NANOPHOTONICS TECHNOLOGY CENTER

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

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MARE2D – I Reunión Española sobre Materiales Avanzados y REdes de Dispositivos en 2D

MARE2D

Materiales Avanzados y Redes de Dispositivos en 2D

18 de Junio de 2025

Centro de Tecnología Nanofotónica (NTC)
Universitat Politècnica de València

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18, Junio, 2025

ETSIT. UPV. Valencia (Spain)

AGENDA

Hora	Sesión
9:00 – 9:10	Llegada
9:10 – 9:30	Bienvenida (Elena Pinilla & Víctor J. Gómez)
9:30 – 10:10	José J. Baldoví
10:10 – 10:50	Luis Hueso
10:50 – 11:30	***Coffee Break***
11:30 – 12:10	Carla Boix
12:10 – 12:50	Pablo Ares
12:50 – 13:30	Andrés Castellanos
13:30 – 15:00	***Comida***
15:00 – 15:40	Mª José Calderón
15:40 – 16:20	Miguel Ugeda
16:20 – 17:00	Mariela Menghini
17:00 – 17:20	***Coffee Break***
17:20 – 18:00	Alberto Curto
18:00 – 18:40	Víctor J. Gómez
18:45	*Visita a NTC*

Chairperson: Elena Pinilla

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Towards molecular controlled magnetism in 2D materials

J. J. Baldoví,[1] A. M. Ruiz,[1] D. L. Esteras,[1] G. Rivero-Carracedo,[1] A. Rybakov,[1]
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The recent isolation of two-dimensional (2D) magnets offers tantalizing opportunities for spintronics, magnonics and quantum technologies at the limit of miniaturization. [1] Among the key advantages of atomically-thin materials are their flexibility, which provides an exciting avenue to control their properties by strain engineering, and the more efficient tuning of their properties with respect to their bulk counterparts.

In this presentation, I will provide an overview of our recent results on this fascinating topic. First, we will take advantage of the outstanding deformation capacity of 2D materials to answer the question: Can we use strain engineering to control spin waves propagation? [2] For that, we will focus on the magnetic properties, magnon dispersion and spin dynamics of the air-stable 2D magnetic semiconductor CrSBr, investigating their evolution under mechanical strain and Coulomb screening using first-principles. Then, we will introduce the modulation of the magnetic properties, magnon dispersion and spin dynamics of this 2D magnet after the deposition of sublimable organic molecules in a journey towards molecular controlled magnonics. [3] On the other hand, we will look for topological magnons in chromium trihalides (CrX_3), [4] investigate magnetostriction effects in 2D van der Waals antiferromagnets such as $FePS_3$ and $CoPS_3$, [5] we will delve into the origin of above-room-temperature magnetism in Fe_3GaTe_2 [6] and, finally, we will propose a new molecular 2D ferromagnet, the so-called graphendofullerene. [7]

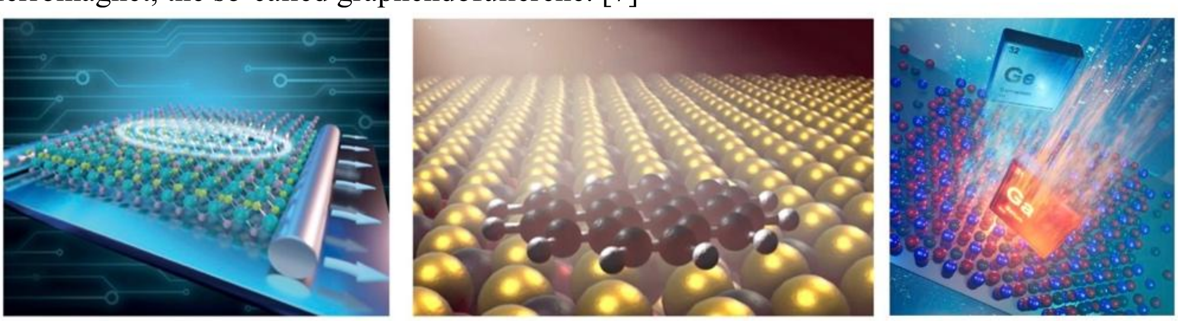

Fig. 1: *Artistic representation of (left) magnon straintronics device showing the chemical structure of CrSBr; (center) an irradiated coronene molecule on the surface of a 2D magnetic material; (right) formation of a Fe_3GaTe_2 single-layer representing the enhancement of TC with respect to Fe_3GeTe_2.*

References

1. B. Huang *et al*., *Nature*, **546**, 270–273 (2017).
2. D. L. Esteras *et al*., *Nano Lett.* **22**, 8771–8778 (2022).
3. A. M. Ruiz *et al*., *Nanoscale Adv.* **6**, 3320 – 3328 (2024).
4. D. L. Esteras *et al*., *Materials Today Electronics,* **6**, 100072 (2023).
5. M. Houmes *et al*., *Nature Commun.* **14**, 8503 (2023).
6. A. M. Ruiz *et al*., *Nano Lett.* **24**(26), 7886–7894 (2024)
7. D. López-Alcalá *et al*., *Chem. Sci.* **16**, 7659–7666 (2025)

Spin texture control with low symmetry 2D heterostructures

Luis E. Hueso[1,2]

[1] *CIC nanoGUNE BRTA, San Sebastian, Spain*
[2] *IKERBASQUE, Basque Foundation for Science, Bilbao, Spain*

Spintronics has made important contributions to electronic devices, fundamentally in the fields on magnetic recording and non-volatile random-access memories. More recently, post-CMOS applications, such as the MESO one from Intel, aim to integrate logic and memory in spin-based devices [1,2]. A key player in several recent spintronic proposals is the spin-to-charge conversion, which permits to electrically create and detect pure spin currents without using ferromagnetic materials.
In this talk I will show how low symmetry materials can add new possibilities to spin-to-charge conversion. Moving beyond single crystalline bulk materials such as chiral Tellurium [3], I will show how twisted, low symmetry, graphene/chalcogenide structures display a complex spin texture and charge-to-spin conversion effects that could allow us to move beyond spintronic devices with standard metallic layers [4].

References

[1] S. Manipatruni et al., *Nature* **565** (2019) 35.
[2] V.T. Pham et al., *Nature Electron.* **3** (2020) 309; D.C Vaz et al., *Nature Commun.* **15** (2024) 1902 (2024).
[3] F. Calavalle et al., *Nature Mater.* **21** (2022) 526; M. Suarez-Rodriguez et al., *Phys. Rev. Lett.* **132** (2024) 046303; M. Suarez-Rodriguez et al., *Adv. Mater.* (2024) 202400729; M. Suarez-Rodriguez et al., *Nature Mater.* (2025).
[4] W. Yan et al., *Nature Commun.* **7** (2016) 13372; C.K. Safeer et al., *Nano Lett.* **19** (2019) 1074; C.K. Safeer et al., *Nano Lett.* **19** (2019) 8758; C.K. Safeer et al., *Nano Lett.* **20** (2020) 4573; F. Herling et al., *APL Mater.* **8** (2020) 071103; J. Ingla-Aynés et al., *Phys. Rev. Lett* **127** (2021) 047202; C.K. Safeer et al., *2D Mater.* **9** (2022) 015024; J. Ingla-Aynés et al., *2D Mater.* **9** (2022) 045001; N. Ontoso et al., *Phys. Rev. Appl.* **19** (2023) 014053; H. Yang et al., *Nano Lett.* **23** (2023) 4406; H. Yang et al., *Nature Mater.* **23** (2024) 1502; Z. Chi et al, *Adv. Mater.* **36** (2024) 2310768, H. Yang et al., Nature Elec. **8** (2025) 15

Tuning the Properties of Two-Dimensional Magnetic Heterostructures with Molecular and Inorganic van der Waals Crystals

Carla Boix Constant[1]

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Two-dimensional (2D) materials offer a rich phenomenology – both from the point of view of pure physical characterization and applications – that is still being explored [1]. In this context, van der Waals (vdW) heterostructures – formed by assembling layers of different materials used as building blocks – provide a new playground with the possibility of engineering new materials with emergent functionalities that are not accessible in another way. In this talk, two main approaches in the design of novel vdW heterostructures using thin layers of magnetic materials will be discussed. On the one hand, new chemically designed molecular building blocks are combined with 2D materials to afford hybrid devices. We demonstrate the potential of spin transition molecular systems (particularly, of spin-crossover materials) to control the properties of 2D materials, allowing us to change their electrical and optoelectronic properties via the local strain generated due to the change in volume of the spin transition, adding therefore a new molecular building block into the family of layered materials with potential use in the field of straintronics [2] . On the other hand, the focus will be in the A-type antiferromagnet CrSBr, a semiconducting metamagnet with field-induced magnetic phenomena. Each layer orders ferromagnetically – spins oriented along the in-plane easy b axis – with interlayer antiferromagnetic interactions. We have isolated and measured the magneto-transport properties of the pristine monolayer/bilayer cases, which mimics a spin-valve-like behaviour [3]. In addition, we are able to tailor the spin reversal by fabricating artificial orthogonally twisted bilayers [4]. Our results show a new generation of van der Waals heterostructures with programmable properties that depend on the magnetic anisotropy, the antiferromagnetic interlayer interactions and the applied magnetic field, which can be controlled by the selection of the stacked magnetic layers and the twist angles between them, being of interest towards the miniaturization of spintronic devices [5]. By implementing state-of-the-art nanofabrication techniques on 2D-based heterostructures, the resulting configurations enable us to explore new synergistic combinations of materials by integrating in the same heterostructure both inorganic and molecular layered systems, thus broadening the horizon of magnetic van dew Waals heterostructures of direct application in spintronics (as magnetic sensors and memories) and magnonics [6].

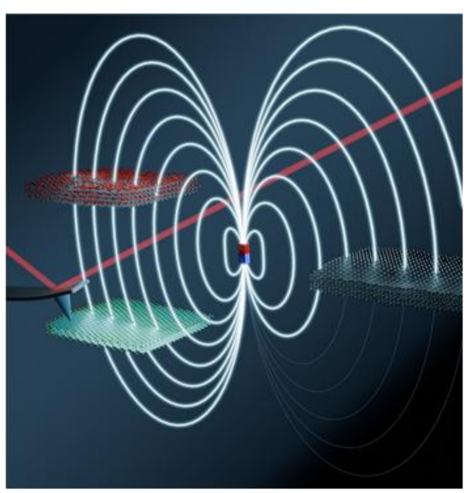
[1] Nat. Mater. 19, 1276-1289 (2020). [2] Adv. Mater. 34, 2110027 (2022). [3] Adv. Mater. 34, 2204940 (2022). [4] Nat. Mater. 23, 212-218 (2024). [5] Adv. Mater. 37, 2415774 (2025). [6] Nano-Micro Lett. 16, 119 (2024).

Magnetic Field Screening by 2D Materials

Pablo Ares[1]

[1] *Departamento de Física de la Materia Condensada, Condensed Matter Physics Center (IFIMAC), and Instituto Nicolás Cabrera (INC), Universidad Autónoma de Madrid, Madrid 28049, Spain*

Two-dimensional (2D) materials exhibit a wide range of electronic, mechanical, and optical properties, making them highly attractive for integration into nanoscale devices. Understanding their fundamental behavior is essential for unlocking their full potential in emerging technologies such as spintronics and high-density data storage. Among the many open questions, the ability of 2D materials to interact with or screen magnetic fields remains largely unexplored. In this talk, I will present our recent results on the interaction between 2D materials and magnetic fields generated by underlying magnetic nanostructures. Using Magnetic Force Microscopy (MFM), we systematically investigated graphene, graphene oxide (GO), and MoS_2. We find that graphene exhibits a weak but measurable magnetic field screening effect, approximately 0.5% per layer. In contrast, both GO and MoS_2 display negligible interaction with the magnetic fields [1].These findings suggest that graphene could be employed for controlled modulation of magnetic fields at the nanoscale, while GO and MoS_2 may serve as protective layers with minimal influence on magnetic functionalities. This opens up opportunities for tailoring 2D material integration in devices where precise magnetic control is essential, such as in spintronic architectures and advanced data storage technologies.



References

[1] D. A. Aldave et al., Magnetic Field Screening of 2D Materials Revealed by Magnetic Force Microscopy. Adv. Electron. Mater. 11, 2400607 (2025).

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Scalable High-Throughput Mechanical Exfoliation for Cost-Effective Production of van der Waals Nanosheets

Andres Castellanos-Gomez[1]

[1] *2D Foundry group. Instituto de Ciencia de Materiales de Madrid (ICMM-CSIC). Madrid, Madrid, Spain.*

Efforts in nanoscience have long sought scalable methods for producing van der Waals materials, following the landmark discovery of graphene via mechanical exfoliation. While this technique offers superior material quality, its scalability is limited by challenges in controlling thickness and lateral size. In this talk, we will introduce a novel approach utilizing a roll-to-roll setup and an automated, massive parallel exfoliation process to address these limitations. Our method yields adhesive tapes densely populated with nanosheets of van der Waals materials over large areas, achieving a notable balance between large lateral size, scalability, and cost-efficiency. Notably, our technique avoids harsh treatments and is compatible with air-sensitive materials. Through successful fabrication of field-effect transistors and flexible photodetectors in large batches, we demonstrate the practicality and versatility of our approach. By providing a low-cost, scalable pathway for producing large-area films, our method promises significant advancements in the fabrication of high-performance nanoscale devices.

Understanding Strong Correlations in Twisted Bilayer Graphene

María José Calderón[1]

[1] *Quantum Materials for Quantum Technologies. Instituto de Ciencia de Materiales de Madrid ICMM-CSIC.*

Twisted Bilayer Graphene (TBG), when tuned to a "magic angle," hosts nearly flat electronic bands that dramatically enhance electron-electron interactions. This makes TBG a rich platform for exploring correlated electronic phenomena, with direct implications for future device applications. One of the most robust and intriguing effects is the emergence of *cascades*: sharp, doping-dependent changes in the electronic spectrum and compressibility near integer band fillings, which remain stable up to tens of Kelvin. These cascades are also accompanied by resistivity anomalies that challenge conventional band-based interpretations.

We have recently shown [1,2] that these phenomena can be explained as intrinsic consequences of strong electronic correlations — without requiring symmetry breaking, which occurs only at very low temperatures. Dynamical mean-field calculations reveal that the formation of heavy quasiparticles and local moments drives the cascades and their associated transport signatures. I will also discuss experimental avenues to probe these correlation effects, including optical conductivity and new momentum-resolved tools like the Quantum Twisting Microscope, as well as the unconventional temperature dependence of the electronic properties.

References

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Novel collective electronic phenomena in engineered 2D quantum materials

Miguel Ugeda[1]

[1] *Donostia International Physics Center (DIPC). San Sebastian, Spain*

In this seminar, I will present an overview of the key current research directions of our group at the DIPC/CFM. Our work focuses on the nanoscale exploration of novel collective electronic phenomena in 2D quantum materials. I will highlight our major findings, with a particular focus on the study of 2D unconventional superconductivity. Additionally, I will describe our advanced capabilities in both bottom-up and top-down synthesis of 2D materials and their integration into complex heterostructures, including moiré quantum materials.

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Layered quirks of van der Waals materials

Mariela Menghini[1]

[1] *IMDEA Nanociencia, Madrid, Spain*

van der Waals (vdW) materials are in the spotlight of different research fields as they offer excellent ground for exploring novel physical and chemical phenomena close to the 2D limit. Besides, their layered structure and the possibility to mix-and-match different type of materials have allowed the design of novel and multifunctional devices with possible applications in electronics, spintronics, non-conventional computing, sensing and energy storage.

In the Transport of Quantum Materials group at IMDEA Nanociencia, we design and fabricate devices based on different types of vdW materials focusing mainly in their electrical properties. In this talk, I will present our work on the Quantum Hall Effect in graphene and its applications in metrology. Besides, I will also highlight and discuss the optical and structural properties of a strongly correlated vdW oxide and the memristive behavior of layered materials.

2D materials for nanophotonics: from superlattices to metadevices

Alberto Curto[1]

[1] *Ghent University – imec. Department of Information Technology. Belgium.*

Monolayer materials hold potential for miniaturized and high-performance nanoscale optoelectronic devices thanks to their outstanding optical properties. In this presentation, I will demonstrate high optical absorption in WS2 monolayers and their superlattices and briefly explore some of the opportunities offered by valleytronics using this material. Second, we will introduce a photodetector metadevice exploiting graphene in an integrated photonics platform with ultrahigh responsivity. We will conclude with a discussion of some of the challenges and opportunities for the scalability of 2D materials from the lab to industry, including our results on metrology techniques.

Towards a silicon nitride fully integrated photonic circuit: The role of 2D materials

Víctor J. Gómez[1]

[1] *Nanophotonics Technology Center. Universitat Politècnica de Valéncia. Valencia. Spain*

Very low propagation losses, CMOS compatibility, large fabrication tolerance... There are many reasons why silicon nitride (SiN) is the ideal platform for photonic integrated circuits (PICs) in applications such as LiDAR, gas sensing, bio-spectroscopy, communication, quantum communications, computing and sensing. The integration of active devices on SiN photonic integrated circuits is the main challenge to the realization of dense photonic chips. We aim to develop highly integrated photonic circuits by combining III-V semiconductors and 2D materials on a SiN photonics platform. III-V semiconductors enable active components such as integrated lasers and optomechanical cavities, while 2D materials offer novel functionalities for mode filtering, photodetection, and optical isolation. In this talk, I will first present the overall strategy behind our integration approach. Then, I will focus on the design, simulation, fabrication and characterization of 1550 nm TE_0 mode filters based on graphene nanoribbons integrated into silicon nitride waveguides. These results demonstrate the potential of 2D materials to expand the capabilities of SiN photonics.

Actividades en grafeno, materiales 2D y materiales con funcionalidades inteligentes para el desarrollo tecnológico (ARCANGEL)

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