IBERLEEM

Madrid 2025

Place:
Salón de Actos
Instituto de Química Física Blas Cabrera
c/Serrano, 119
Madrid 28006

Dates: 15-17 October 2025

Comité Organizador

Adrian Quesada
Arantzazu Mascaraque
Clara Gutiérrez-Cuesta
José Emilio Prieto
Juan de la Figuera
Michael Foerster
Miguel Angel Niño
Victor Rojo

Organization details

A laptop computer with Windows will be available for the presenters. Personal computers can be used, provided they have HDMI output.

Talks at the Salón de Actos of the Instituto de Química Física. Posters at the main hall.

Tutorials and Status talks

30 minutes total (25 min talk + 5 min discussion)

Contributed Talks

25 minutes total (20 min talk + 5 min discussion)

Posters

A0 Size.

Thursday Lunch at the CSIC Mensa.

IBERLEEM PROGRAM

Short Scientific Program

Wednesday 15th, October

14:45 Opening Ceremony
15:00-16:30 Status and perspectives
16:30-18:00 tutorials

Thursday 16th, October

9:15 am-10:55 am Session I Magnetism: oxides
10:55 am-11:25 Coffee Break
11:25 am-1:05 pm Session II Electronic Structure
1:05 pm-3:00 pm Lunch Break
3:00 pm- 4:40 pm Session III Magnetism: Interfacial effects in heterostructures
4:40 pm-6:00 pm Posters
8:00 pm-10 pm Conference dinner

Friday 17th, October

10:00 am- 11:15 am Session IV Thin films and nanostructures growth
11:15 am-11:45 am Coffee Break
11:45 am-12:45 am Session IV Continuation
12:45 pm Closing remarks and visit to the Madrid LEEM

Complete Scientific Program

Wednesday 15th, October

Chairperson: Adrian Quesada
14:45-15:00 Opening Ceremony
15:00-15:30 Juan de la Figuera, “State and Future of the Madrid LEEM“
15:30-16:00 Michael Foerster , “State and Future of the Alba PEEM”
16:00-16:30 Manuel Izquierdo, “Perspectives for Femtosecond Time-Resolved PEEM Experiments at Free Electron Laser Facilities”
16:30-17:15 Miguel Angel Niño, LEEM Tutorial
17:15-18:00 Natalia Kwiatek-Maroszek, PEEM Tutorial
18:00 End of day one

Thursday 16th, October

I Magnetism: oxides

Chairperson: Saúl Vélez
9:15-9:40 Anna Mandziak “Distribution of antiferromagnetic domains in Fe-doped NiO thin films on Ru(0001)”

9:40-10:05 Arantxa Fraile Rodríguez “Size-dependent antiferromagnetism and direct observation of Néel axes in NiO nanoparticles”
10:05-10:30 Clara Gutiérrez Cuesta “Structural and magnetic properties of the Fe_3O_4 (110) surface below the Verwey transition”
10:30-10:55 Álvaro Blázquez “Microspectroscopy study of the magnetic textures in a permalloy/hematite bilayer across the Morin transition”

10:55-11:25 Coffee break

II Electronic structure

Chairperson: Manuel Izquierdo
11:25-11:50 Mariela Menghini “Resistive switching in a Mott insulator initiated by topological defects”
11:50-12:15 Raquel Sánchez “Correlating LEEM and NAP-XPS in ceria-based model catalysts for CO_2 activation”
12:15-12:40 Trung-Phuc “Layered multiple scattering approach to X-ray photoelectron diffraction: theory and application”
12:40-13:05 Nekane Aramburu “Electronic structure of Gd/W(110): from one atomic layer to bulk”

13:05-15:00 Lunch (at the CSIC mensa)

III Magnetism: Interfacial effects in heterostructures

Chairperson: Arantxa Fraile Rodríguez
15:00-15:25 Saúl Vélez “X-ray detection of current-induced orbital angular momentum accumulation at Cu/oxide interfaces”
15:25-15:50 Alba Guio “Chiral Magnetic Configurations in Graphene-Based Heterostructures with Tuned Dzyaloshinskii–Moriya Interaction”
15:50-16:15 Alejandro Álvarez-Chico “Synthetic ferrimagnets based on Fe/Gd ultrathin films: the role of interfaces in ultrafast magnetization dynamics”
16:15-16:40 Adrián Quesada “A SPLEEM study of the non-monotonic behavior of magnetic anisotropy near the spin reorientation transition of Fe ultrathin films”

16:40-18:00 Poster Session

P1-Bejarano, Iván “Fundamental understanding of the magnetism of $SmCo_5$ nanostructures”
P2-Fornal, Kalina, “High-temperature oxygen-assisted MBE growth and characterization of MnO on Ru(0001)”
P3-Kwiatek-Maroszek,Natalia “ Implementation of the virtual electrode method in a synchrotron LEEM-PEEM station for in-situ studies of Li and Na anode formation in solid state batteries”
P4-Orero, Guzmán “Magnetic Optical Kerr Effect Microscopy for studying magnetic textures”
P5-Perna, Paolo “Enhanced spin-orbit torque efficiency via graphite thickness in Co/Pt multilayers”
P6-Santos, Benito “Tailoring the spin reorientation transition of Co films by Pd monolayer capping”

20:00-22:00 Conference Dinner

Friday 17th, October

IV Thin films and nanostructures growth

Chairpersons: Anna Mandziak, Mariela Menghini
10:00-10:25 José Emilio Prieto “Growth and characterization of nanostructures of Ba, Fe and Mn tungstates by single-metal MBE on W(110)”

10:25-10:50 Pablo Hernández “Nanoscale imaging of solid-state battery anodes grown by VE-LEEM”
10:50-11:15 Bjon Riedel “Heteroepitaxial Growth of Sm_2O_3 Nanoislands on Cu(111)”

11:15-11:45 Coffee break

11:45-12:10 Carmen del Pino “*In-situ* solid-state dewetting of Ag nanoparticles by LEEM”
12:10-12:45 Adrián Sáez “Synthesis and characterization of a two-dimensional ionic hydride”

12:45-13:30 Final remarks and visit to Madrid LEEM

Contributions

Contribution List: Talks

1- Álvarez-Chico, Alejandro “Synthetic ferrimagnets based on Fe/Gd ultrathin films: the role of interfaces in ultrafast magnetization dynamics”
2- Aramburu, Nekane “Electronic structure of Gd/W(110): from one atomic layer to bulk”
3- Blázquez, Álvaro “Microspectroscopy study of the magnetic textures in a permalloy/hematite bilayer across the Morin transition”
4- Fraile Rodríguez, Arantxa “Size-dependent antiferromagnetism and direct observation of Néel axes in NiO nanoparticles”
5- Guio, Alba “Chiral Magnetic Configurations in Graphene-Based Heterostructures with Tuned Dzyaloshinskii–Moriya Interaction”
6- Gutiérrez Cuesta, Clara “Structural and magnetic properties of the Fe_3O_4 (110) surface below the Verwey transition”
7- Hernández, Pablo “Nanoscale imaging of solid-state battery anodes grown by VE-LEEM”
8- Izquierdo, Manuel “Perspectives for Femtosecond Time-Resolved PEEM Experiments at Free Electron Laser Facilities”
9- Mandziak, Anna “Distribution of antiferromagnetic domains in Fe-doped NiO thin films on Ru(0001)”
10- Menghini, Mariela “Resistive switching in a Mott insulator initiated by topological defects”
11- del Pino, Carmen “*In-situ* solid-state dewetting of Ag nanoparticles by LEEM”
12- Prieto de Castro, José Emilio “Growth and characterization of nanostructures of Ba, Fe and Mn tungstates by single-metal MBE on W(110)”
13- Quesada, Adrián “A SPLEEM study of the non-monotonic behavior of magnetic anisotropy near the spin reorientation transition of Fe ultrathin films”
14- Riedel, Bjon “Heteroepitaxial Growth of Sm_2O_3 Nanoislands on Cu(111)”
15- Sáez, Adrián “Synthesis and characterization of a two-dimensional ionic hydride”
16- Sánchez, Raquel “Correlating LEEM and NAP-XPS in ceria-based model catalysts for CO_2 activation”
17- Trung-Phuc “Layered multiple scattering approach to X-ray photoelectron diffraction: theory and application”
18- Vélez, Saúl “X-ray detection of current-induced orbital angular momentum accumulation at Cu/oxide interfaces”

Contribution List: Posters

1- Bejarano, Iván “Fundamental understanding of the magnetism of $SmCo_5$ nanostructures”
2- Fornal, Kalina, “High-temperature oxygen-assisted MBE growth and characterization

of MnO on Ru(0001)”
2- Kwiatek-Maroszek,Natalia “ Implementation of the virtual electrode method in a synchrotron LEEM-PEEM station for in-situ studies of Li and Na anode formation in solid state batteries”
3- Orero, Guzmán “Magnetic Optical Kerr Effect Microscopy for studying magnetic textures”
4- Perna, Paolo “Enhanced spin-orbit torque efficiency via graphite thickness in Co/Pt multilayers”
5- Santos, Benito “Tailoring the spin reorientation transition of Co films by Pd monolayer capping”

Cena de la conferencia (16th October, 20:00

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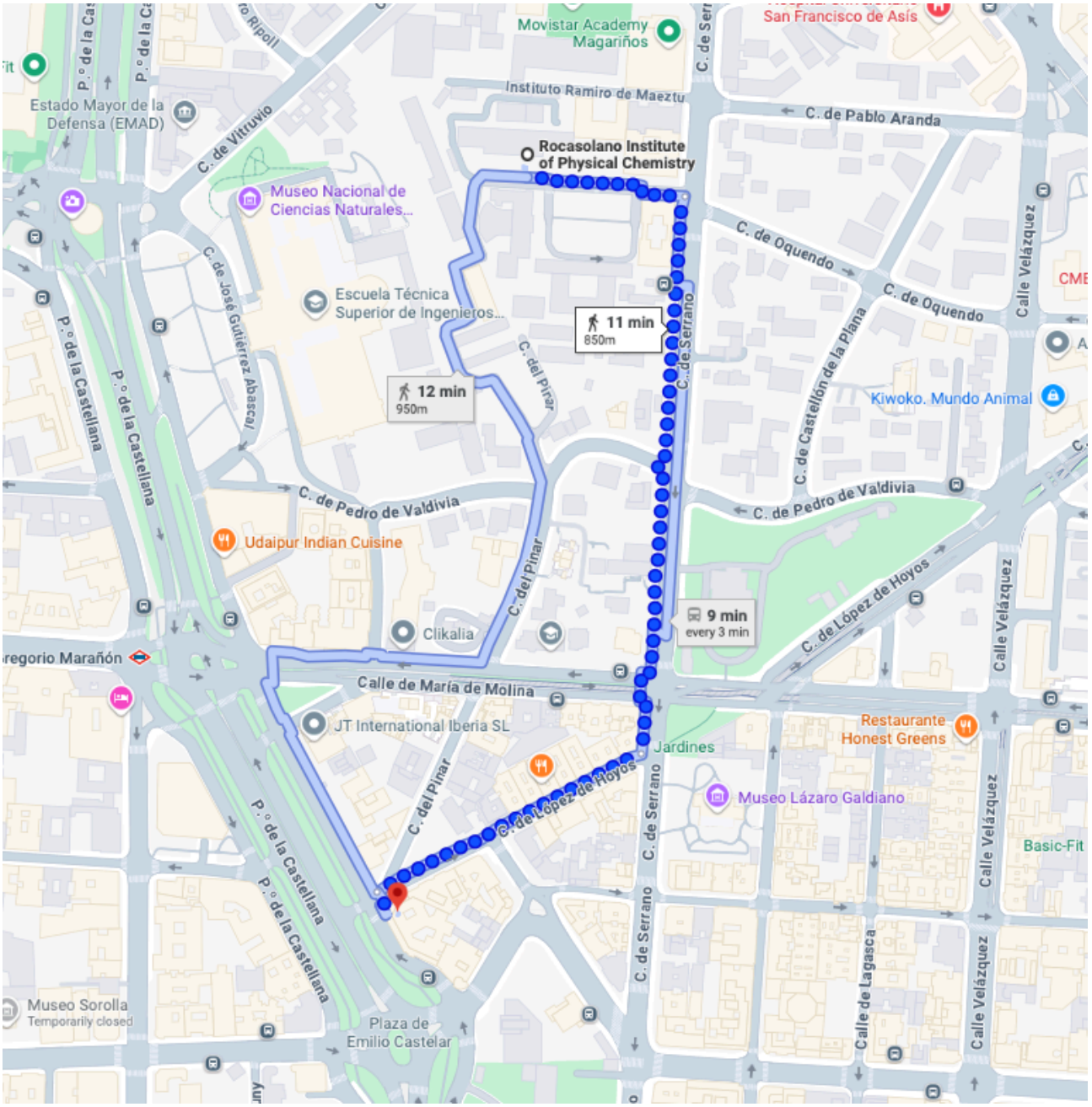

Synthetic ferrimagnets based on Fe/Gd ultrathin films: the role of interfaces in ultrafast magnetization dynamics

Alejandro Álvarez-Chico [1 2], Álvaro González-García [1], Jairo Obando-Guevara [1], Iulia Cojocariu [3], Matteo Jugovac [3], Tevfik Onur Menteş [3], Andrea Locatelli [3], Arantzazu Mascaraque Susunaga [1], Miguel Ángel González Barrio [1], Unai Atxitia[2], Silvia Gallego Queipo[2]

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The rapid advancement of neural networks and artificial intelligence is outpacing the capabilities of traditional memory storage devices. This has created a demand for a new class of low-power, faster magnetic memories. Among the promising candidates are novel ferrimagnetic devices, which offer low magnetization switching energy and ultrafast magnetization dynamics [1,2]. To date, ferrimagnetic FeGd alloys constitute one of the best systems to achieve laser induced ultrafast magnetization switching [3]. Here we explore their ordered counterpart, i.e., synthetic ferrimagnets composed of ferromagnetic Fe and Gd ultrathin layers coupled antiferromagnetically. In this type of ferrimagnets, the magnetizations of the two sublattices respond differently to temperature, leading to a compensation temperature (Tcomp) where the opposing magnetizations cancel out. Near this point, the system exhibits distinctive and potentially useful magnetic dynamics. The introduction of an ordered thin film geometry emerges as an interesting route to gain control over Tcomp. Here we explore their ordered counterpart, i.e., synthetic ferrimagnets composed of ferromagnetic Fe and Gd ultrathin layers coupled antiferromagnetically.

Our study focuses on epitaxial Fe/Gd films grown on a W(110) substrate. To gain deeper insight into the relationship between structure and magnetism, we investigated two complementary systems: ultrathin Fe/Gd bilayers and $Fe_{1-x}Gd_x$ alloy films. Using the SPELEEM end-station at the Nanospectroscopy beamline of Elettra, we performed structure-sensitive LEEM and LEED measurements to thoroughly characterize the layer-by-layer growth of these films. We also acquired XMCD images across a range of temperatures to correlate structural and surface changes with magnetic behaviour. Interpretation of these measurements was supported by multiscale theoretical models, from density functional theory that thoroughly characterizes the structural and electronic properties and their correlation to atomistic simulations that provide information about the temperature dependent magnetic properties as well as ultrafast, laser-induced magnetization switching. Further, the structural properties were refined based on a combined experimental and theoretical analysis of LEED IV curves.

Based on these results, we propose a scenario to rationalize the influence of different types of structural order on the ferrimagnetic exchange, in particular elucidating the role of the interface in the dynamic magnetic response. By analyzing the magnetic coupling between Fe and Gd, quantified through their element-specific spin and orbital moments, and examining the onset of domain wall dynamics in Fe/Gd and Gd/Fe ultrathin bilayers, we can assess how structure influences the magnetic properties of a model synthetic two-component ferrimagnet.

References

[1] Kim, S.K., Beach, G.S.D., Lee, KJ. *et al.* Ferrimagnetic spintronics. *Nat. Mater.* **21**, 24–34 (2022).
[2] V. Baltz, Rev. of Modern Phys. 90, 015005 (2018).
[3] Radu, I., Vahaplar, K., Stamm, C. *et al.* Transient ferromagnetic-like state mediating ultrafast reversal of antiferromagnetically coupled spins. *Nature* **472**, 205–208 (2011).

Electronic structure of Gd/W(110): from one atomic layer to bulk

N. Aramburu-Merino,[1] Á. González-García,[1] A. Álvarez-Chico,[1, 2] S. Gallego,[2] U. Atxitia,[2] I. Cojocariu,[3] M. Jugovac,[3] T. O. Mentes,[3] A. Locatelli,[3] A. Mascaraque,[1] and M. Á. González-Barrio[1]

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Gadolinium (Gd), a rare-earth metal with a half-filled 4f shell and a ferromagnetic ground state near room temperature (Curie temperature: 293 K), has long served as a model system for studying the interplay between localized and itinerant electrons in solids. Its 4f electrons are highly localized and contribute predominantly to its magnetic moment, while the more delocalized 5d and 6s electrons are responsible for its conduction properties [1]. In this work, we investigate the growth, structural properties, and electronic structure of ultrathin Gd films epitaxially grown on a W(110) substrate, with particular focus on the evolution from monolayer to bulk-like behavior using a spectroscopic photoemission and low-energy electron microscope (SPELEEM).

LEED measurements reveal that 3 ML Gd films adopt the in-plane lattice constant of bulk Gd, indicating rapid structural relaxation and high crystalline order. Photoemission spectroscopy shows the absence of distinct Gd-derived states at low thicknesses and that the Fermi surface retains the twofold symmetry of the substrate. Constant energy maps (Fig. 1) for clean W(110) and for 1, 3, and 6 ML Gd illustrate the evolution from substrate-derived features and replicas of the W(110) bands to the emergence of Gd-derived parabolic bands at 3 ML. By 6 ML, the Fermi surface exhibits the sixfold symmetry characteristic of bulk Gd. These results are further supported by DFT calculations, which provide complementary insight into the surface and bulk contributions, the orbital character, and the parity of the states. This study represents the first comprehensive PES and LEED investigation of Gd/W(110) across this thickness range, filling a significant gap in the understanding of dimensional crossover in rare-earth systems.

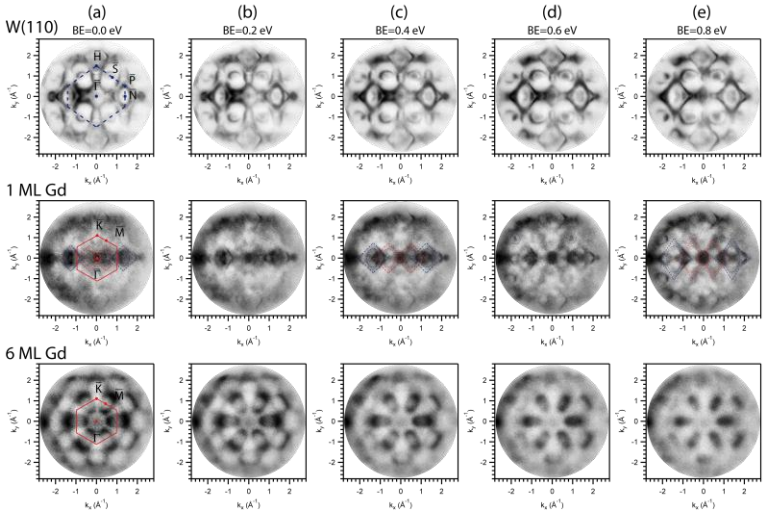

Figure 1: Constant energy maps for clean W(110) (upper row), 1 ML Gd (middle row) and 6 ML Gd (lower row).

References

[1] J. Jensen and A. R. Mackintosh, Rare Earth Magnetism: Structures and Excitations (Oxford University Press, Oxford, 1991).

Microspectroscopic study of the magnetic textures in a permalloy/hematite bilayer across the Morin transition

Álvaro Blázquez[1], Tianxing Wang[2], Juan Andrés Hofer[2], Ali C. Basaran[2,3], Deepak Dagur[4], Miguel Ángel Niño[4], Michael Foerster[4], Mariela Menghini[1], Oscar Rodríguez de la Fuente[1,2]

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[2] Department of Physics, Center for Advanced Nanoscience, University of California, San Diego, CA 92093, USA
[3] General Atomics, San Diego, CA 92186, USA
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Interfaces between antiferromagnetic (AFM) and ferromagnetic (FM) materials have long been studied, as they exhibit complex interactions which are the source of new phenomena. In the proximity of these interfaces, mutual interactions may determine the nature of the magnetic textures, which is relevant the in the context of AFM spintronics. Hematite is an AFM material that undergoes a temperature-controlled spin-flop transition: the Morin transition. This transition gives an extra degree of freedom, making hematite an intriguing component to study the exchange coupling when interfaced with a FM material. We have observed, in very recent experiments [1], changes in the magnetic properties of soft magnetic permalloy thin films grown on hematite: they show a remarkable change in coercivity across the Morin transition. We attribute this effect to the magnetic domain mixture of hematite across the Morin transition. Here we report the preliminary results of a study in the CIRCE beamline at Alba. We have carried out an XMCD analysis of permalloy thin films grown on epitaxial hematite, focused on the texture of the FM domains. After applying in-situ magnetic pulses, we have observed that the texture of the FM domains is qualitatively different below and above the Morin transition, occurring at T_M: the grayscale distribution of the dichroic contrast above T_M is more continuous (Figure 1), indicating a larger diversity of the in-plane orientations of the magnetic moments. We propose that this is mainly due to the magnetic interactions at the AFM/FM interphase. Below T_M, the AFM moments point perpendicular to the surface, while above T_M the AFM moments lie along any of the 3 equivalent directions in the (0001) plane. Therefore, there is a larger and more diverse interaction with the FM moments of the Py. These interactions tend to rotate the FM moments to accommodate them into a state with lower energy, considering all different interaction terms. Atomistic micromagnetic simulations help us understand the textures, revealing that the Néel state of the AFM phase may have a strong influence on the FM texture.

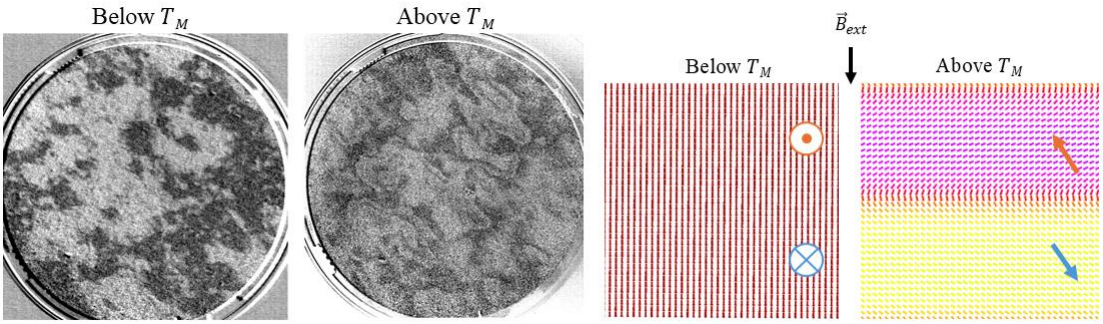

Figure 1: Left, XMCD images of the same area of permalloy on hematite below and above the Morin transition. The dichroic contrast is qualitatively different. Right, simulated images of the average ferromagnetic moment (below and above the Morin transition) after applying an external field. The circles and arrows show the direction of the Néel vectors of the underlying AFM layer (out- and in-plane, respectively).

References

[1] Wang, T.D., Basaran, A.C., El Hage, R., Li J., Navarro H., Torres, F.E., Rodríguez de la Fuente, O, Schuller, I.K. (2024). Coercivity enhancement in hematite/permalloy heterostructures across the Morin transition. Journal of Magnetism and Magnetic Materials, 597, 172024.

Size-dependent antiferromagnetism and direct observation of Néel axes in NiO nanoparticles

J. Ara[1,2], C. Moya[1-3], M. García del Muro[1,2], A. I. Figueroa[1,2], M. X. Aribó[1,2], Ò. Iglesias[1,2], A. Kleibert[4], A. Labarta[1,2], X. Batlle[1,2], A. Fraile Rodríguez[1,2]

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Nickel oxide (NiO) nanoparticles (NP) have drawn significant attention due to their distinctive antiferromagnetic properties and p-type semiconductor behaviour, which are leveraged in electronics, catalysis, and antimicrobial applications [1]. From a fundamental perspective, a comprehensive understanding of the weak ferromagnetism appearing at small sizes remains elusive [2-4]. This work elucidates this phenomenology by studying three samples, with mean particle sizes of 6, 20, and 34 nm, prepared by a two-step synthesis. Structural analysis confirms the high crystalline quality of the particles up to the outermost layers, regardless of their size. Antiferromagnetic properties are size-dependent: 6 nm NP show a weak superimposed superparamagnetic behaviour, while 34 nm NP display antiferromagnetic features closely resembling those of bulk counterparts and 20 nm NP corresponds to an intermediate behaviour. This is attributed to uncompensated spins associated with surface and structural modifications, particularly in smaller particles.

Using synchrotron-based X-ray photoemission electron microscopy (PEEM) combined with X-ray magnetic linear dichroism (XMLD), a quantitative, unambiguous 3D determination of the antiferromagnetic Néel axis was obtained for a subset of individual, single-phase, 34 nm NiO NP [5]. The observed Néel axes are robust against thermal fluctuations at room temperature and are stochastically distributed along the 12 possible easy directions considering the most plausible crystal facets resting on the substrate, as identified through structural characterization [5]. Contrary to seminal theoretical predictions suggesting a multi-sublattice spin arrangement of NiO NP within this size range [2], our findings show no evidence of a breakdown in the two-sublattice model and are entirely consistent with single-domain states.
These findings provide significant insights into antiferromagnetism in three-dimensional nanostructures and open new possibilities for applications requiring precise control over the reading and writing of information based on specific states of the antiferromagnetic Néel axis.

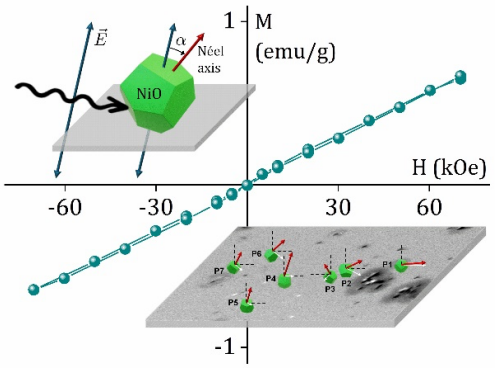

Figure 1: Magnetization curve at room temperature and distribution of Néel axes in a subset of single 34 nm NiO NP.

References

[1] C. Moya, J. Ara, A. Labarta, X. Batlle. Magnetism, 2024, 4(3), 252.
[2] R. H. Kodama, S. A. Makhlouf, A. E. Berkowitz. Phys. Rev. Lett., 1997, 79(7), 1393.
[3] X. Batlle, C. Moya, M. Escoda-Torrella, Ò. Iglesias, A. Fraile Rodríguez, A. Labarta. J. Magn. Magn. Mater., 2022, 543, 168594.
[4] A. I. Figueroa, C. Moya, M. X. Aribó, J. Ara, M. G. del Muro, A. Kleibert, S. Valencia, A. Labarta, X. Batlle, A. Fraile Rodríguez. Low Temp. Phys., 2024, 50(10), 852.
[5] J. Ara, C. Moya, M. García del Muro, A. I. Figueroa, M. X. Aribó, Ò. Iglesias, A. Kleibert, A. Labarta, A. Fraile Rodríguez, and X. Batlle, Nanoscale 2025, 17, 17719.

Enhanced spin-orbit torque efficiency via graphite thickness in Co/Pt multilayers

Alba Guio[1], Adrian Gudin[1], Haripriya Madathil[2], Guzman Orero[2], Fernando Ajejas[1], Saul Velez[2], and Paolo Perna[1]

[1] IMDEA Nanoscience, 28049 Madrid, Spain
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The use of the spin in devices –spintronics – has led to remarkable fundamental discoveries and applications ranging from the giant magnetoresistance, hard-disks read heads or the magnetic random-access memory (MRAM). Until very recently, the most efficient way found to operate magnetic memory devices relied on the use of spin currents generated from the electric flow (spin-charge inter-conversion, SCC) in systems with strong spin-orbit coupling (SOC). When transverse spin currents are absorbed by a magnetic material, they produce spin-orbit torques (SOT), an emerging technology that enables the efficient manipulation of magnetic order parameters in spintronic devices [1]. To date, most memory applications have primarily focused on utilizing torques generated from the bulk of the films, with interfacial effects receiving less attention. The antidamping-like (AD) torque originating in the bulk of heavy metals (HMs) plays a dominant role in switching the polarization of magnetic dots [2]. However, symmetry breaking at interfaces can also be a powerful tool for controlling field-like (FL) torques and switching dynamics.

In this study, we investigate the properties of spin-orbit torques (SOT) in thin metallic structures grown, namely, 0.6nm Co layer sandwiched between Pt and graphite overlayers ranging from 0.5nm to 4nm. Using the second harmonic Hall measurement technique, combined with Kerr microscopy, we precisely determine the amplitude of the SOT vs the graphite thickness and study the microscopic mechanisms of the magnetization switching. We find an increase of the Damping-like torque for thinner graphite layers together with a drastic rise in the Field-like torque, resulting in unexpectedly HFL/HDL ratios much larger than 1. The obtained values are comparable to what found in recent works [3,4] for Al capped Co/Pt systems.
The results indicate that the enhancement of torque efficiencies of a purely interfacial origin [5], and that at low graphite interlayer thickness, the enhancement is due to the generation of extra spin/orbital current by a Rashba-Edelstein effect/Orbital-Rashba-Edelstein effect [6,7,8].
Our findings evidence the role of interfacial effect and pave the way towards the optimization of low consumption spin-orbit electronics.

References

[1] A. Manchon, et al. Phys. Rev. B. 79, 094422 (2009)
[2] Dieny et al. Nature Eelectronics 3, 446–459 (2020)-
[3] S. Krishnia et al. Nano Lett. 2023, 23, 15, 6785–6791
[4] B. Han, et al. J. Appl. Phys. 130, 213902 (2021)
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[6] S. Krishnia et al. APL Mater.12, 051105 (2024)
[7] Anadon et al. Adv. Mater. 2025, 2418541
[8] P. Pradeep et al. In-preparation(2025)

Structural and magnetic properties of the Fe_3O_4 (110) surface below the Verwey transition

Clara Gutiérrez-Cuesta[1], Anna Mandziak[2], Pawel Nita[3], Miguel Ángel Niño[1], Michael Foerster[4], José Emilio Prieto[1], Alexander Stibor[5], Arantzazu Mascaraque[6], and Juan de la Figuera[1].

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[2]Solaris National Synchrotron Radiation Centre.
[3]Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University
[4]Alba Synchrotron Light Facility.
[5]Molecular Foundry, Lawrence Berkeley National Lab.
[6]Departamento de Materiales, Universidad Complutense de Madrid and Unidad Asociada "Surface Science and Magnetism of Low Dimensional Systems", UCM, Unidad Asociada al CSIC/IQF, Spain.

We have studied the Fe_3O_4 (110) surface using various techniques. This is one of the compact faces of magnetite and has been previously studied by Scanning Tunneling Microscopy (STM) and Low-Energy Electron-Diffraction (LEED) [1]. We have imaged the topography of the sample and characterized its structure in reciprocal space by Low-Energy Electron-Microscopy (LEEM) and LEED. The magnetic domains of the surface have been imaged using X-Ray Photoemission Electron Microscopy (PEEM) and Spin-Polarized Low-Energy Electron-Microscopy (SPLEEM). We have also obtained the vector magnetization map of the surface [2]. In addition, we have made square-shaped marks by Focused Ion Beam (FIB) of different sizes to study the dependence of the magnetization on these surface features. Finally, we have cooled down the sample reaching the Verwey transition, a metal-insulator transition that also changes the magnetic domain structure of the magnetite surface. Our work presents a comprehensive analysis of the evolution with temperature of the domain structures and the magnetization vector in the same regions at room temperature and below the Verwey transition temperature.

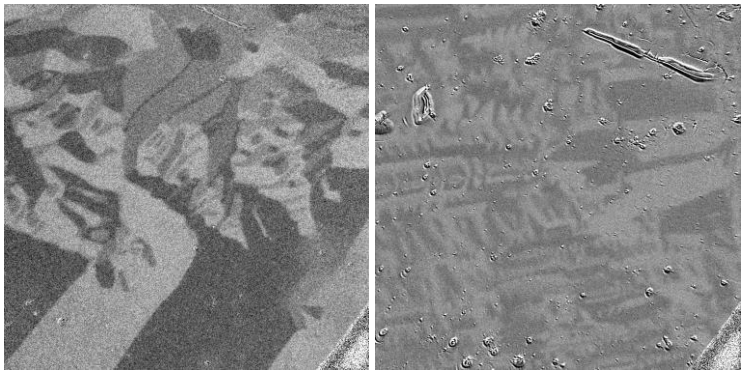

Fig 1. (Left) SPLEEM image, FOV 50µm, measure at room temperature. (Right). Same region and FOV taken at low temperature, after crossing the Verwey transition.

References

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Nanoscale imaging of solid-state battery anodes grown by VE-LEEM

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Anode-free solid-state batteries (SSB), where the anode is formed and striped electrochemically during charge and discharge, are the new candidate for liquid-ion batteries replacement, thanks to higher energy densities and improved safety[1]. The nucleation and early growth of anodes is a key component for battery stability and dendrite formation prevention. In this work, we studied Na and Li anodes on solid-state electrolytes using a Low Energy Electron Microscope (LEEM) to grow anodes via the virtual electrode (VE) method, removing the constraints of a physical current collector and leaving the surface accessible for surface-sensitive probes[2]. We've achieved the first Na and Li anode visualization with simultaneous chemical and morphological nanoscale resolution, thanks to the combination of Photoemission Electron Microscopy (PEEM) techniques such as X-ray absorption and photoelectron spectroscopies (XAS, XPS), and Atomic Force Microscopy (AFM).

The plating of Na and Li has been characterized as function of the areal capacity. With the study of anode roughness, clusters lateral size and grain boundaries height, we uncover the anode kinetic roughening mechanisms. Along with systematic AFM measures of early nucleation stages and Na anodes striping, the growth mechanisms were deemed a combination of grain boundaries energies and strain energies imbalances. With this work, we aim to better understand a key component of SSB and argue that a good adhesion current collector is needed, due to the changing anode roughness.

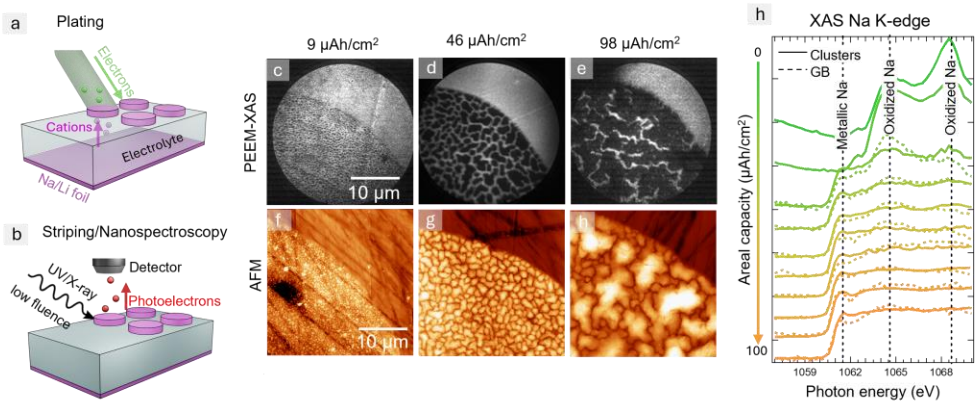

Figure 1: a-b, virtual electrode method. A LEEM electron gun is used as source for anode plating (a), and UV photons are used for anode striping or X-ray beams are used for spatial resolved chemical and morphological resolution (PEEM) (b). c-e, PEEM-XAS measures of Na anodes over NaGdSiO solid ceramic electrolyte, as the areal capacity is increased. f-g, AFM topographies of Na anodes. h, PEEM-XAS Na K-edge, where the chemical composition is studied, distinguishing Na clusters and grain boundaries as areal capacity is increased.

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Perspectives for Femtosecond Time-Resolved PEEM Experiments at Free Electron Laser Facilities

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The continuous miniaturization and increasing complexity of electronic devices place ever greater demands on analytical instruments used for their development and characterization. A comprehensive understanding of such systems requires knowledge of their overall geometry, chemical composition, electronic and atomic structure, and their response to environmental changes and external excitations. These properties ultimately determine the applicability of the devices. Ideally, a single characterization technique would be capable of probing all of them within one experiment.

Photoelectron spectroscopy (PES) comes close to this goal. By exploiting a wide variety of photon sources and photoelectron spectrometers, PES enables the detection and analysis of photoelectrons with respect to multiple observables such as energy, spin, emission angle, and lateral position [1]. The breakthrough that established PES as a key analytical method was its implementation at synchrotron facilities, which provide intrinsic energy and polarization tunability. In the soft X-ray regime, PES has enabled detailed studies of the elemental composition and chemical states of materials, also known as ESCA or XPS. Furthermore, the development of Photoemission Electron Microscopy (PEEM) has made it possible to combine chemical sensitivity with spatial resolution.

The pulsed time structure of synchrotrons extended PES from static to time-resolved experiments, allowing access to the picosecond regime. This time scale is particularly relevant for studying magnetic processes. Further extension into the femtosecond and attosecond domain became possible with laser-based high harmonic generation (HHG) sources, although these are limited to photon energies below ~100 eV. This constraint has been overcome with the advent of Free-Electron Lasers (FELs), which provide femtosecond time resolution together with high photon flux at much higher photon energies.

The European XFEL is the first MHz-repetition-rate Free-Electron Laser operating in the X-ray regime. Its SASE3 undulator system covers a photon energy range from 300 to 3000 eV, enabling femtosecond time-resolved photoelectron spectroscopy on solids at photon energies above 1 keV at the Soft X-ray Port (SXP).

This contribution reports on the implementation, first results, and future prospects of femtosecond time-resolved PEEM experiments at the European XFEL.

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Distribution of antiferromagnetic domains in Fe-doped NiO thin films on Ru(0001)

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Antiferromagnetic (AFM) oxide materials in low-dimensional geometries, either in nonmagnetic or magnetic environments, display a rich variety of magnetic behavior. They are very interesting materials to investigate the fundamental physics of finite-size effects in magnetic systems. Despite the limited applications in current technology, AFM oxides are important reference and model systems for studying the interface coupling phenomena that are ultimately exploited in devices such as spin-valves. Furthermore, they are the current focus for next generation of spintronic devices. Here we demonstrate a route for preparing high quality ultrathin ternary transition metal oxide films on a metallic substrate. Nickel oxides with a small content of iron have been grown on Ru(0001) by oxygen-assisted molecular beam epitaxy at elevated temperatures (1150 K). The nucleation and growth is observed in real time by means of Low Energy Electron Microscopy (LEEM. This enables the optimization of the growth parameters. A comprehensive characterization is performed combining LEEM and LEED for structural characterization and PEEM (PhotoEmission Electron Microscopy) with synchrotron radiation for chemical and magnetic analysis via X-ray Absorption Spectroscopy and X-ray Magnetic Linear Dichroism (XAS-PEEM and XMLD-PEEM, respectively). We have been able to obtain high quality 2D islands with atomically flat surfaces and a low density of defects. The high crystalline and morphological quality result in optimized properties with respect to films grown by other methods, such as magnetic domains whose size are larger by several orders of magnitude.

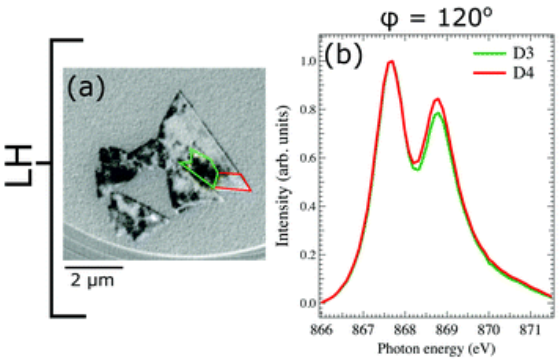

Fig. 1 (a) XMLD PEEM image of Fe-doped NiO triangles and (b) Ni L2 XAS microscpectra

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Resistive switching in a Mott insulator initiated by topological defects

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Avalanche resistive switching is the fundamental process that triggers the sudden change of the electrical properties in solid-state devices under the action of intense electric fields. Despite its relevance for information processing, ultrafast, electronics, neuromorphic devices, resistive memories and brain-inspired computation, the nature of the local stochastic fluctuations that drive the formation of metallic regions within the insulating state has remained hidden.

Here, using operando X-ray nano-imaging, we have captured the origin of resistive switching at low temperatures in a V_2O_3-based device under working conditions. V_2O_3 is a paradigmatic Mott material, which undergoes a first-order metal-to-insulator phase transition together with a lattice transformation that breaks the threefold rotational symmetry of the rhombohedral metallic phase [1]. We reveal a new class of volatile electronic switching triggered by nanoscale topological defects appearing in the shear-strain based order parameter that describes the insulating antiferromagnetic phase [2]. Our results pave the way to the use of strain engineering approaches to manipulate such topological defects and achieve the full dynamical control of the electronic Mott switching. Topology-driven, reversible electronic transitions are relevant across a broad range of quantum materials, comprising transition metal oxides, chalcogenides and kagome metals.

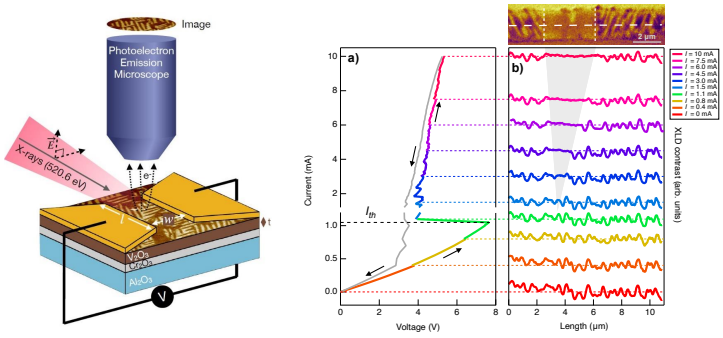

Figure 1: Left: Schematics of the experimental setup used to study the resistance switching in V_2O_3 at low temperatures. Right: Metallic filament formation in the antiferromagnetic insulating phase as a function of applied current.

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In-situ solid-state dewetting of Ag nanoparticles by LEEM

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Solid-state dewetting (SSD) is a thermally activated process through which a continuous thin film on a substrate breaks up into isolated nanostructures, such as nanoparticles (NPs), as a result of surface and interface energy minimization. This phenomenon provides a simple and scalable route for the self-assembly of NPs with relative controlled size, shape, and spatial distribution, making it highly attractive for applications in plasmonics, catalysis, and nanofabrication [1]. Among the various materials used in SSD, silver (Ag) is particularly appealing due to its high surface diffusivity at relatively low temperatures, which facilitates efficient morphological evolution during annealing. Additionally, Ag exhibits a strong plasmonic response in the visible range, making it ideal for applications in plasmon-enhanced spectroscopy, photovoltaics, and biosensing [2].

In this study, we employed low-energy electron microscopy (LEEM) to directly observe the *in-situ* morphological evolution of Ag thin films on NiO platforms during SSD. This real-time imaging technique allowed us to monitor the nucleation, growth, and coarsening of Ag NPs with spatial and temporal resolution. The LEEM observations revealed the dynamic nature of the dewetting process, including the early-stage rupture of the film, the migration of material *via* surface diffusion, and the eventual formation of stable NPs. The resulting Ag NPs exhibit epitaxial relationship with the underlying substrate, aligning preferentially along the (001) crystallographic direction. This alignment leads to the formation of rectangular NPs with well-defined facets, reflecting the anisotropy of surface energy and the influence of the substrate crystalline symmetry. These insights provide a deeper understanding of the kinetic pathways and energetics governing nanoparticle formation by thermal processes in metallic thin films on oxide substrates.

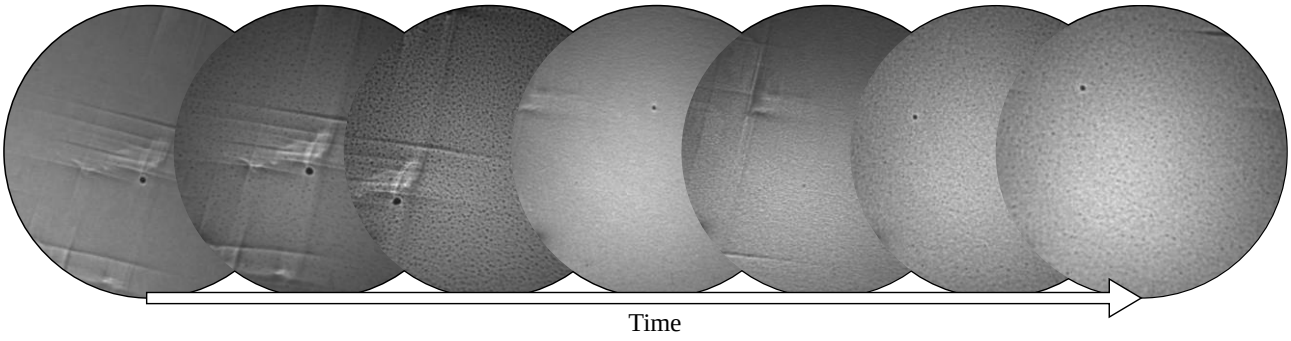

Figure 1: LEEM images of Ag time evolution during solid state dewetting process.

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Growth and characterization of nanostructures of Ba, Fe and Mn tungstates by single-metal MBE on W(110)

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Tungstates are oxides of the form $MeWO_4$, where Me is typically a transition- or an alkaline earth metal. In addition to being the usual commercial ores for the production of tungsten, tungstates are multifunctional materials used, or proposed to be used in fields as diverse as catalysis, photodetection, second harmonic generation, etc., or as multiferroic materials.

Reactive molecular beam epitaxy has long been used to grow highly perfect films and nanostructures of a variety of oxides on refractory or noble metal substrates, such as ruthenium or platinum single crystals or epitaxial films. This requires the substrate to be less reactive towards oxygen than the metal whose oxide is intended to grow. However, exposure of W(110) to oxygen at high temperatures leads to the formation of highly mobile WO_x species that supply the tungsten cations which, together with the metal atoms being deposited, produce nanostructures of tungstate compounds.

We show that this procedure, applied on W(110), allows for the growth of highly perfect epitaxial crystals of $BaWO_4$, with the scheelite structure, and of ferberite ($FeWO_4$) and hübnerite ($MnWO_4$), both with the wolframite structure. We have used low-energy electron microscopy to follow the growth process in real time and we have characterized the grown nanostructures by a combination of *in situ* selected-area low-energy electron diffraction, x-ray absorption spectroscopy and x-ray photoemission spectroscopy, as well as *ex situ* by Raman spectroscopy and atomic force microscopy. We find that highly perfect triangular, micrometric wide islands of $BaWO_4$ are formed, while in the case of the transition-metal tungstates $FeWO_4$ and $MnWO_4$, nanowires of widths of tens of nanometers are produced with lengths in the millimeter range.

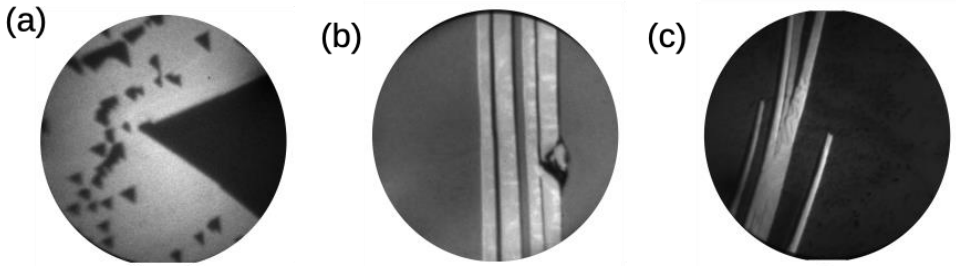

Figure: X-ray absorption images at (a) the M_5 edge of Ba, the L_3 edges of (b) Fe and (c) Mn of a $BaWO_4$ island and nanowires of $FeWO_4$ and $MnWO_4$, respectively. The fields of view are 15 μm, 10 μm and 15 μm.

A SPLEEM study of the non-monotonic behavior of magnetic anisotropy near the spin reorientation transition of Fe ultrathin films

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The micromagnetic structure of thin magnetic films is determined by a delicate equilibrium between the different contributions to the magnetic free energy. In the ultrathin limit, surface and interface effects often dictate the magnetic properties; however, as thickness increases, magnetocrystalline and magnetostatic terms usually become dominating. At thickness near the transition between interface- and bulk-dominated regimes, this equilibrium can be strongly influenced by subtle morphological, thermal or chemical changes, and many studies of these phenomena have contributed to a deep understanding of the critical parameters that govern magnetic transitions in the ultrathin regime.

In particular, Carbon monoxide (CO) adsorption on ultrathin fcc Fe films is known to result in the rotation of magnetization from out-of-plane to in-plane. By imaging in real time the magnetic domain structure of perpendicularly magnetized Fe/(2 ML)Ni/Cu(100) films during exposure to CO, we demonstrate that the effect of adsorption on the magnetic properties occurs in two distinct stages [1]. Initially, when CO bonds preferentially on bridge sites, perpendicular magnetic anisotropy is enhanced. Later, when on-top adsorption dominates, magnetization rotates towards in-plane in agreement with previous studies.

This CO-induced spin reorientation transition (SRT) is not reversible by annealing, as CO desorption would require high temperature cycles which yield permanent structural changes in the metal films. This study demonstrates the existence of a novel non-monotonic behavior of the magnetic anisotropy as a function of adsorbate coverage. Spin-Polarized Low Energy Electron Microscopy (SPLEEM) allows us to reveal the previously elusive influence of CO on ultrathin film magnetism in real time near critical points.

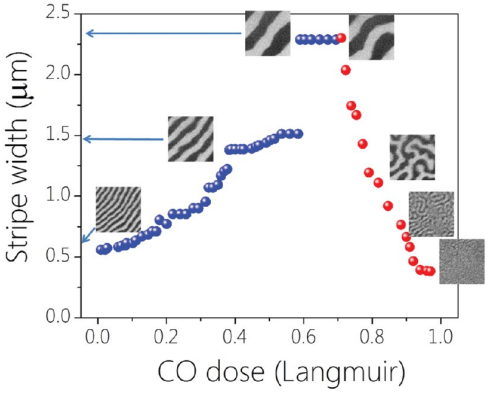

Figure 1: Magnetic domain width as a function of CO dose at 293 K in a perpendicularly magnetized Fe(2.4 ML)Ni(2 ML)/Cu(100) film. SPLEEM images with a field-of-view of 13 mm showing out-of-plane magnetic contrast at each stage of CO adsorption are included.

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Heteroepitaxial Growth of Sm_2O_3 Nanoislands on Cu(111)

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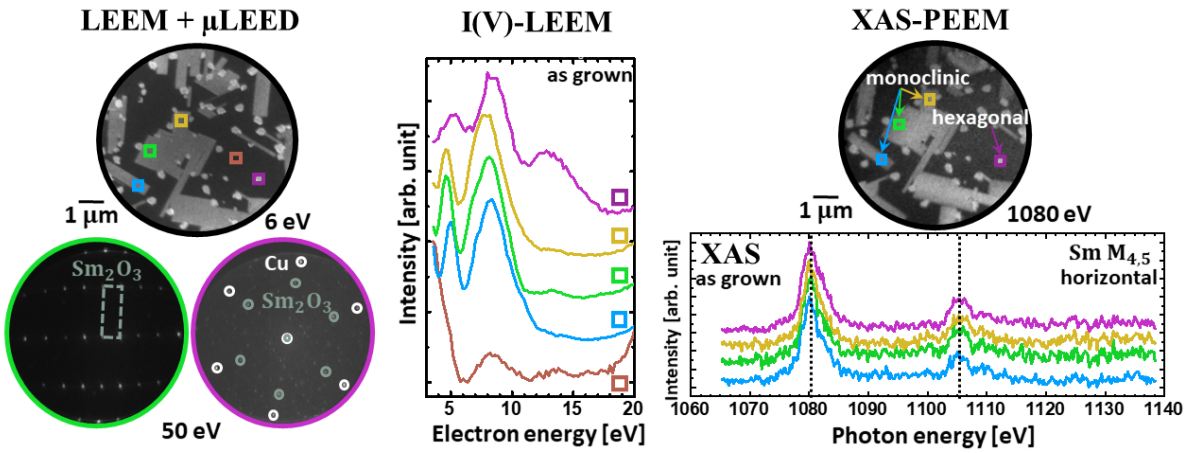
Samarium, which forms sesquioxides (Sm_2O_3), can significantly influence the redox behavior of ceria by promoting the formation and stabilization of reduced Ce^{3+} species [1], which have been postulated to be active sites for CO_2 hydrogenation in the CeO_x/Cu(111) inverse catalytic system [2]. However, to understand analytically the role of Sm in this process, the interaction with the support needs to be studied. Yet, only a few studies have focused on studying samaria on well-defined single-crystal surfaces [3], and the lack of combined structural and spectroscopic studies in model systems results in a gap in understanding the relation between the samaria structure and its chemical behavior.

Here, a multi-method approach has been employed to investigate Cu(111)-supported Sm_2O_3 nanoislands with high structural and chemical sensitivity, using low-energy electron microscopy (LEEM) and micro-spot diffraction (µLEED) and I(V)-LEEM in combination with X-ray absorption spectroscopy photoemission electron microscopy (XAS-PEEM).

Our measurements reveal the phase coexistence of small hexagonal A-Sm_2O_3(0001) islands and rectangular-shaped monoclinic B-Sm_2O_3(100) islands with various rotated rectangular domains after the heteroepitaxial growth of Sm_2O_3 on Cu(111). To investigate the influence of structural differences in the grown Sm_2O_3 nanoislands on their chemical behavior, we examine the redox properties. By exposing the system to reducing conditions (H_2), a phase transition at 500 °C is observed at the edges of the initial monoclinic Sm_2O_3 islands into a mixture of hexagonal and cubic Sm_2O_3, while this transition in the initial hexagonal Sm_2O_3 islands occurs gradually with increasing temperature. These findings indicate a highly dynamic system that can be easily adjusted by modifying the deposition conditions, such as growth temperature and oxygen partial pressure. To explore this tunability in more detail, we employ a range of growth conditions, systematically varying the temperature and oxygen partial pressure. Based on these results, a phase diagram is constructed to map out the structural regimes of Sm_2O_3 nanoislands.



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Synthesis and characterization of a two-dimensional ionic hydride

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Hydrogen is a clean energy vector that is gaining significant attention for a wide range of applications. However, its storage remains a major challenge, limiting its potential as a green fuel. Traditional storage methods, such as high-pressure gas or liquid hydrogen, fail to meet the required energy density and safety standards, highlighting the need for new storage approaches. One promising alternative is the storage of hydrogen in solid-state materials such as hydrides. Ionic hydrides in their 3D form have been proposed, and their hydrogen sorption kinetics have been characterized [1]. However, little is known about the properties of these materials under low-dimensional conditions, particularly at the atomic scale [2]. In this work, we report the synthesis of a novel material, referred to as *hydrene*: a two-dimensional layer of lithium hydride. Hydrogenation of a monolayer of lithium adatoms adsorbed on Au (111) leads to the formation of a honeycomb crystalline structure composed of lithium hydride. We have characterized LiH hydrene using scanning tunnelling microscopy (STM), low-energy electron microscopy/diffraction (LEEM/LEED), angle-resolved reflected-electron spectroscopy (ARRES), X-ray photoelectron spectroscopy (XPS), and density functional theory (DFT). The results confirm the formation of a bidimensional network of lithium and hydrogen atoms arranged in a honeycomb lattice. This novel hydride structure paves the way for a new family of two-dimensional materials composed of ultra-light elements, enabling high gravimetric hydrogen densities [3].

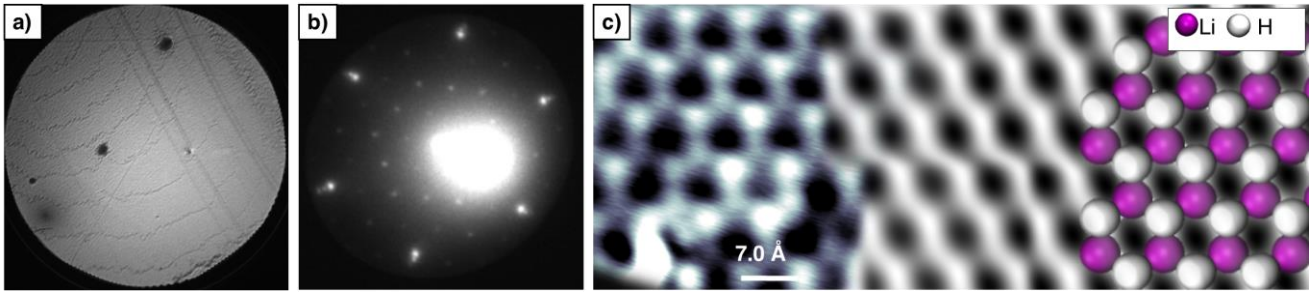

Figure 1. a) LEEM image with the clean terraces of the substrate of reference, the Au (111), with a FOV of 7 µm b) LEED pattern of the structure of the lithium hydride 2D network taken at 35 eV c) Experimental (left) and DFT best-fit simulation (center) STM images (T = 77 K, I = 100 pA, V = -1.5 V) of the lithium hydride 2D network. Both images are merged in the central part. A schematic atomic model has been overlaid at the right part.

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Correlating LEEM and NAP-XPS in ceria-based model catalysts for CO_2 activation.

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Reducible oxides play an important role in catalysis because of their ability to store oxygen and undergo redox changes. Cerium oxide is commonly used in various fields of heterogeneous catalysis due to its ability to change between Ce^{4+} and Ce^{3+} states under reducing and oxidizing conditions [1]. Additionally, Ce^{3+} cations are known to actively participate in methanol synthesis, where they have been suggested to be the active phase [2]. Therefore, catalytic activity can be improved by increasing the Ce^{3+} sites and stabilizing them through alloying with trivalent, catalytically active rare-earth metals that also form cubic sesquioxides (RE_2O_3), such as Sm [3].

Using low-energy and X-ray photoemission electron microscopy (LEEM/XPEEM), we explore how Sm modifies the properties of the well-known CeO_2 islands on Ru(0001) [4,5]. We show that Sm incorporates into the CeO_2 ceria lattice, causing a lattice expansion that, along with charge compensation due to the lower oxidation state of Sm, promotes the formation of intrinsic oxygen vacancies. Additionally, the incorporation of Sm stabilizes the reduced ceria lattice, promoting the phase transition to hexagonal Ce_2O_3. Complementary in situ near-ambient-pressure x-ray photoemission spectroscopy (NAP-XPS) measurements have shown the presence of a component associated with the carboxylate species $CO_2^{\delta-}$, a signature of CO_2 molecule activation, only in samples containing Sm. Therefore, the presence of Sm at the surface enhances the activation of CO_2 compared to undoped CeO_x/Ru(0001). This finding is supported by DFT calculations, which show a negative adsorption energy for the CO_2 molecule on the doped ceria.

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Layered multiple scattering approach to X-ray photoelectron diffraction: theory and application

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Photoelectron diffraction (PED) is a powerful experimental technique for determining the lattice structure near surfaces with sub-ångstrom resolution. The strong energy dependence of Kikuchi patterns [1,2] complicates their interpretation further, necessitating advanced theoretical approaches. In the high-energy regime, PED effects are observed in angle-resolved photoemission spectroscopy (ARPES) measurements alongside other challenges, such as low cross-sections, large photon momentum transfer, and significant phonon scattering). To improve structural analysis and distinguish these PED effects, we present a comprehensive theoretical study [3] of fine diffraction patterns and how they evolve with energy. This study involves simulating core-level emissions from Ge(100) and Si(100) [4]. Using multiple-scattering theory and the fully relativistic one-step photoemission model [5], we simulated faint pattern networks for various core levels across different kinetic energies (106 eV - 4174 eV), avoiding cluster size convergence issues inherent in cluster-based methods. We discuss broadening in patterns via the inelastic scattering treatment. Experimental results from a time-of-flight (ToF) momentum microscope (MM) are reproduced. For the first time, we observe and successfully reproduce circular dichroism in the angular distribution of Si (100) 1s, revealing detailed features and asymmetries of up to 31%. Notably, we successfully replicate both bulk and surface-sensitive diffraction patterns, further validating the robustness of our simulations. The results show remarkable agreement with the experimental data obtained using circularly polarized radiation, demonstrating the potential of this methodology for advancing high-energy PES investigations.

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X-ray detection of current-induced orbital angular momentum accumulation at Cu/oxide interfaces

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Orbital angular momentum currents generated from current flow in light materials and interfaces have emerged as a promising route for operating magneto-electronic devices. However, most experiments to date relied on indirect techniques based on orbit-to-spin conversion to investigate orbital phenomena. Here, we report the direct detection of orbital angular momentum accumulation driven by electric currents at Cu/oxide interfaces via x-ray circular dichroism (XMCD) experiments across the $L_{2,3}$ absorption edges of Cu. Our experiments reveal a dominant orbital origin of the detected signals with an estimated average orbital momentum at the probing depth of the x-ray beam of $(-2.1 \pm 0.2) \times 10^{-12}$ and $(-0.84 \pm 0.36) \times 10^{-12}$ $\mu_B A^{-1} cm^2$ in Cu/CuO_x and Cu/AlO_x, respectively, per Cu atom. By considering the orbital diffusion length and relaxation time inferred from transport experiments in Cu, we estimate the charge-orbit conversion efficiency at the Cu/CuO_x interface to be $q_{OREE} \sim 0.17 \pm 0.03$, which is ~20 times that of the effective charge-to-spin conversion q^*_{REE} in Pt and similar to conversion efficiencies found in 2D electron gases. Our results show that XMCD synchrotron techniques can be used to disentangle spin and orbit contributions and quantify charge-to-orbit conversion efficiencies.

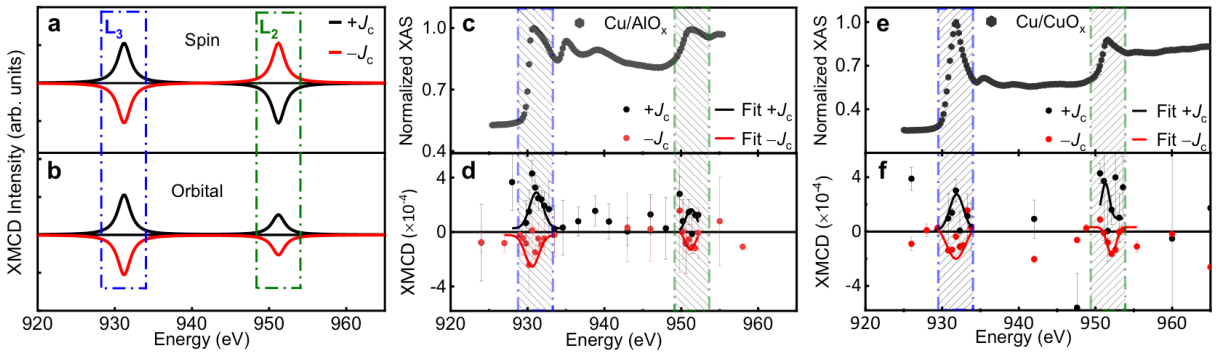

FIG. 1. (a),(b) Expected XMCD signal for the detection of angular momentum of pure spin and orbital origin in a system with positive Rashba coefficient. (c),(e) X-ray absorption in Cu(10nm)/AlO_x and Cu(20nm)/CuO_x. (d),(f) XMCD spectra obtained at different current densities and current polarities in both Cu/AlO_x and Cu/CuO_x [$|J_c| = +4{,}5 \times 10^7$ Acm^{-2} in (d), and $|J_c| = +1{,}6 \times 10^7$ Acm^{-2} in (f)]. The lines are Gaussian fits to the data points at the L_3 and L_2 absorption edges (dashed regions). The error bars in (d), (f) are the uncertainty in the estimates of the XMCD signal from PEEM images (Figs. 1b,c).

Fundamental understanding of the magnetism of $SmCo_5$ nanostructures

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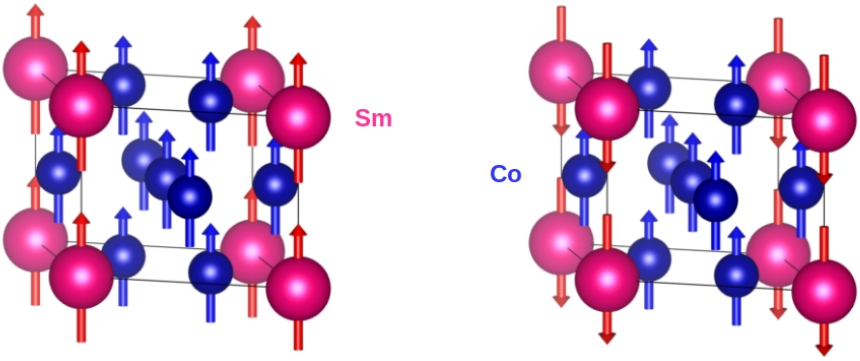
$SmCo_5$ represents one of the most promising rare-earth magnets, with excellent magnetic features and advantages over critical materials based on Nd or Dy. At present, large efforts are being invested to characterize, control and optimize the performance of low dimensional $SmCo_5$ forms, that find application in areas as diverse as green energy production, advanced electronics or magnetic catalysis. LEEM/PEEM techniques are particularly adequate to explore these systems. However, a previous necessary step is the fundamental understanding of the magnetic features of the raw $SmCo_5$ material. In spite of several fundamental studies, even the actual ferro- or antiferro-magnetic coupling between Sm and Co remains under discussion. At the root of the discrepancies is the complex interplay between spin and orbital magnetic moments, the complexity of the electronic interactions involving *f* shells and the subtle dependence on thermal and volume effects. Here we address a first principles study of the electronic and magnetic properties of $SmCo_5$ based on the density functional theory. Our aim is to provide a solid basis for the characterization of this material, while identifying the role of different electronic features on its magnetic response. We explore the effect of both electronic correlations and the spin-orbit coupling on the magnetic exchange, the relation between magnetic orbital moments and magnetic anisotropy, and the influence of the atomic structure on the magnetic configuration.



Madrid, 15-17 October 2025

High-temperature oxygen-assisted MBE growth and characterization of MnO on Ru(0001)

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MnO is one of the classic Mott-Hubbard insulators, with a half-filled Mn 3d shell (Mn^{2+}: $3d^5$, high-spin) with should make it a conductor. Instead, electron correlation makes it an insulator with a gap of 3.9 eV. It has a simple rock-salt structure with Mn in octahedral environment. In this work, we present the growth of MnO on Ru(0001) by high-temperature oxygen-assisted molecular beam epitaxy. We dose Mn from a home-made electron bombardment doser at a rate of one monolayer per 15 minutes, and deposit it on a Ru(0001) single crystal heated to 800ºC under a background pressure of 10^{-6} mbar of oxygen. The growth is monitored by low-energy electron microscopy in our laboratory in Madrid. MnO grows as 3-dimensional islands from the start, and does not wet the Ru substrate. The islands are roughly triangular in shape and present an (111) orientation. Selected-area low-energy electron diffraction on the islands shows a 2x2 diffraction pattern, indicating a surface reconstruction.

The MnO islands have been further characterized ex-situ by selected-area x-ray absorption spectroscopy of the Mn L_{23} edge, and of the oxygen K edge. The Mn XAS spectrum indicates that Mn is in the high-spin Mn^{2+} configuration within an octahedral environment. The O K edge shows peaks which are likely to arise from the hybridization of the oxygen unoccupied p-states with the Mn d and sp unoccupied states. Additional ex-situ characterization by atomic force microscopy indicate that the islands have a distinctive profile, with a higher thickness around the edge of the islands. In some cases, a triangular region is embedded between a larger triangular islands with the opposite orientation. Spot-Raman spectra acquired from a single islands shows the characteristic Ru shear-mode peak at 200 cm-1, together with the 539 and 1050 cm-1 characteristic modes of MnO above the Néel temperature.

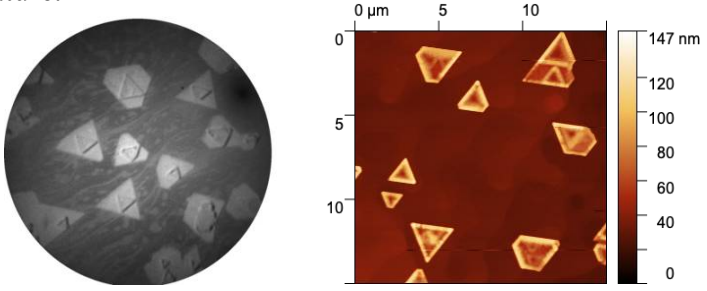

Figure 1: Left: PEEM image with a FOV of 30 um, photon energy of 640eV. Right: Atomic Force microscopy image.

Implementation of the virtual electrode method in a synchrotron LEEM-PEEM station for in-situ studies of Li and Na anode formation in solid state batteries

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In this work we present the application of the virtual electrode method for the study of Zero-Excess Solid-State Batteries (ZESSBs) in a combined Low Energy and PhotoEmission Electron Microscope (LEEM-PEEM). This method enables the study of anode growth (plating) and dewetting (stripping) on a solid-state electrolyte (SSE) surface using the LEEM electron gun. During plating (corresponding to battery charging) an area of the surface is irradiated with an electron beam with the diameter of 100 µm creating a negative surface charge, which promotes the cation migration and the formation of metallic Li or Na clusters on the electrolyte surface (Fig.a). This method is combined with in-situ nanoscale chemical and morphological analysis with PEEM using synchrotron based, lateral-resolved nano-spectroscopy and nano-microscopy, giving insight into the early-stage nucleation and revealing the influence of the various experimental parameters impacting the anode morphology and growth efficiency (Fig.c). We implemented this method for the alkali anodes in Li/LiLaZrTaO and Na/NaGdSiO characterizing the initial anode formation and the crucial electrolyte-anode interface which is otherwise not accessible with surface science techniques (Fig.b). Also, the battery discharge process - stripping - can be simulated in-situ. It is realized by illumination of the electrolyte/anode with a UV photon beam which promotes the extraction of photoelectrons (by the PEEM extractor voltage), thus inducing a positive surface charge. This drives Li or Na ions migration back into the electrolyte. Therefore, the combination of LEEM growth and UV light stripping is suitable for simulating the repeated cycling of a ZESSB.

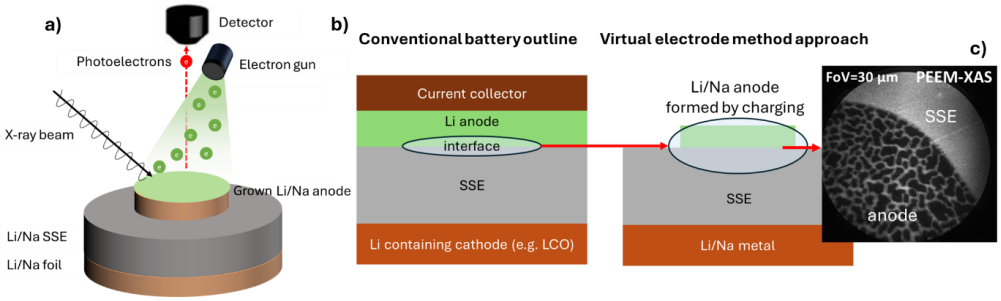

Figure 1: Scheme of the virtual electrode-LEEM approach to grow the Li/Na anodes (a), showing the profitable access to SSE/anode interface (b) and resulting XAS-PEEM image of the anode edge (c).

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Magnetic Optical Kerr Effect Microscopy for studying magnetic textures

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In recent years, there have been an increasing interest in understanding complex magnetic structures emerging from interactions such as the Dzyaloshinskii-Moriya interaction (DMI). This interaction is capable of stabilizing chiral textures due to its antisymmetric exchange interaction, which originates from the heavy metal interface. This symmetry breaking enables the motion of the domain walls (DW) with spin orbit torques induced by current pulses [1], which is the fundamental principle of the racetrack memories [2].

The velocity of these DW is mostly determined by the magnetization of the material, thus ferrimagnets, materials with almost compensated magnetization, promise substantially higher velocities compared to the ferromagnets. To study these velocities, a cost-efficient standard laboratory technique is the Magneto Optic Kerr Effect Microscopy (MOKE microscopy), which enables the direct observation of the magnetic domains of the sample, allowing precise measurement of the DW velocities, from which we can extract characteristics of the material such as the strength of the DMI [3].

Here, we present our new state-of-the-art MOKE microscope developed at UAM, capable of resolving textures of >300nm, and with a high acquisition time of ~30ms per frame. This allows the study of magnetic textures in real time, and so far, it has been used to measure GdFeCo, the dynamics of in-plane Co layers under the excitation of surface acoustic waves, and the static magnetic textures formed in room temperature 2D Van der Waals ferromagnets.

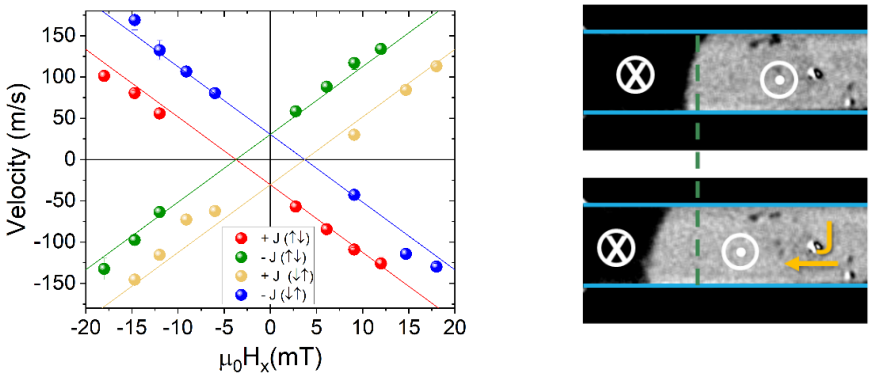

Figure 1: (left) HDMI estimation by the DW velocities on GdFeCo**.** (right) Displacement of a DW driven by a current pulse.

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Enhanced spin-orbit torque efficiency via graphite thickness in Co/Pt multilayers

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The use of the spin in devices –spintronics – has led to remarkable fundamental discoveries and applications ranging from the giant magnetoresistance, hard-disks read heads or the magnetic random-access memory (MRAM). Until very recently, the most efficient way found to operate magnetic memory devices relied on the use of spin currents generated from the electric flow (spin-charge inter-conversion, SCC) in systems with strong spin-orbit coupling (SOC). When transverse spin currents are absorbed by a magnetic material, they produce spin-orbit torques (SOT), an emerging technology that enables the efficient manipulation of magnetic order parameters in spintronic devices [1]. To date, most memory applications have primarily focused on utilizing torques generated from the bulk of the films, with interfacial effects receiving less attention. The antidamping-like (AD) torque originating in the bulk of heavy metals (HMs) plays a dominant role in switching the polarization of magnetic dots [2]. However, symmetry breaking at interfaces can also be a powerful tool for controlling field-like (FL) torques and switching dynamics.

In this study, we investigate the properties of spin-orbit torques (SOT) in thin metallic structures grown, namely, 0.6nm Co layer sandwiched between Pt and graphite overlayers ranging from 0.5nm to 4nm. Using the second harmonic Hall measurement technique, combined with Kerr microscopy, we precisely determine the amplitude of the SOT vs the graphite thickness and study the microscopic mechanisms of the magnetization switching. We find an increase of the Damping-like torque for thinner graphite layers together with a drastic rise in the Field-like torque, resulting in unexpectedly HFL/HDL ratios much larger than 1. The obtained values are comparable to what found in recent works [3,4] for Al capped Co/Pt systems.
The results indicate that the enhancement of torque efficiencies of a purely interfacial origin [5], and that at low graphite interlayer thickness, the enhancement is due to the generation of extra spin/orbital current by a Rashba-Edelstein effect/Orbital-Rashba-Edelstein effect [6,7,8].
Our findings evidence the role of interfacial effect and pave the way towards the optimization of low consumption spin-orbit electronics.

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Tailoring the Spin Reorientation Transition of Co Films by Pd Monolayer Capping

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Palladium (Pd) is widely used in gas sensor technology due to its high hydrogen absorption capacity. However, in ultrathin films, hydrogen solubility is often limited by substrate-induced lattice constraints. Beyond sensing applications, Pd/Co systems are also relevant in magnetic recording technologies, owing to their strong perpendicular magnetic anisotropy (PMA) and tunable magnetization axis. When Pd is deposited on magnetic substrates such as Co, its electronic interaction can significantly alter the magnetic properties, especially under hydrogen exposure.

In this work [1], we investigate the magnetic behavior of ultrathin cobalt (Co) films (2–5 atomic layers) grown on Ru(0001), before and after capping with a single atomic layer of Pd. Using low-energy electron microscopy (LEEM) and spin-polarized LEEM (SPLEEM), we observe that Pd capping enhances surface anisotropy, shifting the spin reorientation transition (SRT) from 2 AL (uncapped) to 5 AL (capped). Specifically, Pd induces a transition from in-plane to out-of-plane magnetization in 3 and 4 AL Co films, while 5 AL films remain in-plane. To test the robustness of this Pd-induced anisotropy, the system was exposed to molecular and atomic hydrogen, as well as CO. Despite clear evidence of hydrogen incorporation at the Pd/Co interface, no changes in the magnetization direction were detected, indicating that the enhanced anisotropy is resilient to adsorbate effects. These findings provide insights into the control of magnetic anisotropy in nanoscale systems and have implications for sensor and spintronic device design.

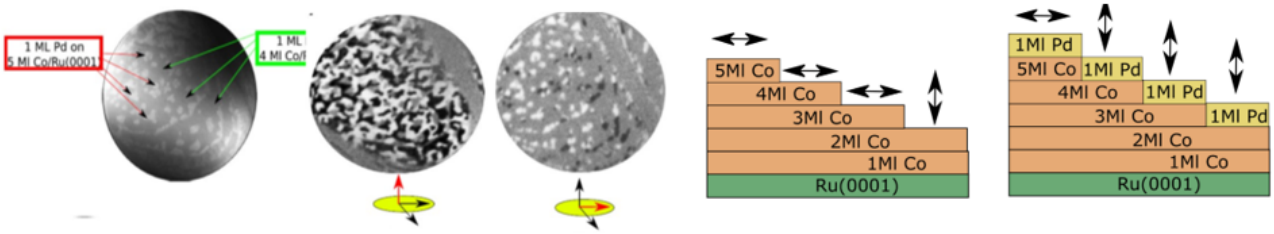

Figure 1: (a) LEEM image acquired after growing 1 AL of Pd on 4 and 5 AL of Co/Ru(0001) and SPLEEM images showing spin contrast with out-of-plane and in-plane spin polarization of the same area. FOV is 8 µm and start voltage is 5.2 eV. (b) Schematic of magnetization reorientation induced by Pd capping.

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