INTERNATIONAL WORKSHOP ON SPINTRONICS

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LOCATION	TIME	SUNDAY, 25TH	MONDAY, 26TH	TUESDAY, 27TH	WEDNESDAY, 28TH	THURSDAY, 29TH	FRIDAY, 30TH
CHARLES DARWIN CONVENTION CENTER	8:30AM		ANDREW KENT	YAYOI TAKAMURA	TOUR DAY (Tour is not included in registration fee)	J. CARLOS ROJAS-SANCHEZ	TERUO ONO
	9:00AM		GIOVANNI FINOCCHIO	AXEL HOFFMANN		PEDRO LANDEROS	GERRIT BAUER
	9:30AM		HYNSOO YANG	PETER WADLEY		P. PERNA	ERNESTO MEDINA
	10:00AM		KLEBER ROBERTO PIROTA	L. MICHEZ		JAGODA SLAWINSKA	SILVIA VIOLA KUMSINSKIY
	10:30AM		COFFEE BREAK	COFFEE BREAK		COFFEE BREAK	COFFEE BREAK
	11:00AM		SOLANGE M. DI NAPOLI	YONG XU		JUAN GABRIEL RAMIREZ	SARA A. MAJETICH
	11:30AM		M. ROMERA GEN TATARA	PETR NEMEC JULIAN MILANO		C. RINALDI F. AJEJAS	SHUICHI MURAKAMI D. PEDDIS
	12:00PM		ARUNAVA GUPTA ANNA DELIN	HANS J. HUG RAFAEL GONZALEZ-HERNANDEZ		PEDRO DUCOS C. K. SAFEER	OLEG A. TETRIAKOV R. TOMASELLO
	12:30PM		JUAN ESCRIG P. MARTINS	LUNCH BREAK		LUNCH BREAK	ANDREI SLAVIN CLOSURE
	1:00PM						
	1:30PM						
	2:00PM						
	2:30PM			IGOR ZUTIC		JOSE J. BALDOVI	
	3:00PM			S. MANGIN		L. AVILES-FELIX	
	3:30PM			ERIC E. FULLERTON		C. P. QUINTEROS	
	4:00PM			M. PRZYBYLSKI CLODOBALDO I. LEVARTOSKI		ANDERSON L. R. BARBOSA GANG LU	
	4:30PM			KAREL CARVA EDGAR J. PATIÑO		K. SCHLAGE ALEXANDER GRAY	
USFQ CAMPUS	5:00PM	REGISTRATION					
	5:30PM						
	6:00PM	WELCOME COCKTAIL		POSTERS SESSION & BIERSTUBE		POSTERS SESSION & BIERSTUBE	
	6:30PM						
	7:00PM				CONFERENCE DINNER AT HOTEL INDIGO		
	7:30PM			SCIENCE NIGHT: NETWORKING FOR EQUAL OPPORTUNITIES		BEST STUDENT POSTER AWARDS	

SPINTRONICS & NOVEL COMPUTING DEVICES

MONDAY, 26TH

CHAIRS:
YAYOI TAKAMURA
PEDRO LANDEROS

ANDREW D. KENT andy.kent@nyu.edu

Solving Combinatorial Optimization Problems and Generating Random Numbers with Stochastic Magnetic Tunnel Junctions

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Can stochastic magnetic tunnel junction arrays solve complex optimization problems better than existing methods? The first part of this talk addresses this question by presenting the Sherrington–Kirkpatrick (SK) spin-glass model, which is an NP-complete problem with a known solution in the thermodynamic limit. Remarkably, we show by numerical modeling that coupled macrospins emulating the SK model and evolving according to Landau-Lifshitz Gilbert dynamics can get closer to the true ground state energy than state-of-the-art numerical methods and discuss the possible reasons [1]. In the second part of my talk, I will present our work on stochastic magnetic tunnel junctions based on perpendicular magnetic tunnel junctions. In contrast to superparamagnetic MTJs, we experiment with magnetically stable MTJs and actuate them with nanosecond pulses to make them behave stochastically. We denote this a stochastic magnetic actuated random transducer (SMART) pMTJ device because a pulse generates a random bit stream on-demand, much like a coin flip. SMART-pMTJs produce truly random bit streams at high rates while being more robust to environmental changes, such as their operating temperature and device-to-device variations, compared to other stochastic nanomagnetic devices. By interfacing a pMTJ to an FPGA, we have generated over 1 trillion bits at rates greater than 100 MHz that pass multiple statistical tests for true randomness, including all the NIST tests for random number generators with only one XOR operation. Finally, I will discuss opportunities to advance the science and applications of stochastic MTJs toward the goals of having better sources of random numbers and addressing complex optimization problems.

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GIOVANNI FINOCCHIO gfinocchio@unime.it

New Directions in Probabilistic Computing with P-Bits

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The development of more efficient and high performance spintronic devices and the efforts to have co-integration of spintronics with CMOS technology is driving the development of hybrid CMOS-spintronic solutions for applications where one can take the advantages of both technologies while minimizing their disadvantages. In this talk, I will present our recent developments on new potential applications of magnetic tunnel junctions (MTJs) in probabilistic computing.

I will focus on probabilistic computing with probabilistic-bits (p-bits) which is emerging as a computational paradigm able to be competitive in solving NP-hard combinatorial problems. I will show how to map hard combinatorial optimization problems (Max-Sat, Max-Cut, Traveling Salesman problem) into probabilistic Ising machine.[1] We will discuss the potential of advanced annealing schemes comparing simulated annealing, parallel-tempering, and simulated-quantum-annealing and how it will be possible to implement an efficient probabilistic co-processor. Finally, we will present a CMOS architecture which implement the simulated quantum annealing. I will finally discuss the application of the voltage controlled magnetocrystalline anisotropy magnetic tunnel junctions in the generation of random number and their heterogeneous integration with CMOS technology.

The author acknowledges the support of Petaspin team in implementing these research activities. This work was supported under the project number 101070287 — SWAN-on-chip — HORIZON-CL4-2021-DIGITAL-EMERGING-01, the project PRIN 2020LWPKH7 and PRIN 20225YF2S4 funded by the Italian Ministry of University and Research, and by the PETASPIN association (www.petaspin.com).

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Spin-Based Non-Volatile Memories, Unconventional Computing, and Energy Harvesting

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Spin-based magnetic random-access memory is emerging as a key enabling low-power technologies, which have already spread over markets from embedded memories to the Internet of Things. In addition, spin devices can offer alternative solutions for unconventional computing and energy harvesting. We present an experimental Ising computer based on magnetic tunnel junctions, which successfully solves a 70-city travelling salesman problem (4761-node Ising problem) [1]. We also propose a spintronic artificial neuron based on the heavy metal (HM)/ferromagnet (FM)/antiferromagnet (AFM) [2], which can reset itself due to the exchange bias. Using our proposed neuron, we further implement a restricted Boltzmann machine (RBM) and stochastic integration multilayer perceptron (SI-MLP). By integrating the electrically connected eight spin-torque oscillators (STOs), we demonstrate the battery-free energy-harvesting system by utilizing the wireless RF energy to power electronic devices such as LEDs [3,4].

We present our perspective on spin device applications using emerging materials [5]. Previous proposals for spin-orbit torque (SOT) switching of perpendicular magnetic anisotropy (PMA) require an additional magnetic field or complex structures. Exploiting the out-of-plane spins could be a solution to this challenge [6]. Here we experimentally demonstrate field-free switching of PMA CoFeB at room temperature utilizing out-of-plane spins from $TaIrTe_4$ [7] and $PtTe_2/WTe_2$ [8]. Finally, we discuss magnon-mediated spin torques, which could minimize Joule heating and corresponding energy dissipation [9]. We demonstrate magnon current-driven switching of PMA at room temperature and field-free operation [10].

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KLEBER ROBERTO PIROTA krpirota@ifi.unicamp.br

Artificial Kagome Spin Ice: Machine Learning for Magnetic Phase Recognition and Boundary Condition Effects

Breno Malvezzi Cecchi, Danilo R. A. Elias, Marcelo Knobel, Nathan Cruz, Maurice de Konig, and Kleber Roberto Pirota

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Artificial spin ices are arrays of single-domain magnetic nanostructures arranged into two-dimensional lattices through lithographic patterning. Originally designed to replicate the frustrated behavior observed in bulk spin ice materials, these systems have developed into versatile platforms where novel geometries can be explored to emulate the many-body physics of classical spin systems via a lab-on-chip approach. A range of intriguing collective phenomena is accessible in real space and at room temperature, including phase transitions, spin liquid behavior, and emergent magnetic monopoles [1]. The tunability of their magnetic states and dynamics through external magnetic fields makes artificial spin ices promising for applications in information storage, processing, and magnonics.

Alongside a brief overview of the topic, this work presents recent results from our group on artificial kagome spin ice (AKSI), a system that has attracted significant interest due to its rich phase diagram, which includes four distinct magnetic phases: a high-temperature paramagnet, two different spin liquid phases (spin ice 1 and spin ice 2), and a long-range ordered ground state. We discuss two main topics within this context. The first is our recent proposal to use machine learning to recognize AKSI phases [2]. Specifically, we demonstrate that analyzing the initial magnetization curve reveals phase-specific characteristics, allowing a supervised classification algorithm to reliably identify the phase of an initial microstate. The second topic addresses the impact of boundary conditions on Monte Carlo simulations of long-range spin models, commonly used to interpret experimental data. Our results show that the AKSI ground state is highly sensitive to boundary conditions when small, non-zero multipolar corrections are applied to the pure dipolar Hamiltonian.

References

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SOLANGE M. DI NAPOLI solangedinapoli@cnea.gob.ar

Magnetic Transitions and Spin-Polarized Two-Dimensional Electron Gas Controlled by Polarization Switching in Low Dimensional Heterostructures

Solange M. Di Napoli[1], Jhon Ospina[1], Augusto Román[1], Ana María Llois[1], Myriam Aguirre[2], Laura B. Steren[1] and María Andrea Barral[1]

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During the last decades, a lot of effort has been made to design heterostructures consisting of a ferroelectric (FE) and a magnetic material, with a large interfacial magnetoelectric coupling (MEC). In the quest for functional materials, perovskites have emerged as good candidates due to their robust coupling among structural, orbital, charge, and spin degrees of freedom. With remarkable advancements in thin film growth techniques for perovskite oxides, atomic control over surfaces has been achieved, amplifying their technological use.

In this talk, I will show that *ab-initio* calculations predict a strong MEC in a $CaMnO_3$ thin film grown on a strained $BaTiO_3$ FE film. This heterostructure presents a polarization driven magnetic transition, together with a metallic behavior at the interface between these two insulators, where the charge character of the carriers can be tuned from spin-polarized electrons to holes by switching the electric polarization[1].

An alternative route for MEC, beginning to be explored, involves two-dimensional layered materials. Structurally different from conventional ferroelectric oxides, van der Waals ferroelectrics have layered structures with weak interlayer interactions. Among these materials, α-In_2Se_3 shows a robust in-plane polarization coupled to an out-of-plane polarization at the monolayer limit.

In this talk, I will also present our latest findings on the magnetic interactions between transition metal atoms embedded in different structures deposited on an In_2Se_3 monolayer, where we explore the effect of the polarization reversal, searching for a sizable magnetoelectric coupling.

References

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Reconfigurable Classifier Based on Spin Torque Driven Magnetization Switching in Electrically Connected Magnetic Tunnel Junctions

A. López[1,2], D. Costa[3], T. Böhnert[3], P. P. Freitas[3], R. Ferreira[3], I. Barbero[1], J. Camarero[2,4], C. León[1], J. Grollier[5], and Miguel Romera[1]

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A promising avenue in neuromorphic computing aims to perform cognitive operations directly in hardware, leveraging the physics of efficient, well-established nano-devices. Spintronic devices, such as spin torque oscillators and superparamagnetic tunnel junctions, have emerged as promising processing units in neuromorphic networks. However, the most mature and well-established spintronic technology is spin-transfer torque magnetic random-access memories (STT-MRAM), which relies on magnetic tunnel junctions where the spin-transfer torque effect switches the free layer magnetization between two stable states (parallel and antiparallel), characterized by a different resistance. Performing complex computing tasks with the same devices and principles used in industrial STT-MRAM holds great potential for fast, large-scale integration, making it a highly attractive technological prospect. However, so far STT-MRAM devices have been investigated in neuromorphic networks only as synaptic (memory) elements [1], which require additional (software) processing units to perform classification tasks. To date, these devices have not been used experimentally as interconnected processing units capable of learning pattern recognition.
In this work, we present a reconfigurable classifier based on a network of electrically connected magnetic tunnel junctions that categorizes information encoded in the amplitude of input currents through the spin torque-driven magnetization switching output configuration [2]. The network can be trained to classify new data by adjusting additional programming currents selectively applied to the junctions. We experimentally demonstrate that a network composed of three magnetic tunnel junctions can learn to classify seven spoken vowels with a recognition rate of 96%, surpassing the performance of software neural networks with the same number of trained parameters. We also discuss the efficient scaling and integration of this technology into CMOS chips. This first demonstration of real-time learning and pattern recognition using STT-MRAM devices and principles constitutes a significant step toward the rapid, large-scale integration of neuromorphic hardware.

References
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Theory of Spin Transport Induced by Supercurrent in a SNS Junction

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We study theoretically the spin transport induced by superconductivity in a SNS junction based on a microscopic approach. The supercurrent driven by phase of the superconductor is formulated diagrammatically. The spin Hall effect due to the equilibrium supercurrent is investigated in detail and effects of spin relaxation and dissipation on the emergence of non-equilibirium spin accumulation are discussed.

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Revisiting Spinel Ferrites: High-Quality Epitaxial Thin Films on Isostructural Lattice-Matched Substrates

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Spinel ferrite thin films have numerous technological applications, including telecommunications, magneto-electric coupling devices, and emerging spintronic devices. However, conventional deposition techniques often result in spinel ferrite films, such as $NiFe_2O_4$ (NFO), with compromised structural and magnetic properties, including the formation of antiphase boundaries and high magnetic saturation fields. We address these limitations by employing substrates with similar crystal structures and low lattice mismatch, which enables the growth of high-quality NFO films with minimal antiphase boundaries and enhanced magnetic properties, comparable to those of bulk single crystals. Specifically, we utilized spinel $MgGa_2O_4$, $CoGa_2O_4$, and $ZnGa_2O_4$ substrates with lattice mismatches of 0.6%, 0.1%, and 0.05%, respectively, to grow epitaxial NFO films with sharp magnetic hysteresis characteristics and narrow ferromagnetic resonance linewidths similar to those in single crystals [1]. Furthermore, our investigation of the spin transport properties of NFO films grown on these substrates using the longitudinal spin Seebeck effect (LSSE) reveals a correlation between reduced lattice mismatch and enhanced spin voltage signal, consistent with improvements in structural and magnetic properties [2]. Notably, we demonstrate that bidirectional field-dependent LSSE voltage curves can be used to probe the complete magnetization reversal process, providing a novel vectorial magnetometry technique based on the spin caloric effect.
Work done in collaboration with S. Regmi, A. Rastogi, A. Singh, Z. Li, T. Mewes, T. Kuschel, and A. Galazka.

References

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Magnetism and Spin Dynamics in Low-Dimensional Materials

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In this talk, I will give an overview of our recent theoretical work on spin textures and spin dynamics in low-dimensional systems and our recent efforts to develop methods to identify both local and global minima in highly convoluted spin-Hamiltonian potential energy surfaces.
We have, for example, discovered complex magnetic textures in the vanadium stibnites [1], a class of Kagome systems, and large spin-lattice couplings -- i.e, how the magnetic interactions depend on atomic displacement -- in CrI_3. Employing fully relativistic first-principles calculations, we extract an effective measure of the spin-lattice coupling in this prototypical two-dimensional magnet, finding that they are up to ten times larger than what is found for bcc Fe.
Furthermore, we have demonstrated how an anisotropic spin Seebeck effect can be generated in certain van der Waals systems, requiring neither external magnetic field nor Berry curvature [2].
In the area of topological magnetic textures, we have identified a large number of metastable topologically nontrivial spin textures in two-dimensional systems with frustrated exchange, using our newly developed metaheuristic conditional neural-network-based method. We have also developed an efficient genetic-tunneling based algorithm to identify skyrmionic ground states, which in contrast to simulated annealing correctly converges to the correct topological charge state as a function of magnetic field.

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Engineering Core-Shell Magnetic Nanotubes for Spintronic Applications

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Core-shell magnetic nanotubes represent a promising platform for spintronic devices, offering tunable magnetic properties through precise structural engineering. This work demonstrates a scalable and efficient approach to synthesize these nanostructures using electrospinning, atomic layer deposition (ALD), and post-synthesis reduction techniques. Compared to conventional methods employing porous membranes as templates, this technique enables the production of significantly larger quantities of nanotubes in reduced processing times, highlighting its potential for industrial scalability.

Morphological and compositional analyses were performed using scanning and transmission electron microscopy, ellipsometry, and energy-dispersive spectroscopy. X-ray photoelectron spectroscopy confirmed oxidation state transitions critical to magnetic tunability. Magnetic measurements revealed enhanced coercivity and saturation magnetization, demonstrating the efficacy of core-shell designs in modulating magnetic reversal mechanisms. Furthermore, the curling reversal process in these nanotubes was analytically modeled to predict coercivity behavior.

These results underline the advantages of this method for producing high-quality core-shell nanotubes, offering precise control over morphology and magnetic properties while significantly improving synthesis efficiency. This approach paves the way for advanced spintronic applications requiring scalable and tailored nanostructures.

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How Magnetoelectric Polymers Can Shape the Future of Spintronics

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The convergence of magnetism and electronics within spintronics has led to groundbreaking technologies with enhanced functionality and energy efficiency. Spintronics, which leverages electron spin to control electric current, offers a low-power alternative to conventional electronics. Magnetoelectric (ME) materials, capable of switching magnetization states via electric fields, are a new tool to advancing spintronic devices (SD). These materials support high-speed operation, reduced heat dissipation, and scalability, making them ideal for applications such as magnetic memory and logic gates. However, despite extensive research into the direct ME effect, the converse effect—critical for spintronic applications—remains underexplored [1].

This study investigates the potential of P(VDF-TrFE)-based composites, fabricated using printing technologies, for reversible ME coupling. These composites—comprising P(VDF-TrFE) and magnetic fillers (Fe_3O_4, NdFeb, $CoFe_2O_4$)—exhibit high converse ME coefficients, reaching up to 13.9 mOe·cm·V^{-1}. We also explore four ME composite laminates, combining PVDF piezoelectric layers with magnetostrictive materials (Metglas, Vitrovac,and Terfenol-D) and varying PVDF thicknesses, generating magnetic fields up to 150 Oe and an ME coefficient of 200 mOe·cm·V^{-1}. These fields are two orders of magnitude larger than the switching field required to control the spin of the free layer in certain spintronic devices recently proposed [2].

These findings highlight the promise of polymer-based ME materials for developing SDs with enhanced low-power consumption and reduced heat generation, laying the groundwork for their widespread use in next-generation electronics.

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EMERGING ORDERS: ANTIFERROMAGNETS & ALTERMAGNETIC TEXTURES

TUESDAY MORNING, 27TH

CHAIRS:
SARA A. MAJETICH
GERRIT BAUER

YAYOI TAKAMURA

Tailoring Magnetic Spin Textures in $La_{0.7}Sr_{0.3}MnO_3$-Based Micromagnets

Dayne Sasaki[1], Tanaya Sahoo[1], Ishmam Nihal[1], Izoah Snowden[1], Matthew Frame, Scott Retterer[2], Barat Achinuq[3], Andreas Scholl[3], Peter Rickhaus[4], Joerg Lenz[4], and Yayoi Takamura[1]

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The development of next-generation computing devices based on spintronics and magnonics requires an understanding of how magnetic spin textures can be tailored in patterned magnetic materials. Within the wide range of magnetic materials available, complex oxides such as ferromagnetic (FM) $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) and antiferromagnetic (AF) $La_{1-x}Sr_xFeO_3$ (LSFO) provide an ideal platform for tailoring magnetic spin textures when lithographically patterned as nano/micromagnets. This unique tunability arises due to the strong interactions between charge, spin, lattice, and orbital degrees of freedom. In this talk I will demonstrate how an intricate interplay exists between shape and magnetocrystalline anisotropy energies as well as exchange coupling interactions at LSMO/LSFO interfaces, and therefore, the resulting AF and FM spin textures can be controlled using parameters such as the LSMO and LSFO layer thicknesses, micromagnet shape, and temperature.[1] These spin textures are imaged using x-ray photoemission electron microscopy for a variety of shapes (circles, squares, triangles, and hexagons with their edges oriented along different low index crystallographic directions) with and without their core regions removed (aka donut structures). LSMO nanomagnets were also patterned into artificial spin ice (ASI) structures,[2] where large arrays of nanomagnets are arranged into geometries where all the magnetic interactions cannot be satisfied simultaneously. While one might expect shape anisotropy to dictate Ising states in the nanomagnets, the unique combination of magnetic parameters associated with LSMO enables the formation of both Ising and complex spin textures (CSTs) based on the nanoisland width and spacing. These CSTs consist of single and double vortices and alter the nature of dipolar coupling between nanomagnets, giving rise to exotic physics in the ASI lattices. These studies demonstrate that complex oxide provide a unique platform for engineering FM and AF spin textures for next generation spin-based devices.

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Spin Currents with Antiferromagnets

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Metallic antiferromagnets have generated a wide range of interest recently, since they can exhibit a complex interplay between charge transport and magnetic structure [1,2]. In this presentation I will highlight some of our own recent work that explores the interplay between magnetic structure and spin transport. First, I will discuss, how magnetic field induced changes of the antiferromagnetic magnetic structure can result in unexpected magnetoresistance effects [3,4]. In FeRh we have experimentally observed an unusual magnetoresistance, which changes from two-fold to four-fold and back to two-fold symmetries as a function of applied magnetic fields. This evolution of the magnetoresistance finds a natural explanation in how the Fermi surface transforms as the antiferromagnet develops a gradually larger net magnetization [3]. Similarly in Pt/FeRh bilayers the coupling of the induced net magnetization in the antiferromagnet to interfacial Rashba-type spin-orbit coupling leads to a characteristic field dependence of the magnetoresistance, which changes sign at relatively large magnetic fields [4]. Furthermore, I will discuss the electric switching of the spin structure in Mn_3Sn. By systematically varying thermal resistance of the substrate, we demonstrated that thermal effects dominate the electrical switching [5]. Thus, the switching proceeds via thermal demagnetization followed by renucleation of magnetic order in the presence of spin-orbit torques.

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Altermagnetism Imaged and Controlled Down to the Nanoscale

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Altermagnetism is a newly identified class of magnets which combines properties from both ferromagnets and antiferromagnets, making them highly promising candidates for spintronic applications. We recently demonstrated the spin split nature of the altermagnetic electronic band structure in MnTe [1]. In this work, we demonstrate that the unique resultant properties of altermagnets can be used to image them in unprecedented details, and also to control them in unique ways.

Utilising a combination of linearly and circularly polarised x-rays, in a single instrument, we generate a full Neel vector map of the magnetic domain in MnTe, showing all 6 domain types and revealing vortices and their vorticity. In addition, we utilise a combination of patterning and field cooling to nucleate single domains of our choosing from the micron to nanoscale. We also show generation and control of the position and vorticity of single vortices. These experiments showcase the unique properties of altermagnets and also provide a platform for the next stages of research and application [2].

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Epitaxy-Tuning of Magnetotransport in Mn_5Si_3 Thin Films: From Ferro- to Altermagnetism

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For many years, the anomalous Hall was believed to be exclusively present in ferromagnetic materials. However, it has been recently shown that these effects can be finite also in certain collinear antiferromagnets displaying a specific crystal and spin symmetry, which tremendously broadens the number of alternative materials in which spontaneous Hall is expected.
I will focus here on a Si-based system, i.e. Mn_5Si_3, that is known to be antiferromagnetic in bulk up to 100K. I will report routes to grow epitaxial Mn_5Si_3 thin films using molecular beam epitaxy [1]. I will emphasize the role of crystallinity, doping and strain in the stabilization of exotic magnetic structures that, in turn, induce fascinating properties [2].

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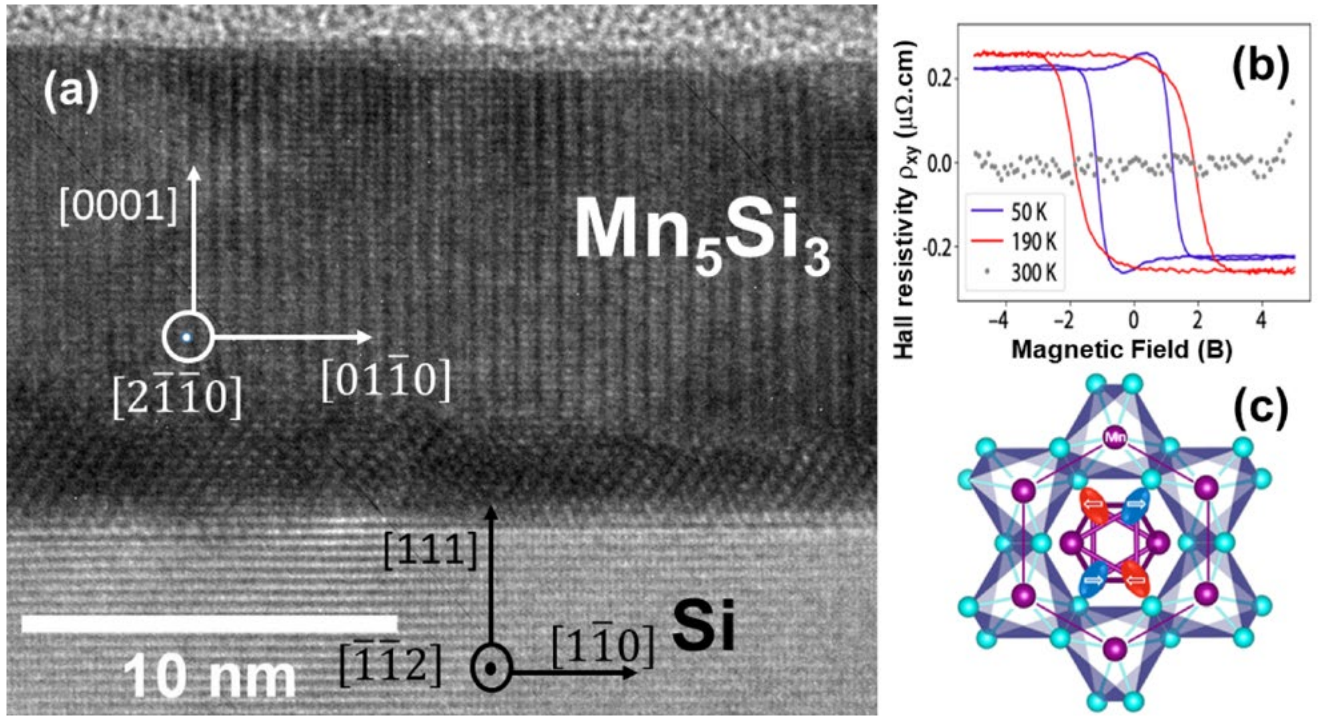

Figure
(a) High-Resolution TEM cross-section of a 13-nm thick Mn_5Si_3 thin film grown on Si(111). (b) Anomalous Hall resistivity in the antiferromagnetic phase measured at 50 K, 190 K and 300 K. (c) Magnetic and crystalline structure of Mn_5Si_3.

YONG XU

Efficient Terahertz Generation from CoPt-based Terahertz Emitters via Orbital-to-Charge Conversion

Yong XU[1], Yongshan Liu[1], Albert Fert[2], Henri-Yves Jaffrès[2], Sylvain Eimer[1], Tianxiao Nie[1], Xiaoqiang Zhang[1], and Weisheng Zhao[1]

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Orbitronics exploits the orbital degree of freedom and paves a new route for developing ultrafast magnetic devices. The orbital source is critical for the performance of ultrafast orbitronic devices. While the orbital generation from Ni upon ultrafast pumping has recently been studied extensively, the application of Ni-based devices is hindered by its low generation efficiency and the low Curie temperature. In our latest findings, we present a more effective method of generating ultrafast light-induced orbital currents using CoPt alloy. The resulting orbitronic terahertz emission from CoPt/Cu/MgO structures exhibits terahertz radiation comparable to benchmark spintronic terahertz emitters. Through systematic adjustments in the composition of CoPt alloy, the thickness of Cu, and the capping layer, we verify that terahertz emission primarily originates from the generation of ultrafast orbital accumulation within CoPt material, which propagates through the Cu layer and achieves orbital-to-charge conversion at the Cu/MgO interface via the inverse orbital Rashba-Edelstein effect. Our work provides a new opportunity for the developing ultrafast orbitronic devices, paving the way to efficient orbital terahertz emitters.

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Ultrafast Laser-Induced Spin Tilt in Non-Collinear Antiferromagnetic Metal Mn_3NiN

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In general, detection and modification of magnetic ordering in antiferromagnetic (AF) thin films is a major challenge [1]. We report on ultrafast modification of spin ordering in 13-nm-thick epitaxial layer of non-collinear cubic antiperovskite AF metal Mn_3NiN with Γ_{4g} spin configuration [2]. The spin tilt is caused by a pump-pulse-induced torque, with a torque direction controlled by pump linear polarization orientation α, and detected as a polarization change of linearly polarized probe pulses transmitted through the film at normal incidence. Interestingly, as illustrated in the figure part (a), the pump-induced spin tilt is very fast, with sub-picosecond rise time and ≈ 1.6 ps decay time. The detected signal magnitude and sign are almost completely controlled by the pump polarization orientation with a degree of linear-polarization-dependence reaching ≈ 95%, which is a value unprecedented in metallic materials. The measured signal harmonic dependence on probe polarization β, see part (b), reveals that quadratic magneto-optical (MO) Voigt effect is detected in our experiment. Positions of nodal points in the harmonic dependences are set solely by pump polarizations, while MO signal amplitude is independent on α, which is rather surprising in an epitaxial layer with a cubic symmetry. The modelling of spin dynamics by LLG equation revealed that while the laser-induced torque is probably directed within the triangular spin magnetic domain plane, which are located in one of eight (111) planes, the detected MO signals are dominated by the out-of-domain-plane spin tilts.

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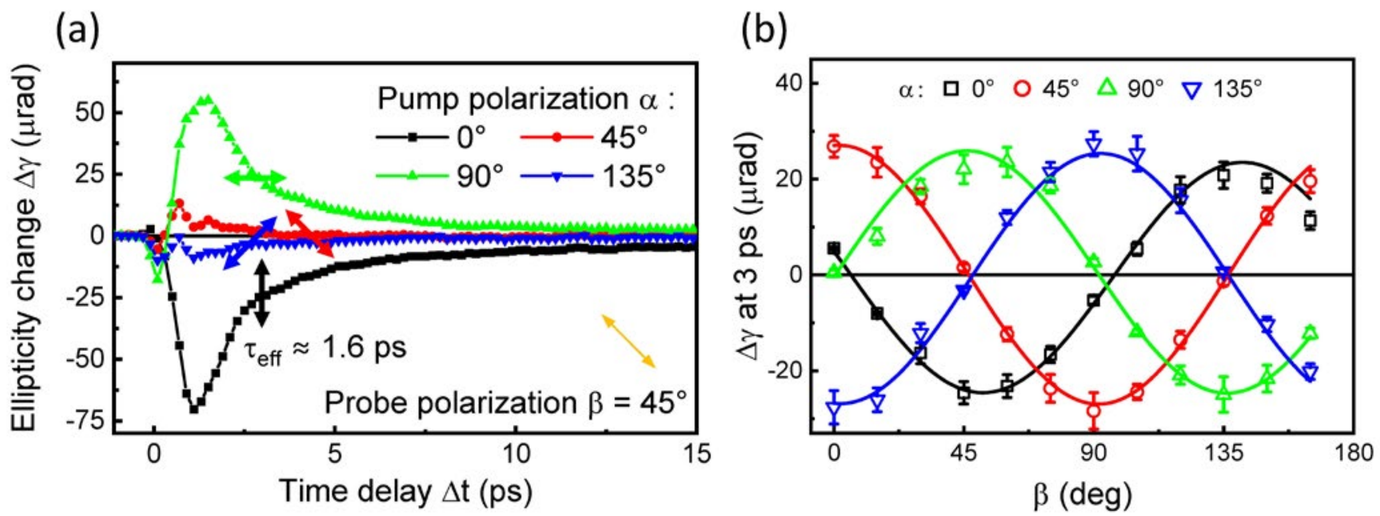

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Magnetic Stripe Domains in Thin Films

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In this presentation, we summarize the advances we have made in recent years in the study of magnetic properties in ferromagnetic thin films that have stripe domains, usually called soft stripes. The appearance of this type of domain is due the presence of an easy anisotropy axis perpendicular to the sample. Stripe domains have a complex three-dimensional structure, which has only begun to be unraveled in recent years. Moreover, these systems have the unique property of presenting the so-called rotational anisotropy, that is, an easy anisotropy axis can be placed in any direction of the film plane just applying a saturating field along such direction.

This type of domain has been discovered during the 1960s in thin films of permalloy. Later, other alloys have been discovered that also present this type of structure such as FePt, Fe-Ga, Ni, Co, FePd, Fe-N, FeCoB and FeCoC.

In this presentation we will present different experiments that we carried out on thin films that present stripe domains of Fe-Ga and FePt grown by Molecular Beam epitaxy and sputtering respectively. We performed experiments in order to address different phenomena specifically present in striped systems related with the rotational anisotropy [1] and the magnetic structure [2]. Electronic transport [3] and magnetic relaxation properties were studied [1] as well.

Through the obtained results, on the on hand, we address new effects that differs of those in planar domains; on the other hand, we go in depth in the understanding of phenomena related with the striped phase that can be used in potential new devices.

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Sub-15nm Skyrmions in Rare-Earth/Transition Metal Alloy – Heavy Metal Multilayers

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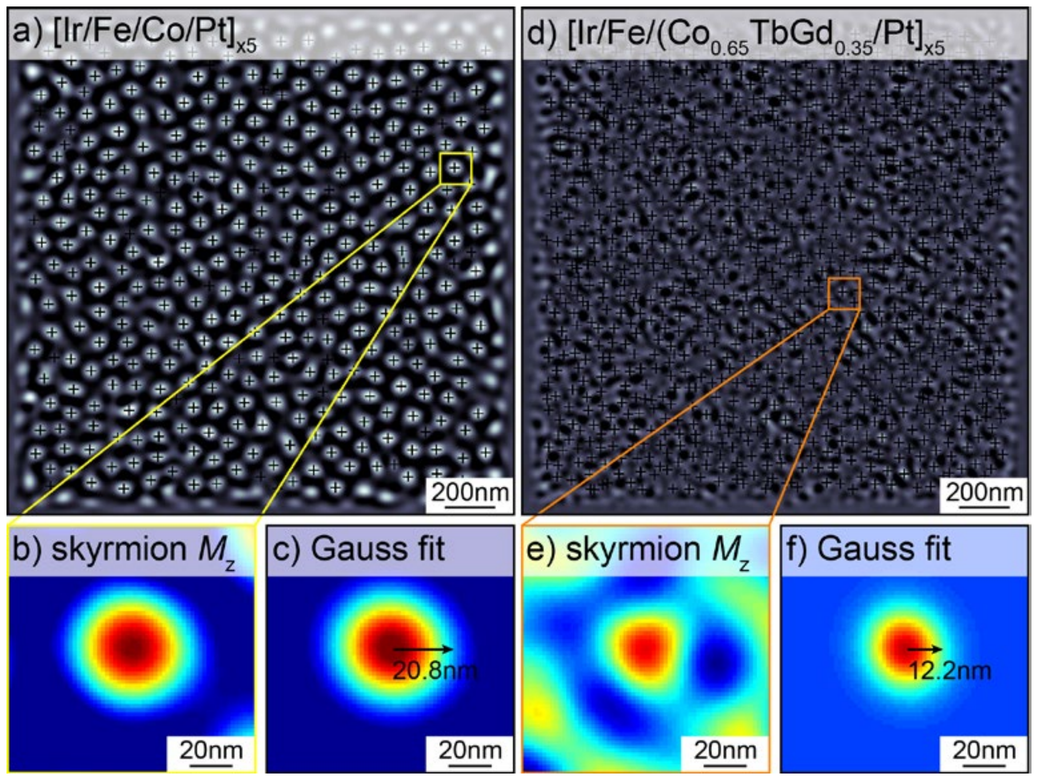
Rare-earth/transition metal alloy heavy metal multilayers offer versatile systems for achieving 3d skyrmion spin textures [1], nanoscale skyrmions and rapid domain wall and skyrmion transport. We report on skyrmions forming in Si/SiOx/Ta(3)/Pt(5)/[Ir(1)/Fe(0.26)/Co_{1-x}/$(TbGd)_x$(0.6)/Pt(1)$]_{x5}$/Pt(4)-multilayers with rare-earth contents of 0 < x < 65. Using in-vacuum magnetic force microscopy (MFM) [2], we observe the transition from stripe domains to skyrmions in applied fields. For higher rare-earth content, skyrmion areal density increases from 100 μm^{-2} to 270 μm^{-2}, while the skyrmion radii decrease from 20.8 nm to 12.2 nm, as obtained from a quantitative MFM analysis. Magnetometry and Brillouin light scattering (BLS) yield values for M_s, K_u, and the Dzyaloshinskii-Moriya interaction D. To determine A, we apply micromagnetic modeling with varying A to match the relaxed zero-field stripe domain to the experimental domain structure. Further micromagnetic simulations, using these A-values together with experimentally-determined values for M_s, K_u, and D, replicate the experimentally observed skyrmion density and radius changes. The agreement between modeling and experimental results suggests that the reduction in skyrmion radius with increased rare-earth content stems from decreased M_s and A.



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Topological Phases in Altermagnets: Insights from Spin Topology

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This work investigates the topological properties of altermagnets, a novel class of collinear magnetic materials. We utilize equivariant K-theory and Hamiltonian models to develop a robust $C_{4z}T$ topological invariant for classifying both 2D and 3D altermagnetic systems. Our results reveal that the spin Chern number acts as a robust topological index, correlating with the half-quantized Chern number of the divided Brillouin zone. This finding facilitates the identification of topologically protected 2D altermagnetic insulators and 3D Weyl altermagnetic semimetals, thereby illuminating the connection between altermagnetism and topological phases. Additionally, our work paves the way for future investigations into topological applications within d-wave altermagnetic materials

ULTRAFAST DYNAMICS & QUANTUM COUPLED SYSTEMS

TUESDAY AFTERNOON, 27TH

CHAIRS:
J.-CARLOS ROJAS-SÂNCHEZ
SILVIA VIOLA KUSMINSKIY

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Spin-Charge-Photon Conversion: From THz Spin-Light Coupling to Electrical Helicity Reversal

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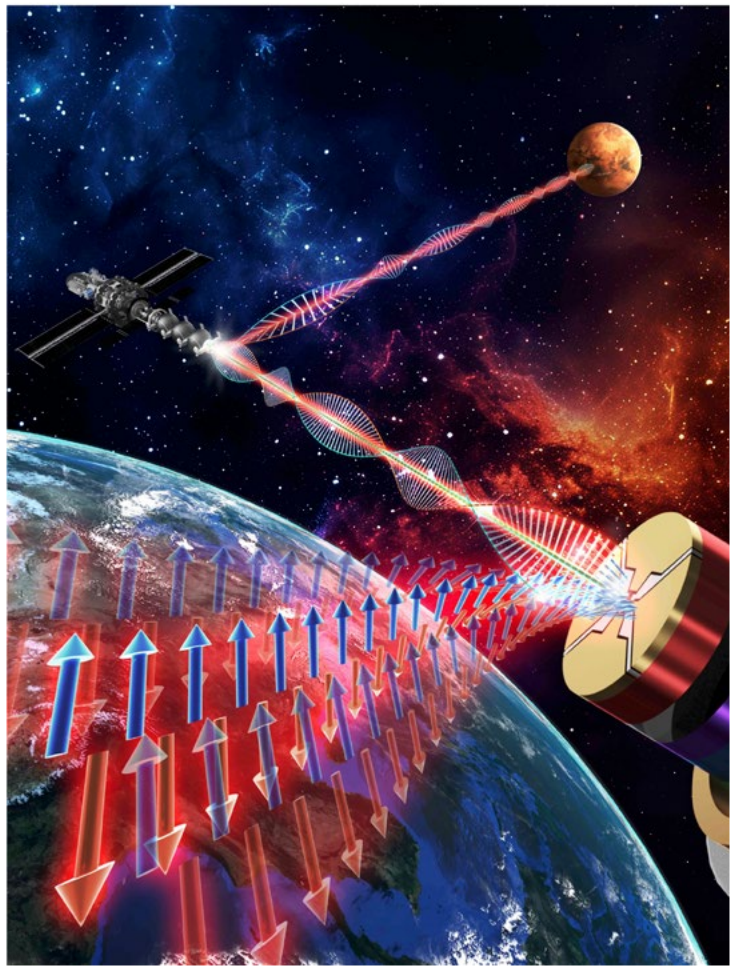
In solid-state systems spin-orbit coupling (SOC) is a friend and foe [1]. While SOC is responsible for the loss of information and spin depolarization, it is also crucial for transferring spin between different systems. We focus on two SOC manifestations. (i) Electric dipole spin resonance in proximitized Dirac material where we reveal an overlooked resonant spin-pseudospin coupling responsible for a huge increase of THz absorption, explained by coupled spin-pseudospin torques [2], (ii) Spin-orbit torque magnetization switching, which allows to electrically reverse the helicity of the emitted light from III-V quantum dots at 300 K and zero applied magnetic field [3]. We discuss the implications of these findings, from elucidating hidden proximity effects to establishing a missing link between photonics, electronics, and spintronics [3-5].



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Ultra-Fast All Optical Switching in Spintronic Devices

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We will focus exclusively on deterministic magnetization switching induced by single femtosecond or picosecond laser pulses in spintronic devices, such as spin valves and tunnel junctions. We will examine magnetization reversal resulting from the direct interaction between the ultra-short laser pulse and the magnetization,. We'll also discuss how light can produce heat pulses or spin-polarized femtosecond current pulses to reverse the magnetization of thin ferromagnetic films in magnetic heterostructures, a topic also recently reviewed. Additionally, we will present our latest results, which demonstrate ultra-fast magnetization reversal (in less than one picosecond) in various perpendicularly magnetized ferrimagnetic and ferromagnetic spin-valve structures [1,2].
More recently, we have demonstrated optically induced ultrafast magnetization reversal occurring in less than a picosecond in rare-earth-free archetypal spin valves ([Pt/Co]/Cu/[Co/Pt]) commonly utilized for current-induced spin-transfer torque (STT) switching [2]. We discovered that the magnetization of the free layer can be switched from parallel to antiparallel alignment, akin to STT switching, revealing the presence of an unexpected, intense, and ultrafast source of opposite angular momentum in our structures. These findings pave the way for ultrafast magnetization control by integrating concepts from spintronics and ultrafast magnetism.

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Ultrafast Coupling of Spin and Lattice Dynamics in Magnetic Materials

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The possibilities of optically manipulating magnetization without applied magnetic fields have attracted growing attention over the last twenty years. There are further opportunities for ultrafast control in strongly correlated systems where the coupling between spin, charge, and lattice degrees of freedom. Recently there has been growing interest into the link between ultrafast optical demagnetization driving ultrafast structural dynamics. One example is elemental chromium, which exhibits an incommensurate spin-density wave (SDW) below its Néel temperature of 311 K and a commensurate charge-density wave (CDW). In this talk I will describe recent experiments probing the ultrafast coupling and control of the SDW and CDW dynamics in response to photoexcitation pumps probed by an X-ray free-electron laser (XFEL) [1,2]. We find that ultrafast suppression of the SDW order converts the static CDW into a dynamic coherent phonon where the amplitude can be further controlled by secondary optical pulses [1]. Further we show critical slowing of the recovery of the ordering near phase transition temperatures of the SDW/CDW order [2]. These results suggest new avenues for manipulating and researching the behavior of photoexcited states in charge and spin order systems out of equilibrium.

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Proximitized Superconductivity in Mn-Doped Bi_2Te_3 Topological Anomalous Quantum Hall Insulators

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3D topological insulators (TIs), such as bismuth telluride (Bi_2Te_3), can be characterized as materials of an insulating/semiconducting volume and topologically protected conductive surface states. The 2D films or exfoliated flakes (quasi 2D) of TIs feature topologically protected conductive one-dimensional boundaries. Moreover, as a consequence of spin-momentum locking the spin of an electron is tied to the direction in which it propagates. Doping a TI with magnetic ions breaks the time reversal symmetry leaving a single chiral state at each edge. Such behavior, called the Quantum Anomalous Hall Effect (QAHE), opens new possible applications.

The 2D/QAHE-TIs can offer exotic forms of superconductivity by exploiting the superconducting proximity effect. Strong spin-orbit coupling allows for the realization of an effective one-dimensional p-wave superconductor that is topological. If the 1D edge state of a QAHE-TIs is proximitized, a Majorana zero mode can be created by coupling two counter-propagating edges by the crossed Andreev reflection process through a superconductor. However, inducing superconducting correlations into a 2D electron gas in the quantum Hall regime is a long-standing challenge.

We discuss the results of magnetoresistance and Hall effect measurements at sub-Kelvin temperatures for 2D flakes of Mn-doped Bi_2Te_3 TI. The Fermi level is fine-tuned into a magnetic gap that opens at the Dirac point of the surface states as a result of a ferromagnetic order (the presence of magnetic dopants resulting in uncompensated net magnetization below 13 K was experimentally verified). The results for a ~30 nm thick flake show that exfoliation does not affect the magnetic properties of the flake and a fractional QAHE can be observed.

If the same flakes of Mn-doped Bi_2Te_3 are contacted to the Al contacts, our studies of U(I) suggest locally proximitized superconductivity below the critical temperature for Al. The resistance measured versus an external magnetic field and the current passing across such a hybrid structure are discussed in details.

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Nonreciprocity in Superconducting Spintronics

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The recent advances in the realization of non-reciprocal superconducting circuits will be reviewed. Starting from a general perspective, I'll show the key concepts to obtain nonreciprocal transport in superconductors, a condition usually forbidden by electron-hole symmetry constraints. As a practical example, I'll present the superconducting spintronic tunnel diode [1], a Shockley-like-diode operating at ultra-cryogenic temperatures. Thanks to the unusual interplay between superconductivity and ferromagnetism engineered Cu/EuS/Al tunnel junctions, a direction-selective electron transport is observed and quantified for charge rectification and thermoelectricity. Complementary to the dissipative Shockley-like-diodes are the supercurrent diodes [2]. This new concept of diodes is based on the dissiptionless supercurrent flowing preferentially in one direction of the device. In the manifold varieties of supercurrent diodes, I will present a sample experiment of a Josephson diode formed by a Nb/InSb/Nb junction [3]. Here the strong spin-orbit interaction of InSb combined with the external magnetic field allows the generation of unidirectional supercurrents based on the magneto-chiral anomalous phase. Promising near-future applications of nonreciprocal spintronic superconductors will be discussed ranging from the implementation of biasless ultrasensitive THz detectors, rectifiers, microwave switches and cryogenic low dissipation electronics.

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Nanoscale Control of Magnetism Via Phonons - A Microscopic Picture

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Strong photon pumping can drive matter to unique transient states otherwise inaccessible in equilibrium conditions, and even change its magnetic properties with the assistance of phonons coherently excited by the photon pulse. If these phonons are strongly coupled to the spin system, this may lead to a change of magnetic order. Phonons excited in a controlled way have indeed been shown to modify magnetic interactions so that the system turns from a collinear antiferromagnet to a canted weak ferromagnet. We investigate microscopic aspects of nonlinear spin-phonon interactions leading to magnetic order modifications. We have evaluated magnetic exchange interactions under the influence of specific non-equilibrium phonon populations for prospective systems, employing first principles calculation methods.
Circularly polarized phonons are capable of modifying or reorienting magnetic moments while the resulting magnetization direction can be controlled by the pulse helicity. These phonons have recently been shown to create transient magnetization in a paramagnet [1], and also reorient magnetization of a ferrimagnet in a heterostrucure The magnetic field due to chiral phonons has been ascribed to an effective coupling between the phonon angular momentum and the electron magnetic momentum [2]. We evaluate the spin and orbital contribution to magnetization induced in the presence of circular ionic motion, and extract the associated coupling described above on the level of first-principles description. This allows us to predict the induced magnetization values for different materials, and study which properties affect it.

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Quantum Spintronic Devices: Towards Full Control of Quantum Tunnelling

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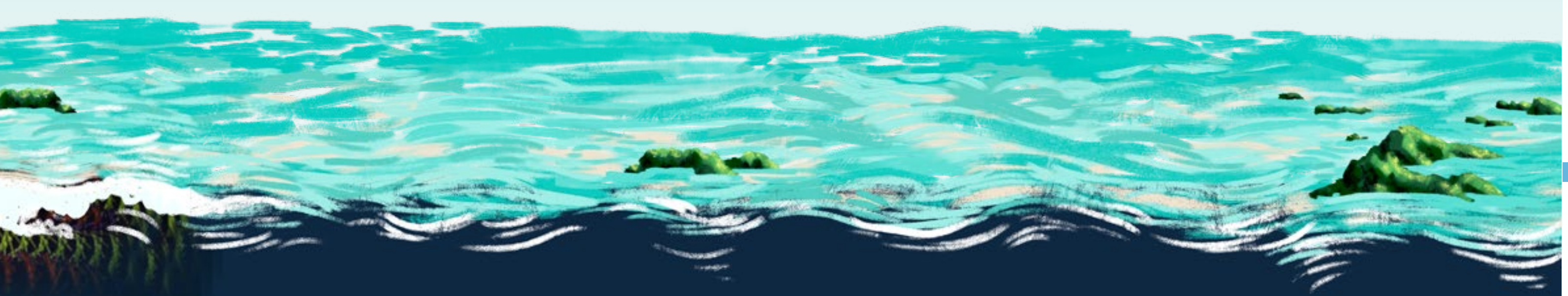
Up to now most quantum devices have been fabricated using superconductors, this requires extremely low temperatures (~ 4.2 K) or complex large optical setups. Because of this, it is challenging to scale up this technology for usage in commercial computers. The development of quantum spintronic devices that could be used for data storage, logic gates and magnetic sensors, and signal processing in the Terahertz regime, is an alternative. Using magnetic tunnel junctions (MTJ), by means of the exchange splitting of the electronic energy bands in ferromagnets, it has been possible to control the tunnelling current. However, it is still difficult to precisely tune the quantum tunnelling probability. To do so it is necessary to understand fundamental aspects of this effect such as tunnelling time, dissipation of energy during tunnelling processes and to find ways to control and change tunnelling barrier characteristics such as width and height by applying magnetic field. During this talk I will describe experimental devices and techniques we have been able to fabricate in our laboratory to investigate these issues using quantum tunnelling devices up to room temperature, maintaining quantum coherence.

INTERFACIAL SPIN-ORBIT EFFECTS & CHARGE CONVERSION

THURSDAY MORNING, 29TH

CHAIRS:
IGOR ŽUTIĆ
ERIC E. FULLERTON



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Giant and Anisotropic Charge Current Production in Double Rashba Interface Fe/Gr/Pt and Towards Pure Orbital Torque

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The Spin Hall effect (SHE) in 3D systems and Edelstein effect (EE) in 2D systems for the interconversion of charge current into spin current due to spin-orbit coupling (SOC) play a crucial role in today's spintronics. A gain for such an interconversion has been shown in 2D systems dominated by the Edelstein effect or its reciprocal, IEE such as on α-Sn in comparison with 3D systems such as Pt [1]. We have recently reported a giant and anisotropic value combining 3D systems such as Fe and Pt, and 2D systems such as epitaxial graphene [2]. We found a 34-fold gain in the double Rashba interface quantum system, Fe/Gr/Pt, with respect to the reference, Fe/Pt. This is in sharp contrast when the ferromagnetic layer is Co where there is a reduction of the overall efficiency in Co/Gr/Pt [2].
In a second part, we will show our results of orbital pumping in Ni/Cu/MgO. By THz emission it has been clearly shown that Ni is a good orbital current producer and an efficient conversion into charge current is obtained at the Cu/MgO interface. These studies are done on as-grown samples, and the quantification of the figure of merit for the interconversion efficiency is missing. After 4 lithography steps we obtain the desired integrated devices each with its coplanar waveguide antenna. Using orbital pumping on the order of GHz, we account for the efficiency of interconversion in Ni/Cu/MgO, among other systems.
Funding from EU-H2020-RISE project Ultra Thin Magneto Thermal Sensoring ULTIMATE-I grant ID 101007825, and ERC CoG project MAGNETALLIEN grant ID 101086807, among others, is gratefully acknowledged.

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The Toroidal Moments in Confined Nanomagnets and its Impact on Magnonics

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The nonreciprocity originated by dipolar coupling, electric currents, and Dzyaloshinskii-Moriya interactions are discussed in cases where the magnon propagation direction has a component parallel to the toroidal moment [1]. A criterion for calculating nonreciprocity is established, addressing the issue of correct origin selection based on compensated and uncompensated magnetizations. This criterion is then applied to various magnetic textures and nonreciprocal systems, with the calculations consistent with those reported in the literature [2-7] and predicting the existence of nonreciprocity in a more general manner. These results broaden the physical significance of the toroidal moment [8,9] and facilitate the identification and estimation of nonreciprocity in magnonic systems. This work also clarifies the interrelations between different definitions of the toroidal moment for confined magnetic structures, where a surface term arising from surface-bound currents connects these definitions without the need for time-averaging. Comparing these quantities applied to different magnetic textures demonstrates that they are always parallel but may differ in magnitude and sign. The discrepancy in the different definitions of the toroidal moment is deemed irrelevant since their direction, rather than its magnitude, primarily predicts the existence of magnon nonreciprocity.

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Interfaces with Graphene: An Amazing Playground for SpinOrbitronics

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The introduction of giant spin-orbit coupling (SOC) in the electronic bands of graphene via proximity with intercalated layers potentially allows the realization of highly efficient, electrically tunable, nonvolatile memories as well as opens up new pathways towards the realization of spintronic devices exploiting novel exotic electronic and magnetic states. In this work, we will examine the properties of Gr epitaxial layer interfaced with different materials and grown on heavy metal/insulating oxide supports.
When interfaces with *3d* ferromagnet (FM), monolayer Gr not only acts as efficient ion migration barrier, but also provides a strong orbital hybridization leading to an enhancement of the PMA driven by the orbital moment anisotropy, and an energy splitting of in-plane spin polarized Gr π bands, consistent with an Rashba-SOC at the Gr/Co interface, as evinced by element dependent and averaged surface/interface sensitive measurements provide evidence of [1].
By resorting to the additional intercalation of rare-earth materials, e.g. via *4f* europium doping, we demonstrate the possibility to generate single-spin polarized bands. The doping is controlled by Eu positioning, allowing for the formation of a localized single spin-polarized low-dispersive parabolic band if Eu is on top, and a π^* flat band with single spin character when Eu is intercalated underneath graphene [2].
The electronic and spin properties of SOC functionalized epitaxial Gr can then be exploited to efficiently control and tune spin-orbit torques and spin-charge interconversion, for example by activating strong Rashba interfaces, as Pt/Gr/FM (with FM=Co, Fe) or Gr/Eu/FM, to induce a magnetic moment in Gr, ultimately driving the appearance of non-trivial, exotic topological spin textures and emerging symmetry-broken phases, and enables the electrical control of the SOC driven.
Financial support AEI/MICINN PID2021-122980OB-C52 (ECLIPSE-ECoSOx), CNS2022-136143 (SPINCODE), CEX2020-001039-S, and from the “(MAD2D-CM)-UAM” is acknowledged.

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Unconventional Charge-To-Spin Conversion in Materials with Low Crystal Symmetry

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Materials that exhibit spin-orbit-related phenomena hold great potential for advancing memory and computing technologies beyond the limits of the von Neumann architecture. One interesting approach toward developing energy-efficient all-electric devices is the symmetry-based design of spintronic materials. In this talk, I will explore the properties of several recently (re-)discovered materials that reveal intriguing spin-orbit-related phenomena, as well as different methods for controlling spins. In particular, the use of symmetries in material design has proven to be a powerful strategy for spin manipulation and enabling unconventional configurations of charge-to-spin conversion, helping in the generation of highly efficient spin-orbit torques. Additionally, I will discuss the potential of chiral crystals that exhibit collinear charge-to-spin conversion, similar to chirality-induced spin selectivity observed in molecules. Examples such as elemental tellurium, the Weyl semimetal $TaSi_2$, and the B20 compound OsSi illustrate efficient charge-to-spin conversion and persistent spin textures, potentially contributing to extended spin lifetimes. Another intriguing class of materials are chiral altermagnets, where time-reversal even and odd charge-to-spin conversion provides new avenues for spin control and transport. In summary, materials with strong spin-orbit coupling and low crystal symmetry—especially chiral crystals—offer promising solutions to one of the most critical challenges of spintronics: achieving high charge-to-spin conversion efficiency while maintaining long spin lifetimes.

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Control Of Metastable States in Phase-Separated Pr-doped Manganites

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Doped manganites are correlated complex oxides that could exhibit electronic phase separation. This is caused by the interruption of the first-order transition between a ferromagnetic metallic (FMM) and an insulator charge-ordered phase (COI). The stabilization of phase-separated clusters is due to quenched disorder, typically associated with chemical doping. Electronic phase separation yields exotic transport and magnetic properties, mainly because it corresponds to a non-ergodic system where unexpected metastable states could be present. The excitation of metastable states could be achieved by optical, magnetic, or electric means. More widely known states are (i) fluid phase separation, where boundaries between FMM and COI phases are unpinned, and (ii) static phase separation produced by supercooling of the fluid state, resulting in a state with glassy behavior. However, multiple hidden states could be present, such as intermediate states between the FMM and COI phases or even electronic liquid-crystal phases. In this talk, I will present a thorough study of the phase separation phenomenon in $La_{5/8-x}Pr_xCa_{3/8}MnO_3$(x = 0.40) using an integrated approach of spin resonance measurements [1-2] alongside susceptibility and magnetotransport. It is demonstrated how separated phases coexist with additional hidden states that are revealed by magnetic resonance. Results are contrasted with additional magnetometry measurements. Finally, the possibility of controlling the phase separation phenomenon via bias voltage and the emergence of hidden states is discussed [3].

Work in collaboration with Diego Carranza-Celis, Ali C. Basaran, Pavel Salev, Ivan K. Schuller. FUNDING: J.G.R. and D.C-C. acknowledge support from Facultad de Ciencias and Vicerrectoría de investigaciones Universidad de los Andes, Convocatoria Facultad de Ciencias, proyecto código INV-2022-150-2627. This work was also supported by project code INV-2021-128-2313 of the Faculty of Science at Universidad de los Andes, Bogotá, Colombia. The research at UCSD was supported by the Department of Energy's Office of Basic Energy Science, under grant # DE-FG02-87ER45332.

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Ferroelectric Control Of Ultrathin Ferromagnets By Proximity With $Hf_{0.5}Zr_{0.5}O_2$

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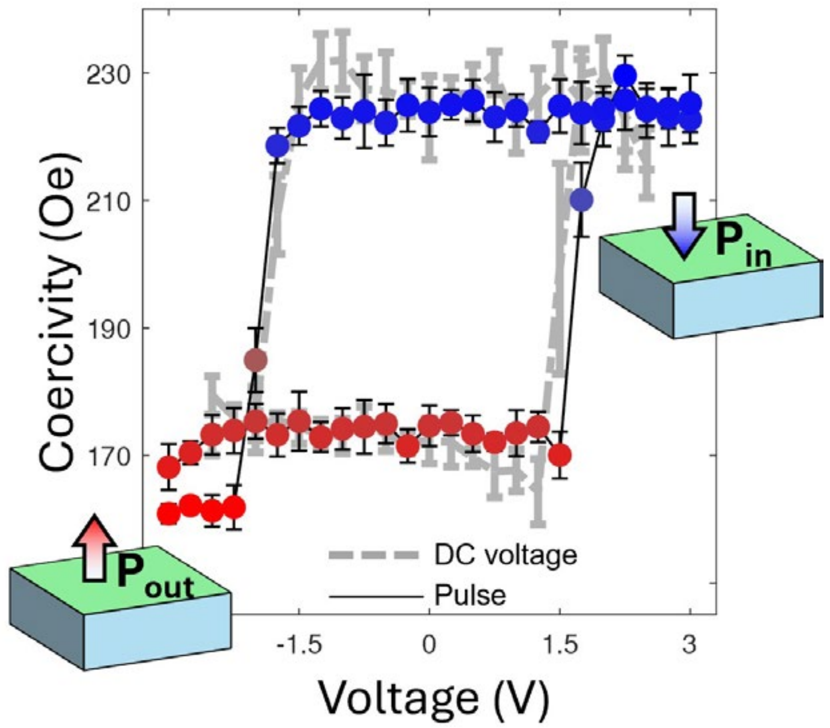
Magnetoelectric multiferroics are promising candidates for energy-efficient in-memory computing. Hafnia stands out as a CMOS-compatible ferroelectric allowing for non-volatile silicon-compatible spin-orbit devices [1, 2]. Here we present the excellent magnetoelectric properties and the occurrence of chiral magnetism in perpendicularly magnetized cobalt ultrathin films on Zr-doped hafnia ($Hf_{0.5}Zr_{0.5}O_2$ - HZO) grown on Si. We show the conditions for achieving perpendicular magnetic anisotropy, with optimal magnetic and ferroelectric properties (saturation polarization up to 20 μC/cm^2, long endurance and cyclability, magnetization close to that of bulk cobalt). The ferroelectric control of magnetism is studied by in-operando magneto-optical Kerr microscopy and Brillouin light scattering on micro-capacitors. The figure shows the purely ferroelectric control of the magnetic coercivity versus ferroelectric state, with a negligible role of the voltage-controlled magnetic anisotropy. Density functional theory calculations provides insights on the coupling mechanism and suggest novel strategies for the manipulation of magnetization and magnetic textures through currents.

The proximity of HZO with an ultrathin perpendicularly magnetized film represent a promising platform for the non-volatile, electric control of magnetization and chiral magnetism through voltages and current, with potential for efficient beyond-CMOS computing. C.R. acknowledges the PRIN 2022 project SORBET (grant no. 2022ZY8HJY), while M. K. the PRIN 2022 project MetroSpin (grant no. 2022SAYARY) funded by MUR.



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Interfacial Dzyaloshinskii-Moriya Interaction Amplitude Modulation and Sign Inversion by Work Function Engineering in Co-Based Metallic Multilayers

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The Dzyaloshinskii-Moriya interaction has received great attention in the last decade due to its importance in stabilizing chiral magnetic textures such as Néel domain walls, 2D magnetic skyrmions and antiskyrmions, or novel 3D chiral textures [1]. However, the mechanism of the antisymmetric interaction in thin films is not fully understood. Our objective in the present study is to unravel the different contributions at the origin of amplitude of the DMI beyond the Fert-Levy 3-site model.

We observe in Pt|Co|*M* (*M* = Metal) [2, 3] that the DMI strength as function of ferromagnetic layer thickness (D_s) has been related to various intrinsic material properties i.e. atomic number, the electronegativity and the work function difference (Δϕ) between Co and top metal layer [Fig.1(a)], finding the best (linear) correlation with the latter.

We go one step further analyzing if the linear correlation is universal regardless of the bottom layer. Asymmetric $(Pt|Co|M)_n$ and $(Pd|Co|M)_n$ have been grown with a moderate number of repetitions (n = 3, 4, 5 and 6). The strength of Ds has been determined by analytical (lambda-delta-psi) [4] model and MuMax3 simulations. We can conclude that the DMI amplitude is found to be constant in multilayers with number of repetitions up to n = 6. Moreover, the linearity vs Δϕ is preserved for both Pt and Pd-based systems [Fig.1(b)].

Finally, we show how keeping spin-orbit strength, identical stacking layers and thicknesses we can modify the DMI sign by varying the surface potential with the grain orientation of the bottom film. Replacing Pt by W, the total DMI amplitude and Δϕ will be much smaller. Moreover, completing the trilayer with Cu, Δϕ=0, we assume that all the interfacial potential gradient contribution arises from the W|Co bottom interface. Therefore, by varying the W orientation from 110 (Δϕ ~ +0.22 eV) to 100 (Δϕ ~ -0.34 eV) we can invert Δϕ and thus the sign of the DMI [Fig.1(c)]. In the same way a variety of interfacial effects can be engineering with Δϕ, i.e. field-like torque. Where depending on the orientation of the W its amplitude can be doubled [Fig.1(d)].

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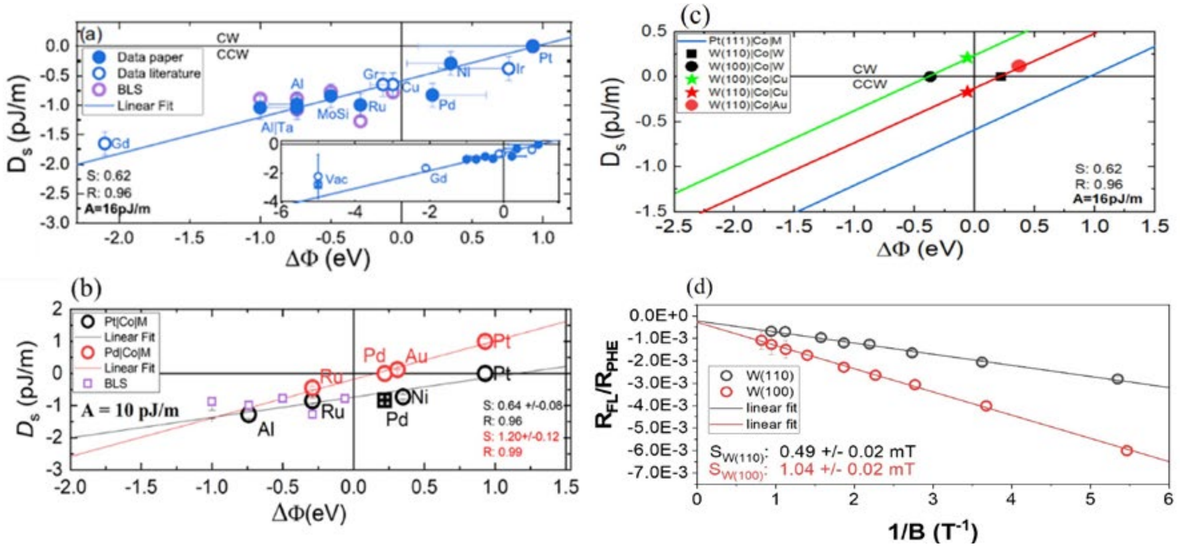

Figure 1 (a) D_s vs Δϕ of Pt|Co|M trilyers (b) D_s vs Δϕ of Pt|Co|M and Pd|Co|M multilayers with n=3 to 6. (c) D_s vs Δϕ of W|Co|M with W 100 (green) and 110 (red), (d) FL torque vs 1/B with W 100 (red) and 110 (black)

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Exchange Coupling Effects on the Magnetotransport Properties of Ni-Nanoparticle-Decorated Graphene

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We characterize the effect of ferromagnetic nickel nanoparticles (size around 6nm) on the magnetotransport properties of chemical-vapor-deposited (CVD) graphene. The nanoparticles were formed by thermal annealing of a thin Ni film evaporated on top of a graphene ribbon. The magnetoresistance (MR) was measured while sweeping the magnetic field at different temperatures and compared against measurements performed on pristine graphene. For our analysis, we fitted the MR curves in terms of existing models for the electronic transport in graphene. Our results show that, in the presence of Ni nanoparticles, the usually observed zero-field peak of resistivity produced by weak localization is widely suppressed (by a factor of around 3), most likely due to the reduction of the dephasing time because of the increase in magnetic scattering at small fields. On the other hand, the high-field magnetoresistance is amplified by the contribution of a large effective interaction field, arising from a strong magnetic interaction of the graphene with the saturated magnetization of Ni. These results are discussed in terms of a local exchange coupling, J~6meV, between the graphene p electrons and the 3d magnetic moment of nickel. Interestingly, this magnetic coupling does not affect the intrinsic transport parameters of graphene, such as the mobility and transport scattering rate, which remain the same with and without Ni nanoparticles, indicating that the changes in the magnetotransport properties have a purely magnetic origin.

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Magnetization Dynamics in Artificial Spin Ice Based on Magnetic Tunnel Junctions

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Magnetic frustration significantly alters the dynamics of magnetostatically coupled nanomagnets. Artificial Spin Ice (ASI), simultaneous frustration of multiple nanomagnets leads to complex and long-range behavior [1, 2], including nonequilibrium excitations known as Emergent Magnetic Monopoles (EMMs). Here the nanomagnets are free layers of magnetic tunnel junctions (MTJs) with in-plane magnetization and a pinned synthetic antiferromagnet (SAF) fixed layer. This enables faster dynamics and has potential for electrical rather than magnetic field control. The focus here is on square lattice ASI made from circular 60 nm diameter MTJs with a 30 nm spacing. The spontaneous magnetization directions of the MTJs follow a pattern similar to that of square lattice ASI made from larger elongated nanomagnets [1] except that the moment directions vary on a millisecond time scale. The symmetry is broken by a small (8 Oe) coupling field between the free layer nanomagnets and unpatterned fixed layer. This symmetry breaking also means that half of the nanomagnets have moments parallel (0°) or antiparallel (180°) to an easy axis, and show typical two level telegraphing, while the other half have moments more or less aligned along the hard axis. The hard axis nanomagnets have time-dependent canting, with an average angle of ± 90° but with significant deviations that depend on the local field due to neighboring nanomagnets. A simple micromagnetics model was used to calculate these local fields for different microstates, estimate canting angles and relative energies and to predict common pathways for relaxation based on spin flip of a single neighbor. Nine of the eleven lowest predicted states are observed experimentally.

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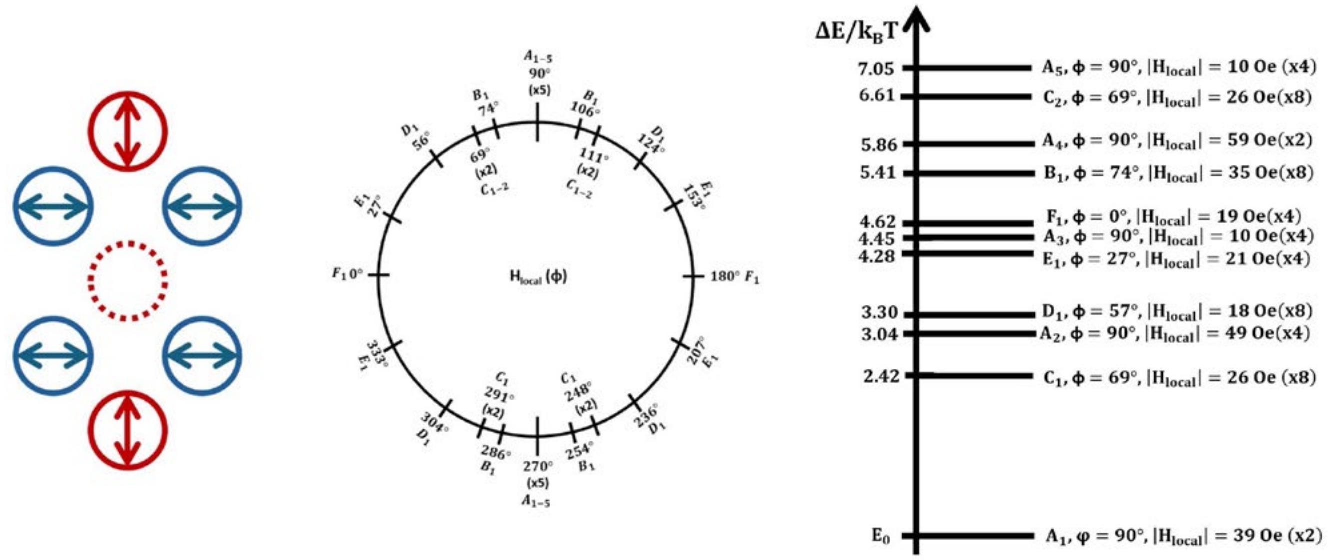
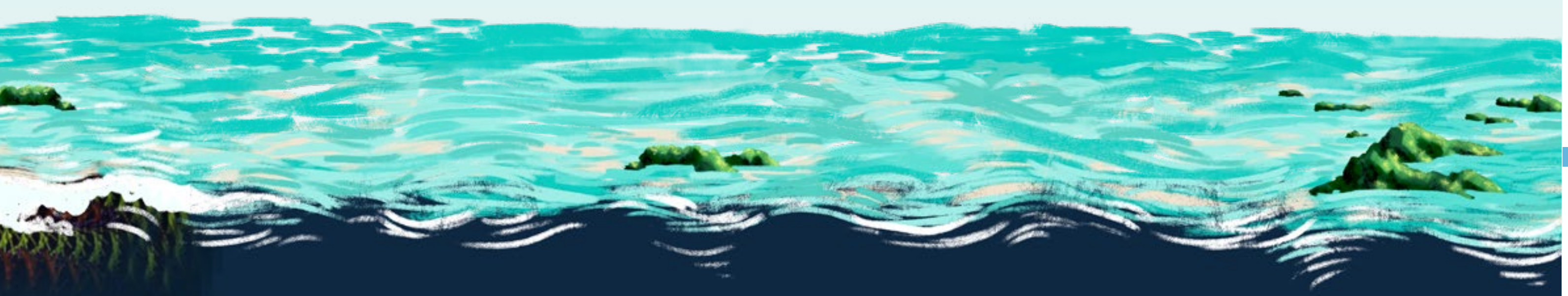


MAGNETISM IN LOW-DIMENSIONAL & VAN DER WAALS SYSTEMS

THURSDAY AFTERNOON, 29TH

CHAIRS:
STEPHANE MANGIN
JAGODA SLAWIŃSKA



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A Chemical Approach to 2D Magnetism in Van Der Waals Materials

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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] 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 properties 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] create new Janus 2D magnetic materials based in MPS_3 in order to answer: what are the effects of mirror broken symmetry on the magnetic properties? [6], and finally, we will delve into the origin of above-room-temperature magnetism in Fe_3GaTe_2 [7].

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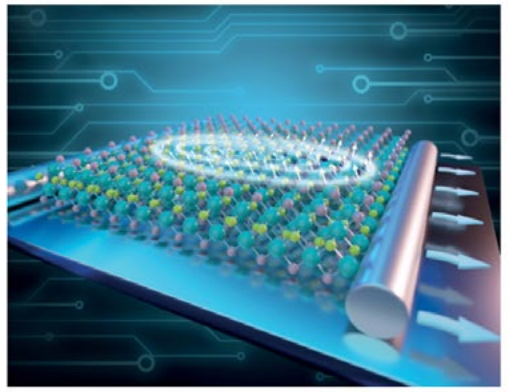

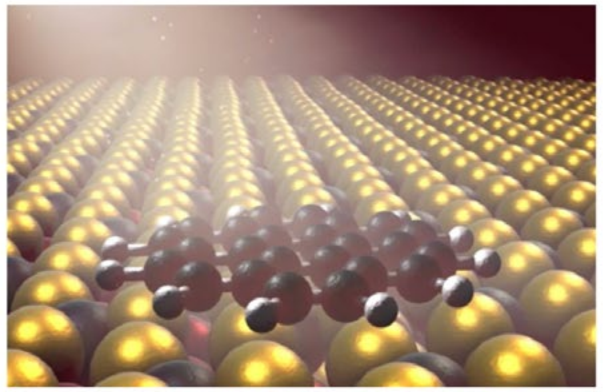

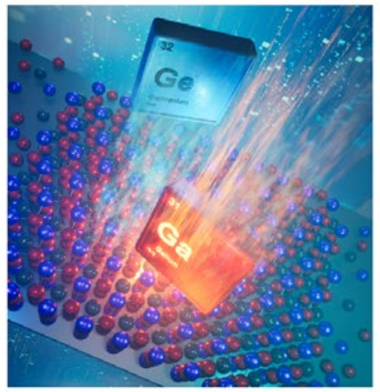

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Spin Transport and Magnetization Dynamics in Ultra-Low Damping $Co_{100-X}Fe_X$/Ta Bilayers

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The manipulation of the electron charge and the spin for the development of more efficient spintronic devices has been a topic of increasing interest in recent years. In particular, systems based on metallic ferromagnets with very low damping, a parameter that determines the speed and energy consumption during the operation of modern electronic devices, are excellent candidates for spin current injection. Recently, it has been reported that the $Co_{25}Fe_{75}$ alloy exhibits low magnetic damping, due to the features of the band structure in $Co_{100-x}Fe_x$ alloys. In this talk I will discuss the magnetic and spin transport characterization in $Co_{100-x}Fe_x$/HM (HM= Pt, Ta) bilayer systems, with x = 65, 70, 75, 80, 85, grown on MgO (100) single crystal substrates. Characterization by Kerr magnetometry, transmission electron microscopy, magnetotransport and ferromagnetic resonance allowed to determine that the $Co_{100-x}Fe_x$ films grow epitaxially with a cubic structure rotated 45° with respect to the (100) direction of the MgO substrate plane, determining the magnetization easy axis. We also investigate the angular dependence of the anisotropic magnetoresistance (AMR) of the epitaxial $Co_{100-x}Fe_x$ films with the applied current parallel and perpendicular to the easy and hard magnetization axes to discuss the magnetization process and to evaluate the tunability of the AMR. Finally, spin transport characterization using spin pumping and inverse spin Hall effect allowed the detection of induced voltages associated to the conversion of spin current to charge current, of the order of 100 µV ($Fe_{80}Co_{20}$), demonstrating efficient conversion of spin current to charge current in Ta layers.

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Ferromagnetic Domain Wall Conductivity in A1 FePt as Self-Assembled Structures for in-Materio Signal Processing

D. Goijman[1,2], J. Milano[1,3], L. Saba[3], D. Pérez Morelo[1,3], M. Granada[1,3], L. Avilés-Félix[1,3], and Cynthia P. Quinteros[4]

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In-materio signal processing is an attempt to project into hardware some of the computational operations currently implemented in software. It requires exploring alternative substrates to CMOS-based ones capable of computing.
In this framework, one aspect reveals the key: if complexity is desired, scale is important. Top-down assembly strategies, in which trillions of structures must be individually defined and interconnected tens of thousands of times, are unsuitable to achieve that required connectivity. On the contrary, self-assemblies appear to be an interesting contender for mitigating such a difficulty. Defined as collective structures that assemble spontaneously, they comprise multiple, simple, and imperfect units whose nature depends on the intrinsic material and/or substrate properties. Silver nanowire networks [1], as well as ferromagnetic [2] and ferroelectric domain walls, are examples of these objects.
In this talk, I will comment on our recent progress on those three types of experimental self-assemblies. Particular emphasis will be made on the magneto-resistance properties of ferromagnetic stripes in the chemically disordered A1-phase of FePt at different temperatures. Specifically, after identifying the multiple contributions to the conductivity, the impact of the domain wall conductivity on the macroscopic electrical response is analyzed under different configurations of externally applied magnetic fields.

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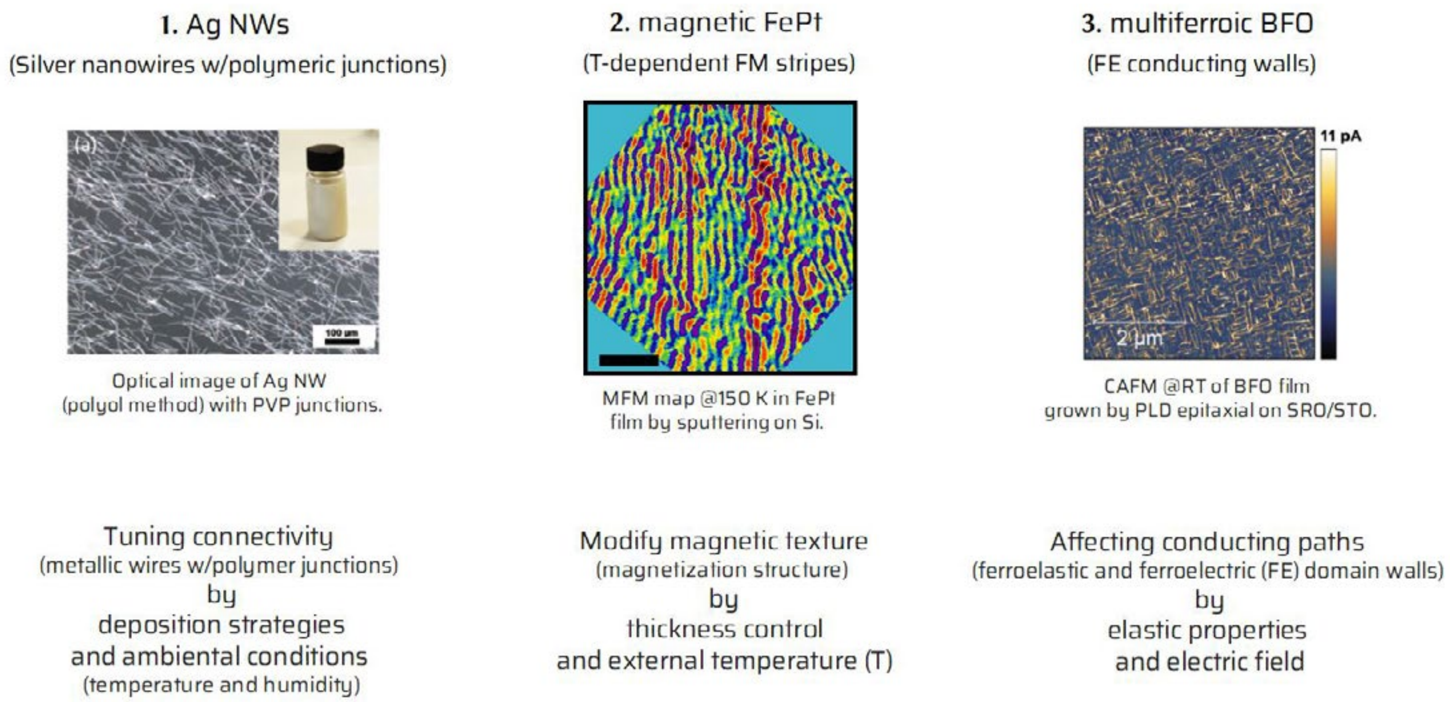

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Extrinsic Orbital Hall Effect and Orbital Relaxation in Mesoscopic Devices

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The first experimental realizations of the orbital Hall effect (OHE) opened the possibility of using a greater diversity of materials beyond the heavy metals frequently used. In addition, they raised new questions that have not yet been fully answered, such as the effect of disorder on the orbital Hall current (OHC) [1,2]. In this work, we designed two mesoscopic devices with orbital angular momentum connecting to four semi-infinite terminals submitted to voltages V_i. The panel left is a square device with dimension LxL, where L is the length. The panel right is a rectangular device with dimension L_0xL, where L_0 is a fixed longitudinal length, and L is the transversal length. The Anderson disorder and spin-orbital coupling are introduced only in the hatched region. We use the Landauer-Büttiker and tight-binding models for a square lattice with four orbitals to calculate the longitudinal charge current conversion into transverse OHC numerically [1]. First, we analyze the OHC as a function of disorder strength through a square device with different lengths L. The OHC increases with the increase in disorder strength, indicating that extrinsic effects dominate conversion. After that, the OHC decreases with increased disorder strength because of Anderson localization. Finally, we analyze the OHC as a function of L through a rectangular device. The OHC decreases exponentially with L for different values of disorder strength. However, the orbital Hall angle is always constant, which means that the localization of OHC has the same localization length as the charge current.

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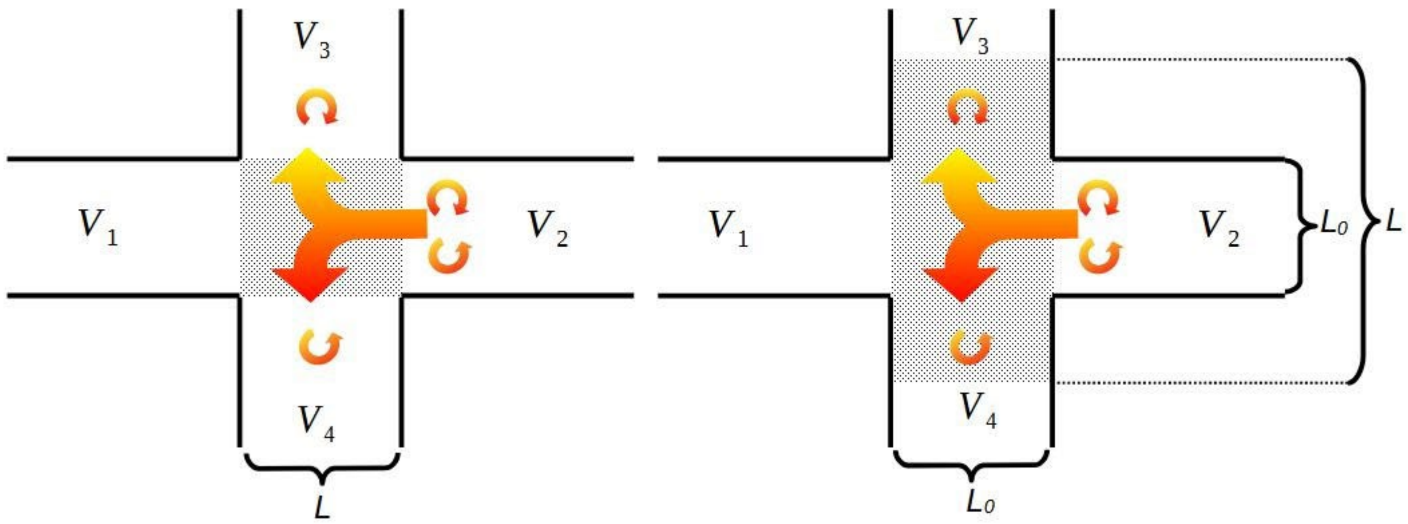

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Moiré Magnetism and Moiré Excitons in Twisted CrSBr Bilayers

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Moiré excitons and moiré magnetism are essential to semiconducting van der Waals magnets. In this work, we perform a comprehensive first-principles study to elucidate the interplay of electronic excitation and magnetism in twisted magnetic CrSBr bilayers [1]. We predict a twist-induced quantum phase transition for interlayer magnetic coupling and estimate the critical twist angle below which moiré magnetism with mixed ferromagnetic and antiferromagnetic domains could emerge. Localized one-dimensional moiré excitons are stable if the interlayer coupling is ferromagnetic and become unstable if the coupling turns to antiferromagnetic. Exciton energy modulation by magnons is estimated and dependence of exciton oscillator strength on the twist angle and interlayer coupling is analyzed. An orthogonally twisted bilayer is revealed to exhibit layer-dependent, anisotropic optical transitions. Electric field is shown to induce net magnetic moments in moiré excitons, endowing them with exceedingly long lifetimes. Our work lays the foundation for using magnetic moiré bilayers in spintronic, optoelectronic and quantum information applications.

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Self-Assembled Magneto-Resistive Multilayer Nanowires

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Complex nano-structuring routines on magnetic multilayers are frequently applied in data storage and sensor technology to functionalize devices via shape anisotropy. Here we test, if sputter deposition onto nano-facetted surfaces can be applied to form self-assembled, high-quality nanowires with adjustable size and anisotropy. Fe/Cr superlattices with intended antiferromagnetic order were deposited in oblique incidence (Fig. a) onto a nano-facetted Al_2O_3 wafer (facet height 25 nm) where the facet morphology was adjusted via high-T annealing [1]. Due to a shadowing effect separated nanowires are expected to form on the surface. A precise nanoscopic characterization, however, is challenging with lab-based techniques. To investigate the structural quality and magnetic properties of the wires we perform conventional and nuclear grazing incidence small angle x-ray scattering [2]. While GISAXS (b) is used to extract the relevant parameters of the multilayer morphology, nuclear GISAXS at the Fe resonance is applied to determine the spin structure of the wires. Fig. c) shows resonant detector line scans along the multilayer GISAXS pattern. In addition to the structural Bragg peak, magnetic superstructure peaks appear, whose intensity is coupled to the strength of antiferromagnetic order. Field-dependent hysteresis curves at these scattering maxima were taken to extract the magnetic reversal. These elegant ways for flexible multilayer nanowire formation and novel characterization are highly interesting for potential sensor and device application requiring tunable anisotropies.

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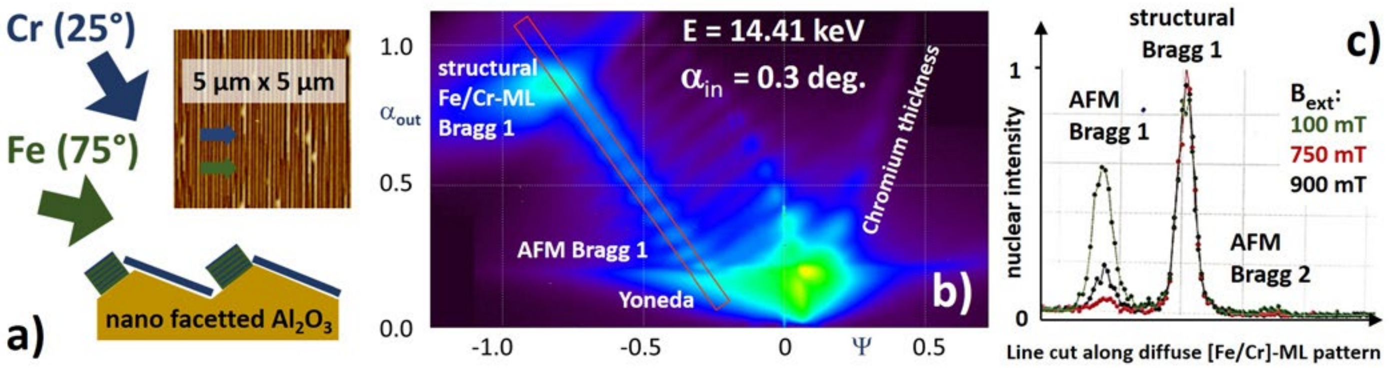

ALEXANDER GRAY

Design and Ultrafast Control of Emergent Interfacial Ferromagnetism in Complex-Oxide Superlattices

Jay R. Paudel[1], Abigail M. Derrico[1], Jak Chakhalian[2], Nicola A. Spaldin[3], Stefano Bonetti[4], and Alexander Gray[1]

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Exploring emergent interfacial ferromagnetism in complex-oxide superlattices offers a promising route to engineer low-dimensional magnetic states for next-generation spintronics. In this talk, we present findings on the $CaMnO_3/CaRuO_3$ and $LaNiO_3/CaMnO_3$ superlattices, where unique ferromagnetic ground states arise at interfaces between nonferromagnetic layers. Using synchrotron-based X-ray spectroscopy, density functional theory calculations, and ultrafast THz-pump tr-MOKE spectroscopy, we probe the atomic-scale magnetic profiles and demonstrate precise tuning of magnetic moments by layer thickness, structure, and controlled point defects [1,2,3]. Time-resolved magneto-optic Kerr effect spectroscopy further reveals dynamic interactions between electronic and magnetic states under intense THz fields, shedding light on ultrafast processes that influence interface magnetism [3]. This work highlights potential pathways for developing tunable magnetic interfaces and advancing energy-efficient spintronic devices.

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CHIRALITY, TOPOLOGY, & NONRECIPROCAL SPIN TRANSPORT

FRIDAY, 30TH

CHAIRS:
JOSÉ J. BALDOVÍ
AXEL HOFFMANN

TERUO ONO

Superconducting Diode Effect

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The diode effect is fundamental to electronic devices and is widely used in rectifiers and AC-DC converters. However, conventional diodes suffer from energy loss due to finite resistance. We found the superconducting diode effect (SDE) in Nb/V/Ta superlattices with a polar structure, which is the ultimate diode effect exhibiting a superconducting state in one direction and a normal state in the other [1-3]. The SDE can be considered as the nonreciprocity of the critical current for the metal-superconductor transition. We have also found the reverse effect, i.e., the nonreciprocal critical magnetic field under the application of supercurrent [4]. We also found that the polarity of the superconducting diode shows a sign reversal when the magnetic field is increased [5], which can be considered as the crossover and phase transitions of the theoretically predicted finite-momentum pairing states [6, 7]. SDE in Nb/V/Ta superlattices requires the application of an external magnetic field to break the time-reversal symmetry, which is a drawback in applications. Recently, we have succeeded in demonstrating zero-field SDE by introducing ferromagnetic layers into superlattices [8, 9]. The polarity of the SDE is controlled by the magnetization direction of the ferromagnetic layer, leading to the development of novel non-volatile memories and logic circuits with ultra-low power consumption.
This work was partly supported by JSPS KAKENHI Grant Numbers (18H04225, 18H01178, 18H05227, 20H05665, 20H05159, 21K18145), MEXT Initiative to Establish Next-generation Novel Integrated Circuits Centers (X-NICS) Grant Number JPJ011438, the Cooperative Research Project Program of the Research Institute of Electrical Communication, Tohoku University, and the Collaborative Research Program of the Institute for Chemical Research, Kyoto University.

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Dynamics of Magnets and Ferroelectrics

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The duality between electric and magnetic dipoles in electromagnetism only partly applies to condensed matter. In particular, the elementary excitations of the magnetic and ferroelectric orders, namely magnons and ferrons, respectively, have received asymmetric attention from the condensed matter community in the past [1]. I will introduce and summarize the current state of magnonics and the budding field of "ferronics". The introduction of dipole-carrying elementary excitations allows the modeling of many observables and potentially leads to applications in thermal, information, and communication technologies. I will introduce these topics and present new results.

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Chiral-induced Spin Selectivity: A Minimal Model

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In this talk, we present a comprehensive model for chirally induced spin-selectivity (CISS) as an intrinsic effect in chiral molecules[1]. We integrate findings from forward scattering in gas-phase experiments, observations of photoelectron behavior in chiral self-assembled monolayers, and recent results from two-terminal transport systems. Key experimental components necessary for CISS to emerge include: (i) molecular chirality, whether point-based, helical, or configurational; (ii) spin-orbit coupling as a spin-sensitive interaction arising from atomic properties; (iii) decoherence, serving as a mechanism for breaking time-reversal symmetry and circumventing reciprocity in linear transport; and (iv) tunneling, which determines the intensity of the spin polarization. While this model does not exclude alternative mechanisms—such as molecule-contact or substrate interactions that may also generate spin effects—it focuses on universally applicable conditions. Lastly, we examine recent developments that suggest CISS plays a role in enantiomeric selection, coherent electron transfer, and spin-influenced chiroptical phenomena.

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SILVIA VIOLA KUSMINSKIY

Cavity Magnonics: Fundamentals and Applications

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The field of Cavity Magnonics strives to control the elementary excitation of magnetic materials, denominated magnons, to the level of the single quanta, and to interface them coherently to other elementary excitation such as photons or phonons. The recent developments in this field, with proof of concept experiments such as a single-magnon detector, have opened the door for hybrid quantum systems based on magnetic materials. This can allow us to explore magnetism in new ways and regimes, has the potential of unraveling quantum phenomena at unprecedented scales, and could lead to breakthroughs for quantum technologies. In this talk, I will introduce the field and present some theoretical results from our group which aim to push the boundaries of the current state of the art.

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Magnetization Dynamics Driven by Displacement Currents Across a Magnetic Tunnel Junction

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Magnetic tunnel junctions (MTJs) are key components in various spintronics applications. They are highly efficient for reading and writing data due to their rapid response, making them ideal for high-speed, GHz-level memory technologies. Beyond data storage, MTJs play a significant role in radio frequency (RF) spintronics, offering promising applications in signal processing, wireless communication, and neuromorphic technologies. Therefore, understanding any frequency-dependent physical effects in MTJs holds both practical and fundamental importance.

MTJs behave like leaky capacitors, and the transport across them can be influenced by frequency-dependent capacitance-related effects. In our work [1], studying specially designed CoFeB/MgO/CoFeB-based MTJ devices (Fig. a), we present a groundbreaking study of magnetization dynamics induced by displacement currents across an MTJ capacitor. First, we optimized the MTJ fabrication to achieve large tunnel magnetoresistance (Fig. b). Using time-resolved MOKE measurements (Fig. c), we discovered that substantial displacement currents, in the mA's range, flow through the MTJ circuit at GHz frequencies. This current generates Oersted fields and spin-orbit torque-induced magnetization dynamics. Notably, this displacement current does not cause charge to flow across the MgO barrier, posing minimal risk of barrier breakdown in MTJ devices. These findings reveal the potential of MTJs for use in high-frequency, high-current conditions, paving the way for more durable and efficient MTJ devices.

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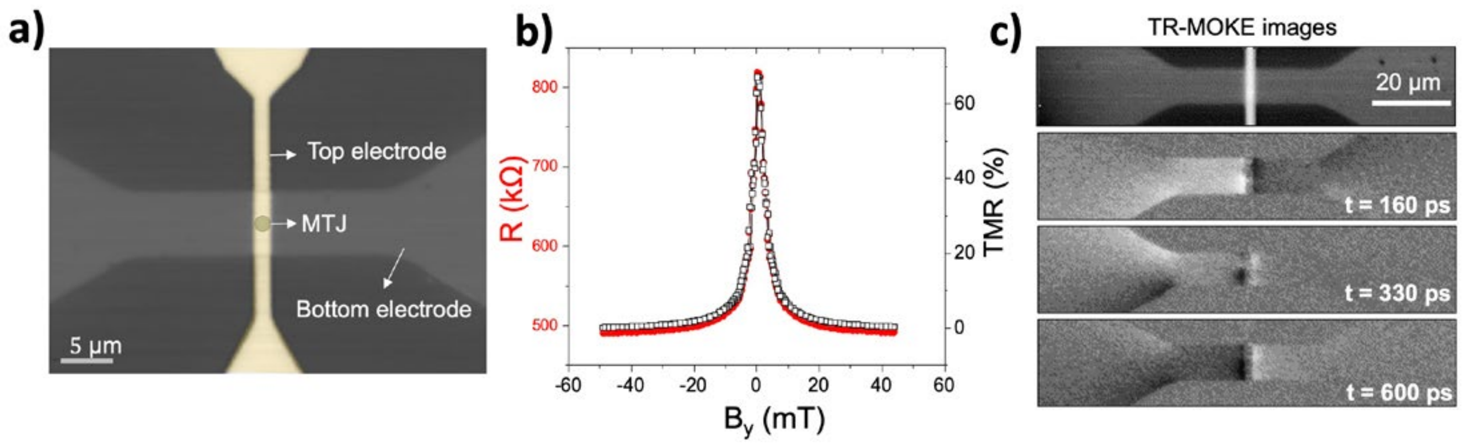

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Theory of Spin Polarizations Induced by Chiral Phonons

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Phonons can have rotational motions in some materials. Such phonons are called chiral phonons. For example, in systems with chiral structure such as tellurium, phonon modes possess angular momenta. We study novel phenomena associated with phonon angular momentum by using an analogy to electron spins. We have theoretically shown that chiral phonons induce spin magnetization in electronic systems [1]. This phenomenon is caused by dynamic modulation of electronics states by chiral phonons, which induces a spin polarization. Furthermore, in ferromagnets and antiferromagnets, we found that chiral phonons induce changes in magnon excitations [2]. This shows that chiral phonons can serve as an effective magnetic field for electrons and magnons [1,2], and this scenario can be a microscopic mechanism for spin-rotation coupling. We also demonstrate the similar physics of the coupling between the surface acoustic wave and the magnetostatic waves.

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Combined Bottom-Up and Top-Down Approach for Highly Ordered One-Dimensional Composite Nanostructures for Spin Insulatronics

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Engineering magnetic proximity effects-based devices requires developing efficient magnetic insulators. In particular, insulators, where magnetic phases show dramatic changes in texture on the nanometric level, could allow us to tune the proximity-induced exchange splitting at such distances. In this paper, we report the fabrication and characterization of highly ordered two-dimensional arrays of $LaFeO_3$ (LFO)–$CoFe_2O_4$ (CFO) biphasic magnetic nanowires, grown on silicon substrates using a unique combination of bottom-up and top-down synthesis approaches. The regularity of the patterns was confirmed using atomic force microscopy and scanning electron microscopy techniques, whereas magnetic force microscopy images established the magnetic homogeneity of the patterned nanowires and absence of any magnetic debris between the wires. Transmission electron microscopy shows a close spatial correlation between the LFO and CFO phases, indicating strong grain-to-grain interfacial coupling, intrinsically different from the usual core–shell structures. Magnetic hysteresis loops reveal the ferrimagnetic nature of the composites up to room temperature and the presence of a strong magnetic coupling between the two phases, and electrical transport measurements demonstrate the strong insulating behavior of the LFO–CFO composite, which is found to be governed by Mott-variable range hopping conduction mechanisms. A shift in the Raman modes in the composite sample compared to those of pure CFO suggests the existence of strain-mediated elastic coupling between the two phases in the composite sample. Our work offers ordered composite nanowires with strong interfacial coupling between the two phases that can be directly integrated for developing multiphase spin insulatronic devices and emergent magnetic interfaces. [1]

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Bimerons in Magnetic Topological Materials

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I will discuss topological magnetic textures, such as skyrmions, half-skyrmions (merons), and bimerons, which constitute tiny whirls in the magnetic order. They are promising candidates as information carriers for next generation electronics, as they can be efficiently propelled at very high velocities employing current-induced spin torques. First, I will talk about anti/bimerons [1] in ferromagnetic systems coupled to heavy metals and topological materials. Then I will show that antiferromagnets can also host a variety of these textures, which have gained significant attention because of their potential for terahertz dynamics, deflection free motion, and improved size scaling due to the absence of stray fields. Finally, I will demonstrate that topological spin textures, merons and antimerons, can be generated at room temperature and reversibly moved using electrical pulses in thin film CuMnAs, a semimetallic antiferromagnet that is a test-bed system for spintronic applications [2].

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Topological Spin-Torque Diode Effect in Skyrmion-Based Magnetic Tunnel Junctions

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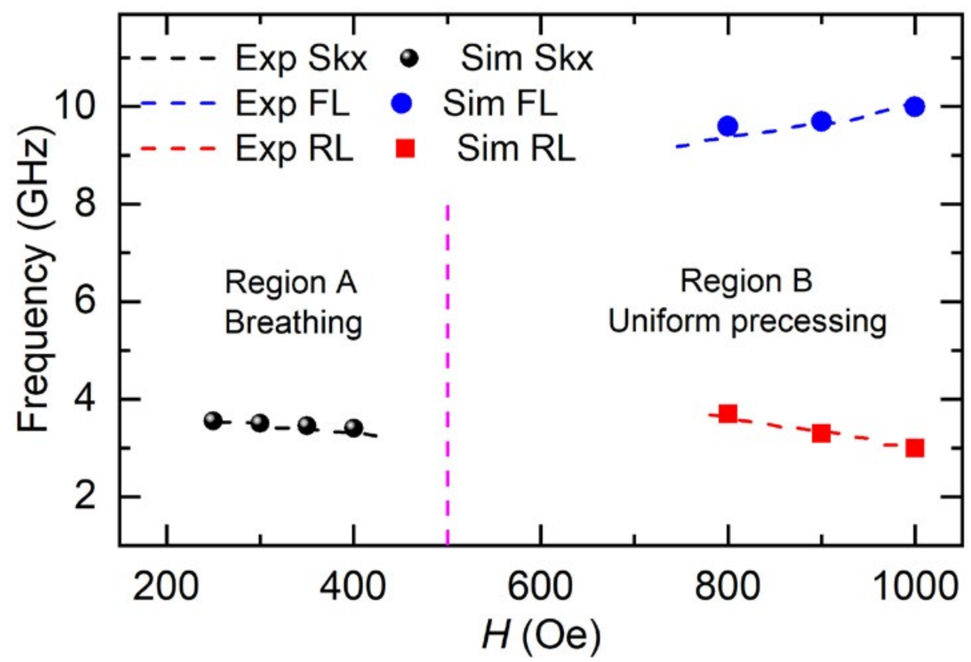
The recent room-temperature observation of skyrmions in magnetic tunnel junctions (MTJs) [1] has opened the way to the combination of Spintronics and Topology to expand the possible applications of skyrmions. Here, we design MTJ devices hosting magnetic skyrmions at room temperature with a diameter of less than 300nm [2]. We perform experimental spin-torque diode measurements, by which we identify three modes as a function of frequency and applied external field (see Figure below): 1 mode at frequency of 4 GHz and low field, which we refer to the skyrmion breathing mode; 1 mode at frequency of 5 GHz at high field with red-shift we associate to the reference layer (RL) dynamics of the MTJ; and 1 mode at frequency of 8 GHz at high field with blue shift we relate to the uniform dynamics of the free layer (FL). To confirm the origin of these modes (i), we use two strategies. One is to grow an MTJ without the skyrmion-hosting layer. The second is to perform state-of-the art micromagnetic simulations of the whole device magnetic stack with layer-dependent parameters and direct and forward spin-transfer torque in the free and reference layer of the MTJ respectively. By engineering the material properties of the MTJ free layer and of the skyrmionic layer, the simulations confirm, both qualitatively and quantitatively, the different origin of the three modes.



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Strong Nonreciprocity of Magnetoelastic Waves in Non-Collinear Magnetic Layered Structures

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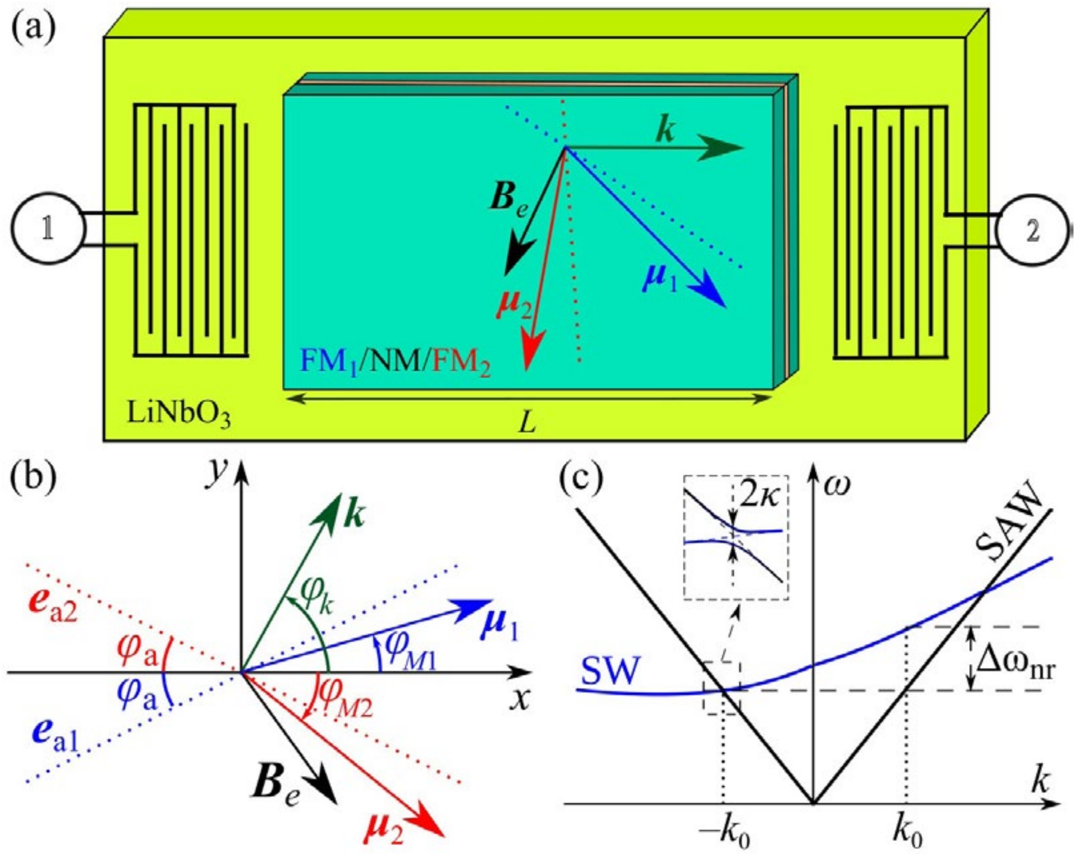
Strong nonreciprocity of surface acoustic waves (SAWs) in a microwave frequency band can be achieved using magnetoelastic hybridization of SAW with spin waves (SWs) propagating in magnetic bilayers with *antiparallel* orientation off the layeres magnetizations [1]. Recent work [2] have shown that a similar effect can be achieved in a simpler system based on a bilayer, where magnetic layers have a general *non-collinear* orientation of magnetizations.

The studied layered structure is shown the frame (a). It is ferromagnetic (FM)-nonmagnetic-FM structure grown on top of a piezoelectric ($LiNbO_3$) SAW waveguide placed between two interdigital transducers (IDTs). Ferromagnetic layers are similar, and differ only by the directions of the in-plane axes of magnetic anisotropy. The coordinate system in the frame (b) shows directions of the layers magnetizations (μ_i, i=1,2) and in-plane bias magnetic field B_e, and the direction of the wave propagation vector k. Frame (c) shows the graphs of SAW and SW dispersion relations, illustrating the SW nonreciprocal splitting $\Delta\omega_{nr} = \Delta\omega_{nr}(k_0)$ and magnetoelastic SAW/SW hybridization gap 2κ (in the inset).

We formulate requirements to relative orientation of the layer's magnetizations and wave vector k direction necessary for the realization of an efficient nonreciprocal SAW/SW isolator, and demonstrate calculated isolation exceeding 40 dB for sub-mm long FM bilayer with insertion losses of just a few dB larger than those of a pure SAW device.



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SPINTRONICS & MAGNETIC PHENOMENA

POSTERS

TUESDAY, 27TH

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Measuring Spin Filtering by Chiral Molecules in Bimetallic Junctions

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Two terminal measurements of spin selectivity of chiral molecules have been made by a few ingenious setups involving self-assembled monolayers and contact AFM and using either a magnetically oriented surface or a three-layered structure: metal-oxide-ferro to detect transient spin accumulation of spin-dependent I-V curves of the chiral molecular junction. Here, we build the experimental setup for two terminal measurements proposed recently[1] for an Au-Ni bimetal break junction. Au wets Ni, which also adds an oxide layer regulating the resistivity of the junction. The resistivity is also dependent on the spin accumulation on the Au. In the presence of a chiral molecule or via light-induced spin polarization, we can either measure transient spin populations on the Au-wetted surface through sensitive changes in the junction's resistance or through I-V curves.

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Behaviour of Symmetric/Asymmetric Ferromagnetic Coupled Layers in the Ghz Regimen

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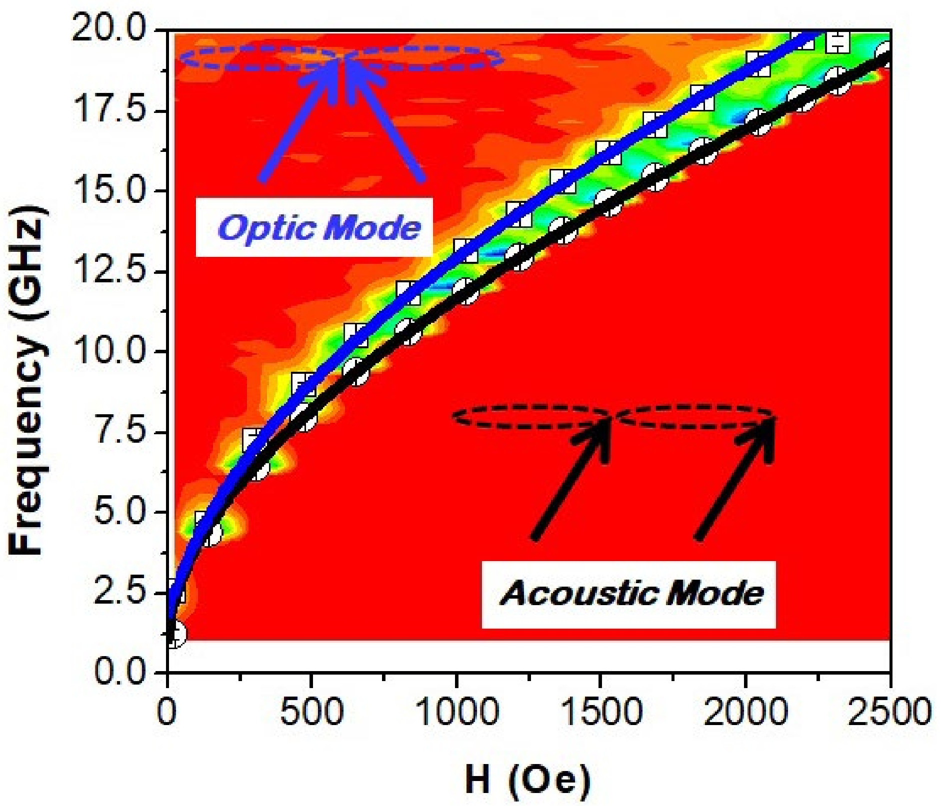
Our society is immersed in a digital revolution where information is continuously transferred between different devices, forcing us to look for new alternatives that allow the faster transfer of information with the lowest possible energy consumption. Magnetic thin films have been successfully used but their related natural resonance frequency is restricted to the range of a few GHz. This is a limitation that must be overcome to satisfy future technological needs.

Regarding this aim, Li *et al.*[1] confirmed that coupled ferromagnetic layers can present two ferromagnetic resonances, the acoustic and optic modes, and the optic mode appears at higher frequencies than those observed in simple ferromagnetic thin films (Figure).

In this work, we have studied the static and dynamic magnetic responses of symmetric and asymmetric layered thin films. The symmetric system is composed of Fe(10nm)/Al(0-2nm)/Fe(10nm), while the antisymmetric one is composed of Co(10nm)/Cu(0-8nm)/CoFeB(10nm)[2]. We have observed the acoustic and optic modes and demonstrated that the resonance frequency of the optic mode is very sensitive to the interlayer coupling constant. We can highlight that high resonance frequencies can be achieved (over 25 GHz) for Co/CoFeB bilayers with interlayer exchange coupling J_{eff} = (2.7 ± 0.8) erg/cm[2].



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Skyrmions in Biased Ferromagnetic and Antiferromagnetic Coupled Multilayers

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Synthetic antiferromagnets (SAFs) are an attractive and advantageous material platform, promising to improve spintronic device performance. When placing a non-magnetic spacer between two ferromagnetic (FM) materials, the FM layers can experience interlayer exchange coupling (IEC). Particular spacers, such as Ir and Ru, cause either FM or anti-FM (AFM) coupling depending on their thickness. AFM-IEC promotes the formation of a SAF, which are appealing for device applications including skyrmion applications due to the suppression of the skyrmion Hall effect (SkHE).

In this work, we advance the knowledge and test the limits of SAF systems when coupling different amounts of magnetic material or when increasing number of repetitions[1].

We design a SAF bias layer, consisting of two Co layers, to be more robust and stable against external fields. This SAF bias layer was used to form skyrmions in a FM multilayer (ML) and a ML SAF; schematics of the stacks are shown in the figure. The figure shows zero field magnetic force microscopy (MFM) images of, on the left, dense skyrmions of 75 nm in the FM ML, and on the right, less dense skyrmions of 40 nm in the ML SAF, with a low contrast compared to the FM ML, indicative of their SAF nature. This research paves the way for more efficient and practical applications of SAF skyrmions in future spintronic devices.

We combined a similar FM ML with a 270 nm wide magnetic tunnel junction and measured it via MFM, and with the correct image processing, we observed an individual skyrmion within it[2].

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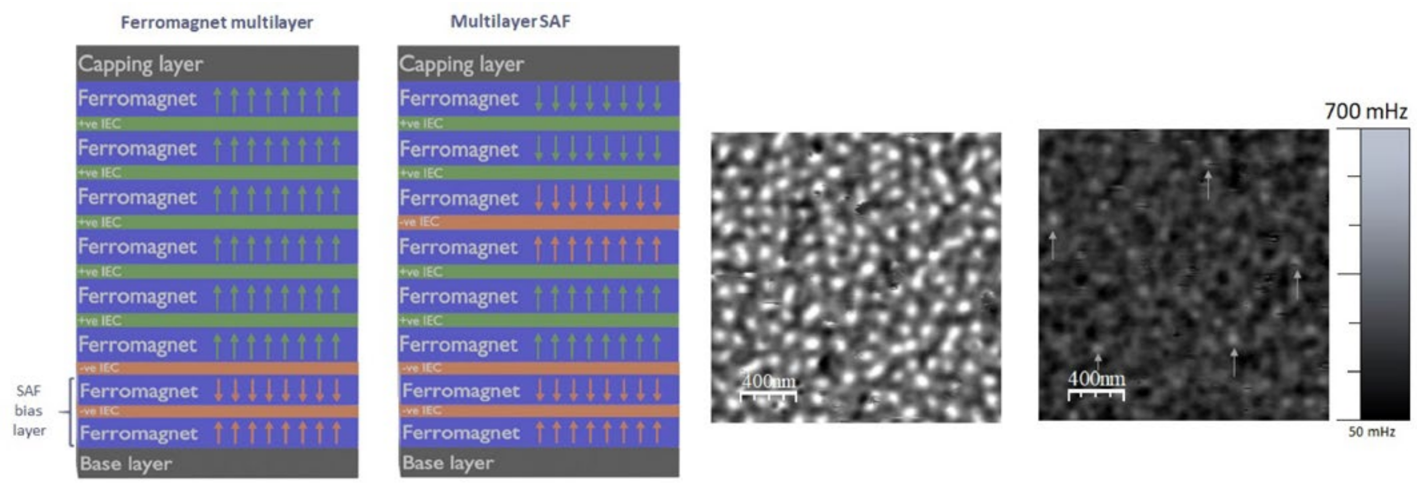

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Impurity Effects on Critical Temperature In Ru_7B_3 Superconductivity

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Ru_7B_3 is a noncentrosymmetric hexagonal superconductor with a high potential for spintronics use. The samples were synthesized in a three-electrode arc furnace with currents from 50-100 A. Replacing crystalline boron (Espi, 99.95%) with amorphous boron (Riedel-de Haën, 99.95%), we improved the phase purity and superconductor properties, obtaining a crystallite phase of Ru_7B_3 with a critical temperature (T_c) of 3.15 K.
The substitutions of Ruthenium by different elements, $Ru_{6.9}X_{0.1}B_3$ (X= Nb, Ni, Pd, Pt, Rh), were investigated to determine their impact on critical temperature and spin-orbit coupling (SOC). The Tc decreased from 3.15 K for pure Ru_7B_3 to varying extents: 3 K (Nb), 2.6 K (Rh), 2.5 K (Pt), 2.3 K (Pd), and 2.3 K (Ni). Nb and Rh produce minimal lattice disruption, causing relatively small reductions in T_c. While Pd and Pt, have stronger SOC effects and significantly suppress T_c by altering the singlet-triplet pairing balance and phonon spectra. On the other hand, Ni substitution introduced magnetic pair-breaking effects, leading to the most pronounced suppression.
These results demonstrate that Ru_7B_3 is sensible to impurity scattering, SOC modification, and magnetic effects, offering insights into controlling spin-polarized transport in superconductors. The findings highlight that this superconductor has potential as a platform for spintronic applications, including hybrid devices with magnetic interfaces, spin-polarized supercurrents, and topological superconductivity.
Acknowledgments to CONAHCYT (CVU 132061), PAPIIT-DGAPA-UNAM Project IN104322 and IN221424. R. E. López-Romero also thanks POSDOC for the scholarship received during his postdoctoral stay.

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Magnetic Interactions In β-Co1-XNix(OH)2 Nanosheets with X =0.25; 0.50 and 0.75

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In this work we propose the discussion of some results regarding magnetic properties, as well as a brief characterization of the crystallographic and morphological structural features for β-$Co_{1-x}Ni_x(OH)_2$ nanosheets. β-$Co_{1-x}Ni_x(OH)_2$ samples were prepared in polycrystalline form through a hydrotermal method. Structural characterization was carried out based on PXRD data measured at room temperature. The structures were refined in the hexagonal space group (#164). Transmission electron micrographs shows that particles are of hexagonal shapes and size of tens of nanometers.
Magnetic properties of all the compositions covering temperature range of 5–300K in magnetic field up to 50 kG are studied. β-$Co_{0.75}Ni_{0.25}(OH)_2$ ZFC-FC curves bifurcate at T~ 20 K, instead with x=0.50 and 0.75 do not. The effective magnetic moments obtained from the fitting with the Curie-Weiss law for each composition are in total agreement with β-$Co(OH)_2$ and β-$Ni(OH)_2$ reported [1,2]. We find a majoritary antiferromagnetic order in all the compositions with 20 K<T_N> 30 K. The isothermal curve of $Co_{0.75}Ni_{0.25}(OH)_2$ reveals a possible intralayer ferromagnetic coupling with a interlayer antiferromagnetic order, as the observed in β-$Co(OH)_2$ [1].

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Magnetic Properties in CaV_2O_4 Doped with Non-Magnetic Sc^{3+} Ions

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Calcium vanadate, CaV_2O_4, has been the subject of various studies aimed at describing the fundamental physics and unusual properties of this low-dimensional system with spin frustration [1-3]. In this work, the structural and magnetic properties of the CaV_2O_4 system doped with Sc are studied, *i.e.* $CaV_{2(1-x)}S_{2x}O_4$. X-ray diffraction patterns confirm the formation of the main phase of CaV_2O_4, where Sc dopant ions enter the system replacing V. The presence of Sc is confirmed by comparing the structural characteristics of the samples studied with the pure compounds, CaV_2O_4 and $CaSc_2O_4$. The magnetic susceptibility measurements as a function of temperature of the doped samples are modeled using a linear combination of the magnetic behavior of the control sample (x = 0) plus paramagnetic impurities, whose concentration depends on the doping percentage. Since Sc^{3+} has spin zero, its contribution to the magnetization is interpreted through a phenomenological model of two effective spins aligned antiparallel. The first of these spins are associated with the antiferromagnetic matrix of the base compound, while the second spin is responsible for the paramagnetic signal when applying an external magnetic field (see Figure). The parameters found when fitting the susceptibility curves using this model successfully show that the number of effective paramagnetic spins is proportional to the Sc doping, but the Curie-Weiss susceptibility is lower than expected by a factor of 2. This result is interpreted as evidence of interactions present in the system, where the external field competes against the internal coupling between the two effective spins at the Sc site.

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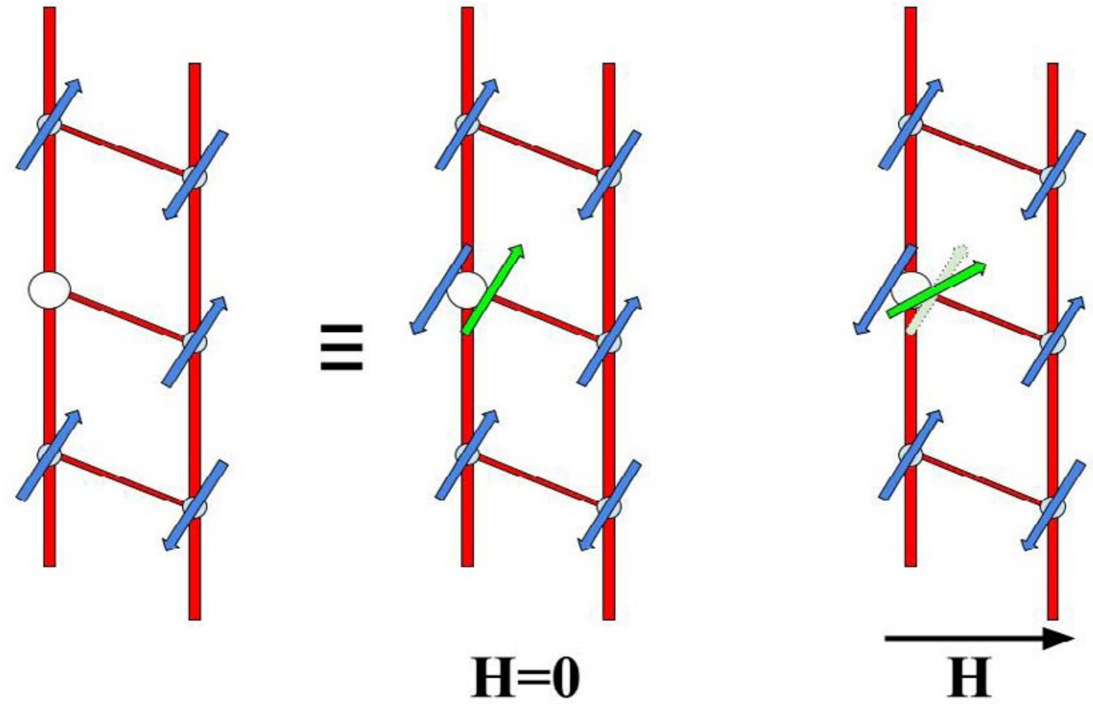

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Novel Spin Phases in $SrCu_2(BO_3)_2$

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$SrCu_2(BO_3)_2$, is a spin S=1/2 model quantum magnet that has challenged our understanding of spin systems. Extensive theoretical studies have predicted a rich phase diagram with many exotic spin phases and arrangements such as supersolid spin lattices, spin liquids, spin plaquettes, spin crystals, fractional magnetization plateaus, frustrated spin dimers, antiferromagnetic order and many others [1,2]. Considerable experimental [2,3] efforts with various techniques (NMR, neutron, X-ray, transport, magnetization, Raman, tunnel diode oscillator, and more) have exhibited some of those phases. We will present here an overview of the novel spin phases discovered so far and the means to transition between them as well as a report of our latest experiments exhibiting novel spin wave patterns [4] and first-order quantum phase transitions [5]. These transitions show potential for spintronic applications where anisotropic spin interactions are key for several the topological properties [5].

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Skyrmions in Synthetic Antiferromagnetic Multilayers

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Ferromagnetic multilayers have demonstrated the ability to stabilize skyrmions at room temperature and enable their motion through low-density current pulses. However, the dipolar interaction limits the formation of ultra-small skyrmions, and the topological charge of these structures gives rise to the Skyrmions Hall Effect (SkHE). To mitigate these undesired effects, synthetic antiferromagnetic (SAF) multilayers have recently been proposed [1]. In this work, we investigate how key magnetic parameters for skyrmions nucleation in SAFs, particularly perpendicular magnetic anisotropy (PMA) and antiferromagnetic exchange coupling, can be controlled by varying the thicknesses of the layers constituting the system. The heterostructure used as the ferromagnetic material was the Pt/Co/Ta multilayer, with Ru chosen as the spacer material [2]. The results reveal the crucial role of Co thickness in the system's PMA and the impact of both Ru thickness and the amount of non-magnetic material on the strength of the antiferromagnetic coupling. This study contributes to the understanding of SAFs and offers new perspectives for the fabrication of spintronic devices, where skyrmions nucleation and SkHE suppression can be controlled through layer thickness.

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Design of NV-BCAM Using STT-MRAM MTJ Devices

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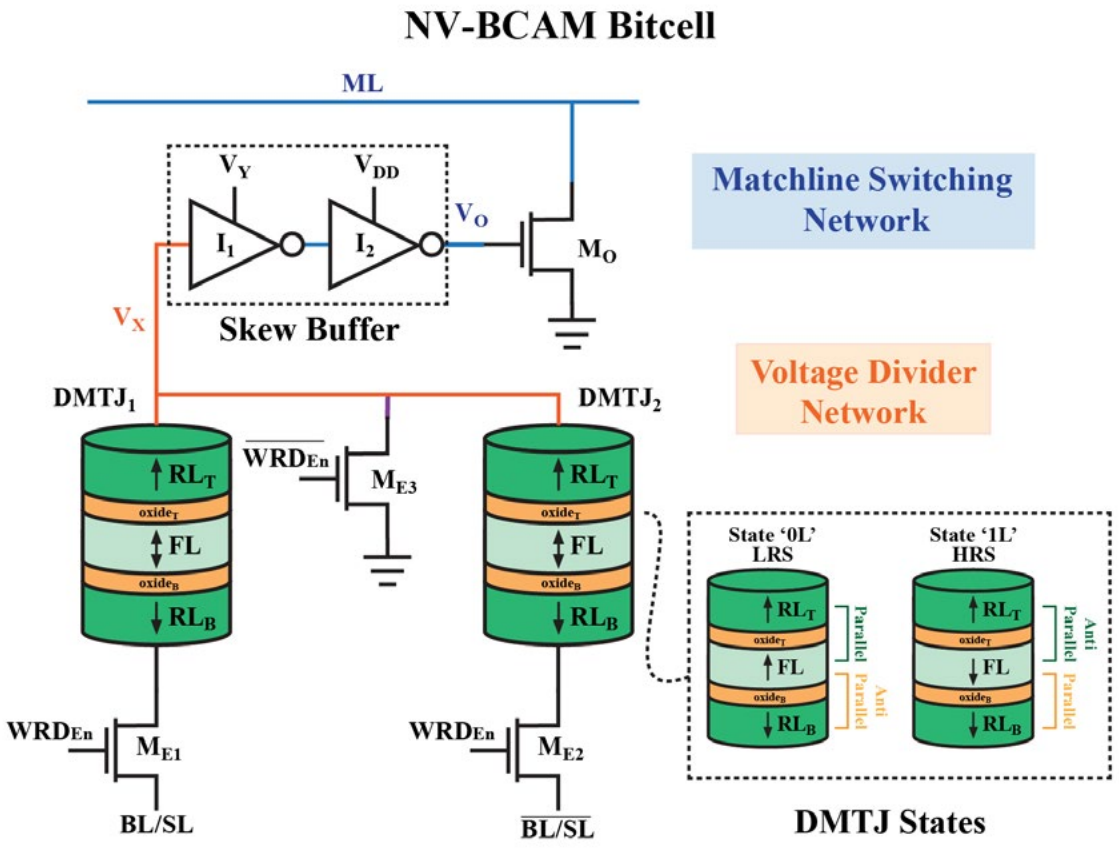
Content Addressable Memories (CAMs) have raised interest in Artificial Intelligence applications due to their ability for fast and intensive search operations. However, CMOS CAMs are power-hungry due to leakage current. To address this, hybrid Non-Volatile (NV) memory alternatives exploiting MRAM through Magnetoresistive Tunnel Junction (MTJ) devices have been explored. These devices use the Spin Transfer Torque (STT) mechanism to switch the magnetization of their free layer (FL) relative to their reference layers (RL), forming two stable resistive states. Search and write operations in the memory are conducted by current flowing in opposite directions, enhanced through the voltage-divider topology presented in the figure. This current allows programming a desired value into the cell by switching the state of the MTJs in write mode and determining the stored value through its voltage-divider in search mode.
This work presents a performance and power analysis of an NV-BCAM memory described in [1], along with a Dual Voltage Level Control Circuitry (DVLCC). The memory design is implemented using a full-custom methodology in a TSMC 65nm technology node. The memory is evaluated under nominal conditions as well as process variation using Monte Carlo simulations for search and write operation performance and power. Compared to state-of-the-art designs, the proposed NV-BCAM offers a lower Search Error Rate (SER) at the expense of a slight increase in search delay and search energy per bit. However, the DVLCC enables combining search and write operations through a single VDD supply.



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Spintronic Hamiltonians for Single and Double Stranded Helices from Line Symmetries

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When building tight-binding models, one generally relies on selecting a set of orbitals including partially filled electron orbitals as pivot points. Nevertheless, this procedure, even in the simplest cases, ignores many spin active channels that limit the validity of the model selection. Missing those channels can be avoided by using the mobile electron-bearing orbitals as a starting point and using the symmetries[1] of the structure to determine allowed and disallowed channels that include all connecting orbitals[2]. This procedure can then guide more quantitative DFT and Ab initio computations. In this sense, the problem of spin selection in chiral structures. Using the line symmetry groups for single and double helices, we derive the total Hamiltonian for electron transport in direct space and then derive the corresponding Hamiltonians in the Bloch basis. We find very few no-go processes on a structure that breaks inversion symmetry (chiral) and thus enables many spin active mechanisms not considered currently in the literature.

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Curved Nanomagnets to Explore Skyrmionic States

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In the fields of nanomagnetism and spintronics, the controlled stabilization of skyrmionic states has garnered significant attention due to its promising applications in data storage and next-generation computing systems. This study investigates the captivating phenomena of skyrmion and skyrmionium within a hexagonal array of curved nanomagnets. Utilizing a combination of atomistic calculations, micromagnetic simulations, and experimental observations through magnetic force microscopy and electron holography, we examine the complex interplay among magnetic parameters, curvature, and interfacial Dzyaloshinskii-Moriya interaction (iDMI) in the formation of these topologically non-trivial magnetic structures. We have identified the spontaneous formation of isolated skyrmions and a mixed state of skyrmionic phases within a curved nanomagnet matrix composed of symmetric Pt/Co/Pt multilayers, achieved without the application of external magnetic fields [1]. Our research elucidates the significant influence of geometric curvature on iDMI, providing essential insights for the engineering and manipulation of skyrmionic states. This work contributes to the advancement of knowledge in nanomagnetism/spintronic and lays the groundwork for the development of skyrmion-based technologies.

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Magneto-Transport Measurements in Altermagnetic Semiconductor MnTe

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Recently, collinear magnets were classified by spin-group symmetry into three distinct classes. In addition to the conventional ferromagnets and antiferromagnets a third class, altermagnets, was established. In altermagnets [1], the spin polarization in both real space and electronic structure alternates. Consequently, altermagnetism enables effects that were believed to be limited to ferromagnets. However, many of the predicted altermagnetic phenomena await their experimental confirmation. Here, we present a magneto-transport characterization of the semiconducting, compensated collinear altermagnet MnTe [2].
We manipulate the magnetic order by an applied magnetic field and experimentally confirm the symmetry components of the anisotropic magnetoresistance in thin films of MnTe. The longitudinal and transverse resistivities are presented in the figure. Furthermore, we discuss which contributions to the measured transversal and longitudinal signals can be signatures of the unconventional altermagnetic phase.

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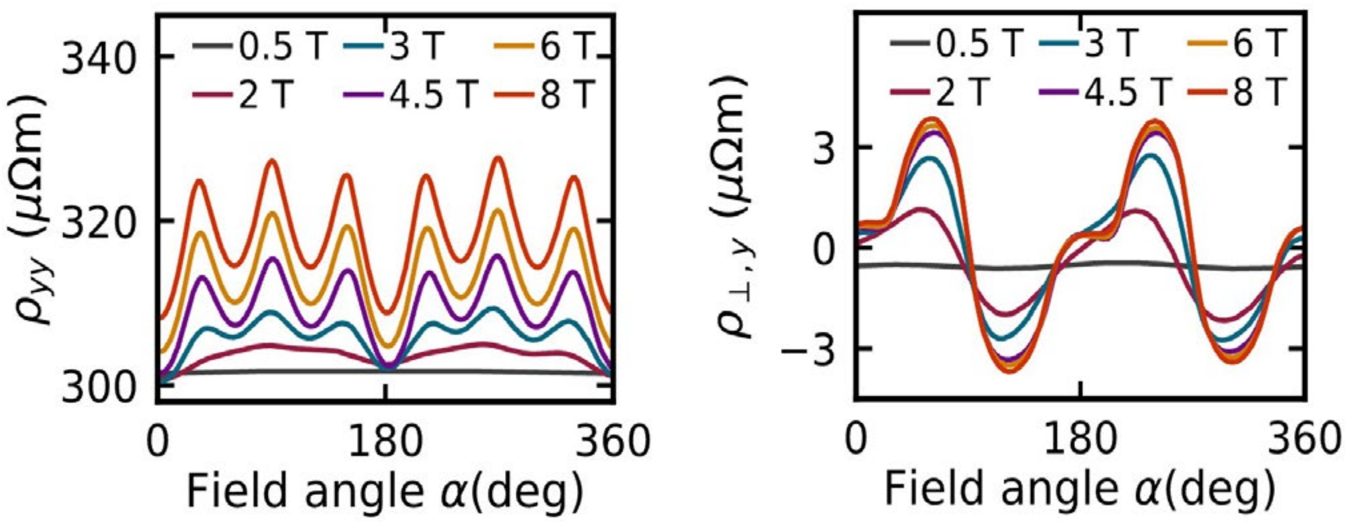

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Skyrmion Stabilization and Switching Mechanisms in Nanodisks

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In recent years, magnetic skyrmions have gained significant attention due to their potential use in next-generation storage devices. Their nanoscale size, high mobility, and topological stability make skyrmions promising candidates for high-density data storage and low-energy memory applications [1]. The reduced size of nano disks leads to lower energy barriers for skyrmion formation and manipulation, enable more efficient control and switching of skyrmionic structures [2]. This study investigates the effects of confinement on skyrmion stabilization by fabricating Pt/Co/Ta nanodisks with varying diameters through electron beam lithography. We report the successful creation and characterization of nanodisks with diameters from 200 nm to 1000 nm, observing stable skyrmions at zero magnetic field in nanodisks with diameters of 200 nm, 300 nm, and 400 nm. Experimental results are corroborated with micromagnetic simulations, revealing a strong correlation between domain texture and disk topography. A controlled switching mechanism is proposed using a current-induced approach by applying spin-polarized current pulses along the nanodisk.

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Perpendicular Magnetic Anisotropy in Comnfe Alloy Thin Films

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The production of an embedded spin-transfer-torque magnetoresistive random-access memory (STT-MRAM) recently started and those for X-1X nm technology node are being developed. One of the requirements in the current STT-MRAM technology is to find a way to enhance the thermal stability factor Δ for nano-scale perpendicular magnetic tunnel junctions (p-MTJs) composing of FeCoB and MgO. The FeCoB/MgO/FeCoB MTJs show high tunnel magnetoresistance (TMR) effect and high interfacial perpendicular magnetic anisotropy (PMA). The Δ is proportional to the effective PMA as well as the magnetic layer thickness. Since the interfacial PMA of FeCoB/MgO is not enough strong, several structures were proposed to gain the large Δ, e.g., FeCoB/MgO multilayers[1] and of FeCoB/high PMA material bilayers[2]). On the other hand, this issue could be more efficiently addressed using unique ferromagnetic electrode which exhibits both TMR large enough and PMA higher than that in FeCoB/MgO; while no such magnets have been demonstrated yet.
For STT-MRAM applications, here we investigate PMA for thin films of metastable bcc CoMnFe alloy which exhibits large TMR effect in MgO-MTJs[3]). CoMnFe alloy films were fabricated on single crystalline MgO(001) substrates / Cr(001) (/MgO(001)) with various thicknesses using ultra-high vacuum magnetron sputtering. We successfully observed PMA, K_u = 0.5-0.6 MJ/m^3, for CoMnFe films with the thickness of 2-5 nm. Our first-principles calculations indicated that PMA appears in body-centered tetragonal (bct) type CoMnFe. Furthermore, the theoretical value of K_u exceeds 1 MJ/m^3 for CoMnFe films with the axial ratio $c/a < 1$ and a Co-rich composition. The lattice constants of bcc Cr(001) and rock salt-type MgO(001), which form the underlayer of the CoMnFe films, are larger than those of bcc CoMnFe films, therefore it is considered that PMA for CoMnFe originates from the epitaxial strain induced by the underlying crystal lattices[4]).
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Interplay Between Inter- and Intraparticle Interactions in Bi-Magnetic Core/Shell Nanoparticles

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Bi-magnetic nanoparticles of magnetic oxides with a core/shell structure are widely investigated due to their potential use in various applications, ranging from electronics to biomedicine [1]–[3]. The surface/interface effect and interparticle interactions strongly affect their magnetic properties and thus they should be considered to design materials with desired properties. However, all those effects have complex nature, and it is not trivial to consider them at the design step of materials. This work focuses on the study of the magnetic properties of bi-magnetic core/shell nanoparticles of cobalt ferrite (CFO) and nickel ferrite (NFO), also in the inverse configuration. The growth of a magnetically soft NFO shell affects the hard properties of the CFO seeds with a decrease of μ0HC from ~1.3 to 0.8 T. On the contrary, the magnetically harder shell increases the coercivity of the NFO seeds from ~0.025 to 0.03 T. These changes cannot be explained quantitatively by a classical additive rule: a strong influence of the architecture was revealed in a clear interplay among intraparticle (i.e., proximity effects) and interparticle interactions. This effect has been investigated by the remanent plot's technique. Then we applied the Monte Carlo simulation method to better understand the effect of different factors and for the first time in the core/shell system, the contribution of proximity effects in ΔM-plot has been highlighted. Implementation of this model allows one to design the material with desired magnetic properties. [4, 5]

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Coupled Magnetic Tunnel Junctions for Accelerometers and Gyroscopes

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Accelerometer and gyroscopes are sensors that are nowadays commonly found in portable devices, cars, navigation systems and many other various applications. The current technological paradigm is based on micro-electromechanical system (MEMS). Spintronics, in particular in the form of magnetic tunnel junctions (MTJs), is emerging as a candidate for drop-in replacement in current silicon-based technologies thanks to compatibility with CMOS manufacturing processes, versatility, radiation hardness and scalability. We have already proposed and designed [1,2] a spintronic accelerometer exploiting a system of MTJs working as spin torque oscillators (STOs) and spin torque diodes (STDs) integrated on excitable substrates, such as MEMS, that can transduce the external stimulus into a mechanical excitation. When the distance between the MTJs changes, this displacement reflects into a variation of the stray field distribution that results in a change in the output voltage generated by STDs, via spin diode effect. Here we explore different design configurations, such as arrays of MTJs and different mechanical couplings, and present results of systematic studies aimed at finding those conditions that enable to improve the current accelerometers design and to achieve gyroscopic sensing with high output sensitivity and low power consumption.
This work was supported under the project PRIN_20225YF2S4 – Magneto-Mechanical Accelerometers, Gyroscopes and Computing based on nanoscale magnetic tunnel junctions (MMAGYC); and by the PETASPIN association (www.petaspin.com).

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Study of Barkhausen Effect in the Skyrmionium-to-Skyrmion Transition

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Magnetic skyrmions and skyrmioniums hold promise for future data storage applications due to their topologically nontrivial spin structures [1]. The reversible conversion between these two structures has already been experimentally demonstrated [2]. This study employs micromagnetic simulations to explore the effect of disorder, introduced through random variations in magnetic parameters such as anisotropy (Kz), saturation magnetization (Ms) and Dzyaloshinskii-Moriya interaction (Dint), on the magnetic field-induced skyrmionium-to-skyrmion transition. The figure illustrates mz as a function of the applied magnetic field for different disorder configurations. The simulated systems exhibit distinct step-like patterns, known as Barkhausen Jumps. The skyrmionium-to-skyrmion transition occurs during the final step in all simulated scenarios. This finding indicates that any kind of disorder increases the field strength required to induce the skyrmionium-to-skyrmion transition. Our results demonstrate that stronger disorder correlates with higher magnetic fields to induce the skyrmionium-to-skyrmion transition. Analyzing the step sizes for different disorder levels reveals a non power-law scaling behavior. Our system may provide insights on this behavior.

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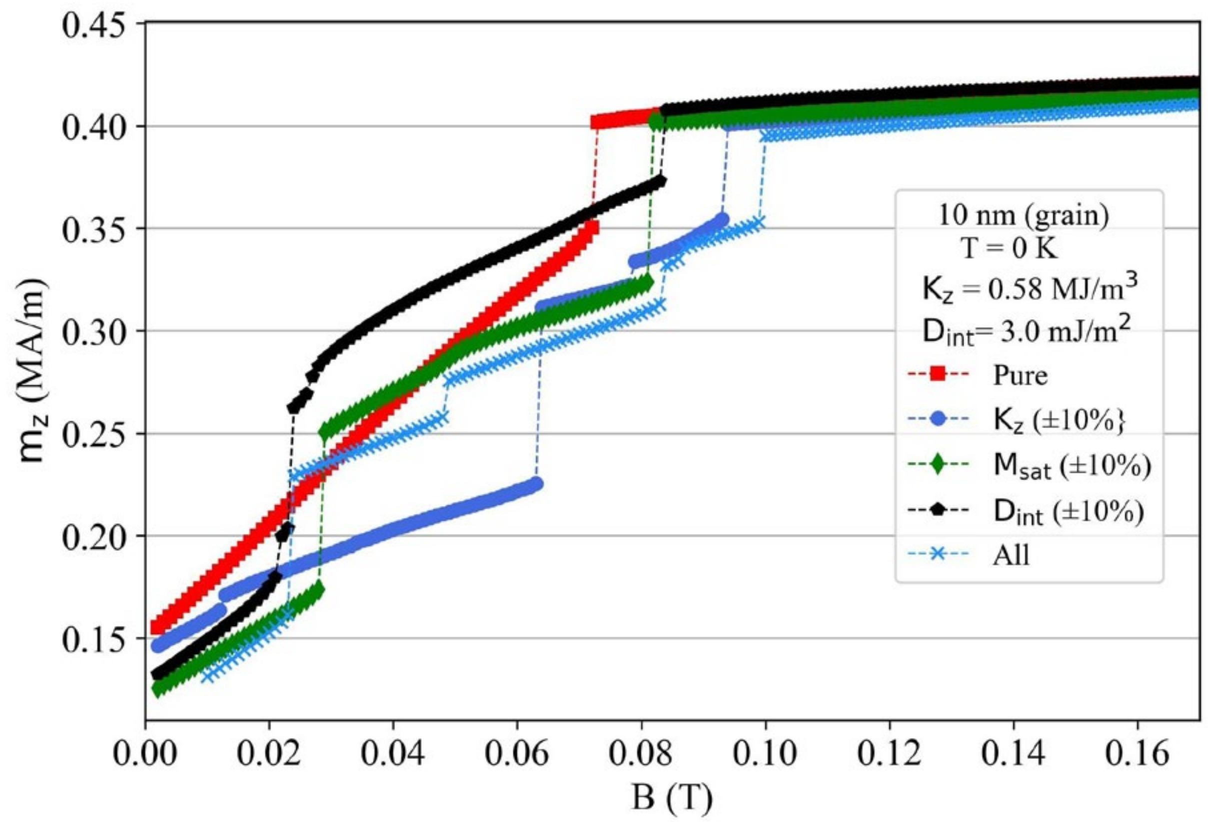

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E-beam and LDWL Fabrication of Superparamagnetic-Like and High Magnetization FeO_x Films and Discs for Medical Applications as Cancer Treatments

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Nanostructured iron compounds offer high magnetization, low coercivity, and biocompatibility properties required for medical advances as improved cancer treatments. Although confining these compounds produces crucial superparamagnetic properties, their magnetic response tends to decrease. This difficulty limits the use of iron oxides in favor of less biocompatible substances [1]. Furthermore, research on magnetic interactions in iron oxide phases could simplify magnetic control to achieve superparamagnetic properties and high magnetic response for medical advances [1][2]. In this work, an e-beam film and direct writing laser lithography (DWLL) discs of respectively 17 and 11 nm in thickness of iron oxides (FeO_x) exhibit a superparamagnetic-like behavior and a magnetization of 91.6 emu cm^{-3} at 300K. The hysteresis curves μ(H) and coercive field H_c as functions of Temperature as well as ZFC-FC of the FeO_x film are correlated as measured by SQUID magnetometry. XPS indicates the FeO_x film is composed of Fe_3O_4 and FeO [2]. Additionally, AFM was used to determine the shape and topography of 1.8μm-diameter FeO_x(11nm) discs. These discs exhibit a superparamagnetic-like response as that of the films from MOKE intensity measurements with a 100 Oe H-field square signal (2 Hz) in water suspension. Thus, discs preserve the behavior observed in film shape. Following this, MUMAX3 micromagnetic simulations for films (16nm thickness) and 2um-diameter discs (11nm thickness) of ferrimagnetic Fe_3O_4 also show a superparamagnetic-like behavior consistent with these experimental measurements. These results show the potential use of FeO_x discs in medical developments as targeted cancer treatments.

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Modeling the Interplay of Bilinear and Biquadratic Exchange Coupling in Weakly Coupled $(Fe/Ti/Fe)_N$ Multilayers

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In the energetic framework of magnetic multilayer systems, the bilinear exchange coupling between adjacent ferromagnetic films is typically introduced to describe the ferromagnetic and antiferromagnetic alignments. However, structural imperfections such as surface roughness, pin-holes, and loose spins necessitate the inclusion of a biquadratic exchange term, leading to nonparallel magnetic configurations between neighboring layers. Understanding the interplay between these bilinear and biquadratic couplings is essential, especially since nonparallel alignments have the potential to enhance spintronic device performance, such as in spin-transfer torque magnetic random-access memory (STT-MRAM) devices [1-2].
In this work, we employ the macrospin model to investigate the static and dynamic magnetic properties of a general FM/NM/FM multilayer, with a particular focus on the competition between bilinear and biquadratic exchange coupling. Our results are then applied to experimental data from $(Fe/Ti/Fe)_N$ multilayers. To model hysteresis, the equilibrium magnetizations are projected along the externally applied field. We developed a conjugate gradient method to numerically calculate the equilibrium orientations of the magnetizations by locally minimizing the system's free energy. Additionally, we derived the dispersion relation to model the ferromagnetic resonance (FMR) signal. As a result, we constructed a phase diagram that illustrates the interplay between bilinear and biquadratic exchange terms as a function of temperature and the repetition number of the tri-layer structure.
Our approach successfully captures key experimental features observed in ferromagnetic resonance (FMR) and hysteresis data, particularly the temperature-dependent behavior of the hysteresis loops. Moreover, our model suggests that the formation of oxide at the interface enhances the biquadratic interlayer exchange coupling.
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Optimization of Magnetic Iron Oxide Nanoparticles Synthesized via Microwave for Biomedical and Spintronic Applications

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Magnetic iron oxide nanoparticles, such as magnetite and maghemite, are promising materials in biomedicine and spintronics due to their high spin polarization and ability to integrate into advanced magnetic devices. This work presents a conventional microwave synthesis approach to control nanoparticles' structural and magnetic properties by varying the power applied during synthesis. The results reveal that microwave power significantly affects the magnetic nanoparticles' size, crystallinity, and phase composition, directly influencing key parameters such as saturation magnetization and superparamagnetic behavior. Additionally, we explore the effect of synthesis-induced defects on spin transport and their potential integration with two-dimensional materials, such as graphene derivatives (graphene oxide and reduced graphene oxide) [1,2], that could open new opportunities for developing hybrid devices with high energy efficiency.

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MATERIALS & INTERFACES FOR ADVANCED APPLICATIONS

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Optimization of Magneto-Optical Sensitivity in Nanostructured Multilayered Heterostructures by Surface Plasmon Resonance

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The transverse magneto-optical Kerr effect (T-MOKE) is a fundamental phenomenon for developing advanced magneto-optical sensors in low-dimensional materials. In this study we analyze the behavior of T-MOKE in nanoscale multilayer heterostructures using canonical surface plasmon resonance (SPR) setup known as Otto and Kretschmann configurations. The studied systems are designed to optimize the plasmonic resonance between the electromagnetic field and electron oscillations at the metal-dielectric interface, thereby enhancing the magneto-optical response of the ferromagnetic layers within the heterostructure. We specifically study multilayers made of BK7/Au/Co/Au/Air in the Kretschmann configuration [1] and BK7/Air/Ag/Co/Si in the Otto configuration [2].

We optimize the plasmonic resonances by using the quality factor (Q-factor), defined as the ratio of maximum reflectivity variation to the full width at half maximum (FWHM) of the resonance peak as a figure of merit. We found that the T-MOKE intensity primarily depends on the plasmonic resonance and on the non-magnetic layer thickness, with a minimal influence from the FWHM. This behavior arises from the modulation of the resonance coupling through thickness, affecting the evanescent decay of the plasmonic fields and amplifying the magneto-optical response. We optimize these conditions in two stages: first, by adjusting the parameters related to the plasmonic resonances (Q-factor), and then by analyzing the conditions that maximize the T-MOKE effect.

Our findings highlight the potential of nanostructured multilayer heterostructures with plasmonically optimized magneto-optical layers as effective platforms for studying magneto-optical phenomena in low-dimensional materials. Furthermore, they emphasize the importance of these systems in developing advanced sensor technologies and applications in the field of nano magnetism.

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Quantization of Spin Circular Photogalvanic Effect in Altermagnetic Weyl Semimetals

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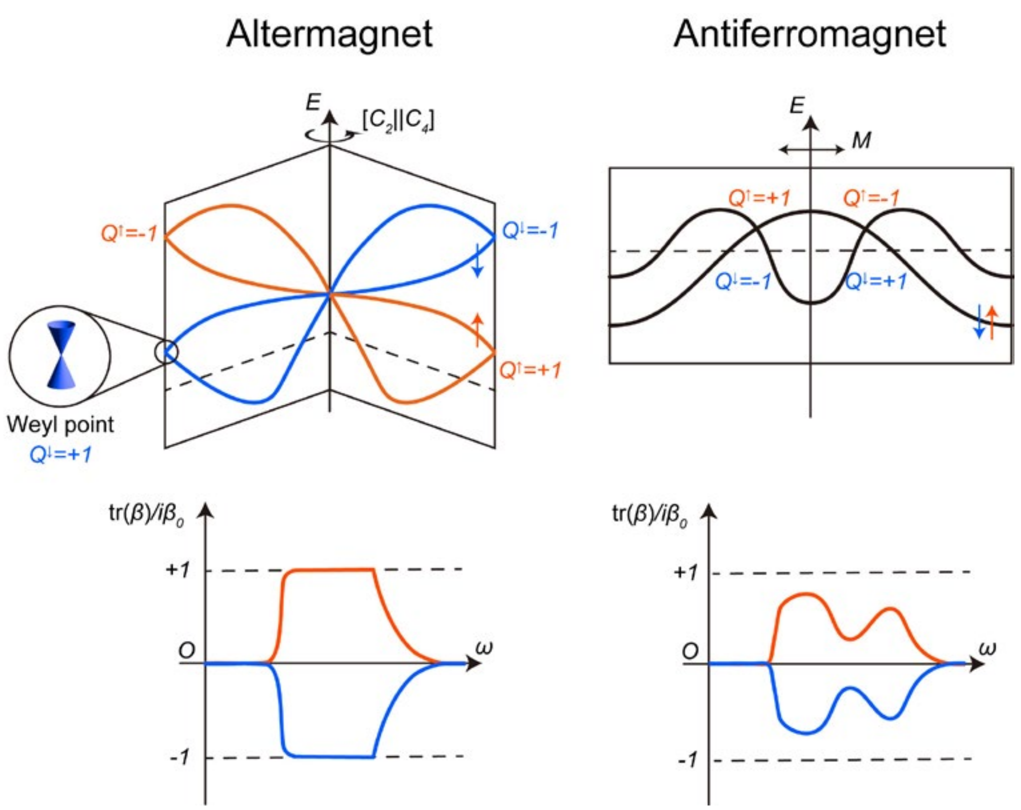
The generation of dc current in bulk materials under illumination of uniform light, known as the bulk photovoltaic effect (BPVE), offers a promising pathway for next-generation solar cells due to its ability to generate voltages exceeding the material's energy band gap—unlike traditional interfacial photocurrents. The injection current is one of BPVE and linked to the Berry curvature of the system. This connection is exemplified by the quantized circular photogalvanic effect (CPGE) in chiral Weyl semimetals, where the injection conductivity under circularly polarized light is proportional to the topological charge of a Weyl point [1].

In this study, we demonstrate that a spin current analog of this quantization can be realized in altermagnetic Weyl semimetals. While previous research has investigated pure spin current generation through BPVE in antiferromagnets, the presence of mirror symmetry in these materials, while necessary for separating electric and spin currents, precludes the quantization of spin CPGE. Altermagnets, which are described by spin point groups (SPGs), present a compelling alternative due to symmetry operations that enable the separation of electric and spin currents without compromising quantization (Figure). We systematically analyzed 27 non-centrosymmetric SPGs, identifying 17 that can generate pure spin currents, including 7 SPGs capable of supporting spin CPGE quantization. Using a toy model, we numerically validated our symmetry-based findings, confirming the potential for spin CPGE in these altermagnetic systems.



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Nucleation, Stabilization, and High-Frequency Spectral Analysis of Skyrmion Crystals Transitioning from Square to Hexagonal Symmetry

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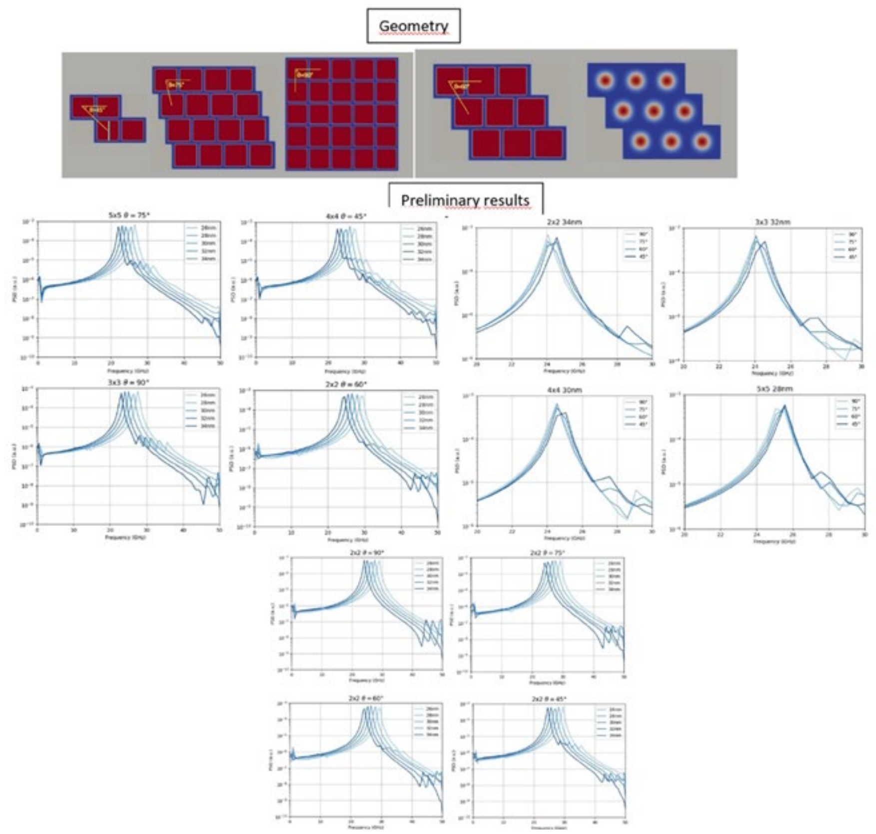
Magnetic skyrmions are intricate spin configurations within magnetic textures as ultrathin films, where the Dzyaloshinskii-Moriya (DMI) interaction is present at the interface. These nanoscale magnetic structures exhibit inherent topological protection, which enhances their energetic stability and makes them promising candidates for spintronic applications. Skyrmions can be utilized individually in racetrack memory devices or collectively as skyrmion magnonic crystals. The crystalline arrangement of skyrmions facilitates the propagation of spin waves, enabling efficient information transfer, and holds potential for use in ultra-sensitive magnetic sensors and skyrmion-based reservoir computing systems.

One of the main objectives of this work is to achieve the nucleation and stabilization of various magnetic skyrmion lattices arranged in rows within an ultrathin magnetic film with perpendicular magnetic anisotropy (PMA). This process involves the stabilization of individual skyrmions within a square geometry and an external region characterized by a higher uniaxial PMA constant. Each skyrmion is equidistantly stabilized along a row. In each lattice, we will vary the number of skyrmions per row and the displacement between adjacent rows, with the latter parameterized by the angle θ. This approach enables the formation of skyrmion crystals with symmetries ranging from square to hexagonal. This study is conducted using micromagnetic simulations in MuMax3, with magnetic parameters for skyrmion nucleation referenced from [1]. The system's initial magnetization is uniform and oriented perpendicular to the surface, with regions of reduced anisotropy defined around square skyrmion nucleation sites. These regions start with an initial magnetic state antiparallel to the easy axis, facilitating relaxation and enabling skyrmion nucleation at well-defined locations [2]. Using this approach, we generate grids of varying sizes N×N (where N=1–5), with angles θ set to 90°, 75°, 60°, and 45°. The nucleation regions are squares with side lengths ranging from 26 nm to 34 nm. After obtaining these configurations, the next objective is to perform spectral analysis by applying a sinc function signal to excite the system in the plane. This approach enables the characterization of resonance modes and the dynamic behavior of the system at high frequencies. Spectral analysis is conducted up to 50 GHz over a simulation duration of 2 ns, with data sampled every 5 ps. The processed signal is defined as ⟨mx(t)⟩– ⟨mx(t=0)⟩, where ⟨mx(t)⟩ denotes the average magnetization along the x-axis.

The results are shown in the figures and demonstrate a notable dependence of the primary mode frequency on the nucleation square size: as the square side length decreases, the frequency corresponding to the main spectral peak increases. Additionally, as the dimensions increase, the number of secondary modes in the crystal spectrum also rises. For any N×N crystal, a decrease in the angle θ shifts the dominant spectral peak toward lower frequencies, with a maximum observed shift of approximately 3 GHz. Specifically, 2×2 arrays exhibit an additional resonance mode at θ values of 75°, 60°, and 45°, while this mode is absent at θ=90°.



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Towards Cocoons Electrical Control: Nucleation and Motion

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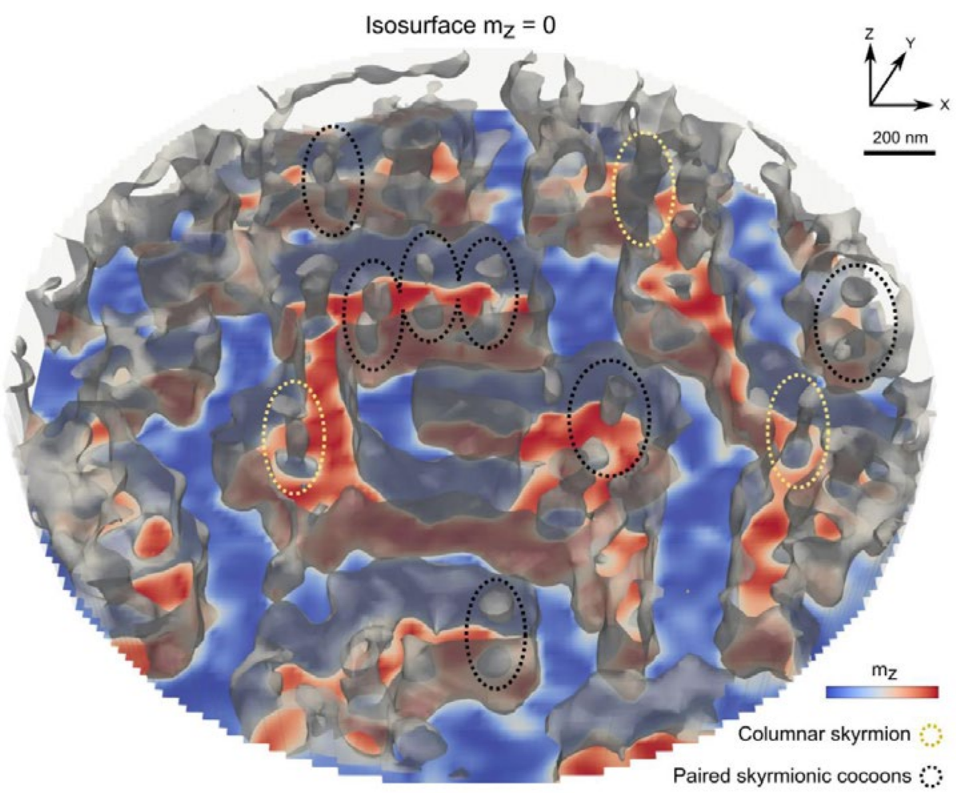
Topological magnetic textures have been rigorously studied as they could represent an asset for the development of next-generation spintronics devices. Chiral magnets and magnetic multilayers allow for the stabilization of two-dimensional (2D) textures, like the magnetic skyrmion. Beyond these 2D textures, research interest has expanded to more complex three-dimensional (3D) textures that vary structurally across their thickness. Recently, our group has reported a new type of 3D texture called skyrmionic cocoon [1,2]. They were found in Pt/Co/Al based aperiodic multilayers with variable Co thickness. These multilayers have demonstrated the capability to host multiple objects, such as columnar skyrmions. The figure shows an X-ray laminography reconstruction of such system. However, these stacks were optimized for 3D imaging using large thicknesses—several times the vertical resolution of the probe. This feature makes them unsuitable for current-induced motion of magnetic objects since high currents are required. Furthermore, cocoons in these multilayers show no displacement under current pulses due to changes in rotation sense along their structure. To improve energy-efficiency, we aim to reduce the number of repetitions in these stacks. We also investigated approaches to nucleate and move cocoons through electrical currents, potentially advancing 3D spintronics applications.



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Influence of Nanostructuring and Temperature on the Magnetic Properties of the Al64Cu23Fe13 Icosahedral Quasicrystal

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The discovery of quasicrystals has profoundly challenged foundational concepts in crystallography, revealing that rotational symmetry can exist without translational order, as seen in the AlCuFe alloy with its characteristic icosahedral structure. This distinctive arrangement gives rise to unusual physical properties that markedly diverge from those of conventional crystals. Specifically, the magnetic behavior of quasicrystals is complex, exhibiting a range of phenomena, including diamagnetism, paramagnetism, ferromagnetism, and spin-glass-like behavior. These magnetic properties are influenced by various factors, such as synthesis technique, impurity levels, crystallographic domain size, and, most critically, temperature [1,2].

In this study, we focus on synthesizing the $Al_{64}Cu_{23}Fe_{13}$ quasicrystal using an arc furnace technique, followed by nanostructuring through high-energy mechanical milling. Structural characterization was performed via X-ray diffraction (XRD), and magnetic properties were investigated using vibrating sample magnetometry (VSM) across a temperature range from 300 K to 50 K.

The findings reveal a notable increase in saturation magnetization (Ms) with decreasing temperature, along with a strong correlation to crystallographic domain size. This suggests that nanostructuring exerts a beneficial influence on the material's magnetic properties. Furthermore, by analyzing the zero-field-cooled and field-cooled (ZFC-FC) curves of the quasicrystal system, we developed a framework to explain how magnetic properties vary with temperature and domain size. This model offers deeper insight into how nanostructuring and thermal energy interact to impact magnetic properties, highlighting the potential of these materials for future technological applications in fields such as spintronics.

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Exchange Bias in All-Oxide Ferromagnetic/Anti-Ferromagnetic Heterostructures

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$La_{0.7}Sr_{0.3}MnO_3$ (LSMO), a room temperature perovskite ferromagnet (FM) has attracted huge interest in recent times due to its low damping [1], 100% spin polarization [2] and colossal magnetoresistance [3]. All these properties have applications in various memory and spintronic devices [4] [5] [6] [7]. To further exploit these novel properties, it is worthwhile to probe the interaction between ferromagnet / anti-ferromagnet bilayer. $La_{0.3}Sr_{0.7}FeO_3$(LSFO) shows a first order paramagnetic insulator to an AFM insulator phase transition at Neel temperature (T_N)=190K [8] [9]. We grow epitaxial LSMO (15nm) /LSFO(6,12 and 24 nm) bilayers on NdGaO3(110) (NGO)substrate. Interestingly, we observe directional AFM coupling which is stronger along the hard axis (001 axis of NGO). We observe constant T_N for LSFO thickness down to 6nm indicating high quality film growth and demonstrate robust exchange bias (EB) for 12 and 24 nm LSFO thicknesses in its AFM phase. Figures 1(a) and (b) show the EB for LSMO(15)/LSFO(24) in the two orthogonal in-plane directions. A hitherto unexplored second phase of LSFO manifests itself in the said bilayer via the behavior of the exchange field with temperature below 80K, which is anisotropic along the (001) and (1-10) axes of NGO (Figure 1(c)). We have observed this second phase by resonant x ray scattering experiments on LSFO thin film. Robust ferromagnetic properties coupled to the AFM interaction has can have efficient magnon transport, which has immense potential in spintronic, magnonic and memory-based device applications.

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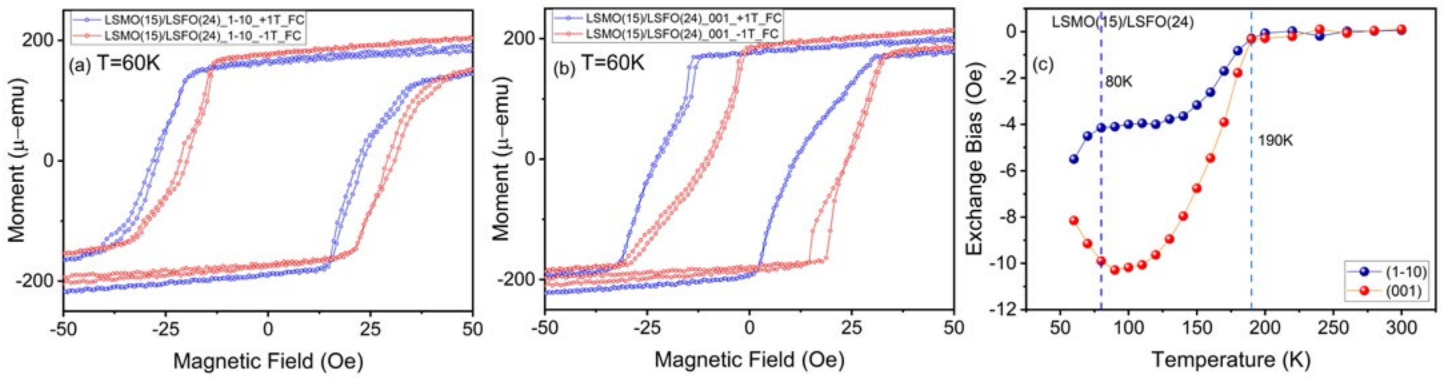

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Mechanism of Oxygen Reduction via Chemical Affinity in NiO/SiO_2 Interfaces Irradiated with keV Energy Hydrogen and Helium Ions for Heterostructure Fabrication

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Low-energy light ion beams are an essential resource in lithography for nanopatterning magnetic materials and interfaces due to their ability to modify the structure and properties of metamaterials. Here we create ferromagnetic/non-ferromagnetic heterostructures with a controlled layer thickness and nanometer-scale precision. For this, hydrogen ion (H^+) irradiation is used to reduce the antiferromagnetic nickel oxide (NiO) layer into ferromagnetic Ni with lower fluence than in the case of helium ion (He^+) irradiation. Our results indicate that H^+ chemical affinity with oxygen is the primary mechanism for efficient atom remotion, as opposed to He^+ irradiation, where the chemical affinity for oxygen is negligible.

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Vortex Clusters Induced by Toplogical Defects in Superconducting/Ferromagnetic Hybrids

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Many of the potential applications of superconducting materials require high current densities that can be obtained through different Vortex pinning strategies. We use Magnetic Force Microscopy at low temperatures to investigate the possibility of Vortex clusters forming in the presence of spatial modulation of the magnetic field in thin film superconductor/ferromagnet (S/F) heterostructures, where a type II superconductor (Nb) is deposited on a ferromagnetic (Py) layer. It is well-established that an external magnetic field induces the formation of superconducting Vortices carrying discrete flux quanta in type II superconductors. These Vortices self-organize into a hexagonal, spatially regular arrangement known as the Abrikosov Vortex Lattice, with an inter-vortex distance (d) dependent on the applied magnetic field strength. In Nb/Py S/F heterostructures, the arrangement of these Vortices is also influenced by the stripe-like magnetic domain structure of Py, which imposes a period (w) on the out-of-plane component of the magnetization, depending on the Py layer thickness. Our investigations reveal that after field cooling below the Nb critical temperature (Tc), Vortices nucleate on the underlying Py domains matching the polarity of the applied field, especially when the magnetic stripes are straight and regular. In these conditions, a hexagonal Vortex arrangement with inter-vortex distance d = 2w/cos 30° can still be established at the appropriate field. Conversely, the presence of topological defects or localized magnetization inhomogeneities, such as stripe bifurcations, gives rise to stronger stray fields at these defect sites. Once the temperature is lowered below the Nb Tc, these defects promote the formation of Vortex clusters with reduced inter-vortex spacing compared to the uniform stripe scenario. This phenomenon underscores how local variations in magnetic domain structure, including topological features, can strongly affect Vortex organization in S/F systems, potentially offering new routes for tailored Vortex pinning in future superconducting applications. We show noteworthy synergy in superconductivity and ferromagnetism now enabling fluxonics.

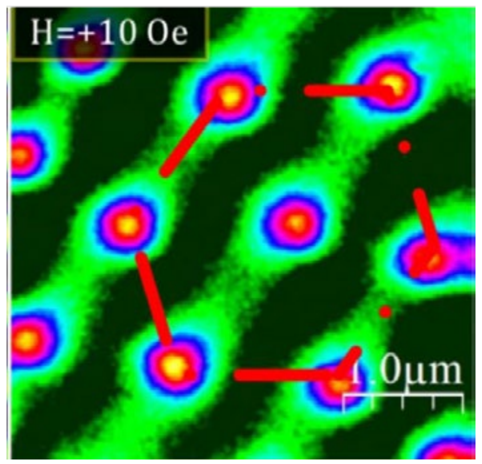

Fig. 1. MFM image at T=6K after a field cooling in H=19 Oe of a Nb(150nm)/Py(1um) hetero-structure

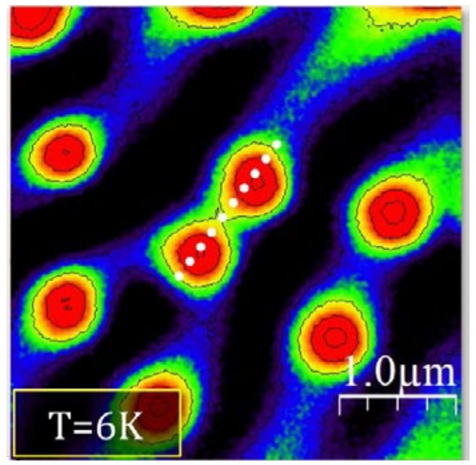

Fig. 2 MFM image of the same sample as in Fig.1 showing a Vortex cluster formed at a Py stripe bifurcation

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The Effects of Swift Heavy Ions Irradiation on Cocrpt Layers for Space and Cryogenic Applications

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The next generations of space missions demand advanced devices based on new concepts and improved materials [1]. Space is a very aggressive environment and may include the exposure to cryogenic temperatures and to different species of energetic particles (protons, heavy ions, …) in a wide range of energy from few keV to GeV. Under these extreme conditions, magnetic materials may suffer remarkable variations and degradation of their expected properties, compromising critical components or devices. CoCrPt is a material of interest for spintronics applications e.g. magnetic tunnel junctions due to its low magnetization and its large out-of-plane anisotropy [2]. We have chosen magnetron sputtered CoCrPt thin films on Si to perform preliminary radiation qualification tests. This work presents the first results of the irradiations of Ti/CoCrPt/Ti (5/20/5 nm) films with Cl^{+3} 16 MeV up to a total fluence of $5 \cdot 10^{14}$ cm^{-2}, and their magnetic characterization from 300 K down to 2 K. As expected from simulations (SRIM code) and confirmed by AFM images, the exposure to swift heavy ions of MeV energy did not induce detectable surface sputtering on the samples. However, the hysteresis loops, at 300 and 2 K, present evident modification of their coercivity and remanence values. These tests initiate prospective works to ensure the suitability of these materials as part of devices or structures for space missions.

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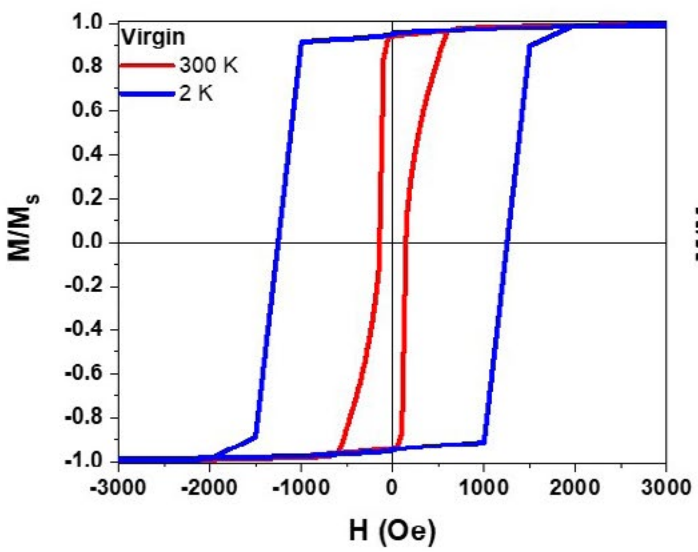

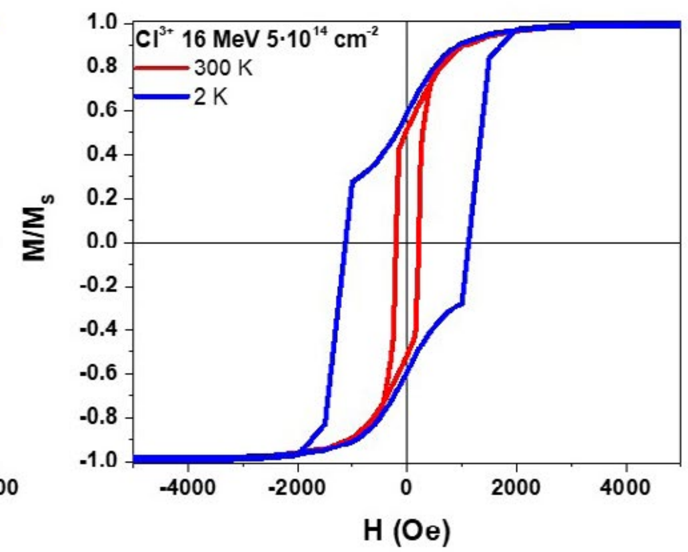

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Sputtered Epitaxial Perpendicular MTJs for Next-Generation MRAM

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The semiconductor industry is experiencing a transformative shift driven by the increasing demand for AI-powered applications, underscoring the need for advanced memory technologies. Conventional memory solutions such as SRAM, DRAM, and Flash are constrained by limitations in performance and energy efficiency, while Magnetic Random Access Memory (MRAM) has emerged as a promising alternative, offering advantages such as low latency, high power efficiency, and scalability. Despite the potential of MRAM, writing mechanisms like spin-transfer torque (STT), spin-orbit torque (SOT), and voltage-control magnetic anisotropy (VCMA) face persistent challenges, including high switching energy and reliability concerns.

This research addresses these challenges by advancing the material design of epitaxial Magnetic Tunneling Junctions (MTJs). By enabling epitaxial growth through strategic material selection for multilayer structures and optimized magnetron sputtering processes, scattering within the MTJ during read/write operations is minimized, resulting in improved tunneling magnetoresistance (TMR) ratios. Specifically, the study investigates seed layers such as NiAl and TiN to support the epitaxial growth of CoFeB/MgO/CoFeB MTJ systems on industrial-standard silicon wafers.

The findings lay a foundation for the development of high-performance MTJs that can be seamlessly integrated into standard MRAM manufacturing workflows. Furthermore, the successful implementation of epitaxial growth using optimized seed layers enables the exploration of novel magnetic materials and metals, paving the way for next-generation MRAM breakthroughs and providing fundamental insights into the magnetic and structural properties of MTJs.

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Reciprocity Breaking and Tunneling in Two Terminal Chiral-Induced Spin Selectivity

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The phenomenon of Chirally Induced Spin Selectivity (CISS) in biological molecules has garnered significant attention due to its unexpected spin polarization, even in systems devoid of magnetic centers and operating at room temperature. Remarkably, experiments show spin polarizations reaching up to 50-60%[1], surpassing traditional ferromagnetic materials and apparently contradicting Onsager's reciprocity in the linear transport regime. This research aims to resolve these discrepancies by developing a tight-binding model for DNA and oligopeptides in real space. We explain the observed spin transport behavior by incorporating key symmetry-relevant features: atomic spin-orbit (SO) coupling, molecular chirality, and environmental interactions. The model focuses on constructing an s- and p-orbital Hamiltonian that captures the key overlaps between neighboring bases in biological chiral molecules. These overlaps include the helical structure and base tilting, which are crucial for gauging the strength of the spin activity. The model is connected to metallic p-orbital reservoirs in the two-terminal transport configuration to compute the linear regime's spin filtering and I-V characteristics. Coupling to the environment is emulated by multiple lateral decoherence probes that introduce time-reversal symmetry breaking and account for inelastic impurity scattering, electron-phonon, and electron-electron interactions. This allows us to introduce the character of these interactions through the respective self-energies. Simulations are carried out through the Green's function formalism using the KWANT quantum transport software, with the semi-infinite probe approach or the D'Amato Pastawski voltage probe for decoherence effects. Our results show a substantive spin selectivity resulting from an interference effect between coherent and incoherent transport contributions induced by non-spin-selective probes. While tunneling is essential for enhancing spin activity exponentially, off-resonance conditions in transport also contribute significantly to spin selectivity.

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Efficient Field-free Switching of Perpendicular Magnetization Induced by Dominant Out-of-Plane Torque Generated by $NbIrTe_4$

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Spin-orbit torque (SOT) has emerged as a promising mechanism for electrically manipulating magnetic states, which is vital for the development of high-speed, low-power memory technologies. Despite its potential, the traditional spin Hall effect (SHE) primarily produces in-plane spin currents due to symmetry constraints. This limitation necessitates the use of external magnetic fields or complex structures to achieve effective switching of perpendicular magnetization, hindering device efficiency and versatility.
In this study, we explore the unique properties of the Weyl semimetal $NbIrTe_4$, which can generate a significant out-of-plane spin current. This characteristic allows for reliable, field-free switching of perpendicular magnetization with improved efficiency. Through a combination of experimental results and theoretical analysis, we reveal that $NbIrTe_4$ exhibits substantial out-of-plane spin Hall conductance of ,and . These insights into the spin-orbit coupling mechanisms of $NbIrTe_4$ highlight its potential in advancing scalable, energy-efficient spintronic devices, particularly for applications requiring robust and efficient control of perpendicular magnetization without external magnetic fields.

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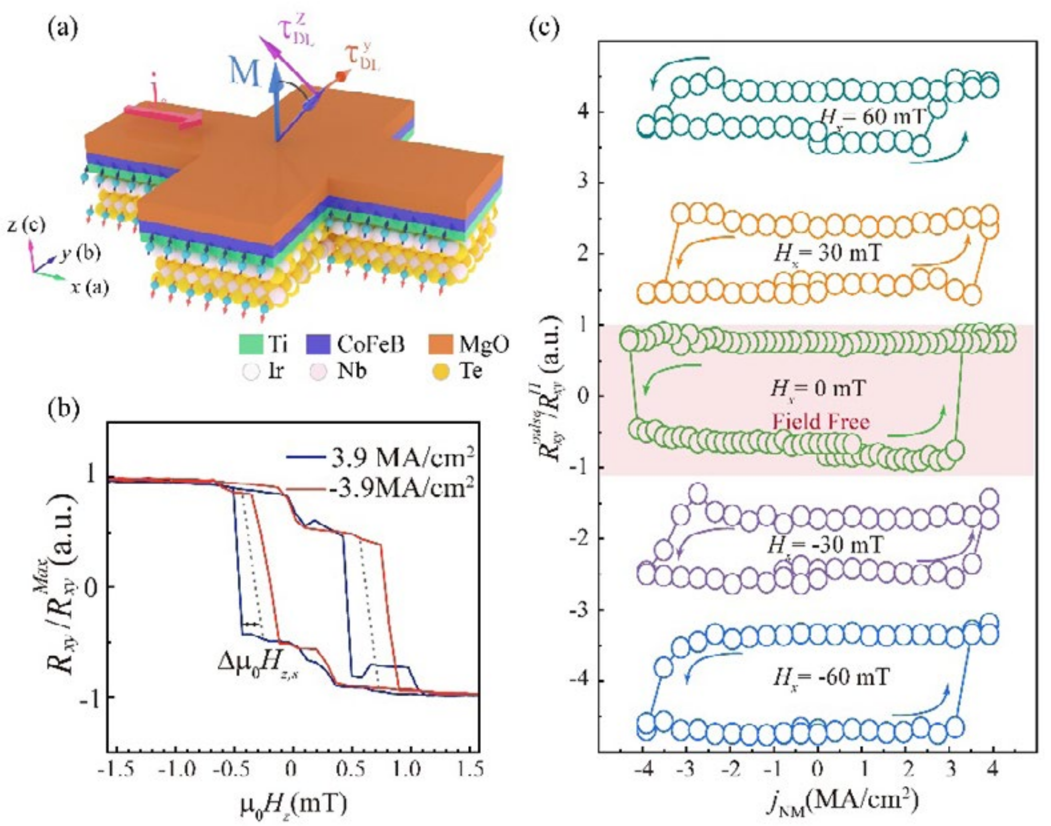

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New Take on the Electron Spin Polarization of Ferromagnets and Its Role Moving Towards Altermagnetic Spintronics

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Although central for spintronics, the interplay between magnetism and transport in metallic ferromagnets remains incompletely understood. In particular, the finite temperature resistivity of elemental Fe, Co, Ni could only be modelled until recently using sophisticated ab-initio methods [1]. In this work, we address this interplay experimentally in MgO/Fe/MgO thin films, using the recently developed current-induced spin-wave Doppler shift technique: we measure the shift of the spin wave resonance field due to the spin-transfer torque from the electric current.
Following precisely the shifts of counterpropagating spin waves, we extract the temperature dependence of the degree of spin-polarization of the electrical current *P*. This is found to increase from 75% up to 85% when cooling the sample from 300K down to 10K. Our observation contradicts earlier predictions and measurements on the ballistic regime, which, in agreement with the global density of states (DOS), establish a weak spin-polarization for Fe. On the contrary, we propose a change of perspective: the spin-polarization of the current is not directly linked to the DOS, but it is determined by the scattering experienced by the electrons with other degrees of freedom like film surfaces, phonons and magnons. For the case of Fe, we argue there is a majority electron channel that is much less affected by scattering compared to minority electrons.
This observation opens the door for a new type of spintronics where instead of avoiding electron scattering, it could be engineered to enhance the current spin-polarization in magnetic materials. This is particularly interesting for heterostructures that incorporate ferromagnets and altermagnets: the possibility of modulating the spin-polarization in the former combined with the intrinsically anisotropic nature of the latter [2] result in a versatile set of physical variables for technological applications. Here we also present the initial steps in this direction by combining ferromagnet/altermagnet bilayers.

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Interfacial Modulation of Spin-Charge Conversion by $NbIrTe_4$/Pt

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Current-induced spin-orbit torque (SOT) is attracting increasing interest and exciting significant research activity. However traditional SOT materials can only provide in-plane spin current, and achieving perpendicular magnetization switching often necessitates the assistance of an external field. This complicates the device structure and makes efficient utilization challenging.
In this work, we demonstrate a large out-of-plane damping-like SOT at room temperature using the Weyl semimetal candidate NbIrTe4 with a lower crystal symmetry. We performed spin–torque ferromagnetic resonance (STFMR) and discovered that $NbIrTe_4$ exhibits significant out-of-plane spin Hall conductivity. Then, we regulated the interface of NbIrTe4 material through Pt intercalation, effectively controlling the generation of out-of-plane spin current. The spin-charge conversion efficiency in both the z-direction and y-direction has changed. This is of great significance for studying NbIrTe4 interface regulation and field-free out-of-plane spin devices.

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Magneto-Controlled Reentrant Superconductivity Effect in Superconductor/Antiferromagnet Heterostructures: Exploring a Viable Alternative to the Superconducting Spin-Valve Effect for Spintronic Applications

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The superconducting (SP) spin-valve effect has been proposed as a viable mechanism to manipulate and control the SP transition temperature Tc in Ferromagnet/Superconductor/Ferromagnet (FM/S/FM) heterostructures. Research in this field establishes that the Tc can be decreased or increased, or eventually nullified, when FM layers are magnetized parallel (P) or antiparallel (AP). However, since the variation Tc is smaller than the width of the SP transition itself, it has not been possible to establish an optimal T at which the system is in the normal state in the P configuration and becomes completely SP in the AP configuration [1, 2]. In this work, we explore an alternative variant to the SP spin-valve effect, which consists of studying the influence of the antiferromagnetic (AFM) order on the SP state in heterostructures formed by an SP core of $YBa_2Cu_3O_{7-\delta}$ (YBCO) and an AFM shell of Terbium Oxalate in order to promote a magneto-controlled effect of reentrant superconductivity in the heterostructure, and thus lead to a possible switching effect between normal and SP states by applying small magnetic fields. The heterostructures are magnetically studied by varying the weight ratio between the SP core and AFM shell. Our results show that composites with 10% YBCO content present a magneto-controlled effect of reentrant superconductivity promoted by the strong electromagnetic interaction between AFM order and SP state. In the presence of small magnetic fields, the spin polarization of the AFM shell induces an exchange field in the SP core, promoting electronic decoupling and then suppressing the SP state at T_{c2}. When evaluating the critical temperatures in 10:90 composites, T_{c1} and T_{c2} were found to be 92 ± 0.1 K and 3 ± 0.5 K, respectively, the latter being set by the AFM ordering at T_N = 3.8 K. These data suggest that, if an optimal operating temperature $T<T_{c2}$ is established in S/AFM heterostructures, they could exhibit a switching effect between the normal and SP states by applying small magnetic fields. If this SP effect is confirmed by measurements, it would represent a serious alternative to the SP spin-valve effect in developing switchable electronic devices for spintronic applications.

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Magnetic Phase Diagram and Antiferromagnetic Spin Canting in FeRh

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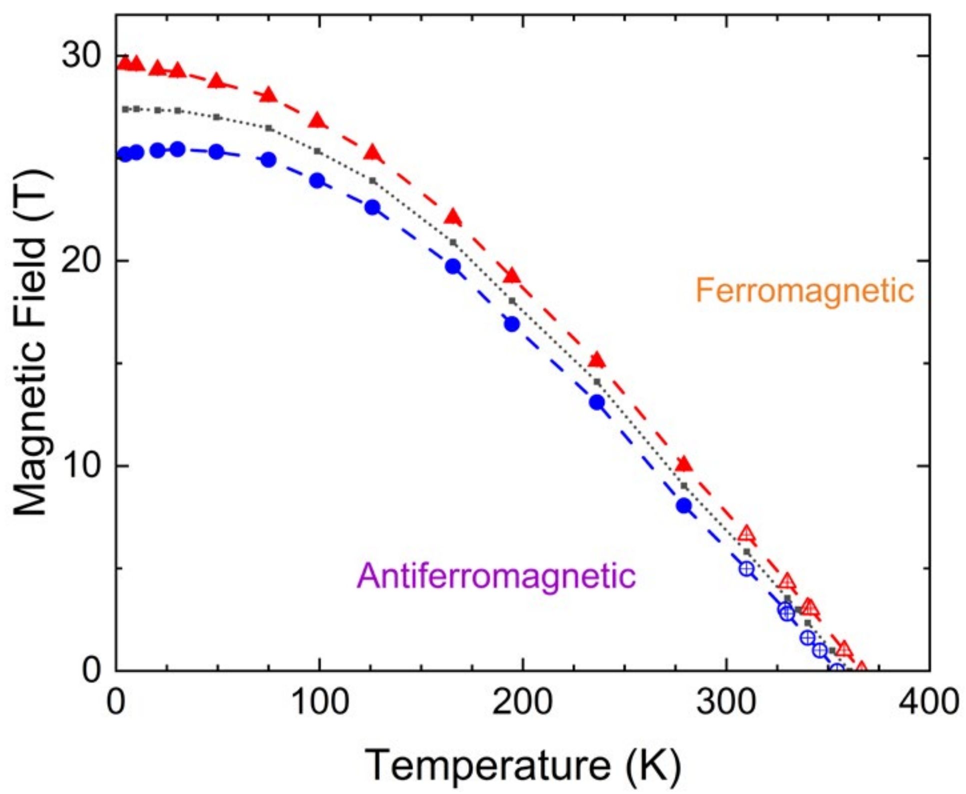
FeRh is a material that has been of increasing interest, primarily because it exhibits strong coupling of spins, charges, and lattice and a first-order hysteretic phase transition near room temperature between a low-temperature high-resistance antiferromagnetic state and a higher-temperature low-resistance ferromagnetic state, along with a 1-2 % isotropic change in unit cell volume. The application of an external magnetic field is known to shift the transition to lower temperatures by 8-10 K/T [1], however the phase transition has not previously been studied above the 9 T commonly reachable in laboratory measurements. In addition, there is no previously reported experimental work studying the nature of the antiferromagnetic phase and the canting of the spins under application of a field. In this work [2], we conduct high-field and low-temperature resistance measurements of the phase transition in an FeRh wire to map out the field-temperature phase diagram, as shown in the figure. X-ray magnetic circular dichroism (XMCD) measurements of an FeRh film are made in order to study the antiferromagnetic phase, demonstrating the presences of a spin-canted rather than a collinear antiferromagnetic state. These measurements contribute to mean-field modeling of the phase diagram and understanding of some of the material properties such as anisotropy.



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Magnetic Characterization and Domain Wall Dynamics in Tb/Co Ferrimagnetic Multilayers

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In ferromagnetic materials, the ability to modify different parameters and thus tune their magnetic properties is essential for the development of different spintronic and optoelectronic devices such as magneto-optical recording, high-frequency oscillators and others [1]. On other hand, in ferrimagnetic materials (FiM) it was observed a more complex scenario; which make their applications even more interesting. Depending on its composition, there is a magnetic compensation temperature (T_M) and also an angular compensation temperature (T_A). These phenomena, which are a fingerprint of the FiM materials, remarkably enriches the physics of this kid of systems.

In this work, we present the structural and magnetic characterization of a series of ferrimagnetic multilayers composed of five periods Tb/Co, see figure. All the samples have a constant Co thickness of 1.7 nm and the Tb thickness ranging between 0.5 nm and 1.2 nm; moreover, they exhibit a dominant perpendicular magnetic anisotropy (PMA). For the whole family of samples, a systematic study of the magnetic compensation temperature (T_M) and its magnetization curves was carried out.

Additionally, a modified Stoner-Wohlfarth model was developed to minimize the magnetic free energy and reproduce qualitatively and quantitatively the experimental magnetic hysteresis loops of the multilayers. The modified model takes into account that the magnetization reversal is given by domain nucleation instead of coherent rotation; and its strengths and limitations are analyzed and discussed.

Furthermore, domain wall dynamics was systematically studied for samples with different Tb thicknesses by PMOKE microscopy. Different roughnesses of domain wall were observed which depend on the magnitude of driving force regardless of Tb thickness. The parameters of the domain wall dynamics obtained using a self-consistent model [2] are presented.

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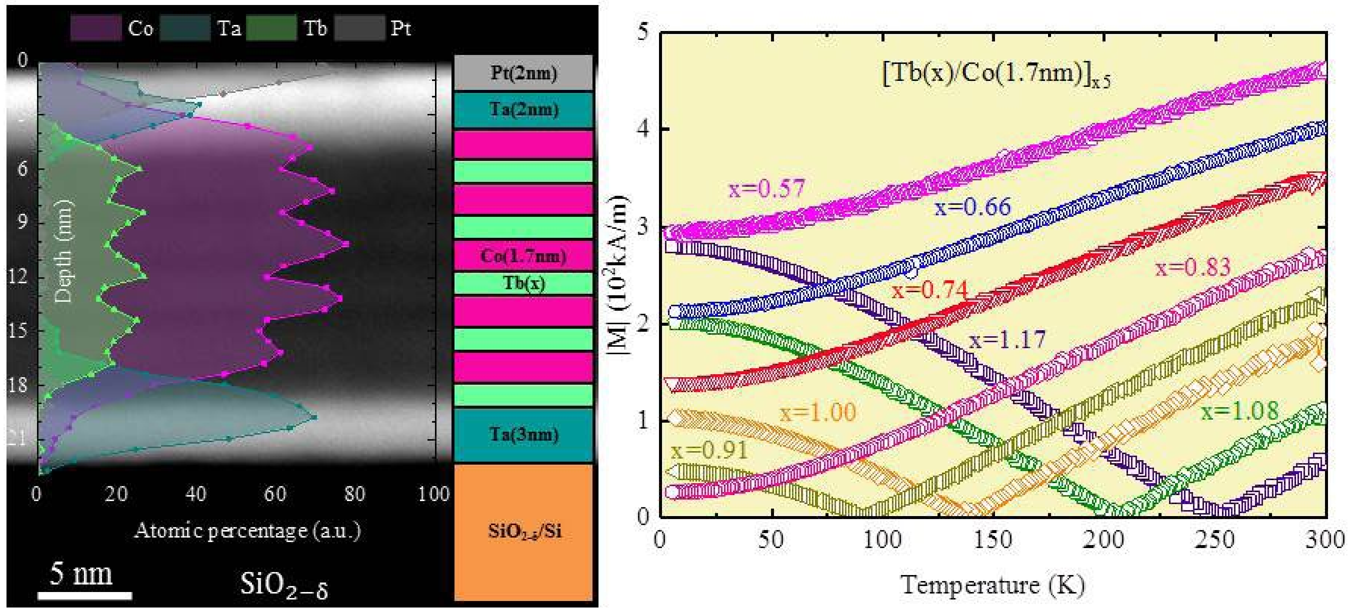

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Study of the Spin Wave Amplitude in Fe85CO15/Py Bilayers

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We present a detailed study of the dependence of the spin wave amplitude on the ferromagnetic coupling and thickness of FM/FM bilayers. A series of Fe85Co15/Py bilayers deposited on MgO substrates [100] were grown using the Sputtering technique. Magnetic characterization of the samples was performed by using the vibrating sample (VSM) and the magneto-optical Kerr effect (MOKE) magnetometers. The hysteresis loops reveal the existence of an hard axis of magnetization along [100] direction of MgO, and an easy axis of magnetization along [110]. To determine the thickness of the bilayers, X-ray reflectometry and TEM studies were carried out, obtaining results similar to those expected. Using ferromagnetic resonance (FMR), the angular dependence of the resonance field was obtained, and it was fitted with the Smit and Beljers model. The resonance field was measured for various frequencies using a vector network analyzer (VNA) in the direction of the hard axis of magnetization. Besides this, we calculated the amplitude of the spin waves in each layer. To do this, we proposed the magnetization equation of motion in which we use the Landau damping. The calculation results show that the ratio of spin wave amplitudes of the layers depends on the exchange coupling and their thicknesses. Moreover, the maximum ratio value is reached for an intermediate exchange coupling. These results could be interesting thinking the studied bilayers as spin pumping system, where th magnitud of the spin current can be tuned by modifying the exchange coupling and/or thicknesses of the bilayer system.

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Ultra-Thin Films Studied by Low Temperature MOKE

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The transversal Magneto-Optical Kerr Effect (T-MOKE) refers to the change in reflectivity of surfaces with a nonzero net magnetization. By using this effect, it is possible to probe the magnetization of ultra-thin magnetic films obtaining it´s hysteresis loops. In this case, we use a T-MOKE setup to measure changes in intensity from ultra thin magnetic films. The films are placed within a cryostat connected to a helium compressor, enabling measurements at low temperatures [1]. T-MOKE and VSM techniques were used and compare to characterize ultra thin films of cobalt oxide heterostructures, CoO(2.5)/Al2O3(5) and CoO(2.5)/Al2O3(5)/CoO(2.5)/Al2O3(5)[2], where the numbers in parentheses indicate thicknesses in nm, for fields below 1000 Oe in a temperature range of 30 K to 450 K as is shown in the figure. Variations of the hysteresis loops were observed with changes in temperature and magnetic field. The coercive field (Hc) and remanence (Vr) point to a phase transition between 147 K and 150 K, along with a decrease in remanence at very high or low temperatures. Both systems showed similar behaviors between 150 K and 300 K. Temperature effects on magnetic properties were more notizable in the T-MOKE techniques, highlighting the need for more precise and sensitive techniques por such meassurements.

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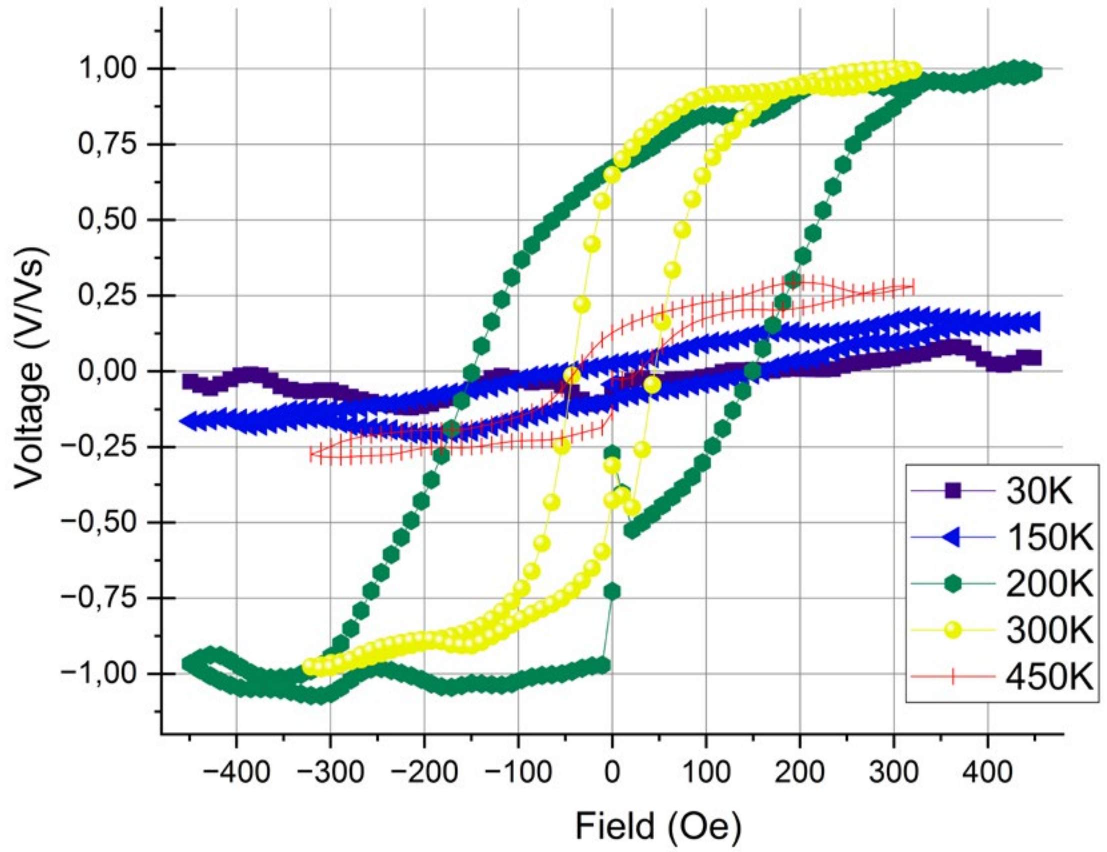

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