CALL FOR PhD STUDENTSHIP

The Material Physics Center (MPC) and “Centro de Física de Materiales (CFM)” in Donostia / San Sebastián (the Basque Country, Spain) is currently seeks bright, highly motivated PhD candidates. The successful students will work in an intellectually stimulating environment to develop cutting-edge research on Materials Science, exploring physical and chemical properties of advanced materials, nanostructures and nanodevices, either theoretically or experimentally.

They will have access to the most advanced techniques in the field and develop industry-transferable skills. The PhD candidate will work in close interaction with all our scientific staff and a wide group of postdoctoral researchers, and will take advantage of a continuous flow of prestigious international visitors. CFM is a joint center of the University of the Basque Country - UPV/EHU and the Spanish Research Council - CSIC. The center combines several research teams with international recognition and positioning, developing cutting-edge materials science in state-of-the-art facilities.

CFM's headquarters are located in Donostia / San Sebastián, a vibrant city on the northern coast of Spain, featuring an intense cultural life (including international cinema and jazz festivals) and an extraordinary natural landscape. Donostia is a unique place to conduct research, as it is home to several world-leading research centers, such as the CFM, the Donostia International Physics Center (DIPC), the CIC Nanogune or the CIC Biomagune, among others.

The successful candidates will benefit from an environment that fosters the cross-fertilization of ideas between different research topics. This year, the CFM is focused on the following research projects[1]:

Project S1. Phase and magnetic dynamics of superconducting devices with unconventional magnets

Project S2. Tuning light-matter interactions: Exploring optical properties of quantum emitters for advanced photonics applications and quantum technologies

Project S3. Exploring ion transport dynamics in solid polymer electrolytes for high-performance batteries

Project S4. Exploring Magnetic Phenomena in Low-Dimensional Materials Using DFT

Project S5. Molecular dynamics simulations of complex vitrimers: structure and dynamics

Project S6. Controlling non-equilibrium spin signals in hybrid superconducting devices

Project S7. On surface synthesis of carbon-based materials for sensing and quantum technologies

Project S8. Towards carbon-based quantum nanocircuitry

Project S9. Quantum nanophotonics: Control of light emission from quantum emitters coupled to optical nanoresonators

Project S10 Advanced functionalized nanoparticles as artificial enzymatic catalysts

Project S11 Rational design, synthesis and characterization of single-chain polymer nanoparticles with intrachain covalent, dipolar and electrostatic interactions for applications in nanomedicine

Project S12 Growth and electronic structure of 2D material heterostructures for quantum materials

Project S13 Optical trapping and levitation with helical beams

Project S14 Exploring novel quantum sensing paradigms with nitrogen vacancy centers in diamond

The candidates are expected to work in these areas. More details on these research lines can be found in our web page: https://cfm.ehu.es/research-lines

4 PhD studentships available

We will follow an online selection process. The details will be defined and published in CFM's website and will include interviews and discussions with the supervisor of the different research projects and/or the Evaluation Committee.

[1] *Please mind that candidates can choose a maximum of 4 projects.*

From the interviews, four (4) candidates will be selected and granted full studentships. Each studentship consists of the financing of a pre-doctoral position for a maximum of three years. The gross annual salary for the first year will be 18.180,36 euros. This salary will be increased in accordance with the applicable regulations.

The PhD studentship will only be granted to successful candidates whose PhD project will be formally registered at the University of the Basque Country UPV/EHU before 31st December 2025 for the PhD contract to be continued. Therefore, **the candidates are required to hold a Master degree granted before the end of 2025**.

Application Process: Find all the necessary information about how to apply, as well as future updates and publications here: https://cfm.ehu.es/education/phd-recruitment-fair/

The following documentation is required for the application:

1. Fill in relevant data in the on-line form.
2. **Updated CV.** Please provide clear contact information.
3. **Reference letters** (if more than one, please merge all of them in a single e-file).

The deadline for the application is 28th February 2025, at 13:00 Central European Time (CET)[2].

Pre-Selection Process: The applications will be evaluated by an academic Evaluation Committee composed by permanent CFM faculty members, who will consider the CVs of the candidates, the adequacy of their background to the selected projects and the provided reference letters.

Pre-Selection Results: All candidates will be notified of the results by email and the pre-selected candidates will be contacted personally for arranging the calendar of the on-line interviews with the different research-project supervisors and/or the Evaluation Committee.

Final Selection Process: Soon after the on-line interviews, the committee will select the 4-awarded students and the final decision will be communicated to the applicants and published in the CFM website (http://cfm.ehu.es/about-cfm/job-offers).

If you need further information about this call or about any general queries on the selection process, please contact phdstudents.cfm@ehu.es

[2] *Only applications received before the deadline (28th February 2025 at 13:00 CET) will be evaluated.*

LIST OF AVAILABLE PROJECTS

Project S1. Phase and magnetic dynamics of superconducting devices with unconventional magnets

Contact person: F. Sebastian Bergeret Sbarbaro (fs.bergeret@csic.es)

Motivated by recent advances in material research and low-dissipation electronics using superconductors, we propose the study of transport properties in hybrid systems consisting of superconductors and magnets with unconventional magnetic textures. The study will be carried out using quantum kinetic equations recently developed within our group's research, focusing on the non-equilibrium dynamics of the superconducting phase as well as the magnetization, and their coupling.

During the thesis, the PhD student will acquire skills in various topics and techniques of condensed matter theory, including superconductivity, magnetism, altermagnets, the Keldysh Green's function method, quasiclassical approaches, and effective modeling of superconducting circuits and phase dynamics in Josephson junctions.

The project involves two distinct types of activities that will converge as the development progresses. On one hand, the student will explore purely theoretical systems and scenarios, first developing effective models and making predictions by solving the key equations both analytically and numerically. On the other hand, the student will engage in strong collaboration with experimental groups specializing in electronic transport and low-temperature physics, who are regular collaborators of the Mesoscopic Physics Group. Through this interaction, the student will have the opportunity to test the models and predictions, as well as provide theoretical insights to help explain the experimental results.

Most of the activities will be carried out within the framework of two ongoing projects: one European project, *JOSEPHINE*, focused on Josephson junctions as elements for neuromorphic computations, and another from the Spanish Research Agency, *SUNRISE*, which focuses on the study of magnetoelectric effects in superconductor/magnetic structures.

Project S2. Tuning light-matter interactions: Exploring optical properties of quantum emitters for advanced photonics applications and quantum technologies

Contact person: Yury Rakovich (yury.rakovich@ehu.eus)

This PhD project focuses on advancing quantum technologies by optimizing the optical properties of single quantum emitters, such as semiconductor quantum dots, and their interactions with engineered nanophotonic structures. Single quantum emitters are key for applications in quantum communications, sensing, and quantum photonic devices due to their ability to produce deterministic single photons with high efficiency and tunability.

Specifically, we will explore the novel effects based on the integration of these emitters into engineered nanophotonic structures, leading to the enhancement of emission efficiency, spectral stability, and photon directionality. These nanostructures will allow the tuning of photon emission properties, enabling the realization of high-performance quantum photon sources.

A key part of the research involves experimental design and characterization of the quantum optical properties of the emitters by the optimization of the light-matter coupling and environmental conditions using advanced nanoengineering and nano-spectroscopy techniques, including time-resolved photon counting and photon correlation spectroscopy. Computational modelling will also play a crucial role in designing nanophotonic environments to maximize emission efficiency.

The findings will enable the development of new experimental designs in the field of secure quantum information communications and processing, as well as nanoscale sensing through the engineering of versatile and efficient quantum light sources.

Project S3. Exploring ion transport dynamics in solid polymer electrolytes for high-performance batteries

Contact person: Jon Maiz Sancho (jon.maizs@ehu.eus) and Guiomar Hernández

Solid polymer electrolytes (SPEs) hold significant promise for next-generation solid-state batteries (SSBs) by offering enhanced safety and high energy density. However, their adoption is limited by challenges in ionic conductivity, driven by polymer segmental motion, structural heterogeneity, and ion-polymer interactions. Overcoming these limitations involves two key steps: developing advanced polymer systems with tailored properties and gaining a deeper understanding of ion transport dynamics within these materials.

This PhD project aims to investigate the ion transport dynamics in SPEs via advanced scattering techniques, focusing on the impact of residual solvents on ion mobility, segmental polymer dynamics, and overall ionic conductivity across various polymer matrices, comparing their dynamics with those of cations. In parallel, the project will examine the use of novel block copolymer-based systems for high-performance SPEs. These materials, renowned for their ability to self-assemble into well-defined nanostructures, will allow the creation of continuous ion-conducting pathways while ensuring mechanical robustness and tunable properties.

Thus, through a detailed analysis of ion dynamics, and the exploration of novel polymer morphologies, this project aims to develop innovative strategies for enhancing conductivity and stability in SPEs. These advancements will contribute to the development of high-performance SSBs, driving the future of energy storage technologies.

Project S4. Exploring Magnetic Phenomena in Low-Dimensional Materials Using DFT

Contact person: Andrés Ayuela Fernández (a.ayuela@csic.es)

The project aims to explore the magnetic properties of low-dimensional materials using Density Functional Theory (DFT). With a focus on two-dimensional materials such as graphene derivatives and Van der Waals magnets, this research will investigate how atomic-level defects, adatoms, and heterostructures influence magnetism. One core objective is to understand the interplay between localized magnetic moments and long-range magnetic ordering in these systems, which is pivotal for spintronic applications.

Advanced DFT methods, including meta-GGA and Van der Waals-corrected functionals, will be employed to study exchange interactions, anisotropy, and spin-orbit coupling. Additionally, the project will analyze the effects of external fields on the stability and tunability of magnetic states, laying the groundwork for designing materials for quantum computing and energy-efficient memory devices.

The student will also develop and implement computational workflows to bridge atomistic insights into mesocale properties, using high-performance computing. Collaborations with experimental groups in USA will validate the predictions, enabling a robust connection between theory and application. By addressing key challenges in computational magnetism, this project aspires to contribute to the development of next-generation magnetic materials.

Project S5. Molecular dynamics simulations of complex vitrimers: structure and dynamics

Contact person: Angel Moreno Segurado (angeljose.moreno@ehu.eus)

Vitrimers are polymer materials of high technological interest because they share properties with both thermoplastics and thermosets. A vitrimer consists of a dynamic covalent network that can rearrange its topology through reversible exchange reactions that preserve the total number of bonds in the network. As a consequence, they combine self-healing properties, mechanical strength, malleability, solvent resistance and reprocessability. Key factors that ultimately control such properties are the specific topology of the polymeric building blocks (linear, star, ring, nanogel, etc.) and the competition between reversible intra- and inter-molecular bonding. Moreover, complexity can be increased through the use of copolymer sequences and different types of reversible bonds (weak and strong), allowing for nanostructuration of the network and selective response to stimuli (through dual or interpenetrated networks).

The aim of this PhD project is to systematically investigate, by means of large-scale molecular dynamics simulations, the role of such factors on the structure and dynamics of vitrimeric materials. The project will benefit from the close collaboration with experimentalists of the CFM (particularly through neutron scattering techniques). We look for a young candidate interested in theory/simulation and in soft matter physics. Background in both of them and in programming skills will be highly esteemed.

Project S6. Controlling non-equilibrium spin signals in hybrid superconducting devices

Contact person: Sara Catalano (sara.catalano@ehu.eus)

The project aims to explore the use of hybrid superconducting interfaces for the generation and read-out of non-equilibrium spin current densities. The candidate will design, fabricate and measure Josephson Junction and spin valve devices combining superconducting electrodes with magnetic interfaces and spin-orbit coupling elements. The focus of the project will be: 1) the identification of systems in which non-equilibrium spin current densities, such as those generated by the spin Hall effect, can coexist with the superconducting condensate; 2) demonstrating the mutual interaction between non-equilibrium spin currents and the superconducting phase with experimental transport measurements.

The device fabrication will be carried out in the cleanroom of the CIC nanoGUNE research centre, and the devices will be characterized in the dilution refrigerator chamber of the Nanophysics Lab, fitted with both DC and RF lines. The ideal candidate shall have a MSc or equivalent degree in Physics, Materials Science, Engineering or related fields and a basic understanding of superconducting transport effects. Hands-on experience in cryogenic transport measurements will be an advantage.

Project S7. On surface synthesis of carbon-based materials for sensing and quantum technologies

Contact person: Martina Corso (martina.corso@ehu.eus) and Ignacio Piquero Zulaica

Advanced materials with new properties and functionalities will drive the digital and green transition planned by the European Union in the next years. A new manufacturing method that enables fabricating with atomic scale precision surface supported novel carbon based nanomaterials in ultra-high vacuum (UHV) conditions is the *on surface synthesis*.

In this project we are looking for motivated students to work on the on surface synthesis and characterization of the morphology and emergent electronic, magnetic and optical properties of low dimensional carbon based materials to establish their suitability for chemical sensing, nanoelectronics and molecular quantum technologies. By using de novo synthesized molecular

linkers (provided by our synthetic chemist collaborators), we will fabricate on catalytic substrates, as well as on more weakly interacting interfaces, materials as nanoporous graphene, graphene nanoribbons, metal-organic coordination networks and covalent organic frameworks. A full characterization of these materials and heterostructures will be achieved with our multi-technique surface science approach in the Nanophysics lab that combines scanning probe, diffraction and photoemission techniques together with complementary synchrotron experiments. The experimental findings will be supported by theoretical calculations (in collaboration). The applicant will combine in-house experimental campaigns with external (national and international) visits to other research centers and synchrotron facilities.

We look for highly motivated and engaged candidates holding a Master degree in chemistry or physics (or related subjects). We offer a supportive and friendly working environment as well as access to excellent experimental infrastructure.

Project S8. Towards carbon-based quantum nanocircuitry

Contact person: Daniel Sánchez Portal (daniel.sanchez@ehu.eus) and Aran Garcia Lekue (wmbgalea@ehu.eus)

Controlling electron propagation at the nanoscale is essential for future nanoelectronics, quantum computing or sensing applications. Carbon-based nanoarchitectures have emerged as promising candidates due to, for example, the recently demonstrated possibility of phase-coherent electron transport along 1D graphene nanoribbons integrated into a 2D platform.

In this theory project, quantum electronic transport calculations will be used to study electron propagation in 1D or 2D graphenic platforms. To this end, density functional theory (DFT) in combination with non-equilibrium Green's function (NEGF) method will be employed. Larger systems will be tackled using multiscale methods that combine DFT and simplified tight-binding (TB) models to describe different regions of the device. The formation of lateral and vertical heterostructures, and the presence of dopants and functional groups that add functionalities like magnetic moments, spin-selective transport or optical switching will be considered. Additionally, we will explore the use of methods beyond DFT to describe the electronic and magnetic properties of localized regions of the devices that need such improved descriptions, e.g., multielectron radicals, transition metal centers, etc. These localized regions will be embedded into larger systems using strategies similar to those used in dynamical mean-field theory (DMFT) and similar methods. Our results will be useful towards developing carbon-based nanocircuits and could guide future experiments in this direction.

Project S9. Quantum nanophotonics: Control of light emission from quantum emitters coupled to optical nanoresonators

Contact person: Ruben Esteban Llorente (ruben.esteban@ehu.eus)

The objective of this theoretical thesis is to investigate quantum effects that emerge in the interaction between state-of-the-art optical nanoresonators and quantum emitters. The emitters can be organic molecules or quantum dots, for example, and the nanoresonators are often plasmonic nanoantennas that enable extreme light localization due to the collective oscillations of the free electrons in the metal. The molecule-nanoresonator interaction is exploited to manipulate the properties of the emitted light and in improved molecular spectroscopy techniques. Classical calculations have been traditionally used in these studies. However, due to recent improvements in fabrication and characterization, quantum treatments are increasingly necessary to analyze a large variety of novel effects. Notably, the quantum state of the emitted light can potentially be exploited for improved molecular characterization and quantum information applications.

The student will develop and apply classical and quantum methodologies, based for example in cavity quantum electrodynamics, in the search of new quantum effects in emitter-nanoresonator systems. In additional to the control of light emission, a variety of other phenomena can be explored, depending on the thesis progress, including non-linear, atomistic or charge transfer effects. It is expected that the student will contribute actively in collaboration with experimentalists.

Project S10. Advanced functionalized nanoparticles as artificial enzymatic catalysts

Contact person: Ester Verde Sesto (mariaester.verde@ehu.eus)

This project aims to develop advanced functionalized nanoparticles as artificial enzymatic catalysts for applications in catalysis, photocatalysis, and sustainable chemical synthesis. We will design single-chain nanoparticles (SCNPs) that mimic the active sites of natural enzymes, achieving high catalytic efficiency and specificity under mild conditions.

The research will involve synthesizing nanoparticles with precise control over their size and shape, incorporating catalytic metal centers, organic ligands or hybrid materials. Advanced techniques (NMR, DLS. SEC/GPC, UV-Vis) will be used to study how their structure influence their catalytic function. The activity of these SCNPs will evaluate in key enzymatic reactions (e.g. oxidation, hydrolysis, or reduction) to optimize their stability and reusability.

This interdisciplinary research provides a unique opportunity to gain expertise in nanotechnology, catalysis, and materials science, with the goal of advancing the development of next-generation biomimetic catalysts for a variety of green chemistry applications.

Project S11. Rational design, synthesis and characterization of single-chain polymer nanoparticles with intrachain covalent, dipolar and electrostatic interactions for applications in nanomedicine

Contact person: Jose A. Pomposo Alonso (josetxo.pomposo@ehu.eus)

The folding of individual synthetic polymer chains into single-chain polymer nanoparticles (SCNPs) -mimicking the folding of proteins and nucleic acids in Nature- paves the way to the development of innovative sensors and drug delivery vehicles. Internal confinement upon SCNPs formation allows immobilizing luminophores or drugs within the resulting local pockets of these ultrafine nanoparticles. As demonstrated by our group, entrapment within such nanocavities can be adjusted from permanent to merely transient. This Project aims to the development of adaptive SCNPs with intrachain covalent, dipolar and electrostatic interactions guided by a recent theoretical approach to control the size and number of nanocavities in these responsive SCNPs. This will lead to the practical design of advanced nanomaterials of great interest for applications in nanomedicine as SCNPs probes for biomarker detection, multi-responsive hydrogels or antifouling surfaces.

Project S12. Growth and electronic structure of 2D material heterostructures for quantum materials

Contact person: Frederik Schiller (frederikmichael.schiller@ehu.eus)

2D materials are low-dimensional structures that can be obtained by top-down (scotch tape) or bottom-up (molecular beam epitaxy-MBE) methods. While the first one allows easy preparations of new devices, the second method is preferred for fundamental investigations. Such 2D materials enable new physical and chemical properties down to the quantum limit with the further advantage of less material. Famous examples for such materials are graphene-Gr, hexagonal boron nitride-hBN, silicene, phosphorene or dichalcogenides. Our team is expert in growing 2D materials on different substrate materials by means of catalytic growth, see e.g. [1],[2]. For this purpose, we use single crystal curved substrates featuring surfaces of high and low symmetry Miller indices, including flat, stepped, or kinked surfaces. These substrates allow the growth of different orientations or allotropes of the 2D materials ranging from semimetallic Gr via semiconducting silicene and phosphorene to isolating hBN.

The aim of this project is the growth of stacked and lateral 2D materials mainly with MBE-like methods. The structure will be analysed with Low Energy Electron Diffraction and Scanning Tunnelling Microscopy. Electronic properties will be investigated with X-ray and angle-resolved photoemission spectroscopies as well as X-ray absorption, both in the laboratories located in San Sebastian and synchrotron radiation facilities.

The applicant should have finished university studies of physics, chemistry or similar and should have obtained a Master's title in one of such subjects. Furthermore, the applicant should speak fluent English and integrate into an international team in collaboration with other European entities.

[1] A.M. Idris Bakhit, K. Ali, A.A. Makarova, I. Piš, F. Bondino, F. Schiller "Structure and electronic properties of stable facets in the 2D material hexagonal boron nitride (hBN) on curved platinum", Science Talks 4, 100071 (2022) https://www.sciencedirect.com/science/article/pii/S2772569322000718 .

[2] K. Ali, L. Fernández, M.A. Kherelden, A.A. Makarova, I. Píš, F. Bondino, J. Lawrence, D.G. de Oteyza, D.Yu. Usachov, D.V. Vyalikh, F.J. García de Abajo, Z.M. Abd El-Fattah, J.E. Ortega, F. Schiller "Atomically-Precise Texturing of Hexagonal Boron NitrideNanostripes", Adv. Sci. 8, 2101455 (2021) https://onlinelibrary.wiley.com/doi/epdf/10.1002/advs.202101455

Project S13. Optical trapping and levitation with helical beams

Contact person: Gabriel Molina Terriza (gabriel.molina@ehu.eus) and Miguel López Varga (miguel.varga@ehu.eus)

In this project the candidate will use some exotic properties of light, such as its orbital angular momentum or the polarization structure, in order to achieve an unprecedented control of optical forces. Small particles, such as microspheres or even bacteria and cells, can be manipulated with focused optical beams, which exert a force on the particle. These forces can be so high that the particle can be trapped in vacuum and achieve regimes where the motion of the particle is cooled down to a quantum regime.

In this project, we will exploit the full properties of electromagnetic fields to optimize these optical traps and achieve regimes where the particle can rotate at high speeds, as well as, ideally embed quantum emitters in the particle to observe the quantum emission in non-inertial frames of reference.

Project S14. Exploring novel quantum sensing paradigms with nitrogen vacancy centers in diamond

Contact person: Ruben Pellicer Guridi (ruben.pellicer@ehu.eus) and Gabriel Molina Terriza (gabriel.molina@ehu.eus)

Quantum sensors have a vast potential to overcome classical sensors and open-up detection paradigms unthinkable up to date. Yet, most existing quantum sensing platforms can only be used in controlled laboratory environments and require expensive, bulky and fragile

instrumentation. Nitrogen Vacancies in diamonds are arguably one of the most promising quantum sensing platforms in the near-middle term as they offer superb sensitivity even at room temperature.

This PhD project aims to envision novel quantum control mechanisms that unleash the potential of this solid state sensor to be used in practical environments. The candidate will have access to the Quantum Nanophotonics Lab, which is equipped with state-of-the-art instrumentation and two working nitrogen vacancy center setups. This project has a strong overlap with other activities ongoing in the team, providing the candidate with the opportunity of working in a vibrant team with a collaborative spirit. The expertise of the group enables that this project can cover all the way from basic science explorations for novel sensing approaches up to developing advanced instrumentation for a new range of applications such as early disease detection for medical diagnosis.