8th Young researchers in magnetism conference

University of Cantabria, Santander, Spain
November 7th 2024

YRinM 2024

Book of abstract

UC UNIVERSIDAD DE CANTABRIA

CITIMAC Grupos de Física de Nuevos Materiales

IEEE MAGNETICS

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Welcome

The annual meeting of the Spanish Magnetism Club and the Spanish Chapter of the IEEE Magnetics Society will be held in the University of Cantabria, Spain. The 8th Young Researchers in Magnetism, the traditional special session devoted to young researchers will take place during this meeting, on November 7th. This year, it is again organized for and by the young researchers.

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Conference Venue

Location

Universidad de Cantabria,
Facultad de Ciencias
Av. de los Castros, 48, 39005 Santander, Cantabria

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YRinM Conference Program

7 November 2024

8:45 - 9:00	Registration
9:00 - 9:07	Opening Ceremony

Session 1: 9:07 - 10:55

9:07	José Luis Garrido	*Neutron Diffraction as a tool for Studying Magnetic Effects on RFe-based Intermetallic Alloys*	O1
9:20	Aun Nawaz	*Magnetostructural transition and magnetocaloric response in Mn(Fe)-Ni-Si(Al) alloys.*	O2
9:33	Jorge Revuelta	*Lock-in infrared thermography for magnetocaloric materials characterization*	O3
9:46	Deborah Liguori	*Exploring the High Magnetic Anisotropy of Cobalt-Ferrite Nanoparticles: Influence of Cation Composition*	O4
9:59	Jorge Vergara	*MnAl Alloy powder produced via ultrasonic atomization*	O5
10:12	Elisa Guisado-Arenas	*Novel low criticality Mn(Fe)Ni(Cu)Si high entropy alloys for magnetocaloric applications*	O6
10:25	Laura Álvaro	Invited talk: *Chirality, topology and timescales of magnetization dynamics in cylindrical nanowires*	
10:55-11:20	Poster Session and Coffee Break		

Session 2: 11:20 - 13:10

11:20	Mariana Rios	*Effect of Fe-doping in $Ni_{35}Co_{13}Mn_{35-x}Fe_xTi_{17}$ melt spun-ribbons*	O7
11:33	Shirin Talebniya	*Magnetic Nanoparticles in Sensor Technology: DFT Analsysis of Carbon Monoxide Adsorption on Fe_3O_4 Surfaces*	O8
11:46	Alix Tatiana Escalante	*Enhancing Magnetic Force Microscopy with FEBID-grown Nanotips*	O9
11:59	Clara Miranda	*Stacking engineering in orthogonally-twisted two-dimensional CrSBr magnets*	O10
12:12	Zhe Cui	*High-Throughput DFT Screening of MnMX Alloys for Magnetic Refrigeration Applications*	O11
12:25	Jorge Alejandro Lopéz	*Magnetic Nanostructures for Biomedical Applications*	O12
12:38	Jorge Marqués	Invited talk: *Advances imaging with non-standard Magnetic Force Microscopy*	
13:10-14:40	Lunch		

YRinM Conference Program

7 November 2024

Session 3: 14:40 - 16:48

14:40	Yolanda Álvarez	*Influence of Chemical and geometrical modulations on magnetic properties of Co & Ni Bisegmented nanowires*	*O13*
14:53	Gloria Guerrero	*Influence of Polymer Matrix on the Manufacturability and Performance of Soft Magnetic Filaments for Additive Manufacturing*	*O14*
15:06	Andrés García	*Fabrication and characterization of Sm-based $ThMn_{12}$-type compounds for permanent magnet applications.*	*O15*
15:19	James Romo	*Fabrication, Magnetic and Structural Properties of MnFePSi Microwires and Bulk Alloys.*	*O16*
15:32	Santiago Ceballos	*Exploring $Pd_{1-x}Fe_x$ alloy thin films and ribbons: a breakthrough in ultrasensitive and wireless hydrogen detection*	*O17*
15:45	Lina Vanessa	*Improving the magnetic properties of τ-MnAl by low Cu doping*	*O18*
15:58- 16:48	Special Talk*: From basic research to technological transfer*		
16:48 -17:40	Poster Session and Coffee Break		
17:40- 18:00	Awards & Clossing Ceremony		

YRinM Poster Session

7 November 2024

Miguel Barquín	*Future perspectives on the evolution of graphene-magnetic nanoparticle hybrid structures as revealed by neutron scattering analysis*	*P1*
Leyre Bei	*Radiofrequency characterization of magnetic nanoparticle distributions on rigid substrates for biosensing applications*	*P2*
Moisés Gilberto Zarzoza	*Magnetic SAR calculations by using micromagnetic simulations and a simple model at different wave shapes.*	*P3*
Palmerina González	*Tailoring the properties of multifunctional hybrid compounds via molecular design.*	*P4*
Raúl López	*Expanding the nanomagnetism chart: Non-dipolar interparticle interactions and Non-exchange bias.*	*P5*
Inés Sánchez de Movellán	*Magnetic Insulators: a First-Principles Study of Superexchange Interaction.*	*P6*
Hamida Gouadria	*Synthesis and characterization of 2-dimensional chiral hybrid organic-inorganic metal halides*	*P7*
Adrián Fernández	*High-Coercivity Ferrite Nanocomposites without Critical Raw Materials*	*P8*
Enrique Conde	*Development and Optimization of Probes for Near-Field Microwave Microscopy in Magnetic Material Characterization.*	*P9*
Raquel Loriente	*Studying the Advanced Interaction of Magnetic Microwires and Ferrofluids for Breakthrough Biosensor Development*	*P10*
Pablo Martínez	*Magneto-thermoelectric energy harvesting through the Nernst Effect*	*P11*
Alba Martínez	*Intelligent magnetically activated drug delivery devices fabricated by 4D printing*	*P12*
Saioa Sierra	*Synthesis and characterization of Fe_3O_4-C nanoparticles as efficient nanoadsorbents*	*P13*
Elisa Herrera	*3D-printable composites for magnetic refrigeration based on Ni-Mn-In-Co magnetic shape memory alloys*	*P14*
Elisa Herrera	*Fe_3O_4-TiO_2 nanophotocatalysts for water remediation applications*	*P15*
Joep Van Deursen	*Magnetite nanoclusters for detection labels in magnetic lateral flow immunoassays*	*P16*
Ana Isabel Jiménez	*Magnetic Properties of Electroless-Plated Ni-based Rhombohedral Nanotubes*	*P17*
Manuel Horcajo	*Optimization of Magnetite Nanoparticles for Combined Hyperthermia*	*P18*
Alicia Gascón	*Temporal and spatial resolution of magnetosome degradation at the subcellular level in a 3D lung carcinoma model*	*P19*
Sedef Özel	*Innovative magnetic transduction methodology for DNA detection in liquids*	*P20*
José Ángel Fernández	*How Curvature-Induced Effects Emerging in Corrugated Strips can shape Magnetic Domain Walls*	*P21*
Rodrigo Cubero	*Tuning the magnetic properties of Fe-Co structures through the addition of B*	*P22*
Alba Sanz Prada	*Magnetic structure study of the ternary rare based TbFeSi*	*P23*

Oral Talks
Abstracts

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Neutron Diffraction as a Tool for Studying Magnetic Effects on R-Fe-based Intermetallic Alloys

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R-Fe-based intermetallic systems (R = rare earth) are a rich source of magnetic structures due to the interaction between 3d and 4f electrons, making them ideal for studying the foundations of Magnetism. Among the R-Fe-based families, R_2Fe_{17} and RFeSi compounds display diverse magnetic phase diagrams and exhibit a wide variety of magnetic effects, such as spin reorientation transitions, magnetocaloric and magnetovolume effects [1,2]. Neutron diffraction (ND), one of the most powerful techniques for investigating magnetic materials, is crucial for unraveling the changes in the nuclear and magnetic structures [3]. In this work, we present a case study using ND to determine the intrinsic magnetic properties of R_2Fe_{17} and RFeSi alloys and explore their relationship with the anomalous temperature evolution of the cell parameters [see Fig.1(a)]. Particularly, the previously unresolved question of the magnetic moment of Fe in the TbFeSi alloy has now been addressed, demonstrating that the magnetic moment of Fe is non-zero. By combining ND analysis with Density Functional Theory (DFT) calculations, we conclude that the collinear ferrimagnetic configuration [see Fig.1(b)] best aligns with the experimental data for both compounds.

Index Terms — Neutron diffraction; Tb_2Fe_{17} and TbFeSi compounds; DFT calculations.

Acknowledgements

The authors acknowledge the financial support from Spanish MICINN (MAT2011-27573-C04-02), LINAN, CONACYT (CF-2023-I-2143) and COPOCYT (23871), the ILL and CRG-D1B for allocating beamtime and the TU of Ostrava for the calculation time on the Barbora server.

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[3] G. L. Squires, Ed. Dover Publications, New York, 1996.

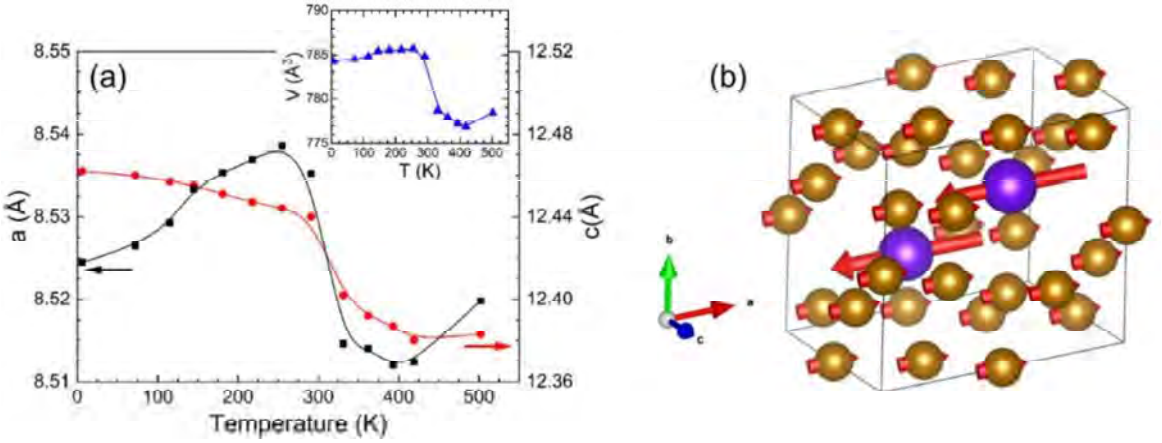

Figure 1. (a) Thermal dependence of cell parameters and volume (inset) and (b) magnetic structure of Tb_2Fe_{17}.

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Magnetostructural transition and magnetocaloric response in Mn(Fe)-Ni-Si(Al) alloys

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The rare-earth free and low-critical Mn(Fe)-Ni-Si(Al) alloys are gaining attention in the magnetocaloric community due to their tunable magnetostructural transition and large magnetocaloric response for moderate magnetic field changes. This class of materials undergoes a structural transformation from a high-temperature Ni_2In-type structure to a low-temperature TiNiSi-type structure. However, looking into the literature, large variations in the magnetocaloric responses of similar compositions are widely found. In this work, we present a systematic analysis of the influence of heat treatment and variation in Si:Al ratio on the magnetostructural and magnetocaloric properties of the $Mn_{0.5}Fe_{0.5}NiSi_{1-x}Al_x$ alloys. Starting with x = 0.0525 composition (designated as $Al_{0.0525}$), the alloys were heat treated at various temperatures (1073 K, 1173 K and 1273 K for 7 days) followed by quenching in water. After establishing the optimal annealing temperature, the investigations were extended to the influence of variation in Si:Al ratio, with Al content increasing: 0.0525 → 0.060 → 0.0685 [1].

It is found that annealing the sample at 1173 K led to a sharp magnetostructural transformation occurring near-room temperature (**Fig. 1a**), along with no traces of impurities. Under these conditions, a large magnetocaloric response (- 11.5 J kg^{-1} K^{-1} for 1 T) is obtained, representing the highest value reported so-far for the Mn(Fe)-Ni-Si(Al) alloys near-room temperature. Upon increase in Al content from 0.0525 to 0.0685, the transformation shifts to lower temperatures (100 K decrease) whereas the temperature average entropy change, *TEC* (5), shows a rather similar performance for the investigated alloy series (**Fig. 1b**).

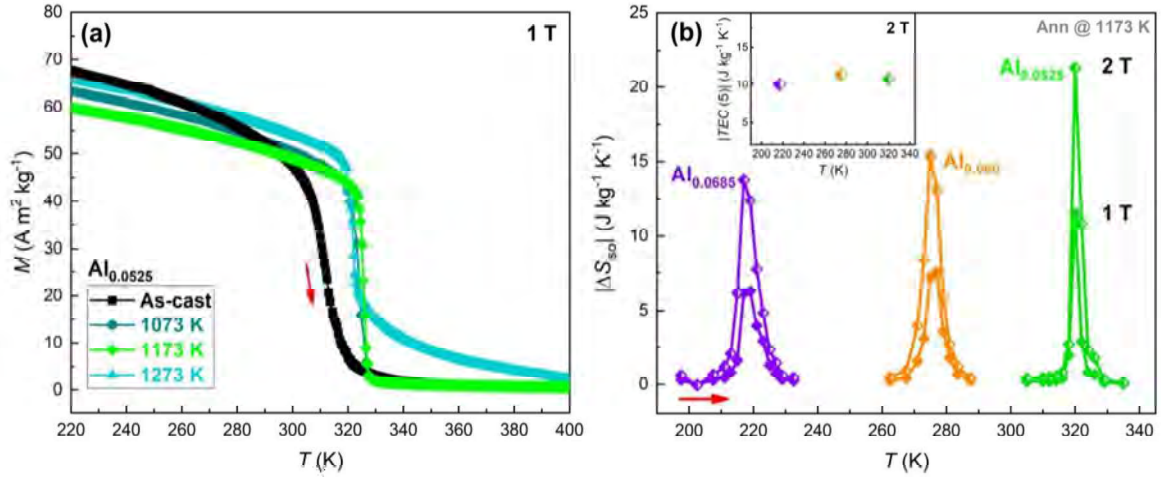

Fig. 1: Temperature dependence of (a) magnetization for heat-treated $Al_{0.0525}$ samples and (b) isothermal entropy change for the Al-doped series for 1 and 2 T. *The inset shows the TEC* (5) *values obtained for 2* T.

Acknowledgments

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Reference

[1] A.N. Khan, L.M. Moreno-Ramírez, J.Y. Law, V. Franco, J. Alloy. Compd. **1008** (2024) 176724.

Index Terms — MnNiSi alloys; magnetostructural transition; magnetocaloric response

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Lock-in infrared thermography for magnetocaloric materials characterization

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Characterizing the cyclability and phase transformation dynamics of magnetocaloric materials is vital for elucidating their applicability in magnetic refrigeration devices. To assess the reversible performance of the materials in conditions similar to the practical operation, a direct characterization method for the adiabatic temperature change has to be implemented. For this purpose, contact temperature sensors are generally more suitable for large samples [1]. Alternatively, infrared thermography (IRT), a non-contact measurement, allows the simultaneous characterization of multiple small samples, potentially making it a high-throughput technique [2]. However, conventional IRT using low-cost infrared cameras has the limitation of a noise level of the order of 150 mK, which affects the type of materials that can be studied and the magnitude of applied magnetic field that is required.

In this work, we present a device for characterizing the reversible magnetocaloric response based on a low-cost infrared camera and the implementation of lock-in analysis via software. Using AC magnetic field excitation, lock-in amplification allows us to obtain the reversible adiabatic temperature change with a resolution that is two orders of magnitude larger than conventional thermography (Fig. 1 *a*). Furthermore, the system allows the extraction of the phase shift with respect to the excitation field, providing insight into the dynamics of the transition, and indicating whether the response is inverse or direct. The performance of the device is demonstrated by characterizing several magnetocaloric materials with different types of phase transitions: (1) Gd, undergoing a second-order transition; (2) $LaFe_{11.38}Mn_{0.28}Si_{1.34}$ undergoing a magneto-elastic first-order transition; (3) $Ni_{48.6}Mn_{35.9}In_{15.5}$ (Fig. 1 *b*, *c*) and (4) $Ni_{36}Co_{14}Mn_{35}Ti_{15}$ Heusler alloys, which undergo magneto-structural first-order transition with different degrees of overlap with the austenite's second-order transition and hysteresis.

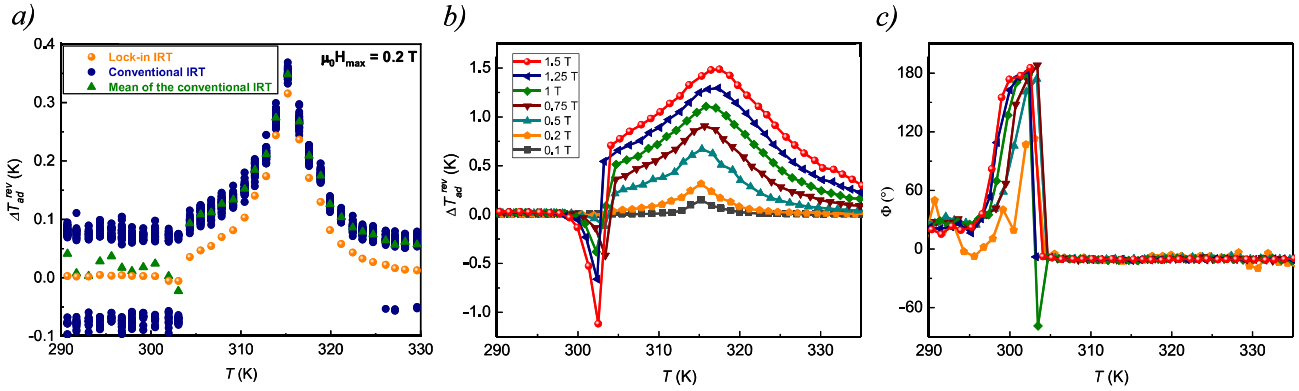

Fig. 1. $Ni_{48.6}Mn_{35.9}In_{15.5}$ sample: (a) Lock-in compared to conventional thermography, (b) its reversible adiabatic temperature change, and (c) the phase shift with temperature for different magnetic fields.

Acknowledgments

Work funded by PID2019-105720RB-I00 and PID2023-146047OBI00 from MCIN/AEI and US Air Force Office of Scientific Research (FA8655-21-1-7044).

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Index Terms — Magnetocaloric effect, Device development, Direct characterization, Infrared thermography, Lock-in.

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Exploring the High Magnetic Anisotropy of Cobalt-Ferrite Nanoparticles: Influence of Cation Composition

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Cobalt-doped iron oxide ($Co_xFe_{3-x}O_4$) nanoparticles (NPs) have been extensively studied in recent years for its potential application in rare-earth-free permanent magnets (PM)[1]. Despite extensive studies, the magnetic anisotropy origin in $Co_xFe_{3-x}O_4$ remains poorly understood, dependent on both composition and particle size[2, 3]. In this study, we performed chemical synthesis by thermal decomposition (TD) to produce a series of $Co_xFe_{3-x}O_4$ NPs with varying composition ($0.1 \leq x \leq 0.9$) while maintaining a uniform large particle size, surpassing the superparamagnetic limit[4.5]. Aiming for large NPs, we substituted $CoCl_2$ for the commonly used $Co(acac)_2$ precursor in TD, mixing $CoCl_2$ and $Fe(acac)_3$ in a high-boiling-point solvent, benzyl ether, along with oleic acid and oleylamine as surfactants. The mixture was heated to the decomposition temperature (270 ºC) and maintained the reaction for 15 minutes. We obtained large NPs of roughly 24(4) nm (Figure 1a). Rietveld refinement from x-ray diffraction patterns confirmed these values, revealing a pure-phase spinel structure without satellite peaks. The observed increase in the cell parameter with the rising x, attributed to the larger ionic radius of Co^{2+} in comparison with Fe^{2+}/Fe^{3+}, was accompanied by negligible microstrain values, providing additional evidence of the large particle size. On the other hand, the NPs exhibit PM properties, as evidenced by open hysteresis loops at RT (Figure 1b), confirming that we surpassed the superparamagnetic limit. Interestingly, while the saturation magnetization (M_S) remains roughly constant with increasing cobalt content, the reduced remanence ($R = M_R/M_S$, where M_R is the remanent magnetization) and coercive field (H_C) demonstrate a non-monotonic dependence on x. These parameters, as well as the BH_{max} product, the figure of merit of PM, reach their maximum values at x = 0.6 - 0.7 (Figure 1c). To sum up, our study successfully synthesized a controlled series of $Co_xFe_{3-x}O_4$ NPs with uniform particle size, revealing the optimal Co content for maximizing the PM properties in the system.

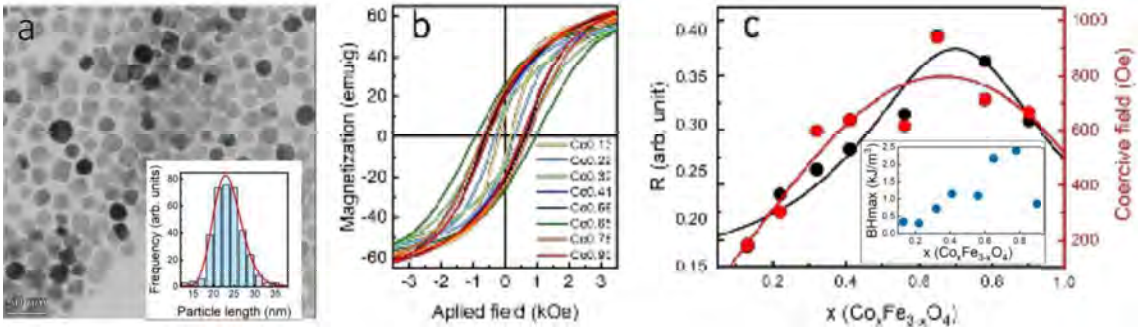

Figure 1 a) Transmission electron microscopy image and histogram for x = 0.65 NPs. b) RT hysteresis loops for the series. C) R (black symbols), H_c (red symbols) and BHmax (inset) dependence on cobalt content. The lines are guide for the eyes.

Acknowledgements

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Index Terms — Rare-earth-free permanent magnets. Cobalt ferrites. Spinel ferrites. Thermal decomposition.

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MnAl alloy powder produced via ultrasonic atomization

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Magnetic materials play a vital role in the development of greener technologies, including efficient cooling systems and electrical generators. The growing demand for permanent magnets, particularly in electric vehicles and wind turbines, highlights concerns about rare earth elements (REEs) such as Nd, Dy and Tb, the extraction of which is environmentally damaging. Moreover, the geographical concentration of these resources poses significant geopolitical challenges. In addition, heavy REEs, which are essential for optimum magnet performance, are becoming increasingly scarce. To address these issues, research is focusing on RE-free alternatives, such as MnAl-based compounds, which offer high performance at reduced cost.[1]

In this work, MnAl powder was produced for the first time with an ultrasonic atomizer. The material cleaned by sandblasting was deposited in a graphite crucible heated by induction. The melting chamber was filled with Argon ensuring an oxygen concentration below 0.5 ppm. The atomization was conducted on a vibrational plate in a lower chamber, which also was filled with Argon. Almost pure ε-phase powder was produced in spherical shapes, highly looked for 3D printing applications due to its increase of the fluidity of the mixtures at high loads. The samples were then sieved to different particle sizes to see the differences in behaviours.

Heat treatment was conducted to confer magnetic properties to the alloy by transformation from the highly pure ε-phase to the τ-phase. This route allows the reduction of the number of twining and enhances the magnetic properties [2]. A Vibrational Sample Magnetometer and X-Ray Diffractometer were used to understand the properties of the sample. Also, SEM microscopy was employed to investigate the particle shape/morphology. After treatment, the particles present a 39 emu/g and 2 kOe of coercivity. This is comparable to other flash-milled alloys produced by casting.

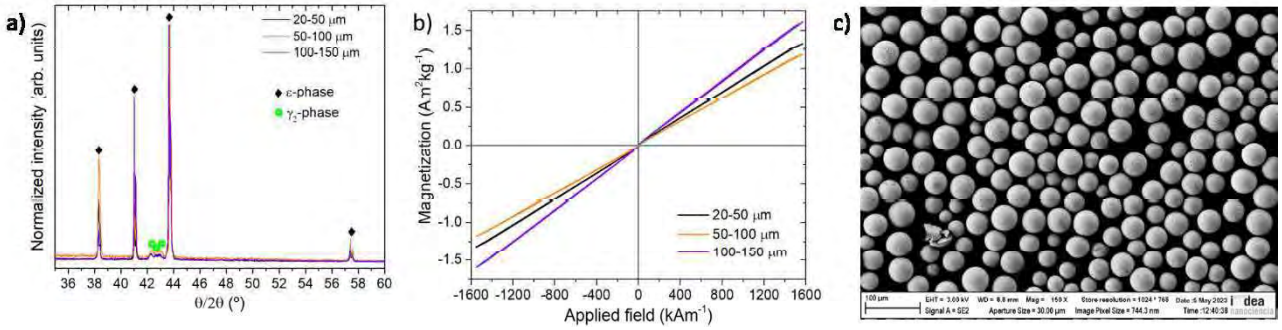

Figure 1: (a) XRD pattern and (b) VSM of ultrasonic atomized powder for different particle sizes; (c) SEM image of the powder.

Acknowledgements

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Novel low criticality Mn(Fe)Ni(Cu)Si high entropy alloys for magnetocaloric applications

E. Guisado-Arenas[1], L.M. Moreno-Ramírez[1], J.Y. Law[1] and V. Franco[1]

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Magnetocaloric materials (MCM) are called to play an essential role in the energy transition due to their superior refrigeration performance and environmental safety compared with current gas compression-based technologies. However, high-performance MCM usually contain elements such as rare-earths (RE), cobalt or germanium, which are identified with high supply risk. In recent years, the MnNiSi-related system has attracted a lot of attention due to its low material criticality and, simultaneously, the possibility of large magnetocaloric effect (MCE). MnNiSi, itself, possesses a structural transition from a high-temperature Ni_2In-type hexagonal phase to a low-temperature TiNiSi-type orthorhombic phase at 1210 K, while the Curie temperature of the orthorhombic phase (T_c^o) is located at 622 K. Therefore, the structural transition occurs in the paramagnetic region, contributing to the low magnetocaloric responses of the system. One possible approach to enhance the MCE of these alloys is to couple the magnetic and structural transitions together to obtain a first order magnetostructural transition. For achieving the magnetostructural coupling, it is necessary to bring T_t of the system below T_c^o, which can be done by compositional tunning of the alloys. Other authors have shown that replacing half of the Mn with Fe, T_t is decreased to 840 K and T_c^o is also reduced to 455 K [1], thus, the two transitions remain decoupled and additional tuning is necessary.

In this work, we study the low-criticality $Fe_{0.5}Mn_{0.5}Ni_{1-x}Cu_xSi$ series (x = 0, 0.10, 0.15, 0.20 and 0.23), based on abundant elements. By gradually replacing Ni with Cu, we achieve a remarkable decrease in T_t of more than 500 K, while only slight reductions in T_c^o are noticed. This enables us to couple the magnetic and structural transitions, leading to a transformation from a ferromagnetic orthorhombic structure to a paramagnetic hexagonal phase for $x \geq 0.15$ (Fig. 1a). Furthermore, for x=0.20-0.23, the first order magnetostructural transition occurs near room temperature. For x=0.20-0.23 samples, we also enter in the high entropy alloy (HEA) space according to their configurational entropy value [2], potentially improving their mechanical reliability. The magnetocaloric response of samples is also enhanced with Cu additions (Fig. 1b), obtaining an isothermal entropy change (ΔS) of 6.5 $JK^{-1}kg^{-1}$ (2.2 T) for the x=0.20 sample, which is one of the highest ones reported for magnetocaloric HEAs free of RE, Co and Ge [2].

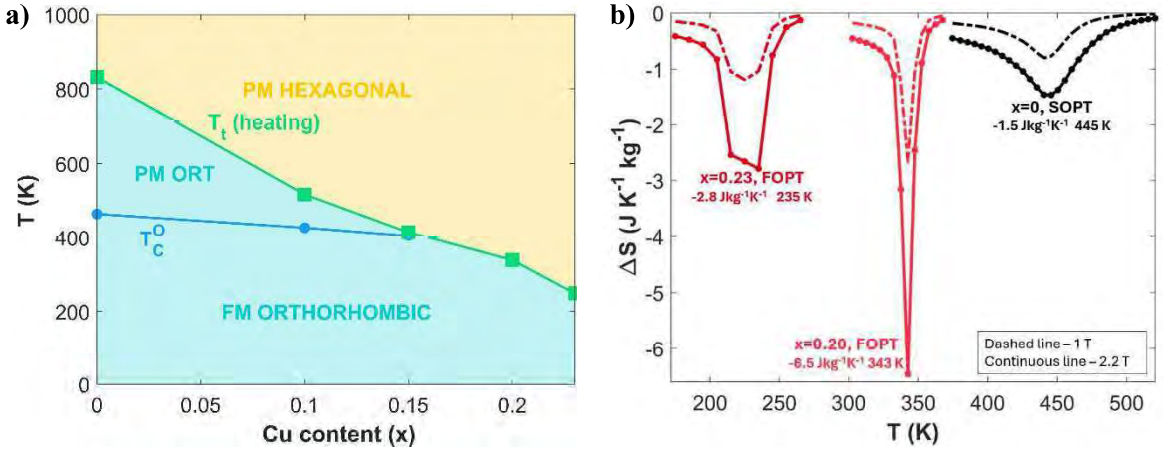

Figure 1. (a) Magnetostructural phase diagram and (b) magnetocaloric response for $Fe_{0.5}Mn_{0.5}Ni_{1-x}Cu_xSi$ series.

Acknowledgements

Work funded by PID2019-105720RB-I00 and PID2023-146047OBI00 from MCIN/AEI, US Air Force Office of Scientific Research (FA8655-21-1-7044) and the European Innovation Council via project CoCoMag (ID: 101099736).

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Magnetocaloric, MM'X alloys, first order magnetostructural transitions, low-criticality materials, high entropy alloys

Effect of Fe-doping in $Ni_{35}Co_{13}Mn_{35-x}Fe_xTi_{17}$ melt spun-ribbons

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"All-d-metal" Heusler alloys have garnered significant attention due to their remarkable magnetocaloric effect at low temperatures, making them promising for magnetocaloric applications in cryogenic ranges [1, 2]. The hybridization of d-d orbitals plays a crucial role in enabling the martensitic transformation, which is fundamental to the emergence of shape memory behavior and magnetically controlled thermal effects [3]. In this work, a series of $Ni_{35}Co_{13}Mn_{35-x}Fe_xTi_{17}$ (x = 0, 1, 2, 3, 4, 5, 6) ribbons were prepared using the melt-spinning technique. Macroscopic magnetic measurements indicate that the change in magnetization (ΔM) during the martensitic transformation strongly depends on the alloy composition (see Figure 1, left). The Curie temperature, austenite temperature, and martensitic temperature were determined using the first-order derivative and slope methods (see Figure 1, right), and the maximum values of magnetic entropy change were calculated under an applied field of 2T. The inclusion of Fe atoms in the structure shifts martensitic transformation (MT) to lower temperatures. Microstructural analysis using SEM-EDX revealed surface grains, which correlate with anomalous behavior in some of the samples (see Figure 2). Additionally, preliminary X-ray and neutron diffraction studies confirmed the presence of the austenitic B2 cubic phase and the orthorhombic Pnma martensitic phase.

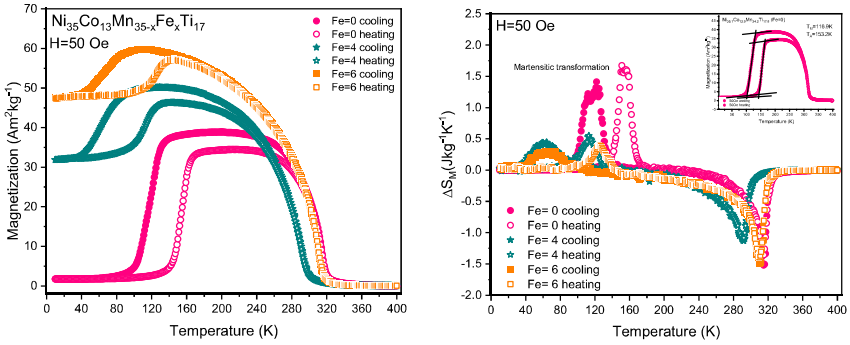

Figure 1. Thermomagnetization for some representative ribbons (left). Isothermal magnetic entropy change curves, inset shows the conventional method for martensitic transformations (right).

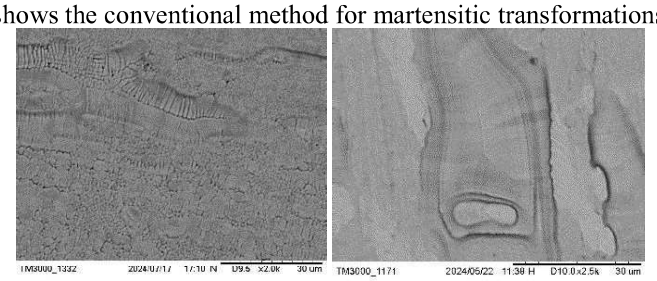

Figure 2. SEM images of the free surface for the ribbons without Fe and 2 at. % Fe respectively.

Index Terms — All-d-metal Heusler alloys, Martensitic transformation, Magnetocaloric effect

Acknowledgements

This work has been carried out with the financial support of the Spanish Ministry of Science, Innovation and Universities (PID2022-138256NA-C22 and PID2022-138108OB-C33 funded by MCIN/AEI/10.13039/501100011033). M. Ríos wants to thank the Basque Government (Department of Education) for providing funding under the specific program IKUR-Neutronics.

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Magnetic Nanoparticles in Sensor Technology: DFT Analysis of Carbon Monoxide Adsorption on Fe_3O_4 Surfaces

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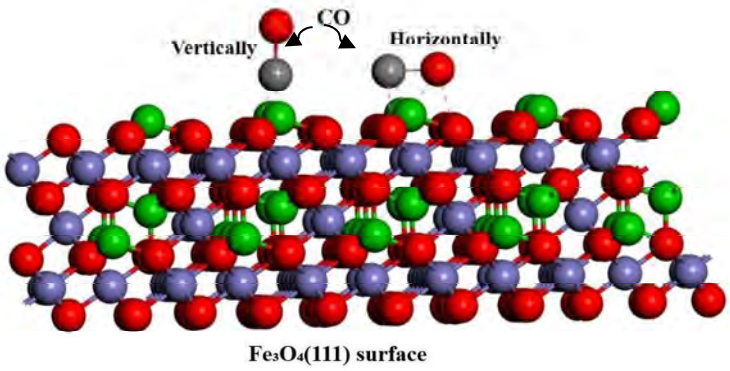
The development of chemical sensors using magnetic nanoparticles shows great potential due to their strong interactions with external magnetic fields, enabling precise control and detection. Changes in surface properties, in particular on magnetic and electronic characteristics, have a significant impact on the overall performance of these sensors. These variations in surface interactions must be effectively translated into measurable signals to accurately detect target substances at specific concentrations [1].

To enhance sensor performance and gain a deeper understanding of atomic-level interactions, Density Functional Theory (DFT) simulations are invaluable. They allow researchers to model and predict how modifications to the surface properties of nanostructured materials influence sensor behavior. DFT provides a detailed understanding of electronic, magnetic and chemical interactions, which are often challenging to capture experimentally. By offering precise information on charge distribution, adsorption mechanisms, and surface stability, DFT aids in the streamlined design of more efficient and selective sensors, particularly those based on magnetic properties [2].

In this study, the adsorption properties of carbon monoxide (CO) on the Fe_3O_4 (magnetite) surfaces are investigated, with a particular focus on the (111) surface. Fe_3O_4 is an attractive material for sensor technology due to its unique electronic and magnetic properties. Among the six possible terminations of the Fe_3O_4(111) surface, the Fe_{tet}- and Fe_{oct}-terminated surfaces were identified as the most stable. A comparative analysis of their stability, electronic properties, and adsorption behaviors revealed that the Fe_{oct}-terminated surface is thermodynamically more favorable for CO adsorption, exhibiting stronger interactions and higher selectivity at the octahedral Fe site. These findings provide valuable insights for optimizing Fe_3O_4-based materials in sensor technology.



Model of CO adsorption configurations on the Fe_3O_4(111) surface.

Acknowledgements

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Index Terms — Fe_3O_4(1 1 1) surface, Adsorption behavior, First principles calculation.

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Enhancing Magnetic Force Microscopy with FEBID-grown Nanotips

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Focused electron beam induced deposition (FEBID) is a maskless nanolithography technique that enables direct fabrication of nano- and micro-structures with high lateral resolution, typically below 100 nm and even as low as 10 nm. FEBID has proven to be a rapid and efficient method for functionalizing Magnetic Force Microscopy (MFM) tips [1]. Commercial MFM tips are often non-magnetic atomic force microscopy (AFM) probes coated with a ferromagnetic material. However, the thickness of the ferromagnetic coating is a crucial factor in optimizing resolution and sensitivity in these tips. A thicker coating enhances magnetic sensitivity but also increases the tip diameter, leading to reduced spatial resolution [2]. Various techniques have been proposed to address this limitation, but they frequently involve complex and time-consuming multi-step processes. Instead, FEBID offers precise control over the size, shape, and magnetic properties of the magnetic deposit grown on the MFM cantilever, allowing for its optimization for specific applications. FEBID-based tips demonstrate superior resolution, sensitivity, and control of the stray field compared to commercially available tips [3].

Here, FEBID is used to fabricate magnetic tips for magnetic force microscopy (MFM), as shown in Figure 1, for comparison with commercial magnetic tips. The FEBID-grown tips offer several advantages for combined topographical and magnetic characterization. Notably, they exhibit low non-magnetic interaction with the sample, high lateral resolution with tip diameters as small as 10 nm, and a high coercive field of 900 Oe. Moreover, their excellent performance in liquid environments makes them suitable for investigating magnetic biological samples [4]. The versatility of FEBID allows for precise tailoring of the tip shape, length, and diameter to meet specific sample requirements, resulting in durable and magnetically robust tips for a wide range of applications [5]. A magnetic bilayer sample ($Ni_{80}Fe_{20}/NdCo_5$) is used as a reference for comparing the performance of commercial and FEBID-grown magnetic tips [6].

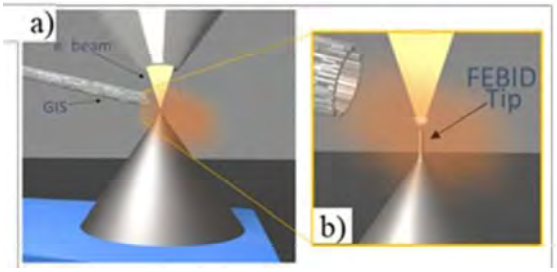

Figure 1. Schematic FEBID-tip growth process (a, b).

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Index Terms — magnetic force microscopy, magnetic tips, nanofabrication, focused electron beam induced deposition.

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Stacking engineering in orthogonally-twisted two-dimensional CrSBr magnets

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Two-dimensional (2D) magnetic crystals are impacting the field of magnetism due to their fundamental relevance and easy implementation into multilayer heterostructures [1]. Indeed, not only the nature of the layers forming the heterostructure, but their relative twist angle, are key for tailoring the magnetic properties. In this regard, twisted 2D magnetic heterostructures [2] represent a new platform to create artificial magnets, allowing the control and formation of novel spin-textures, such as skyrmions or magnetic domains. Beyond the rotation angle, different spin reversal processes can be engineered by increasing the number of magnetic layers forming the twisted van der Waals (vdW) heterostructures. This versatility is of important relevance in the field of spintronics, since twisted-2D magnetic heterostructures enable the development of new non-volatile magnetic information storage devices [2, 3].

Here [4], we consider pristine monolayers and bilayers of the A-type antiferromagnet CrSBr as building blocks. By rotating 90 degrees these units, we fabricate symmetric (monolayer/monolayer and bilayer/bilayer) and asymmetric (monolayer/bilayer) heterostructures. The magneto-transport properties reveal the appearance of magnetic hysteresis, which is highly dependent upon the magnitude and direction of the applied magnetic field and is determined, not only by the twist angle, but also by the number of layers forming the stack, see Fig. 1. This high tunability allows switching between volatile and non-volatile magnetic memory at zero-field and controlling the appearance of abrupt magnetic reversal processes at either negative or positive field values on demand. The phenomenology is rationalized based on the different spin-switching processes occurring in the layers, as supported by micromagnetic simulations. Our results highlight the combination between twist-angle and number of layers as key elements for engineering spin-switching reversals in twisted magnets, of interest towards the miniaturization of spintronic devices and realizing novel spin textures.

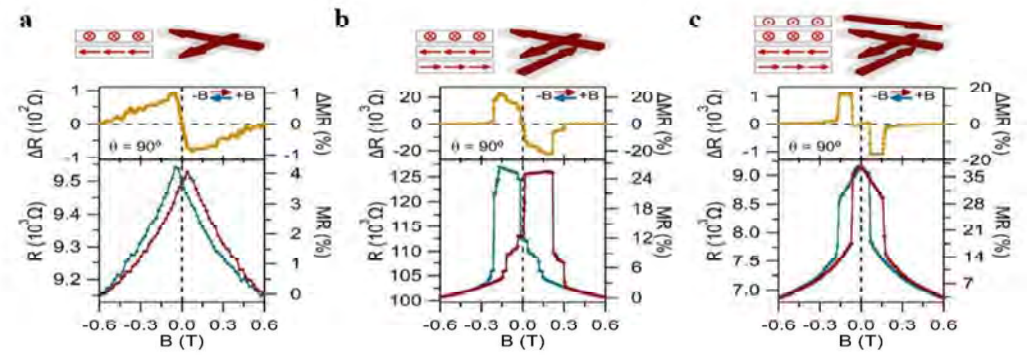

Figure 1.- Field dependance of the resistance (R), the magneto-resistance (MR) and its increment (Δ), defined as $\Delta X = X_{+B\rightarrow -B} - X_{-B\rightarrow +B}$ (X indicates either the R or the MR) for a) monolayer/monolayer, b) monolayer/bilayer and c) bilayer/bilayer orthogonally-twisted CrSBr at T = 2 K.

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High-Throughput DFT Screening of MnMX Alloys for Magnetic Refrigeration Applications

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MM'X alloys are emerging as promising candidates for magnetic refrigeration, due to their ability to achieve a large magnetocaloric effect (MCE) via compositional tuning that enables magnetostructural transitions [1]. In this work, we perform high-throughput (HTP) density functional theory (DFT) calculations for over 250 compositions of MnMX alloys including two crystallographic phases and several magnetic orderings. Based on the values of formation energies (E_f) and a relative structural deformation parameter (Σ_D), we have identified 122 compositions as thermodynamically stable. Using the concept of a temperature window [2], we have applied the energy difference between the ferromagnetic and antiferromagnetic orderings (ΔE_M) to estimate the Curie temperature (T_c) [3], while the energy difference between the orthorhombic and hexagonal crystal structures (ΔE_{st}) can be used to estimate the structural transition temperature (T_m) [4]. This approach allowed us to filter 14 compositions that exhibit magnetostructural transitions within the appropriate temperature range. Further screening, based on magnetic deformation (Σ_M) [5] and relative lattice vector change (λ_2) [6], narrowed the selection to 12 and 7 potential compositions, respectively, that may display high magnetic entropy change and low thermal hysteresis. Several of these materials have been experimentally validated, supporting the accuracy of our HTP-DFT calculations.

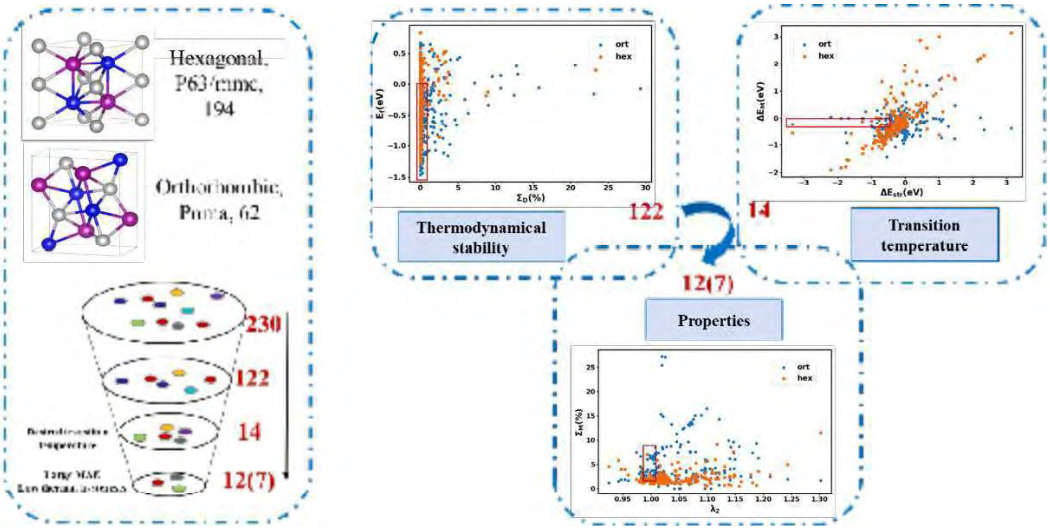

Fig 1 High-Throughput DFT Screening for MnMX Alloys

Acknowledgements

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Index Terms — MnMX alloys, high-throughput DFT, magnetostructural transitions.

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Magnetic Nanostructures for Biomedical Applications

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The research on magnetic nanostructures has become one of the most interesting areas in recent years for the development of nanotechnology [1]. This work explores nanofabrication routes for active surfaces aimed at cellular stimulation, based on magnetic Janus nanoparticles (NPs).The surfaces are fabricated via combination of Langmuir-Blodgett technique for forming self-assembled silica NP monolayers [2] with physical vapor deposition methods to add a magnetic coating(Co, Fe, Terfenol-D).

For their magnetic characterization, techniques such as vibrating sample magnetometry (VSM) or magnetic force microscopy (MFM) have been employed to understand the magnetic response of our nanostructured surfaces [3]. Additionally, living human glioblastoma cells have been used to analyze the stimulation capacity via magnetostrictive effects of surfaces coated with Terfenol-D [4].

The results obtained demonstrated the effectiveness of the Langmuir-Blodgett technique for the fabrication of compact monolayers (Figure 1.a). Moreover, the effects of the nanostructuration on magnetic properties have been determined. Finally, the response of the cells to the magnetic stimulus has been analyzed by using fluorescence images (Figure 1.b).

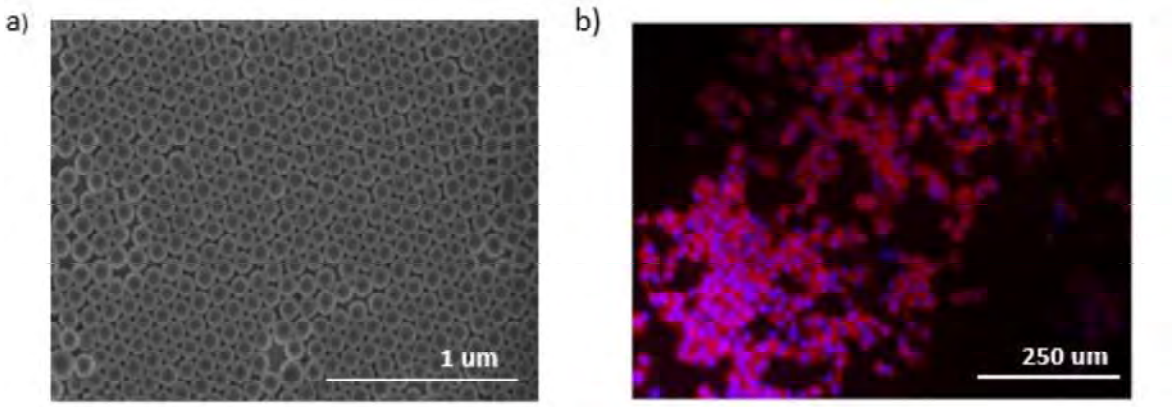

Figure 1. (a) Scanning electron microscope image of a compact monolayers obtained by the Langmuir-Blodgett technique of 200 nm diameter nanoparticles. (b) Fluorescence image of human glioblastoma cells incubated on a surface with Janus nanoparticles, after magneto-mechanical stimulation.

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Index Terms — Nanofabrication, Cellular stimulation, Magneto-mechanical action.

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Influence of chemical and geometrical modulations on magnetic properties of Co & Ni bisegmented nanowires

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The recent and innovative progress in fabrication and characterization techniques has enabled the design of metallic and magnetic multisegmented nanowires (NWs) with tailored physico-chemical properties. Ferromagnetic NWs can exhibit controlled features such as peculiar magnetic anisotropy, enhanced coercivity and well-defined pinning of magnetic domain walls, among others, achieved through precise tuning of the geometry and composition of the NWs modulations. Although such modulations have been studied independently, the achievement of simultaneous modulations in composition and diameter has been challenging [1].

In this study, we developed both at once, compositionally and diameter modulated Co&Ni bi-segmented NWs, whose composition is different for each NW segment and changes at the interface between the wide and narrow segments. Former nanoporous alumina membranes (NAMs) are made by combining electrochemical anodization, pore widening and atomic layer deposition (ALD) processes, obtaining a well-defined pores diameter modulation with a sharp transition between the two diameter segments. Afterwards, NAMs are filled by electrodeposition techniques by carefully controlling the current profile, which allows to fill each of the bi-segmented nanopores with different magnetic materials, thus resulting in compositionally and geometrically modulated NWs. Therefore, four different samples were fabricated with a fixed 3:1 ratio in the diameter modulation of bi-segmented NWs and varying the composition of the thinner and wider segments (Co-Co, Ni-Ni and Co-Ni or Ni-Co, respectively). Morphological and compositional analysis were conducted by SEM and HR-TEM techniques. Temperature dependent magnetic hysteresis loops (HLs) have been measured by VSM to determine the influence of geometrical and chemical modulations on the magnetic behaviour. The intrinsic magnetization reversal of the NW segments and the magnetostatic interactions among NWs are strongly dependent on the different combinations between the composition and diameter modulations of the segments.

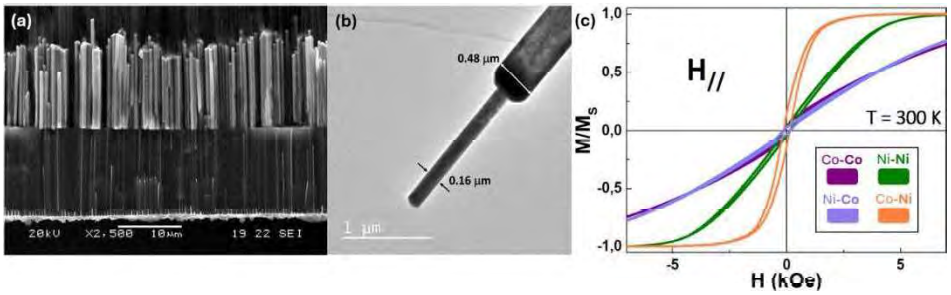

Figure 1: (a) SEM image of Co-Co NWs inside the NAM (equal geometry for each type of NWs), (b) Co-Ni NW TEM image and (c) normalized HLs for the four samples at RT with applied field parallel to the NW axis.

Acknowledgements

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Index Terms — Modulated nanowires, nanomagnetism, nanoporous alumina membranes.

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Influence of Polymer Matrix on the Manufacturability and Performance of Soft Magnetic Filaments for Additive Manufacturing

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The fabrication of components with complex shapes and magnetic functionality requires the use of additive manufacturing. However, not all 3D printing techniques are suitable for all materials, as the melting of magnetic phases by laser can alter their properties. Thus, our focus is on utilizing fused deposition modeling (FDM), though it requires high-quality filaments. Given the limited availability and variety of commercially produced magnetic filaments, we undertake the task of developing composite filaments with magnetic properties. Following a methodology developed by our research group for producing filaments with well-distributed fillers and the desired functionality for specific combinations of polylactic acid (PLA) and fillers at the laboratory scale [1]. In this work, we further extend and optimize the methodology for a wider range of composite filaments produced. We analyzed polymers including PLA, glycol-modified polyethylene terephthalate (PETG), and thermoplastic polyurethane (TPU), for their compatibility with soft magnetic powder (EOS Maraging).

The particle distribution and homogeneity of the filament have been demonstrated by the backscattered electrons (BSE) micrograph from the scanning electron microscopy (Figure 1a) for PLA+ EOS Maraging composite filament). The observed good correlation between the nominal filler concentration and experimental magnetization values indicates the reproducibility of the procedure, even for different types of polymers (see Figure 1 (b)). Results show that PLA and TPU allow a lower weight percentage of EOS Maraging to produce continuous, high-quality filaments, while PETG can host a higher loading.

Due to the better homogeneity and extrusion capability of PETG-based filaments, we have used this matrix to enhance the soft magnetic properties of the filaments by employing gas-atomized powders of an amorphous Finemet-type alloy. This results in filaments that are magnetically softer than those with EOS Maraging, and even softer than the initial Finemet alloy powder, due to the stress-relaxation process of the magnetic particles during extrusion, thereby improving their applicability.

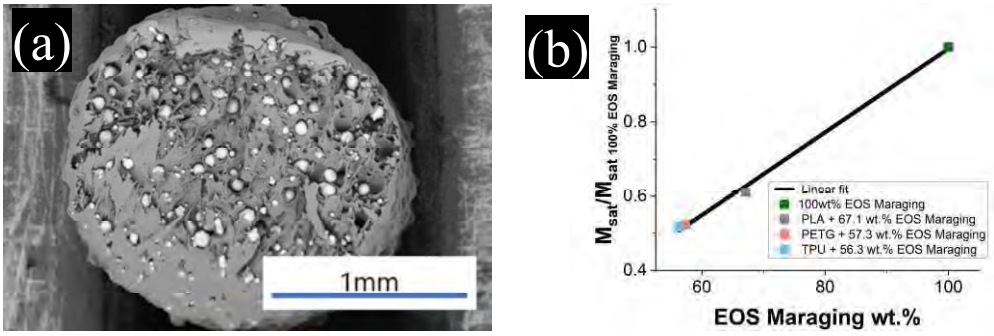

Figure 1. (a) BSE micrograph of PETG /EOS Maraging filament, (b) Plot of the saturation magnetization versus the content of EOS Maraging powder

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Additive Manufacturing, Fused Deposition Modelling, Soft Magnetic Filament, Magnetic Composites

Fabrication and characterization of Sm-based $ThMn_{12}$-type compounds for permanent magnet applications

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Alloys like NdFeB and SmCo5 are widely used as permanent magnets in energy applications, particularly in the renewable energy sector. However, their high concentration of critical raw materials (CRMs), such as rare earth elements and cobalt, has driven recent scientific efforts to find alternative, eco-friendly materials that offer comparable performance. Materials with a $ThMn_{12}$-type structure, which contain fewer rare earths and CRMs, are considered promising candidates due to their high magnetic saturation and Curie temperature. Despite this, two major challenges must be addressed before these compounds can be used in permanent magnets. The first challenge is reducing the use of elements like molybdenum, titanium, or vanadium (V), which help stabilize the 1:12 structure. The second challenge involves lowering the amount of samarium (Sm), which has been reported to be double the stoichiometric ratio (15 at. %) in magnets with 1 T coercivity. [1].

In this work, we studied the extrinsic properties of $Sm_{1.2}Fe_{11-x}Co_xV_1$ alloys by reducing the V content while keeping a stoichiometric amount of Sm. The samples were synthesized via arc-melting and subsequently melt-spun using different linear wheel speeds of the copper wheel to evaluate the impact of cooling rate on their extrinsic properties, particularly the influence of grain size and microstructure on the resulting coercivity. Coercive fields of up to 0.54 T were achieved for these compositions after a specific heat treatment. X-ray diffraction was used to identify crystalline phases, while SEM/EDX was employed to analyse microstructure and elemental composition. Surface topography was obtained using atomic force microscopy. Magnetic characterization was performed with DC magnetometry using a vibrating sample magnetometer. Our results confirm that $Sm_{1.2}Fe_{11}V$ alloys with the 1:12 structure are promising candidates to substitute commercial NdFeB magnets.

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Index Terms —$ThMn_{12}$-type structure, SmFe-based alloys, rare-earth-lean magnets.

Fabrication, Magnetic and Structural Properties of MnFePSi Microwires and Bulk Alloys.

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Glass-coated microwires are advanced materials composed of a metallic core enveloped in a thin glass layer, offering unique properties suitable for various applications. The glass coating acts as an insulating barrier, providing chemical resistance and mechanical protection. These microwires demonstrate excellent magnetic, electrical, and thermal characteristics, making them ideal for use in sensors, actuators, and advanced electronic devices. The fabrication methods, typically involving the drawing of metal through a glass preform, allow for precise control over the dimensions and properties of the microwires.

$Mn_{48}Fe_{22}P_{15}Si_{15}$ glass-coated microwires (GCMWS) were successfully prepared for the first time, with a metallic nucleus diameter (d) of 11.2 μm and a total diameter (D) of 28.3 μm (geometrical aspect ratio d/D = 0.4) using the Taylor–Ulitovsky Technique. This cost-effective, single-step fabrication approach enabled the preparation of kilometers-long GCMWS from a few grams of low-cost components (Mn, Fe, P, and Si) for a variety of applications [1]. The change in the magnetic properties of MnFePSi-glass-coated microwires is attributed to the presence of various magnetic phases resulting from internal stresses induced by the glass coating. Additionally, the observed elevated Curie temperature (T_c > 400 K) in the investigated sample makes this material an appealing choice for several industrial applications[2]. Recent research has focused on optimizing their performance through material selection and coating techniques, leading to enhanced functionality in fields such as telecommunications, biomedical engineering, and energy storage. As technology advances, GCMWS hold significant potential for the development of next-generation smart materials.

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Exploring $Pd_{1-x}Fe_x$ alloy thin films and ribbons: a breakthrough in ultrasensitive and wireless hydrogen detection

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Hydrogen technologies have gained increasing importance due to rising global energy demand and the need for sustainable energy solutions. However, working with hydrogen requires specific safety measures, including the accurate and rapid detection of the gas [1, 2]. This work explores the use of thin films and ribbons that take advantage of the chemical sensitivity of palladium (Pd) for hydrogen absorption [1]. By incorporating small amounts of iron (Fe) into the Pd structure ($Pd_{1-x}Fe_x$), the magnetic properties of the material can be monitored around room temperature, introducing a novel approach to detecting hydrogen levels. This magnetic component enables the quantification of hydrogen present in the sensor, offering a promising solution for hydrogen detection technologies.

In this work, thin films ($Pd_{1-x}Fe_x$, with x between 7 and 23 at. %) were deposited using magnetron sputtering, while ribbons ($Pd_{1-x}Fe_x$, with x = 12, 14, 16 at. %) were melt spun via the melt-spinning technique. Characterization was performed using SEM-EDS, AFM, and SQUID systems, and VSM was used for detecting hydrogen absorption magnetically. The results indicate that both the thin film and ribbon with a composition about $Fe_{0.84}Fe_{0.16}$ exhibit the best performance as magnetic hydrogen detectors, with a Curie temperature (T_C) around 300 K and a significant difference in magnetization values between the absence and presence of hydrogen at room pressure. Additionally, the structure and magnetic properties of $Pd_{1-x}Fe_x$ alloys (x = 9.4, 12.5, 15.6, 18.8, and 21.9 at. %), including volume, density, magnetization saturation (M_s), anisotropy constant (K_1), and exchange stiffness constant (A), were calculated using density functional theory (DFT).

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Index Terms — "Hydrogen Sensing" "Magnetism" "Energy" "Thin Films" "Ribbons" "DFT" Index terms follow after a blank line after the end of the abstract's text, in 12pt Times New Roman.

Improving the magnetic properties of τ-MnAl by low Cu doping

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The hard ferromagnetic τ-phase in the Mn-Al material system continues to attract attention due to its potential for development into a permanent magnet without relying on critical or expensive elements. This phase typically exhibits a manganese concentration ranging from 53 to 65 at. %. However, it is metastable and requires controlled processing techniques or the addition of dopants to improve its stability and prevent decomposition into non-magnetic gamma (γ_2) and beta (β) phases. To address this, research has focused on the Mn-Al system using various dopants, such as titanium, copper, nickel, carbon, boron, and others in small concentrations [1,3], as well as different production methods [4]. This project investigates the effect of copper (Cu) doping on phase formation and its role in enhancing the coercive field, attributed to the beta phase, in melt-spun ribbons.

Mn-Al-Cu alloys have been studied using hysteresis loop and first order reversal curves (FORC) analysis. The effect of adding different Cu content (0, 0.5, 1.0, 1.5, 2.0 and 2.5 wt. %) on the magnetic properties and behavior of Mn-Al nanostructured magnets were investigated. The Mn-Al-Cu samples were produced by melt spinning and annealing, aiming to maximize the ferromagnetic τ-phase partially decomposed into gamma (γ_2) and beta (β) phases, resulting in a reduction of the magnetic properties. Hysteresis loop shows a hard-magnetic behavior, with the sample containing 1.5 wt. % Cu content exhibiting the best magnetic properties, including a coercive field (Hc) of 0.146 T and a remanent magnetization (Mr) of 50.8 emu/g. FORC analysis indicated that increasing Cu concentration heightened the competition between magnetic dipolar and exchange interactions in the alloys.

Index Terms: *First order reversal curves (FORC) analysis, exchange interaction, Mn-Al magnet*

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Future perspectives on the evolution of graphene-magnetic nanoparticle hybrid structures as revealed by neutron scattering analysis.

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Neutron scattering techniques played an important role in enhancing research on magnetic nanostructures. At the outset, many studies focused on layered structures (often using reflectometry), eventually incorporating magnetic nanoparticles. Subsequently, due to the significant growth in the popularity of magnetic nanoparticles, neutron instruments were used more widely and their performance was optimized. A possible constraint for these magnetic nanoparticles (especially iron oxides) and other structures is their mass, as chemical or natural synthesis routes yield low sample quantities.

Currently, remarkable neutron scattering results can be achieved through careful tuning and optimization of the materials. These results are reported by means of neutron diffraction, small-angle neutron scattering (SANS), and inelastic neutron scattering (INS) [1-3]. At the moment, we are working in the challenging task of combining nanoporous graphene 2D structures [4] as pinning centres for magnetic materials in various forms (individual entities, clusters, magnetic nanoparticles and/or magnetotatic bacteria) to achieve dual functionalities in hybrid structures. This work outlines potential future developments.

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Radiofrequency characterization of magnetic nanoparticle distributions on rigid substrates for biosensing applications

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Magnetic nanoparticles are excellent candidates for labeling and detecting biomarkers. Studying magnetic nanoparticles deposited on solid substrates could open the door for using rigid samples, since antidots and other examples are promising for biological applications and present technical challenges that warrant further study.

In this work, we designed and optimized a new measurement system using a refractometry radio frequency sensor [1]. We synthesized magnetic biofunctional nanoparticles based on manganese ferrites using the hydrothermal coprecipitation method [2]. Afterward, we deposited the synthesized magnetic nanoparticles in a solid substrate and quantified their signals, obtaining calibrations with a R^2 of 0.9963, and with a very big signal-to-noise ratio for this type of measurement. Finally, we cultured HeLa cells with the magnetic nanoparticles previously synthesized, attached to a rigid substrate, and measured their signal, with positive results. Therefore, our results support the promising use of this new measurement system for biosensing applications.

Index terms – biosensing, magnetic nanoparticles, cell culture, radiofrequency refractometry sensor, sensors.

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Magnetic SAR calculations by using micromagnetic simulations and a simple model at different wave shapes

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Magnetic hyperthermia (MH) has become an important topic in the nanomedical field due to its multitude of advantages for effective antitumor therapy, such as high biosafety, deep tissue penetration, and targeted selective tumor killing. It utilizes the heat generated by magnetic nanoparticles when they are exposed to an alternating magnetic field. However, for MH to progress and realize its paramount potential as an alternative for cancer treatment, some challenges must be overcome [1].

The effectiveness of MH improves when high frequencies are utilized (100 kHz - 1 MHz), resulting in increased heat production with low concentrations of MNPs. However, there are clinical and equipment limitations to achieving high frequencies, which may lead to a loss of control over the treatment's effects. One promising alternative is to use pulses of different shapes at high frequencies, which increase the heat that the MNPs can generate.

Physical models for a mono-frequency signal (sinusoidal pulses) have been proposed and experimentally validated [2]. Therefore, if this model is extended to encompass all frequencies present in a non-sinusoidal signal, it should match the data for any signal shape. In this work, we use this principle to predict the behavior in a hyperthermia treatment with seven different signal shapes at various magnetic field amplitudes of 1-5 mT at frequencies of 100-1000 kHz.

To test the model, we use micromagnetic simulations for an independent MNP system with known parameters under the influence of an alternating magnetic field of known amplitude and frequency. By calculating the Specific Absorption Rate (SAR), the simulations show a good agreement with the mathematical model, as shown in Figure 1. Therefore, the model could be used to predict the applicability of a previously characterized sample, and by knowing the material parameters, deduce what kind of signal could be used to improve the treatment based on the limitations of the sample and available equipment.

The results show that, while preserving the Brezovich limit, the square signal is the best option for this type of treatment (higher SAR with low concentrations of MNPs), regardless of the frequency and magnetic field amplitude used. The sawtooth signal could perform better if smaller MNPs are available. Trapezoidal signals show higher SAR than sinusoidal signals. Therefore, the shape could be an additional parameter depending on equipment capabilities. Additionally, SAR is predicted for functionalized $MnFe_2O_4$ MNPs as an example of the application of the theoretical model.

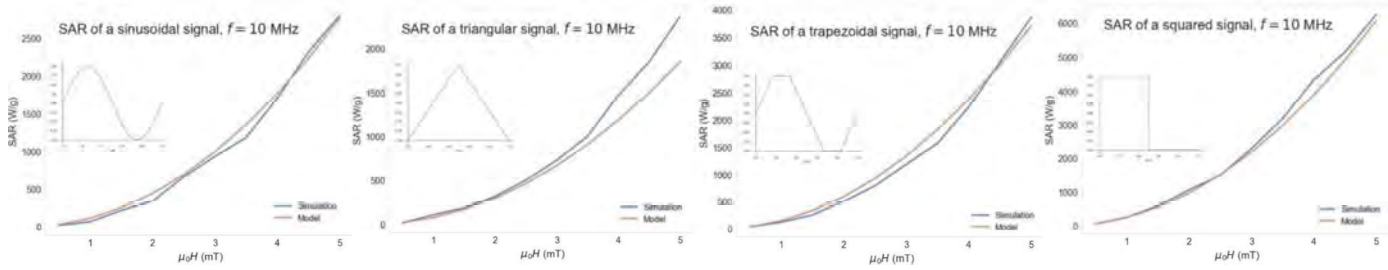

Figure 1 Simulation and model data of magnetic hyperthermia at 10 MHz at various magnetic field amplitudes. The high frequency was used due to simulation time cost.

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Tailoring the properties of multifunctional hybrid compounds via molecular design

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Hybrid halometallate materials that integrate organic and inorganic components are of significant interest for various applications, including energy harvesting, energy storage, catalysis, and electronics. The combination of plastic and ferroelectric phases above room temperature (RT) is particularly valuable because it enables switchable polarization by applying electric fields, making these materials ideal candidates for electronic devices, such as ferroelectric random access memories (FeRAMs). Furthermore, the inclusion of a magnetic atom enhances their multifunctionality and can lead to multiferroicity. However, achieving the combination of plastic with ferroelectric phases remains a significant challenge due to the tendency of high-symmetry molecular components to crystallize in centrosymmetric structures. In this study, we synthesized and characterized two novel hybrid magnetic compounds: (quinuclidinium)[$FeCl_4$] (A) and its modified derivative (R)-(−)-3-hydroxyquinuclidinium[$FeCl_4$] (B). By introducing a hydroxyl group into the organic cation of compound A to form compound B, we reduce the molecular symmetry (quasi-spherical theory) and introduce homochirality, a strategy aimed at increasing the likelihood of achieving plastic and ferroelectric phases.

Compound A [1] exhibits a plastic phase above 390 K, with dielectric permittivity reaching a remarkable maximum of 10^5. This value is giant compared to similar compounds [2] and highlights its potential for electrochemical applications. Following this, A transitions into a polar orthorhombic phase, allowing polarization along one axis, before transitioning to a non-polar orthorhombic space group at 280 K. At low temperatures, a paramagnetic-to-antiferromagnetic transition occurs around 3.5 K. Neutron diffraction reveals a ferrimagnetic structure that allows a net ferromagnetic signal along the c-axis. In contrast, compound B [3] adopts a lower-symmetry monoclinic polar space group below the plastic phase (370 K). Notably, we observe direct evidence of electric ferroelectric behavior at room temperature, with a low coercive voltage of approximately 10 V, which is in the limit for application in FeRAMs. Moreover, at lower temperatures, the system crystallizes in the triclinic P1 space group, allowing the polarization tensor to remain unconstrained by symmetry. This freedom of rotation could facilitate the development of new thin-film devices, as polarization may be switched more easily among multiple ferroelectric axes. Neutron diffraction results reveal long-range magnetic order below 4 K, characterized by a markedly different structure compared to compound A, featuring a globally antiferromagnetic structure, in this case with no ferromagnetic component.

The comparison between A and B illustrates how subtle modifications in molecular symmetry, as elucidated by the quasi-spherical theory, can profoundly influence the crystal and magnetic structures of hybrid materials. This study emphasizes the critical role of structural modifications in tailoring the electric and magnetic properties of hybrid halometallates [4] and highlights the importance of neutron diffraction in resolving the complex magnetic structures inherent to these systems.

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Expanding the nanomagnetism chart: Non-dipolar interparticle interactions and Non-exchange bias

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Nanomagnetism explores the magnetic behavior of nanoparticles (NPs) and their applications, representing one of the most innovative areas in materials science. Two well-established phenomena—collective behavior in highly concentrated NP systems and exchange bias, characterized by a loop shift in multiphase and single-phase nanoparticles—are frequently studied, with dipolar interactions [1] and interfacial exchange coupling [2] as their archetypal origins, respectively.

In this study, we expand upon the current understanding of these phenomena using iron oxide-based nanoparticles synthesized via thermal decomposition of metal precursors. First, we investigate a series of 5 nm maghemite (γ-Fe2O3) nanoparticles subjected to different degrees of partial removal of their native oleic acid shell, ranging from fully coated to barely coated (8 wt% oleic content). Upon compaction, the systems with a high packing fraction (low oleic acid content) exhibit collective behavior. Interestingly, the temperature corresponding to the maximum in the ZFC curve, which marks the onset of collective behavior, deviates from the expected trend for purely dipolar systems [3]. Coupled with the observed increase in low-temperature coercivity with packing fraction, these findings suggest that the collective state is driven by superexchange propagation between contacting nanoparticles rather than dipolar interactions. This hypothesis is further supported by SAXS measurements, which indicate an increasing number of direct NP contacts as oleic acid is progressively removed, consistent with the low-temperature coercivity trend.

Secondly, we examine binary systems composed of equally-sized (6.7 nm) maghemite (soft, unbiased) and Co-doped maghemite (hard, exchange-biased) nanoparticles mixed at different soft-hard ratios. These systems exhibit weakly exchange-coupled hysteresis loops. A systematic magnetometry study reveals a peak in loop shift at a soft NP proportion of 23%. Numerical simulations, based on the superposition of soft and hard loops, indicate that this "bias enhancement" arises from asymmetric reversal of the hard hysteresis loop, rather than interfacial exchange coupling between the two populations. Furthermore, the discrepancy between the bias values from simulated and experimental loops suggests that dipolar interactions may also contribute to the overall loop shift.

These two studies open up new possibilities of enhancing the magnetic stability of nanoparticle system and tailoring the loop shift respectively.

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Magnetic Insulators: a First-Principles Study of Superexchange Interaction

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In magnetic insulators, the exchange interaction between two magnetic ions is not direct but mediated by a non-magnetic ion, known as the superexchange interaction. In cubic perovskites containing transition metal ions, this interaction leads to antiferromagnetic (AFM) ground states. However, the energy difference between the ferromagnetic (FM) and AFM states is only a few meV. The concept of superexchange was introduced by Kramers[1] in 1934 and further developed by Anderson[2], Goodenough-Kanamori[3,4] and Hay, Thibealt and Hoffmann[5] using dimer models. However, these models can provide at most semi-quantitative information and rough chemical insights into magnetism. In our work, we have employed first principles calculations together with both orbital-based (LOBSTER)[6] and density-based (QTAIM[7], TOPOND[8]) tools to unravel the chemical origin of superexchange interaction. A underlying symmetry-breaking principle and slightly larger covalency in the AFM state are the driving forces for the stabilization of the AFM phase below the FM phase. The results for model systems $KNiF_3$, KVF_3 and $KMnF_3$ shows that the key element in the stabilization of the AFM state is a more diffuse electron density associated with the spin-minority electrons, as confirmed by all chemical indicators such as COHP, COBI or kinetic energy at bond critical point.

Acknowledgements

The authors acknowledge financial support from Grant PGC2018-096955-B-C41 funded by MCIN/AEI/10.13039/501100011033. I. S-M acknowledges financial support from grant BDNS:589170 (Gobierno de Cantabria and Universidad de Cantabria)

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Synthesis and characterization of 2-dimensional chiral hybrid organic-inorganic metal halides

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Two-dimensional hybrid organic-inorganic metal halides (2D-HMHs) are materials where inorganic layers, arranged in octahedral structures, are separated by organic molecules via van der Waals interactions. This layered architecture creates natural quantum wells and offers design flexibility using diverse organic molecules. Introducing homochiral organic spacers can break inversion symmetry, leading to spin polarization due to the chiral-induced spin selectivity (CISS) effect. These materials also absorb light strongly, making them candidates for spin-polarized photo-generated charge applications. The main aim of this research is to create semiconductor materials with customizable magnetic properties for spintronics.

Various compounds were synthesized using homochiral organic ligands, resulting in chiral structures that influence the crystal lattice. In these contexts, we are interested in the synthesis and the study of some of these materials 2D-HMHs using different homochiral organic part. We have synthesis the R- and S-phenylethylamine bismuth bromide (R/S PEA BiBr). Additionally, $(PEA)_4Bi_2Br_{10}$ (phenylethylamine) shows promise due to the spin-orbit coupling of the heavy metal bismuth, which could affect the material's magnetic properties what makes them interesting candidates for magnetic and/or spintronics applications.

Acknowledgements

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Index Terms — Chirality, spintronics, spin-orbit coupling.

High-Coercivity Ferrite Nanocomposites without Critical Raw Materials

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The use of hard ferrite-based magnets has the potential to expand in the electromobility sector due to their improved magnetic properties and the possibility of redesigning end products to take full advantage of these advances and ultimately improve their performance [1]. This development could help reduce Europe's dependence on critical raw materials in the permanent magnet industry.

This study demonstrates the feasibility of producing high coercivity Sr-ferrite powders with excellent low temperature performance without the use of critical raw elements (e.g. La, Co). This was achieved by starting with a commercially available ferrite and nanostructuring it (Fig. 1a, b) using the in-house developed 'flash milling' method [2,3]. The resulting Sr-ferrite/hematite ($SrFe_{12}O_{19}$ / Fe_2O_3) nanocomposite exhibited a room temperature coercivity exceeding 475 kA/m with increasing milling time (Fig. 1c). The addition of Fe2O3 powder prior to milling reduced the required processing time and produced a nanocomposite with high coercivity at low temperatures, reaching 430 kA/m at -100ºC (Fig. 1d), opening the door for future applications.

A sintering study was carried out to verify the suitability of this processing method for improving the permanent magnet properties of our ferrite-based nanocomposites. The results were very promising, showing improved magnetic properties compared to magnets made from the original commercial materials (coercivity of 400 kA/m vs. 300 kA/m), highlighting the importance of an optimized nanostructuring in the search for new, effective and sustainable alternatives in this field.

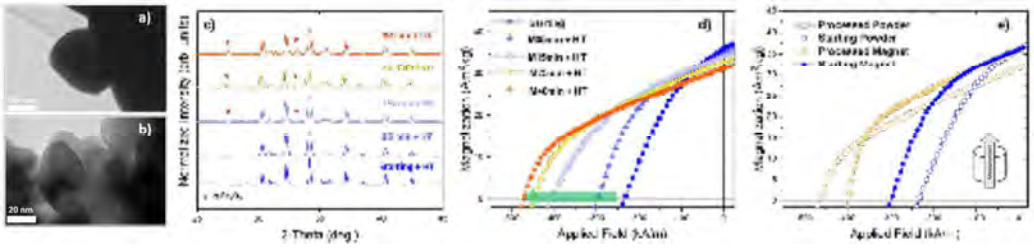

Figure 1. TEM images of (a) starting (commercial) powder and (b) this same powder after milling. (c) XRD pattern of processed powder samples where hematite is being formed. Room temperature VSM hysteresis loops (second quadrant) (d) after flash-milling and annealing, and (e) after the compaction and sintering.

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Index Terms — Permanent Magnet, Sustainability, Magnetism

Development and Optimization of Probes for Near-Field Microwave Microscopy in Magnetic Material Characterization

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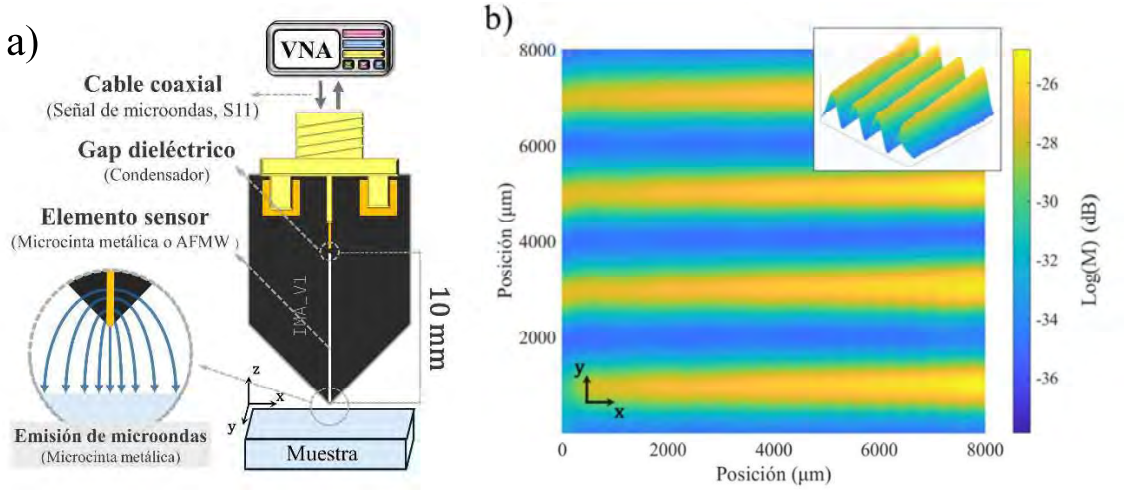
This project focuses on the development and optimization of probes for a near-field microwave microscope (NFMM), specifically designed to accurately characterize the electrical and magnetic properties of various materials. The probes utilize amorphous ferromagnetic microwires (AFMW) and metallic microstrips, providing high sensitivity in detecting changes in the surrounding electric and magnetic fields. Through a series of experiments, the effectiveness of these probes in detecting weak magnetic fields and variations in the electrical properties of the materials studied was demonstrated. The results show that AFMW-based probes are particularly useful for investigating magnetic materials, enhancing characterization capabilities without the need for direct contact. [1],[2],[3]



a) Schematic diagram of the probes manufactured during the project.
b) Result of scanning a common ferrite magnet, where its magnetic domains can be distinguished.

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Studying the Advanced Interaction of Magnetic Microwires and Ferrofluids for Breakthrough Biosensor Development

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The magnetic properties of microwires render them as excellent candidates for biosensor development. Specifically, the phenomenon of magnetoelasticity resonance influenced by a range of physical parameters including microwire length, magnetic field, mass, and other parameters, has demonstrated promising potential for biosensor development [1]. For instance, these sensors have shown a significant ability to interact with a liquid medium, accurately determining the viscosity and density of the liquid [2].

The modulation of magnetic domains dynamics within the microwire, influenced by their interactions with magnetic nanoparticles, supports the notion that combining ferrofluids and microwires can result in promising biosensors based on magnetoelastic resonance. This coupling between magnetic nanostructures and the microwire domains can alter the magnetoelastic resonance, a phenomenon that can be harnessed to enhance sensors that rely on this property.

Magnetoelastic resonance in a microwire composed of an Fe-Nb alloy has been assessed under various conditions: in air, distilled water, with dry magnetite magnetic nanoparticles on its surface, and in a ferrofluid state at differing concentrations. In all the scenarios mentioned, a distinct variation in the magnetoelastic resonance was observed. It has been demonstrated that external modifications to the nanoparticles influence the resonance and, consequently, the dynamics of the domains. Preliminary data suggest that this principle can be utilized across a wide range of biosensors.

Thus, while the magnetic properties of microwires and nanoparticles each hold promise for biosensor development, their synergetic combination could lead to the creation of advanced wireless biosensors that are reusable prove real-time measurements, are cost-effective and eco-friendly.

Acknowledgements

This work has been funded and supported by the Community of Madrid and the Government of Spain, whose support is deeply appreciated.

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Magneto-thermoelectric energy harvesting through the Nernst Effect.

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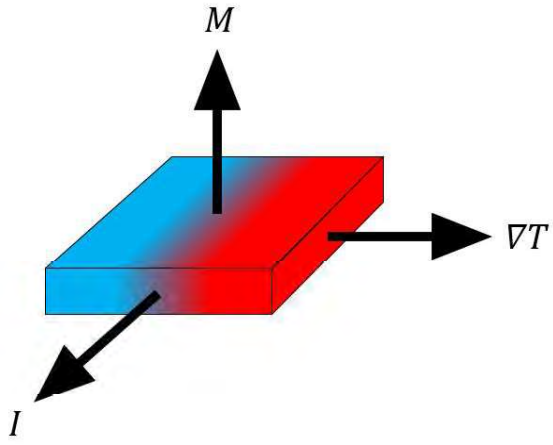
In a global world, where the demand for Internet of Things technologies will keep growing exponentially [1], the ability to reuse the waste heat they generate has become critical for reducing the environmental impact. In this context, thermomagnetic generation through the Anomalous Nernst Effect (ANE) has been proposed as an alternative to the Seebeck Effect. While the latter exhibits high thermopower efficiency, the Nernst Effect, due to its transverse nature (see Figure 1) allows for the design of simpler generators in which the thermal gradient and the generated electric field are perpendicular to each other [2].

In the field of thermoelectric generation, Bismuth has emerged as a highly promising material due to its highly anisotropic semimetallic properties, characterized by small electron/hole effective masses, as well as a thermal conductivity approximately one order of magnitude lower than that of typical semimetals [3]. However, a significant drawback is that when deposited at room temperature, bismuth tends to form large grains rather than thin films (see Figure 2).

The main purpose of this work is to reduce the roughness of the bismuth layers in multilayers of Fe-Bi [4]. Various growth conditions (specially the low temperatures) have been explored. Additionally, the thickness of the layers is varied to enhance the perpendicular magnetic anisotropy (PMA). As the generated current of the ANE arises from the interplay between three different components through a tensorial product, having the magnetization in a well-defined direction becomes crucial for enhancing this effect [2].

The fabricated multilayers of Fe-Bi are characterized both structurally and magnetically to determine the thickness parameters that optimize the Nernst Effect.



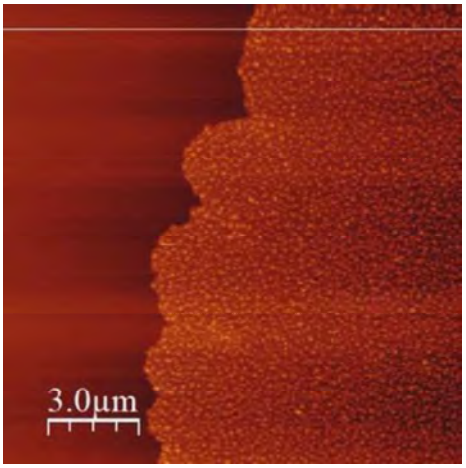


Figure 1: Sketch of the Nernst Effect and Figure 2: AFM image of a [Co(1nm)/Bi(2nm)]x10 multilaygrown at 300K

Acknowledgements

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Index Terms — Nernst Effect, Perpendicular Magnetic Anisotropy, Thin Films, Fe-Bi

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Intelligent magnetically activated drug delivery devices fabricated by 4D printing

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In recent years, the use of nanoparticles (NPs) has grown significantly in the field of biomedicine. In particular, magnetite (Fe_3O_4) nanoparticles are widely employed in numerous applications due to their low toxicity, superparamagnetic properties and excellent biocompatibility. [1] Additionally, we have recently demonstrated that Fe_3O_4 NPs can be used to develop 4D-printable polymeric structures with efficient heating capacity under alternating magnetic fields, envisioning several potential applications. [2]

Building on this framework, we have developed a novel nanocomposite that combines the previously mentioned Fe_3O_4 polymer structure with various non-steroidal anti inflammatory drugs (NSAIDs) for the 4D printing of intelligent, contactless drug delivery devices. This process enables us to integrate the full versatility of 3D printing in terms of customizable sizes and shapes, low production costs, and manufacturing simplicity with the functionality of the diverse materials that make up the device.

The system was made combining Fe_3O_4 NPs synthesized through different wet chemical co-precipitation and thermal decomposition approaches; [3] while the Fe_3O_4-polymer-NSAID composite was fabricated following a traditional solid casting method. [2] Figure 1a depicts some examples of 3D-printed devices using polycaprolactone (PCL) polymer as the base material.

Finally, the drug delivery effectiveness of the device was demonstrated by comparing the drug release efficiency with and without exposure to an external alternating magnetic field. Initial results depicted in Figure 1b show that the application of the field increases drug release efficiency by 23 times compared to the intrinsic release without the field.

In conclusion, the results obtained demonstrate that the proposed devices have the potential to serve as novel intelligent drug delivery platforms with significant therapeutic impact.

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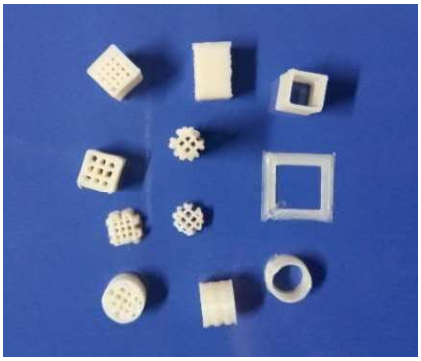
a)



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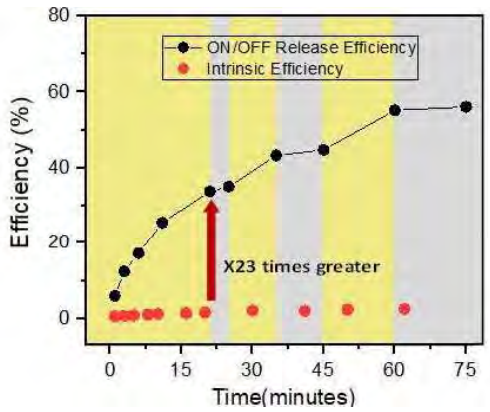

Figure 1. a) Different 3D printed devices b) Intrinsic and magnetic field induced (ON/OFF curves) efficiency curves in function on time. Periods of magnetic field ON in yellow and OFF in grey.

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Synthesis and characterization of Fe_3O_4-C nanoparticles as efficient nanoadsorbents

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Water pollution has been a persistent environmental problem due to urbanization and industrialization. Large amounts of pollutants such as pesticides, heavy metals, and dyes, among others, have been detected in water sources and effluents [1]. Among these dyes is methylene blue (MB), a heterocyclic aromatic compound that can cause physical discomfort such as vomiting, paralysis of the limbs, and increased heart rate. In addition, it is a compound with low biodegradability and high stability, which makes it difficult to remove from water [2]. Magnetic nanoadsorbents as carbon-coated magnetite nanoparticles (NPs), are widely used in the decontamination of industrial wastewater due to their simplicity in synthesis and easy subsequent separation [3]. In addition, the carbon coating provides specific characteristics on the surface, such as a high surface area and porosity, which would facilitate the adsorption of the contaminant [4].

In this study, Fe3O4-C particles were synthesized by coprecipitation (magnetic core) and subsequent hydrothermal method by mixing Fe_3O_4 and glucose (carbon source) in different proportions (1:1.25; 1:2.5; 1:5; 1:10) using an autoclave at 200°C for 12h [5]. The structural characterization (X-ray diffraction, Transmission Electron Microscopy, TEM) indicates the formation of a carbon matrix surrounding the magnetite NPs without clear indications of Fe reduction after the hydrothermal process. Regarding the magnetic characterization performed at room temperature through Vibrating Sample Magnetometry (VSM), the nanocomposites show the characteristic superparamagnetic behavior, with a decrease in the saturation magnetization for the highest Fe_3O_4/glucose ratio (**Figure 1 a**). Furthermore, it is found a decrease of the surface area (BET) of the nanocomposites with the increase of the amount of glucose employed in the synthesis process, which determines the adsorption capacity of the NPs. As an example, **Figure 1 b)** shows the adsorption results obtained employing different amounts of MB and the same amount of solution and nanoadsorbent in each experiment.

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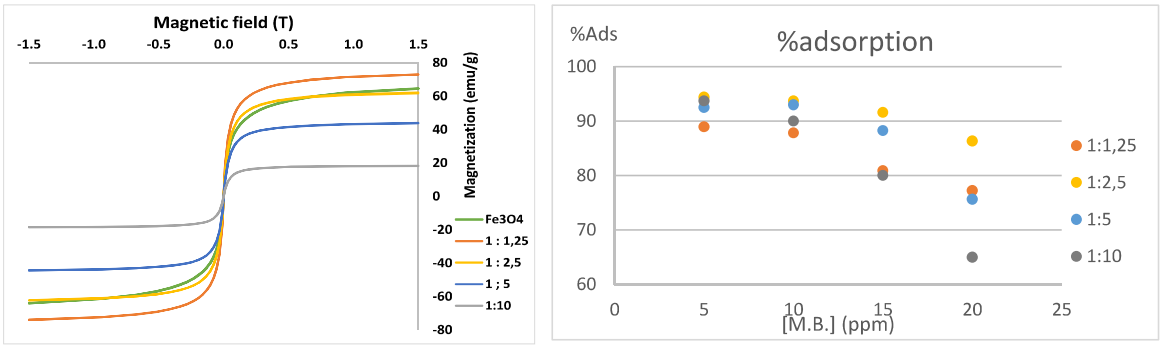

Figure 1: **a)** VSM result of Fe_3O_4-C NPs. **b)** Adsorption results of the series of NPs at different M.B.

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3D-printable composites for magnetic refrigeration based on Ni-Mn-In-Co magnetic shape memory alloys

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In the seek of a reduction of the energy consumption and the replacement of harmful gases required by the traditional refrigeration technologies, magnetic refrigeration through the magnetocaloric effect (MCE) appears as a viable clean and energy-efficient alternative. Ni-Mn-In-Co alloys present one of the highest MCE values among magnetocaloric materials, but its intrinsic brittleness highly limits almost any practical application. The use of microparticles embedded into a polymer matrix to form a tough composite has been considered as an alternative to the bulk material to address such shortcoming. If the functional particles are embedded in printable thermoplastic polymers, the obtained composite material could be also used to feed a standard Fused Deposition Modelling (FDM) 3D printer, which would allow the growth of complex geometries (crucial to obtain good performance in the heat exchange) otherwise not achievable from the brittle bulk. The relatively low extruding temperatures used in FDM prevent the possible deterioration of the physical properties of the metallic particles, contrary to what occurs in Selective Laser or Electron Beam Melting techniques used for direct 3D printing of metallic materials.

In order to obtain particles with reduced size and acceptable MCE response, the effect of ball-milling and thermal treatments on the MT and magnetic properties of several Ni-Mn-In-Co alloys has been analyzed. A similar very high degradation of both the MT and the austenite magnetization has been observed both with the increasing milling time and, for each selected milling time, with the decreasing particle size, from which a direct correlation between the particle size and the magnetostructural properties has been proposed. On the other hand, in Cu-doped Ni-Mn-In-Co alloys it has been shown that the atomic ordering increases the magnetization of the austenite without changing the transformation temperatures, thus improving the magnetocaloric effect, the reversibility and, subsequently, the refrigeration capacity. Finally. A Ni-Mn-In-Co/PCL magnetic composite with a filler load close to 70% has been elaborated and characterized.

Keywords: Metamagnetic shape memory alloys; Microparticles, Magnetic composite, magnetic refrigeration; Additive manufacturing.

Fe_3O_4-TiO_2 nanophotocatalysts for water remediation applications

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Titanium dioxide (TiO_2) nanoparticles (NPs) have been widely analyzed due to their extensive applications in different fields, among which their use in photocatalysis for water remediation stands out. Core-shell magnetic photocatalysts combine the advantages of TiO_2 with the possibility of easily recovering them from treated water by applying an external magnetic field. The photocatalytic efficiency of TiO_2 depends on different factors as grain size, surface area and the type of crystalline phases, where the optimum photocatalytic anatase phase can be properly controlled by synthesis conditions. Regarding the magnetic core, superparamagnetic magnetite NPs Fe_3O_4 are usually used and the control of their crystallinity, avoiding oxidation to the hematite phase and the optimal interface with the photocatalytic TiO_2 (introduction of an additional SiO_2 layer) are some of the main challenges. Additionally, the increase of temperature of magnetite NPs under *ac* magnetic field (Magnetic Induction Heating, *MIH*) can provide an additional functionality to the core-shell photocatalysts through the control of pollutant adsorption/desorption processes on the photocatalyst surface.

In the present work, two sets of core-shell magnetite nanoparticles are analysed: (*A*) Fe_3O_4@TiO_2 and (*B*) Fe_3O_4@SiO_2@TiO_2. Starting from Fe_3O_4 obtained through co-precipitation, and modified Stöber process for the addition of SiO_2, two different methodologies were used in the synthesis of the core-shell NPs during the addition of Titanium (IV) tert-butoxide (TBOT): a dropping method (*A1*, *B1*) and a single-step approach (*A2*, *B2*). In both cases, a thermal treatment at 450 ºC was performed to obtain the anatase phase. Samples were characterized by Transmission Electronic Microscopy (TEM), X-Ray Diffraction (XRD), Vibrating-Sample Magnetometry (VSM) and Magnetic Induction Heating (*MIH*). Photocatalysis tests were made employing phenol as organic pollutant model in an aqueous medium at pH 6.5. XRD shows the coexistence of Fe_3O_4 and anatase TiO_2, with changes in the anatase crystallite size from 4 nm for *A1* and *B1*, to 7 nm for *A2* and *B2* samples. TEM results show a flower type magnetic nucleus surrounded by spherical morphology (mean diameters ranging from 220 nm to 450 nm). The samples display photocatalytic activity in the UV-Vis range, with enhanced performance of *B* NPs around 90 % linked to the higher crystallinity degree of the anatase TiO_2 and the protective role of the SiO_2 shell. Despite the samples show similar magnetizations, enhanced *MIH* performance were found in the *A* samples (without SiO_2 coating) for high amplitudes of *ac* magnetic fields, H_{ap} (*A1* sample: *SAR* = 465 W/g , H_{ap} = 50 kA/m at 311 kHz). An increment of almost 20ºC for mg/mL at 311 kHz (H_{ap} = 20 kA/m, 25 mT) was observed in *A1* sample. The results show the possibility of using the designed core-shell TiO_2 NPs in combined photocatalytic and adsorption/desorption MIH processes, improving the multifunctional performance of the system.

Acknowledgments.

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Magnetite nanoclusters for detection labels in magnetic lateral flow immunoassays

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Lateral flow immunoassays (LFIA) are point-of-care test devices that can be effectively used to detect several biomarkers. While often based on colloidal gold or latex beads, recent studies have proposed the use of magnetic nanoparticles as detecting labels in LFIA owing to their ability to be detected and quantified by means of magnetic readers. Furthermore, they can be used for immunomagnetic separation to increase sensitivity and limits of detection [1]. Studies have suggested that magnetic nanoclusters can increase the sensor sensitivity of lateral flow immunoassays [2].

In this work, we investigated PAA-coated magnetite (Fe_3O_4) nanoparticles (NPs) and its densely compacted assemblies in spherical nanoclusters [2] with sizes of 80 nm and 150 nm. We investigated their sensing performance by directly depositing aqueous dispersions of such NPs in a nitrocellulose and using a magnetic inductive sensor [3]. We also measured their AC magnetic susceptibility in the MHz frequency range to better understand their sensitivity for detection in the sensor. This will provide us with a better insight into how the size of nanoclusters and their AC magnetic behavior can impact the sensitivity of a LFIA.

Acknowledgements

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Magnetic Properties of Electroless-Plated Ni-based Rhombohedral Nanotubes

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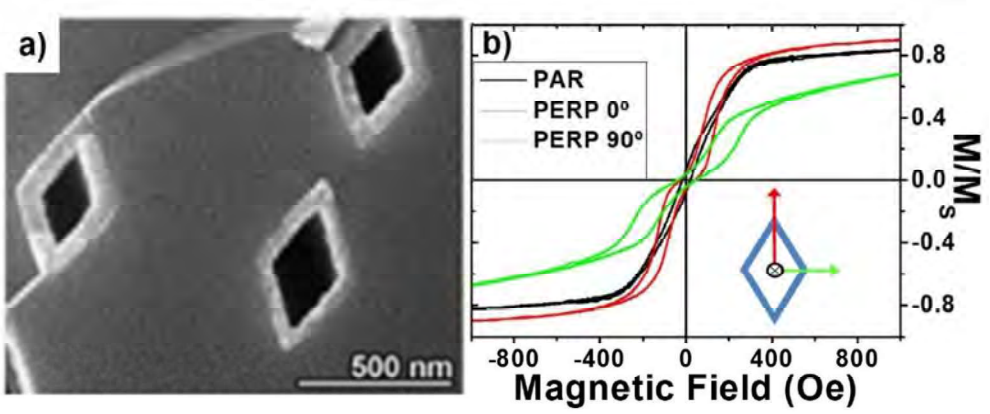
Magnetic nanowires (MNWs) have been extensively studied across a wide range of compositions, diameters, and packing densities within MNW arrays, as documented in the scientific literature [1]. These nanostructured systems exhibit unique magnetic properties compared to their bulk counterparts, characterized by enhanced shape anisotropy and strong magnetic interactions due to their dense packing [2]. However, magnetic nanotubes (MNTs) offer several advantages over MNWs—such as an empty core suitable for functionalization or filling for applications like drug delivery in biomedicine [3], and independent control over tube diameter and wall thickness, allowing for the selection of magnetization reversal modes (e.g., coherent, transverse, vortex) [4]—they have received comparatively less attention. MNTs are seen as promising building blocks for three-dimensional nanomagnetism, with potential applications in spin-wave spintronics. Moreover, most research on MNTs has focused on cylindrical geometries, while other alternative morphologies remain largely unexplored. This work introduces the electroless deposition of both Ni–B and pure Ni MNTs within track-etched mica templates, featuring a rhombohedral cross-section geometry [5]. The influence of boron doping on the microstructure and magnetic behavior of these Ni-based MNTs was investigated. Due to their distinct geometry, rhombohedral Ni MNTs exhibit a unique three-fold magnetic anisotropy, offering an additional degree of freedom for tuning their magnetic response. This opens new possibilities for applications in areas such as subwavelength waveguiding, magnetocalorics, and drug delivery, among others. Additionally, variations in magnetic properties with wall thickness were studied using micromagnetic simulations and experimental measurements, highlighting the potential of this emerging nanomaterial for 3D nanomagnetism applications.



Acknowledgements

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Index Terms — Nanotubes, nanostructures, nanomagnetism, micromagnetic simulations.

Optimization of Magnetite Nanoparticles for Combined Hyperthermia.

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The design of magnetic nanoparticles (NPs) capable of generating heat to destroy tumors efficiently, quickly, and safely for patients, while minimizing collateral damage, is one of the major challenges in nanomedicine. In this work, a system that combines magnetic hyperthermia (MH) and photothermal therapy (PT) has been developed into a single platform. Magnetite nanoparticles were studied, varying their size and shape to identify the characteristics that optimize both therapeutic modalities.

The nanoparticles were synthesized using a solvothermal method [1], modifying the oven temperature and coating agents to adjust their size and shape. The structure was analyzed using X-ray diffraction (XRD), confirming that all the particles obtained were magnetite. Morphology and size were evaluated by high-resolution transmission electron microscopy (HRTEM), showing a variety of shapes and sizes ranging from 10 to 30 nm. Magnetic properties, measured with a SQUID magnetometer, indicated that the nanoparticles were in the superparamagnetic regime, which is essential for their application in magnetic hyperthermia. The photothermal heating efficiency was evaluated under laser irradiation at 808 nm [2].

Figure 1 shows two representative examples: Figure 1.a presents 12 nm nanoparticles (N-12) with a magnetization of 20 emu/g (Figure 1.c), while Figure 1.b shows nanoparticles with a truncated octahedral geometry of 25 nm (N-25) and a magnetization of 52 emu/g. Figure 1.d displays the specific absorption rate (SAR) obtained in PT, where both samples show similar heating efficiency, around 400 W/g.

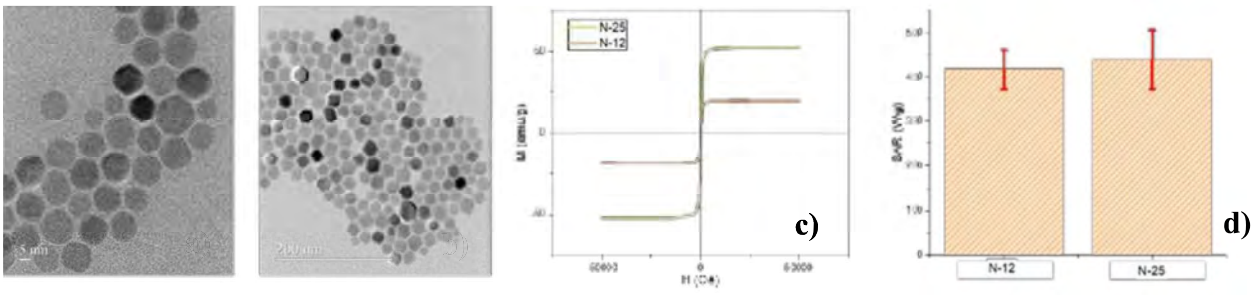

Figure 1. (a) 12 nm spherical nanoparticles (N-12). (b) Truncated octahedral nanoparticles (N-25). (c) Magnetization curves of N-12 and N-25 samples. (d) SAR values obtained during photothermal therapy for both nanoparticle samples.

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This work was supported by the PID2021-123112OB-C21 grant and the Community of Madrid.

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Temporal and spatial resolution of magnetosome degradation at the subcellular level in a 3D lung carcinoma model

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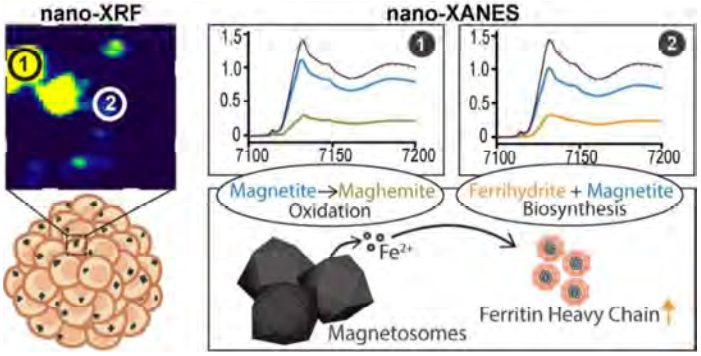
Magnetotactic bacteria are a group of bacteria that can align themselves along the earth's magnetic field thanks to organelles called magnetosomes. Magnetosomes are magnetic nanoparticles enveloped by a lipid bilayer membrane that can be made of magnetite (Fe_3O_4) or greigrite (Fe_3S_4) of high chemical purity, and have very uniform morphology and a narrow size distribution. These properties, together with their low toxicity and their bio-compatibility make them good candidates for many biomedical applications [1-3]. Despite the biomedical potential of magnetosomes, very little is known about their degradation in human cells, and even less so of their degradation within tumours, which are the target of many intended treatments.

In an effort to explore the potential of magnetosomes for cancer treatment, we have investigated the degradation process of magnetosomes isolated from *Magnetospirillum gryphiswaldense* in a 3D human lung carcinoma model over 36 days after internalisation. We describe the degradation process at the subcellular level and with nanometre resolution, using state of the art hard X-ray probes, nano-XANES and nano-XRF. The spatial resolution of these methods allows for the detection of iron phases even if they are minoritary within the global sample.

Our results reveal two different processes with spatial and temporal resolution. On the one hand, we observed an oxidation of magnetosomes to maghemite, which occurred mainly during the first 10 days and then the magnetite/maghemite content continued stable with maghemite taking up to 36% of the iron of the cell. On the other hand, we detected the de novo mineralisation of small particles of magnetite and ferrihydrite by ferritin. Therefore, the low degradation rate of magnetosomes within tumours and their ability to biosynthesise magnetite suggests that low magnetosome dosages could be used for prolonged periods for cancer treatments.



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Innovative magnetic transduction methodology for DNA detection in liquids

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In recent years, magnetic nanoparticles (MNPs) have been extensively employed for applied research in different disciplines thanks to their interesting dynamical magnetization properties. Biosensing is one application example exploiting MNPs magnetization dynamics to transduce biomolecular recognition phenomena to detect the presence of biomarkers in liquid samples. Recent works reported on a novel methodology based on variation of AC magnetization cycles of MNPs conjugated with receptors in absence or presence of the targeted biomolecule [1]. Here, we report on the latest methodology to detect DNA molecules in buffer saline solutions. Biotinylated DNA of different pair bases ranging from 10 up to 88 with persistent length were incubated with streptavidin conjugated cobalt ferrite nanoflowers (bs-MNPs) for 60 min at room temperature to unveil the sensitivity of this methodology. The AC magnetization cycles of bs-MNPs were analyzed in absence and presence of DNA molecules at different AC magnetic field conditions ranging from 5 up to 100 kHz and field intensities up to 32 kA/m. Different parameters such as MNPs concentration, number of streptavidin per bs-MNPs, and field conditions were explored to modulate the detection sensitivity by AC magnetometry. Molecular recognition phenomena between bs-MNPs and DNA chains result in multiple DNA chains bounded to individual bs-MNPs. Such specific interactions strongly influence the MNPs diffusion, which tightly depends on the number of streptavidin per bs-MNPs, DNA length and concentration. In the results depicted in the figure, AC magnetic area (b) varies up to 25% when MNPs surface is fully modified (i.e. bs-MNPs + 3 μM), or 12% when no DNA chains are bounded to streptavidin receptors (i.e. bs-MNPs + 0 μM) with respect to bare surface (i.e. MNPs). Hence, the distinct capacity of MNPs to bind DNA molecules results in different variation of AC magnetic area. This change can be adequately employed to detect DNA chains of distinct length and concentration in liquids. This approach provides optimal detection conditions for quantifying single DNA strands by simply modelling the dynamical magnetization behavior of individual bs-MNPs.

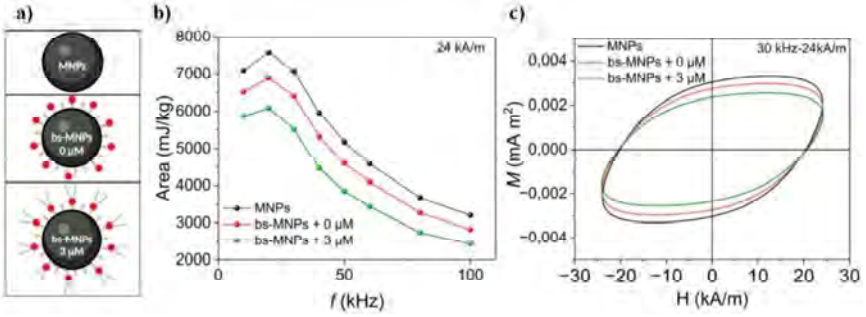

Figure: a) Schematic representation of the studied nanoparticle formulations; b) Frequency dependence of AC magnetic hysteresis area at 24 kA/m for different MNPs formulations at 1 g/L dispersed in 25 mM Tris solution; c) Comparison of AC magnetization cycles obtained from suspensions of different MNPs formulations at 30 kHz and 24 kA/m and 1 g/L.

Acknowledgements

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How Curvature-Induced Effects can shape Magnetic Domain Walls in Corrugated Strips.

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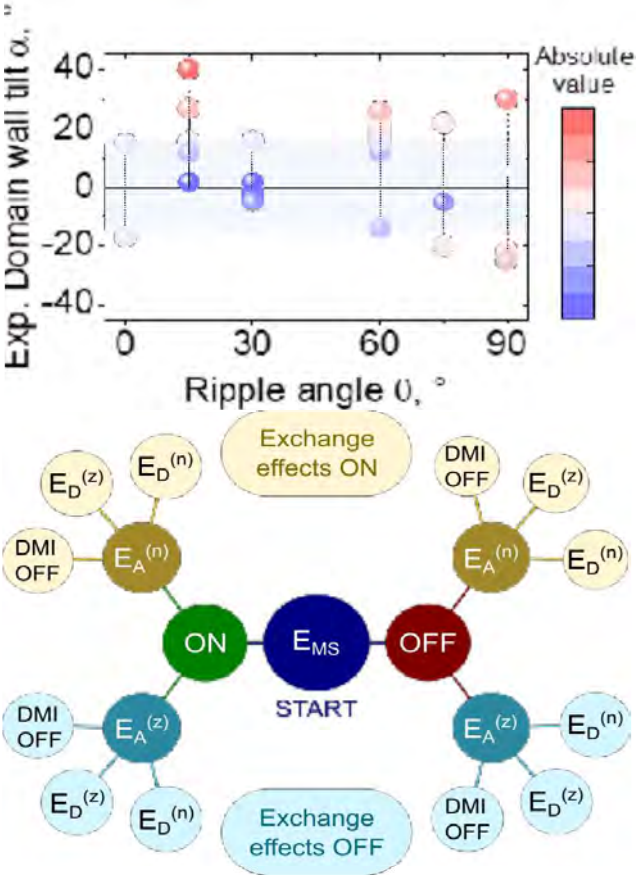

FIG 1. Domain wall tilts extracted from XMCD Experiments (Upper), and decision tree enabling interpretation of magnetic curvilinear effects (Bottom).

In recent years, curvilinear magnetism is garnering attention for effects emerging in curved geometries that are appealing for the innovative developments in stretchable and magnetoelectric devices, microrobots, sensors, flexible magnetic memories and nanoelectronics [1, 2].

These phenomena encompass exchange- and Dzyaloshinskii-Moriya (DMI)- induced interactions that can result in topological magnetization patterning in shells, symmetry breaking, and pinning of domain walls [1,2]. Less attention has been paid though to the role of the curvilinear effects in domain walls in curved geometries [1,2]. From application perspectives, spin-orbit torques are appealing as an alternative to achieve the manipulation of magnetic domain walls and magnetization [3] with the breakthrough of lower power consumption. Recent developments in ultra-thin planar asymmetric multilayered strips describe a method to extract DMI and damping estimations from the dynamical tilt of domain walls from static measurements [4]. Following a similar approach, here we provide first results in single 100 nm-wide thin periodically corrugated strips of CrOx/Co/Pt with thickness of 2 nm and average curvature of 0.06 nm^{-1}, tailored for an enhanced exchange-induced DMI. The orientation of the corrugation is tuned from the parallel to the perpendicular direction of the axis in several strips.

Our results indicate that curvature plays a crucial role in the pinning and tilting of domain walls through DMI-induced and exchange-induced effects. DMI-induced anisotropy leads a pinning mechanism, while it enhances the domain wall tilt in combination with exchange-induced effects. All this opens an unforeseen perspective for shaping future spin-based nanoelectronics via curvature-induced effects [5].

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Index Terms — Curvilinear magnetism, Dzyaloshinskii-Moriya Interaction, Domain Walls

Tuning the magnetic properties of Fe-Co structures through the addition of B

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In this study, the impact of boron addition on the magnetic properties of 50 at.% iron-cobalt powder mixtures was investigated, with the aim of synthesizing rare-earth-free permanent magnets. High-energy ball milling was employed for the synthesis of the powders, performing multiple milling stages and adjusting both, the components, and their proportions. The material obtained at different stages was characterized using X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), and Vibrating Sample Magnetometry (VSM). The results show that, although the saturation magnetization decreases with milling time, this reduction is less pronounced in powders containing a small amount of boron (1.5 wt.%). Boron acts as a refining and passivating agent, allowing fine-tuning of the saturation magnetization of the resulting microstructures. [1,2,3].

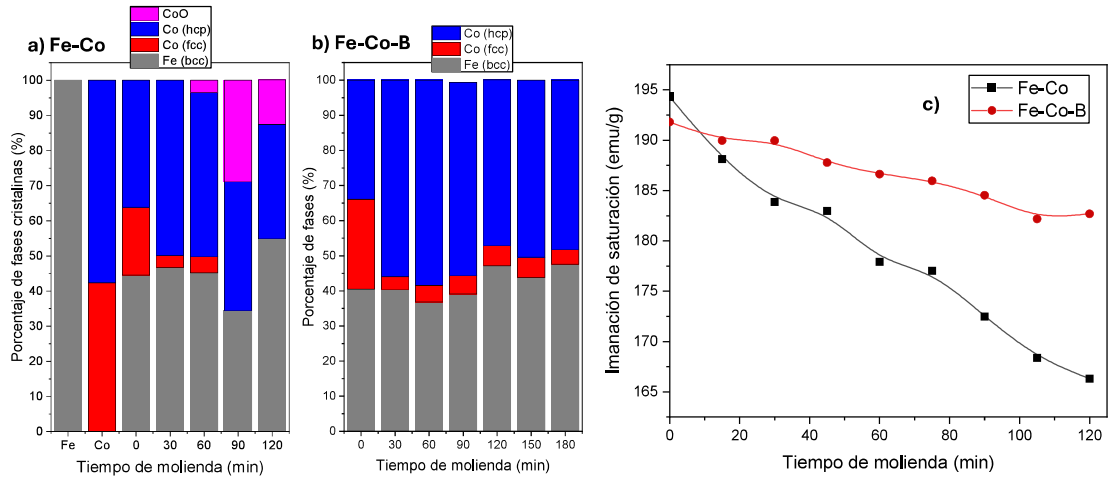

Figure: a) and b) Evolution of the percentages of crystalline phases with milling time extracted from Rietveld refinements of the XRD patterns for the Fe-Co and Fe-Co-B powder mixtures, respectively. c) Effect of boron addition on the saturation magnetization of Fe-Co structures.

Acknowledgements

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Index Terms

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Magnetic structure study of the ternary rare-based TbFeSi

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In recent decades, magnetocaloric materials have proven to be more efficient and environmentally friendly than gas compression technology. RFeSi intermetallic compounds (where R represents a rare earth element) have an application range between 10 and 150 K, which can be used for hydrogen liquefaction. These compounds exhibit a second-order magnetic transition that varies according to the radius of the rare earth element [1]. They crystallize in a tetragonal phase with the *P4/nmm* space group, where R and Si occupy the 2*a* Wyckoff position and Fe occupies the 2*c* Wyckoff position [2]. However, the thermal treatments required to obtain a single phase are expensive and time-consuming (taking 35 days at 1373 K) [1]. In this context, the melt spinning method emerges as a fast and easy technique for obtaining single and nanostructured phases.

In this work, we analyze the magnetic structure of TbFeSi ribbons using magnetic measurements, neutron powder diffraction, and Density Functional Theory (DFT) calculations. Through ZFC-FC measurements, the magnetic ordering temperature was determined to be 130 K, which is 20 K higher than that in the bulk state. We also observed the evolution of the volume with temperature, revealing anomalous behavior around the Curie temperature (T_C), related to magnetovolume effects. In contrast to previous neutron analyses, the Fe atoms exhibit a non-zero magnetic moment. This finding aligns with the value obtained from the approach to saturation law and band structure calculations.

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