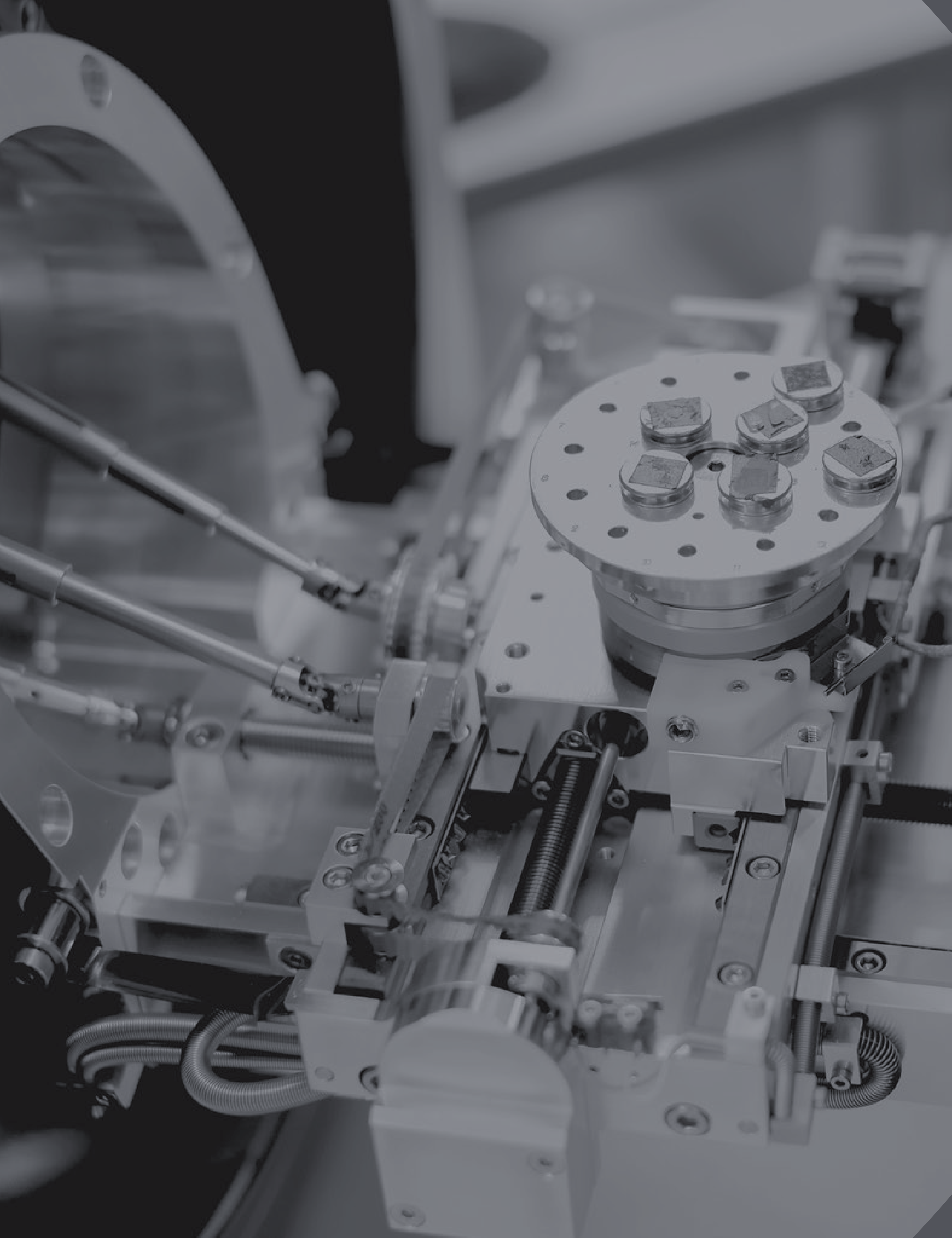
CIC nanoGUNE

Activity Report

2019-2020



CIC nanoGUNE

Activity Report

2019-2020


CIC
nanoGUNE
NANOSCIENCE COOPERATIVE RESEARCH CENTER

1

nanoGUNE in Numbers

2019-2020

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

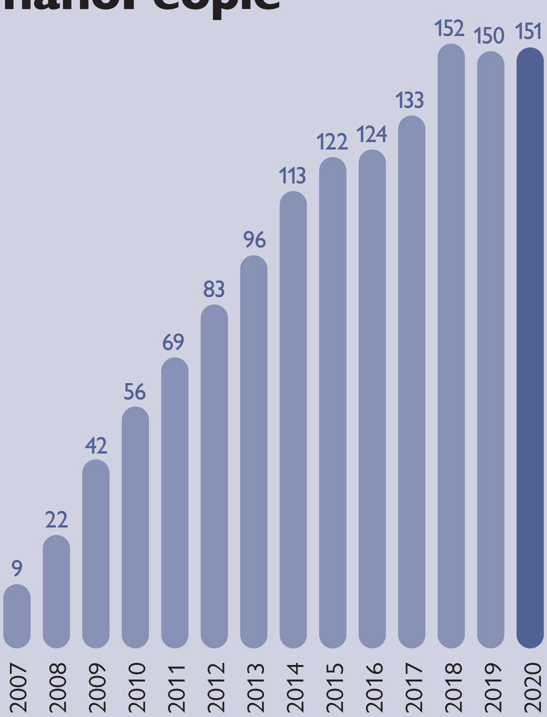
- 186 ISI publications
- 10 PhD theses accomplished
- 9 437 Citations
- 36 PhD theses ongoing*
- 7.9 Average impact factor
- 88 Grants in place
- 10 Research groups
- 33 Students and Guests*
- 118 Employees
- 9 Patents submitted
- 64 Seminars
- 5 Startups
- 30 Invited talks
- 672 Times in the media
- 4 Conferences and workshops organized
- 90 Visitors from high school and universities

*On 31 December 2020

Researchers from 26 countries

Argentina	2	Italy	12
Armenia	1	Japan	2
Austria	1	Korea	2
Belarus	1	Mexico	1
China	5	Morocco	1
Colombia	3	Netherlands	1
Croatia	1	Portugal	1
Cuba	1	Russia	11
France	2	Spain	79
Germany	13	Sweden	1
Greece	2	Switzerland	1
India	2	Ukraine	1
Ireland	1	United Kingdom	3

nanoPeople



93 ♂ 58 ♀

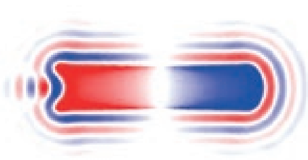
Senior Scientists	12	12♂	
Research Fellows	5	4♂	1♀
Post-docs	37	22♂	15♀
Pre-docs	35	21♂	14♀
Specialists	4	3♂	1♀
Technical Team	14	11♂	3♀
Management&Services	11	4♂	7♀
Master Students	6	3♂	3♀
Undergraduates	1		1♀
Guest Researchers	26	13♂	13♀

nanoGUNE personnel (including students and guests) on 31 December 2020

2

Message from the Director

"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"



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 world-class nanoscience research with a focus on knowledge and technology-transfer activities. In 2019, we celebrated our 10th anniversary with the satisfaction of having made good progress both in research and in the translation of that research into our society, thanks to the continuous support of a good number of individuals, public institutions, especially the Basque Government, and our International Advisory Committee. Many are the researchers that have passed through our Center, some of them now working at Technology Centers and companies in the Basque Country, and others enjoying academic positions worldwide. We have been publishing in the very best journals research papers that have enjoyed and are still enjoying a significant international impact. We have been recognized as a Maria de Maeztu Center of Excellence, a recognition given to centers that stand out for the international impact of our research activity; and all this has put us in a privileged situation allowing to address technology transfer and, in particular, the creation of new technology-based companies in extremely competitive areas like that of the well-known nanomaterial graphene. Some of these startup companies are still hosted at nanoGUNE. Others (Graphenea and Biotech Foods) have already fledged and now they have their own laboratories. Biotech Foods, dedicated to the production and commercialization of cultured meat, fledged its wings in 2020 to the Gipuzkoa Technology Park in San Sebastian after two years of incubation at nanoGUNE.

José M. Pitarke
Director

In the period 2019-2020, our state-of-the-art research has been ongoing, we have intensified our technology-transfer activities, and we have designed a new tech-transfer plan for the period 2021-25, based on three main areas of activity: (i) working with industry through privately funded research projects, (ii) licensing our technologies to third parties, and (iii) promoting technology-based new companies for the exploitation of specific in-house capabilities.

In the framework of this plan, our technology-transfer activities are expected to benefit from the recent creation, in 2019, of the Basque Research and Technology Alliance (BRTA), which counts with our participation together with other Cooperative Research Centers and Technology Centers in the Basque Country.

The period 2019-2020 has also been particularly fruitful with respect to the management of the Center. Our Innovation Management System, which had been certified in 2017 according to the standard UNE 166.002:2014, has been externally audited successfully in 2019 and 2020; in 2019, we were granted by the European Commission the *HR Excellence in Research* award, which gives public recognition to research institutions that have made progress in aligning their human-resource policies with the principles of the so-called European Charter&Code for Researchers; a Corporate Compliance Program has been designed; and a Gender-Equality Plan has been launched for the promotion of gender equality at the workplace and outside.

We were entrusted with a mission: to carry out world-class nanoscience research for the competitive growth of the Basque Country. We can proudly say that we are fulfilling our mission. World-class nanoscience research, in close collaboration with research laboratories and with industry, and a commitment to the society define the way we understand our activity. In order to stay there, at the top, in order to put the Basque Country at the forefront of nanoscience research, we need to keep doing a kind of cutting-edge research that would take us to unknown territories, still responding at all times to our commitment with industry: the industry of the present and, above all, the industry of the future. This is the big challenge of the small.

3

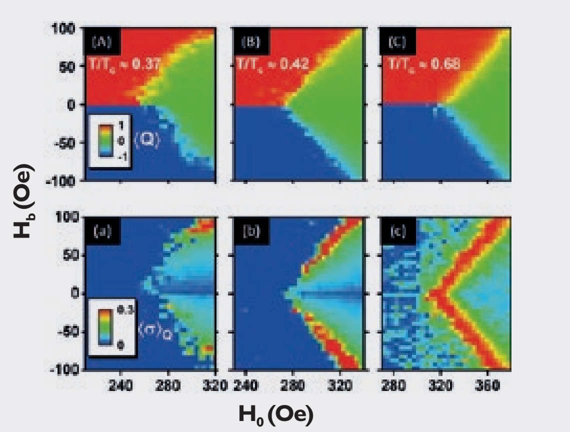
Research Groups

Nanomagnetism

The Nanomagnetism group conducts world-class fundamental and applied research in nanomagnetism and related characterization techniques. The group has developed a broad-based expertise in the fields of thin-film and multilayer growth, nanostructure fabrication, and magnetic-materials characterization. Furthermore, the group has established itself in an internationally leading position for investigations of advanced magneto-optical and magneto-plasmonic effects and their utilization for fundamental and applied purposes, which also include unique tool and device development. The group's expertise and activity profile are completed by the development of theoretical and computational models for quantitative descriptions of magnetic and optical properties at the nanoscale.

During the 2019-20 period, the Nanomagnetism group has achieved key progress in a number of fields, some of which were accomplished jointly with collaborators from all over the world. One such key accomplishment was the demonstration that magnetic layers separated by a non-magnetic layer can exhibit helical interlayer coupling, driven by the so-called Dzyaloshinskii-Moriya interaction, in addition to the conventional collinear interlayer coupling that was discovered more than 30 years ago. In the field of magneto-plasmonic metamaterials, we have proposed theoretically and demonstrated experimentally a novel conceptual roadmap to boost a magnetization-induced polarization modulation using multipolar dark plasmon modes. For this purpose, symmetry broken non-concentric magneto-plasmonic-disk/plasmonic-ring nanostructures were designed and nanofabricated in order to enable the free-space light excitation of multipolar dark modes in the plasmonic ring as well as their hybridization with the dipolar plasmonic resonance of the magneto-plasmonic disk, leading to a hybrid multipolar mode. The excitation of such hybrid high-order multi-polar dark modes resulted in a strongly amplified magneto-optical activity, allowing an unprecedented active control of light polarization under a magnetic field. Our new design could thus lead to broad applications in optical communications, sensing, and imaging.

Besides the above fundamental research activities, more applied research work is also of crucial relevance in our research portfolio. One example is the application of magneto-optical ellipsometry for investigations of ultrathin buried interfaces, a study that was conducted jointly with Kyushu University, one of Japan's preeminent universities. While conventional magnetometry measurements were unable to identify the magnetic nature of ultrathin alloy films that are used to increase the efficiency of magneto-thermal device structures, our magneto-optical ellipsometry demonstrated unambiguously that the most effective interface layers are non-magnetic. Another example was the demonstration of the use of hybrid magnetic-plasmonic elements to facilitate contactless and selective temperature control in magnetic functional metamaterials (nanomagnetic networks). Compared to so-far used global heating schemes, which are slow and energy-costly, light-controlled heating, using optical degrees of freedom such as light wavelength, polarization, and power, allows the implementation of local, efficient, and fast heating schemes to be used in heat-assisted nanomagnetic computation or to quantify collective emergent phenomena in artificial spin systems.



Demonstration of the influence that the temperature *T*, relative to the Curie temperature T_C of a magnetic material, has onto its dynamic behavior in the vicinity of the dynamic phase transition. Figures (A), (B), and (C) show the experimentally determined phase diagram of the dynamic order parameter <Q>, whereas (a), (b), and (c) show the associated fluctuation. While (A)–(C) have a rather similar appearance, (a)–(c) clearly visualize that fluctuations (more precisely, the so-called anomalous meta-magnetic fluctuations) are more important as T/T_C increases.

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Nanooptics

The Nanooptics group performs experimental and theoretical research in nanooptics and nanophotonics, covering both fundamental and applied aspects in these fields. 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 various areas of science and technology. Both techniques offer a wavelength-independent spatial resolution of about 10 to 20 nm at visible, infrared, and terahertz frequencies, thus beating the conventional diffraction resolution limit by a factor of up to 1 000.

During the 2019-2020 period, the Nanooptics group has kept working on the instrumental development of near-field microscopy in order to push the spatial resolution towards the single-molecule level, to enable three-dimensional (3D) infrared-spectroscopic nanoimaging, and to enable novel imaging modalities.

Furthermore, near-field microscopy has been applied to study plasmons in metal and graphene nanostructures as well as phonons in polar crystals, for the development of ultra-compact nanophotonic devices and their application.

We have been working on various advances in nanoimaging and nanospectroscopy: the application of infrared nanospectroscopy for the nanoscale mapping of chemical polymer composition, the secondary structure of proteins, the carrier distribution in semiconductor nanowires, and the optoelectronic properties of novel two-dimensional (2D) materials.

We have also been working on the development and application of theoretical models for the description of:

(i) the propagation and scattering of waves/surface waves in natural, artificial, and 2D materials,
(ii) near-field spectroscopy, and
(iii) the reconstruction of materials properties from near-field data.

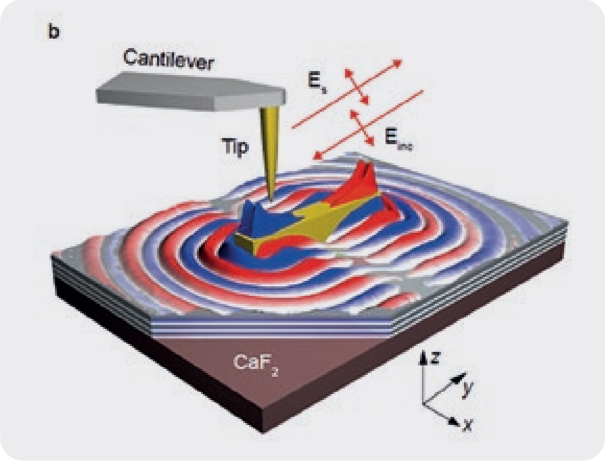

Illustration of the antenna launching of h-BN hyperbolic phonon polaritons (HPhPs). The spatial distribution of the near-field is shown by red and blue colors.

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Self-Assembly

The Self-Assembly group works on expanding the idea of "self-assembly" from classical molecular arrangements by mutual recognition towards externally forced assembly and towards nanoscale morphology of wetting layers. The focus is always on natural biomolecules, such as proteins and viruses, and on related biomimetic systems.

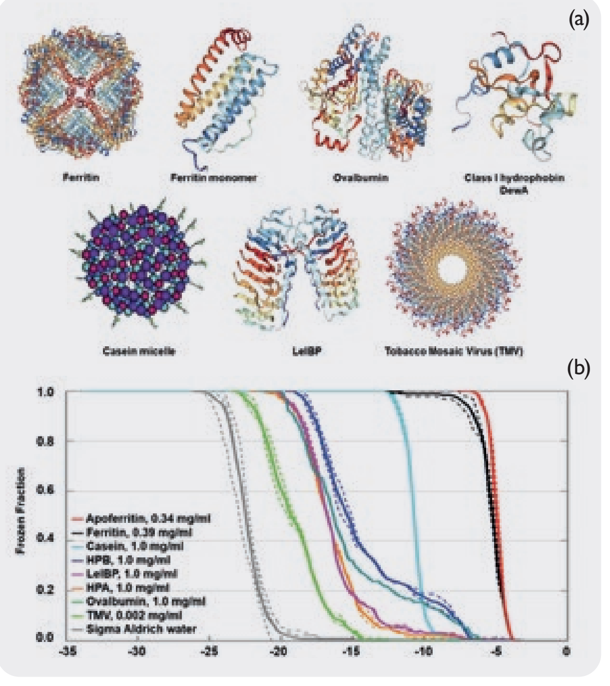
We explore classical self-assembly based on biochemical modification of cage-like protein assemblies (DPS), e.g. with mutually recognizable peptide tags. This allows specific assembly routes for these huge protein complexes, even towards new crystals. The highly variable biomineralization of protein cages opens routes to new microelectronic, magnetic, and optical devices.

Electrospinning is our method of forced assembly. We are constantly exploring and expanding our methods towards the production of fibers made of pure peptides/proteins without the usual polymer matrix. We are discovering new modes of molecular arrangement, also for proteins that cannot form fibers naturally, and expand the known, mainly natural protein assemblies. To this end, we are improving the technical capabilities of atomic-force microscopy on highly curved surfaces.

Ultrathin water or ice layers engulf almost all biological structures in contact with air, but their structure, dynamics, and role in biology are nearly unknown. Understanding drying and hydration of viruses during transmission is our most important aim. So far we have been focusing, however, on ice surfaces and on ice nucleation in supercooled water.

Our main experimental methods are based on our homebuilt electrospinning tools and our now commercial "novaspider" electrospinning/3D printing device. We employ and develop atomic-force microscopy and scanning (transmission) electron microscopy in a water vapor atmosphere of controlled humidity. We also make use of our spectromicroscopy facilities –Raman and (nano)FTIR–.

During the period 2019-2020, we have been collaborating with research groups at ETH Zürich (Switzerland), University of Milano (Italy), University of Grenoble (France), and locally with biomaGUNE and the Materials Physics Center in San Sebastian.



Supercooling of aqueous solutions of proteins. (Apo)ferritin solutions freeze at around -3°C, so these protein cages are potent ice nucleators. Other protein solutions (casein, HydroPhobins A and B, Leucosporidium Ice Binding Protein, ovalbumin, Tobacco Mosaic Virus) freeze between -10°C and -18°C, and pure water below -22°C.

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Nanobiotechnology

The Nanobiotechnology group is successfully developing a research line focused on the study of protein and cell mechanics. This research line is centered in the study of microbial infections from a mechanical point of view, using physical principles.

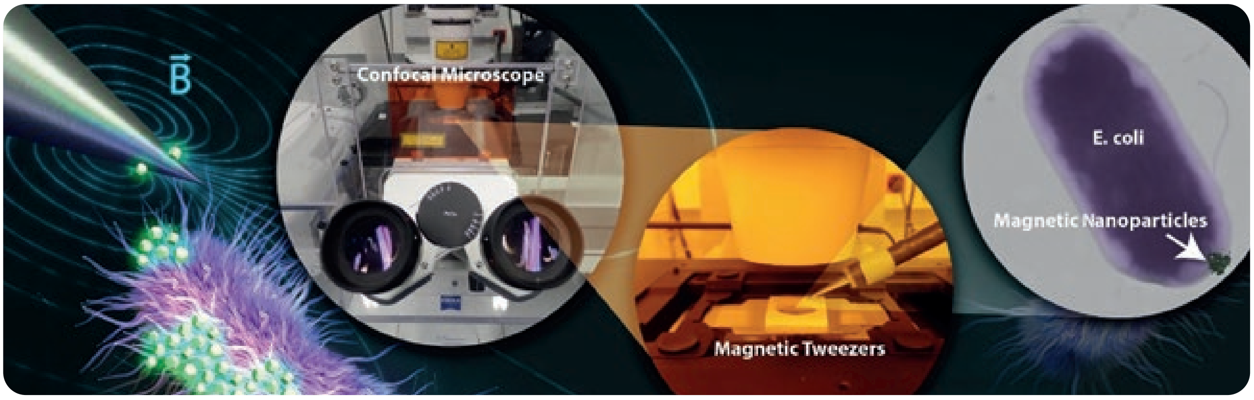
Bacteria and viruses infect organisms by using proteins that attach to molecules in the surface of the host. HIV-1 uses its envelope glycoprotein gp120 to attach to CD4 in the surface of T cell. Similarly, bacteria use an array of proteins called virulence factors for establishing mechanical anchoring to tissues. These proteins withstand mechanical forces going from few to hundreds of picoNewtons. The effect of these forces in the structure and chemistry of the proteins is not understood; but they may have implications in the infection process.

We investigate the role of mechanical forces in the structure and chemistry of microbial attachment proteins as well as in the infection process. We use an array of techniques to study the nanomechanics of viral and bacterial infections progressively from single molecules to cells. We aim at establishing new knowledge on the molecular aspects driving the mechanical interaction of microbes with their targets. We use atomic-force spectroscopy (AFS) to explore the effect of mechanical forces on microbial attachment proteins, human CD_4, and E. coli pilus. This technique allows monitoring chemical reactions under force such as bond rupture, the binding of peptides, small molecules, and antibodies, processes which are known to be implicated in microbial infections and that may have a mechanical origin.

We also use imaging techniques and magnetic tweezers (MT) in order to design molecular force sensors based on fluorescence for establishing correlations between cellular and molecular mechanics, and we are developing a high-throughput screening methodology to search for molecules that alter the mechanical properties of viral and bacterial proteins, serving as potential drugs against microbial attachment into host cells.

The Nanobiotechnology group is also working on a research line that directly connects with industrial biotechnology. This research line is focused on the design of enzymes with improved properties to be used in a number of industrial applications. Enzymes are widely used in industry and biomedicine. They need to be improved in order to be usable in processes outside their natural environment. We have specialized in the art of Ancestral Sequence Reconstruction (ASR). This technique uses phylogeny to bring back to life proteins and genes from extinct organisms and to study their physicochemical properties. We have discovered that enzymes belonging to organisms that lived a few thousand million years ago have properties that reflect the harsh conditions of ancient environment. We use these properties to design improved enzymes with industrial applications.

Scheme of our MT setup and detail of the magnetic needle. The magnetic field induces a force that moves the beads attached to the bacterial cell wall.



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Nanodevices

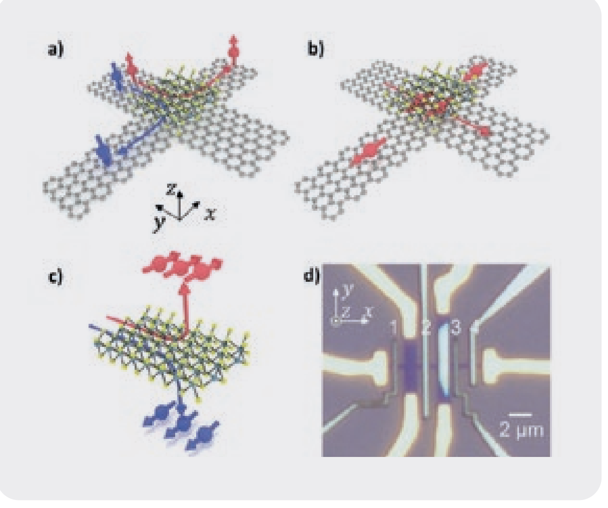
The Nanodevices group studies the electronic properties of materials at the nanoscale. For this, we use advanced nanofabrication methods and we measure the electron transport of materials in extreme conditions, such as low temperatures and high magnetic fields. We work along three main research lines: spintronics, the electronic properties of van der Waals heterostructures, and advanced nanofabrication.

Spintronics has emerged as an active field of research that aims at the development of a new generation of devices relying on the manipulation of the electron spin. Here we focus on the study of spin-orbit-coupling related phenomena, such as the spin Hall effect in heavy metals, the Rashba-Edelstein effect at interfaces, and the spin-momentum locking in topological insulators, which we study in metallic as well as two-dimensional (2D) nanodevices. These phenomena allow electrical spin-charge current interconversion, giving rise to interesting applications such as spin-orbit torques to write magnetic memories, or the integration of magnetic memory and spin-based logic, as recently proposed by Intel Corporation. Using state-of-the-art nanofabrication, our main goal is to devise alternative geometries that unlock innovative architectures for spin-based computational devices.

Since graphene –a monolayer of carbon atoms– was first isolated in 2004, a plethora of 2D materials have been characterized, as they range from unprecedently high carrier mobilities to record light-absorption efficiencies. Moreover, the layered nature of these materials enables the creation of new metamaterials by stacking a number of them on top of each other. These metamaterials are called van der Waals heterostructures. Here we use 2D layered materials and their van der Waals heterostructures as building blocks for novel (opto-)electronic, spintronic, and magnetic devices.

As for advanced nanofabrication, we use state-of-the-art techniques to build devices allowing us to explore the world at the nanoscale. Our expertise includes methods as diverse as electron-beam lithography (EBL) or focused-ion-beam and focused-electron-beam induced deposition (FIBID/FEBID). We can engineer improved materials with a high degree of control in order to explore the extreme possibilities of our techniques. The extensive knowledge that we have been acquiring during the last few years enables us to build final devices with high performances.

During the 2019-2020 period, we have initiated the coordination of the so-called SPEAR project, which seeks to explore new materials for the next generation of computer memories and processors; six European academic institutions (CEA-France, ETH Zürich-Switzerland, IMEC-Belgium, University of Hamburg-Germany, Martin Luther University Halle-Germany, and nanoGUNE) and three European companies (ANTAIOS-France, QZabre-Switzerland, and NanOsc-Sweden) participate in this project. SPEAR has been selected by the European Commission for funding as a *Marie Sklodowska-Curie Innovative Training Network* (ITN). We have also initiated a new industrial project funded by Intel Corporation on spintronics with van der Waals heterostructures.



An artist impression of the representation of a possible spin-charge conversion geometry together with a microscopy image of a 2D van der Waals heterostructure.

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Electron Microscopy

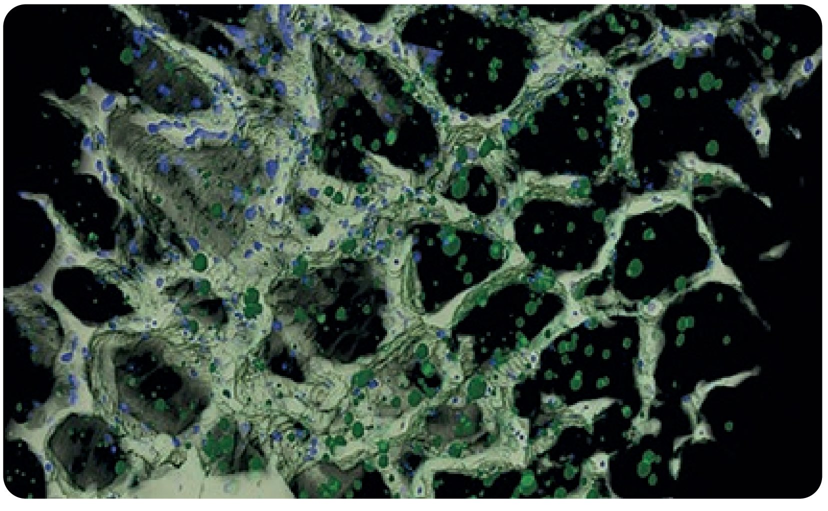
The Electron-Microscopy laboratory provides a high-end electron-microscopy support to research institutions and industry in the Basque Country and worldwide.

Though the main activity of the group is devoted to providing service to other researchers and industrial partners, currently there are two research lines maintained by the group itself.

The first research line is related to the study of the structure, solidification processes, and plasticity mechanisms in metals and alloys. This line is developed in collaboration with the Engineering department at Mondragon University in the part related to plasticity and machining of metals and with the University of the Basque Country (UPV/EHU) in the part related to solidification processes and metals three-dimensional (3D) printing.

The second research line is related to the development and utilization of the novel microscopic technique Liquid-Phase Transmission Electron Microscopy (LP-TEM). Here we collaborate with a company producing the equipment for this method; our aim is to make it robust, reliable, and quantitative. Applications of this method range from liquid nanoscale chemical kinetics to biomedicine.

Regarding the service provided to other researchers and industrial partners, we have a great diversity of methods that we can apply. Morphology, composition, and surface microstructure can be characterized by a variety of scanning electron/ion microscopy techniques like electron and ion-beam imaging, Energy-Dispersive X-ray (EDX) analysis, and Electron BackScatter Diffraction (EBSD). Peculiarities of the atomic structure and chemical composition can be studied by a set of Transmission Electron Microscopy (TEM) methods like conventional TEM, high-resolution TEM and Scanning TEM (STEM), electron diffraction including Convergent-Beam Electron Diffraction (CBED), EDX, and Electron-Energy-Loss Spectroscopy (EELS). We can access the magnetic properties of materials at the scale of a few nanometers utilizing electron holography, Lorentz microscopy, and differential phase imaging. The 3D structure of the samples can be revealed at different scales either by (S)TEM tomography or FIB Slice&View approaches. Stand-alone is a high-resolution EELS method used to characterize plasmons and phonons in nanomaterials.



3D structure of as printed Inconel 718 alloy obtained by FIB Slice&View.

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Theory

The Theory group does theory and simulation of systems at the nanoscale, especially first-principles simulations, meaning simulations solely based on the fundamental theory of quantum physics controlling the behavior of electrons and nuclei composing matter. This normally implies the use of heavy computation in high-performance computer centers.

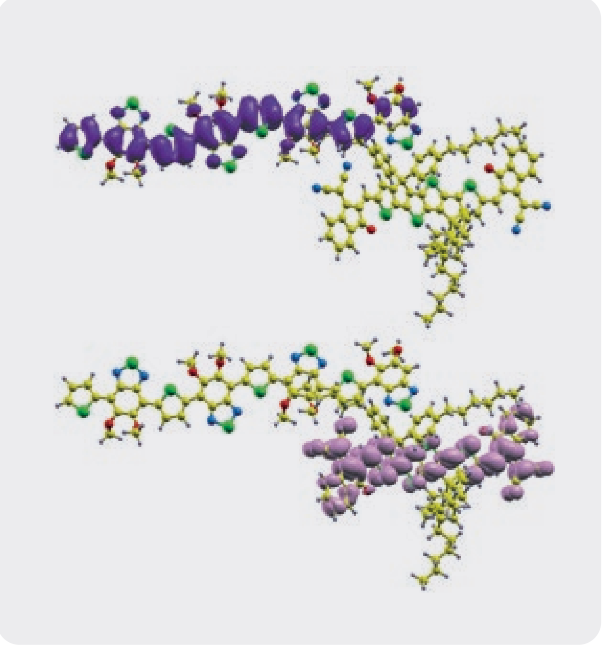
In the period 2019-2020, we have been improving the efficiency and scalability of our methods within large-scale European Centers of Excellence (MaX and ECAM).

We have also been involved in a European project using simulations to better understand the damage of space radiation in space exploration, both in spacecraft materials (mostly solar cells) and in the living tissue of people in space. Our on-going work is also of interest for the improvement of novel radiotherapy techniques in the treatment of cancer.

In collaboration with Merck, a multinational chemical company, we have studied new candidate molecules for organic photovoltaics, which means flexible, cheap solar cells for windows and intelligent buildings. We have studied the effect on their efficiency of the way molecules arrange themselves in the cells.

On the fundamental side, we are interested in the study of problems far from equilibrium at the nanoscale in a variety of contexts. Lately, we have been working to understand, from a non-equilibrium thermodynamics perspective, experiments pulling proteins that are being carried out at the Nanobiotechnology group. We have also been working on the understanding of stationary states arising in the quite violent disruption of solids when a high-energy ion projectile shoots through them.

Furthermore, the CECAM Electronic Structure Library represents quite an achievement. It is the result of a leadership effort at nanoGUNE. A number of computational physicists developing the most widely used methods and programs in the world in condensed matter physics, chemical physics, and materials science have been working together towards jointly renewing our codes for the new supercomputers to come, which will run with around one million processors in parallel. Revamping our programs separately (as done historically) represented a huge waste, which was stifling innovation and further development. The joining together of such a community has represented a great achievement.



Frontier orbitals involved in the photovoltaic process of two organic molecules, donor and acceptor.

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Nanomaterials

The Nanomaterials group is dedicated to the development of functional materials from various perspectives. Primarily, we synthesize and investigate polymer-inorganic hybrid materials with the perspective of applications in food packaging, catalysis, textile, or energy storage.

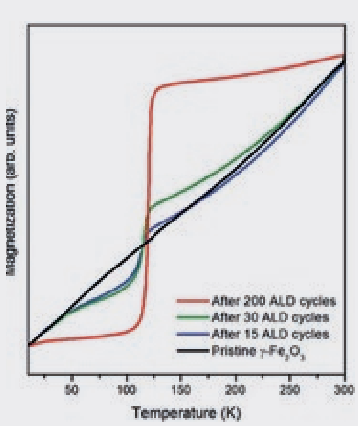
In the period 2019-2020, we have been working on the development of Li-S batteries, flexible electronics, antimicrobial coatings, and biomimetic catalysis.

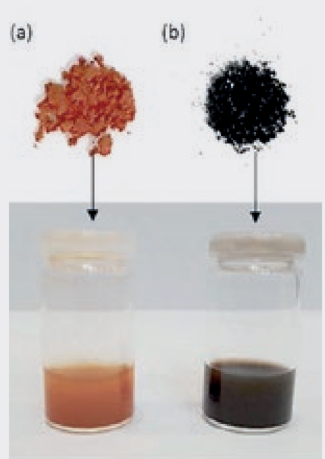
In the area of Li-S batteries, we have built a coating reactor for atomic-layer coatings on nanoparticles. With this reactor we can modify powders which are used for constructing electrodes for batteries. At the current time, we are working together with the Technology Center Cidetec on the improvement of cathodes for lithium sulphur batteries.

Regarding flexible electronics and antimicrobial coatings, we are performing infiltration of polymers with inorganic materials to enhance the functionality of the polymers. Within a *Marie Sklodowska-Curie Innovative Training Network* (ITN), we are making polymers electrically conductive and antimicrobial for a possible later use in flexible electronics or smart packaging.

Finally, in the research line of biomimetic catalysis we are creating hybrid materials out of proteins and inorganics. The proteins under study are enzymes (biological catalysts) which upon hybridization and stabilization can act as solid catalysts with a higher catalytic activity and chemical stability.

In the period 2019-2020, the Nanomaterials group leader, Mato Knez, has become honorary professor at the University of Rijeka in Croatia.





Left panel: magnetization vs. temperature curves of Fe_3O_4/TiO_2 core/shell nanoparticles after various numbers of Atomic-Layer-Deposition (ALD) coating cycles and a concerted reduction of the g-Fe_2O_3 nanoparticles to Fe_3O_4. Right panel: visual color change of the particles in powder form (top) and dispersed in water (bottom); (a) untreated commercial g-Fe_2O_3 nanoparticles and (b) the same particles after applying various ALD cycles, forming Fe_3O_4/TiO_2 core/shell nanoparticles. The color change from orange to black is indicative of a transformation from g-Fe_2O_3 to magnetite.

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Nanoimaging

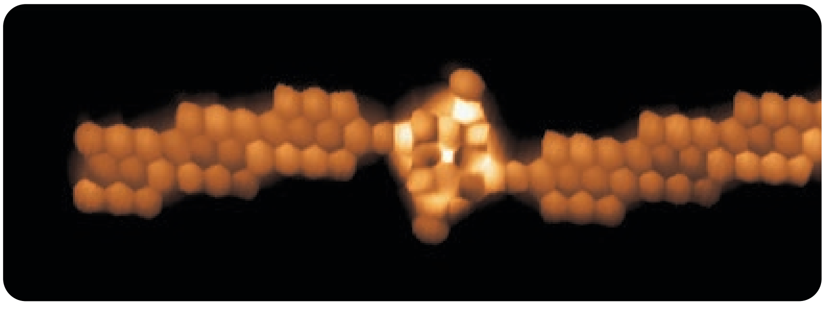
The Nanoimaging group is focused on the study of the quantum behavior of small objects formed by a small number of atoms or molecules, by using scanning probe microscopies. We search for effects related to their optical, magnetic, or electronic properties, which could help to understand the fundamentals 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.

In the period 2019-2020, we have focused our research along the study of superconductivity and the fabrication of atomically precise graphene nanostructures. The fundamental properties of quantum materials are based on complex electronic phenomenology emerging at the atomic scale. For example, while magnetism is known to destroy superconductivity, a single magnetic atom simply modifies the superconducting properties locally, perturbing the material in short length scales. Interestingly, when atoms are close and interact magnetically, the superconducting properties may be distorted in such a way that non-conventional pairing schemes emerge. Their detection and identification will provide basic rules for creating artificial quantum materials. Our research line in this direction envisions the creation of novel superconducting states of matter that cannot naturally emerge in existing materials by fabricating predesigned atomic-scale structures of magnetic atoms/molecules on a superconductor. We use the atom-by-atom manipulation technique of a scanning tunneling microscope to fabricate atomic-scale model systems and study the novel superconducting state they provoke by means of high-resolution tunneling spectroscopy.

As for the fabrication of atomically precise graphene nanostructures, there is a consensus that spins will expand our current information-technology landscape, based on the electron charge, into a class of faster and more efficient components, these representing also a basic element –a qubit– in the second quantum revolution for computation. Optimal materials are required that combine a well-defined spin localization and coherence with electrical addressability and integrate well into mesoscopic architectures. A promising material combining these properties is graphene. Graphene is a diamagnetic material, but upon being shaped in specific forms can host localized spins. We are fabricating graphene flakes with atomic-scale precision on a surface by triggering synthesis reactions of pre-defined organic precursors, and we study their magnetic properties by using low-temperature scanning tunneling microscopy (STM).

In the period 2019-2020, we have published the first demonstration of magnetism in zigzag sites of graphene flakes and we have uncovered the triplet ground state of triangulene, a triangular graphene nanoflake.

A molecular-scale device formed by two graphene nanoribbons contacting a magnetic iron porphyrin. The fabrication of this device is done by mixing two organic molecular precursors on a gold surface and annealing the substrate to high temperatures. The device is atomically perfect, and the connections to the porphyrin are done with atomic precision. Electronic transport through this system was further studied with low-temperature STM; here we found that the electronic spin of this system could be excited by injected electrons.



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Nanoengineering

The Nanoengineering Group focuses on new photonic solutions -in terms of methods, devices, and instrumentation- that face global challenges related to health, nutrition, and environmental problems.

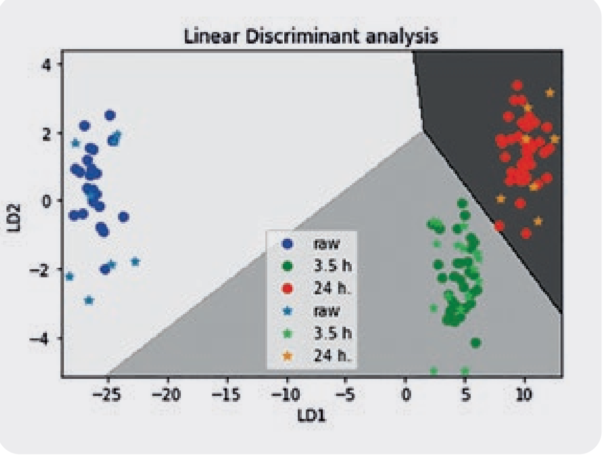
One research line concentrates on the development of spectroscopy instrumentation. We developed a new spectroscopy platform that combines Raman and FTIR (Fourier transform infrared) spectroscopy, such that both methods analyze the same sample at the same time without any interference. The optical design features an ATR-based (attenuated total reflection) FTIR path with aspheric optics and an off-axis Raman path that allows for optical sectioning. The objective is to provide complementary information for machine learning for a robust prediction and classification of biochemical conditions.

In a second research line, we work on the detection of Alzheimer's disease by machine learning-assisted multispectroscopy. Alzheimer is generally diagnosed in an advanced stage with serious symptoms. For an early diagnosis, we follow a multispectroscopy approach combining the information obtained from Raman, SERS (surface-enhanced Raman scattering), FTIR, and fluorescence spectroscopy. We investigate human samples from cerebrospinal fluid and combine the complementary spectroscopic information mathematically by machine learning. Our ambitious goal is to identify the disease in an early stage by an increased number of specific features of the physiological condition.

Our third research line investigates the detection of perinatal asphyxia by machine learning-assisted Raman spectroscopy. Here, we develop a non-invasive clinical tool for continuous and real-time monitoring of hypoxia-ischemia events in newborns during delivery. We aim at detecting physiological risks, which allow for immediate medical action. The technology includes application-specific Raman probes and machine-learning algorithms that take into account the systemic picture of physiological anomalies, in contrast to state-of-the-art methods where only one single parameter, as pH, serves for decision making.

Plasmonics for biodetection is our fourth research line. Here we are developing a highly sensitive detection system based on propagating and localized surface-plasmon resonances for specific biomarkers related to a variety of diseases. To overcome current detection limits, we focus on several engineering research topics, as Gaussian beam shaping, plasmonic nanostructures, specific biofunctionalization, optimized microfluidics, and multivariate analysis. Moreover, we develop self-assembled superlattices of Au nanoparticles for optimized SERS signals.

We are also working on food quality control by machine learning-assisted Raman/FTIR spectroscopy. In several projects, we make use of extended information delivered by the combination of several spectroscopy methods, supported by machine learning and considering the entirety of information instead of a single spectroscopic line. In this context, we investigate the quality of food, for example in terms of fraud where we analyze raw versus heated honey. Furthermore, we look at the content of microplastics in seafood, which nowadays is becoming a more and more serious global problem in our food chain.



Linear Discriminant Analysis (LDA) of eucalyptus honey under thermal treatment, as a demonstration of fraud with a clear classification of various conditions. The analysis is based on spectroscopic data from FTIR. Samples of raw honey were heated at 40°C for 3.5 and 24 h. Circles: training set (75% of data, randomly chosen). Stars: test set (25% of data).

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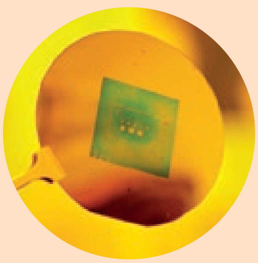
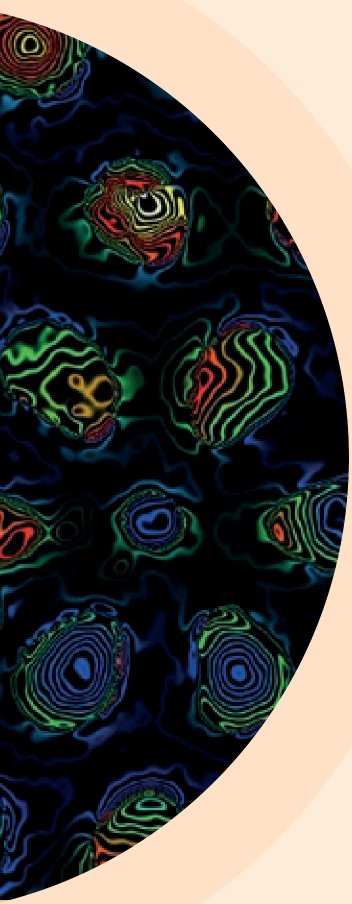
4

Research Outputs

Highlighted Publications





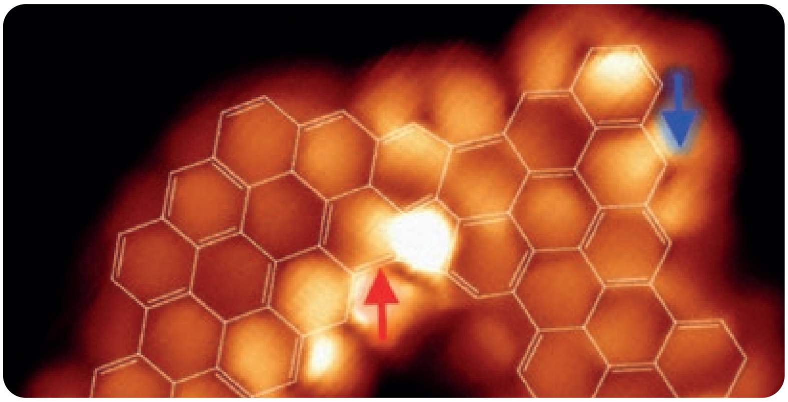
Single spin localization and manipulation in graphene open-shell nanostructures

Nature Communications
10, 200 (2019)

J. Li, S. Sanz, M. Corso, D.-J. Choi, D. Peña, T. Frederiksen, and **J. I. Pascual**

Turning graphene magnetic is a promising challenge to make it an active material for spintronics. We report on the observation of intrinsic π-paramagnetism of graphene nanostructures, and we demonstrate the ability to manipulate individual magnetic moments on these structures.

STM images of graphene nanostructures with localized spins. Coupled spins are indicated with red and blue arrows.



Research on carbon-based magnetism has been attracting great interest for a long time; but it has suffered from a poor reproducibility of the experimental results. Interest in this area arouse again with the isolation of graphene and the promising perspective of using graphene for spin transport and spin-based quantum information processing. While graphene is, in principle, diamagnetic, theory predicts that π magnetism can be induced by shaping graphene with zigzag edges. The experimental observation of graphene magnetism has been hindered by the lack of atomic control on the zigzag edges and the lack of sensitive spin measurements.

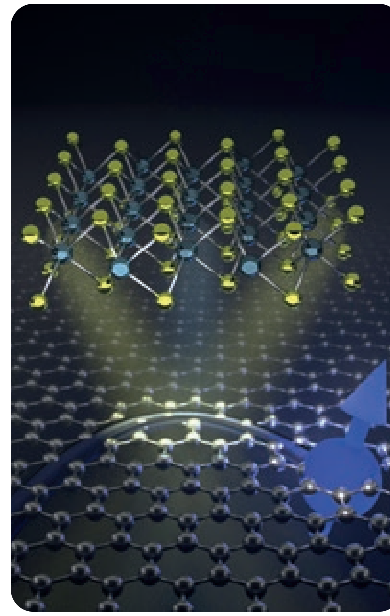
We have produced graphene nanostructures with atomic precision using an organic synthetic reaction over a metallic substrate. Our scanning tunneling microscopy (STM) measurements resolve the atomic structure, and we identify single electron spins localized around certain zigzag sites of the graphene nanostructures via the detection of the Kondo effect on top. Furthermore, the exchange coupling of nearby spins is quantified by singlet-triplet inelastic electron excitations. Using theoretical simulations, we demonstrate that electron correlations represent the basic ingredient for the emergence of intrinsic π-paramagnetism on graphene nanostructures.

In our results, the spin state of the graphene nanostructures can be manipulated by hydrogen passivation or by tip contact. Moreover, we demonstrate the electrical addressability of localized magnetic moments in graphene devices, which shows the potential of utilizing graphene in spintronic applications.

Room-temperature spin Hall effect in graphene/MoS_2 van der Waals heterostructures

Nano Letters **19**, 1074 (2019)

C. K. Safeer, **J. Ingla-Aynes**, **F. Herling**, J. H. Garcia, M. Vila, **N. Ontoso**, **M. R. Calvo**, S. Roche, **L. E. Hueso**, and **F. Casanova**



Artistic representation of the spin Hall effect in graphene induced by proximity with MoS_2

In this work, we report the first experimental observation of spin-to-charge current conversion (SCC) in graphene. To achieve this remarkable goal, we placed a flake of MoS_2, a semiconductor with high spin-orbit coupling (SOC), on a graphene Hall bar to induce SOC. The graphene, that otherwise does not show any SCC, generates out-of-plane spins when applying a charge current through it. This effect occurs up to room temperature and generates very large spin signals, which is very appealing for the realization of new spin logic devices, such as the magnetoelectric spin-orbit logic proposal by Intel.

The realization of on-chip logic operations using the spin degree of freedom requires an easy and efficient way to convert charge currents to spin currents. Currently this is realized using ferromagnets, the spin direction depending on their magnetizations. However, that is not desirable for operation in magnetic-field-free chip environments; hence, the ferromagnet-free injection and detection of spins is a major goal of spintronics.

Graphene is an outstanding material from the perspective of spin transport. On the one hand, its intrinsically low SOC allows for exceptionally long-distance spin transport at room temperature. On the other hand, graphene's two-dimensional (2D) nature enables the control of its properties by proximity with other materials. When a layered material is placed in close contact with graphene, a van der Waals heterostructure is formed, thereby modifying the properties of the graphene layer. When this material is MoS_2, a semiconductor with high SOC, graphene inherits the SOC. In heterostructures of graphene and MoS_2, the spin transport is affected by the large SOC which, together with its exceptional band structure with two inequivalent valleys, leads to a highly anisotropic spin transport where out-of-plane spins live for much longer than the in-plane ones.

To further exploit the mentioned system for spin-to-charge conversion, we prepared graphene Hall bars and placed a flake of MoS_2 on top of them. Additionally, we connected the graphene using nonmagnetic and magnetic contacts to unambiguously separate the spin from the charge currents. Our experiment shows that out-of-plane spins are efficiently converted to in-plane voltages at room temperature. This phenomenon is known as the spin Hall effect, where the spin propagation, the spin polarization, and the induced voltage are mutually perpendicular. Additionally, we observed that certain in-plane spins are also converted; but we did not conclude from the experiment whether the conversion occurs in the graphene or in the MoS_2 channel.

Our results have opened the way to spin-to-charge conversion in layered materials and have added an essential functionality in spintronic devices, including novel perspectives in spin-based logic. Indeed, a significant amount of related works from a variety of research groups have already appeared following the publication of this work.

Electrically addressing the spin of a magnetic porphyrin through covalently connected graphene electrodes

Nano Letters **19**, 3288 (2019)

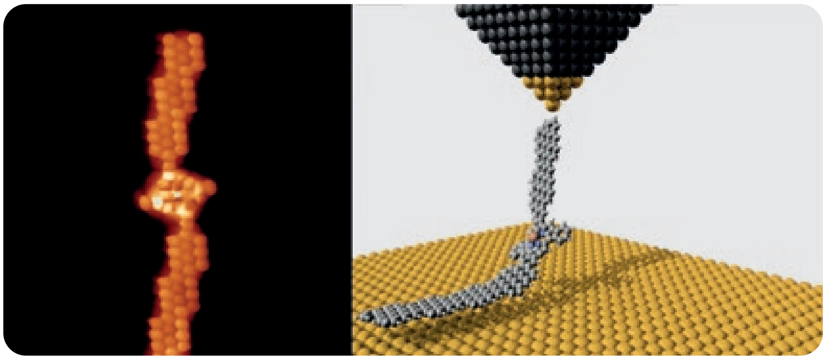
J. Li, N. Friedrich, N. Merino-Diez, D. G. de Oteyza, D. Peña, D. Jacob, and **J. I. Pascual**

The smallest imaginable electronic device consists of a single molecule connected by narrow wires, combining in a few nanometers an input port, the signal output, and a logic functionality. In this work, we have fabricated with atomic precision such a single-molecule device and we have tested our device by using graphene nanostructures and a magnetic molecule. Our results demonstrate that such a device is not only thinkable, as it can be physically realized.

Small carbon-based materials hosting magnetic moments are highly interesting for potential molecular spintronic devices. A promising approach is to use organometallic molecules as building blocks. These units provide both a specific spin, due to the transition metal atom in the interior of the unit, and a conjugated electron system for its electrical accessibility. Here, we show a method to interface the molecular units with electrodes in order to power the device with electrical currents.

We used thermally activated chemical reactions of specifically designed organic precursors over a metal substrate, in order to steer covalent bonds and assemble them into complex graphene structures with atomic precision. In combination with functionalized magnetic porphyrins, we fabricated a carbon-based, two-terminal molecular device hosting a single spin. In our experiments, we image the structure with high-resolution scanning tunneling microscopy.

The molecular spin can exist in two configurations and switching between them is possible by means of inelastic electronic currents. We have demonstrated this function by electrical transport measurements. Using the tip of a scanning tunneling microscope (STM), we lift the end of one of these devices from the underlying substrate. We then perform electronic transport measurements and simulations that reveal the characteristic fingerprint of switching the molecular spin between states. These results open the way to design more complex functional units in order to be able to continue shrinking the electronic devices we rely on every day.



The left panel shows an STM high-resolution image of the fabricated device, revealing the atomic structure. Two leads of chiral graphene nanoribbons (GNRs) connect an iron porphyrin molecule with atomic precision. The right panel exhibits an artistic interpretation of a molecular device bridging the tip and the substrate.

Interlayer Dzyaloshinskii-Moriya interactions

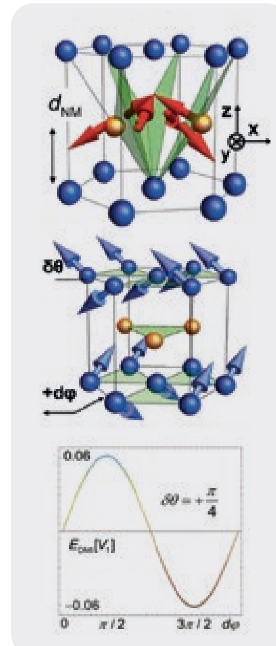
Physical Review Letters **122**, 257202 (2019)

E. Vedmedenko, **P. Riego**, **J. A. Arregi**, and **A. Berger**

Interlayer coupling phenomena in magnetic multilayer structures are among the most studied and most relevant research topics in magnetism, in terms of both their fundamental quantum mechanical origin and their vital importance for magnetoelectronic devices.

The initial observations, in the 1980s, of interlayer exchange coupling in multilayers that are fabricated from alternating stacks of magnetic and non-magnetic materials represented a watershed moment in magnetism research, because they enabled for the first time a magnetic state control at the nanoscale and thus facilitated the observation of the giant magneto-resistance (GMR) effect, another stellar scientific breakthrough that was awarded the Nobel Prize in physics in 2007. Both aspects became crucially relevant for high-tech devices in magnetic storage applications already in the 1990s and are still indispensable in magnetoelectronic and spintronic device technology today. A large number of materials combinations for the ferromagnetic and non-magnetic layers were studied, and all observed interlayer interactions were explained by an energy term that is bilinear or biquadratic in the spin variables of adjacent ferromagnetic layers and thus exhibits a Heisenberg exchange coupling mechanism.

Our work here demonstrates that other interlayer coupling mechanisms are possible as well, and we demonstrate, in particular, that Dzyaloshinskii-Moriya interactions (DMI) can facilitate an effective interlayer coupling that exhibits a preferred rotation sense, i.e. helicity, in terms of the magnetic orientations of the adjacent ferromagnetic layers. Following our theoretical predictions, experimental verifications of this mechanisms were also successful and, thus, open up new magnetic multilayer designs, where various kinds of helical magnetization states can be realized. Such magnetization states are not only fundamentally interesting but should also enable technical utilizations in terms of improved or entirely novel devices. The relevance of DMI interlayer coupling is hereby related to the fact that helicity induced symmetry reduction of magnetic states and magnetization reversal paths can be core ingredients of more deterministic magnetic state processing and thus can lower noise or error rate performances of devices.

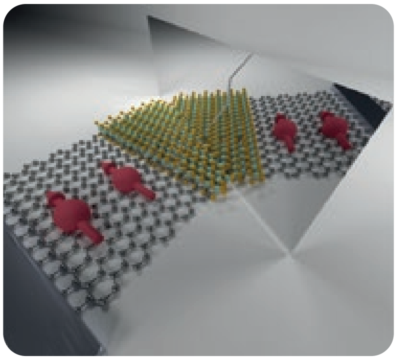


The top panel shows the computed geometry, where two magnetically ordered layers (whose atoms are represented by blue spheres) are coupled by means of interlayer impurities (represented by orange spheres) that facilitate an interatomic DMI whose vectorial orientations are shown by red arrows. The central panel displays an exemplary spin alignment in such a multilayer structure, in which the spins within each layer have the same in-plane orientation but a modulated out-of-plane component (modulation angle $\delta\theta$). Also, there is a rotated in-plane orientation considered in between both magnetic films (rotation angle $\delta\varphi$). The bottom panel shows the resulting DMI energy for such a spin structure and demonstrates that (I) the total DMI energy can be lowered by allowing for non-collinear magnetization states in each layer ($\delta\theta \neq 0$) and (II) for such non-collinear intralayer states the interlayer alignment has a preferred helicity, in which one perpendicular interlayer orientation represents the energy minimum whereas an inverted bottom layer spin orientation leads to an energy maximum.

Large multi-directional spin-to-charge conversion in low-symmetry semimetal $MoTe_2$ at room temperature

Nano Letters **19**, 8758 (2019)

C. K. Safeer, **N. Ontoso**, **J. Ingla-Aynes**, **F. Herling**, **V. T. Pham**, A. Kurzman, K. Ensslin, **A. Chuvilin**, I. Robredo, M. G. Vergniory, F. de Juan, **L. E. Hueso**, **M. R. Calvo**, and **F. Casanova**



Artistic representation of a mirror view of spin current generation in $MoTe_2$. Since the crystal mirror symmetry along the b-c plane is broken, the symmetry constraints of the spin-charge current conversion are lifted, resulting in generated spins with different orientations as shown in the mirror plane.

Spin-charge current interconversion (SCC) has been widely studied in heavy metals with strong spin-orbit coupling. The high crystal symmetry in these materials dictates the SCC symmetry where spin polarization, charge current, and spin current directions should be mutually orthogonal to each other. We studied SCC in $MoTe_2$, a Weyl semimetal with low crystal symmetry, and observed unconventional SCC allowed by broken mirror symmetries. These exotic components can be used for the electrical injection and detection of pure spin currents with multiple spin polarizations and a more flexible device design.

SCC can be obtained via spin-orbit phenomena, such as the spin-Hall or Rashba-Edelstein effect. The usefulness of these phenomena has already been demonstrated in the framework of magnetic memories and spin-based logics. While increasing the SCC efficiency will lead to the reduction of energy consumption in these devices, lifting the SCC symmetry constraints can provide flexibility to the device design and integration. In this regard, transition metal dichalcogenides (TMDs), two-dimensional (2D) van der Waals materials possessing strong spin-orbit coupling and low crystal symmetries, are promising for SCC research, as recent theoretical studies predicted a versatile SCC with large efficiency in these materials. Using a graphene lateral spin valve device as a tool, we have shown an experimental demonstration of these theoretical predictions in $MoTe_2$, a TMD semimetal having a distorted 1T octahedral crystal structure.

We first prepared graphene/$MoTe_2$ van der Waals heterostructures using a mechanical exfoliation followed by viscoelastic stamping. Using electron-beam lithography followed by metal evaporation, Au electrical contacts and ferromagnetic electrodes were patterned forming lateral spin valve devices. By applying a charge current across the graphene/ferromagnet interface, a pure spin current is injected into the graphene channel which is subsequently absorbed into the $MoTe_2$. The SCC creates a voltage along the $MoTe_2$ flake, which was probed using the Au contacts. By applying a magnetic field, the directions of the spin polarization were varied along different directions and corresponding changes in the SCC voltage were analyzed. Along with the conventional SCC with the orthogonal constraint, we also observed an unconventional SCC where the spin polarization and the charge current are parallel. We repeated the experiments at a wide range of temperatures from 75 K to 300 K and we extracted the corresponding efficiencies. Both contributions, which could arise from either a bulk spin Hall effect or a surface Edelstein effect, showed large efficiencies comparable to the best spin Hall metals and topological insulators.

Our unprecedented experimental observation deepens the understanding of spin phenomena in exotic low-symmetry materials. Also, the simultaneous efficient spin-charge current conversion with any in-plane spin orientation in a single material is promising for future spintronic device applications.

Spin-orbit magnetic state readout in scaled ferromagnetic/heavy metal nanostructures

Nature Electronics 3, 309 (2020)

V. Pham, **I. Groen**, S. Manipatruni, **W. Choi**, D. Nikonov, **E. Sagasta**, C. Lin, T. Gosavi, A. Marty, **L. E. Hueso**, I. Young, and **F. Casanova**

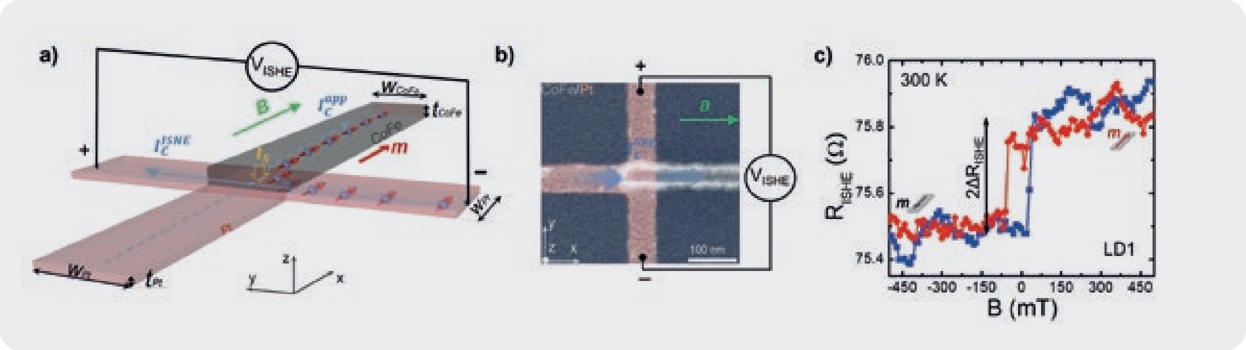
The so-called MESO technology integrates logic and memory in the same circuit, and for this it needs to read and write the information stored in magnetic bits. For the circuit to work, we need the two functions to operate at the same voltage. Here, we have achieved an increase by a factor of 10 000 in the output voltage for the "reading" operation.

In electronics, finding a replacement to current CMOS technology that can be smaller and faster and, most importantly, can operate with less energy consumption is a global challenge. Recently, Intel proposed the so-called "MESO" logic, a new technology that combines memory, interconnections, and logic requirements for future computing needs, thereby allowing to maintain Moore's law beyond CMOS while being more energy efficient.

In order to prove the feasibility of this disruptive technology, we have been joining forces with Intel. The core element of the MESO logic has two active parts. One part "reads" the information from the memory (a magnetic bit) by using the spin Hall effect. The other part "writes" the magnetic bit by using the magnetoelectric effect of certain materials. According to the calculations performed by Intel researchers, these two parts need to operate at the same voltage: 0.1 V. The problem here is that existing devices using the spin Hall effect could only provide 10 nV, which is 10 million times below the required voltage. Our challenge is to increase this "reading" output voltage.

So far, we have been able to increase the "reading" output voltage by a factor of 10 000 by simply using a better design but with the standard material for this effect, platinum. We have not reached yet the minimum voltage for this technology to work; but we unveil different paths on how to achieve it. First of all, the signal given by our device scales when the dimensions are reduced, which is a requirement for any technology to be introduced in the market (otherwise miniaturization would not be possible). Secondly, we identify the exact role that the materials play in the device, and we estimate that certain materials (like the recently discovered topological insulators) have the necessary properties that should allow us to bridge the remaining factor of 1 000 in order to reach the goal of 0.1 V. We conclude that our results bring the MESO technology a step closer to reality.

Sketch, image, and room-temperature measurement of the vertical spin injection device used for in-plane magnetic-state detection.



Broad spectral tuning of ultra-low-loss polaritons in a van der Waals crystal by intercalation

Nature Materials **19**, 964 (2020)

J. Taboada-Gutierrez, G. Alvarez-Perez, J. Duan, W. Ma, K. Crowley, I. Prieto, **A. Bylinkin**, **M. Autore**, H. Volkova, K. Kimura, T. Kimura, M. Berger, S. Li, Q. Bao, X. Gao, I. Errea, A. Nikitin, **R. Hillenbrand**, J. Martin-Sanchez, and P. Alonso-Gonzalez

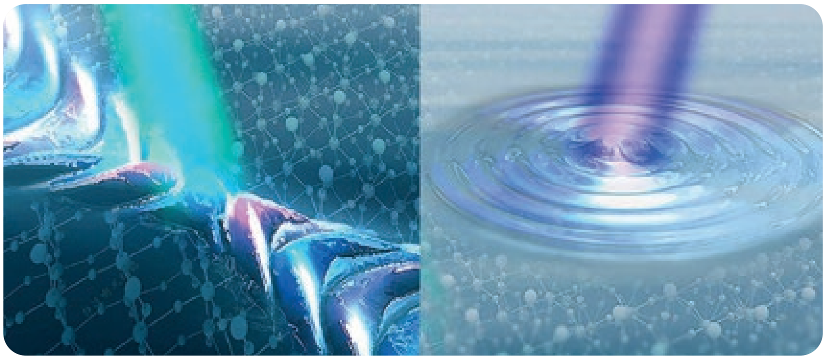
In this work, an effective method is discovered for controlling the frequency of confined light at the nanoscale in the form of phonon polaritons (light coupled to crystal vibrations).

Nanolight research based on phonon polaritons has developed considerably in recent years thanks to the use of sheet-structured nanomaterials such as graphene, boron nitride, or molybdenum trioxide: the so-called van der Waals materials. Nanolight based on phonon polaritons is very promising, because it can live longer than other forms of nanolight. There is, however, an important drawback of this type of nanolight for technological applications, due to the fact that it exists only in a narrow frequency region for each material.

Here, we widely extend the frequency range associated to phonon polaritons in van der Waals materials with the intercalation of alkaline and alkaline-earth atoms, such as sodium, calcium, or lithium in the laminar structure of vanadium pentaoxide, thus allowing to modify its atomic bonds and, consequently, its optical properties.

Considering that a large variety of ions and ion contents can be intercalated in layered materials, an on-demand spectral response of phonon polaritons can be expected in van der Waals materials, eventually covering the whole mid-infrared range, which is expected to be critical for the emerging field of phonon-polariton photonics.

Our finding should allow considerable progress in the development of compact photonic technologies, such as highly-sensitive biological sensors or information and communication technologies at the nanoscale.



A novel method has been proposed to widely extend the range of phonon-polariton working frequencies in van der Waals materials.

Uncovering the triplet ground state of triangular graphene nanoflakes engineered with atomic precision on a metal surface

Physical Review Letters
124, 177201 (2020)

J. Li, S. Sanz, J. Castro-Esteban, M. Vilas-Varela, **N. Friedrich**, T. Frederiksen, D. Peña, and **J. I. Pascual**

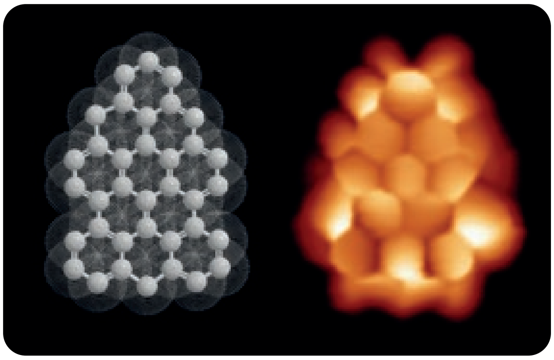
Extended graphene is a diamagnetic material, which means that it is unable to become magnetic. However, a triangular piece of graphene is predicted to be magnetic. This apparent contradiction is a consequence of "magic" shapes in the structure of graphene flakes, which force electrons to "spin" easier in one direction. Triangulene is a triangular graphene flake, which possesses a net magnetic moment; it is, therefore, a nanometer-size magnet. This new magnetic state opens fascinating technological perspectives in the use of pure-carbon magnets.

Existing predictions of triangulene magnetism were stumbling in the absence of clear experiments, as the production of triangulene by organic synthesis methods in solution represented a difficult task. The bi-radical character of this system caused it to be very reactive and difficult to fabricate, and the magnetism appeared to be very elusive in the few successful cases.

We have revisited this challenge by using a scanning tunneling microscope (STM). After assembling a triangular-like piece of graphene on a clean gold surface, high-resolution scanning tunneling spectroscopy measurements revealed that this compound has a net magnetic state characterized by a spin *S=1* ground state and, therefore, that this small molecule is a pure carbon paramagnet. Our results represent the first experimental demonstration of a high-spin graphene flake.

Our findings have been further complemented with atomic manipulation steps of hydrogen-passivated triangulene side-products occasionally found in the experiment. By controlled removal of these additional hydrogen atoms, the spin state of the flake could be modified from a closed-shell doubly hydrogenated structure to an intermediate *S=1/2* spin state and finally to the high-spin *S=1* state of the ideal molecular structure.

The experimental proof of a spin state in the absence of a magnetic quantization axis (detectable by spin-polarized STM) or magnetic anisotropy (detectable by spin-flip inelastic tunneling spectroscopy) is not simple. In this work, the spin signature was obtained from the under-screened Kondo effect – an exotic version of the standard Kondo effect of the 1960s – that can arise in high-spin systems. The observation of this effect in a graphene flake on a metal had not been reported before and brings novel insights to the understanding of spins interacting with surfaces.



The image on the right shows a bond-resolved STM image of a modified triangulene on an Au(111) substrate, and the image on the left is an artistic representation of the structure of its carbon lattice.

Subsurface chemical nanoidentification by nano-FTIR spectroscopy

Nature Communications **11**, 3359 (2020)

L. Mester, A. A. Govyadinov,
S. Chen, **M. Goikoetxea**,
and **R. Hillenbrand**

Here we demonstrate that nanoscale infrared imaging –which is established as a surface-sensitive technique– can be employed for the chemical nanoidentification of materials that are located up to 100 nm below the surface. Our results further show that the infrared signatures of thin surface layers differ from those of subsurface layers of the same material, which can be exploited to distinguish the two cases. Our findings push this technique one important step further to quantitative nanoscale chemometrics in three dimensions.

Infrared optical spectroscopy, such as Fourier-transform infrared (FTIR) spectroscopy, allows for the chemical identification of organic and inorganic materials. However, the smallest objects which can be distinguished with conventional FTIR microscopes have sizes at the micrometer scale. With a technique called nano-FTIR spectroscopy, which we have been developing in recent years, it is possible to resolve objects down to the nanoscale.

In nano-FTIR (based on near-field optical microscopy), infrared light is scattered at a sharp metallized tip of a scanning-probe microscope. The tip is scanned across the surface of the sample of interest and the scattered-light spectra are recorded using Fourier-transform detection principles. Recording the light scattered by the tip yields the infrared spectral properties of the sample and, thus, the chemical composition of the area that is located directly below the tip apex. Because the tip is scanned across the sample surface, nano-FTIR is typically considered to be a surface characterization technique.

Importantly though, the infrared light that is nano-focused by the tip does not only probe a nanometric area below the tip, as in fact it probes a nanometric volume below the tip. We now could show that spectral signatures of materials located below the sample surface can be detected and chemically identified up to a depth of 100 nm. Furthermore, we have found that nano-FTIR signals from thin surface layers differ from those of subsurface layers of the same material, which can be exploited for the determination of the material's distribution within the sample. Remarkably, surface layers and subsurface layers can be distinguished directly from the experimental data without involving time-consuming modeling.

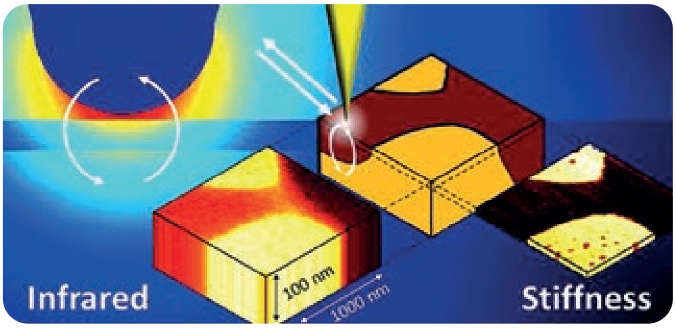


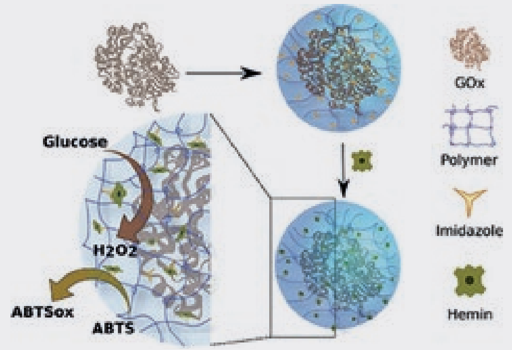
Illustration of subsurface infrared nanoimaging.

Nanoconfined (bio) catalysts as efficient glucose-responsive nanoreactors

Advanced Functional Materials **30**, 2002990 (2020)

A. Rodriguez-Abetxuko, **P. Muñumer**, **M. Okuda**, J. Calvo, **M. Knez**, and **A. Beloqui**

Herein, a new type of chemoenzymatic nanoreactor is shown, where the (bio) catalysts are confined at the nanospace and are conveniently arranged. The encapsulation of glucose oxidase into a peroxidase-mimetic catalytic polymer gives rise to the fabrication of a highly stable and robust bifunctional nanoreactor used for the concurrent degradation of aromatic compounds using glucose as the only fuel.



Chemoenzymatic nanoreactor

In this work, we show the design, synthesis, and characterization of bifunctional hybrid nanoreactors for the performance of concurrent one-pot chemoenzymatic reactions. The spatial arrangement of the catalysts, i.e. the hemin molecule and the glucose oxidase enzyme, is optimized for extremely responsive chemoenzymatic reactions in which the enzyme catalyzes first. Finally, the new nanoreactors are applied to the efficient degradation of organic aromatic compounds using glucose as the only fuel.

The design of new hybrid nanostructures which integrate two or more connected functions into a single entity are sought for further advances in the development of nanomaterials for biosensing and chemical applications. Certainly, the close positioning and the correct spatial arrangement of distinct functional, i.e. catalytic units into a confined volume at the nanoscale, resembling metabolic channels in cells, is beneficial for the development of one-pot reactions within the hybrid complex.

Despite the fact that a combination of bio- and chemo-catalysts has been proven successful in chemical synthesis, their joint utilization as chemoenzymatic one-pot reactors becomes challenging due to operational limitations related to the incompatibility and the mutual inactivation of the catalysts.

In this work, the glucose oxidase enzyme is wrapped with a peroxidase-mimetic catalytic polymer. The immobilization of hemin molecules through the imidazole ligands of the polymeric mantel mimics the chemical environment of iron-porphyrin molecules in the active center of peroxidase enzymes. Moreover, the advantageous assembly of the catalyst into a core-shell format, in which the biocatalyst is located in the core and the chemical catalyst in the shell, leads to a very efficient hybrid nanoreactor. In fact, a deep characterization of the integrated nanoreactors demonstrates that the confinement of two distinct catalytic sites in the nanospace is very effective in one-pot reactions.

The chemoenzymatic catalysis taking place within our nanoreactors involves the *in situ* transformation of glucose into hydrogen peroxide, which is then immediately used for the efficient peroxidation of recalcitrant aromatic compounds. Furthermore, compared to free enzyme systems, the nanoreactors show higher affinity and activity under diluted conditions and noticeably higher stability in the presence of organic solvents.

Highlighted Grants

Graphene Flagship

Graphene Core 2

START-END DATE ...... **01/04/2018 — 31/03/2020**
PARTNERS....... **130 academics and companies**
TOTAL FUNDING.................... **88 000 000 €**
CONTRIBUTION TO nanoGUNE .... **220 800 €**

This project represents the third stage of the EC-funded part of the Graphene Flagship. It builds upon the results achieved in the ramp-up phase (2013 - 2016) and the first core project (2016 - 2018).

The progress of the Flagship follows the general plans set out in the Framework Partnership Agreement, the second core project representing an additional step towards higher technology and manufacturing readiness levels. The Flagship is built upon the concept of value chains, one of which is along the axis of materials-components-systems; the ramp-up phase placed substantial resources on the development of materials production technologies, the first core project moved to emphasize components, and the second core project is moving further towards integrating components in larger systems.

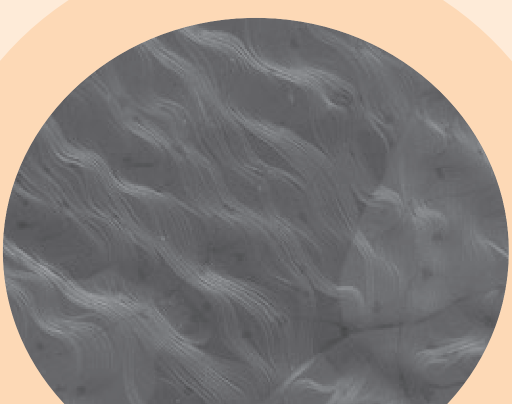
This evolution is manifested, e.g. in the introduction of six market-motivated spearhead projects during this Core 2 project.

Graphene Core 3

START-END DATE ...... **01/04/2020 — 31/03/2023**
PARTNERS....... **150 academics and companies**
TOTAL FUNDING................... **150 000 000 €**
CONTRIBUTION TO nanoGUNE .... **221 875 €**

The Graphene Flagship is research, innovation, and collaboration. The EU-funded GrapheneCore3 project aims at securing a major role for Europe in the ongoing technological revolution, helping to bring graphene innovation out of the lab and into commercial applications by 2023. In its third core project, the Graphene Flagship gathers over 150 academic and industrial partners from 23 countries, all exploring different aspects of graphene and related materials. Bringing diverse competencies together, the Graphene Flagship facilitates cooperation between its partners, accelerating the timeline for industry to accept graphene technologies.

This project, which represents the third core project of the Graphene Flagship, is characterized by a continued transition towards higher technology readiness levels without jeopardizing our strong commitment to fundamental research. Compared to the second core project, this phase includes a substantial increase in market-driven technological spearhead projects, which account for about 30% of the overall budget. The broader fundamental and applied research themes are pursued by 15 work packages and are supported by four work packages on innovation, industrialization, dissemination, and management.



FET Open

Femtoterabyte

START-END DATE ...... **01/03/2017 — 29/02/2020**
PARTNERS....... **8 academics and 2 companies**
TOTAL FUNDING....................... **3 712 833 €**
CONTRIBUTION TO nanoGUNE .... **316 616 €**

This project aims at elucidating the fundamentals of the emergence and manipulation of light's orbital and spin angular momenta to achieve a non-thermal momentum-transfer-driven ultrafast switching process and to demonstrate its practical realization; its suitability will then be mapped for a future upscaling towards industrial device implementation. Here we are developing the conceptually new paradigm of ultra-dense and ultrafast magnetic storage that would exceed the current technology by two orders of magnitude in storage density (going from terabit / $inch^2$ to tens of terabytes / $inch^2$) and by about four orders of magnitude in operation speed (going from low GHz to THz for read/write). This will be achieved in an all-optical platform that allows deterministic, non-thermal, low-energy, and ultrafast magnetization switching at a few nanometers and potentially down to a molecular length scale. The main building block of the envisioned memory unit in this new paradigm is a spinoptical nanoplasmonic antenna that concentrates pulsed polarized light at the nanoscale and enables non-thermal spin-orbit mediated transfer of the light's angular momentum (orbital and/or spin) to nanoscale magnetic architectures. In this way, fs-pulsed light, assisted by a plasmonic optical spin-selective antenna and a local electromagnetic field enhancement, allows for the precise control of the magnetic state of nanometer-sized molecular magnetic structures.

Peter

START-END DATE .... **01/01/2018 — 31/12/2020**
PARTNERS.......... **3 academics and 1 company**
TOTAL FUNDING...................... **2 898 684 €**
CONTRIBUTION TO nanoGUNE .... **613 353 €**

Here we propose to establish Plasmon-enhanced Terahertz Electron Paramagnetic Resonance spectroscopy and scanning microscopy as a unique Electron Paramagnetic Resonance (EPR) platform for a high-sensitivity local analysis of paramagnetic organic and inorganic species and materials. Here, we deliver novel hardware and infrastructure providing groundbreaking innovation in magnetic sensing and imaging. The platform is conceptually based on incorporating THz plasmonic antennas onto surfaces (spectroscopy) and scanning probe tips (microscopy), resulting in a strong, local enhancement (about two orders of magnitude) of the magnetic sensing field. Extending to the THz region enables an effective utilization of plasmonic structures resulting in a radical improvement of EPR sensitivity (about four orders of magnitude) and a spatial resolution going beyond the diffraction limit, thus introducing a scanning probe microscopic regime into this field. This will make possible to map the sample over its area and so to localize its properties with unprecedented resolution (below one micrometer). Such a significant enhancement of the EPR performance will open new ways in magnetic sensing technologies, enabling for instance to study *in situ* functional centers in a wide variety of materials and, generally, setting a new direction in the development of the EPR-employing industry. EPR finds its applications in many scientific areas covering chemistry, biology, medicine, materials science, and physics. Hence, introducing this new method should have a profound impact on scientific, technological, and societal stakeholders in many research and industrial communities.

Spring

START-END DATE . . . . **01/10/2019 — 30/09/2023**
PARTNERS . . . . **5 academics and 1 company**
TOTAL FUNDING . . . . **3 486 536 €**
CONTRIBUTION TO nanoGUNE . . . . **667 561 €**

Magnetism is something that had been missing –until very recently– in graphene's impressive list of physical properties. Due to its unconventional magnetic behavior, graphene has been touted as a promising material for spintronic applications. The main goal of this project is to develop an all-graphene platform where spins can be used for transporting, storing, and processing information. Researchers from different disciplines are collaborating to first fabricate atomically precise open-shell graphene nanostructures and then manipulate their electron spin and charge as well as their nuclear spin state. The aim here is to test the potential of graphene as a fundamental building block for spintronic devices.

Future Information Technologies will take advantage of quantum materials for an efficient information processing and communication. In the framework of this project, we utilize custom-crafted graphene nanostructures as elementary active components of a new generation of nanoscale quantum spintronic devices. Graphene structures can spontaneously develop intrinsic π-paramagnetism from topological frustrations of their structure. This unconventional magnetism is mobile, long-ranged, and can be electrically addressable. Our targeted long-term vision is the development of an all-graphene platform, where spins can be used for transporting, storing, and processing information. This new technology paradigm should combine a fast electron mobility with electrically addressable quantum spins in a customizable semiconducting platform, envisioning a clear impact on scientific, technological, and societal stakeholders.

To advance towards this goal, this interdisciplinary project combines research in physics, chemistry, and engineering to (i) fabricate graphene nanostructures with atomic precision, (ii) demonstrate and manipulate their electron and nuclear spin states, and (iii) test their potential as basic elements in quantum spintronic devices. On-surface synthesis strategies are being utilized to create atomically precise open-shell graphene nanostructures with radical character, including frustrated magnetic states, spin-polarized bands, spin chains, and nuclear spins embedded at specific sites. We will demonstrate the emergence of π-magnetization, we will unveil the time and energy scales of spin open-shell structures through a combination of scanning-probe and electron-spin resonance spectroscopies, and we will develop novel predictive models of the quantum functionality of these structures. The potential of graphene open-shell platforms as a novel paradigm in spin-based logic devices will be tested by (i) incorporating them into model devices and (ii) electrically addressing and manipulating spins.

Innovative Training Networks (ITNs)

SPM2.0

START-END DATE .... **01/01/2017 — 31/12/2020**
PARTNERS....... **7 academics and 3 companies**
TOTAL FUNDING: .... **3 593 489 €**
CONTRIBUTION TO nanoGUNE .... **495 746 €**

Advanced-Microscopy techniques are widely recognized as one of the pillars onto which the research and manufacture of nanotechnology-based products is sustained. At present, the greatest challenge faced by these techniques is the realization of fast and non-destructive tomographic images with chemical composition sensitivity and with sub-10 nm spatial resolution, in both organic and inorganic materials and in all environmental conditions. Scanning-Probe Microscopes are currently the Advanced-Microscopy techniques experiencing the fastest evolution and innovation towards solving this challenge. Scanning-Probe Microscopes have crossed fundamental barriers, and novel systems exist that show potential unparalleled performance in terms of three-dimensional (3D) nanoscale imaging capabilities, imaging speed, and chemical sensitivity mapping. The objective of this Innovative Training Network is to train a new generation of researchers in the science and technology of these novel Scanning-Probe Microscopes, in which Europe is currently in a leading position, in order to enforce a further development of these tools and their quick and wide commercialization and implementation in public and private research centers and industrial and metrology institutions. The young researchers participating in this network will acquire a solid state-of-the-art multidisciplinary scientific training in this field of research, covering from basic science to industrial applications, which should enable them to generate new scientific knowledge of the highest impact. In addition, they will receive a practical training on transferable skills in order to increase their employability perspectives and to be qualified to access responsibility job positions in the private and public sectors. The final aim of this network is to consolidate Europe as the world leader in Scanning-Probe Microscopy technologies and their emerging applications in key sectors like Materials, Microelectronics, Biology, and Medicine.

QuESTech

START-END DATE .... **01/01/2018 — 31/12/2021**
PARTNERS....... **7 academics and 2 companies**
TOTAL FUNDING. .... **3 884 019 €**
CONTRIBUTION TO nanoGUNE .... **445 698 €**

Quantum Electronics provides a challenging and innovative multidisciplinary arena for training young researchers with excellent prospects for a career in either industry or academia. In the framework of QUESTech (Quantum Electronics Science and Technology), a European network of experts has been created, thereby providing a state-of-the-art training for young researchers in the general field of experimental, applied, and theoretical Quantum Electronics.

The overarching science and technology goal of our research program is to build, study, and qualify quantum electronic devices. QuESTech is training 15 PhD students through research in the sub-fields of spintronics, single-electronics, quantum dots, and quantum thermodynamics. Individual research projects include technological developments in terms of nanomaterials growth, nanostructuring, near-field microscopies, transport measurements under extreme conditions, and theoretical calculations. Several QuESTech results are already identified to be of commercial interest for the emerging Quantum-Electronics industry.

Systematic secondments are being organized, including (for every researcher) a secondment of two months to a partner of the private sector. QuESTech is organizing three sessions of the European School On Nanosciences and Nanotechnologies (ESONN) devoted to Quantum Nanoelectronics, combining theoretical and practical training, which are open to young researchers outside the consortium. By 2021, we aim to have prepared a new generation of young researchers able to address the emergence of beyond-CMOS nanoelectronics.

Hycoat

START-END DATE .... **01/01/2018 — 31/12/2021**
PARTNERS........................... **10 academics**
TOTAL FUNDING...................... **3 898 798 €**
CONTRIBUTION TO nanoGUNE .... **430 946 €**

HYCOAT is the first ITN at the intersection of chemistry, physics, materials science, and engineering dealing with the synthesis and applications of hybrid coatings grown by molecular layer deposition (MLD). With self-limiting binary reactions, MLD is the ideal ultra-thin film deposition technique, offering unique advantages for growing uniform, conformal hybrid films that provide a precise and flexible control over film thickness and chemical composition at the molecular scale. This new field of MLD is pioneered at nanoscience laboratories across Europe. HYCOAT provides a European approach to facilitate an interdisciplinary and multi-environment platform for training a new generation of MLD researchers. A coordinated effort of 10 beneficiaries and 16 partner organizations from 7 European countries (Belgium, Finland, Germany, Ireland, Netherlands, Norway, and Spain), HYCOAT targets (i) the development of novel MLD precursor chemistries, processes, characterization, and modeling, and (ii) the demonstration of hybrid coatings in four key high-impact fields of application relevant for European industries: packaging, biomedicine, electronics, and batteries. The understanding and engineering of hybrid MLD coatings is essential for its wide range of applications, and the interaction with european high-tech industries is ensured through the active participation of 10 industries, 2 university hospitals, and a synchrotron facility.

Training is taking place through research projects, courses, and workshops, with emphasis on self-directed, hands-on, collaborative learning. This European knowledge alliance with an inter- and trans-disciplinary mobility and an intense collaboration between private and public entities should be able to equip the next generation of researchers.

Spear

START-END DATE ...... **01/03/2021 — 28/02/2025**
PARTNERS....... **6 academics and 3 companies**
TOTAL FUNDING...................... **3 975 822 €**
CONTRIBUTION TO nanoGUNE .... **806 270 €**

Spin Orbitronics provides a challenging and innovative framework for training early-stage researchers (ESRs) with excellent prospects for a career in industry and academia. In this promising area, the SPEAR project proposes a multidisciplinary European network composed of 7 universities, 3 research centers, and 7 small and medium sized companies, which will provide state-of-the-art training for ESRs in the field of fundamental and applied spin orbitronics.

The overarching scientific and technological objective of our research program is to study materials with strong spin-orbit coupling and to build devices for the next generation of memories, such as magnetic random-access memory (MRAM), and beyond-CMOS technology, as spin-orbit-based logic, machine learning, or neuromorphic computing. SPEAR will train 15 ESRs through research in the physics of spin-orbit torques, spin-to-charge conversion, two-dimensional (2D) magnetic materials, spin Hall nano-oscillators, voltage control of magnetic anisotropy, and skyrmions. The ESRs to be recruited will develop state-of-the-art technologies and materials, including device nanofabrication, high-resolution microscopies, and theoretical calculations. The results to be achieved by SPEAR are already identified to be of commercial interest for the emerging MRAM industry.

Interdisciplinary secondments are organized, including for every researcher a secondment of three months to the industrial sector. SPEAR will organize five focus topic sessions on various sub-fields of spin orbitronics, these sessions being open to junior researchers outside the consortium as well.

Conferences & Workshops

2019

10th Anniversary Scientific Workshop

DATE.................................30/01/2019
ORGANIZER........................nanoGUNE
PARTICIPANTS 100

Hybrid nanocoatings through molecular layer deposition

DATE............................02-06/09/2019
ORGANIZER........................nanoGUNE
PARTICIPANTS 20

Workshop organized in the framework of the European Innovative Training Network on Functional Hybrid Coatings by Molecular Layer Deposition (HYCOAT). A workshop on biomaterials was combined with training lectures on intellectual property, entrepreneurship, and the exploitation of research results.

Plastics in our ocean: a micro or macro challenge?

DATE............................ 01-02/10/2019
ORGANIZER........... nanoGUNE and Eklipse
PARTICIPANTS 18

A hands-on workshop tailor made for participants to co-understand the existing challenge and co-construct actions.

2020

2020 nanoGUNE PhD Workshop

DATE.................................30/01/2020
ORGANIZER........................nanoGUNE
PARTICIPANTS 100

Invited Conference Talks

2019

Spin-to-charge current conversion for logic devices
07/01/2019, **Felix Casanova**
WE Heraeus-Seminar, Bad Honnef (Germany)

Phonon polaritons in two-dimensional materials
14/01/2019, **Rainer Hillenbrand**
Nanophotonics of 2D Materials Conference, Shanghai (China)

Tips for atomic-scale physics: exciting electrons and spins in cool nanomaterials
16/01/2019, **Jose Ignacio Pascual**
X Escuela de Nanoestructuras, Valparaiso (Chile)

Surface functionalization and materials engineering by atomic layer processing
18/01/2019, **Mato Knez**
RSC Symposium, London (UK)

On the thermal relaxation of artificial spin ices
06/02/2019, **Paolo Vavassori**
Workshop on Frontiers in Artificial Spin Ice, Bad Zurzach (Switzerland)

Phonon-polariton nanophotonics based on two-dimensional materials
11/03/2019, **Rainer Hillenbrand**
International Winterschool on Electronic Properties of Novel Materials, Kirchberg in Tirol (Austria)

Mapping Yu-Shiba-Rusinov states in atomic and molecular impurities
21/03/2019, **Jose Ignacio Pascual**
Joint Workshop between MOLSPIN and NANOCOHYBRI - Superconductivity meets Molecular Spins, Lisbon (Portugal)

Magnetoelectric inversion of domain patterns
02/04/2019, **Naemi Leo**
DPG Spring Meeting, Regensburg (Germany)

Amplification of magneto-optical activity via hybridization with dark plasmons in magnetoplasmonic nanocavities
10/04/2019, **Paolo Vavassori**
2nd Photonic and OptoElectronic Materials Conference, London (UK)

Spintronics with 2D-material-based heterostructures
19/05/2019, **Felix Casanova**
12th European School on Molecular Nanoscience, Elche (Spain)

Amplification of magneto-optical activity with dark plasmons
02/07/2019, **Paolo Vavassori**
The 6th International Conference from Nanoparticles and Nanomaterials to Nanodevices and Nanosystems, Kanoni (Greece)

Mid-infrared nanophotonics with hyperbolic phonon polaritons: from antennas to photonic crystals
15/07/2019, **Francisco Javier Alfaro**
IV International Conference on Metamaterials and Nanophotonics, St. Petersburg (Russia)

Magneto-plasmonic nanostructures and crystals
12/08/2019, **Paolo Vavassori**
Spintronics XII, San Diego (USA)

Plasmon-assisted photoheating for nanomagnetic computation
28/08/2019, **Naemi Leo**
Joint European Magnetic Symposia, Uppsala (Sweden)

Magneto-plasmonic nanostructures and crystals
09/09/2019, **Paolo Vavassori**
XXXVII Symposium on Dynamical Properties of Solids, Ferrara (Italy)

Spinoptical nanoantenna-assisted magnetic storage at few nanometers on a femtosecond timescale
09/09/2019, **Mario Zapata-Herrera**
XXVIII Congreso Nacional de Física, Bogota (Colombia)

Phonon-polaritonic metasurfaces based on 2D materials
19/09/2020, **Rainer Hillenbrand**
The 13th International Congress on Artificial Materials for Novel Wave Phenomena, Rome (Italy)

Spin control and related effects at interfaces and heterostructures
23/09/2019, **Felix Casanova**
Quantum Materials Symposium 2019, Oxford (UK)

Infrared near-field nanoscopy and nanospectroscopy
26/09/2019, **Rainer Hillenbrand**
10th International Workshop on Infrared Microscopy and Spectroscopy with Accelerator Based Sources, Campinas & Ubatuba (Brazil)

Engineering thermal relaxation pathways for nanomagnetic computation
04/10/2019, **Naemi Leo**
11th International Workshop on Nanomagnetism and its Novel Applications - SpinS-2019, Mülheim an der Ruhr (Germany)

Bottom-up nanofabrication based on biomolecular functions and structures
07/10/2019, **Mitsuhiro Okuda**
The 19th International Conference on Solid Films and Surfaces - ICSFS19, Hiroshima (Japan)

Vapor-phase infiltration: a top-down approach towards functional hybrid-materials fabrication
16/10/2019, **Mato Knez**
Workshop on Sequential Infiltration Synthesis - SIS2019, Milan (Italy)

Engineering the magnetic properties of graphene nanostructures by edge topology
31/10/2019, **Jingcheng Li**
Exploring the Limits of Nanoscience with Scanning Probe Methods, Bad Honnef (Germany)

Spin manipulation with van der Waals heterostructures
05/11/2019, **Luis Hueso**
Carrier Doping in Two-Dimensional Layered Materials: Toward Novel Physical Properties and Electronic Device Applications, Naples (Italy)

Manipulating spin currents with graphene-based heterostructures
07/11/2019, **Felix Casanova**
Magnetism and Magnetic Materials Conference 2019, Las Vegas (USA)

Approach to the nanoscale analysis of humid virions
14/11/2019, **Alex Bittner**
Spanish Network of Excellence in Physical Virology: Bridging Biomedical and Nanotechnology Applications, Derio (Spain)

Capsid protein use for bionanotechnology
15/11/2019, **Mitshuhiro Okuda**
Spanish Network of Excellence in Physical Virology: Bridging Biomedical and Nanotechnology Applications, Derio (Spain)

Atomic-layer processing: a toolbox for fabricating novel functional hybrid materials
05/12/2019, **Mato Knez**
Materials Research Society Fall Meeting, Boston (USA)

2020

Sensing and manipulating electron spins in graphene nanostructures
08/03/2020, **Jose Ignacio Pascual**
International Winterschool on Electronic Properties of Novel Materials, Kirchberg in Tirol (Austria)

Nanophotonics with phonon polaritons in two-dimensional materials
09/03/2020, **Rainer Hillenbrand**
Nanolight, Benasque (Spain)

Seminars

NanoGUNE organizes weekly seminars to be given by both nanoGUNE personnel and external invited speakers.
All these seminars take place at the nanoGUNE seminar room.

2019

Ancestral enzymes for nanocellulose isolation
04/02/2019, **Borja Alonso**
nanoGUNE

Room-temperature spin Hall effect in graphene/MoS_2 van der Waals heterostructures
11/02/2019, **Safeer Chenattukuzhiyil**
nanoGUNE

COLLOQUIUM
Nanoscale functionalities in oxide films with controlled epitaxy
18/02/2019, **Beatriz Noheda**
University of Groningen (Netherlands)

Quantum computing with silicon transistors
25/02/2019, **Fernando Gonzalez-Zalba**
University of Cambridge (UK)

Magnetism in carbon materials: detection and manipulation of single spins in graphene nanostructures
04/03/2019, **Jose Ignacio Pascual**
nanoGUNE

Fabrication and applications of polymer optical fibers
11/03/2019, **Joseba Zubia**
University of the Basque Country (Spain)

Beam shaping and adaptive optics with electrons
18/03/2019, **Johan Verbeeck**
University of Antwerp (Belgium)

Building a programmable artificial protein cage
25/03/2019, **Jonathan Heddle**
Jagiellonian University (Poland)

Colloidal cybernetic systems: from information processing to energy harvesting
01/04/2019, **Alessandro Chiolerio**
Istituto Italiano di Tecnologia (Italy)

Equality with a gender perspective at nanoGUNE
08/04/2019, **Gender equality committee**
nanoGUNE

Physics of femtosecond laser-excited magnetic metasurfaces
15/04/2019, **Vasily Temnov**
Centre National de la Recherche Scientifique (France)

Spin-orbit magnetic-state readout with favorable miniaturization
06/05/2019, **Van-Tuong Pham**
nanoGUNE

Versatile tools towards real-time single-molecule biology
08/05/2019, **Aida Llauro**
Lumicks (Netherlands)

Organic-based magnets: new chemistry physics and materials for this millennium
13/05/2019, **Joel Miller**
University of Utah (USA)

Magnetic impurities on superconducting Bi_2Pd
20/05/2019, **Javier Zaldivar**
nanoGUNE

Ultrasensitive detection of the transverse magneto-optical Kerr-effect signal
27/05/2019, **Eva Oblak**
nanoGUNE

Molecular spin excitation by electron injection through a single graphene nanoribbon
27/05/2019, **Niklas Friedrich**
nanoGUNE

MID-PHD SEMINAR
Self-assembly of gold nanoparticles for nanoplasmonics
03/06/2019, **Matthias Charconnet**
nanoGUNE

The Hall effects Edwin Hall never imagined
14/06/2019, **Xiaofeng Jin**
Fudan University (China)

Novel on-chip magnetometries using planar Hall resistance sensors with high thermal stability
21/06/2019, **Cheolgi Kim**
Daegu Gyeongbuck Institute of Science & Technology (Korea)

Electrochemical microcalorimetry: measuring the entropy of electrochemical reactions
24/06/2019, **Rolf Schuster**
Karlsruhe Institute of Technology (Germany)

COLLOQUIUM
Exploration for beyond CMOS integrated circuit technology for computing
01/07/2019, **Ian Young**
Intel Corporation (USA)

Ferrimagnetic Tb-Fe based heterostructures: intriguing properties and applications
16/07/2019, **Manfred Albrecht**
University of Augsburg (Germany)

Scanning SQUIDS investigations of $SrTiO_3$ domain walls
22/07/2019, **Yiftach Frenkel**
Bar-Ilan University (Israel)

The chemistry of quantum materials
27/08/2019, **Leslie Schoop**
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Materials Physics Center (Spain)

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BIC Gipuzkoa (Spain)

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Unité Mixte de Physique CNRS/Thales (France)

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ETH Zurich (Switzerland)

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Kiel University (Germany)

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University of Central Florida (USA)

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University of Mainz (Germany)

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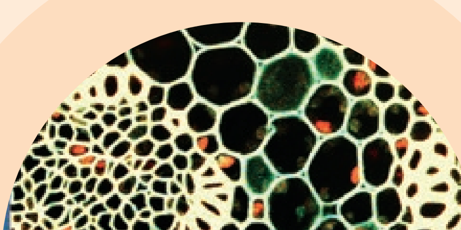

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73 S. Castilla, I. Vangelidis, V. Pusapati, J. Goldstein, M. Autore, T. Slipchenko, K. Rajendran, S. Kim, K. Watanabe, T. Taniguchi, L. Martin-Moreno, D. Englund, K. Tielrooij, R. Hillenbrand, E. Lidorikis, and F. Koppens
→ Nature Communications **11**, 4872 (2020)
Plasmonic antenna coupling to hyperbolic phonon-polaritons for sensitive and fast mid-infrared photodetection with graphene

74 J. Kruse, S. Merkens, A. Chuvilin, and M. Grzelczak
→ ACS Applied Nano Materials **3**, 9520 (2020)
Kinetic and thermodynamic hysteresis in clustering of gold nanoparticles: implications for nanotransducers and information storage in dynamic systems

75 M. Quintana, E. Oblak, J. Marin-Ramirez, and A. Berger
→ Physical Review B **102**, 094436 (2020)
Experimental exploration of the vector nature of the dynamic order parameter near dynamic magnetic phase transitions

76 N. Friedrich, P. Brandimarte, J. Li, S. Saito, S. Yamaguchi, I. Pozo, D. Pena, T. Frederiksen, A. Garcia-Lekue, D. Sanchez-Portal, and J. I. Pascual
→ Physical Review Letters **125**, 146801 (2020)
Magnetism of topological boundary states induced by boron substitution in graphene nanoribbons

77 C. Sanz-Fernandez, V. Pham, E. Sagasta, L. E. Hueso, I. Tokatly, F. Casanova, and F. S. Bergeret
→ Applied Physics Letters **117**, 142405 (2020)
Quantification of interfacial spin-charge conversion in hybrid devices with a metal/insulator interface

78 I. Olaetxea, A. Valero, E. Lopez, H. Lafuente, A. Izeta, I. Jaunarena, and A. Seifert
→ Analytical Chemistry **92**, 13888 (2020)
Machine learning-assisted raman spectroscopy for pH and lactate sensing in body fluids

79 M. Schnell, M. Goikoetxea, I. Amenabar, P. Carney, and R. Hillenbrand
→ ACS Photonics **7**, 2878 (2020)
Rapid infrared spectroscopic nanoimaging with nano-FTIR holography

80 L. Bigiani, C. Maccato, T. Andreu, A. Gasparotto, C. Sada, E. Modin, O. Lebedev, J. Morante, and D. Barreca
→ ACS Applied Nano Materials **3**, 9889 (2020)
Quasi-1D Mn_2O_3 nanostructures functionalized with first-row transition-metal oxides as oxygen evolution catalysts

81 **G. Bianca, M. Zappia, S. Bellani, Z. Sofer, M. Serri, L. Najafi, R. Oropesa-Nunez, B. Martin-Garcia, T. Hartman, L. Leoncino, D. Sedmidubsky, V. Pellegrini, G. Chiarello, and F. Bonaccorso**
→ACS Applied Materials & Interfaces **12**, 48598 (2020)
Liquid-phase exfoliated GeSe nanoflakes for photoelectrochemical-type photodetectors and photoelectrochemical water splitting

82 **I. Ardizzone, M. Zingl, J. Teyssier, H. Strand, O. Peil, J. Fowlie, A. Georgescu, S. Catalano, N. Bachar, A. Kuzmenko, M. Gibert, J. Triscone, A. Georges, and D. van der Marel**
→Physical Review B **102**, 155148 (2020)
Optical properties of $LaNiO_3$ films tuned from compressive to tensile strain

83 **I. Larraza, B. Alonso-Lerma, K. Gonzalez, N. Gabilondo, R. Perez-Jimenez, M. Corcuera, A. Arbelaiz, and A. Eceiza**
→Express Polymer Letters **14**, 1018 (2020)
Waterborne polyurethane and graphene/graphene oxide-based nanocomposites: reinforcement and electrical conductivity

84 **E. Vedmedenko, R. Kawakami, D. Sheka, P. Gambardella, A. Kirilyuk, A. Hirohata, C. Binek, O. Chubykalo-Fesenko, S. Sanvito, B. Kirby, J. Grollier, K. Everschor-Sitte, T. Kampfrath, C. You, and A. Berger**
→Journal of Physics D-Applied Physics **53**, 453001 (2020)
The 2020 magnetism roadmap

85 **D. Grzelak, P. Szustakiewicz, C. Tollan, S. Raj, P. Kral, W. Lewandowski, and L. Liz-Marzan**
→Journal of the American Chemical Society **142**, 18814 (2020)
In situ tracking of colloidally stable and ordered assemblies of gold nanorods

86 **V. Temnov, A. Alekhin, A. Samokhvalov, D. Ivanov, A. Lomonosov, P. Vavassori, E. Modin, and V. Veiko**
→Nano Letters **20**, 7912 (2020)
Nondestructive femtosecond laser lithography of Ni nanocavities by controlled thermo-mechanical spallation at the nanoscale

87 **D. Bennett, M. Munoz-Basagoiti, and E. Artacho**
→Royal Society Open Science **7**, 201270 (2020)
Electrostatics and domains in ferroelectric superlattices

88 **N. Koval, F. Da Pieve, and E. Artacho**
→Royal Society Open Science **7**, 200925 (2020)
Ab initio electronic stopping power for protons in Ga0.5In0.5P/GaAs/Ge triple-junction solar cells for space applications

89 **P. Riego, L. Fallarino, C. Martinez-Oliver, and A. Berger**
→Physical Review B **102**, 174436 (2020)
Magnetic anisotropy of uniaxial ferromagnets near the Curie temperature

90 **A. Bylinkin, M. Schnell, M. Autore, F. Calavalle, P. Li, J. Taboada-Gutierrez, S. Liu, J. Edgar, F. Casanova, L. E. Hueso, P. Alonso-Gonzalez, A. Nikitin, and R. Hillenbrand**
→Nature Photonics **15**, 197 (2021)
Real-space observation of vibrational strong coupling between propagating phonon polaritons and organic molecules

91 S. G. Stolyarova, A. A. Kotsun, Y. V. Shubin, V. O. Koroteev, P. E. Plyusnin, Y. L. Mikhlin, S. Mel'gunov, A. V. Okotrub, and L. G. Bulusheva
→ACS Applied Energy Materials **3**, 10802 (2020)
Synthesis of porous nanostructured MoS_2 materials in thermal shock conditions and their performance in Lithium-ion batteries

92 S. Syubaev, S. Gurbatov, E. Modin, D. Linklater, S. Juodkazis, E. Gurevich, and A. Kuchmizhak
→Nanomaterials **10**, 2427 (2020)
Laser printing of plasmonic nanosponges

93 E. Azaceta, S. Garcia, O. Leonet, M. Beltran, I. Gomez, A. Chuvilin, A. Mainar, J. Blazquez, and M. Knez
→Materials Today Energy **18**, 100567 (2020)
Particle atomic layer deposition as an effective way to enhance Li-S battery energy density

94 J. Etxebarria, M. Mowat, E. Lopez, C. Rodriguez, I. Olaetxea, and A. Seifert
→Analytical Chemistry **92**, 16236 (2020)
Gaussian beam shaping and multivariate analysis in plasmonic sensing

95 C. Chen, S. Chen, R. Lobo, C. Maciel-Escudero, M. Lewin, T. Taubner, W. Xiong, M. Xu, X. Zhang, X. Miao, P. Li, and R. Hillenbrand
→ACS Photonics **7**, 5499 (2020)
Terahertz nanoimaging and nanospectroscopy of chalcogenide phase-change materials

96 M. Autore, I. Dolado, P. Li, R. Esteban, F. J. Alfaro-Mozaz, A. Atxabal, S. Liu, J. Edgar, S. Velez, F. Casanova, L. E. Hueso, J. Aizpurua, and R. Hillenbrand
→Advanced Optical Materials **9**, 2001958 (2021)
Enhanced light–matter interaction in 10B monoisotopic boron nitride infrared nanoresonators

97 R. Weber, C. Martin-Valderrama, L. Fallarino, and A. Berger
→Physical Review B **102**, 214434 (2020)
Dependence of the magneto-optical signal on the Co layer thickness asymmetry in Co/Pt/Co films

5

Business Connection

Technology Transfer

A highly-efficient technology-transfer process naturally allows for an integration of innovative and disruptive technologies into current industrial products or processes. In this framework, nanoGUNE, as per its international intrinsic nature, brings a state-of-the-art research infrastructure and a high-quality worldwide research to the doorstep of Basque companies. This is being made possible thanks to (i) a good balance of local and international research projects, industry/academia connection tools, and business innovation centers, and (ii) an alignment of our research activities with the Basque Science, Technology, and Innovation Plan (PCTI).

In this context, the launch of the Basque Research and Technology Alliance (BRTA) in 2019 and a synergetic effort between the research and technology centers belonging to this alliance are expected to provide a comprehensive solution to companies with approaches covering the full range of technology readiness levels (TRLs).

In the current times of uncertainty with a pandemic that is shaking our economy, the establishment of resilient research guidelines is of great importance. At nanoGUNE, we have been working on the design of a technology-transfer plan that will serve as our route towards an effective exploitation of our research for the period 2021-2025 to come.

The three main pillars holding this plan are, (i) the direct absorption of our knowledge by industry through privately funded contract research, (ii) a targeted licensing of our technologies to third parties, and (iii) the launching of technology-based new companies –startups– for the exploitation of specific in-house capabilities.

The ecosystem for an efficient technology-transfer mechanism is based on technological clusters and platforms, policies for the transfer of highly qualified researchers to industry, a solid innovation management system, and a solid communication strategy.

We have been providing services to an increasing number of local and international companies, as nanotechnology is already becoming part of our daily lives. Indeed, we have a strategic technology portfolio that offers a number of technologies of high social impact such as birth monitoring, early Alzheimer detection, ocean microplastic detection, or even sustainable food-packaging and textiles. This represents, after all, a market-driven research allowing for the internationalization of the Basque Research, Technology, and Innovation Network (RVCTI) and bringing to the country the most innovative developments.

Contact

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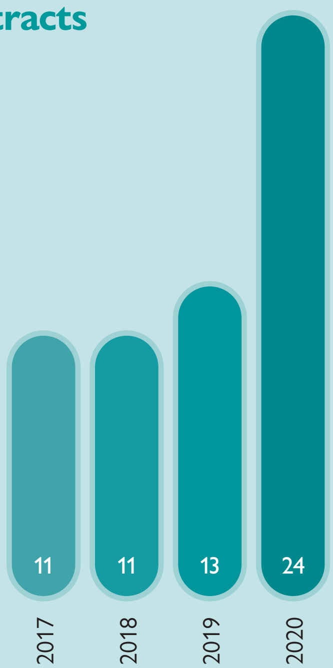
TechTransfer Manager
+34 943 57 40 13
a.garciagallastegui@nanogune.eu


PATENT LICENSING
CONTRACT RESEARCH
STARTUPS
TECHNOLOGY TRANSFER PLAN
EXTERNAL SERVICES
COMMUNICATION
RESEARCH GROUPS
OUTPLACEMENT
SECONDMENTS

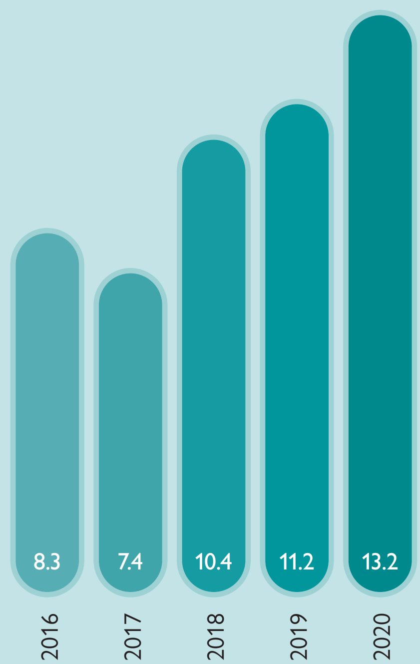
Contract Research

The number of research contracts having increased substantially within the last few years, our private funding now stands above 10% of our total income. On the other hand, our number of clients has doubled in the last year, and private invoicing is still increasing steadily.

Number of research contracts



Private-income percentage



Contract Research 2020

INTERNATIONAL COMPANIES

FEI

intel

neaspec

attocube

regineering

SRC Semiconductor Research Corporation

SCALE Nanotech

KUBOS SEMICONDUCTORS

BASF We create chemistry

SPANISH COMPANIES

DYNAMIC ABUTMENT SOLUTIONS

IT3D GROUP

BASQUE COMPANIES

AEG

ASTILLEROS BALENCIAGA S.A. SHIPYARD

GSR

i+Med BIOTECHNOLOGY FOR HEALTH

FAGOR FAGOR ALUMINIO

ELZAR TECHNOLOGIES

IKERLAT polymers

microLIQUID

KUSUDAMA

RVCTI* CENTERS

tecnalia Inspiring Business

DIPC

CIC bioGUNE MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

CIC biomaGUNE MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

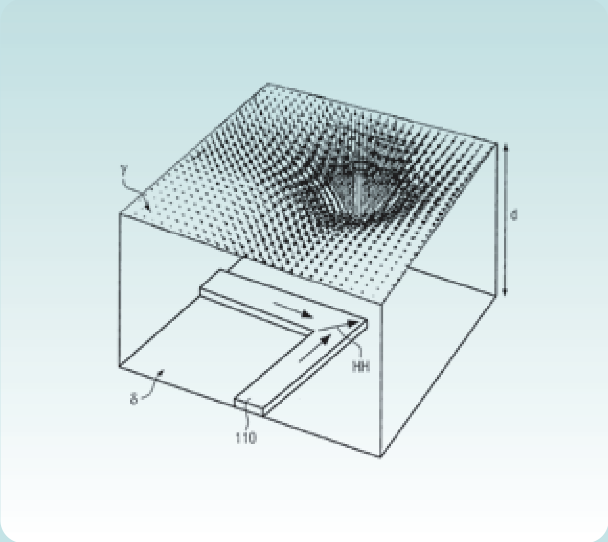
* Basque Research, Technology, and Innovation Network

Health

Manipulation of magnetic particles in conduits for the propagation of domain walls

P. Vavassori, R. Bertacco, M. Cantoni,
M. Donolato, M. Gobbi, S. Brivio, and D. Petti

Priority date: 12/02/2009
Granted: Japan (17/05/2013), USA (04/11/2014), Europe (24/06/2015)



Biosensor based on measurements of the clustering dynamics of magnetic particles

M. Donolato, P. Vavassori, and M. Fought-Hansen

Priority date: 28/06/2013
Granted: Europe (15/03/2017), USA (10/10/2017), Australia (02/08/2018)

USAGE

- Using an Immuno-Magnetic Assay for high standard diagnostics, Blusense combines cutting-edge micro and nanotechnologies in order to develop an unprecedented technology to fight infectious diseases worldwide, COVID-19 as well.

- Shared with the Technical University of Denmark (DTU)
- Licensed to Blusense Diagnostics, ApS

BLUSENSE DIAGNOSTICS

DTU

Combined selective plane illumination Raman and infrared absorption spectrometer

G. P. Singh and A. Seifert

Priority date: 12/05/2020

USAGE

- Early-stage Alzheimer's detection

DESCRIPTION

- Beta-amyloid protein folding detection at low concentration
- Based on a portable multi-spectroscopy approach
- In-house designed learning algorithms
- Analysis of human blood and cerebrospinal fluid
- Looking for investors for implementation

Method and device for the determination of hypoxia

A. Seifert, A. Valero, I. Olaetxea, I. Jaunarena, A. Izeta, and H. Lafuente

Priority date: 18/08/2020

USAGE

- Photonic monitoring of perinatal asphyxia
- Monitoring of hypoxia, ischemia, sepsis, fatigue, and acidosis
- Sports industry

DESCRIPTION

- Based on portable multi-spectroscopy
- In-house designed learning algorithms
- Portable, reliable, real-time, continuous mode
- Non-invasive and minimally invasive monitoring

▸ Shared with Biodonostia

biodonostia
health research institute

HIGHLIGHTS 2020

- Selected at the first stage of the BBK Venture Phylanthropy Program
- Best pitch presentation at the European Technology Platform in Nanomedicine (ETPN)
- Selected technology for the Health Tech Translation Advisory Board at the ETPN

bbk
nanomedicine
Healthtech TAB

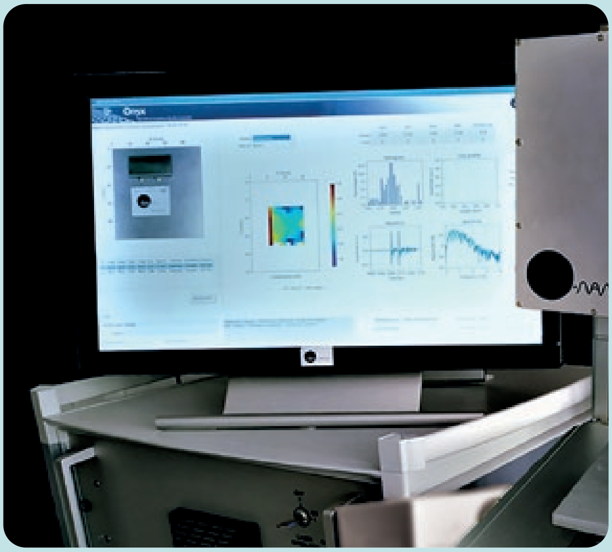
Electronics

Quality inspection of thin-film materials

L. E. Hueso, E. Azanza, M. Chudzik, A. Lopez,
A. Zurutuza, and D. Etayo

Priority date: 23/12/2014
Granted: USA (23/04/2019)

- Shared with das-Nano, S.L.
- Licensed to das-Nano, S.L.



Materials Science

Endocellulases and uses thereof

R. Perez-Jimenez

Priority date: 15/01/2016

- Licensed to Evolgene, S.L.

Atomic Layer Deposition Chamber

M. Knez, M. Beltran, D. Talavera, and M. Vila

Priority date: 22/09/2016
Granted: Spain (03/03/2020)

- Shared with Ctech-nano, S.L.
- Licensed to Ctech-nano, S.L.

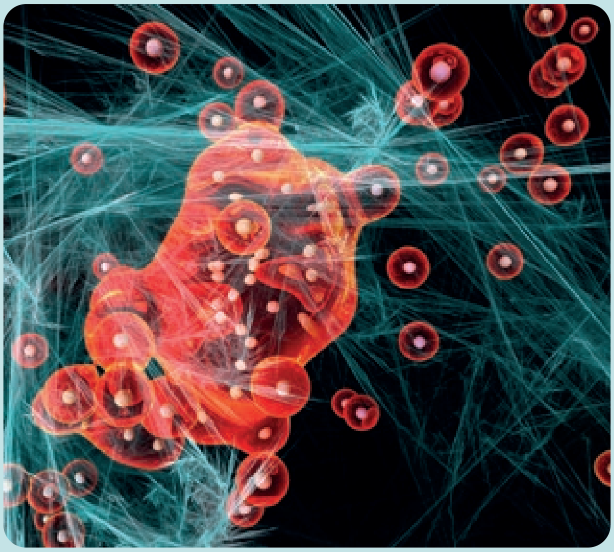
Materials Science

Ancestral cellulases and uses thereof

R. Perez-Jimenez, N. Barruetabena, and M. A. Eceiza

Priority date: 19/12/2017

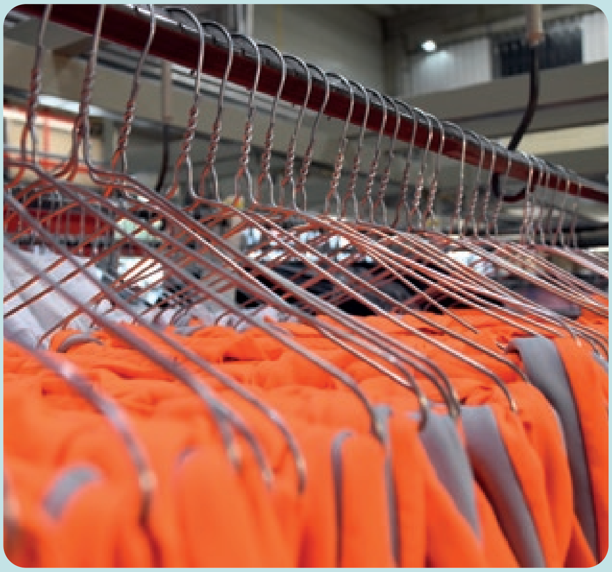
- Shared with UPV/EHU
- Licensed to Evolgene, S.L.



Method for producing organic-inorganic hybrid materials

I. Azpitarte and M. Knez

Priority date: 24/07/2018



A highly corrosion protective thin bi-layer stack for steel

C. Agustin, F. Brusciotti, M. Brizuela, M. Knez, and J. Willadean-Dumont

Priority date: 11/10/2018

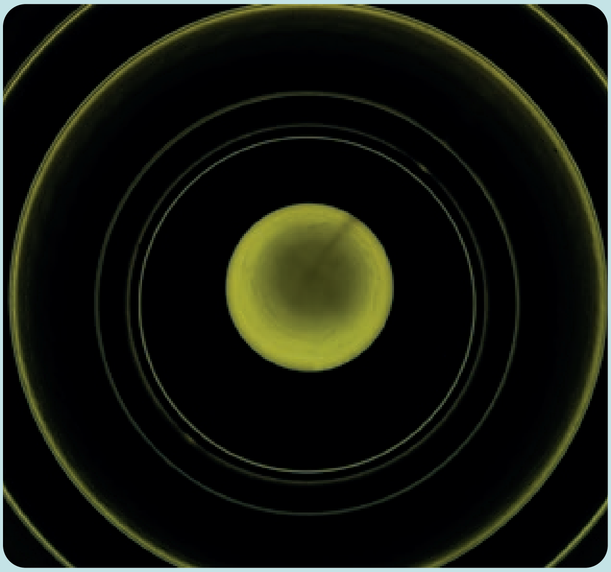
▸ Shared with Tecnalia Research & Innovation

Method for extracting a transverse magneto-optic effect signal

E. Oblak, A. Berger, P. Riego, A. Garcia-Manso, A. Martinez-deGuerenu, F. Arizti, and A. Irizar

Priority date: 30/04/2019

▸ Shared with CEIT



Materials Science

System for manufacturing a composite fiber structure

J. Latasa, W. Nuansing, and A. M. Bittner

Priority date: 27/08/2019

HIGHLIGHTS 2020

- Selected technology for the Health Tech Translation Advisory Board at the European Technology Platform in Nanomedicine (ETPN)
- Youth Entrepreneurship scholarship from UPV/EHU to Maider Rekondo
- 5 machines sold worldwide in 2020

Method for producing crystalline cellulose

R. Perez-Jimenez, B. Alonso-Lerma, and A. Eceiza

Priority date: 28/02/2020

- Shared with UPV/EHU
- Licensed to Evolgene, S.L.

Conductive cellulose composite materials and uses thereof

R. Perez-Jimenez, B. Alonso-Lerma, and A. Eceiza

Priority date: 28/02/2020

- Shared with UPV/EHU
- Licensed to Evolgene, S.L.

eman ta zabal zazu

UPV EHU

Evolgene

Layered substrate and uses thereof

J. Plou, L. Liz-Marzan, I. Garcia-Martin, and M. Charconnet

Priority date: 21/12/2020

- Shared with biomaGUNE and CIBER-BBN

CIC biomaGUNE
MEMBER OF BASQUE RESEARCH
& TECHNOLOGY ALLIANCE

ciber-bbn

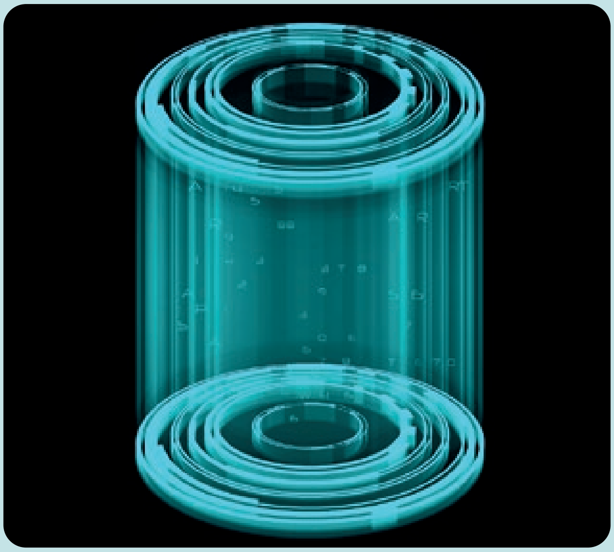
Optics

Synthetic optical holography

R. Hillenbrand, P. Scott-Carney, and M. Schnell

Priority date: 25/09/2012
Granted: USA (15/12/2015)

- Shared with the University of Illinois
- Licensed to Neaspec, GmbH

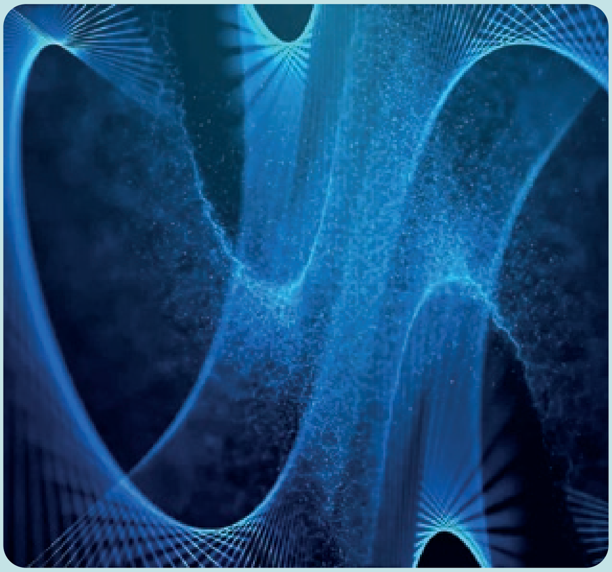


Optical devices and authentication methods

M. Knez and E. Azanza

Priority date: 27/06/2013

- Shared with das-Nano, S.L.
- Licensed to das-Nano, S.L.



Method for producing a barrier layer and carrier body comprising such a barrier layer

K. Gregorczyk, M. Knez, F. Vollkommer, J. Bauer, and K. Dieter-Bauer

Priority date: 24/07/2014

- Shared with Osram, GmbH
- Licensed to Osram, GmbH

OSRAM

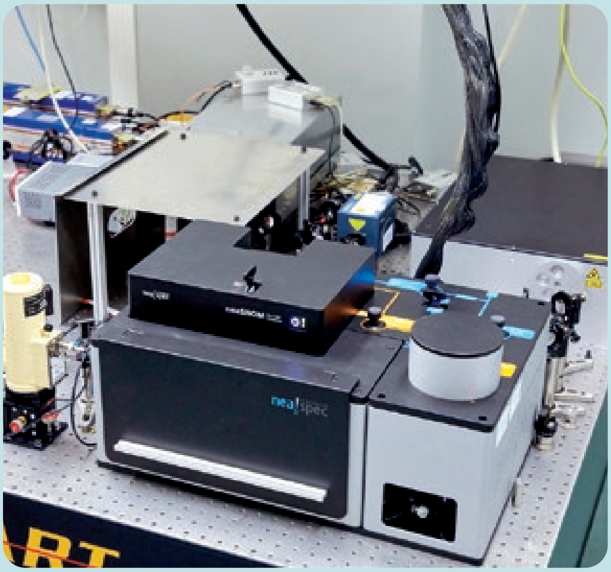
Near-field optical microscope for acquiring spectra

R. Hillenbrand, E. Yoxall, and M. Schnell

Priority date: 13/03/2015
Granted: USA (21/05/2019)

- Licensed to Neaspec, GmbH

neaspec see the nanoworld attocube WITTENSTEIN Group



Optics

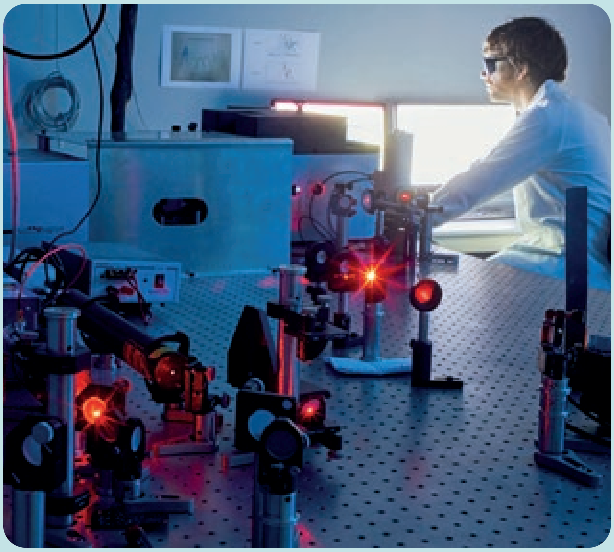
A device for operating with THz and/or IR and/or MW radiation

R. Hillenbrand, M. Autore, K.-J. Tielrooij, and F. Koppens

Priority date: 22/12/2017

Granted: Europe (09/12/2020)

- Shared with ICFO

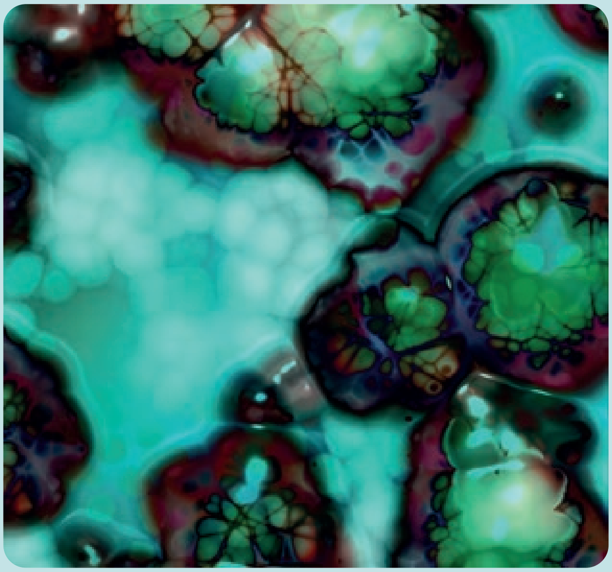


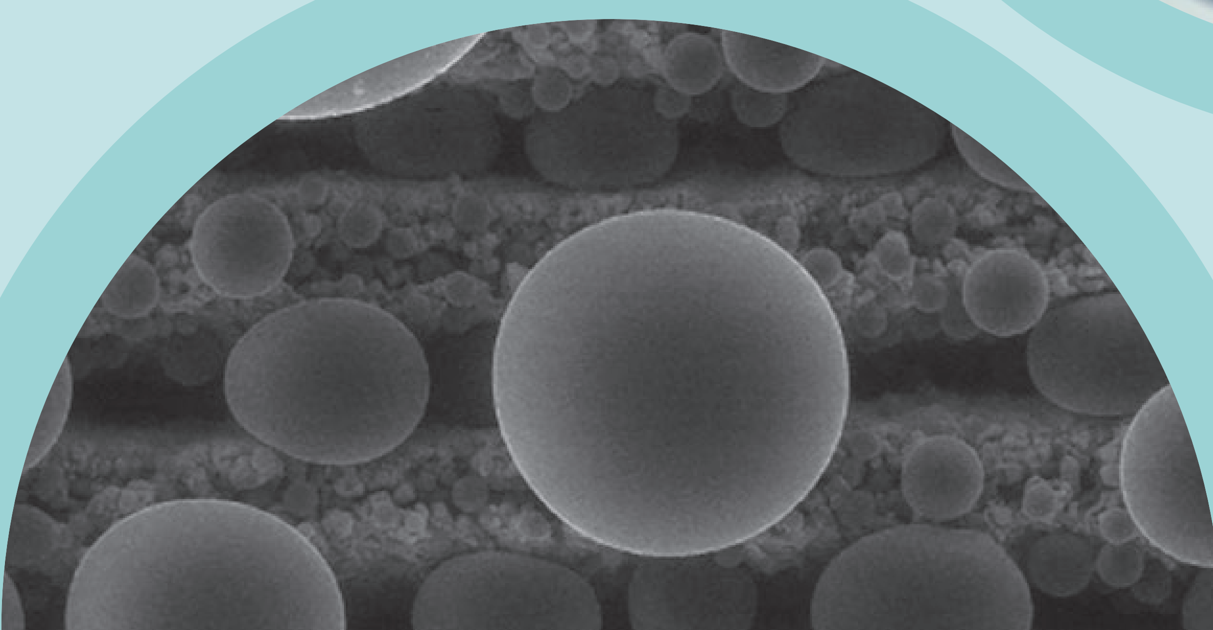
Infrared optical hybrid imaging technology for all digital histopathology

M. Schnell, P. Scott-Carney, and R. Bhargava

Priority date: 03/01/2019

- Shared with the University of Illinois





Startup Companies

Graphenea

A High-Quality Graphene Producer

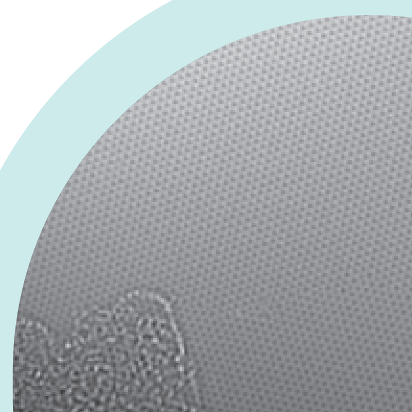
graphenea.com

Graphenea, nanoGUNE's first startup company launched in April 2010 as a joint venture with private investors, 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 Graphenea fledged in April 2015 and new laboratories were opened in September 2017 at the Science and Technological Park of Gipuzkoa. In 2018, Graphenea launched sales of Graphene Field-Effect Transistors (GFETs) aimed at lowering barriers for the adoption of graphene, especially the existing barriers in the market of sensors.

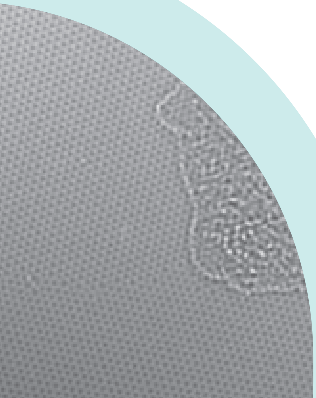
The company, which at the end of 2020 was employing 30 people and was exporting graphene to 60 countries, supplies its products to universities, research centers, and industries worldwide. It has more than 800 customers worldwide.

Graphenea is 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 would help its customers advance their work.



Graphenea's main industrial focus is the production of high-quality graphene 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, opto-electronics and sensors, and, on the other hand, it is operating an industrial pilot unit with the capacity to produce 1 ton per year of graphene oxide in dispersion and powder forms.



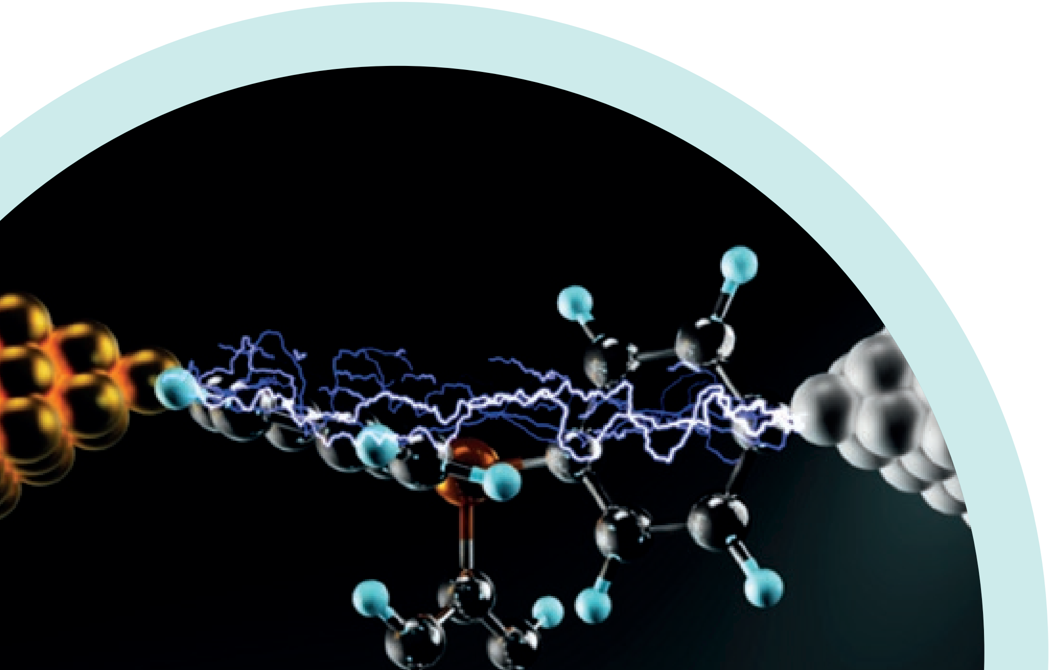
Simune Atomistics

Atomistic Simulations

simuneatomistics.com

Simune Atomistics was launched in January 2014 as a joint venture of nanoGUNE with a group of scientific experts, some of them developers of the well-known SIESTA code. Simune was joined in July 2014 by a group of private investors who became shareholders of the company. In 2016, Simune received a TechConnect Innovation Award as one of the top early-stage innovators chosen worldwide. Being a spin-off of nanoGUNE, Simune is actively involved in a number of research projects with the Center.

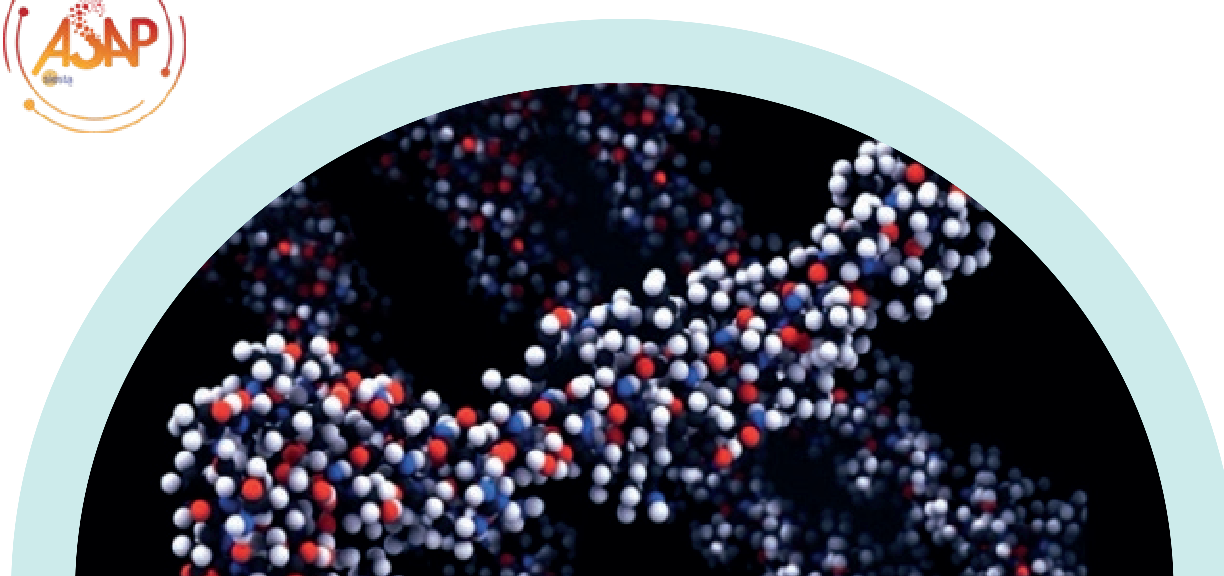
Simune is a company that provides cutting-edge scientific software tools and expertise to academic and industrial segments. Our board of experts in quantum-mechanical simulations includes world-leading scientists that are widely known in the academic community. This provides the company with a long-track record of publications and open-source scientific tools. Simune offers a range of software products for quantum-mechanical modeling of materials properties at the nanoscale. The company focuses on identifying the best solution for materials-design related challenges with its main expertise based on applications related to advanced materials with high-technology needs. Apart from scientific software development, Simune also offers consultancy services, expert support, and training in quantum-mechanical atomistic simulations with the use of high-performance computation facilities.



In October 2020, Simune launched an Atomistic-Simulation Advanced Platform (ASAP). ASAP currently offers a flexible environment for advanced materials design, thereby offering solutions to specific industrial applications in many different markets. ASAP provides an integrated scientific software tool for various applications including clean-energy solutions, energy storage, automotive market, consumer electronics, novel solutions for food and beverages, smart packaging, and many other industrial areas. ASAP offers software tools with an advanced theory, enabling atomistic simulations for academic and industrial clients. ASAP allows the design process to be more efficient and accurate before prototyping, saving costs and time-to-market for the client's new cutting edge products. Conceived with a modular approach by design, ASAP offers a flexible set of modules customized for a specific problem. The platform is capable of providing different levels of theory from a full quantum-mechanical description necessary for the cutting edge products of many traditional industries to a simplified level required for large scale modeling with atomistic resolution. ASAP provides a set of robust tools for drug design, modeling drug delivery, and drug interactions with DNA and body fluids, which are all essential for the biotech and pharmaceutical sectors. The platform provides a set of acceleration tools to optimize and automate the workflow in new materials design, combining artificial intelligence and a clever user interface that should allow new users to execute advanced atomistic simulations in a very short time.

Simune is a rapidly-growing company with international reputation. The company has established a long-term and successful partnership with JSOL Corporation in Japan (*jsol.co.jp*), which consists in offering software solutions to most prominent companies worldwide, such as DuPont, Panasonic, Toyota, Honda, Daihatsu, Sumitomo, and the National Institute of Advanced Industrial Science and Technology (AIST) in Japan. Simune is also partner with DHIO Engineering in India (*dhioresearch.com*) to provide atomistic-modeling software for academic and industrial sectors.

Simune has been actively participating in various national and European projects, thus bringing together academic and industrial sectors in several ongoing collaborative efforts such as TOCHA, COST, TQ, XCHEM, Bed4Best, and QMCC EJD, and it has successfully completed other projects such as RETOS, ERANET-Nanogram, and ITN-EJD. The company has been funded by the European Commission, in the framework of the H2020 SME program, and will continue its rapid growth with new and ambitious plans.



Ctech-nano

Innovation with ALD Solutions

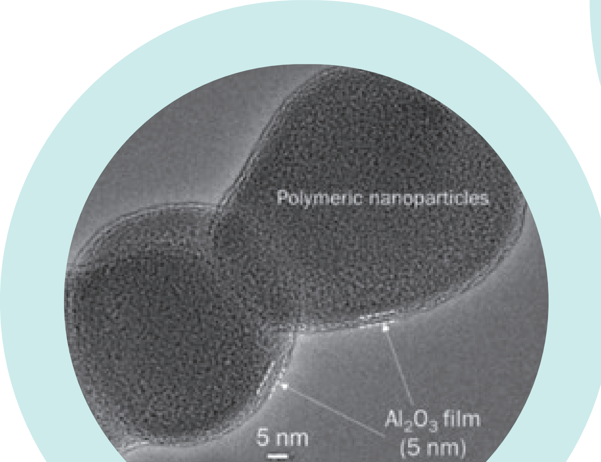
ctechnano.com

Ctech-nano was launched in July 2014 as a joint venture with two Basque companies, AVS and Cadinox. Ctech-nano offers versatile and high-quality Atomic-Layer-Deposition (ALD) and Vapor-Phase-Infiltration (VPI) systems with a portfolio of ALD tools oriented to a wide variety of customers: from low-cost high-quality basic models for research and development activities to customized industrial equipment for production lines. Ctech-nano also provides R&D services related to advanced ALD coating solutions.

The core technology of Ctech-nano is based on ALD, which is a coating technique for covering surfaces with complex morphology with various coating reactants. The technique allows to produce stress-free, adhesive, conformal films with an accurate control of their composition and thickness at the nanoscale.

Due to the high precision of the process and its reproducibility, ALD is a well-established processing technology in the field of modern microelectronics and nanoelectronics. Ctech-nano offers solutions for high-k gate oxides, memory capacitor dielectrics, ferroelectrics, metals, and nitrides for electrodes and interconnects.

A specific advantage of ALD is the ability to coat the surfaces of nanoporous materials with a uniform film. Nanoporous materials are emerging throughout the biomedical industry in drug delivery, implants, and tissue engineering. Ctech-nano provides solutions for the surface treatment of biomedical devices, implants, mesh polymers, as well as TiO_2 films for optical waveguide sensors in diagnostic tools.



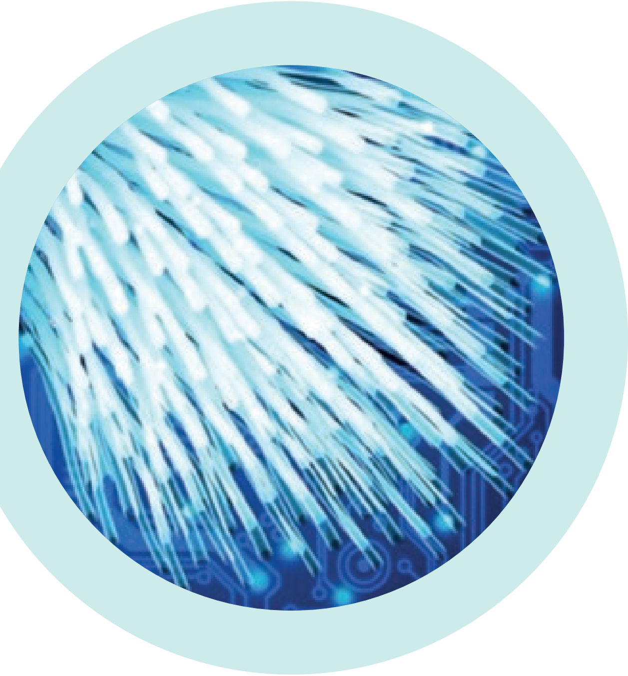
Ctech-nano offers a wide spectrum of materials to be coated: oxides, nitrides, carbides, metals, sulfides, fluorides, and various organic molecules, providing high-tech solutions for a number of applications. ALD is typically used for high-value products, as the average cost of a running cycle is relatively high depending on the nature, quality, and purity of the substrates, as well as the reactant, temperature, and time of machine operation.

The customers of Ctech-nano are commonly oriented to innovation, new product functionalities, and the improvement of existing processes and products. Ctech-nano has established a number of successful commercial partnerships with national and international companies such as Repsol, Fagor, Angulas Aguinaga, Gaiker, Fagor, AJL, Danobat, Denka, Cemex, Duglass, and FNMT. Our tools are also found in academic institutions such as Paderborn University (Germany), Humboldt University (Germany), University of Central Florida (USA)[1], and others.

Ctech-nano is actively involved in the optimization of the ALD process and the development of new precursors; in particular, a family of novel anticorrosive precursors has been designed in a close collaboration with Liquid Inc. Ctech-nano has been developing new technological processes and tools, with the newly granted patent ES2712868B1 (Chamber for depositing atomic layers).

Ctech-nano has also been actively participating in a number of European research projects in the framework of Horizon 2020.

[1] G. Gregory, C. Feit, Z. Gao, P. Banerjee, T. Jurca, and K. O. Davis, Phys. Status Solidi A **217**, 2000093 (2020).

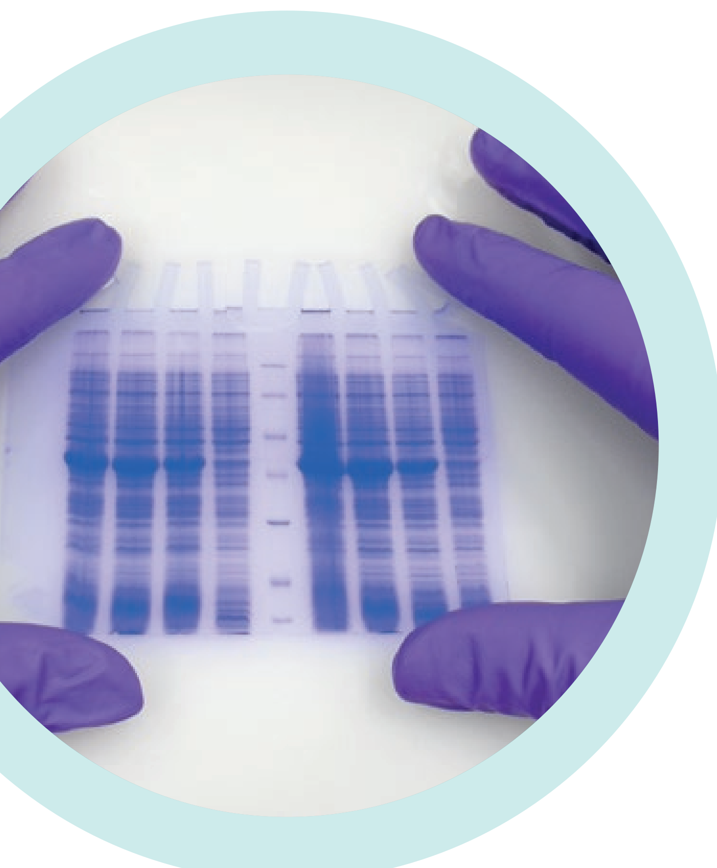


Evolgene Genomics

A new frontier in nanobiomaterials

evolgene.com

Evolgene Genomics, founded in February 2018, is a company devoted to the development, production, and commercialization of high-quality crystalline nanocellulose by using a proprietary biological technology. Evolgene combines three key enabling technologies (KETs): Nanotechnology, Industrial Biotechnology, and Advanced Materials.



Nanocellulose has emerged in recent years as a new wonder material with a myriad of applications. Obtained from natural cellulose and with properties that are superior to substitutive synthetic plastics, nanocellulose has boomed the demand of very diverse industrial sectors including pharma, food, cosmetics, electronics, paints, and packaging. There are also high-value applications like in the nascent technology of tissue and organ engineering, where nanocellulose is being adopted for (i) manufacturing scaffolds for three-dimensional (3D) tissue engineering of e.g. blood vessels, bones, and cartilages, and (ii) producing contact lenses and protective barriers.

Promising applications can also be found in bioelectronics. This nanobiomaterial has key advantages, combining a high mechanical strength, biocompatibility, resistance to degradation, and a high water-absorption capacity. Currently, several companies are producing cellulose nanocrystals and nanofibers using physical and chemical methods to cover the increasingly growing demand for industrial applications. However, the production of naturally structured, size-controlled cellulose nanocrystals for high-value applications in biomedicine (3D-bioprinting) and bioelectronics (wearable biosensors) is limited, because existing industrial methodologies do not allow for the production of cellulose nanocrystals with the required quality.

Evolgene has developed a new method to produce ultra-pure, size-controlled cellulose nanocrystals by using highly-active enzymes based on ancestral sequence reconstruction. The specially designed enzyme endocellulase patented by nanoGUNE can produce cellulose nanocrystals in a fast and reliable manner. These enzymes can be reutilized to improve the profitability of the process. Evolgene is currently producing high-quality cellulose nanocrystals at multigram level. Comparative studies with cellulose nanocrystals from competitors have demonstrated the physicochemical differentiation and improved material properties of our product.

Compared to current chemical production methods, Evolgene's crystalline nanocellulose provides a natural cellulose chemical structure free of sulphate radicals, which allows a higher purity and crystallinity, a higher thermostability and mechanical stability, and a better biological compatibility for biomedical applications; furthermore, it is environmentally friendly, as it is produced under mild conditions with no use of hazardous chemicals. Compared to other biological processes using commercial enzymes, the main advantages of our technology are the higher catalytic efficiency and the higher thermostability of the enzyme.

Prospero Biosciences

New applications within the mass-spectrometry industry

prospero-biosciences.com

Prospero Biosciences, nanoGUNE's 5th spin-off company, was launched in October 2015 by a group of entrepreneurs that included Robert Blick (professor of Physics at the University of Hamburg), two nanoGUNE researchers, and Hasten Ventures, a company devoted to the acceleration and promotion of business ideas. Prospero seeks to take advantage of the potential of nanotechnology in order to develop and commercialize an innovative technology capable of opening up a new field of applications within the mass-spectrometry industry.

Prospero is 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, which are already being successfully tested by various end users in the health sector.

Global Graphene Call

Global Graphene Call launched in 2020

In march 2020, the so-called Global Graphene Call was launched for the first time with the aim of supporting the development of business ideas related to graphene. This call was launched together with nanoGUNE´s first startup company Graphenea and BerriUP –a startup accelerator in San Sebastian–. Applications were received from all over the world. The elected candidate was Graphene Pioneer, a company from the Netherlands dedicated to the use of graphene for the optimization of the physical properties of concrete.

Business culture in the training of scientists

In the framework of our 2015-2020 Strategic Plan, specific training activities have been programmed 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 and post-doctoral researchers 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 November 2019 and November 2020. 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 **12** researchers have participated in this course.

Entrepreneurship

This course, mainly oriented to second-year PhD students, has been offered in October 2019 and October 2020. The goal of this course is to train 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 **18** researchers have participated in this course.

Take the step. From academia to industry

This course, mainly oriented to third-year PhD students, has been offered in November 2019 and October 2020. The goal of this course is to train the 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** researchers have participated in this course.

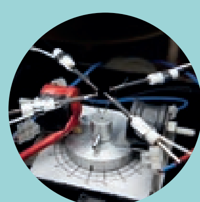
Outplacement Service

An outplacement service has been initiated in collaboration with **ieTeam Consulting**, in order to support those researchers that would like to pursue their professional career in local industry.

ieteam
people consulting people

External Services

externalservices.nanogune.eu



Our External-Services department is designed with a double goal: (i) to contribute with our know-how to the innovation processes of industrial and technological companies, and (ii) to open our facilities to external users so that they can benefit from nanoGUNE's unique infrastructure.

Our expertise is particularly strong in three specialization areas:

Electron Microscopy. Understanding the behavior of materials from their crystalline structure, stress, tomography, and morphology.

Nanofabrication of membranes and multilayers for chemical sensors and biosensors, patterns for microfluidics, and electronic devices.

Chemical characterization, with the use of Scanning Near-field Optical Microscopy (SNOM), of polymers, biomaterials, active ingredients, and cosmetic products at the nanoscale, as well as chemical analysis of precipitations in alloys and advanced materials.

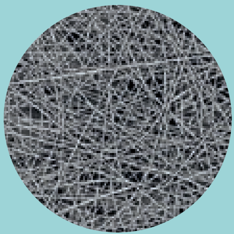
Novaspider

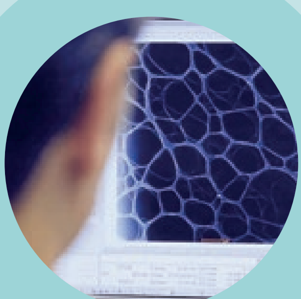
A new range of tools to revolutionize the way nanofibers are produced

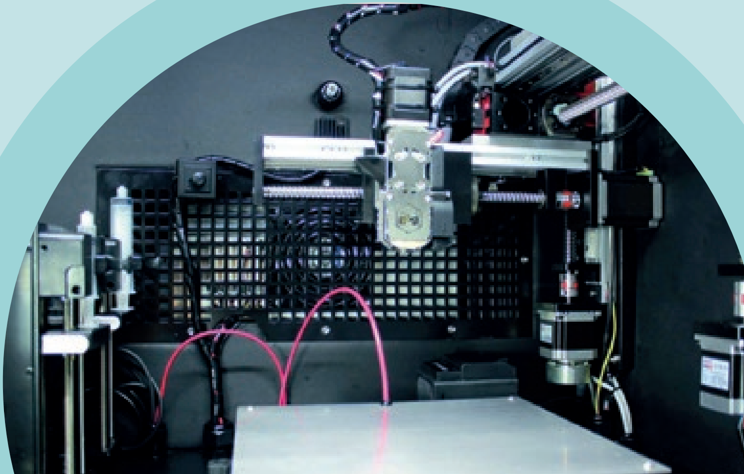
novaspider.com

Novaspider is an advanced materials fabrication tool to produce three-dimensional (3D) structures with nanofibers. Combining 3D printing and electrospinning techniques, this tool enables the creation of hybrid nano- and micro-fiber composite structures. Developed at nanoGUNE, this tool is the result of a close cooperation between top-class scientists, experienced engineers, and experts from the 3D printing industry.

As it is possible to functionalize materials by adding additives, our technology opens up an immense horizon of possibilities. NanoGUNE offers electrospinning tools and process-development services for nanofiber production in order to bring this innovative technology closer to a great variety of fields. A team of materials scientists and engineers is available to support the creation of nanofibers based on any material.







NanoGUNE´s TechTransfer and Communication plans go hand to hand. Indeed, the communication and outreach of our research results to our society represent a key ingredient of our TechTransfer plan, as the recipients of this communication strategy (society, research&technology institutions, and companies) are the ones that are expected to pull our knowledge and technology towards the market.

Berria
15/11/2019

Grafeno xafletan elektroien karga magnetikoa kontrolatu eta manipulatu ahal izateko ikerketa proiektu bateratua abiatu dute CIC Nanogunek eta DIPCek, beste lau ikerketa zentrorekin batera. Informazioa transmititzeko etorkizuneko teknologia berrien oinarria izan daiteke.

Nanourratsen oinatz erraldoiak

Jakes Goikoetxea *Donostia*

Grafeno geruza bat. Grafeno geruza osatzen duten karbono atomoak. Grafeno geruza osatzen duten karbono atomoen elektroiak. Eta grafeno geruza osatzen duten karbono atomoen elektroien espinak. Aldapeko sagarraren adarraren puntan, puntaren puntan lanean ari dira Europako Spring ikerketa proiektua abiatu duten sei ikerketa zentroak. Spin Research in Graphene (espinen ikerketa grafenoan) hitzen akronimoa da Spring.

Seikotean daude Euskal Herriko bi: CIC Nanogune eta DIPC Donostia International Physics Center. Nanogune izango da, gainera, proiektuaren koordinatzailea. Europako Batasunaren Horizon 2020 FET-Open deialdian aukeratu dute proiektua. 3,5 milioi euro emango dizkiete lau urterako. Etorkizunean berritzaileak eta baliagarriak izan daitezkeen teknologiak ikertzeko deialdia da. FET-Openen kasuan, hastapenetan dauden ikerketak laguntzen dituzte.

Espintronika eta grafenoa uztartuko ditu ikerketa proiektuak. Etorkizuneko teknologien oinarria izan daitezkeen bi elementu. «Bi kontzeptuak nahastu nahi ditugu: grafenoaren propietate batzuk oso erakargarriak dira elektronikarako, eta horri magnetismoa gehitu nahi diogu», azaldu du Thomas Frederiksenek. DIPCko Ikerbasque ikerketa irakaslea da, proiektuko ikerlaria. Munduan ikerketa zentro gutxitan aztertzen ari dira grafenoaren magnetismoa.

Atomoek elektroiak dituzte. Elektronikak elektroien karga negatiboa baliatzen du informazioa alde batetik bestera mugitzeko eta biltzeko. Etorkizunean, ordea, espintronikak ordezkatuko du elektronika. Ondo bidean, hori izango da etorkizuneko ordenagailuen oinarria. Espintronikak, elektroien karga baliatu beharrean, haien espina baliatzen du. Espina elektroien oinarrizko propietate bat da, magnetikoa. Elektroien imana, nolabait esateko, eta, gainerako imanen moduan, iparra eta hegoa ditu. Sinpleago esanda, gora edo behera begira egoten da. Horixe baliatu nahi dute informazioa garraiatzeko eta biltzeko.

Spintronikak aurrera eginez gero, elektronika baino teknologia iraunkorragoa izango litzateke. Elektronikan korronte elektrikoak behar dira informazioa batetik bestera mugitzeko, energia. Espintronikan ez litzateke korronte elektrikorik beharko edo, behar izatekotan, txikia, energia aurreztuz. Eta espintronika grafenoan, karbonoan, oinarrituz gero, karbono ugari dago munduan.

> **Zeharka edo zati txikietan, espina 'idatz' daiteke, baina gailu batean egin nahi dugu, kontrolatuta»**
>
> **Jose Ignacio Pascual**
> CIC Nanoguneko Ikerbasque ikerketa irakaslea

> **«Grafenoaren propietate batzuk elektronikarako oso onak dira, eta magnetismoa gehitu nahi diogu horri»**
>
> **Thomas Frederiksen**
> DIPCko Ikerbasque ikerketa irakaslea

Spring proiektuak spin horiek *irakurri* eta *idatzi* egin nahi ditu grafeno geruzetan. Irakurri: espinak noiz dauden gora edo behera begira jakin. Idatzi: espinak gora edo behera begira jarri. Grafenozko nanoimanak izango lirateke. Zertarako? Espinen bidez informazioa transmititzeko.

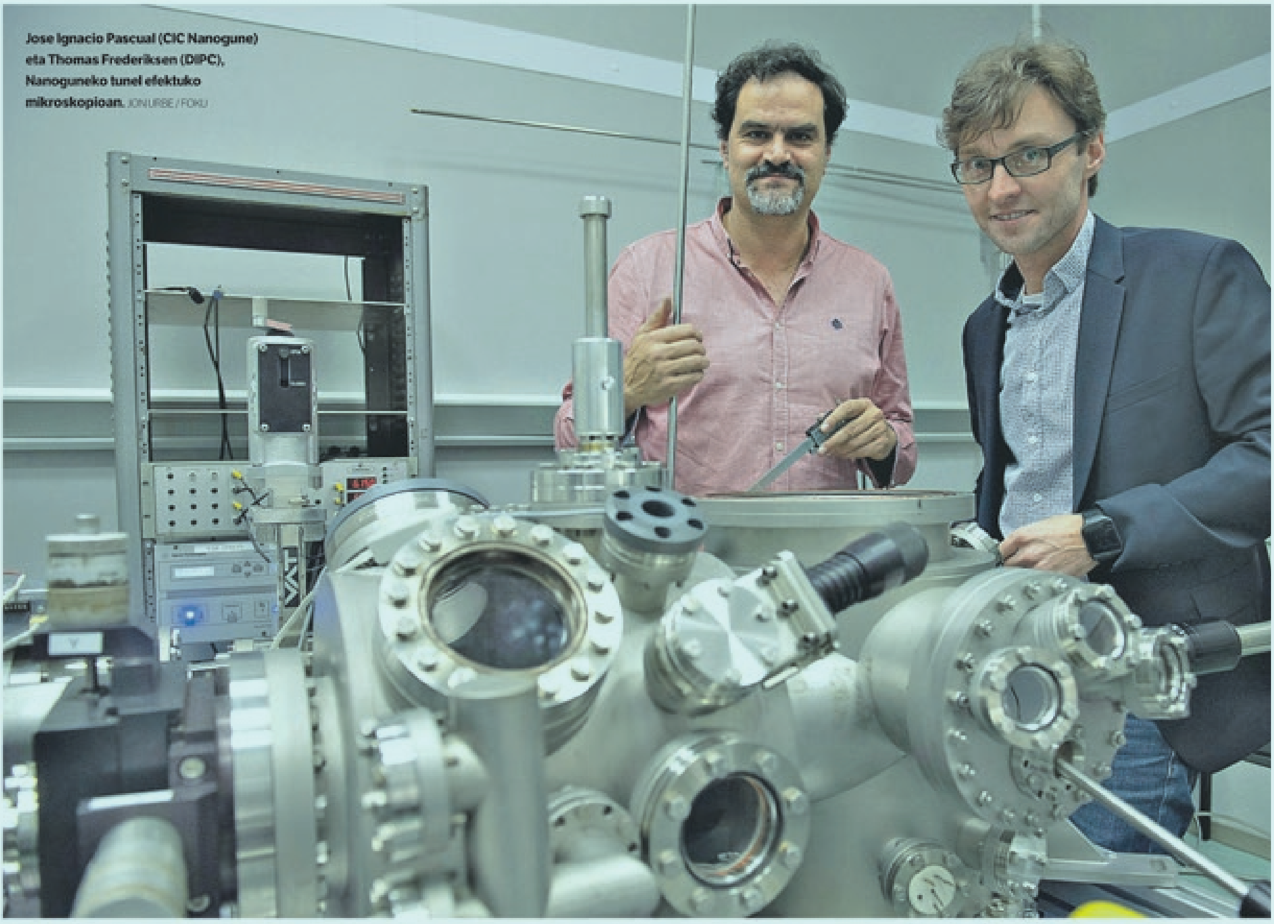
Berez, «zeharka edo zati txikietan» espina *idatz* daiteke, «baina gailu batean egin nahi dugu, kontrolatuta», Jose Ignacio Pascual ikerlariaren esanetan. CIC Nanoguneko Ikerbasque ikerketa irakaslea da eta Spring proiektuaren koordinatzailea. Oinarrizko esperimentuetan lortu dute, baita Nanogunek berak ere, zenbait korronte elektrikorekin espinak gora mugitzea. «Baina hori prozesua erakustea da; beste kontu bat da informazioa biltzeko erabilgarria izatea».

Horregatik aukeratu dute grafenoa. Espinak garraiatzeko oso ona delako: «Espinen orientazioari tarte handi batean eutsiko dioten materialak behar dira, eta grafenoa horrelakoa da». Material «perfektua» deitu dio, besteak beste, oso egonkorra delako.

Grafenoaren ezaugarri izugarrien artean (gogortasuna, malgutasuna...), baina, ez dago magnetismoa. Hala ere, ikusi dute grafenoa modu jakin batzuetan moztuta —atomoz atomo egindako geruzak dira—, magnetiko bihurtzen dela; baita grafeno geruzak hidrogeno atomoekin ukituz gero ere, Nanogunek beste ikerketa talde batzuekin batera erakutsi duenez.

Bi dimentsioko materialak

Grafenoari eta beste zenbait materiali bi dimentsioko materialak deitzen diete, atomo bakarreko lodiera dutelako. Grafenoa ez da bakarra. Badira silizenoa, germanenoa... ere. Horien propietate batzuk ezagunak dira, beste ba-



Jose Ignacio Pascual (CIC Nanogune) eta Thomas Frederiksen (DIPC), Nanoguneko tunel efektuko mikroskopioan. JON URBE / FOKU

tzuk ez. Grafenoarekin egin den bidea ez da oraindik urratu bi dimentsioko beste material horiekin. «Gure ikerketan ezingo genituzke erabili», zehaztu du Pascualek, «ez baitakigu nola moztu horiek modu perfektuan». Eta Pascualek behin eta berriro nabarmentzen duenez, ezinbestekoa da zehaztasun atomikoarekin lan egitea. Grafenoarekin ahal dute; beste material batzuekin, oraindik ez. Hala ere, erronka bakarra ez da grafeno zati perfektuak, zehaztasun atomikoa dutenak, moztea; baita atomo horiek inguruko faktoreetatik babestea ere, magnetismoak irauteko.

Oinarrizko ikerketa da. Etorkizunean baliagarriak izan daitezkeen bideak urratuko eta ikertuko dituzte, «ikusteko ea zenbateraino konpon ditzakegun sortzen diren arazoak, gero erabilgarri izateko». Arazo «asko» baitaude grafenoa sortzen hasten direnetik zirkuitu batean integratu arte: «Forma eta zehaztasun atomikoa kontrolatzea; ingurua ere bai, ez kutsatzeko; korronteak sartzea…». Ikasitakoa oinarrizko gailu espintroniko batean probatu nahi dute. «Ziurrenik, gero ezingo da erabili», ohartarazi du Pascualek, «baina sekulako urratsa izango da».

Sei ikerketa zentrok bat egin dute Spring proiektuan. Bost esperimentalak dira; DIPCen, berriz, teoria eta simulazioa egiten dituzte. «Ikertuko diren egiturak perfekzionatzea da gure lana», Frederiksenen esanetan. «Maila teorikoan lan egiten dut, formulekin eta simulazioekin. Molekula bat zer atomok osatzen duten baldin badakigu, atomo horiek simulazio batean sar ditzakegu, superordenagailuen bidez molekulen propietateak kalkulatzeko». Nanoegituren propietate elektronikoak eta espinak, besteak beste. «Gure lana ere bada daukaguna baino urrunago joatea, zer egin dezakegun urrats bat harago iristeko».

Teorikoa eta praktikoak. Frederiksenen formulak eta simulazioak, batetik; Pascual eta gainerako ikertzaileen esperimentuak, bestetik. Bi norabideko harremana dute: Frederiksenek teorien eta simulazioen emaitzak helarazten dizkie, laborategietan probatzeko eta frogatzeko; eta laborategietako emaitzak Frederikseni jakinarazten dizkiote, ikusitako zenbait fenomeno teoriaren bidez azaltzeko eta berresteko.

Zalantzak eta galderak

Askotan ez datoz bat. «Baina kasu horietan aurrera egiten dugu», nabarmendu du Frederiksenek. «Dena baieztatzen badugu, aspergarria da, esan nahi du dena ulertu dugula; dena bat ez badator, elkarri galdetzen diogu zer falta den zer gertatzen den ulertzeko». Orduak eta orduak norberaren buruari eta gainerakoei galderak egiten.

Europako sei talde elkartu dira proiektuaren partzuergoan: CIC Nanogunez eta DIPCez gain, Santiago de Compostelako Unibertsitateak (Galizia), Delft-eko Unibertsitate Teknikoak (Herbehereak), Oxfordeko Unibertsitateak (Erresuma Batua) eta IBM Researchek (Zurich, Suitza).

Guztiek dituzte grafenoa edota espinak langai edo ikerketagai. Guztiek erdietsi dituzte hainbat lorpen: «Batetik, gai gara grafeno egiturak sortzeko, grafenoa bitarteko kimikoak baliatuz eta zehaztasun atomikoarekin mozteko. Gai gara, esaterako, bost atomoko aldeak dituen hiruki bat sortzeko, sekulako urratsa da. Bestetik, teknika esperimentalak dauzkagu, behin grafeno egiturak sortuta, haien magnetismoa detektatzeko».

Hala ere, bakoitza teknika edo lan molde batean espezializatua dago, eta partzuergoan esperientzia osagarriak bildu dituzte. Santiago de Compostelako taldeak, esaterako, kimika lanak egiten ditu. «Kimika baliatuz egiten ditugu nanografenoak», Pascualek azaldu duenez. «Molekula batzuk prestatzen dituzte; molekula horiek geruza batean jartzen ditugu, eta berotu; orduan haiek bakarrik elkartu eta lotu egiten dira, *lego* baten moduan; eta guk nahi dugun grafenoa osatzen dute». Molekula horiek sortu aurretik simulazioak egiten dituzte, lortuko litzatekeen grafenoaren propietateak aurreikusteko, magnetikoak izango diren edo ez, esaterako.

Nanogunek, hiru teknika baliatuz, ikusiko du ea grafenoa ondo osatzen den. Oxfordeko eta Delfteko taldeak, berriz, espinen manipulazioa ikertzen saiatuko dira: «Oxfordeko taldean espinak gora eta behera mugiarazten dituzte irrati frekuentziarekin edo mikrouhinekin. Prozesu hori esploratzen ari dira, informazio kuantikorako».

Izan ere, espinak baliagarriak izan daitezke ordenagailu kuantikoetarako. Hala nabarmendu du Frederiksenek: «Gaur egungo bitez hitz egin ordez [0 eta 1en arteko konbinazioa], *cubit*-ez hitz egiten ari dira [bit kuantikoa], eta badaude proposamenak espinak cubit gisa erabiltzeko».

EL DIARIO VASCO

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Dos investigadores trabajan en una sala especial de Nanogune. ■ LOBO ALTUNA

NANOGUNE, VANGUARDIA DE INVESTIGACIÓN

El centro científico cumple diez años consolidado como referente en nanociencia P6

El Diario Vasco
27/01/2019

NANOTECNOLOGÍA

CIC nanoGUNE y Cikautxo trabajan en la obtención de caucho de alto valor

EMPRESA XXI. Bilbao

CIC nanoGUNE y la unidad de I+D+i de Cikautxo, Cikatek, trabajan conjuntamente en un proyecto Elkartek con el fin de obtener caucho de alto valor añadido mediante la aplicación de nanotecnología. Para ello, recurren a dos tecnologías disruptivas propuestas por los grupos de nanobiotecnología y nanomateriales de nanoGUNE.

El primero de esos grupos propone un nuevo material ideal para la fabricación de composites y matrices en una multitud de aplicaciones, que abarcan desde la construcción hasta la medicina. El uso de ese nuevo material incorporado en materiales elastoméricos está muy poco explorado, pese a que puede dotar al caucho de mayor resistencia dinámica y corrosión. Es por ello que el proyecto, al no existir por el momento productos comerciales o testados, supone una gran oportunidad tanto en adquisición de conocimiento como en el impacto comercial que pueda tener a futuro.

El grupo de Nanomateriales, por su parte, propone la fabricación de materiales híbridos poliméricos-inorgánicos en los que es posible establecer sinergias dando lugar a nuevas propiedades que los materiales elastoméricos no presentan de forma individual.

Ambas tecnologías punteras, aún por explorar, permitirán dar un salto cualitativo en el aumento de prestaciones de los componentes.

Empresa XXI
15/07/2020

José María Pitarke, director del NanoGune, explica el funcionamiento de la sala limpia que se ve a través de la ventana. | Miki López

Los ordenadores del futuro se gestan aquí

La multinacional Intel trabaja con el centro vasco de nanociencia para mejorar el rendimiento de las computadoras actuales y ahorrar energía

San Sebastián,
M. G. SALAS

NanoGune significa lugar enano. Pero de pequeño el centro vasco de investigación en nanociencia tiene poco: está ubicado en un gran edificio en el campus universitario de San Sebastián y las líneas de investigación que desarrolla son punteras en el mundo. De hecho, la multinacional Intel, que es el mayor fabricante de circuitos integrados, trabaja junto al equipamiento vasco para fabricar los ordenadores del futuro. El objetivo del proyecto "Meso", dotado con 595.000 euros y en el que participan también el laboratorio del Premio Nobel Albert Fert en Francia y un grupo de la Universidad de California, es mejorar el rendimiento y el ahorro energético de las computadoras actuales. El científico del Ikerbasque Félix Casanova tiene mucho que decir en este campo, gracias a su trabajo sobre la espintrónica, una tecnología que está llamada a convertirse en la alternativa a la electrónica de hoy.

"Estamos muy orgullosos de este proyecto y nos gustaría tener muchos más como este. Intel nos ha buscado", afirma el director del centro de investigación en nanociencia, José María Pitarke. En concreto, los retos del proyecto son dos, los mismos que tienen los ordenadores: que llegará un momento en el que no se podrán hacer transistores más pequeños y que la cantidad de información guardada es enorme y eso está produciendo un consumo eléctrico brutal. Según un estudio reciente, el consumo de electricidad por el uso y transferencia de datos digitales podría representar en 2030 el 20% del consumo mundial.

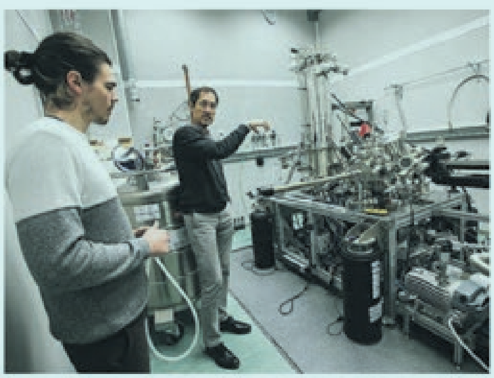
El CIC (Centro de Investigación Cooperativa) NanoGune se inauguró en 2009 con el objetivo de situar al País Vasco a la vanguardia de la investigación en nanociencia. En él trabajan un centenar de personas, la mayoría científicos (89). "Desde que empezamos, esto ha ido creciendo, pero en los últimos dos años estamos más o menos estabilizados. Los investigadores están rotando", cuenta José María Pitarke, que cree que ninguna comunidad "debe obsesionarse con el retorno mientras exista un flujo adecuado de científicos". Es decir, que "no sean más los que salen que los que entran". La mayoría de los talentos en el Nanogune son jóvenes –los que rotan–: hay unos sesenta entre predoctorales y postdoctorales. Los grupos de investigación, que son diez, están dirigidos exclusivamente por personal del Ikerbasque. Pitarke señala que es una condición "necesaria" para tener un contrato fijo pero "no suficiente", ya que deben estar alineados con la estrategia del centro.

"Que nuestros investigadores permanentes pertenezcan al programa Ikerbasque nos da prestigio. Han salido de una selección a nivel global y se entiende que son los mejores que ha podido atraer el País Vasco. Y por otro lado, nos facilita el funcionamiento, porque Ikerbasque tiene sus propios mecanismos de gestión, los mismos para todos los centros", asegura el director, que es catedrático de Física de la Universidad del País Vasco. Con esto último, José María Pitarke se refiere a las evaluaciones que tienen que pasar cada tres años los 240 talentos mundiales fichados por la Fundación Vasca para la Ciencia. Los investigadores del centro de nanociencia pertenecen a diferentes áreas, no sólo a la física, y hacen principalmente ciencia fundamental.

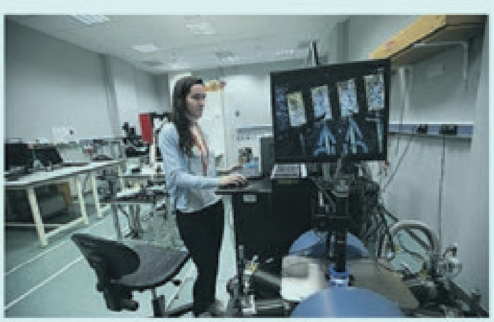
Las instalaciones del NanoGune, con una veintena de laboratorios, están dotadas de equipos de última generación, por valor de unos veinte millones de euros. El más "potente" es un microscopio electrónico, una máquina gigante, en la que los electrones se comportan como ondas igual que la luz y permiten formar imágenes de objetos diminutos. Entre sus múltiples laboratorios, destacan las salas blancas o limpias, cuyo acceso es restringido, el personal tiene que ir cubierto de arriba a abajo de trajes especiales y la luz del habitáculo es de un amarillo intenso. "Dentro, hay unos extractores que están continuamente limpiando la sala y eliminando el polvo. Estas condiciones son necesarias para el desarrollo de dispositivos electrónicos", aclara Pitarke, que durante el recorrido por el centro enseña el laboratorio donde trabajó el físico asturiano Pablo Alonso. "Seguimos colaborando con él y de vez en cuando viene por aquí", apunta. Alonso, que ha conseguido una ayuda de 1,5 millones de euros del Consejo Europeo de Investigación (ERC), trata de construir desde Oviedo los cimientos de un nuevo campo, la nanoóptica bidimensional.

Carne de cerdo y ave que crece en el laboratorio

El NanoGune se ha convertido en poco más de diez años en un vivero de empresas. Tiene cinco startups. En una de ellas, Graphenea, que se dedica a la producción y comercialización de grafeno, trabaja la química ovetense Alba Centeno. "Producimos grafeno en dos formatos: en polvo con aplicación en materiales estructurales y baterías, y en CVD (creado por depósito químico en fase de vapor), al que yo me dedico y que se utiliza para sensores", cuenta. Graphenea estuvo ocho años en Nanogune y en 2018, dado su crecimiento, se trasladó al parque tecnológico de Miramón, en San Sebastián. "Ahora somos 27 personas y la idea es ir a más. El mercado del grafeno es todavía pequeño, pero está aumentando la demanda", indica. El centro de investigación en nanociencia participa en una sexta empresa, Biotech Foods, que produce carne cultivada. "Carne –aclara Pitarke– que en vez de crecer en el cuerpo del animal, crece en el laboratorio". El director de las instalaciones explica más: "Tomamos células de animales, ahora de cerdos y aves, y en el laboratorio se posibilita que crezcan de igual forma que lo hacen en la naturaleza". De momento, esta carne cultivada no se comercializa, pero todo llegará.



Pitarke, con el científico Stefano Trivini, al lado de un microscopio de efecto túnel. | Miki López



Otro de los laboratorios del centro de investigación. | Miki López

Ikerbasque

▶ **Así funciona.** Es una fundación, impulsada por el Gobierno vasco en 2007, para atraer talento científico de todo el mundo. Está formado por 240 investigadores de 30 países. Tiene tres convocatorias: para captar científicos seniors, con carrera consolidadas y jóvenes promesas. Por cada euro que pone el contribuyente vasco en el programa, retornan dos. Existen una veintena de instituciones de acogida, entre universidades, centros de investigación y centros tecnológicos.

Laboratorios de Graphenea en Donostia, la primera start-up de nanoGUNE, creada con el propósito de fabricar y comercializar obleas de grafeno de alta calidad. GARA

Grafeno, el futuro escondido en la punta del lápiz

Científicos vascos y gallegos avanzan en la investigación del grafeno, llamado a revolucionar la electrónica del futuro, y descifran el magnetismo de una pequeña estructura triangular de este material

J.S. | DONOSTIA

El grafeno es considerado ya como uno de los mayores descubrimientos de este siglo. Sus numerosas propiedades junto a la simplicidad de su estructura y composición están revolucionando la fabricación de componentes electrónicos e informáticos. Así, por ejemplo, puede multiplicar por cien la velocidad del mejor procesador actual, y hacerlo en una lámina flexible, ligera y más dura que el diamante.

Pero, ¿qué es el grafeno? Sencillamente, es uno de los componentes del grafito con el que están hechas las minas de los lápices. Lo descubrieron en 2004 los científicos rusos André Geim y Konstantin Novoselov, a quienes se ocurrió analizar los restos de una mina de lápiz pegados a una tira de celo.

Y descubrieron que el grafeno está compuesto tan solo por átomos de carbono, como el diamante y el grafito, aunque la diferencia es que su estructura es una lámina de tan solo un átomo de espesor, y que estos átomos forman hexágonos a modo de colmena de abejas. Esta peculiar estructura concede a este material las propiedades de ser transparente, flexible y muy resistente, además de poseer una alta conductividad térmica y eléctrica. Así, además de sus propiedades mecánicas, tiene increíbles propiedades electrónicas, químicas, magnéticas y ópticas.

El grafeno promete miles de aplicaciones en sectores muy dispares y se cree que llegará a sustituir a materiales tan importantes como el silicio. El abanico de posibilidades que abre es de una amplitud y versatilidad tal que augura una verdadera revolución tecnológica.

De hecho, este material podrá adoptar la forma de un despertador, un GPS o un ordenador portátil ultrafino, recargable con la energía solar y capaz de enrollarse en nuestra muñeca como un reloj.

AMPLIAR EL CAMPO DE APLICACIONES

Los investigadores han logrado descifrar el estado magnético de una pequeña estructura triangular de grafeno, de apenas 40 átomos de carbono, lo que amplía el campo de aplicaciones de este material en áreas como las TIC.

Descifrando su magentismo

Pues bien, en esta carrera por avanzar en la investigación de las propiedades del grafeno, investigadores del Donostia International Physics Center (DIPC), del CIC nanoGUNE y del CiQUS de la Universidade de Santiago de Compostela (USC) han logrado descifrar el estado magnético de una pequeña estructura triangular de grafeno, de apenas 40 átomos de carbono, lo que amplía el campo de aplicaciones de este material en áreas como las TIC.

Esta investigación ha corroborado los cálculos teóricos que predecían que una estructura triangular de este material podría llegar a ser magnética, pese a que el grafeno es un material reacio a magnetizarse. Esta aparente contradicción es consecuencia de que para ciertas formas «mágicas» del grafeno los electrones parecen «girar» más fácilmente en una dirección determinada, forma coloquial para decir que tienen un mismo espín, y con ello lo vuelven magnético.

Se trata, pues, de la primera evidencia experimental realizada con un microscopio de efecto túnel (que permite captar imágenes de superficies a nivel atómico) del magnetismo innato en una pequeña estructura triangular de grafeno.

Este trabajo científico se ha desarrollado en el marco del proyecto europeo SPRING FET Open, Spin Research in Graphene (Investigación del espín en grafeno), liderado por el investigador Ikerbasque en nanoGUNE, Jose Ignacio Pascual.

El objetivo del proyecto a largo plazo es el desarrollo de una plataforma hecha totalmente de grafeno, respetuosa con el medio ambiente, en la cual los espines se puedan usar para transportar, almacenar y procesar la información.

Gara
29/05/2020

Videoconferencia. Marco Donolato en pantalla, y Paolo Vavassori a la derecha de la mesa. JOSE USOZ

Doce minutos para detectar anticuerpos de Covid-19

Tecnología. El nuevo dispositivo 'ViroTrack' detecta si una persona ha desarrollado anticuerpos y, por tanto, si se ha recuperado de una infección en los últimos meses

PABLO SÁENZ
SAN JUAN

Basta con una gota de sangre del paciente para que el dispositivo denominado 'ViroTrack', diseñado por la empresa danesa Blusense Diagnostics en colaboración con CIC NanoGUNE, produzca en tan solo 12 minutos un resultado que indica si la persona ha desarrollado anticuerpos contra la Covid-19 y, por tanto, si ha estado infectada por el coronavirus y se ha recuperado en los últimos meses. También funciona con otros virus y enfermedades. «Es un test rápido, sencillo y barato», además de fiable, ya que garantiza «un 90-95% de fiabilidad». El dispositivo es portátil y fácil de usar. Ha obtenido la certificación de la Unión Europea y ya se ha lanzado al mercado italiano y sudamericano.

«No es un test PCR», aclara Marco Donolato, uno de los tres desarrolladores del dispositivo, junto con Paolo Vavassori y Mikkel F. Hansen. El italiano, que vino a Donostia para terminar su postdoctorado en el CIC NanoGUNE, señala que este test analiza los niveles de anticuerpos de una persona que está contagiada o lo ha estado. «Los test de anticuerpos pueden dar resultados positivos» pero no significa que el paciente «tenga el virus y esté infectado». Según explica Donolato, el cuerpo mantiene los anticuerpos meses después de haber pasado un virus. «No son falsos positivos», asegura. «El problema es que los niveles de anticuerpos cambian con el tiempo. Los primeros días de infección son muy altos y luego bajan», señala. 'ViroTrack' es capaz de detectar si una persona ha tenido el virus en los últimos tres meses. «Esto será de gran ayuda en los diagnósticos en los hospitales y podrá monitorizar los niveles de anticuerpos de los pacientes», asegura el italiano.

El proyecto empezó estudiando la diabetes y luego enfermedades como la fiebre dengue o zika. También analiza y detecta todo tipo de virus. Pero, con la irrupción de la Covid-19, centraron su estudio en analizar esta enfermedad y detectarla. Actualmente están desarrollando un cartucho con un test «más fiable que un PCR», según asegura Vavassori, investigador experto en nanomagnetismo en CIC NanoGUNE, para determinar si una persona es portadora del coronavirus o no.

El actual dispositivo cuenta con distintos cartuchos que contienen una disolución química y unas partículas que se mezclan con la sangre para realizar el análisis y detectar anticuerpos. El paciente debe pincharse el dedo y depositar una gota en la pieza de plástico. Una vez depositada la sangre, esta se mezcla con la disolución. Esta pieza se introduce en una ranura del dispositivo 'ViroTrack' y, en la pantalla, se introducen los datos personales y se selecciona el tipo de análisis que se quiere realizar según la enfermedad o virus. Cada análisis cuenta con un cartucho específico. En cuestión de 12 minutos, el profesional sanitario obtiene un resultado cuantitativo con la cantidad de anticuerpos desarrollados por el paciente. Además, los datos y resultados introducidos se suben instantáneamente a la nube. Esto facilita realizar un seguimiento médico del paciente en los hospitales.

Tecnología Blu-ray

El dispositivo salió al mercado en junio en Italia y Sudamérica. «Es una tecnología única y diferente en su sector. No hay otro test similar». El precio del aparato depende del país. No obstante, Donolato asegura que su precio es «menor a mil euros». Cada cartucho cuesta 10 euros.

El prototipo inicial utilizaba un láser de laboratorio para detectar el movimiento de las partículas en la sangre. Donolato tuvo la idea de utilizar algo más simple como la fuente de luz de un Blu-ray. En Blusense Diagnostics, la empresa que fundó Donolato en Dinamarca, comenzaron a desarrollar esta tecnología en colaboración con una empresa de blue-rays de Taiwán. «Fue un matrimonio perfecto», afirma Vavassori. En Dinamarca tenían la idea y en Taiwán tenían los conocimientos técnicos para elaborar un aparato compacto para esta detección. El desarrollo comenzó en CIC NanoGUNE en colaboración con la Universidad Técnica de Dinamarca.

La idea original fue de su tutor anterior, Mikkel F. Hansen, profesor de la Universidad Técnica de Copenhague. Entonces, una vez comenzaron a desarrollar el prototipo, lo patentaron entre los tres: Donolato, Vavassori y Hansen. No obstante, CIC NanoGUNE posee un tercio de la patente. Después de siete años de trabajo, han desarrollado un dispositivo que se puede adaptar prácticamente a la detección de cualquier tipo de virus.

LA CLAVE

12

minutos de espera y el paciente obtiene un resultado cuantitativo del test

TECNOLOGÍA

El nuevo dispositivo utiliza tecnología blu-ray para realizar el análisis de sangre

DESARROLLO

El estudio comenzó en CIC NanoGUNE en Donostia y terminó en Blusense Diagnostics, en Dinamarca

RESULTADO

Con un pinchazo en el dedo muestra la cantidad de anticuerpos que ha desarrollado el paciente

Los miembros del equipo de CIC nanoGune que han desarrollado la tecnología.

El CIC nanoGune lanza una tecnología «no invasiva» para favorecer un parto más seguro

El sistema permite monitorear «en tiempo real» a los bebés durante el alumbramiento, lo que ayudará a los obstetras a tomar decisiones rápidas y reducirá las cesáreas

A. C.

SAN SEBASTIÁN. Una tecnología nueva para facilitar partos más seguros, permitir la toma inmediata de decisiones en caso de que se presente alguna complicación durante el alumbramiento y reducir el número creciente de cesáreas que se practican en todo el mundo. Esa es la potencialidad de la nueva «tecnología disruptiva» que ha lanzado el equipo de Nanoingeniería del CIC nanoGUNE de San Sebastián. Un sistema «no invasivo» que permite el monitoreo «continuo de los riesgos fisiológicos» de los bebés durante el parto «en tiempo real», lo que, aseguran, ayudará a los obstetras y profesionales sanitarios que lo atiendan a «tomar decisiones rápidas y disminuir el número de cesáreas, que en algunos países llega hasta el 40%, la media mundial se sitúa en el 22%, pero la OMS recomienda que no se supere la tasa del 15% porque según sus datos, «las tasas de cesáreas superiores al 10% no están asociadas a reducciones en las tasas de mortalidad materna ni neonatal, sino todo lo contrario».

Esta tecnología busca, por tanto, contribuir a reducir esa práctica. Ya que, según explicó nanoGune en un comunicado, la decisión de realizar una cesárea «se basa principalmente en un análisis invasivo de pH y lactato en sangre que se realiza mediante una muestra del cuero cabelludo del feto durante el parto», un método que –según su investigación– funciona «de forma discontinua» y requiere de un «tiempo de medición excesivamente alto» por lo que se producen un «número considerable de fallos».

La OMS recomienda que la tasa de cesáreas no supere el 10% y en el mundo la media llega al 22%, en algún país al 40%

Andreas Seifert, responsable del equipo de investigadores del centro donostiarra que ha desarrollado este avance, explica que la nueva tecnología «se basa en la combinación de la espectroscopia Raman, equipada con sondas específicas para cada aplicación, y algoritmos multiparamétricos de aprendizaje de máquinas que tienen en cuenta la imagen sistémica de las variaciones o anomalías fisiológicas» para la toma de decisiones, y no se basa en un «único parámetro como el pH o el lactato» como la tecnología actual.

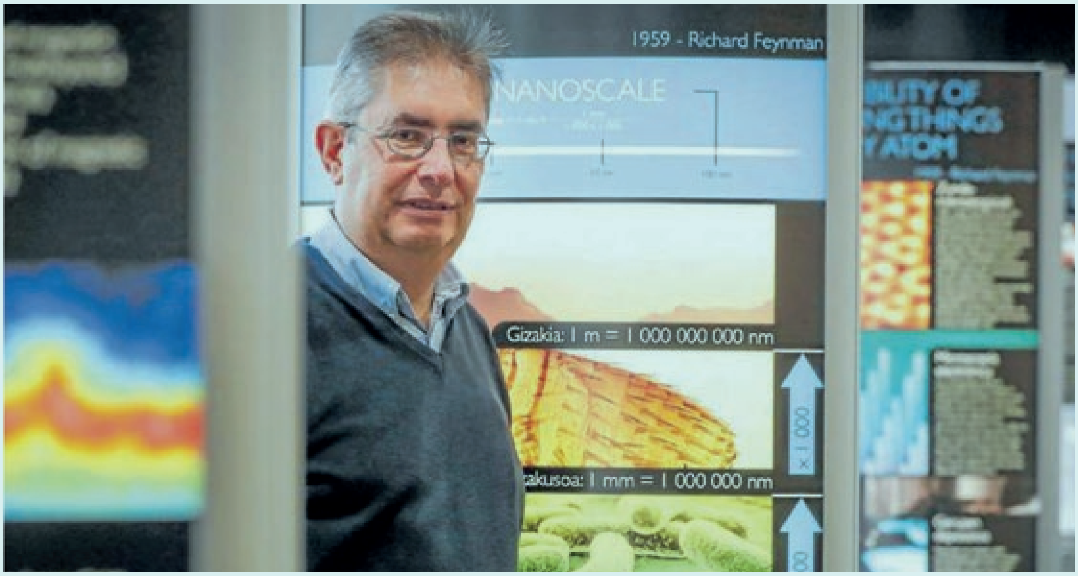
La espectroscopia Raman, explica el investigador, «puede detectar cambios de parámetros bioquímicos directa o indirectamente» y, utilizando el aprendizaje por máquina y considerando todos los cambios bioquímicos, se obtiene como resultado «una clasificación más estable y sensible» de los parámetros asociados a la asfixia perinatal, causante del 23% de las muertes de recién nacidos en el mundo, unos 4 millones. «Con nuestra tecnología –añade el investigador–, se podrían minimizar las cesáreas y los riesgos para la salud durante el parto, junto a los costes que llevan asociados y las implicaciones sociales y legales».

Sin competidores

Esta tecnología no tiene «competidores directos», asegura Ion Olaetxea, otro investigador, quien asegura que la «vigilancia no invasiva, en tiempo real y continua nos proporciona una ventaja competitiva tangible» que les diferencia de los métodos actuales. Ainara García, responsable de Transferencia de Tecnología de nanoGune asegura que la tecnología «está protegida mediante una solicitud de patente y presenta un buen nivel de preparación, lo que la hace atractiva para los inversores privados». De hecho, dijo, ya han recibido «llamadas de interés».

La iniciativa, fruto de una idea que se originó en 2017, ha sido premiada en la fase 1 del programa BBK Venture Philanthropy y demuestra que «el mercado está preparado para absorber alternativas al método convencional».

El Diario Vasco
18/09/2020



Emilio Artacho, científico del CIC-nanoGUNE de San Sebastián, trabaja para poder llegar a Marte algún día. *Foto: Efe*

Un pueblo en la Luna, "a la vuelta de la esquina"

EL CENTRO DONOSTIARRA DE INVESTIGACIÓN ESPACIAL TRABAJA PARA AVERIGUAR LAS CLAVES DE LA RADIACIÓN CÓSMICA Y SOLAR

✎ *Un reportaje de* ***Carlos López Izquierdo***

Crear un pueblo en la Luna será solo el paso previo a poder ir a Marte. "Está a la vuelta de la esquina", así lo afirma Emilio Artacho, científico del CIC-nanoGUNE, centro vasco de investigación creado con el objetivo de llevar a cabo investigación en nanociencia y nanotecnología y con sede en San Sebastián.

Si el utópico viaje *De la Tierra a la Luna* que el francés Julio Verne noveló en 1865 tardó poco más de un siglo en hacerse realidad con la llegada del Apolo XI a nuestro satélite (1969), el reciente hallazgo por la NASA de agua helada en algunos de sus cráteres hace pensar que los próximos lustros podrían ser testigos de la primera base selenita de la humanidad.

'HORIZON 2020' Un desafío para el que será fundamental el trabajo de investigadores como los del Grupo de Teoría del CIC-nanoGUNE que lidera Artacho, enfrascado actualmente en el proyecto europeo *Horizon 2020* para entender "mejor" el daño de las radiaciones solares y cósmicas en los astronautas, las naves espaciales y los paneles solares de los satélites.

La Universidad de Lille (Francia) y la Queen's Universtity de Belfast (Reino Unido) son, junto al centro de investigación donostiarra, otros de las participantes en este proyecto, liderado por el Instituto Belga de Aeronomía Espacial (BIRA) y dotado con más de un millón de euros de presupuesto.

"Nuestro empeño es proponer soluciones para proteger la materia orgánica e inorgánica. Se trata de entender lo que pasa, para mejorar la durabilidad de materiales como los de los paneles solares y hacerlos más eficientes para generar energía a través de luz, a la vez que resultan resistentes a la radiación", explicó el científico.

Una resistencia también muy necesaria para los recubrimientos de las aeronaves espaciales o de los edificios que eventualmente lleguen a levantarse en la Luna con vocación de durabilidad, si bien el programa *Horizon 2020* se enfoca en estudiar el impacto de la radiación en naves que orbitan cerca de la Tierra.

La influencia del daño por radiación durante un hipotético viaje a Marte y determinar los lugares de menor exposición a ella para que un vehículo espacial pueda posarse en el planeta rojo son otros de los campos de estudio de esta iniciativa que, debido a la dificultad de los experimentos en el espacio, se lleva a cabo mediante "métodos teóricos y simulaciones computacionales".

"Se trata de simulaciones basadas en la física cuántica, utilizando leyes fundamentales que nos dicen cómo se comporta cualquier conjunto de partículas elementales", concreta Artacho, quien precisa que estos simulacros pueden durar meses.

Es una especie de "realidad virtual" que se entiende mejor si se piensa en un "videojuego" en el que "se puede ver algo que está pasando en una pantalla pero que no sucede en la realidad", detalla.

Algunas conclusiones podrían mejorar los satélites, cada vez más protagonistas en las comunicaciones diarias de la humanidad

El investigador aclara que un buen ejemplo del valor de las simulaciones es el "gran control" sobre los datos que se tiene en las misiones espaciales, como la que recientemente permitió a una sonda "aterrizar un momento en un asteroide" para tomar unas muestras.

"El control que se tiene es brutal –agrega– y es porque todo ha sido predefinido basándose en las leyes de la física que ya conocemos, que son universales y que sirven para saber que el comportamiento de algo va a ser el mismo, aunque estés en un sitio en el que no hayas estado nunca".

CONOCIMIENTO INTERDISCIPLINAR A pesar de que su proyecto esté enfocado al espacio, el experto aclara que estas investigaciones también se puede utilizar en "otros muchos contextos" como la medicina, pues la forma en la que la radiación afecta a los humanos a veces se traduce en cánceres y los hallazgos que se logren podrían ser útiles también para los hospitales.

Otras conclusiones obtenidas podrían valer en cambio para mejorar los satélites, cada vez más protagonistas en las comunicaciones diarias de la humanidad, así como para desempeños meteorológicos y medioambientales.

"Es curioso que la gente pregunte para qué se estudian cuestiones del espacio mientras hay tantos problemas en nuestro planeta, cuando, de hecho, mucha de la investigación que se está llevando a cabo en este ámbito solucionará muchos problemas en la Tierra", concluye Artacho. ●

Diario de Noticias
01/11/2020

Miembros de un equipo de investigación trabajan en una sala blanca de Nanogune.
FOTOS LOBO ALTUNA

El año del salto para Nanogune

Un paso. El centro de investigación donostiarra ha consolidado este ejercicio su evolución de la frontera del conocimiento a la transferencia tecnológica

JAVIER GUILLENEA

Después de todo lo que ha pasado, quizás suene extraño escucharlo, pero el año 2020 «ha sido especialmente bueno» para CIC Nanogune. Eso es al menos lo que asegura José María Pitarke, que dirige el centro de investigación de nanociencia desde su nacimiento, el 30 de enero de 2009. En sus casi doce años de existencia, las instalaciones ubicadas en San Sebastián han recorrido un largo camino que en este último ejercicio ha desembocado en un salto cualitativo, el que marca el paso de la frontera del conocimiento a la transferencia tecnológica.

Un año después de su apertura, en Nanogune trabajaban 61 personas de 15 países, de las que 44 eran investigadores repartidos en cinco equipos. En la actualidad, la plantilla está compuesta por 117 profesionales y diez grupos de investigación, una cantidad que ha sido buscada por el propio centro. «Nuestro objetivo ha sido siempre contar con un centenar de personas, que es un tamaño manejable», explica Pitarke.

El flujo es constante. «Siempre anda entrando y saliendo gente», afirma el director de Nanogune. 60 personas, de las que la mitad aún permanece en el centro. Además, otras treinta han salido en busca de otros destinos. Es así, con un intercambio continuo, como se mantiene sin demasiados cambios la cifra del centenar de investigadores.

«Los investigadores principales, que son doce, se mantienen, pero hay mucha rotación de gente. Eso permite que el centro sea siempre joven», explica Pitarke. Quienes abandonan Nanogune lo hacen para integrarse en otros centros de investigación, en universidades o en empresas. «Exportamos gente a todo el mundo, pero más que eso, también importamos. Traemos a muchos investigadores y muchos se quieren quedar en el País Vasco, parece que les gusta esto», dice el director de Nanogune.

Este es el caldo de cultivo que le ha permitido al centro de investigación donostiarra tener visibilidad internacional y haber ascendido un peldaño más en una evolución que resume Pitarke. «Los primeros años de andadura estuvimos centrados en la puesta en marcha de un centro de investigación de excelencia. En la medida en la que hemos logrado consolidar esa masa crítica, hemos podido reforzar la transferencia de tecnología. Es algo que ya hacíamos, pero los últimos dos años, con la incorporación de la responsable de transferencia de tecnología Ainara García, hemos dado un salto cualitativo. No solo somos buenos en generación de conocimiento sino también en transferencia».

En dos años, Nanogune ha doblado el número de clientes, entre los que se hallan empresas como Intel, Thermo Fisher, Attocube, BASF, Regineering, Fagor, sudama. Este ejercicio ha alcanzado un volumen de facturación privada próximo al millón de euros. «Supone más de un 10% de nuestros ingresos, lo que para nosotros es un logro», subraya.

Parece ser que la investigación sí que es un buen negocio. «Lo es en muchos sentidos», ratifica el responsable de Nanogune. Es negocio la transferencia a empresas de base tecnológica y «la atracción de fondos de convocatorias competitivas que generan aquí actividad y empleo». También «la investigación es parte de una sociedad avanzada y sin ella no hay futuro». Además, añade, «se genera un ecosistema atractivo que nos da visibilidad internacional y atrae a proyectos innovadores».

Atracción de talentos

Gracias a este ecosistema, que se centra en San Sebastián y se extiende a otras localidades, Gipuzkoa se está convirtiendo en un foco de atracción de talentos. Es un mérito en el que tiene mu-

LAS FRASES

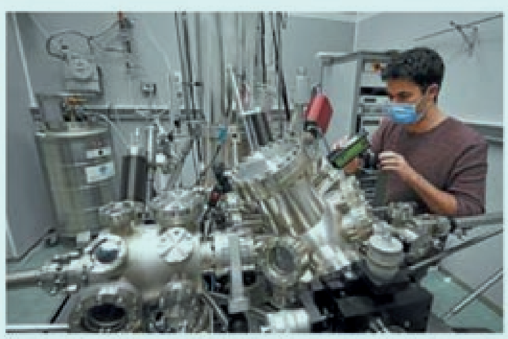
José María Pitarke
Director de Nanogune

«Exportamos gente a todo el mundo, pero más que eso, también importamos. Y muchos se quieren quedar aquí»

«Se ha generado un ecosistema atractivo que nos da visibilidad y atrae proyectos innovadores»

José María Pitarke, director de Nanogune, ante su sede en Donostia.

Nanogune cuenta en la actualidad con una veintena de patentes.



El centro se está convirtiendo en un foco de atracción de talentos.

yectos de centros y empresas» que hay en el territorio. Y, sobre todo, la «atmósfera colaborativa en Euskadi». «La aportación de un solo centro puede ser pequeña, pero suma si todos remamos en la misma dirección», opina Pitarke. Una muestra de ello son los recientes fichajes en la UPV/EHU de los premios Nobel Albert Fert y George Smoot. «Si no hubiera habido esta atmósfera no estarían aquí», asegura.

Un ejemplo de la atracción que genera Donostia es la visita que nogune. «Vinieron unos americanos de Berkeley que buscan abrir una línea de negocio en Europa y una de las posibles ubicaciones es esta. Se fueron encantados». Quizá no se decidan por San Sebastián, pero el hecho de que se hayan interesado por la ciudad ya indica que no es una desconocida en el campo de la investigación.

Un ejemplo de ello es la colaboración de Nanogune con Intel. «Nos ha contratado para que llevemos una determinada línea de no físico de la mecánica cuántica. Ellos necesitaban grupos de investigación que fuesen capaces de explorar la utilidad de ciertos materiales para hacer dispositivos de memoria y vinieron a buscarnos porque tenemos personas que están en la frontera del conocimiento en esta área. Querían estar con los mejores del mundo en este campo y contactaron con Félix Casanova, uno de nuestros investigadores Ikerbasque».

Nanogune cuenta en la actua-

CIFRAS

117

personas de 26 países componen la plantilla de CIC Nanogune.

1

millón de euros de facturación privada ha alcanzado este año el centro.

campo de la medicina y salud, óptica, materiales avanzados, magnetismo y electrónica. Once de ellas las tiene licenciadas a empresas regionales e internacionales, como Neaspec y Blusense, que vende equipos para detección de anticuerpos Covid cuya tecnología ha sido creada por el centro donostiarra. «También hemos desarrollado tecnología no invasiva para ver el nivel de oxígeno en los recién nacidos y prevenir así la hipoxia de los neonatos. Es una colaboración con Biodonostia y estamos negociando la patente para que alguien la explote. Se trata de una tecnología muy competitiva», explica Pitarke.

Durante sus primeros años de existencia, Nanogune se volcó en la creación de nuevas empresas con las que compartía edificio. La primera fue Graphenea, que nació en 2010 para producir grafeno. Esta compañía, que ya ha cortado amarras con su mentor, tiene su sede en Miramon y ha alcanzado una cuota mundial de mercado del 30%. Después, llegaron Simune, que ya ha comenzado a dar beneficios, Ctech-nano, Evolgene, Prospero Biosciences y Biotech Foods, en la que tam-

CIC Nanogunek urteak daramatza electrospinning edo elektroirute bidez nanohariak eta ehun zatiak egiten, biomedikuntzan erabiltzeko, batez ere. Orain, AEGrekin bat egin du, modarako ehun berriak sortzeko, material birziklatuak eta biodegradagarriak erabiliz.

Ehungintza mikroskopikoa

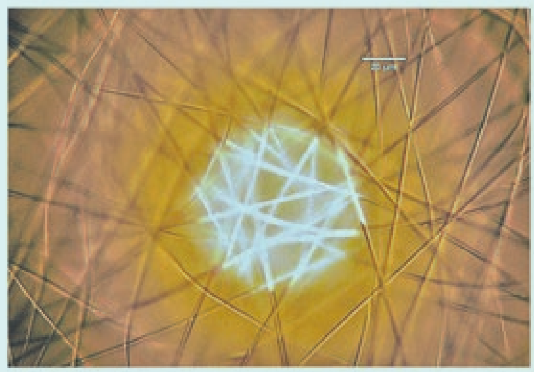
Jakes Goikoetxea

Alde batetik, polimero disolbatu edo urtu bat, biltegi txiki batetik orratz baten muturreraino. Beste alde batetik, materiala biltzeko geruza bat edo hodi bat. Eta bataren eta bestearen artean, tentsio garaiko korrontea. Ondorioa: eremu elektrikoak indar elektroestatiko bat sortzen du, indar horrek tira egiten du orratzaren muturreko material likidotik, likidoa luzatu egiten da eta zuntz fin-fina bihurtu. Armiarmek sarea eraikitzeko erabiltzen duten hariaren modukoa. Mikro eta nano hariak dira, eta, elkarren gainean eta ondoan metatuz, ehun itxurako geruza bat osatzen dute. Electrospinning teknika da. Elektroirutea edo elektroharitzea. Goruetan eta txabilan egin ohi zen prozesuaren I+G+B bertsioa, laborategikoa.

Aspalditik ezagutzen eta erabiltzen da electrospinninga. Gero eta erabilera gehiago ditu, ordea. CIC Nanogune ikerketa zentroan urteak daramatzate elektroirutea erabiltzen. Zuntzak sortzeko makina propioa garatu dute eta saldu egiten dute: Novaspider.

Orain CIC Nanogunek eta Donostiako AEG Berrikuntza Profesionalen Eskolak bat egin dute, elektroirutea eta hiru dimentsioko inprimatzea baliatuz, ehun berriak sortzeko, material birziklatuekin eta biodegradagarriekin.

AEGn batez ere hiru dimentsioko inprimatzea erabiltzen zuten ehun berriak sortzeko. Material birziklatuekin eta biodegradagarriekin ehunak sortzeko metodoak bilatzen aritu dira, eta hiru dimentsioko inprimatzean oinarritutako teknika bat lortu dute.



Nanohariz osatutako egitura. CIC NANOGUNE

«Ehun testurako materialak lortzeko, oihal itxura izateko, mugara eramaten zuten inprimagailuekin jarritako material geruza», zehaztu du Javier Latasak. Ingeniari elektrikoa, proiektu honen eta Novaspiderren arduraduna da Nanogunen.

«Guk, ordea, hiru dimentsioko inprimatzea elektroirutearekin konbinatzen dugu», azaldu du Latasak Nanoguneren ekarpena. «Horrekin irungabeko nanoehunen eta mikroehunen geruzak lortzen ditugu».

«Kasualitatea»

«Kasualitatez» sortu zen elkarrekin lan egiteko aukera. Nanoguneko Transferentzia Teknologikorako Departamentua AEGrekin harremanetan jarri zen, eta AEGko ordezkariek azaldu zieten zer-nolako lana egiten ari ziren moda mundurako ehun berriak sortzeko, hiru dimentsioko inprimagailuen bidez.

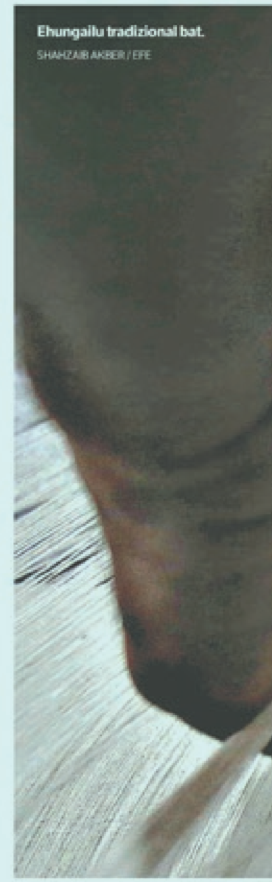
Nanogunekoei iruditu zitzaien ikerketa ildo horrek harremana izan zezakeela Nanogunen electrospinningarekin eta nanohariekin egiten ari ziren lanarekin. Donostiako Sustapenaren bonu teknologikoak baliatu zituzten elkarrekin lan egiteko. Donostiako Udalaren garapen ekonomikorako sozietatea da Donostiako Sustapena. *Bonu teknologiko* deitutakoen bidez hiriko enpresei diru laguntzak ematen dizkiete proiektu teknologikoak garatu ahal izateko —produktuak edo zerbitzuak—, zentro teknologikoekin elkarlanean, zentroen ezagutza eta eskarmentua baliatuz.

Nanogunen eskarmentua dute electrospinningaren edo elektroirutearen erabileran. Ez dute ehungintzarako erabili izan, beste sektore batzuetarako baizik: bioteknologiarako eta energiarako batez ere. Orain ehungintzara hurbiltzen ari dira.

AEGen tereftalato polietilenozko (PET) botilen hondakinekin lan egiten dute. Xehagailu batean txikitu egiten dituzte, plastikozko zati txikiak, pelletak, lortu arte. Material hori erabiltzen dute gero hiru dimentsioko inprimagailuan ehunak sortzeko.

Nanogunen, ordea, elektroirutea egiteko, plastiko zati horiek likido bihurtu behar dira, bai disolbatzaile batean disolbatuta, bai kartutxo batean urtuta (fusio elektroirutea, *melt electrospinning*). Elektroirutearen bidez plastikozko nanohariak lortzen dira.

Giza ile batek 17-181 mikrometro arteko diametroa izaten du.



Ehungailu tradizional bat.
SHAHZAIB AKBER / EFE

«3Dko inprimatzea elektroirutearekin konbinatzen dugu. Nanoehunen geruzak lortzen ditugu»

«Materialaren propietateak aldatzeko, osagarriak edo nanopartikulak gehi dakizkioke»

Javier Latasa
CIC Nanoguneko ingeniaria

Elektroirutearen bidez lortutako harietan diametroa ezberdina da, erabiltzen den teknikaren arabera: plastiko disolbatua erabiltzen baldin bada, harien diametroa 200-600 nanometro inguru iza-

ten da; plastiko urtua erabiliz gero, ordea, 10-20 mikrometrokoa, giza ilerik finenen parekoa. Milimetro baten milarena da mikrometroa; milioirena, berriz, nanometroa. Fusio elektroirutea erabiltzen ari dira proiektuan, plastiko urtua baliatzen duen teknika.

Ehun zatiak, ez haria

Ehun zatiak lortzen dituzte. Ez haria iruna. «Ez dugu haria iruten eta hodietan jasotzen, gero hari hodi horiekin ehunak egiteko», argitu du Latasak. Proiektuaren hasierako helburuetako bat bazen harilak sortzea, baina oraingoz ez dute bide horretan sakondu. «Oraingoz, ez gara gai hari horiek manipulatzeko».

Mintz baten moduko zatiak lortzen dituzte, baina, aztertuz gero, nanohariz edo mikrohariz osatuta daudela ikusten da. «Hari horiek ausaz jartzen dira», Latasaren arabera. «Hariak modu ordenatuan ere jar daitezke, patroi jakin batzuei jarraituta, hirukiak edo laukituak, baina proiektu honetan modu aleatorioan egiten ari gara».

Lehen urratsa egiten ari dira oraindik: lortutako mintz zatien testura material naturalen antzekoa izatea. Horretarako, harien izaerarekin, diametroarekin eta morfologiarekin jokatzen dute, eta sortutako zuntzen egiturarekin, sendotasunarekin, arintasunarekin, porositatearekin... Pentsatuta dute bigarren urratsa: «Zati horiei propietate magnetikoak eta elektrikoak gehitzen saiatzea».

Laborategiko lana egiten ari dira. Gauza bat da laborategian ehun edo oihal itxura izan dezaketen mintzak edo geruzak lortzea, eta beste bat, horien ekoizpena handitzea eta jantziak sortu ahal izatea. Hala ere, Latasaren esanetan, laborategiko emaitzak gehitzea eta ekoizpen prozesuetara eramatea posible da, eta gaur egun egiten da zenbait makinekin.

Elektroirutea ez baita berria, eta haren bidez lortzen diren zuntz zatien erabilgarritasuna ere oso zabala baita. Iragazteko gaitasun handia duten materialak sortzeko, esaterako: «Partikula oso txikiak harrapatzeko gai dira, mikra bat baino txikiagoak, birusak, adibidez. Horregatik, nanozuntzak erabiltzen dituzte gehien iragazten duten maskaretan, eta normalean elektroirutearen bidez lortzen dira nanozuntzak».

Elektroirutean erabiltzen diren materialen arabera, mintzek propietate batzuk edo beste batzuk izatea lortzen da. «Gainera», gehitu du Latasak, «azken emaitza aldatu nahi denean, azken materialaren propietateak aldatu nahi direnean, funtzionalizatu egin daitezke, osagarriak edo nanopartikulak gehituz». Horrela, eroankortasuna alda dakioke, ura erakartzen duena bihurtu, ura hartzen ez duena, biodegradagarritasuna kontrolatu... «Materialari funtzioak eman dakizkioke».

Aplikazio ugari

Elektroirutearekin lotuta, Novaspider proiektua dute Nanogunen, duela hiru urtetik. Elektroirutea eta hiru dimentsioko inprimatzeak konbinatzen dituzten makinak ekoizten eta saltzen dituzte. Hiru dimentsioko inprimagailuak dira, baina fusio eta disoluzio bidezko elektroirutea egiten dute. Teknologia bakoitzaren bidez ezaugarri ezberdinetako egiturak lortzen dira. Fusio elektroirutean, plastiko urtuarekin, esaterako, ordenagailu batean egiturak diseinatu eta inprimagailuaren bidez nanohariz osatutako hiru dimentsioko egiturak egin ditzakete, geruzaz geruza.

Aurten bost makina saldu dituzte eta hurrengo urtean hamazazpi saltzea espero dute. Biomedikuntzan erabiltzeko saltzen dituzte batez ere: «Zuntzen ingeniaritzarako aldamioak eraikitzeko. Zuntz biologikoen birsorkuntza eta hazkuntza eusten duten egiturak egiteko». Egitura horiek biobateragarriak eta bioxurgagarriak izan daitezke, eta hezurren, giharren edo neurona zuntzen hazkuntza lagundu eta bultzatu dezakete.

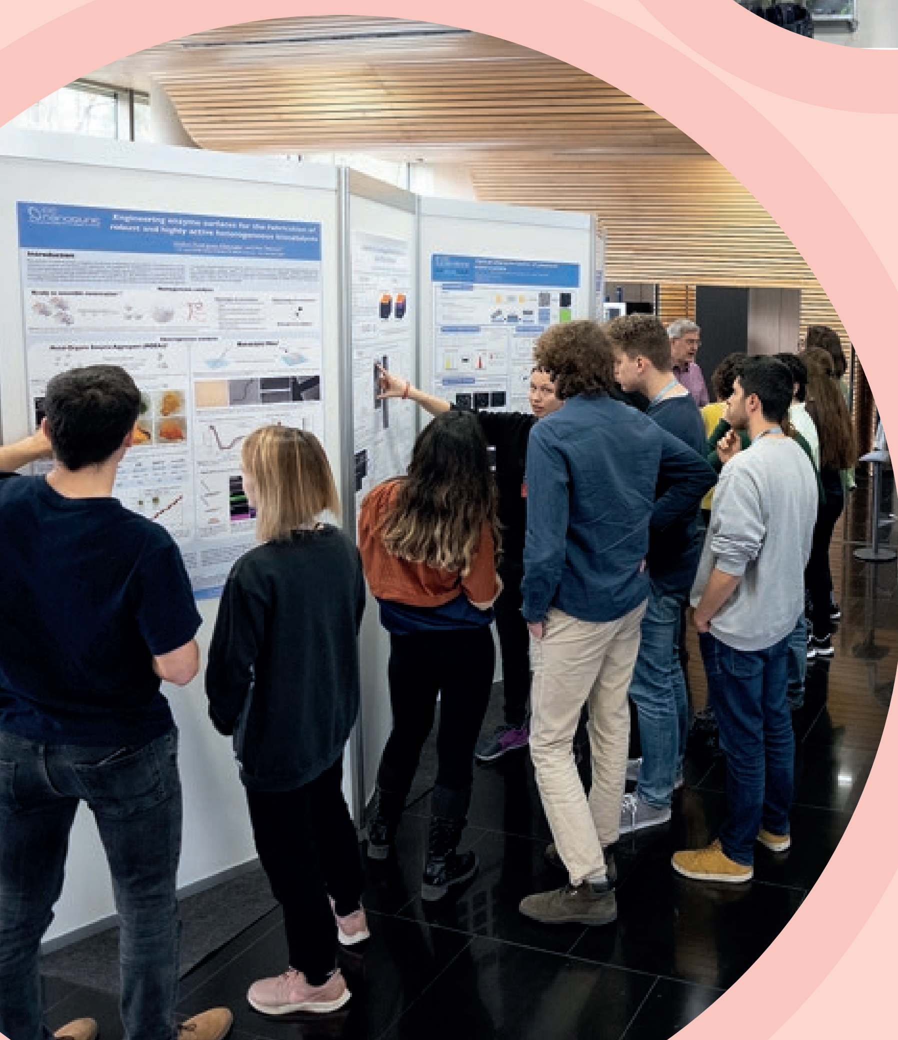
Aplikazio errealen eta balizko aplikazioen zerrenda oso zabala da: biosentsoreak egiteko, gorputzean botiken dosiak modu kontrolatuan askatzeko, energian (baterietako katalizatzaile gisa), ehungintzan, janariak biltzeko (mikrobioei aurre egiteko eta elikagaien iraupena luzatzeko), iragazkiak egiteko... Bide batzuk urratzen ari dira, beste batzuk urratzeko daude oraindik.

Berria
13/11/2020

6

Connecting with Society


the challenge of reducing
d preventing the presence
lastics and microplastics
in our oceans



Connecting with Society

The role of science and technology in society has never been so important as it is today. Science and technology are directly related to social and economic development. This is why it is so important for individuals to be able to understand and value the key role that scientific development plays in our society.

Nanotechnology is not the future. It is the present already. Nevertheless, a large majority of our society does not really understand yet what it is. NanoGUNE aims at spreading a scientific culture, in order to inspire a critical society capable of building a future in a sustainable and intelligent manner.

At nanoGUNE, we are convinced that achieving great scientific and technological advances is not enough: we are committed to disseminating truthful information in a responsible and understandable way. To achieve this goal, we organize visits for educational centers and offer young people the possibility to see more closely our nanoscience research; we also offer summer internships to undergraduates and the supervision of bachelor and master theses.

The dissemination of scientific culture contributes to building a more educated and critical society; indeed, a society that is scientifically cultured is always a richer society. This is the reason why we are particularly active in the promotion of the dissemination of a scientific culture.

Events

Zientzia Azoka

We have been actively participating in a Science Fair (Zientzia Azoka) organized by Elhuyar. The purpose of this fair is to awaken scientific and technological vocations among young people in order to disseminate science and promote the scientific culture of our society. A collaboration agreement with Elhuyar has been signed.

Science Week

NanoGUNE, together with the Donostia International Physics Center and the Materials Physics Center, has been collaborating in the Science Week organized every November by the University of the Basque Country through a nanoscience and materials-science exhibition.

Donostia WeekINN

NanoGUNE participates in the Week of Innovation, Donostia weekINN, organized by Fomento of San Sebastian. This event offers a complete program of activities around the innovation strategy that takes place in the city.

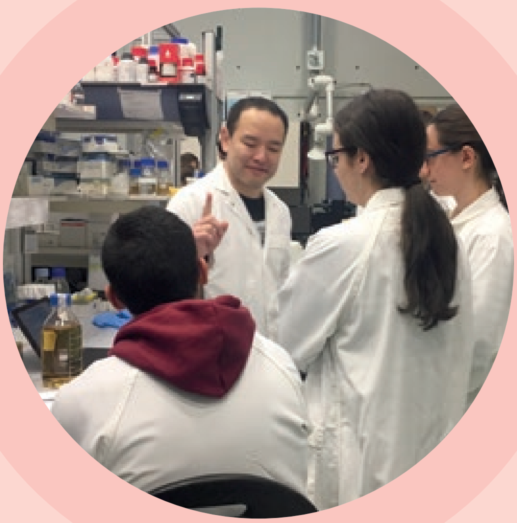
Women in Science

In order to achieve full and equal access and participation of women in science, the United Nations General Assembly decided in 2016 to proclaim February 11 as the International Day of Women and Girls in Science.

In the period 2019-2020, we have been celebrating this day together with other centers in San Sebastian, with the aim of bringing visibility to the activity of women that are doing scientific research, thereby breaking the archetypical masculine roles usually attributed to science and technology and encouraging scientific career choices among girls and teenagers.

In an unprecedented collaboration, in 2020 nine centers (nanoGUNE, the Materials Physics Center, biomaGUNE, the Donostia International Physics Center, Biodonostia, Tecnum, Ceit, Polymat, and Elhuyar) joined forces to present a full-week program aimed at teenagers, school kids, elder women (above 55), the scientific community, and citizens in general.

Our initiative "Emakumeak Zientzian" was recognized with the STEAM Euskadi Seal of the Basque Government for the promotion of STEAM education in the Basque Country. The Committee was composed of representatives from the Department of Education of the Basque Government, the Research Center for Scientific and Mathematical Education (CRECIM) of the Autonomous University of Barcelona, and the Basque Innovation Agency Innobasque.



Undergraduates: summer internship and bachelor thesis

In the period 2019-2020, 30 undergraduate students have joined nanoGUNE's summer-internship program and/or have done their bachelor thesis under the supervision of our researchers.

Winter School

In the period 2019-2020, 59 undergraduate and master students have joined nanoGUNE´s Winter School. The event is primarily aimed at undergraduate and master students of physics, chemistry, biology, and engineering. The School includes a combination of academic lectures, soft-skills training sessions, and hands-on lab practices.

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 90 students have visited nanoGUNE during the 2019-2020 period.

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 Nanosctructures and Advanced Materials (PNAM)" offered by the UPV/EHU. Currently, we have 36 ongoing PhD theses at nanoGUNE and we are cosupervising the thesis of another 5 PhD students that are enrolled at other research centers or universities in the Basque Country.

Master

NanoGUNE collaborates with the Master in Nanoscience and the Master in New Materials of the University of the Basque Country (UPV/EHU), and we give master students the opportunity to join our research groups in order to do their master thesis under the supervision of one of our principal investigators.

7

Organization and Funding

Organization

NanoGUNE is a non-profit making Association promoted by the Basque Government in 2006 and officially inaugurated in 2009.

The Governing Board, currently composed by all partners, is the final responsible for the overall management of the Center.

An International Advisory Committee, composed of internationally renowned researchers and professionals, advises on the orientation that should be given to the Center.

Regarding the management of the Center, the period 2019-2020 has been particularly fruitful. Thanks to the effort of the administration&services team, the following achievements have been reached:

- The Innovation Management System, which had been certified in 2017 according to the standard UNE 166002:2014, was externally audited successfully in 2019 and 2020. This standard aims to guide organizations in the development, implementation, and maintenance of a framework for systematic innovation management practices, integrating them within a R&D and innovation management system. The person responsible for the Innovation Management System is the Finance Director.

- In 2019, nanoGUNE was granted by the European Commission the 'HR Excellence in Research' award, which gives public recognition to research institutions that have made progress in aligning their human-resources policies with the principles of the so-called European Charter&Code for Researchers. A team composed of various representatives of the Center is responsible for the follow-up and monitoring of the implementation, until November 2021, of an action plan to be reviewed by the European Commission.

- In 2019, nanoGUNE's Governing Board approved a Criminal Risk Prevention Program. The main objective of this Program is to promote a corporate culture of compliance (Corporate Compliance), aiming to achieve a responsible management of the activities that are being undertaken at nanoGUNE and promoting a culture of integrity, honesty, transparency, and respect for ethical standards and rules. NanoGUNE declares an absolute rejection of any irregular behavior in the development of its activities, mainly those conducts that by their nature may constitute a potential crime, whose prevention is the Program's primary objective. The Finance Director is the Compliance Officer and the compliance program is supervised by a team composed of various representatives of the Center.

- A Gender Equality Plan was approved in 2019. The Plan is structured around five main key areas and 10 strategic objectives, and it includes an action plan with a total of 39 actions to be developed in the period 2019-2022. The implementation of the Plan is led by the Outreach Manager and the Director, in close collaboration with the Gender Equality Committee.

On 11 March 2020, the World Health Organization declared the emergency situation caused by the epidemic outbreak of COVID-19 as a pandemic. For the management of the health crisis caused by this pandemic, on 14 March 2020 the Spanish Government declared a state of alarm that would be extended until 20 June 2020. At nanoGUNE, a contingency plan was adopted in order to provide advice and support in the actions to be carried out to eliminate, reduce, and control the risk of exposure to COVID-19. The following measures were adopted during the state of alarm and the subsequent phases of deconfinement:

- Preventive hygiene measures such as the use of face masks, hydroalcoholic gel dispensers, and body-temperature screening terminals were put in place.
- Organizational measures related to physical distancing and the gathering of people were announced. Social-distancing screens were installed between contiguous desks.
- Telework was recommended.
- Seminars and language classes have been held online.
- Limitations in the capacity of laboratories were established.

Experimental onsite research work was only interrupted from March 30th to April 9th, as all non-essential activity was ordered to be shut down in Spain during that period of time. Most research projects have been executed as originally planned.

Funding

In the period 2019-2020, we have been able to attract a considerably large amount of public funding from the Regional Government of Gipuzkoa, the Basque Government, the Spanish Government, and the European Commission, and our private funding has increased considerably. We have also benefited from the support we have received from the Basque Science Foundation (Ikerbasque) through its program to attract talented researchers from all over the world. The overall funding (both public and private) that we have received has allowed us to comply with our mission to carry out world-class nanoscience research for the competitive growth of the Basque Country.

	2019	2020
Personnel (on 31 December)	109	118
Full-Time Equivalent (FTE)	106	106
R&D exploitation income (in thousand EUR)	7 389	7 292
% of non-competitive public funding from the Basque Government	38	29
% of competitive public funding from the Regional Government of Gipuzkoa	2	2
% of competitive public funding from the Basque Government	19	21
% of competitive public funding from the Spanish Government	15	16
% of competitive public funding from the European Commission	15	19
% of private funding	11	13

Governing Board

Chair	**Construcciones y Auxiliar de Ferrocarriles, S.A. (CAF)** Javier Martínez-Ojinaga (since 13/02/2019)
Vice-chair	**Gipuzkoa Regional Council** Jabier Larrañaga (since 01/12/2020)
Secretary - Treasurer	**Donostia International Physics Center (DIPC)** Ricardo Díez-Muiño (since 13/02/2019)
Board members	**University of the Basque Country (UPV/EHU)** Fernando Tapia (since 03/09/2019) **Ikor Sistemas Electrónicos, S.L. (Ikor)** Aitor Larruskain (since 03/06/2020) **Petróleos del Norte, S.A. (Petronor)** Elías Unzueta
Guest members, on behalf of the Basque Government	**Department of Economic Development, Sustainability, and Environment** Alberto Fernández (since 02/10/2019) **Department of Education** Adolfo Morais
Former members in the period 2019-2020	**Pedro Miguel Echenique** (until 12/02/2019), Chair, DIPC **Josu Imaz** (until 12/02/2019), Board member, CAF **Arturo Muga** (until 02/09/2019), Board member, UPV/EHU **Ainhoa Aizpuru** (until 10/09/2019), Board member, Gipuzkoa Regional Council **Jon Sierra** (until 29/11/2019), Board member, Ikor **Jose Miguel Erdozain** (until 31/12/2019), Secretary-Treasurer, IK4 Research Alliance **Mikel Álava** (from 30/11/2019 until 06/04/2020), Board member, Ikor **Carmen Urizar** (from 07/04/2020 until 02/06/2020), Board member, Ikor **Joseba Iñaki San Sebastián** (until 16/07/2020), Vice-chair, Tecnalia Technology Corporation **Imanol Lasa** (from 11/09/2019 until 30/11/2020), Board member, Gipuzkoa Regional Council **Iosu Madariaga** (until 01/10/2019), Guest member, on behalf of the Basque Government, Department of Economic Development and Infrastructure

Grants in Place 2019/2020

European Commission

Graphene Flagship	2
H2020 Coordination and Support Actions	3
H2020 FET Open	3
H2020 Research and Innovation Actions	1
Marie Sklodowska-Curie Actions (CIG, ITN, European and Global Fellowships)	14
M-ERA.NET	1

Spanish Government

Europa Excellence	1
Excelencia	1
Explora	1
FPI Pre-doctoral Grants	14
FPU Pre-doctoral Grants	1
Infrastructure	1
Juan de la Cierva Incorporation	3
Maria de Maeztu	1
Research Networks	1
Retos	17
Retos Collaboration	1

Basque Government

Elkartek	4
Emaitek	2
Ikerbasque Fellows	2
Infrastructure	1
Pre-doctoral Grants	4

Gipuzkoa Regional Council

Gipuzkoa Fellows	5
Infrastructure	2
Research Projects	2

International Advisory Committee

The International Advisory Committee gives advice on the orientation to be given to the Center

Prof. Sir John Pendry
Chair
Imperial College, London (UK)

Prof. Anne Dell
Imperial College, London (UK)

Prof. Marileen Dogterom
Delft University of Technology, Delft (Netherlands)

Prof. Jean-Marie Lehn
Chemistry Nobel Laureate, 1987
Strasbourg University, Strasbourg (France)

Dr. José A. Maiz
Intel Fellow, Oregon (USA)

Prof. Emilio Méndez
Brookhaven National Laboratory, New York (USA)

Prof. Sir John Pethica
CRANN, Dublin (Ireland)
University of Oxford (UK)

Funding Institutions

EUSKO JAURLARITZA
GOBIERNO VASCO

ikerbasque
Basque Foundation for Science

EUROPEAN UNION
"A way to make Europe"

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

Gipuzkoako Foru Aldundia

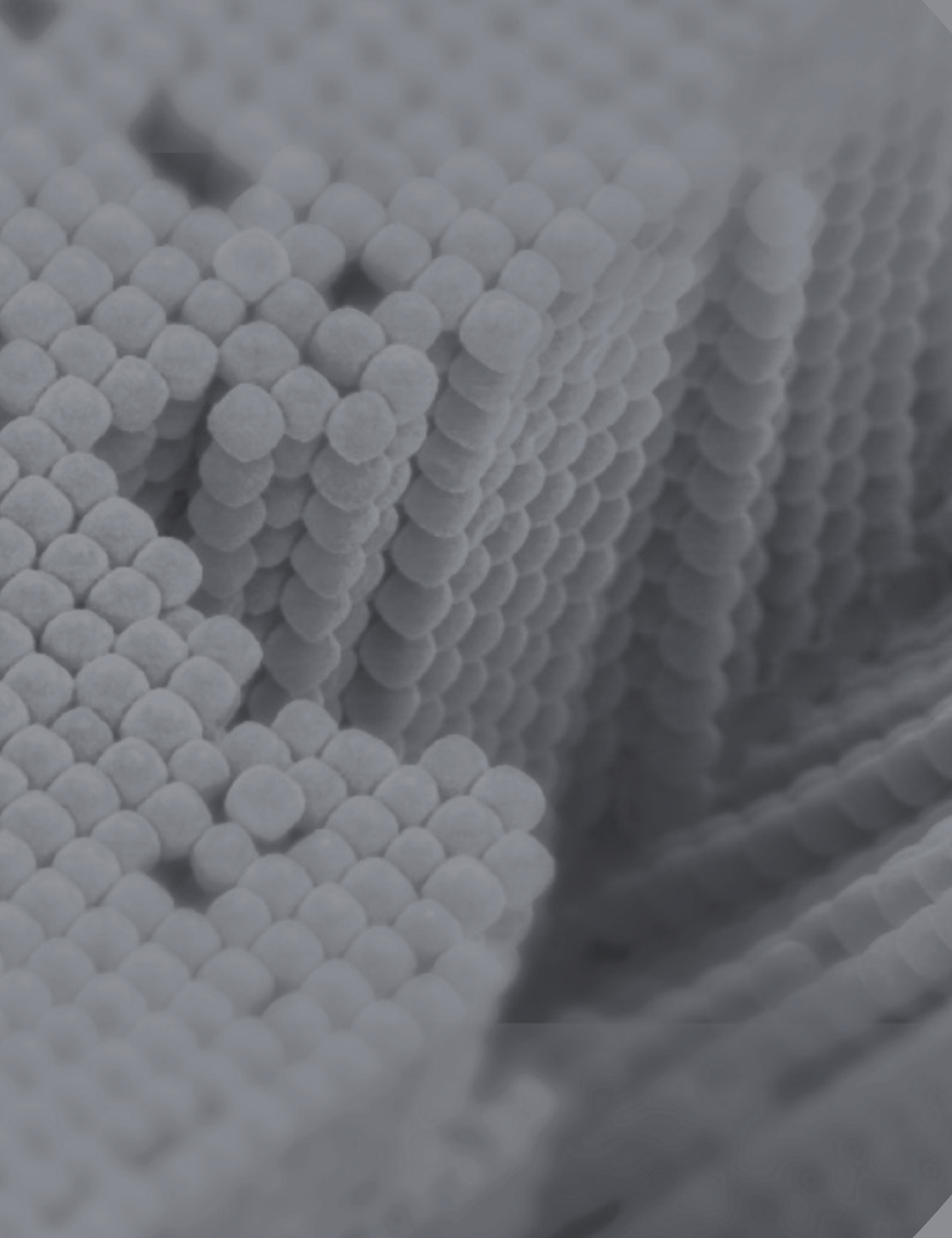
Distinctions

EXCELENCIA MARÍA DE MAEZTU

SYSTEM CERTIFICATION UNE 166002 SGS

HR EXCELLENCE IN RESEARCH

nanoPeople



CIC nanoGUNE

Activity Report

2019-2020


CIC
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