fields. The idea of bringing light and magnetism together at the nanoscale using plasmons led, in the past decade, to the rapidly developing field of magnetoplasmonics, which deals with novel and unexpected phenomena and functionalities for the manipulation of light and/or spin states at the nanoscale.

Now we have discovered a new way of optical sensing, using the magneto-optical Kerr and Faraday effects in ferromagnetic nanoantennas. We have shown how such nanoantennas can be designed to achieve a perfect phase compensation in their electromagnetic response that can be used for ultrasensitive label-free molecular-level sensing. Most remarkably, they have shown a raw surface sensitivity (that is, without applying any procedure for data analysis) of two orders of magnitude higher than the current values reported for nanoplasmonic sensors. Such sensitivity corresponds to a mass of 0.8 ag per nanoantenna of polyamide-6.6, which is representative for a large variety of polymers, peptides, and proteins. This proof of concept opens the pathway for the designing of a new type of practical devices, which can be magnetically activated and controlled to achieve very high sensing performances up to the molecular level.

The discovery of these ultrasensitive capabilities is primarily directed towards biomedicine and diagnostics as an efficient way to retrieve more information from smaller amount of biological fluids or to study protein dynamics upon surface functionalization. In addition to biosensing, there are also many other potential applications that do not require surface functionalization and would enormously benefit from this novel approach, like chemical sensing of toxic materials and explosives, or ultra-precise thickness-monitoring applications.



Light polarization manipulation enabled by phase compensation in the electric response of a magneto-plasmonic nanoantenna controlled through a precise design of the LPRS resonance induced by the magneto-optical activity (MO-LSPR) of the ferromagnetic constituent material (Ni) and exploitation of the effect for ultrasensitive molecular sensing.

3

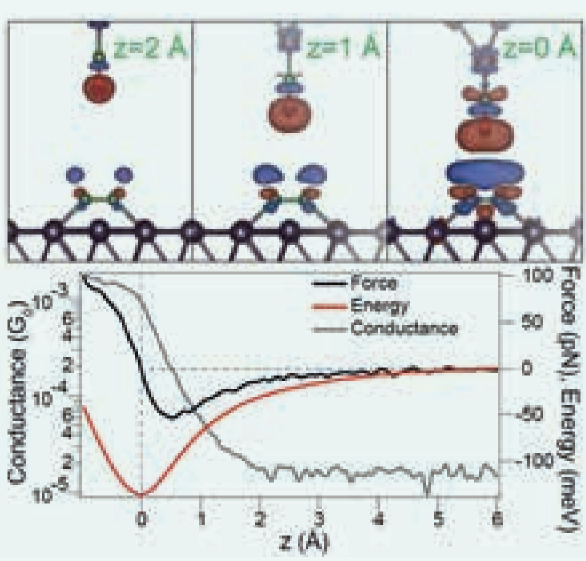
# Charge redistribution and transport in molecular contacts

Physical Review Letters **115**, 136101 (2015)

M. Corso, M. Ondracek, C. Lotze, P. Hapala, K. J. France, P. Jelinek, and **J. I. Pascual**

A challenge in materials science and engineering is to study the contact between two materials at the atomic scale. Many relevant processes in nanoelectronics and nanotribology, such as friction, adhesion, or charge transport through a nanodevice depend on the nature of mechanical forces and electronic resistances at the contact between two solids. The onset of contact formation is, however, not well defined: mechanical and electrical contact does not necessarily occur at the same point. In metals, for example, the electrical contact occurs before frontier atoms reach equilibrium bonding configuration. This makes a one-atom metal contact a good conductor of electricity. However, for close-shell species such as molecules, the behaviour is quite different.

Using high-resolution force and electron spectroscopy with a scanning tunneling microscope, we identified the mechanisms behind the formation of a contact between two neutral molecules. In our experiment, we approach an acetylene and carbon monoxide molecule against each other with picometer resolution and follow the creation of a weak van der Waals bond between them. Forces of only a few picoNewtons stabilize the molecular junction, whereas resistances of mega-ohms makes these contacts non-conducting. Supported by Density-Functional Theory (DFT) simulations from our collaborators in the Czech Academy of Sciences, we find that the absence of wave-function overlap between the molecules (i.e. no chemical bond) causes the tunneling barrier to survive, even when the molecules are pushed one against the other. Molecular junctions of this type are thus good electrical spacers. However, even in the limit of no chemical forces, electrical charges of one molecule rearrange due to the presence of the other and the contact develops electrostatic forces, which helps in its stabilization.




**(Top)** DFT simulations of the approach of a CO molecule on the STM tip towards an acetylene molecule, on a Cu(100) surface. The three snapshots show how charges at the molecules rearrange (red and blue shadows are isosurfaces of negative and positive induced charge density, respectively).

**(Bottom)** Experimental results showing the evolution of intermolecular forces, bonding energy, and charge transport as the two molecules are brought into contact. At the point of mechanical contact, i.e. at the minimum bond energy, the conductance of the junction is very small and is governed by the tunneling effect.

4

# Direct observation of ultraslow hyperbolic polariton propagation with negative phase velocity

Nature Photonics **9**, 674 -678 (2015)

**E. Yoxall, M. Schnell, A. Y. Nikitin, O. Txoperena,** A. Woessner, M. B. Lundeberg, **F. Casanova, L. E. Hueso,** F. H. L. Koppens, and **R. Hillenbrand**

We developed a new microscopy technique to image how light moves inside an exotic class of matter known as hyperbolic material. We observed, for the first time, ultraslow pulse propagation and backward propagating waves in deep subwavelength-scale thick slabs of boron nitride – a natural hyperbolic material for infrared light. Our microscopy technique lays the foundations for studying the precise manner in which light travels through complex optical systems at the nanometer scale. Such a capability will be vital for verifying the function of future nanophotonic devices.

Hyperbolic materials are very special because they behave like a metal in one direction, but like an insulator in the other. Until now, these materials have been used to fabricate complex nanostructures that permit subwavelength-scale waveguiding as well as the focusing and controlling of light at the nanometer scale. However, in order to fully exploit their potential, it is necessary to image how light behaves inside them.

When light moves inside a hyperbolic material – in our case mid-infrared light in a 135 nm boron-nitride slab - it travels in the form of what we call a polariton, where the light is actually coupled to the vibrations of the matter itself. These polaritons can be considered a double-edged sword to the scientists trying to study them. On the one hand, they can squeeze light into extremely small volumes, which is helpful for a wide range of applications such as detecting and identifying molecules. On the other hand, we cannot use conventional optical equipment, such as lenses and cameras, to image them. Instead, we have to use a special type of microscope. This microscope - a scattering-type scanning near-field infrared microscope (s-SNOM) - is capable of seeing details 100 times smaller than a standard infrared microscope. But it is not just the spatial resolution that makes tracking polaritons difficult. In order to see how a polariton moves, we need to detect and track it in both space and time. This can be accomplished by using extremely short infrared pulses that are just 100 femtoseconds long. By using these very short flashes in combination with our s-SNOM, we were able to watch the polaritons passing different locations along the boron-nitride slab, allowing for measuring their speed.

The space and time information gathered during the experiment allowed us to exactly determine how the polariton was traveling. The time -and space- resolved maps revealed a range of intriguing behaviors of the polaritons, including a dramatic slowing down of the pulse velocity - below 1 percent of the light velocity in vacuum - and a reversal of the direction in which the polariton waves were propagating in relation to the direction of the energy flow.

An exciting result is the speed at which the polariton moves. There is a lot of interest in slow light, and what we have shown here is a novel way of achieving this. Slow light in conventional photonic structures has great potential for manifold applications in sensing and communication technologies, owing to enhance light-matter interactions. The deep subwavelength-scale confinement of slow polaritons in hyperbolic materials could help to miniaturize these devices.

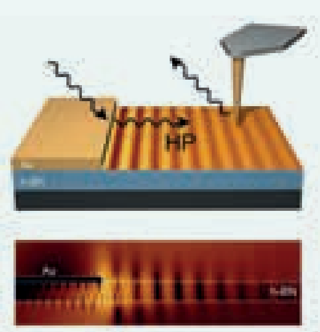



Illustration **(top)** and simulation **(down)** of nanoimaging slow nanolight in a thin boron-nitride slab. Incident light pulses are converted by a gold (Au) film into slow hyperbolic polariton (HP) pulses propagating in the boron-nitride (h-BN) slab. The HPs are traced in space and time by first scattering them with a nanoscale sharp scanning tip and then measuring the time delay between the scattered and the incident pulse as a function of tip position.

5

# Enhanced magneto-optical edge excitation in nanoscale magnetic disks

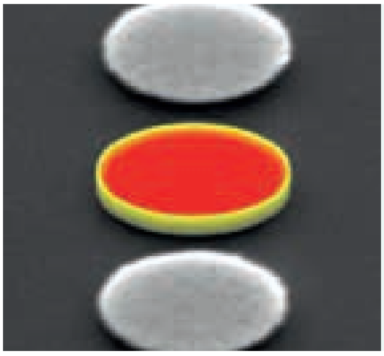
Physical Review Letters **115**, 187403 (2015)

**A. Berger,** R. Alcaraz de la Osa, **A. K. Suszka, M. Pancaldi,** J. M. Saiz, F. Moreno, H. P. Oepen, and **P. Vavassori**

The study reports a massive increase of magneto-optical effects near the edges of nanoscale disks, where enhancements of over 1 000% can be produced. This novel observation was made possible by combining precise nanofabrication, ultra-sensitive magneto-optical measurements, and modeling of magneto-optical effects in nanoscale confined geometries. This combination not only allowed for the observation of these strong enhancements, but also enabled the identification of the underlying physical phenomena that drive these edge-excitation effects.

Magneto-optics is a crucial characterization and detection technique for materials and devices. Hereby, the technique benefits from its high sensitivity and its compatibility with almost any environment due to its contact-free nature. Recently, numerous efforts have been made to pair magneto-optics with plasmonics to achieve even higher sensitivities in designer materials or applications. The present work now demonstrates that nanofabrication and nanoshape design allow for an increase and tunability of magneto-optical effects that is completely independent from optical or plasmonic resonances and does not depend on the photon energy of the exciting radiation, making it widely applicable. Specifically, this combined experimental and modeling study shows that in disk shaped samples a magneto-optical response can be generated that is massively enhanced at the edges, leading to a "ring of fire" for the magneto-optical effect as being shown in the figure below.

In general, magneto-optical effects are caused by the quantum-mechanical spin-orbit interaction and its influence on the electronic band structure. Correspondingly, magneto-optics is strongly associated with materials properties that result from the electronic structure. The influence of sample geometry onto magneto-optical effects, on the other hand, has so far only been associated with optical resonances, but resonance independent effects that originate from the specific self-interaction of the magneto-optically induced radiation pattern have not been observed. The reason for this is the fact that such behavior is extremely localized and thus only observable for small nanoscale structures. We have succeeded in demonstrating that in such nanoscale structures geometry-induced effects can be extremely strong and they even can result in a doubling of the area averaged magneto-optical signal for a 100 nm diameter disk. Therefore, this new work opens up excellent nanoengineering opportunities towards enhanced and generally designed magneto-optical properties in nanomaterials.



Secondary electron microscopy image of one of the nanoscale engineered samples consisting of 400 nm diameter permalloy disks that were fabricated by means of electron-beam lithography. The center disk has the lateral distribution of the magneto-optical response superimposed as a color-coded image. The strongly enhanced edge-excitation of the magneto-optical response is visible here as a yellow rim structure.

6

# Characterization of collective ground states in single-layer $NbSe_2$

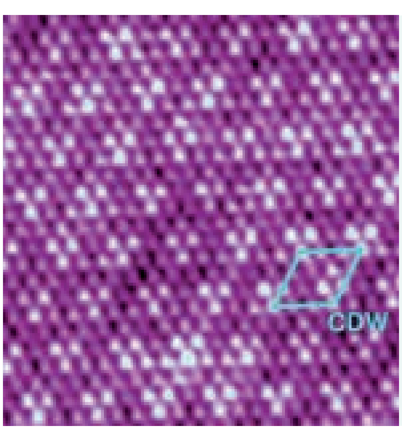
Nature Physics **12**, 92-97 [2016]

**M. M. Ugeda,** A. J. Bradley, Y. Zhang, S. Onishi, Y. Chen, W. Ruan, C. Ojeda-Aristizabal, H. Ryu, M. T. Edmonds, H. Tsai, A. Riss, S. Mo, D. Lee, A. Zettl, Z. Hussain, Z. Shen, and M. F. Crommie

We have demonstrated the coexistence of superconductivity and charge-density-wave (CDW) order in a single layer of $NbSe_2$, a model transition-metal dichalcogenide (TMD) metal. The demonstration that a single layer of $NbSe_2$ is a true two-dimensional (2D) superconductor is a breakthrough in the field of 2D materials. Very few 2D superconductors exist in nature, and single-layer $NbSe_2$ is the first among them that remains a superconductor in its isolated 2D form without the need of a special substrate. Furthermore, CDW order - spatial modulation of both the electron density and the atomic lattice (see figure below) – has been revealed to be a genuine 2D electronic phenomenon in $NbSe_2$.

Many-body interactions in solids are at the core of stunning collective electronic phenomena such as CDW order and superconductivity, which are found to exist in some TMD metals in their three-dimensional (3D) bulk form. In reduced dimensions, materials usually exhibit remarkable differences in their properties with respect to their 3D bulk counterparts due to quantum confinement effects. In bulk NbSe, CDW sets in at $T_{cdw}$ = 33 K and superconductivity sets in at $T_c$ = 7.2 K. Below 7.2 K these electronic states coexist but their microscopic formation mechanisms in bulk remain controversial after nearly four decades of intense research. Furthermore, the fate of its CDW and superconducting phases in the ultimate single-layer limit has also remained mysterious until now. We have characterized the electronic structure of a single layer of $NbSe_2$ directly grown on graphene, which experimentally confirms that $NbSe_2$ undergoes a reduction in the number of electronic bands involved in its collective phases (from three bands in bulk $NbSe_2$ to just one for single-layer $NbSe_2$). Despite significant changes in the $NbSe_2$ electronic structure upon dimensional reduction, the authors show that - in stark contrast to recent theoretical predictions - the CDW phase of single-layer $NbSe_2$ remains unaffected when the material is thinned down to the single-layer limit. The robust 2D character of the CDW in $NbSe_2$ enables to experimentally rule out two well-known mechanisms proposed to explain the origin of the CDW in $NbSe_2$. On the contrary to the CDW phase, the material remains a superconductor although with a critical temperature $T_c$ = 1.9 K, a significant departure from the behavior of bulk $NbSe_2$ ($T_c$ = 7.2 K).

In summary, these results paint a clear picture of the effects of reduced dimensionality on the CDW and superconducting phases of a model strongly correlated system. This creates exciting new opportunities for directly exploring the interplay between superconductivity and other competing collective phases in 2D.




Atomically resolved STM image of the $NbSe_2$ surface showing CDW modulation.

7

# Enhanced configurational entropy in high-density nanoconfined bilayer ice

Physical Review Letters **116**, 085901 (2016)

**F. Corsetti, J. Zubeltzu, and E. Artacho**

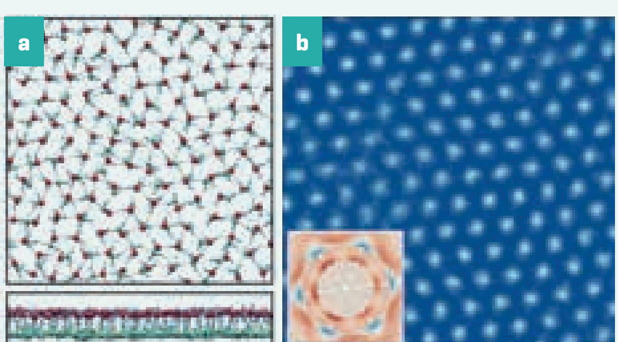
A very intriguing new phase of ice is found for water confined to a film of one nanometer across. Unlike what observed in other known phases of ice, this one displays an unprecedented simplicity, with oxygen atoms arranging in a triangular lattice, as in a two-dimensional layer of closed packed spheres. The key is the surprising fact that under certain conditions the oxygen atoms freeze while the hydrogen atoms do not.

In addition to being very important for life and for science, water is an incredibly surprising liquid. It displays a very large number of anomalies, starting with the well-known fact that ice floats in water. These anomalies stem from the peculiar structure of the water molecule, its tendency to form weak bonds with other molecules along tetrahedral directions, and the subtle interplay between these bonds and other weaker interactions among molecules.

But what happens when confining it to nanoscale dimensions? This is not an idle question; nano-confined water is found between organelles and macromolecules in living cells, potentially affecting their behaviour. It is now suspected that some properties of important objects in molecular biology depend crucially on the behaviour of water in the tiny spaces left by such objects.

We started by asking how is water in a simple, featureless nanoconfined environment. What would be its behaviour if the confining walls were neutral. This would allow us to characterize its intrinsic tendencies under confinement. Of course, in a real setting water molecules will interact with whatever confines it, but we think it is important to distinguish what behaviors are induced by the wall from those intrinsic ones.

Having established such ideal walls, we started by exploring the ice phases that arise by computer simulation (from first principles). Among other interesting but complicated ice phases, we found something absolutely unexpected: an ice of astonishing simplicity, reflecting the structure that is obtained when packing a layer of marbles on a table, a triangular lattice (see panel b in the figure). Interestingly, if one looks at it in an instantaneous snapshot (panel a) it does not show that structure at all (previous researchers talked about amorphous layers when seeing such snapshots); but if one lets it evolve, the hydrogen atoms wash out of the picture and the oxygen atoms end up displaying that simple structure. Further analysis showed that although oxygens were frozen, hydrogens were not. This peculiar "being frozen but not quite so" is the key for the simple arising from the complex in this case.




The structure of nanoconfined ice from molecular-dynamics simulations in its triangular phase. (a) Instantaneous snapshot, shown parallel (top) and perpendicular (bottom) to the confinement direction. The oxygens in the two layers are colored differently to help visualization. (b) Oxygen positions averaged over 10 nanoseconds. The inset shows the average nearest-neighbor positions with respect to a central molecule, including H atoms (red) and O atoms (blue).

8

# Real-space mapping of tailored sheet and edge plasmons in graphene nanoresonators

Nature Photonics **10**, 239-243 (2016)

**A.Y. Nikitin, P. Alonso-Gonzalez, S. Velez, S. Mastel,** A. Centeno, A. Pesquera, A. Zurutuza, **F. Casanova, L. E. Hueso,** F. H. L. Koppens, and **R. Hillenbrand**

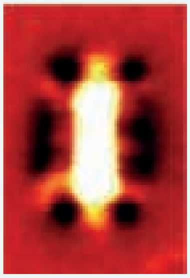
The coupling of light with charge oscillations – called plasmons – in graphene allows for squeezing light into nanoscale dimensions. Using our state-of-the-art near-field microscope to study graphene nanostructures, we obtained the first images of resonating graphene plasmons that exhibit record-small mode volumes. With the help of theory, we could identify two types of plasmons - edge and sheet modes - propagating either across the nanostructures or along their edges. The edge plasmons are unique for their ability to channel electromagnetic energy in one dimension. This work opens new opportunities for ultra-small and efficient photodetectors, sensors, and other photonic and optoelectronic nanodevices.

The wavelength of light captured by a graphene sheet – a monolayer sheet of carbon atoms - can be shortened by a factor of up to 100 compared to light propagating in free space. As a consequence, this light propagating along the graphene sheet - called graphene plasmon - requires much less space. For that reason, photonic devices can be made much smaller. The plasmonic field concentration can be further enhanced by fabricating graphene nanostructures acting as nanoresonators for the plasmons. The enhanced fields have been already applied for enhanced infrared and terahertz photodetection or infrared vibrational sensing of molecules, among other applications.

The future development of efficient devices based on graphene plasmonic nanoresonantors will critically depend on a precise understanding and control of the plasmonic modes inside them. For that reason, we performed real-space imaging of graphene nanoresonators (disks and rectangles) with a near-field microscope.

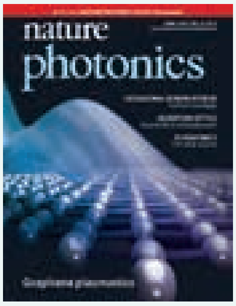
We observed a large diversity of plasmonic contrasts, which could be identified by theoretical modeling of the graphene nanoresonators and the near-field imaging process. The individual plasmonic modes could be separated into two different classes. The first class of plasmons – "sheet plasmons" - can exist "inside" graphene nanostructures, extending over the whole area of the graphene. Conversely, the second class of plasmons – "edge plasmons" – can exclusively propagate along the edges of graphene nanostructures, leading to whispering gallery modes in disk-shaped nanoresonators or Fabry-Perot resonances in graphene nanorectangles due to reflection at their corners. The edge plasmons are much better confined than the sheet plasmons and, most importantly, they transfer the energy only in one dimension. The real-space images reveal dipolar edge modes with a mode volume that is 100 million times smaller than a cube of the free-space wavelength.

We also measured the dispersion (energy as a function of momentum) of the edge plasmons based on the near-field images, which reveals a shortened wavelength of edge plasmons compared to sheet plasmons. Because of their unique properties, edge plasmons could be a promising platform for coupling quantum dots or single molecules in future quantum optoelectronic devices.



200 nm

Near-field image of a rectangle graphene nanoresonator.




Scanning near-field optical microscopy reveals the structure of plasmon sheet and edge modes in graphene disk and rectangular nanoresonators.

9

# Nanopatterning reconfigurable magnetic landscapes via thermally assisted scanning--probe lithography

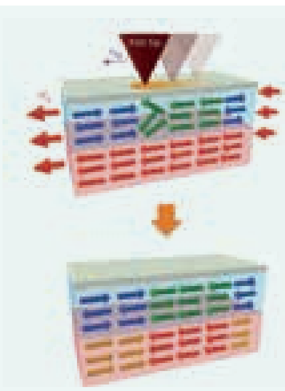
Nature Nanotechnology **11**, 545–551 [2016]

E. Albisetti, D. Petti, **M. Pancaldi,** M. Madami, S. Tacchi, J. Curtis, W. P. King, A. Papp, F. G. Csaba, W. Porod, **P. Vavassori,** E. Riedo and R. Bertacco

Tools for controlling magnetism at the nanoscale are crucial for the development of new paradigms in optics, electronics, and spintronics.

A novel approach, called thermally assisted magnetic scanning probe lithography, has been demonstrated for designing fully reconfigurable magnetic nanopatterns whose properties and functionality can be programmed and reprogrammed on-demand. The method is based on thermal scanning probe lithography and uses a hot nanotip to perform a highly localized field heating and cooling in antiferromagnetic and ferromagnetic thin films. The hot tip is then used, together with an externally applied magnetic field, to align the spins in the material in any desired direction with nanoscale resolution, in a reversible manner and without changing the film chemistry and topography.

This novel approach offers researchers the opportunity to control magnetism at the nanoscale as never before. This ability can be used to draw a novel class of magnetic metamaterials that will open the way for the development of innovative devices for information processing based on logic cells as well as on magnonic structures for the propagation and manipulation of spin waves (spin waves are propagating dynamical disturbances of the magnetization in a material). As a demonstrative application in this sense, we used this novel methodology to draw reconfigurable channels and networks in a continuous film, where spin waves can propagate and interfere. These demonstrative examples are particularly significant since a new generation of computing and sensing devices can be fabricated based on the propagation of spin waves instead of the more conventional electric current.




**Left panel.** Schematic of the operation principle: a hot nanotip performs a highly localized field heating and cooling in antiferromagnetic and ferromagnetic thin films; the spins in the material are aligned in any desired direction with nanoscale resolution by a momentary external magnetic field applied during the process.
**Right panel.** Cover image with an artist's impression of the excitation and propagation of spin waves in a magnonic conduit patterned with the proposed technique.

10

# A simple two-state protein unfolds mechanically via multiple heterogeneous pathways at single-molecule resolution

Nature Communications **7**, 11777 (2016)

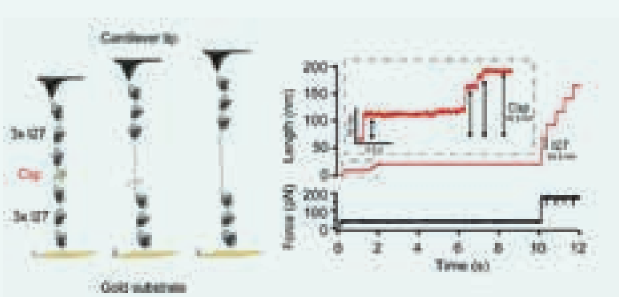
**J. Schoenfelder, R. Perez-Jimenez,** and V. Munoz

Using single-molecule force spectroscopy (SMFS) combined with steered molecular dynamics (SMD) simulations we find a highly complex mechanical unfolding behaviour of the cold shock protein B (Csp) from Thermotoga Maritima. This behavior contrasts with the simple two-state unfolding of Csp found by experiments using chemical denaturant. Our paper reflects that mechanical force can drive the unfolding of Csp from a simple to a heterogeneous unfolding behaviour.

Decoding the mechanism by which a protein folds into its 3D structure would have a deep impact into many fields of modern life science. While protein folding theory and simulation predict a highly heterogeneous protein folding process, detecting such complexity experimentally has remained elusive even when using methods with remarkable improved time, structural, or single-molecule resolution. Here we investigate the mechanical unfolding of Csp, a typical example for a simple two-state folder, using SMFS with the atomic-force microscope (AFM).

We construct a so-called polyprotein containing the Csp and 6 titin I27 domains, which act as a molecular fingerprint. The polyprotein is then adsorbed on a gold surface, and an AFM cantilever is used to apply mechanical forces in the low pN range. We first characterize the mechanical unfolding behaviour of Csp using different AFM modes and force, and then we show that with different constant forces between 20 and 80 pN, Csp can unfold via up to 4 intermediates.

Finally, by conducting an SMD simulation we can confirm the mechanical unfolding of Csp through intermediates.




Schematic representation of the mechanical unfolding of the engineered polyprotein consisting of one Csp and six titin I27 domains using AFM. On the right a 40 pN constant-force experimental trace is shown, revealing the unfolding of Csp through three intermediates.

# Highlighted Grants

# ERC

The European Research Council (ERC) supports individual researchers of any nationality and age who wish to pursue their frontier research. The ERC encourages in particular proposals that cross disciplinary boundaries, pioneering ideas that address new and emerging fields, and applications that introduce unconventional, innovative approaches.

## TERATOMO

### Near-field spectroscopic nanotomography at infrared and terahertz frequencies

Rainer Hillenbrand

Start-date: **01/11/2010**

End-date: **31/10/2015**

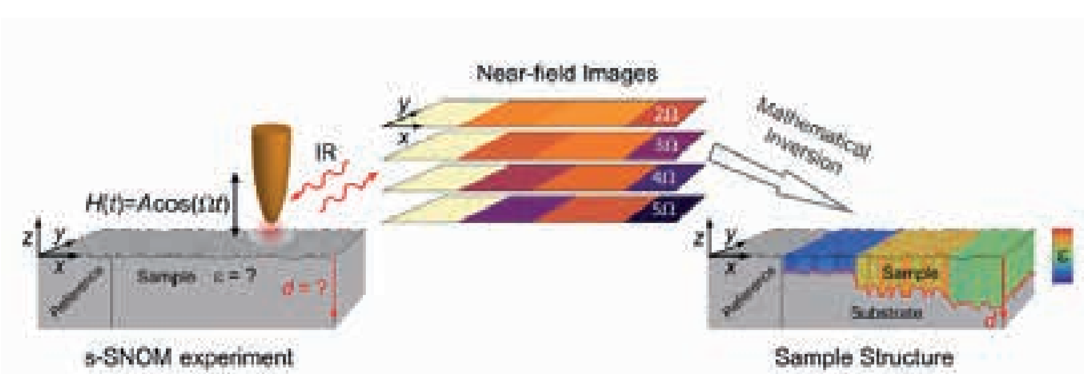
Funding: **1 455 600 €**

Fundamental understanding and engineering of nanoscale materials, biological structures, and building blocks for electrical and optical devices require advanced microscopy tools for mapping their local chemical, structural, and free-carrier properties. The core objectives of this project were thus to develop novel methods for spectroscopic and three-dimensional (3D) nanoimaging at infrared (IR) and terahertz (THz) frequencies.

Based on scattering-type scanning near-field optical microscopy (s-SNOM), we developed Fourier transform IR nanospectroscopy (nano-FTIR) with a spatial resolution of about 20 nm, which is more than 100 times improved compared to conventional far-field FTIR spectroscopy. We also invented and developed synthetic optical holography (SOH), allowing for rapid infrared nanoimaging. As a first step towards infrared nanotomography, we developed a simple, fast, and robust method for the quantitative reconstruction of the complex-valued permittivity and thickness of thin films based on nano-FTIR and s-SNOM data.

We envision nano-FTIR to open a new era in IR spectroscopy and to become a highly valuable tool for non-invasive nanoimaging of chemical composition in various fields of science and technology. As an application example, we demonstrated nanoscale analysis of the secondary structure of proteins in viruses, membranes, and insulin fibrils.

Employing s-SNOM and nano-FTIR to study graphene, we succeeded in visualizing IR graphene plasmons and their propagation for the first time. Because of their dramatically reduced wavelength and strong field confinement compared to IR radiation in free space, graphene plasmons could enable manifold novel sensing and detector applications.

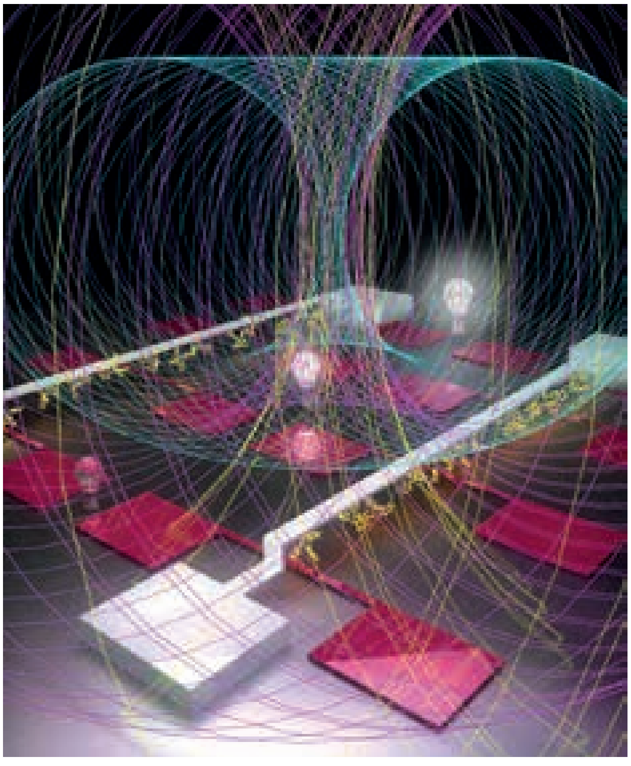


# SPINTROS

## Spin transport in organic semiconductors

Luis Hueso

Start-date: **01/04/2011**
End-date: **31/03/2016**
Funding: **1 283 400 €**



This project aimed at exploring new materials and functionalities in order to design and develop new electronic devices. The project focused on the design, manufacture, and study of electronic devices based on organic semiconductors.

Based on the potential of spintronics, this project has tried to understand and control spin transport in organic semiconductors, which play an important role in the development of the field as they have very small spin-orbit and hyperfine interactions, which lead to very long spin coherence times and make them ideal for spin transport.

To achieve this ambitious objective a multidisciplinary approach has been employed, merging materials science, electronics, and physics. First, the unique combination of ferromagnetic spin-polarized injectors and OSC spin transporters, especially their energetic and magnetic interactions at the interface, was studied. At the same time, optimized organic field-effect transistors (OFET) with nanometer channel lengths were created, in order to understand spin transport in a controllable fashion. Thanks to this device it has been possible to quantify the spin coherence length of OSC and to control spin transport either by external (magnetic or electric field) or internal (crystallographic) effects. Finally, spin single molecular FETs were produced and characterized to explore effects inaccessible in other transport regimes.

# FET Open

FET (Future and Emerging Technologies) Open is a european program under Horizon 2020, which is the largest EU program for research and innovation ever. The ambition is for the FET Open projects to help Europe grasp leadership early on in promising future technology areas and in so doing renew the basis for future European competitiveness and growth.

## 2D-INK

### Developing inks of novel two-dimensional (2D) semiconducting materials for low-cost large-area fabrication processes

Start-date: **01/01/2016** End-date: **31/12/2018**

Partners: **7 universities, 1 research organization, and 1 industry partner**

Total Funding: **2 962 661 €** Contribution to nanoGUNE: **297 600 €**

2D-INK is targeted at developing inks of novel 2D semiconducting materials for low-cost large-area fabrication processes on insulating substrates through a new methodology, which will exceed the properties of state-of-the-art graphene and graphene-oxide based inks.

Achieving this would represent an important step forward in the processing of 2D semiconducting materials and would provide the key parameters for fabricating the next generation of ultrathin electronic appliances and exploring their potential over other scientific and technological disciplines, such as sensing, photonics, energy storage and conversion, spintronics, etc.

# Initial Training Networks

Initial training networks of the European Union (EU) bring together universities, research centers, and companies from different countries worldwide to train a new generation of researchers. The funding boosts scientific excellence and business innovation, as well as the career prospects of researchers through developing their skills in entrepreneurship, creativity, and innovation.

## Q-NET Quantum NanoElectronics Training

Start-date: **01/04/2011** End-date: **31/03/2015**
Partners: **5 universities, 2 research organizations, and 1 industry partner**
Total funding: **4 022 055 €** Contribution to nanoGUNE: **454 959 €**
**www.quantum-net.org**

The Q-NET project represents a European network of experts providing state-of-the-art training for young researchers in the general field of experimental, applied, and theoretical quantum nanoelectronics.

Improving our conceptual understanding of quantum electron transport at the nanoscale is needed for enabling the emergence of "Beyond C-MOS" nanoelectronics devices. This implies a combined effort in the topics of spintronics, molecular electronics, single electronics, quantum dots and nanowires, and nano-cooling. Rapidly-progressing studies on quantum nanoelectronics rely on state-of-the-art technologies of nanofabrication, electron and near-field microscopies, transport measurements under extreme conditions (low temperatures, magnetic field, radio-frequency irradiation), and theoretical calculations.

## SPINOGRAPH Spintronics in Graphene

Start-date: **01/09/2013** End-date: **31/08/2017**
Partners: **4 universities, 3 research organizations, and 2 industry partners**
Total funding: **3 783 986 €** Contribution to nanoGUNE: **458 863 €**
**www.spinograph.org**

Spintronics stands for electronics based on the electron-spin degree of freedom. The huge success of spintronics in metals, which started from the pioneering discovery of giant magnetorresistance (GMR), has revolutionized the magnetoelectronics industry. Exploration of spin effects in other types of materials is leading to an array of fascinating physical phenomena and holds the promise of future breakthroughs. The discovery of graphene, the first truly two-dimensional (2D) crystal, together with a remarkable progress in the fabrication of graphene devices, has naturally led to the exploration of hybrid graphene/ferromagnetic devices for the investigation of spintronics in graphene.

## THINFACE Thin-Film Hybrid Interfaces: a training initiative for the design of next-generation energy devices

Start-date: **01/09/2013** End-date: **31/08/2017**
Partners: **6 universities, 1 research organization, and 2 industry partners**
Total funding: **3 873 668 €** Contribution to nanoGUNE: **467 938 €**
**www.thinface.eu**

Our main concern here is to push forward new ideas and techniques within the field of hybrid thin films for new energy devices. The approach focuses on sustainable energy solutions, which represent one of our most challenging societal issues. To solve these challenges in a multidisciplinary and intersectorial network gives outstanding possibilities for the young researchers involved.

In five distinct workpackages we investigate the thin-film formation, the optimization of interfaces, and the lifetime and stability of the devices.

# Graphene Flagship

With a budget of 1 billion €, the Graphene Flagship represents a new form of joint, coordinated research on an unprecedented scale, forming Europe's biggest ever research initiative.

The Graphene Flagship is tasked with bringing together academic and industrial researchers to take graphene from the realm of academic laboratories into the European society in the space of 10 years, thus generating economic growth, new jobs, and new opportunities.

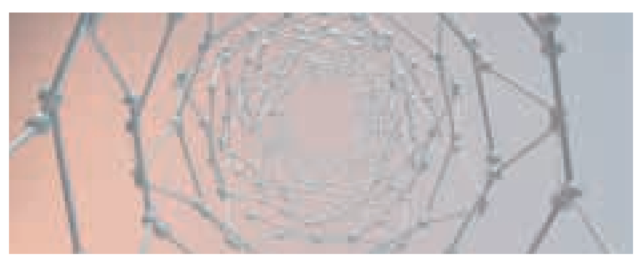
Partners: **150 academic and industrial research groups of 23 countries and close to 50 associate members**
**www.graphene-flagship.eu**

## FP7 GRAPHENE

### Graphene-based revolutions ICT and beyond

Start-date: **01/10/2013** End-date: **31/03/2016**
Total funding: **54 000 000 €** Contribution to nanoGUNE: **330 114 €**

This project aimed at taking graphene and related layered materials from a state of raw potential to a point where they can revolutionize multiple industries – from flexible, wearable, and transparent electronics to high-performance computing and spintronics. The flagship is organized in 11 scientific and technological work packages that target breakthroughs in information and communication technologies, with others providing the necessary support in materials and production technologies, and extending the impact of the flagship to other areas such as energy and transport.

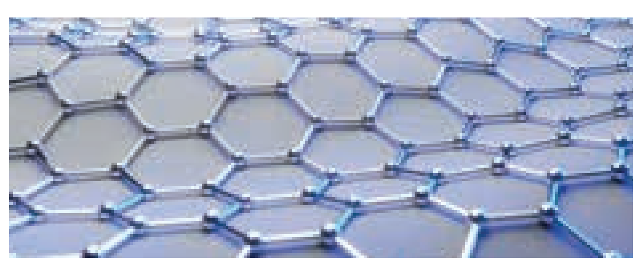


## H2020 GrapheneCore 1

### Graphene-based disruptive technologies

Start-date: **01/04/2016** End-date: **31/03/2018**
Total funding: **89 000 000 €** Contribution to nanoGUNE: **368 000 €**

This project is the second in the series of EC-funded parts of the Graphene Flagship. As time goes, the center of gravity of the Flagship moves towards applications, which is reflected in the increasing importance of the higher-levels of the value chain. In this first core project the main focus is on components and initial system level tasks. It is divided into four divisions, which in turn comprise three to five work packages on related topics. A fifth external division acts as a link to the parts of the Flagship that are funded by the member states and associated countries or by other funding sources.



# Conferences and Workshops

## 2015

nanoGUNE Anniversary Workshop
[30/01/2015]
Organizer: nanoGUNE
80 participants

ELECspin 2015
[12-13/03/2015]
International Workshop on Organic and Graphene Electronics and Spintronics
Organizers: ICMAB-CSIC, University of Strasbourg, nanoGUNE
90 participants

Imaginenano 2015
[10-13/03/2015]
The largest European event on nanoscience and nanotechnology
Organizers: Phantoms Foundation, nanoGUNE, DIPC, CFM, UPV/EHU, BEC
1 500 participants

## 2016

1st nanoGUNE PhD Workshop
[31/01/2016]
Organizers: nanoGUNE
85 participants

Coating-related Technologies Workshop
[21/04/2016]
Organizers: Tecnalia and nanoGUNE
35 participants

Nanotransfer Special Seminar
[28/06/2016]
Development and implementation of nanoscience and nanotechnology in the Basque Country
Organizers: Orkestra and nanoGUNE
59 participants

Novel Applications of Graphene and 2D Materials Workshop
[18/10/2016]
Organizers: nanoGUNE and Tecnalia
40 participants

Nanolito 2016
[20-21/10/2016]
Functional nanomaterials
Organizer: nanoGUNE
28 participants

1st Meeting of the Spanish Thematic Network of Virological Physics
[15-16/12/2016]
Organizers: nanoGUNE and UAM
28 participants

# Invited Talks

## 2015

**Two-dimensional optics with graphene plasmons launched by metal antennas**
05/01/2015, Rainer Hillenbrand
Nanometa 2015, Seefeld (Germany)

**Nanoscale wetting of tobacco mosaic virus**
25/01/2015, Alexander Bittner
Physical Virology 2015, Ventura (USA)

**On the origin and switching of a two-dimensional electron gas under a thin perovskite film**
12/02/2015, Emilio Artacho
2015 nanoPortugal Conference, Oporto (Portugal)

**Magneto-plasmonic nanoantennas: news and views**
17/02/2015, Paolo Vavassori
4th Italian Conference on Magnetism, Bologna (Italy)

**Nanoimaging and manipulation of plasmons in graphene**
02/03/2015, Rainer Hillenbrand
APS March Meeting, San Antonio (USA)

**Hanle measurements in metals: spin accumulation or novel magnetoresistance effect**
03/03/2015, Felix Casanova
APS March Meeting, San Antonio (USA)

**Infrared nanoscopy and nanospectroscopy - From plasmons to proteins**
08/03/2015, Rainer Hillenbrand
2015 Optical Terahertz Science and Technology Conference (OTST), San Diego (USA)

**Electron-beam lithography: spintronics and nanooptics applications**
10/03/2015, Luis Hueso
Imaginenano 2015, Bilbao (Spain)

**Hybrid inorganic-(bio)organic materials through molecular--level modification with vapor-phase infiltration**
10/03/2015, Mato Knez
Imaginenano 2015, Bilbao (Spain)

**Magneto-plasmonic nanoantennas based metamaterials**
10/03/2015, Paolo Vavassori
Imaginenano 2015, Bilbao (Spain)

**Protein and peptide chemistry for nanotechnology: biomineralization, crystallization, patterning, and self-organization**
11/03/2015, Mitshuhiro Okuda
Imaginenano 2015, Bilbao (Spain)

**Mechanical reinforcement of (bio)organic materials with inorganics through vapor-phase processing**
11/03/2015, Mato Knez
SPIE Smart Structures NDE, San Diego (USA)

**Fabrication of individual nanomagnets and nanomagnet arrays by Focused-Electron-Beam Induced Deposition (FEBID)**
15/03/2015, Andreas Berger
79 DPG Annual Meeting and DPG Spring Meeting,Berlin (Germany)

**Nanoscale spectroscopic and microscopic characterization**
22/03/2015, Rainer Hillenbrand
ACS Spring Meeting 2015, 249th American Chemical Society National Meeting & Exposition, Denver (USA)

**Two-dimensional optics with graphene plasmons**
08/04/2015, Rainer Hillenbrand
Discussions on Nano & Mesoscopic Optics 2015, El Chalten (Argentina)

**Light emission from a "hot" tunneling junction**
09/04/2015, Jose Ignacio Pascual
Discussions on Nano & Mesoscopic Optics 2015, El Chalten (Argentina)

**Two-dimensional nanooptics on graphene**
24/04/2015, Pablo Alonso-Gonzalez
ENM Meeting on Optoelectronics, Beijing (China)

**Two-dimensional optics with graphene plasmons launched by metal antennas**
12/05/2015, Rainer Hillenbrand
E-MRS Spring Meeting and Exhibit 2015, Lille (France)

**Background and context to ESL, general aims of the project**
01/06/2015, Emilio Artacho
CECAM Electronic Structure Library Coding Workshop: Utilities Toolbox, Lausanne (France)

**Nanostructured mixed transition metal spinel oxide thin films as efficient electrocatalysts**
03/06/2015, Marie Sylvie Morin
International Workshop on Electrochemistry of Electroactive Materials, Bad Herrenalb (Germany)

**Porous composites and wetting on the nanoscale**
14/06/2015, Alexander Bittner
XXIII International Symposium on Bioelectrochemistry and Bioenergetics, Malmo (Sweden)

**Hybrid inorganic-(bio)organic materials through molecular level modification with vapor-phase infiltration**
14/06/2015, Mato Knez
98th Canadian Chemistry Conference and Exhibition, Ottawa (Canada)

TDDFT with atomic orbitals for non-adiabatic simulations: successes and challenges
**17/06/2015, Emilio Artacho**
CECAM Workshop on Multi-Scale Modelling of Matter Under Extreme Irradiation, Dublin (Ireland)

Structural analysis of cage-shaped protein Dps for the fabrication of rare-earth oxide nanoparticles
**19/06/2015, Mitsuhiro Okuda**
The 4th International GIGAKU Conference, Nagaoka (Japan)

Nanoscale patterning based on biomolecular assembly
**22/06/2015, Mitsuhiro Okuda**
Eight International Conference on Molecular Electronics and Bioelectronics, Tokyo (Japan)

Spin transport in molecular films: beyond conventional spin valves
**06/07/2015, Luis Hueso**
20th International Conference on Magnetism, Barcelona (Spain)

Step coverage, optics, and nanomaterials
**07/07/2015, Mato Knez**
Summer School on Atomic Layer Deposition, Brescia (Italy)

Resistive switching, modeling, and devices
**07/07/2015, Pablo Stoliar**
Barcelona Nanocluster - RBNI Symposium, Barcelona (Spain)

Magnetic molecules on the surface of a superconductor
**14/07/2015, Jose Ignacio Pascual**
XXXV Reunión Bienal de la Real Sociedad Española de Física, Gijon (Spain)

Two-dimensional nanooptics with graphene plasmons
**16/07/2015, Pablo Alonso-Gonzalez**
XXXV Reunión Bienal de la Real Sociedad Española de Física, Gijon (Spain)

Applications of aberration corrected TEM/STEM to nanomaterials characterization
**20/07/2015, Andrey Chuvilin**
International Summer-School Workshop on Transmission Electron Microscopy of Nanomaterials 2015, Cadiz (Spain)

Tocando y midiendo el "sabor" de los átomos: microscopía y espectroscopía con resolución atómica
**21/07/2015, Jose Ignacio Pascual**
Curso "Nanotecnología: La revolución del siglo XXI", Santander (Spain)

Nanomechanics of viral and bacterial infections
**22/07/2015, Raul Perez-Jimenez**
II. Escuela de Biología Molecular y Celular Integrativa / Biología Sintética-Ingeniería de Sistemas Biológicos, Santander (Spain)

ALD for technologies beyond electronics: chances and challenges
**29/07/2015, Mato Knez**
15th International Conference on Atomic Layer Deposition, Portland (USA)

On the origin of the two-dimensional electron gas at the interface between insulating perovskites
**30/07/2015, Emilio Artacho**
Workshop on Superconductivity on the Verge, Leiden (The Netherlands)

Spin-dependent phenomena in magnetic insulator/metal systems
**30/07/2015, Felix Casanova**
Gordon Research Conference on Spin Dynamics in Nanostructures, Hong Kong (China)

Two-dimensional nanooptics with graphene plasmons
**04/08/2015, Pablo Alonso-Gonzalez**
The 6th International Conference on Metamaterials, Photonic Crystals, and Plasmonics, New York (USA)

Optical excitation of graphene plasmons
**05/08/2015, Pablo Alonso-Gonzalez**
The 6th International Conference on Metamaterials, Photonic Crystals, and Plasmonics, New York (USA)

Infrared near-field nanospectroscopy: chemical identification, nanoellipsometry, and nanotomography
**09/08/2015, Alexander Govyadinov**
SPIE Optics & Photonics, San Diego (USA)

Optical, ion, and electron microscopies – a synergy of combined application
**20/08/2015, Andrey Chuvilin**
Third Asian School-Conference on Physics and Technology of Nanostructured Materials 2015, Vladivostok (Russia)

Molecular electronics
**24/08/2015, Luis Hueso**
European School on Nanosciences & Nanotechnologies 2015, Grenoble (France)

Fundamental aspects of atomic layer deposition
**30/08/2015, Mato Knez**
CRC Summer School, Erkner (Germany)

Near-field optics
**31/08/2015, Rainer Hillenbrand**
Frontiers in Nanophotonics 2015, Monte Verita (Italy)

Functionalization of materials with nanoscale coatings
**01/09/2015, Mato Knez**
CRC Summer School, Erkner (Germany)

**Multifunctional magneto-plasmonic metamaterials**
**01/09/2015, Paolo Vavassori**
EMN Spain Meeting - Energy Materials Nanotechnology, Donostia - San Sebastian (Spain)

**Magnetic molecules on the surface of a superconductor**
**08/09/2015, Jose Ignacio Pascual**
5th European Conference on Molecular Magnetism, Zaragoza (Spain)

**Nano-FTIR spectroscopy of individual protein complexes**
**09/09/205, Rainer Hillenbrand**
16th European Conference on the Spectroscopy of Biological Molecules, Bochum (Germany)

**Accessing kinetics of structural rearrangements in graphene via direct atomic imaging**
**10/09/2015, Andrey Chuvilin**
4th Joint Congress of the Portuguese and Spanish Microscopy Societies 2015, Porto (Portugal)

**Optimization of supercapacitor electrodes by atomic layer deposition**
**10/09/2015, Mato Knez**
5th International Workshop on Smart Materials and Structures, Marrakech (Morocco)

**Magnetoplasmonic nanoantennas metamaterials: news and views**
**10/09/2015, Paolo Vavassori**
Trends in Nanotechnology 2015, Toulouse (France)

**Elementary excitations in molecular junctions induced inelastic tunneling electrons**
**15/09/2015, Jose Ignacio Pascual**
International Conference on "Single-Molecule Electronics", Regensburg (Germany)

**Nanoscale assembly at the tobacco mosaic virus**
**16/09/2015, Alexander Bittner**
E-MRS Fall Meeting 2015, Warsaw (Poland)

**Optics with magnetoplasmons for sensing**
**12/10/2015, Paolo Vavassori**
"Core to Core" Kick-off Workshop on Magnetochiral Materials, Glasgow (UK)

**The role of plasmonic and geometric excitation modes in magneto-optics**
**16/11/2015, Andreas Berger**
EMN Ultrafast Meeting 2015, Las Vegas (USA)

**Nanoimaging and manipulation of plasmons in graphene**
**01/12/2015, Rainer Hillenbrand**
MRS Fall Meeting & Exhibit, Boston (USA)

**Electronics and optoelectronics in organic 2D layered materials hybrids**
**03/12/2015, Saul Velez**
III. Workshop on 2D Materials, Valencia (Spain)

**Nanoimaging of graphene plasmons and hyperbolic phonon polaritons in boron nitride**
**10/12/2015, Rainer Hillenbrand**
Lighting the Way Symposyum, Amsterdam (The Netherlands)

**Infrared nanoscopy and nanospectroscopy - from vibrational spectroscopy to plasmon mapping**
**16/12/2015, Rainer Hillenbrand**
The International Chemical Congress of Pacific Basin Societies 2015, Honolulu (USA)

**From nano-FTIR spectroscopy toward infrared nanotomography**
**17/12/2015, Rainer Hillenbrand**
The International Chemical Congress of Pacific Basin Societies 2015, Honolulu (USA)

## 2016

**Perspectives of magneto-plasmonic nanoantennas based metamaterials**
**10/01/2016, Paolo Vavassori**
13th Joint MMM-Intermag, San Diego (USA)

**Spin transport in molecular films: beyond conventional spin valves**
**10/01/2016, Luis Hueso**
13th Joint MMM-Intermag, San Diego (USA)

**Resonant enhancement of magneto-optics via surface Bragg plasmon modes coupling in 2D magnetoplasmonic crystals**
**12/01/2016, Paolo Vavassori**
Mini Symposium on Plasmonics, Uppsala (Sweden)

**Probing bandgap renormalization, excitonic effects, and interlayer coupling in 2D transition metal dichalcogenide semiconductors**
**13/01/2016, Miguel M. Ugeda**
GEFES 2016, Cuenca (Spain)

**Universal electric-field driven resistive transition in narrow-gap Mott insulators**
**13/01/2016, Pablo Stoliar**
GEFES 2016, Cuenca (Spain)

**Infrared nanospectroscopy of biological materials**
**13/01/2016, Rainer Hillenbrand**
The 51st Winterseminar, Klosters (Germany)

**Atomic engineering of nanostructures in STM**
**14/01/2016, Deung Jang Choi**
GEFES 2016, Cuenca (Spain)

**Low-dimensionality effects in single layers of transition metal dichalcogenides**
**22/02/2016, Miguel M. Ugeda**
Spinograph Workshop 2016, Madrid (Spain)

**Infrared nanoscopy and nano-FTIR spectroscopy by elastic light scattering from a scanning probe tip**
**06/03/2016, Rainer Hillenbrand**
80. Jahrestagung der DPG und DPG-Frühjahrstagung, Regensburg (Germany)

**Nanoimaging of polaritons in two-dimensional materials**
**10/03/2016, Rainer Hillenbrand**
Nanolight 2016, Benasque (Spain)

**Water at the tobacco mosaic virus**
**13/03/2016, Alexander Bittner**
251st American Chemical Society National Meeting & Exposition, San Diego (USA)

**Nanoimaging and manipulation of polaritons in graphene and boron nitride**
**15/03/2016, Rainer Hillenbrand**
Nanospain 2016, Logroño (Spain)

**Single-molecule spintrometry: measuring and tuning the spin states of a molecule with STM**
**18/03/2016, Jose Ignacio Pascual**
Nanospain 2016, Logroño (Spain)

**Nano-FTIR spectroscopy of individual protein complexes**
**04/04/2016, Rainer Hillenbrand**
SPIE Photonics Europe 2016, Brussels (Belgium)

**Nanoimaging and manipulation of polaritons in graphene and boron nitride**
**09/04/2016, Rainer Hillenbrand**
The 4th International Conference on Frontiers of Plasmonics, Hefei (China)

**Switching the magnetism of atoms and molecules with hydrogen atoms**
**11/04/2016, Jose Ignacio Pascual**
International SFB658 Symposium: Molecular Switches and Functional Surfaces, Motzener See (Germany)

**Sputter deposition technology: achieving texture control and epitaxy**
**21/04/2016, Andreas Berger**
Surface Technologies Workshop, Donostia - San Sebastian (Spain)

**Exploring the magnetic properties of ferrite nanoparticles for the development of rare-earth free permanent magnets**
**05/05/2016, Alberto Lopez-Ortega**
Energy Materials Nanotechnology - Croatia Meeting 2016, Dubrovnik (Croatia)

**Scanning tunneling spectroscopy characterization of transition metal dichalchogenides**
**06/05/2016, Miguel M. Ugeda**
European Material Research Society Meeting 2016, Lille (France)

**IR and THz near-field nanoscopy of 2D materials**
**14/05/2016, Rainer Hillenbrand**
EMN Meeting on Terahertz, Donostia - San Sebastian (Spain)

**Manipulation of THz electromagnetic fields with graphene plasmons**
**15/05/2016, Alexey Nikitin**
EMN Meeting on Terahertz, Donostia - San Sebastian (Spain)

**Scientific and HPC challenges: simulations from first principles**
**16/05/2016, Emilio Artacho**
PRACE Spring School 2016 and E-CAM Tutorial on Molecular & Atomic Modeling, Dublin (Ireland)

**Water and nanoscale structures**
**19/05/2016, Alexander Bittner**
THINFACE Open Day, Madrid (Spain)

**Spin-orbitronics in metals**
**26/05/2016, Felix Casanova**
International Workshop TOP-SPIN 2, Groningen (The Netherlands)

**Chemistry on the surface of functional graphene nanoribbons**
**02/06/2016, Jose Ignacio Pascual**
9th European School on Molecular Nanoscience, Tordesillas (Spain)

**A two-dimensional field-effect spin transistor**
**02/06/2016, Luis Hueso**
9th European School on Molecular Nanoscience, Tordesillas (Spain)

**Large-scale density-functional calculations for energy**
**06/06/2016, Emilio Artacho**
CECAM Electronic Structure Library Coding Workshop, Zaragoza (Spain)

**Two-dimensional electron gases in oxides and the polarization of centro-symmetric insulators**
**08/06/2016, Emilio Artacho**
Workshop on Engineering Quantum Matter: From Understanding to Control, St. Andrews (UK)

**Mechanochemical evolution of the giant muscle protein titin as inferred from resurrected proteins**
**08/06/2016, Raul Perez-Jimenez**
PRODESTECH Meeting, Madrid (Spain)

**Mechanical force modulates the unfolding pathway of the cold-shock protein B from Thermotoga maritima, a simple two-state protein**
**09/06/2016, Jörg Schönfelder**
PRODESTECH Meeting, Madrid (Spain)

**Mechanochemical evolution of the giant muscle protein titin as inferred from resurrected proteins**
**16/06/2016, Raul Perez-Jimenez**
5th International Iberian Biophysics Congress, Porto (Portugal)

**Patterning magnetic nanostructures for resonant interaction with light: magnetoplasmonic crystals**
**19/06/2016, Paolo Vavassori**
9th International Symposium on Metallic Multilayers, Uppsala (Sweden)

**A two-dimensional field-effect spin transistor**
**22/06/2016, Luis Hueso**
POLYMAT SPOTLIGHT 2016: International Conference on Macromolecular Materials, Donostia - San Sebastian (Spain)

**Synthesis of functional nanostructures by atomic layer deposition**
**23/06/2016, Mato Knez**
Energy Materials Nanotecnology Meeting 2016, Prague (Czech Republic)

**Spin transport, spinterface, and photovoltaics in molecular films**
**29/06/2016, Luis Hueso**
ICSM2016, Guangzhou (China)

**Spin Hall effect in heavy metals: mechanisms, optimization, and related phenomena**
**11/07/2016, Felix Casanova**
International Conference on Spin Caloritronics, Utrecht (The Netherlands)

**Microscopía y espectroscopía con resolución nanoscópica: herramientas fundamentales para resolver los constituyentes de la materia**
**12/07/2016, Jose Ignacio Pascual**
Nanotecnología: luces y sombras del control de la materia a escala atómica, Santander (Spain)

**Real-space mapping of low-energy polaritons**
**12/07/2016, Rainer Hillenbrand**
Gordon Research Conference: From Plasmonic Fundamentals to Nanooptical Applications, Newry (USA)

**Magneto-plasmonics**
**13/07/2016, Paolo Vavassori**
School of Photonics 2016, Cortona (Italy)

**Electron-beam lithography and its application in spintronics**
**17/07/2016, Felix Casanova**
International Summer School on Nanofabrication and Transmission Electron Microscopy Characterization, Jaca (Spain)

**Competing effects at magnetic insulator/metal interfaces: magnetic gating, spin hall magnetoresistance, magnetic frustration, and magnon excitations**
**19/07/2016, Felix Casanova**
Workshop on Interfacial spintronics and spin waves, Donostia - San Sebastian (Spain)

**IR and THz near-field nanoscopy of two-dimendional materials**
**19/07/2016, Rainer Hillenbrand**
International Workshop on Terahertz Science, Nanotechnologies, and Applications, Erice (Italy)

**Why aberration correction in TEM is so good for carbon materials: from imaging atoms to measuring reaction kinetics**
**25/07/2016, Andrey Chuvilin**
Nanocarbon for Optics and Electronics School, Kaliningrad (Russia)

**Recent advances and perspectives of magnetoplasmonic nanomaterials**
**25/07/2016, Paolo Vavassori**
The 7th International Conference on Metamaterials, Photonic Crystals, and Plasmonics, Torremolinos (Spain)

**Accessing kinetics of structural rearrangements in graphene via direct atomic imaging**
**01/08/2016, Andrey Chuvilin**
5th Workshop on Nanocarbon Photonics and Optoelectronics, Imatra (Finland)

**Temperature-dependent magnetic depth profiles of epitaxial films with graded and oscillatory exchange coupling structure**
**26/08/2016, Lorenzo Fallarino**
8th Joint European Magnetics Symposia, Glasgow (UK)

**A two-dimensional field-effect spin transistor**
**31/08/2016, Luis Hueso**
NanoteC16 Carbon Nanoscience and Nanotechnology, Dublin (Ireland)

**Near-field mapping of chiral metasurfaces and spiral antennas**
**05/09/2016, Martin Schnell**
14th International Conference on Near-Field Optics, Nanophotonics, and Related Techniques, Hamamatsu (Japan)

**Basis sets made of atomic-like orbitals**
**06/09/2016, Luis Hueso**
CECAM/Psi-k/CCP9 Graduate School, Daresbury (UK)

**Molecular electronics**
**16/09/2016, Luis Hueso**
European School on Nanosciences & Nanotechnologies 2016, Grenoble (France)

**A two-dimensional field-effect spin transistor**
**26/09/2016, Luis Hueso**
International Conference on Nanotechnology Applications, Valencia (Spain)

**Optimizing the functionality of hybrid materials by atomic-layer deposition**
**18/10/2016, Mato Knez**
3rd International Conference on ALD Applications & 2016 China ALD Conference, Suzhou (China)

**Spin Hall effect in heavy metals: mechanisms and optimization**
**23/10/2016, Felix Casanova**
International Workshop on Nano-Spin Conversion Science & Quantum Spin Dynamics, Tokyo (Japan)

**Mechanochemical evolution of the giant muscle protein titin as inferred from resurrected proteins**
**04/11/2016, Raul Perez-Jimenez**
Mechanical Forces in Physiology and Disease, CNIC Conference 2016, Madrid (Spain)

**Characterization of collective ground states in single-layer $NbSe_2$**
**06/11/2016, Miguel Moreno-Ugeda**
63rd AVS International Symposium and Exhibition, Nashville (USA)

**Characterization of collective ground states in single-layer $NbSe_2$**
**15/11/2016, Miguel M. Ugeda**
WEH628 Trends in Mesoscopic Superconductivity, Bad Honnef (Germany)

**Spin-optical molecular devices**
**16/11/2016, Luis Hueso**
European Conference on Molecular Spintronics, Bologna (Italy)

**Protein fibres and liquids: a nanoscale view**
**22/11/2016, Alex Bittner**
BioNano 2016, Krakow (Poland)

**Imaging thin water layers on single viruses**
**02/12/2016, Alex Bittner**
ESI/CECAM Workshop Water at Interfaces: From Proteins to Devices, Wien (Austria)

**Development and applications of biosupramolecule-nanoparticle composites**
**08/12/2016, Mitsuhiro Okuda**
The 3rd Nanobioceramic-Based Cell Function Control Technology Workshop, Nagaoka (Japan)

**Detecting and tuning the magnetism of individual molecules by STM**
**14/12/2016, Jose Ignacio Pascual**
Advanced Microscopy and Spectroscopy of Supramolecular and Macromolecular Systems on Surfaces Symposium, Hong Kong (China)

**Tobacco mosaic virus and water**
**15/12/2016, Alex Bittner**
I Reunión Red Temática de Física Virológica, Donostia - San Sebastian (Spain)

# Seminars

NanoGUNE organizes research seminars to be given by both nanoGUNE personnel and external invited speakers. All these seminars take place at the nanoGUNE seminar room and are announced at **www.nanogune.eu**

## 2015

**Ferroelectric multilayers as active substrates**
**12/01/2015, Matthew Dawber**
Stony Brook University (USA)

**Are there dead magnetic surface layers near dynamic phase transitions?**
**19/01/2015, Patricia Riego**
nanoGUNE

**Near-field mapping of nanoscale IR modes on FIB fabricated transmission lines**
**26/01/2015, Paulo Sarriugarte**
nanoGUNE

**Structural, chemical, and magnetic properties of surface supported graphene, hexagonal boron nitride, and organic molecules studied by local probes and photoemission spectroscopy**
**02/02/2015, Jens Brede**
Materials Physics Center (Spain)

**First-principles theory of flexoelectricity**
**16/02/2015, Massimiliano Stengel**
Instituto de Ciencia de Materiales de Barcelona (Spain)

**Challenges to the textbook picture in 2D topological insulator materials investigated by novel local probes**
**23/02/2015, Reyes Calvo**
nanoGUNE

**IOP Publishing: Maximizing the impact of your work**
**09/03/2015, Anna Demming**
IOP Publishing (UK)

**Surprising effects in the microwave response of magnetic nanoparticle structures**
**16/03/2015, Bob Camley**
University of Colorado (USA)

**NanoGUNE Colloquium: Yoga and the elasticity of titin - connecting science with life**
**17/03/2015, Julio M. Fernandez**
Columbia University (USA)

**Human-induced pluripotent stem cell for regenerative medicine and drug discovery**
**25/03/2015, Kiyoshi Ohnuma**
Nagaoka University of Technology (Japan)

**In-situ quantitative nanomechanical studies**
**25/03/2015, Rob Claasen**
Hysitron Inc. (USA)

**Study of ice crystal deposition and sublimation using environmental SEM**
**30/03/2015, Maria Cascajo**
nanoGUNE

**Modeling two-dimensional electron gases at ferroelectric thin films**
**13/04/2015, Pablo Aguado**
nanoGUNE

**First-principles reinvestigation of bulk $WO_3$**
**20/04/2015, Hanen Hamdi**
nanoGUNE

**The exotic optics of hyperbolic materials**
**27/04/2015, Edward Yoxall**
nanoGUNE

**E. coli fimbriae mechanochemichal characterization**
**04/05/2015, Alvaro Alonso**
nanoGUNE

**Assembly of graphene nanoribbons on surfaces**
**11/05/2015, Eduard Carbonell**
nanoGUNE

**Electronics and optoelectronics in an organic 2D layered material p-n junction**
**18/05/2015, Saul Velez**
nanoGUNE

**Water footprints in tip-sample force reconstruction from dynamic AFM in ambient conditions**
**01/06/2015, Annalisa Calo**
nanoGUNE

**Ancestral cellulases for bioenergy**
**08/06/2015, Nerea Barruetabeña**
nanoGUNE

The Physical Review journals and Physical Review Applied: An editor's introduction
**13/06/2015, Julie Kim-Zajonz**
American Physical Society (USA)

Spin transfer torques in magnetic materials
**15/06/2015, Andrew Kent**
New York University (USA)

Amorphous metals on the nanoscale: How and why?
**24/06/2015, Jan Schroers**
Yale University (USA)

Magnetoplasmonic nanoantennas: theory and applications
**29/06/2015, Nicolo Maccaferri**
nanoGUNE

Nano-spin conversion science
**03/07/2015, Yoshichika Otani**
ISSP University of Tokyo (Japan)

NanoGUNE Colloquium: MBE-STM - from quantized anomalous Hall effect to high-temperature superconductivity
**03/09/2015, Qikun Xue**
Tsinghua University (China)

Scanning microwave microscopy and electrostatic force microscopy for nanoscale characterization of materials at khz and GHz frequency
**07/09/2015, Georg Gramse**
JKU Linz (Austria)

Interaction of ferromagnetic and supeconducting permanent magnets: superconducting levitation
**11/09/2015, Ludwig Schultz**
IFW Dresden (Germany)

Control of magnetic systems using STM
**14/09/2016, Deung Jang Choi**
nanoGUNE

Gate-controlled energy barrier at a graphene/molecular semiconductor junction
**21/09/2015, Subir Parui**
nanoGUNE

Single-atom catalysis for hydrogen production from formic acid decomposition over supported noble metals
**28/09/2015, Dmitri A. Bulushev**
Boreskov Institute of Catalysis (Russia)

Mid-infrared near-field superlenses to overcome the diffraction limit
**02/10/2015, Peining Li**
Aachen University (Germany)

Viruses have perfect structures
**05/10/2015, Alexander Bittner**
nanoGUNE

Correlated metal oxides with insulator-metal transitions and their nanoscale properties
**15/10/2015, Amos Sharoni**
Bar Ilan University (Israel)

Structural and dynamical properties of nanoconfined liquid water and ice
**19/10/2015, Jon Zubeltzu**
nanoGUNE

Navigating the world of scientific publishing
**26/10/2015, Jennifer Sanders**
IOP Publishing (UK)

Dirac plasmons on topological insulators: experimental observation of plasmon hybridization, plasmon-phonon interaction, and magnetoplasmons
**26/10/2015, Marta Autore**
University of Rome "La Sapienza" (Italy)

Mechanical force modulates the unfolding pathway of the cold-shock protein B from "Thermotoga maritima"
**02/11/2015, Jorg Schönfelder**
nanoGUNE

Artificial spin ices: thermal behavior and asymmetric interactions
**09/11/2015, Matteo Pancaldi**
nanoGUNE

Modification of Kevlar through vapor phase metalation
**16/11/2015, Itxasne Azpitarte**
nanoGUNE

Light emission STM: measuring the temperature of a hot molecule
23/11/2015, Jose Ignacio Pascual
nanoGUNE

Solid-state reduction of graphene oxide
30/11/2015, Maica Morant
nanoGUNE

## 2016

Electrospinning and 3D printing: a good match
11/01/2016, Wiwat Nuansing
nanoGUNE

Supramolecular approaches to tune charge transport physics in conjugated semiconductors
18/01/2016, Emanuele Orgiu
University of Strasbourg (France)

Radiation damage: a biased overview and some calculations
25/01/2016, Emilio Artacho
nanoGUNE

Molecular basis of congenital erythropoietic porphyria
01/02/2016, Oscar Millet
bioGUNE (Spain)

Two-dimensional spin field-effect transistor
08/02/2016, Luis Hueso
nanoGUNE

NanoGUNE Colloquium: Ion beam modification of magnetic materials
16/02/2016, Jürgen Fassbender
Institute of Ion Beam Physics and Materials Research (Germany)

Optimization of multi-walled carbon nanotube properties for composite production
22/02/2016, Vladimir Kuznetsov
Boreskov Institute of Catalysis (Russia)

Wetting dynamics: a review
07/03/2016, Joël de Coninck
University of Mons (Belgium)

Exciton dynamics on atomic length scales
11/03/2016, Pablo Merino
FKF Max-Planck Institute Stuttgart (Germany)

Graphene-molecular magnet hybrids for molecular spintronics
14/03/2016, Lapo Bogani
Oxford University (UK)

Magnetic nanostructures: a promising approach towards rare-earth free permanent magnets
21/03/2016, Alberto Lopez
nanoGUNE

From the PhD to industry
04/04/2016, Eneko Malatsetxebarria
ArcelorMittal (Spain)

Spin transistors based on individual all-organic radical molecules
06/04/2016, Enrique Burzuri
Delft University of Technology (The Netherlands)

NanoGUNE Colloquium: From multiferroics to cosmology; studying the early universe under the microscope
11/04/2016, Nicola Spaldin
ETH Zurich (Switzerland)

Quantum computers and quantum simulators with superconducting circuits
27/04/2016, Enrique Solano
University of the Basque Country (Spain)

Mid-PhD Seminar: Optoelectronics in two-dimensional materials
02/05/2016, Nieves Morquillas
nanoGUNE

Mechanical properties of fluctuating graphene
09/05/2016, Julio Gomez-Herrero
Autonomous University of Madrid (Spain)

Mid-PhD Seminars:
Spin doping using metal Phthalocyanine molecules
Exciting spins: exploring the quantum limits of atomic-scale magnetism
16/05/2016, Ainhoa Atxabal / Carmen Rubio
nanoGUNE

Mid-PhD Seminars:
The water/ice interface
Ancestral cellulases for biotechnology
23/05/2016, Maria Cascajo / Nerea Barruetabeña
nanoGUNE

Single-cycle light: from THz to X-rays
24/05/2016, Vitaliy Goryashko
Uppsala University (Sweden)

NanoGUNE Colloquium: Photon Management in solar cells and solar modules
02/06/2016, Ralf Wehrspohn
IMWS Fraunhofer (Germany)

Self-assembly of virus nanoparticles for materials applications
08/06/2016, Qian Wang
University of South Carolina (USA)

Meet your defects and stress
13/06/2016, Alejandro Lopez-Bezanilla
Argonne National Laboratory (USA)

NanoGUNE Colloquium: Electrodeposited nanophotonics
20/06/2016, Reginald M. Penner
University of California (USA)

Researchers in industry
23/06/2016, Reginald M. Penner
University of California (USA)

How to face the death valley in nanoscience and nanotecnology: the Basque case
28/06/2016, Edurne Magro / Mikel Navarro
ORKESTRA (Spain)

Electromagnetic metamaterials with simultaneous time-reversal and space-inversion symmetry breaking
13/07/2016, Satoshi Tomita
Nara Institute of Science and Technology (Japan)

Temperature-dependent magnetic depth profiles of epitaxial films with graded and oscillatory exchange coupling structure
05/09/2016, Lorenzo Fallarino
nanoGUNE

Observing light trapped in graphene nanostructures
12/09/2016, Alexey Nikitin
nanoGUNE

Recent advances in near-field microscopy
Mechanics of unfolding the cold shock protein from simulation and experiment
19/09/2016, Stefan Mastel / Anne Aguirre
nanoGUNE

Functionalization of nanomaterials by atomic layer deposition
26/09/2016, Fan Yang
nanoGUNE

Biomedical applications of NIR confocal Raman spectroscopy
03/10/2016, Gajendra Singh
nanoGUNE

Degradation of lignocellulose by ancestral enzymes
24/10/2016, Leire Aldazabal
nanoGUNE

Precise chemical, physical, and electronic nanoscale contacts
26/10/2016, Paul Weis
University of California (USA)

Prediction and analysis of the acceptor-donor packing in organic photovoltaic polymers by high-troughput computation with Siesta
31/10/2016, Etienne Plesiat
nanoGUNE

Straightforward generation of Janus micro- and nanoobjects with bipolar electrochemistry
07/11/2016, Alexander Kuhn
University of Bordeaux (France)

Graphene electrodes for solution-processed organic transistors
14/11/2016, Subir Parui
nanoGUNE

Application of  plasmonic nanoparticles in self-assembly and all-metal photochemistry plasmonics
21/11/2016, Marek Grzelczak
biomaGUNE (Spain)

Electronic tailoring of graphene nanostructures via on-surface synthesis
28/11/2016, Eduard Carbonell
nanoGUNE

Biomacromolecules meet nano materials: gaining stability and new properties
12/12/2016, Ana Beloqui
nanoGUNE

# Publications

| ISI Publications | Average Impact Factor | Citations |
|---|---|---|
| 2015 | 2015 | 2015 |
| **80** | **6.4** | **2 036** |
| 2016 | 2016 | 2016 |
| **107** | **7.6** | **2 394** |

## 2015

A. Dols-Perez, G. Gramse, A. Calo, G. Gomila, and L. Fumagalli
Nanoscale **7**, 18327 (2015)
Nanoscale electric polarizability of ultrathin biolayers on insulating substrates by electrostatic force microscopy

S. Velez, D. Ciudad, J. Island, M. Buscema, O. Txoperena, S. Parui, G. A. Steele, F. Casanova, H. S. J. van der Zant, A. Castellanos-Gomez, and L. E. Hueso
Nanoscale **7**, 15442 (2015)
Gate-tunable diode and photovoltaic effect in an organic-2D layered material p-n junction

E. Sancho-Vaello and K. Zeth
Future Microbiology **10**, 1103 (2015)
Antimicrobial peptides: has their time arrived?

A. Belen Marco, D. Cortizo-Lacalle, C. Gozalvez, M. Olano, A. Atxabal, X. Sun, M. Melle-Franco, L. E. Hueso, and A. Mateo-Alonso
Chemical Communications **51**, 10754 (2015)
An electron-conducting pyrene-fused phenazinothiadiazole

A. V. Antanovich, A. V. Prudnikau, D. Melnikau, Y. P. Rakovich, A. Chuvilin, U. Woggon, A. W. Achtstein, and M. V. Artemyev
Nanoscale **7**, 8084 (2015)
Colloidal synthesis and optical properties of type-II CdSe-CdTe and inverted CdTe-CdSe core-wing heteronanoplatelets

A. Sanchez-Iglesias, A. Chuvilin, and M. Grzelczak
Chemical Communications **51**, 5330 (2015)
Plasmon-driven photoregeneration of cofactor molecules

P. Gonzalez de Prado, M. Encinar, A. Alonso, M. Velez, and P. Tarazonaf
Chemistry and Physics of Lipids **185**, 141 (2015)
Modeling the interplay between protein and lipid aggregation in supported membranes

J. Yeom, B. Yeom, H. Chan, K. W. Smith, S. Dominguez-Medina, J. H. Bahng, G. Zhao, W. Chang, S. Chang, A. Chuvilin, D. Melnikau, A. L. Rogach, P. Zhang, S. Link, P. Kral, and N. A. Kotov
Nature Materials **14**, 66 (2015)
Chiral templating of self-assembling nanostructures by circularly polarized light

M. Isasa, E. Villamor, L. E. Hueso, M. Gradhand, and F. Casanova
Physical Review B **91**, 024402 (2015)
Temperature dependence of spin diffusion length and spin Hall angle in Au and Pt

E. Villamor, M. Isasa, S. Velez, A. Bedoya-Pinto, P. Vavassori, L. E. Hueso, F. S. Bergeret, and F. Casanova
Physical Review B **91**, 020403 (2015)
Modulation of pure spin currents with a ferromagnetic insulator

S. Mastel, A. A. Govyadinov, T. V. A. G. De Oliveira, I. Amenabar, and R. Hillenbrand
Applied Physics Letters **106**, 023113 (2015)
Nanoscale-resolved chemical identification of thin organic films using infrared near-field spectroscopy and standard Fourier transform infrared references

K. E. Gregorczyk, D. F. Pickup, M. Garcia-Sanz, I. Azpitarte, C. Rogero, and M. Knez
Chemistry of Materials **27**, 181 (2015)
Tuning the tensile strength of cellulose through vapor-phase metalation

A. Blanco-Redondo, P. Sarriugarte, A. Garcia-Adeva, J. Zubia, and R. Hillenbrand
Journal of Lightwave Technology **33**, 368 (2015)
Local-field enhancement of mid-infrared light in an integrated photonic-plasmonic structure

T. V. A. G. De Oliveira, A. Eleta, L. E. Hueso, and A. M. Bittner
Journal of Materials Chemistry C **3**, 1181 (2015)
Mixed self-assembled monolayer gate dielectrics for low-voltage solution-processed polymer field-effect transistors

I. Soto-Lamata, P. Alonso-Gonzalez, R. Hillenbrand, and A. Yu. Nikitin
ACS Photonics **2**, 280 (2015)
Plasmons in cylindrical 2D materials as a platform for nanophotonic circuits

J. Tranchant, E. Janod, B. Corraze, P. Stoliar, M. Rozenberg, M. Besland, and L. Cario
Physica Status Solidi (a) – Applications and Materials Science **212**, 239 (2015)
Control of resistive switching in AM(4)Q(8) narrow gap Mott insulators: a first step towards neuromorphic applications

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Nature Communications **6**, 6150 (2015)
Ultrasensitive and label-free molecular-level detection enabled by light phase control in magnetoplasmonic nanoantennas

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Analytical Chemistry **87**, 1622 (2015)
Novel readout method for molecular diagnostics assays based on optical measurements of magnetic nanobead dynamics

L. Fallarino, A. Berger, and C. Binek
Physical Review B **91**, 054414 (2015)
Magnetic field induced switching of the antiferromagnetic order parameter in thin films of magnetoelectric chromia

F. Golmar, P. Stoliar, C. Monton, I. Valmianski, I. K. Schuller, L. E. Hueso, and F. Casanova
Physicas Status Solidi A – Applications and Materials Science **212**, 607 (2015)
Cobalt phthalocyanine-based submicrometric field-effect transistors

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Journal of Physical Chemistry C **119**, 4874 (2015)
Diarylethene molecules on a Ag (111) surface: stability and electron-induced switching

E. Villamor, F. Casanova, P. H. F. Trompenaars, and J. J. L. Mulders
Nanotechnology **26**, 095303 (2015)
Embedded purification for electron beam induced Pt deposition using $MeCpPtMe_3$

R. Ullah, F. Corsetti, D. Sanchez-Portal, and E. Artacho
Physical Review B **91**, 125203 (2015)
Electronic stopping power in a narrow band gap semiconductor from first principles

J. M. Vila-Fungueirino, B. Rivas-Murias, B. Rodriguez-Gonzalez, O. Txoperena, D. Ciudad, L. E. Hueso, M. Lazzari, and F. Rivadulla
ACS Applied Materials & Interfaces **7**, 5410 (2015)
Room-temperature ferromagnetism in thin films of $LaMnO_3$ deposited by chemical method over large areas

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Journal of the American Chemical Society **137**, 3283 (2015)
Dependence of internal friction on folding mechanism

G. Winkler, A. Kobs, A. Chuvilin, D. Lott, A. Schreyer, and H. P. Oepen
Journal of Applied Physics **117**, 105306 (2015)
On the variation of magnetic anisotropy in Co/Pt(111) on silicon oxide

N. C. Bigall, E. Dilena, D. Dorfs, M. Beoutis, G. Pugliese, C. Wilhelm, F. Gazeau, A. A. Khan, A. M. Bittner, M. A. Garcia, M. Garcia-Hernandez, L. Manna, and T. Pellegrino
Journal of Physical Chemistry C **119**, 6246 (2015)
Hollow iron oxide nanoparticles in polymer nanobeads as MRI contrast agents

N. Ghenzi, M. J. Rozenberg, R. Llopis, P. Levy, L. E. Hueso, and P. Stoliar
Applied Physics Letters **106**, 123509 (2015)
Tuning the resistive switching properties of $TiO_2$-x films

M. Moreno, C. Lampard, N. Williams, E. Lago, S. Emmett, M. Goikoetxea, and M. J. Barandiaran
Progress In Organic Coatings **81**, 101 (2015)
Eco-paints from bio-based fatty acid derivative latexes

D. De Sancho, A. Kubas, P-H. Wang, J. Blumberger, and R. B. Best
Journal of Chemical Theory and Computation **11**, 1919 (2015)
Identification of mutational hot spots for substrate diffusion: application to myoglobin

A. Woessner, M. B. Lundeberg, Y. Gao, A. Principi, P. Alonso-Gonzalez, M. Carrega, K. Watanabe, T. Taniguchi, G. Vignale, Marco Polini, J. Hone, R. Hillenbrand, and F. H. L. Koppens
Nature Materials **14**, 421 (2015)
Highly confined low-loss plasmons in graphene-boron nitride heterostructures

C. Morice, E. Artacho, S. E. Dutton, D. Molnar, H. Kim, and S. S. Saxena
Journal of Physics: Condensed Matter **27**, 135501 (2015)
Effects of stoichiometric doping in superconducting Bi-O-S compounds

M. Ruby, B. W. Heinrich, J. I. Pascual, and K. J. Franke
Physical Review Letters **114**, 157001 (2015)
Experimental demonstration of a two-band superconducting state for lead using scanning tunneling spectroscopy

M. Bianchi, F. Song, S. Cooil, A. F. Monsen, E. Wahlström, J. A. Miwa, E. D. L. Rienks, D. A. Evans, A. Strozecka, J. I. Pascual, M. Leandersson, T. Balasubramanian, Ph. Hofmann, and J. W. Wells
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A. Magri, P. Friederich, B. Schaefer, V. Fattori, X. Sun, T. Strunk, V. Meded, L. E. Hueso, W. Wenzel, and M. Ruben
Beilstein Journal of Nanotechnology **6**, 1107 (2015)
Charge carrier mobility and electronic properties of Al(Op)(3): impact of excimer formation

F. Bartolome, O. Buñau, L. M. Garcia, C. R. Natoli, M. Piantek, J. I. Pascual, I. K. Schuller, T. Gredig, F. Wilhelm, A. Rogalev, and J. Bartolomé
Journal of Applied Physics **117**, 17A735 (2015)
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I. Zubritskaya, K. Lodewijks, N. Maccaferri, A. Mekonnen, R. K. Dumas, J. Akerman, P. Vavassori, and A. Dmitriev
Nano Letters **15**, 3204 (2015)
Active magnetoplasmonic ruler

E. Yoxall, M. Schnell, S. Mastel, and R. Hillenbrand
Optics Express **23**, 13358 (2015)
Magnitude and phase-resolved infrared vibrational nanospectroscopy with a swept quantum cascade laser

S. Parui, L. Pietrobon, D. Ciudad, S. Velez, X. Sun, F. Casanova, P. Stoliar, and L. E. Hueso
Advanced Functional Materials **25**, 2972 (2015)
Gate-controlled energy barrier at a graphene/molecular semiconductor junction

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Spin-polarized hopping transport in magnetically tunable rare-earth quinolines

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Nano Letters **15**, 3851 (2015)
Near-field imaging of phased array metasurfaces

L. Fallarino, C. Binek, and A. Berger
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Boundary magnetization properties of epitaxial $Cr_{2-x}Al_xO_3$ thin films

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Journal of Physics D: Applied Physics **48**, 215003 (2015)
Spin transport enhancement by controlling the Ag growth in lateral spin valves

T. B. Kahn, J. M. Fernandez, and R. Perez-Jimenez
Journal of Biological Chemistry **290**, 14518 (2015)
Monitoring oxidative folding of a single protein catalyzed by the disulfide oxidoreductase DsbA

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Tuning the magnetic anisotropy of a single molecule

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Effect of the interface resistance in non-local Hanle measurements

L. Zhang, L. Li, A. Di Penta, U. Carmona, F. Yang, R. Schoeps, M. Brandsch, J. L. Zugaza, and M. Knez
Advanced Healthcare Materials **4**, 1305 (2015)
H-chain ferritin: a natural nuclei targeting and bioactive delivery nanovector

P. Riego and A. Berger
Physical Review E **91**, 062141 (2015)
Nonuniversal surface behavior of dynamic phase transitions

A. Manteca and R. Perez-Jimenez
European Biophysics Journal with Biophysics Letters **44**, 127 (2015)
Disulfide bonds drive the nanomechanical evolution of the giant muscle protein titin

A. Alonso-Caballero, S. Poly, and R. Perez-Jimenez
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Nanomechanical and folding characterization of proteins involved in bacterial adhesion

D. Kim, H. Kwon, A. Yu. Nikitin, S. Ahn, L. Martin-Moreno, F. J. Garcia-Vidal, S. Ryu, H. Min, and Z. Hwan Kim
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Stacking structures of few-layer graphene revealed by phase-sensitive infrared nanoscopy

S. Narayana, S. Velez, J. Vanacken, V. V. Moshchalkov, L. F. Chibotaru, J. Tejada, and F. Macia
New Journal of Physics **17**, 073006 (2015)
Spin reversal in Fe-8 under fast pulsed magnetic fields

C. C. Gonzalez-Fuentes, J. B. Gonzalez-Diaz, L. Fallarino, J. A. Arregi, and A. Berger
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Physical Review B **92**, 041113 (2015)
Fermi surfaces and orbital polarization in superconducting $CeO_{0.5}F_{0.5}BiS_2$ revealed by angle-resolved photoemission spectroscopy

P. Aguado-Puente, N. C. Bristowe, B. Yin, R. Shirasawa, P. Ghosez, P. B. Littlewood, and E. Artacho
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E. Gonzalez, C. Tollan, A. Chuvilin, M. Paulis, and M. J. Barandiaran
Colloid and Polymer Science **293**, 2419 (2015)
Effect of alkali-soluble resin emulsifiers on coalescence and interdiffusion between latex polymer particles

J.A. Arregi, J. B. Gonzalez-Diaz, N. Soriano, B. Mora, and A. Berger
Journal of Physics D: Applied Physics **48**, 305002 (2015)
Surface-topography induced optical and magneto-optical anisotropy of permalloy gratings

A. Zuzuarregui, B. Coto, J. Rodriguez, K. E. Gregorczyk, U. Ruiz de Gopegui, J. Barriga, and M. Knez
Applied Physics Letters **107**, 061602 (2015)
Highly reflective polymeric substrates functionalized utilizing atomic layer deposition

B. Yin, P. Aguado-Puente, S. Qu, and E. Artacho
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Two-dimensional electron gas at the $PbTiO_3/SrTiO_3$ interface: an ab initio study

L. Bogner, Z. Yang, M. Corso, R. Fitzner, P. Bäuerle, K. J. Franke, J. I. Pascual, and P. Tegeder
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M. J. Perez-Roldan, F. Tatti, P. Vavassori, A. Berger, and A. Chuvilin
Nanotechnology **26**, 375302 (2015)
Segregation of materials in double precursor electron-beam-induced deposition: a route to functional magnetic nanostructures

M. Corso, M. Ondracek, C. Lotze, P. Hapala, K. J. Franke, P. Jelinek, and J. I. Pascual
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Resistive switching in Mott insulators and correlated systems

A. Eleta, J. Etxebarria, N. Reichardt, R. Georgieva, H. Baeumler, and J. L. Toca-Herrera
Colloids and Surfaces B: Biointerfaces **134**, 355 (2015)
On the molecular interaction between albumin and ibuprofen: an AFM and QCM-D study

E. Yoxall, M. Schnell, A. Y. Nikitin, O. Txoperena, A. Woessner, M. D. Lundeberg, F. Casanova, L. E. Hueso, F. H. L. Koppens, and R. Hillenbrand
Nature Photonics **9**, 674 (2015)
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Enhanced magneto-optical edge excitation in nanoscale magnetic disks

S. Parui, A. Atxabal, M. Ribeiro, A. Bedoya-Pinto, X. Sun, R. Llopis, F. Casanova, and L. E. Hueso
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T. Neuman, P. Alonso-Gonzalez, A. Garcia-Etxarri, M. Schnell, R. Hillenbrand, and J. Aizpurua
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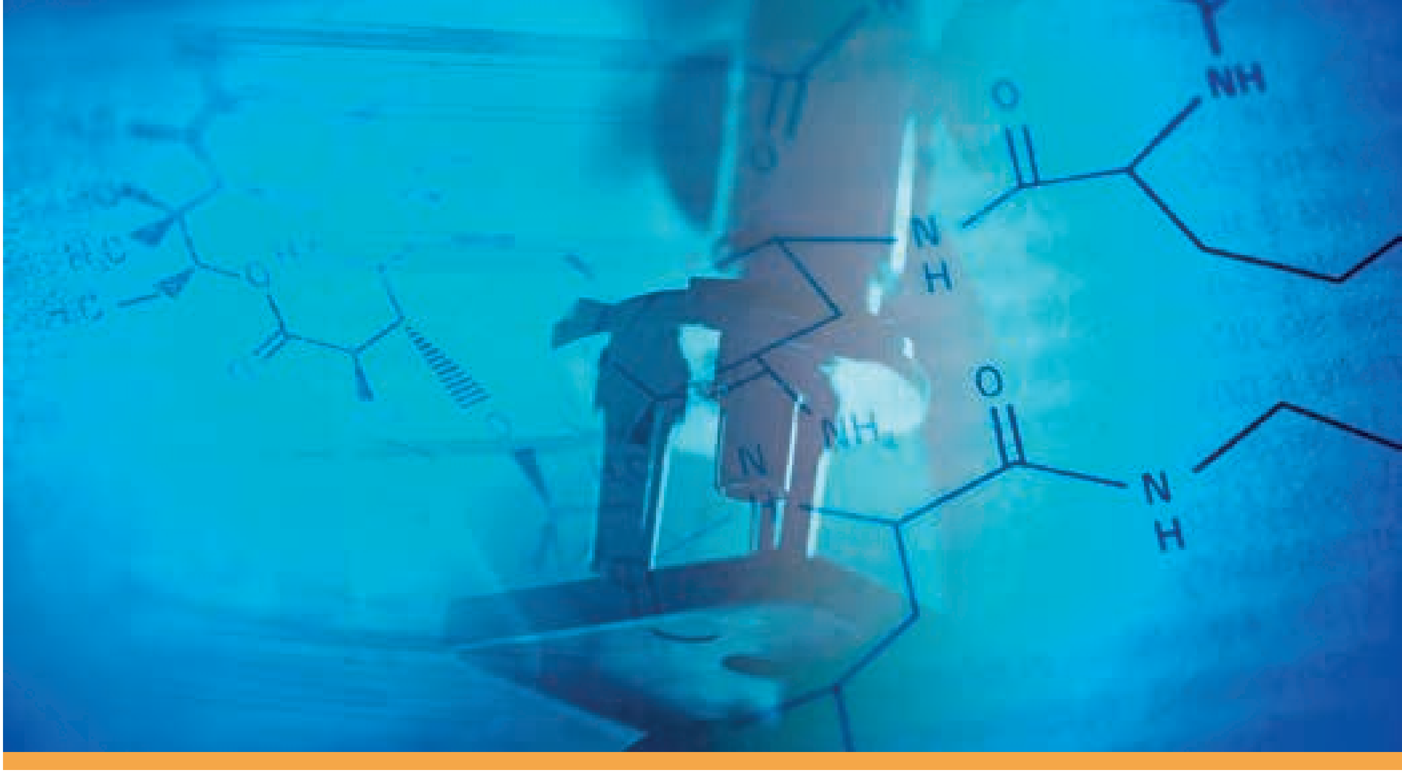
# 3

# Business connection

**4** Consolidated start-ups

**1** New spin-off



# Business connection

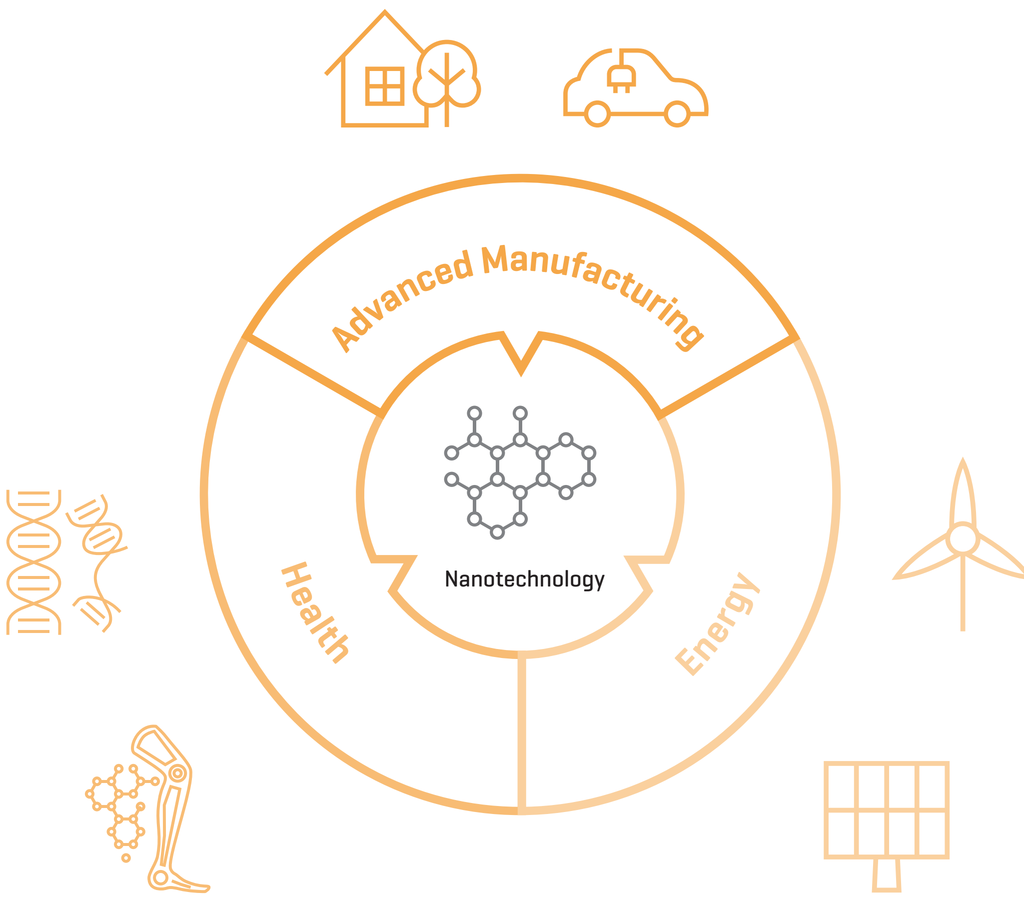
NanoGUNE aims at providing integrated innovative solutions for industry, thus leading to a greater competitiveness of our economy. In the period 2015-2016, a great effort has been made in order to bridge the gap between science and industry, building up a strong technology-transfer policy, putting in place specific initiatives for companies, and including the business culture in our training program.

We have organically reinforced our technology transfer activities by creating an interlocution vehicle with the market, named NanoInnovations. Its objectives are to consolidate the existing interaction with Basque companies and with the market as a whole, to mobilize our knowledge and capacities to collaborate with the private sector, as well as to facilitate and boost the exploitation of our research.

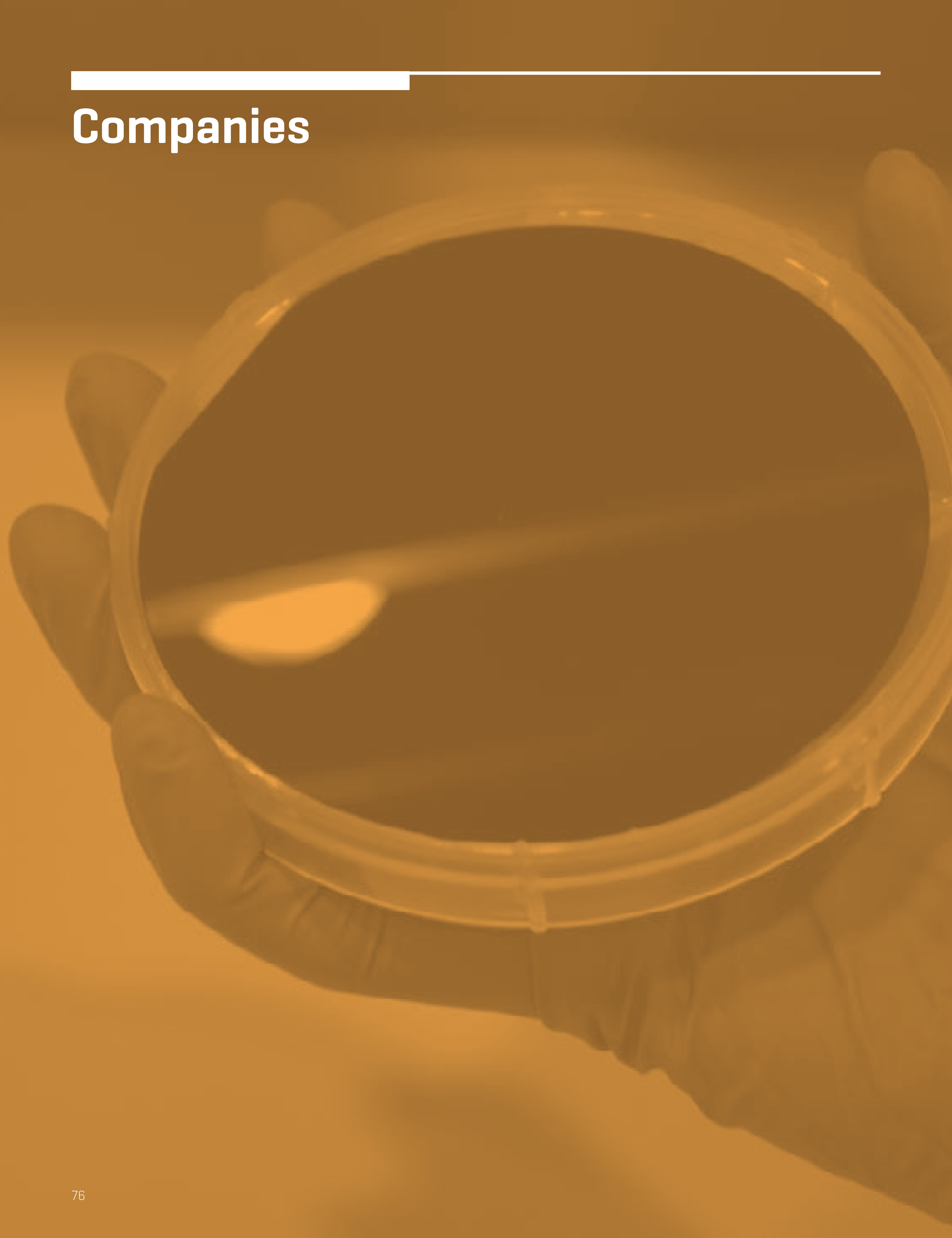
In this period, nanoGUNE's first start-up company, Graphenea, has begun to fly solo. Our spin-offs Simune, Ctech-nano, and Evolgene have started to strengthen their position in an enormously competitive global market, and we have also founded a new company: Prospero Biosciences. Moreover, we have submitted three new international patents and we have signed a good number of collaboration agreements with companies. Finally, our External-Services department has given place to an Industrial-Research and Experimental-Development Platform. Working closely with the research teams, this platform aims at reinforcing cooperative research and strengthening ties with Basque and international companies.

# Smart specialization in the Basque Country

In the framework of the Research and Innovation Strategy for Smart Specialization (RIS3) of the European Commission, the Basque Government is focused on improving three areas in which the Basque Country is already doing well: advanced manufacturing, energy, and health. In this context, nanotechnology has revealed itself as an important Key Enabling Technology (KET), which is able to provide more efficient and less expensive solutions for very diverse industry and service sectors.



# Companies



# GRAPHENEA, a high-quality graphene producer

**www.graphenea.com**

GRAPHENEA, nanoGUNE's first start-up company launched in April 2010 as a joint venture of private investors and nanoGUNE, has become a world leader in the production of high-quality graphene. In 2013, Repsol and the Spanish Center for Industrial Technology Development (CDTI) signed an agreement to invest one million euros in GRAPHENEA. Following the foundational agreement of the company, in April 2015 nanoGUNE let GRAPHENEA fly alone. GRAPHENEA's R&D Laboratory is nonetheless still being hosted at nanoGUNE.

The company, which at the end of 2016 was employing 18 people and was exporting graphene to 40 countries, supplies its products to universities, research centers, and industries worldwide. GRAPHENEA is also a partner of the European Graphene Flagship, which with a budget of one billion euros aims at taking graphene from the realm of academic laboratories into the European society in a period of ten years.

Graphene research represents a rapidly-growing strategic research field with a considerable economic potential. GRAPHENEA aims at collaborating with the global scientific community, thus helping the graphene industry to move forward. GRAPHENEA, committed to innovation, is constantly investing in the development of new products that help its customers advance their work.

GRAPHENEA's main industrial focus is the production of high-quality graphene films grown by chemical vapor deposition (CVD) and also the production of chemically exfoliated graphene oxide. On the one hand, GRAPHENEA develops the potential of CVD graphene for electronic systems, optoelectronics, sensors, etc., and is operating an industrial pilot unit with the capacity to produce 1 ton per year of graphene oxide in dispersion and powder forms.

# SIMUNE, atomistic simulations

**www.simune.eu**

SIMUNE offers atomic-scale simulations to academic and industrial customers in a variety of fields: semiconductors, energy storage, and others. Simulations are oriented to accelerate and optimize the design of new materials and processes, thus providing the best solution for the identification of each property. SIMUNE also offers consultancy services, expert support, and training.

SIMUNE was launched in January 2014 as a joint venture of a group of scientific experts and nanoGUNE. In July 2014, a group of private investors became shareholders of the company.

SIMUNE focuses on applications related to advanced materials with highly-technological needs. The company is expert in identifying the best solution to solve materials-related challenges. Starting from an industrial problem, SIMUNE identifies a workflow for its solution by doing simulations and materials modeling. Some of the advantages of simulations are: to save cost and time by identifying new materials for new products, to understand the results of experimental measurements, and to characterize materials properties.

Simulation is a powerful technique that can help to understand and model real systems or potential situations. With the help of simulations one can also examine problems that are often not subject to direct experimentation.

SIMUNE was selected in 2016 as a Techconnect Innovation Awardee. The Techconnect Innovation Awards select the top early-stage innovations from around the world through an industry-review process of the top 15% of technologies that are annually submitted to the Techconnect National Submission Summit. Rankings are based on the potential positive impact the submitted technology will have on a specific sector.

# Ctech-nano, innovation with ALD solutions

**www.ctechnano.com**

Ctech-nano was launched in July 2014 as a joint venture of two Basque companies (AVS and Cadinox) and nanoGUNE. The company provides thin-film coating solutions with Atomic Layer Deposition (ALD). Ctech-nano provides both R&D services and specific coating tools. The company collaborates with its customers in order to supply custom-made and innovative solutions.

Atomic Layer Deposition (ALD) is a technique that allows changing the properties of materials. A very thin layer only a few nanometers thick is deposited onto a given substrate covering its entire surface. With such a thin coating many properties of the original material are retained; but, at the same time, additional properties can be supplemented.

ALD provides a very controlled way to deposit thin films with an atomic-scale thickness control. The growth of multilayer structures composed of different materials is also straightforward. Due to the precision of the process and its reproducibility, ALD represents a well-establised processing technology in the field of modern micro and nanoelectronics. The temperature that is needed to run this technology is typically lower than the temperature that is needed to run other deposition processes such as chemical vapor deposition and thermal evaporation. The lower processing temperature allows to work with fragile substrates, such as biological or polymeric samples. A wide variety of materials can be deposited with ALD: oxides, nitrides, carbides, metals, sulfides, fluorides, organics, etc.. This small but important difference makes ALD the method of choice for many emerging applications, such as flexible electronics or composite materials design. ALD applications can be found in many different sectors: electronics, optoelectronics, optics, energy, biotechnology, metallurgy, decorative coatings, textile and packaging, and many others. The customers of Ctech-nano are commonly oriented to innovation, looking for new product functionalities and/or trying to improve their existing processes and products.

The industrial partners of Ctech-nano, AVS and Cadinox, have broad experience in the design, manufacturing, integration, test, and delivery of equipment to technology-driven markets. Thanks to the cooperation of nanoGUNE with the industrial partners AVS and Cadinox, Ctech-nano combines an experienced and complementary team with the scientific and technological capability to adapt to the needs of customers.

# EVOLGENE, enzymes from the past for the future

EVOLGENE was launched in September 2014 in the framework of an "Idea" that was supported by the Entrepreneurs Fund of the Spanish oil company Repsol, an initiative designed for entrepreneurs who have created or intend to create an energy efficiency company.

EVOLGENE works in the field of genomics applied to enzyme design and production; its unique method of enzyme design is based on the reconstruction of ultraeficient ancestral enzymes from billions of years back by using bioinformatic resources and genomic data. Evolgene has developed a patented method that allows to design and launch enzymes with unprecedented enhanced properties and in extremely short times. EVOLGENE's disruptive enzymes can be used in a wide range of specialty biotechs and industrial applications: biofuel production, cosmetics, and health, among others.

EVOLGENE focuses on two main lines of activity. On the one hand, an extremely powerful thioredoxin has been developed which exhibits very promising applications in anti-aging cosmetics and health; this represents EVOLGENE's first specialty enzyme out from a roadmap of a wide range of new enzymes to be developed in other fields. On the other hand, a whole family of industrial enzymes is being developed that is expected to play a role in the conversion of cellulosic biomass for a number of final applications: the production of biofuel, nanocellulose, pulp and paper, etc..

EVOLGENE is currently developing various pilots in order to assess the performance of its enzymes in real industrial-scale (or fully commercial-scale) applications.

# PROSPERO BIOSCIENCES, new applications within the mass-spectrometry industry

PROSPERO Biosciences, nanoGUNE's 5th spin-off company, was launched in October 2015 by a group of promoters that included, in addition to nanoGUNE, Robert Blick (professor at the University of Hamburg and visiting professor at nanoGUNE), nanoGUNE researcher Maria Arbulu, and Hasten Ventures, a company devoted to the acceleration and promotion of business ideas. PROSPERO seeks to take advantage of the potential of nanotechgnology in order to develop and commercialize an innovative technology capable of opening up a new field of aplications within the mass-spectrometry industry.

PROSPERO is currently in the process of developing and producing an innovative detector for mass spectrometry, which is based on the use of a nanomembrane enabling a tremendous improvement with respect to existing solutions. There is no technology in the market that can reliably identify high-mass molecules; and this is precisely what PROSPERO is offering. PROSPERO's technology is expected to open the door to a broad field of applications, such as research into biological markers, medical research and diagnosis, or the development of biosimilar drugs that require an accurate identification of high-mass molecules.

PROSPERO is developing various high-mass molecule detector prototypes, whch are already being successfully tested by various end users in the health-science sector.

# Patents

## Blusense Diagnostics

A scientific development by nanoGUNE and the Department of Micro and Nanotechnology of the Technical University of Denmark (DTU) has resulted in the creation of an innovative, low-cost portable device for clinical analyses. The device, based on a patent filed by nanoGUNE and the DTU, is to be marketed by the Danish company BluSense Diagnostics. This company has incorporated the patented technology into a commercial, portable, medical analysis device which, when connected to a mobile phone, is capable of diagnosing and analyzing a range of diseases using a single drop of blood. This is conducted by means of an innovative method comprising nanotechnological biosensors created at nanoGUNE. Given that the analysis takes only 5 minutes, this tool could be of great use in places where there is no healthcare system or where the results of the clinical analyses need to be immediate.

The device is capable of spotting common diseases such as diabetes or high cholesterol, but progress is also being made in the study of epidemic diseases such as dengue fever. BluSense Diagnostics was selected by US-AID (The United States Agency for International Development) to develop new technological solutions in the fight against the Zika virus.

## Granted

## 2015

**Synthetic Optical Holography**
R. Hillenbrand, P. S. Carney, and M. Schnell
Shared with the University of Illinois
Licensed to Neaspec

## Submitted

## 2015

**Near-field optical microscope for acquiring spectra**
R. Hillenbrand, E. Yoxall, and M. Schnell
Licensed to Neaspec

## 2016

**Endocellulases and uses thereof**
R. Perez-Jimenez
To be licensed to Evolgene

**Atomic Layer Deposition Chamber with adaptable volumes**
M. Knez, M. Beltran, D. Talavera, and M. Vila
Shared with Ctech-nano
Licensed to Ctech-nano

# Industrial Collaboration Agreements

## Signed in 2015

AIN (Asociación Euro Invest)
Service provision agreement

University of California Berkeley
Non-proprietary user agreement

Hasten Ventures, A.I.E.
Collaboration agreement

BluSense
License agreement

Consejo Superior de Investigaciones Científicas (CSIC)
Material transfer agreement

Kleindiek Nanotechnik GmbH
Service provision agreement

## Signed in 2016

Graphenea, S.A. and Das Nano, S.L.
Collaboration agreement

Instituto Interuniversitario de Investigación de Reconocimiento Molecular y Desarrollo Tecnológico
Service provision agreement

Consejo Superior de Investigaciones Científicas (CSIC)
Material transfer agreement

Inversión y Estrategia Taurus S.L.
Collaboration agreement

Parque Tecnológico de San Sebastián, S.A.
Collaboration agreement

Fundación CIDETEC
Collaboration agreement

Fundación Barrié
Technology-transfer agreement


# External Services

NanoGUNE offers External Services with the aim of supporting the characterization and fabrication of materials and micro and nanoscale devices for both academic and industrial users. The External-Services Department is designed to be an open facility for researchers and technologists from different business and research fields. Our expertise relies on an advanced microscopy platform, a cleanroom, and various laboratories with state-of-the-art nanomanufacturing and characterization equipment. We work with end users in order to develop and optimize products and techniques. The offered services can be carried out by qualified nanoGUNE personnel or under a self-service mode.

Our **characterization platform** is designed to give full and personalized services for a wide range of products characterization. This platform is divided into three different service units:

- Structural characterization
- Magnetic and electrical characterization
- Chemical characterization

Our **fabrication platform** can encompass and give solutions for a wide variety of research and industrial activities. NanoGUNE is equipped with state-of-the-art techniques for high-quality thin-film growth and for micro and nanoscale fabrication. Most of the services offered in this platform are carried out in our 300 m$^2$ cleanroom, which is divided into four different areas classified from class 100 to class 10 000, assuring the environmental conditions that are required for high-quality fabrication. This platform is divided into three different service units:

- Thin-film growth
- Micro/nano fabrication
- Sample processing

# Novaspider

NanoGUNE also offers cutting-edge products and outstanding service bundles through its External Services Department. One of our products is Novaspider, a 3D electrospinning machine that allows the users to produce advanced nanofibers in their own laboratory. Novaspider is a tool that enables the user to give free rein to his/her creativity in order to build 2D and 3D objects from nanofibers.

Novaspider has created a brand-new concept in the production of 3D nanofibers. This tool provides its users with a new level of expertise in nanofiber manufacture by combining electrospinning with 3D printing techniques and it allows nanofiber-based 3D structures to be manufactured in a straightforward way.

This product is presented as an educational challenge, because the user can set it up on his/her own. It is delivered as a kit to be assembled locally, which helps to offer customers a comprehensive solution at the best price. It could be regarded as a challenge for students and a solution for junior researchers, always with our full support and documentation. Novaspider can also be delivered fully set up.

We also provide full scientific support to the users of Novaspider in order to enable them to achieve a rapid prototyping. A team of experts in materials science, advanced materials, and engineering offers electrospinning tools and processes on all production scales as an open-source hardware platform and closed source. This team of scientists is available to assist the users in creating nanofibers based on any material.

# The Nanotransfer project

The rate of penetration of Basque companies in the field of nanoscience and nanotechnology needs to be increased. In order to analyze the development and implantation of nanotechnology in the Basque Country, a specific project has been developed in the framework of a collaboration of nanoGUNE with Orkestra Basque Institute of Competitiveness, Tecnalia, the University of the Basque Country, and nanoBasque-Spri.

This project has identified the commitment to nanoscience as an essential strategy for the Basque Country and emphasizes the need to speed up the incorporation of nanotechnology into manufacturing processes and into marketed products.

The main conclusions point out that nanotechnology will achieve a widespread permeability and multisectorial presence in the coming few years. In fact, 60% of the Basque companies that have started to incorporate nanotechnology acknowledge that they have obtained a new or improved product, and 30% confirm that they have achieved new or improved production processes.

The major entry barriers that hinder the incorporation of nanotechnology into industry are the need for specific equipment and tools, the required corporate investment, and the lack of qualified staff. In fact, the incorporation into industry of professionals with a scientific knowledge should facilitate the connection between existing research and potential commercialization. The promotion of technology-transfer mechanisms based upon a real collaboration between all scientific and technological players, the shared use of infrastructures, and the staff mobility should also help with the same purpose.

# nano innovations

## Connecting new discoveries with industry

**NanoInnovations** is a new company that has been launched jointly by Hasten Ventures and nanoGUNE with the mission of bridging the gap between state-of-the-art research and the market in the field of nanotechnology. A pan-European platform is being created in order to connect new discoveries and start-ups in this field with industry and investors in the Basque Country and worldwide.

As founding partner of nanoInnovations, nanoGUNE will be the first research center to benefit from this initiative which should soon incorporate other international research centers. The goal is to profit from a pool of inventions, intellectual property, scientific talent, and research facilities with the aim of positioning nanoInnovations as a main European technology-transfer platform in the field of nanotechnology with a primary focus to empower a fruitful relationship between the academia and industry.

NanoInnovations is also aiming at the creation of a capital fund, whose main focus should be to help European start-ups to develop their business and to position themselves as global players in the field of nanotechnology. This initiative should provide investors with the potential to establish strategic medium-long term relationships with innovative scientific activities.

### What do we offer to the scientific community?

- A hub for the sponshorship of industrial research projects and the commercialization of intellectual property.
- Access to active networks, partners, and financial opportunities.
- Prospects for future job opportunities.

### What do we offer to the industry?

- Access to a state-of-the-art pool of knowledge in the field of nanoscience and nanotechnology.
- Access to cooperation with other companies, investors, and administrations.

### What do we offer to investors?

- The opportunity to participate in knowledge-based high-growth ventures from a pre-seed to a scale-up stage.
- A platform to co-invest with other peers at a European scale.

# Business culture in the training of PhD students

In line with our 2015-2020 Strategic Plan, specific training activities have been programed in order to strengthen the business culture of young researchers, thus making it easier for some of them to become part of the industrial world.

A training program with three main courses for PhD students has been designed and implemented, and special seminars have been given by experts with a scientific background that are currently working in industry.

## Oral communication skills

This course, mainly oriented to first-year PhD students, has been offered in February/March 2016 and November 2016. In this training course the participants develop their skills in the preparation and delivery of top-quality presentations, as well as in communicating with different audiences.

A total of 18 students has participated in this course.

## Entrepreneurship

This course, mainly oriented to second-year PhD students, has been offered in October 2015 and December 2016. The goal of this course is to train predoctoral researchers on how to transform an idea into an entrepreneurial project by giving them the basic knowledge about what an entrepreneur is, different business models, and how to write a business plan.

A total of 23 students has participated in this course.

## From the PhD to a company

This course, mainly oriented to third-year PhD students, has been offered in October 2015 and November 2016. The goal of this course is to train pre-doctoral researchers on how to show their skills and attitudes when looking for a job within an industrial environment, as well as to invite them to think over their near future and help them defining their goals and professional expectations.

A total of 17 students has participated in this course.

# 4

# Connecting with society

**24** Open events

**256** Visitors from high school and universities

**493** Times in the media

# Connecting with society

The search for the words nanoscience and nanotechnology in one of the most popular online search engines produced more than 27 million results at the end of 2016. There is no doubt that formal and informal media are increasingly talking about this domain of research and the corresponding technological development. However, we are also aware that an increasing quantity of information does not necessarily mean that a good and accurate communication is being done.

At nanoGUNE, we are convinced that our responsibility for the development of a sustainable society goes beyond the generation of knowledge and technology. This is the reason why sharing the scientific challenges of nanoscience and nanotechnology with society is also part of our mission.

In the period 2015-2016, we have promoted and participated in a good number of initiatives (education-driven activities, open events, science-popularization projects, etc.) targeted to high-school and university students, as well as to the general public. Moreover, we are actively involved (together with other Basque research centers) in the edition of the CICNetwork magazine.

We have also enjoyed an excellent collaboration with the media, which have covered our activity through more than 450 pieces of news during the period 2015-2016. Thanks to the effort of the journalists dealing with the task of translating scientific results into broadly understandable words, the gap between science and society narrows every day.

## Open events

### Science Week
NanoGUNE, together with the Donostia International Physics Center (DIPC) and the Materials Physics Center (MPC), has been collaborating in the Science Week organized every November by the University of the Basque Country through a nanoscience exhibition space.

### Donostia Week INN
NanoGUNE has participated in the Week of Innovation, Donostia Week INN 2015 and 2016, organized by *Fomento de San Sebastián*. This event offers a complete program of activities around the innovation strategy that takes place in the city.

### Urbanzientzia
On 21 May 2016, nanoGUNE, together with the DIPC and MPC, participated in the Urbanzientzia (Urban Science) event organized by Teknahi within the activities of Olatu Talka, a participatory sociocultural initiative that invades the city of San Sebastian every year.

### Passion for Knowledge 2016
NanoGUNE collaborated in September 2016 in the organization of the science-popularization festival *Passion for Knowledge*. This event, organized by the DIPC, takes place every three years with the aim of promoting science as a key activity for the well-being of future generations and highlighting the thirst of knowledge as the driving force behind scientific, technological, and cultural progress.

## Education-driven activities

### Undergraduates: summer internship and final project
29 undergraduate students have joined nanoGUNE's summer-internship program and/or have done their final project under the supervision of one of our principal investigators.

### Master
NanoGUNE collaborates with the Master in Nanoscience, the Master in New Materials, and the Master in Molecular Biology and Biomedicine of the University of the Basque Country by giving master students the opportunity to join us in order to do their master thesis under the supervision of one of our principal investigators.

### PhD
PhD-thesis projects are offered to physics, chemistry, biology, engineering, and materials-science graduates. We closely collaborate, in particular, with the PhD program "Physics of Nanostructures and Advanced Materials (PNAM)" offered by the University of the Basque Country.

### Nanotechnology course for high-school teachers
NanoGUNE offers a nanotechnology introductory course to high-school science teachers in the framework of the "Prest Gara" program launched by the Department of Education, Language Policy, and Culture of the Basque Government.

### Visits for educational centers
Following our open-doors policy, we run a program for high-school and university students to visit our facilities, thus offering them the opportunity to have a closer look at nanoscience research. More than 250 students have visited nanoGUNE during the period 2015-2016.

# nanoKOMIK, nanoscience in comics

Through the nanoKOMIK project, nanoGUNE and the Donostia International Physics Center have created, produced, and disseminated in 2016 the first participatory nanofiction comic.

This project was launched in order to transmit to the general public the potential of the advances that are taking place in the field of nanoscience and nanotechnology, and to stimulate creativity among young people. The project was conceived in two phases.

The first phase involved youngsters between 12 and 18 years old in a free creative process in which they built their own superheroine/superhero in a comic, giving her/him nanopowers based on the amazing properties that matter acquires at the nanoscale. In order to guide the youngsters through the creation of the comic, open science and comic workshops were organized in various cities during the first trimester of 2016. During these two-hour sessions the participants learned about "nanopowers", in other words, sophisticated skills or capabilities acquired thanks to nanoscience and nanotechnology; they also learned to produce their own comic. The youngsters were also able to have contact with the project in the classroom, as a specialized science and comic workshop was run for teachers as well. Over one hundred youngsters participated in this first nanoKOMIK with works in Basque, Spanish, and French. In their creations they tackled a whole range of subjects (health sciences, society, environment, technology, etc.) in a comic format.

In the second phase, the most original ideas from among more than 100 works were recreated in a professional comic entitled "Dayanne and Murillo. The power of nanoscience", which can be found in Basque, Spanish, French, and English at www.nanokomik.com and targeted all audiences. In order to facilitate and maximize its diffusion to society, the comic is available in different formats: magazine for distribution at fairs (comic, science, etc.), individual vignettes for social networks, and posters for exhibitions.

The nanoKOMIK project was cofinanced by the Spanish Foundation for Science and Technology (FECYT) – Ministry of Economy, Industry, and Competitiveness.

# 10ALaMenos9, festival of nanoscience and nanotechnology

10ALaMenos9 is a festival organized by various Spanish institutions and research centers with the aim of bringing the amazing world of nanoscience and nanotechnology to the society. This festival took place on 4 - 8 April 2016 in four different cities: Donostia - San Sebastian, Zaragoza, Barcelona, and Bellaterra.

We live on a scale of meters and kilometers, so it is rather hard for us to imagine a world that is too small to be seen. Ordinary objects are absolutely huge measured at what scientists call the nanoscale. This festival seeks to bring in an enjoyable and exciting way all sectors of the society closer to the nanoscale. By means of information and dissemination activities such as workshops, fascinating experiments, lectures, exhibitions, open days, and much more, researchers of the various participant cities work together in order to raise public awareness of the importance of nanoscience and nanotechnology.

NanoGUNE organized the following activities:

- A nanoforum to review the existing knowledge on the toxicity of nanomaterials for the human health and the environment, and a workshop to show some of the products and applications of nanotechnology that are already in the market.

- An informative seminar given by nanoGUNE's Group Leader and Ikerbaque Research Professor Luis Hueso in order to introduce to the general public the basic concepts related to nanoscience and nanotechnology.

- A guided visit to nanoGUNE's research infrastructure.

- The exhibition "A walk through the nanoworld", which showed a selection of finalist images of the 2007 and 2009 editions of the International Competition SPMAGE organized by researchers of the Autonomous University of Madrid and the Institute of Materials Science of the Spanish Research Council. The exhibition was completed with spectacular images obtained by nanoGUNE researchers.

- The 2nd National Conference on Nanopopularization aimed at involving the attendees in a constructive dialogue on the opportunities and impact of nanotechnology.

The festival was cofinanced by the Foundation for Science and Technology (FECYT) – Ministry of Economy, Industry, and Competitiveness.

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# Organization & Funding

**81** Grants in place

**19** European grants

**12** Marie Sklodowska Curie

**2** ERC

**2** Graphene Flagship

Carlos Garbayo, Maintenance Technician
Yurdana Castelruiz, Projects Manager
Miguel Odriozola, Finance Director

Eider García, Secretary
María Rezola, Director's Assistant
Ralph Gay, Cleanroom Manager

Julene Lure, Secretary
Itziar Otegui, Outreach Manager
Gorka Arregui, Facilities Manager

# Organization and Funding

NanoGUNE is a non-profit making Association that was promoted by the Basque Government in 2006 and was officially inaugurated in 2009. A Governing Board, currently composed by all partners, is the final responsible for the overall management of the center. We also have an International Advisory Committee, composed of internationally renowned researchers and professionals, which advises on the orientation that should be given to the center.

In the last two years we have been working on the accomplishment of the objectives settled in our 2015-2020 Strategic Plan. Thus, three business partners have joined nanoGUNE's Governing Board: CAF, Petronor, and IKOR; these are Basque companies that are leaders in the framework of the Research and Innovation Strategy for Smart Specialization (RIS3) launched by the Basque Government.

All our achievements would have not been possible without the support of the Basque Government and also the Basque Science Foundation (Ikerbasque) through its program to attract talented researchers from all over the world. This support, combined with our capacity to attract a considerably large amount of external competitive funding from the Regional Government of Gipuzkoa, the Spanish Government, the European Comission, and private initiatives, has allowed us to achieve a good progress towards a balanced and sustainable funding structure.

Since the foundation of nanoGUNE ten years ago, we have been able to place the Basque Country at the forefront of nanoscience research. From this position, the challenge for the coming years will be to increase the transfer of our knowledge and technology to our industrial environment, thus contributing to the competitiveness of the Basque economy and the well-being of our society.

| | 2015 | 2016 |
|---|---|---|
| Personnel (on 31 December) | 92 | 93 |
| Full-Time Equivalent (FTE) | 90.6 | 90.3 |
| R&D exploitation income (in thousand EUR) | 5 590 | 5 909 |
| % of non-competitive public funding from the Basque Government | 46 | 40 |
| % of competitive public funding from the Regional Council of Gipuzkoa | 2 | 2 |
| % of competitive public funding from the Basque Government | 16 | 27 |
| % of competitive public funding from the Spanish Government | 10 | 9 |
| % of competitive public funding from the European Commission | 23 | 14 |
| % of private funding | 3 | 8 |

# Governing Board

"Anchored in research excellence, nanoGUNE's vision follows the statement 'insight precedes application'; but it also realizes that 'application must follow insight', thus transforming ideas into wealth and well-being.

In line with this, the incorporation of three new industrial players to our Governing Board has represented a first step towards joining forces with global business leaders, and leads us to the constitution of an International Business Panel that will advise us on the path to fully accomplish our mission"

**Chairman**
Donostia International Physics Center
**Pedro Miguel Echenique**

**Vice-chairman**
Tecnalia Technology Corporation
**Joseba Jaureguizar**

**Secretary - Treasurer**
IK4 Research Alliance
**Jose Miguel Erdozain**

**Board members**
University of the Basque Country (UPV/EHU)
**Fernando Plazaola**

Regional Council of Gipuzkoa
**Oscar Usetxi** (until 17/11/2015)
**Ainhoa Aizpuru** (from 17/11/2015)

CAF
**José Antonio Gortazar**

IKOR
**Jon Sierra** (from 15/06/2015)

PETRONOR
**Valentín Ruiz Santa Quiteria** (from 15/06/2015)

**Guest members, on behalf of the Basque Government**

Department of Economic Development and Infrastructure
**Leire Bilbao**

Department of Education
**Itziar Alkorta** (until 22/06/2015)
**Adolfo Morais** (from 22/06/2015)

# International Advisory Committee

The International Advisory Committee gives advice on the orientation that should be given to the center

**Prof. Sir John Pendry (Chairman),** Imperial College, London, UK
**Prof. Anne Dell,** Imperial College, London, UK
**Prof. Marileen Dogterom,** Delft University of Technology, Delft, The Netherlands
**Prof. Jean Marie Lehn (Chemistry Nobel Laureate, 1987),** Université Louis Pasteur, Strasbourg, France
**Dr. José Maiz,** Intel Fellow, Intel, Oregon, USA
**Prof. Emilio Mendez,** Brookhaven National Laboratory, New York, USA
**Prof. Sir John Pethica,** CRANN, Dublin, Ireland, and University of Oxford, Oxford, UK

# Funding Institutions

EUROPEAN UNION
European Regional Development Fund

GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMÍA, INDUSTRIA Y COMPETITIVIDAD

Gipuzkoako Foru Aldundia

EUSKO JAURLARITZA
GOBIERNO VASCO

ikerbasque
Basque Foundation for Science

# Grants in place 2015 - 2016

## European Comission

**12** Marie Sklodowska Curie Actions (CIG, ITN, IRSES, Individual intra or extraeuropean)

**2** Graphene Flagship

**2** ERC

**1** H2020 FET Open

**1** FP7 Collaboration

**1** H2020 Integrating Society in Science and Innovation

## Spanish Government

**5** National Plan

**8** Retos

**2** Retos Excellence

**1** Retos Collaboration

**1** Europa Excelencia

**1** Innpacto

**2** Fecyt

**1** Ramón y Cajal

**1** Juan de la Cierva incorporation

**4** FPI pre-doctoral grants

**1** FPU pre-doctoral grant

## Basque Government

| | | |
|---|---|---|
| **7** Research projects | **7** Pre-doctoral grants | **6** Ikerbasque start-ups |
| **2** Emaitek | **2** Prest Gara | **3** Etortek / Elkartek |

## Regional Council of Gipuzkoa

| | | |
|---|---|---|
| **5** Red | **1** Gipuzkoa Fellow | **2** Ekintzaile |


center

CIC
nanoGUNE
nanoscience cooperative research center

www.nanogune.eu

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