7th Young Researchers in Magnetism

23rd November, 2023
El Escorial, Madrid, Spain

Book of Abstracts

THE SPANISH MAGNETISM CLUB AND THE SPANISH CHAPTER OF THE IEEE MAGNETICS SOCIETY ANNUAL JOINT MEETING

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7th Young Research in Magnetism

November 23rd, 2023, El Escorial, (Madrid)

Welcome

The annual meeting of the Spanish Magnetism Club and the Spanish Chapter of the IEEE Magnetics Society will be held in San Lorenzo del Escorial (Madrid), Spain.

The 7th Young Researchers in Magnetism, the traditional special session devoted to young researchers will take place during this meeting, on November 23rd. This year, it is again organized for and by the young researchers.

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7th Young Research in Magnetism

November 23rd, 2023, El Escorial, (Madrid)

Conference venue

Location

Paseo de los Alamillos, 2 – 28200
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By suburban train

- Departures from Madrid: Atocha, Chamartín, Nuevos Ministerios and Príncipe Pío stations.
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09:00	**Opening Ceremony**
09:30	Oral presentation 01: Rubén Corcuera
09:45	Oral presentation 02: Eduardo Ordoqui
10:00	Oral presentation 03: Alejandra Guedeja
10:15	Oral presentation 04: Carlos Iglesias
10:30	**Invited Talk 1: Maite Goiriena**
11:00	**Coffee Break**
11:30	Oral presentation 05: Raúl López Martín
11:45	Oral presentation 06: Raquel Loriente
12:00	Oral presentation 07: Ana Isabel Jiménez Ramírez
12:15	Oral presentation 08: Pablo Martínez Outomuro
12:30	Oral presentation 09: Jason Daza
12:45	Oral presentation 10: Lorenzo Gallo
13:00	**Invited Talk 2: Cristina Gila**
13:30	**Lunch**
14:45	Oral presentation 11: Paul Gavriloaea
15:00	Oral presentation 12: Tatiana Escalante-Quiceno
15:15	Oral presentation 13: Francisco J. Vázquez-Pérez
15:30	Oral presentation 14: Isaac Royo
15:45	Oral presentation 15: Leyre Fraile
16:00	Oral presentation 16: Manuel Horcajo
16:15	Oral presentation 17: Pablo Palacios Alonso
16:30	**Poster Session & Coffee Break**
17:15	**Young Professionals, Spain (IEEE)**
17:25	**Students in Magnetism**
17:35	**Awards & Closing Ceremony**

7th Young Research in Magnetism

November 23rd, 2023, El Escorial, (Madrid)

ORAL PRESENTATIONS

OP01	Spin Pumping and Detection in Yttrium Iron Garnet Thin Films Fabricated by Polymer Assisted Deposition. **Rubén Corcuera.**
OP02	Synthesis and pollutant degradation effectiveness of ternary Fe@C@TiO_2 nanocomposites. **Eduardo Ordoqui.**
OP03	Atomic resolution insights into in-situ heating and biasing effects in Bi-doped Cu nanowires for spintronics. **Alejandra Guedeja.**
OP04	Coercivity Evolution in FeNiPC Ribbons: A Precursor Analysis for Sustainable Permanent Magnet Development. **Carlos Iglesias.**
OP05	Non-Exchange Bias in Dense Binary Assemblies of Nanoparticles. **Raúl López**.
OP06	Anomalies in a Magnetostrictive Sensor based on Love Surface Acoustic Waves. **Raquel Loriente.**
OP07	Magnetization reversal processes in ferromagnetic nanowires modulated in geometry and composition**. Ana Isabel Jiménez Ramírez.**
OP08	Investigating the complex coexistence of magnetic interactions in Ni-doped $TbCu_2$ nanostructured alloys. **Pablo Martínez Outomuro**.
OP09	Understanding the Magnetic Behaviour of a $Fe_{65}Co_{35}$ Soft Magnetic Alloy by Means of its Structural, Thermal and Magnetic Analysis**. Jason Daza.**
OP10	Magnetic Shape Memory Heuslers for Low-grade Heat Harvesting. **Lorenzo Gallo.**
OP11	All-optically driven domain-wall dynamics in an antiferromagnetic system. **Paul Gavriloaea.**
OP12	Fe tips Grown by Focused Electron Beam Induced Deposition for high-resolution Magnetic Force Microscopy. **Tatiana Escalante-Quiceno.**
OP13	Soft magnetic actuators based on the pre-alignment of magnetic particles. **Francisco J. Vázquez-Pérez.**
OP14	Low frequency vibration harvester based on the levitation force between permanent magnets**. Isaac Royo.**
OP15	Manganese ferrite nanoparticles for the detection of biomolecules in lateral flow assays. **Leyre Fraile.**
OP16	Multifunctional platform for photothermal hyperthermia combined with luminescence nanothermometry probes. **Manuel Horcajo.**
OP17	Influence of nanoparticle diffusion on AC magnetization cycles : potential for sensing tranduction. **Pablo Palacios Alonso**.

POSTER SESSION

P01	Formation of Micropatterned Hydrogels based on Magnetic Pickering Emulsions. **Alfredo Escribano Huesca.**
P02	Efficient Production of Printable Magnetic Filaments with Recycled Ferrite Cores. **Uxua Jiménez.**
P03	Fast and Reproducible Synthesis of Iron Oxide Nanoflowers by Microwave-assisted Heating. **Rafael Herrera Aquino.**
P04	Innovations in Strontium Ferrite: Nanostructuring Permanent Magnet Materials for a Sustainable Future. **Adrián Fernández Calzado.**
P05	Exploring the magnetocaloric effect on nanocrystalline melt spun R_2Fe_{17} (R= Pr, Nd) ribbons. **José Luis Garrido.**
P06	Synthesis of permalloy nanoclusters using microwave-assisted aqueous method. **Antonio Santana Otero.**
P07	Production of Magnetic Nanoparticles by Recycling Industrial Steel Manufacturing Residues. **Cristina Montero Aguilar.**
P08	Carbon-supported magnetic nanoparticles for combined water decontamination purposes: Fabrication and Characterization. **Mona Fadel.**
P09	Enhancing the Particle Content in 3D-printed Ferromagnetic Objects by tuning the MnAlC / Hydrogel Precursor Inks. **Zaida Curbelo.**
P10	From lab to industry: Industrial development of coercivity in MnAlC alloys. **Jorge Vergara-Ortega.**
P11	Exploring Cobalt Ferrite Nanoparticles as Sustainable Alternatives to Rare-Earth-Based Permanent Magnets. **Deborah Liguori.**
P12	Potential of AC Magnetometry to Display Protein Conformational Changes**. Alejandro Venegas.**
P13	Towards the Standardization of Photothermal Measurements of Iron Oxide Nanoparticles in Two Biological Windows. **Daniel Arranz.**

POSTER SESSION

P14	Preparation of conductive nano-inks for sustainable electronics. **Belén Corrales**.
P15	Design of Magnetic Metal Organic Frameworks for the CO_2 Capture and Conversion under Magnetic Induction Heating. **Álvaro Gallo.**
P16	Theoretical analysis of the interaction between surface acoustic waves and deposited magnetostrictive layer in magnetic Love wave devices. **Juan Diego Aguilera.**
P17	Magnetoelastic resonators functionalized with Metal Organic Frameworks for humidity detection. **Beatriz Sisniega.**
P18	Exchange Bias Effect of Ni@(NiO, $Ni(OH)_2$) Core/Shell Nanowires Electrodeposited in Nanoporous Alumina Membranes. **Yolanda Álvarez.**
P19	Magnetization Reversal Process of Bi-modulated FeCo Cylindrical Nanowires. **Joao Fradet.**
P20	Pressure-tuned interactions in magnetically driven superconductor. **Daniel Margineda.**
P21	Synthesis, characterization, and study of the spin-polarization in 2-dimensional chiral hybrid organic-inorganic metal halides. **Hamida Gouadria.**
P22	High-Precision Magnetic Characterization with the Cryogenic S700XR SQUID Magnetometer. **Ahmed Sedda.**

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Oral presentations

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Spin Pumping and Detection in Yttrium Iron Garnet Thin Films Fabricated by Polymer Assisted Deposition

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The control of the thickness of YIG thin films is crucial for their application in spintronic devices, and so is the crystalline quality. With this purpose, it is mandatory to obtain excellent-quality thin films, but also is using a scalable and affordable technique for thin film fabrication [1]. Chemical solution deposition methods offer these advantages in contrast to techniques which are more oriented to research, such as pulsed laser deposition (PLD). Polymer Assisted Deposition (PAD) has the traditional advantages of chemical solution deposition systems and has the added feature of producing high quality films comparable to physical vapour deposition techniques. Binding the metal ions directly to a polymer offers homogeneous distribution of the metal precursors, and sequesters the metal until the polymer is decomposed, avoiding metal oxide formation in solution [2].

Spin Seebeck Effect (SSE) induced by thermal gradients or spin pumping through ferromagnetic resonance (FMR) are two of the recently highly studied techniques for spin current excitation into ferromagnetic thin films. These techniques are highly dependent on the crystalline structure of the material thus, the understanding and control of this quality becomes crucial to optimize the integration of these materials into spintronic devices [3].

For this work we have fabricated $Y_3Fe_5O_{12}$ (YIG) epitaxial thin films deposited onto $Gd_3Ga_5O_{12}$ (GGG) substrates by PAD. The optimization of the deposition conditions of this structure has been well performed, obtaining excellent-quality ~15 nm thick films [1]. The limitation in the layer thickness that can be grown using this technique is determined by the properties of the used solution (molarity, viscosity) and the deposition conditions (spin-coating velocity). To overcome this limitation, this work is intended to study the effects of the deposition of layer-onto-layer with this method, specially the aim is to study the variations in the crystalline structure of thin films deposited via PAD with a different number of layers.

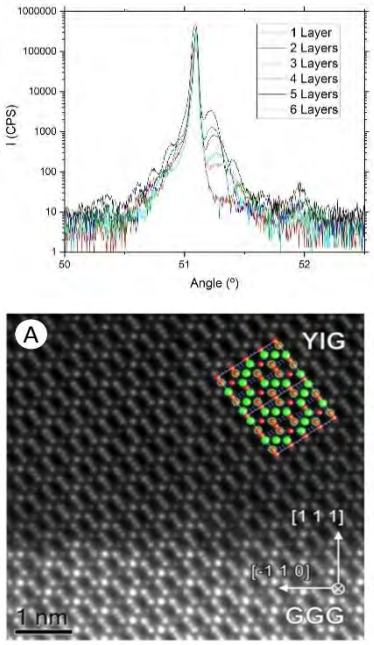

Figure 1. Top, XRD patterns near the GGG (444) diffraction peak for samples with different number of layers. Bottom, HAADF-TEM image of a 1 layer thick sample.

The fabrication of the samples has been performed with the mentioned strategy of depositing layer-onto-layer, obtaining samples with thicknesses varying from 12 to 75 nm. The crystalline quality has been studied using X-Ray Diffraction near the (444) peak of the GGG substrates. These patterns show that we have achieved the growth of monocrystalline samples in the imposed direction by the substrate. For a better understanding of the layer-onto-layer growth, Transmission Electron Microscopy (TEM) has been performed. Also, X-Ray Reflectivity measurements show low rugosity values with increasing thickness of the samples. Topography of the samples has been studied through Atomic Force Microscopy (AFM), characterizing the porosity of the surface. Spin-Seebeck Effect measurements have been performed obtaining the desired behaviour: the spin pumping efficiency is proportional to the thermal gradient applied to the sample, and most important, it is comparable to high quality films reported in literature [4].

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[4] J. Lustikova et al., J. Appl. Phys. 116, 153902 (2014)

Index Terms — Spin-Seebeck Effect, Iron Garnets, PAD

Synthesis and pollutant degradation effectiveness of ternary Fe@C@TiO_2 nanocomposites

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Nowadays, the environmental state of the water that flows through our rivers and pipelines has gained extensive attention. Some of the most challenging pollutants to remove include phenolic and other aromatic organic compounds. The use of magnetic carbon nanoadsorbents allows not only the magnetic separation of the adsorbent from the aqueous media, but also its reuse in various decontamination cycles. The combination of adsorption and photocatalysis improves the pollutant removal from the aqueous media, avoiding secondary contamination [1].

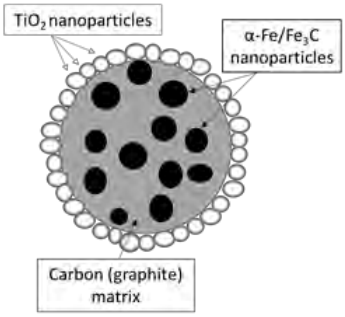

Figure 1. Sketch structure of the ternary nanocomposite.

In this work, the synthesis of magnetic carbon nanocomposites (Fe@C) were performed from the thermal decomposition of fructose, employing $FeCl_3$ as iron precursor [2]. In a second step, TiO_2 anatase nanoparticles were deposited on the surface of the magnetic carbon nanocomposites forming a ternary structure (Fe@C@TiO_2, Figure 1). The formation of this heterostructure required a calcination stage using titanium butoxide as Ti precursor, in which the calcination temperature and the atmosphere played a determinant role.

The structural characterization (X-ray diffraction, Transmission Electron Microscopy, Scanning Electron Microscopy (Figure 2)) confirms the formation of the desired ternary structure. The magnetic characterization of the developed nanocomposites (VSM magnetometry) validate their optimal magnetic response (high saturation magnetization, high magnetic susceptibility) to facilitate the recovery of these nanocomposites after the degradation cycles. Adsorption experiments employing both Fe@C and Fe@C@TiO_2 nanocomposites and phenol and methylene blue as organic pollutant models, show a remarkable decrease in the pollutant concentration after 120 minutes. Furthermore, the photocatalytic response for phenol degradation of the Fe@C@TiO_2 nanocomposites was characterized employing a 300 W Xenon lamp. Results showed an effective depolluting power in these nanocomposites due to the combined effects of adsorption of carbon and the photocatalytic activity of the TiO_2 anatase.

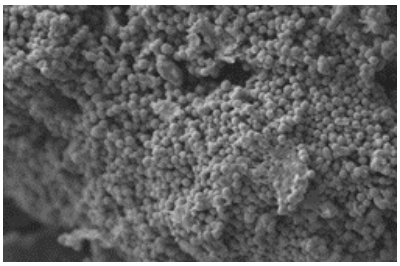

Figure 2. SEM characterization of the ternary nanocomposite.

Acknowledgements

The research was founded by the Navarra Government, Departamento de Universidad Innovación y Transformación Digital, project PC162-163 T3CE.

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Index Terms — Adsorption, Photocatalysis, Anatase, Phenol, Water treatment, Nanocomposites.

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Atomic resolution insights into *in-situ* heating and biasing effects in Bi-doped Cu nanowires for spintronics

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The spin Hall effect (SHE) is a spin-charge conversion phenomenon that plays a key role in spintronics, [1] so the search for materials that exhibit giant SHE has grown significantly within the last decades. [2, 3] Recently, SHE in $Cu_{95}Bi_5$ films has been directly detected by X-ray spectroscopy, [4] confirming this material as a good candidate for integration in spintronic devices. Achieving CuBi structures with tunable composition and structure [5] can provide an ideal model-system for exploring and optimizing the extrinsic SHE .

Here, we present a detailed structural characterization of Bi-doped Cu nanowires (NWs) with different Bi doping levels and degrees of crystallinity, grown by template-assisted electrochemical deposition. *In-situ* heating experiments combining atomic resolution scanning transmission electron microscopy (STEM), electron energy-loss spectroscopy (EELS) and high-resolution synchrotron powder X-ray diffraction (PXRD), allow studying in detail the atomic structure of the NWs along with evolution with temperature, aimed at controlling Joule heating effects in future devices. These results pave the way towards the realization of spin-dependent transport measurements complemented with *in-situ* polarization in CuBi NWs.

Acknowledgements

Electron microscopy observations were carried out at the Centro Nacional de Microscopía Electrónica at Universidad Complutense de Madrid. PXRD experiments were performed at the MSPD beamline, ALBA, Spain, and ID22 beamline, ESRF, France.

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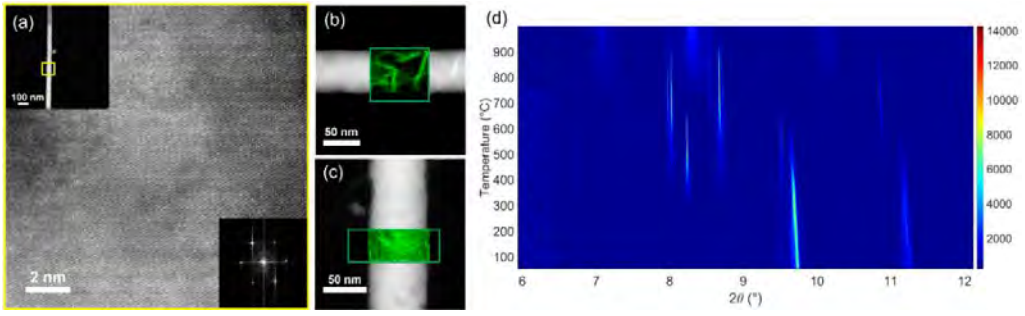

Figure 1: (a) High-angle annular dark field STEM atomic resolution images corresponding to a single-crystal CuBi nanowire. Bottom right (a) image displaying the fast Fourier transform [111] zone axis. EELS maps depicting the Bi $M_{4,5}$ edge integrated signal in a (b) polycrystal and (c) single-crystal NW. (d) PXRD heating 2D map showing the material phase change at around 300ºC.

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Coercivity Evolution in FeNiPC Ribbons: A Precursor Analysis for Sustainable Permanent Magnet Development

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Tetrataenite, characterized as an ordered phase ($L1_0$) with an $Fe_{50}Ni_{50}$ composition, holds promise as a sustainable substitute for rare earths-based permanent magnets owing to its exceptional magnetic attributes. It would exhibit an estimated maximum energy product, $(BH)_{max}$, of approximately 42 MGOe, as seen from theoretical works [1]. While naturally occurring in some meteorites [2], the synthesis of pure $L1_0$-FeNi on practical time scales continues as a considerable challenge.

X-ray diffraction (XRD) analysis indicated the presence of $Fe_{50}Ni_{50}$, $FeNi_2P$, Ni_8P_3 and Fe_3C in both the 12-days annealed (370 °C) and 1-hour annealed (390 °C) samples. Room temperature hysteresis loops were measured using a Vibrating Sample Magnetometer (VSM). A coercivity of 475 Oe, achieved after a 12-days annealing process at 370 °C, aligns with findings reported by J. Kim *et al*. [3], following an extensive annealing duration. Our investigation demonstrates the potential to reduce annealing time from 12 days to 1 hour while not only matching coercivity but surpassing it with a slight increase in annealing temperature. Specifically, annealing at 390 °C for 1 hour resulted in a coercivity of 757 Oe. This heightened coercivity could be attributed to the initiation of the $L1_0$-FeNi phase formation. Ongoing research aims to furnish conclusive evidence and reveal the synthesis mechanism of this promising permanent magnet phase under practical synthesis conditions.

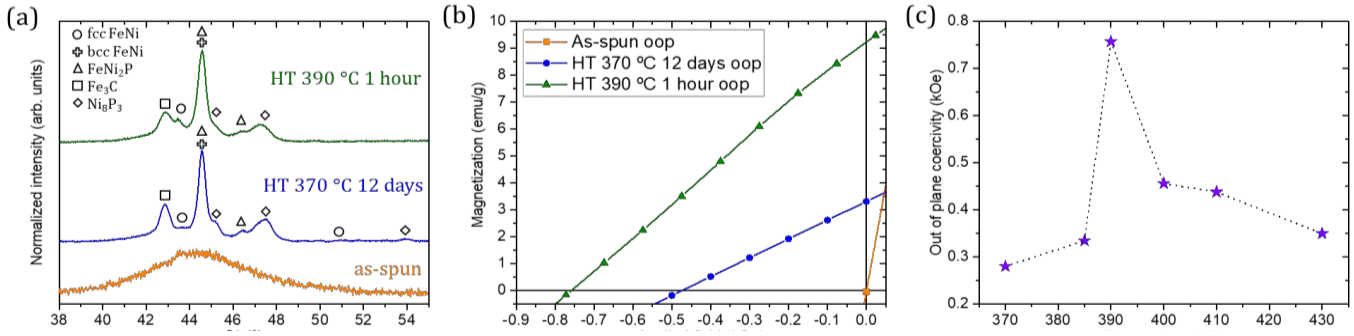

Figure 1. (a) XRD diffractograms with indexed peaks, (b) second quadrant of the room temperature out-of-plane (oop) hysteresis loops for: as-spun ribbons, ribbons annealed at 370 ºC for 12 days and ribbons annealed at 390 ºC for 1 hour; (c) evolution of coercivity *vs* annealing temperature after 1 h annealing at 390 ºC.

Acknowledgements

Authors acknowledge support from EU M-ERA.NET and MICINN through COSMAG (PCI2020-112143) and NEXUS (PID2020-11521RB-C21) projects. A.J.C.-H. and E.M.P. acknowledge support from "La Caixa" Foundation (ID 100010434) through the Doctoral INPhINIT Incoming program (LCF/BQ/DI20/1178002) and AEI through JdC-I program (IJC2020-043011-I/MCIN/AEI/10.13039/501100011033) and EU by NextGenerationEU/PRTR, respectively.

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Index Terms — permanent magnets, sustainability, FeNi, melt-spinning

Non-Exchange Bias in Dense Binary Assemblies of Nanoparticles.

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Exchange bias in both single-phase and multiphase nanoparticles has been widely studied over the years [1,2]. However, the effect of the overall shift in binary systems (comprising two different nanoparticle populations) is yet to be explored. In this contribution, binary *dense* assemblies with different proportions of γ-Fe_2O_3 (soft, non-exchange biased) and Co-doped γ-Fe_2O_3 (hard, exchange biased) nanoparticles are studied by SQUID magnetometry. Due to the differences in magnetic anisotropy of the constituent nanoparticles, the low temperature hysteresis loops show a hummingbird-like loop, typical of weakly coupled systems [3]. Moreover, all of them show a horizontal loop shift, showing a maximum bias for the 23% soft particle concentration system. By comparing the experimental bias and the superposition values (the weighted sum of the soft and hard loops), this maximum shift is concluded to originate from two different mechanisms: dipolar interactions and an effect (confirmed by numerical simulations) driven by the asymmetry in the reversal of the hard particles. The latter produces a bias enhancement of ~ 20% with respect to the bias of the hard particles, while the former produces a maximum enhancement of 90% with respect to the corresponding superposition bias. The results highlight the utility of binary nanoparticles assemblies as a tool to explore non-exchange bias effects beyond the archetypal core-shell exchange-coupling scenario.

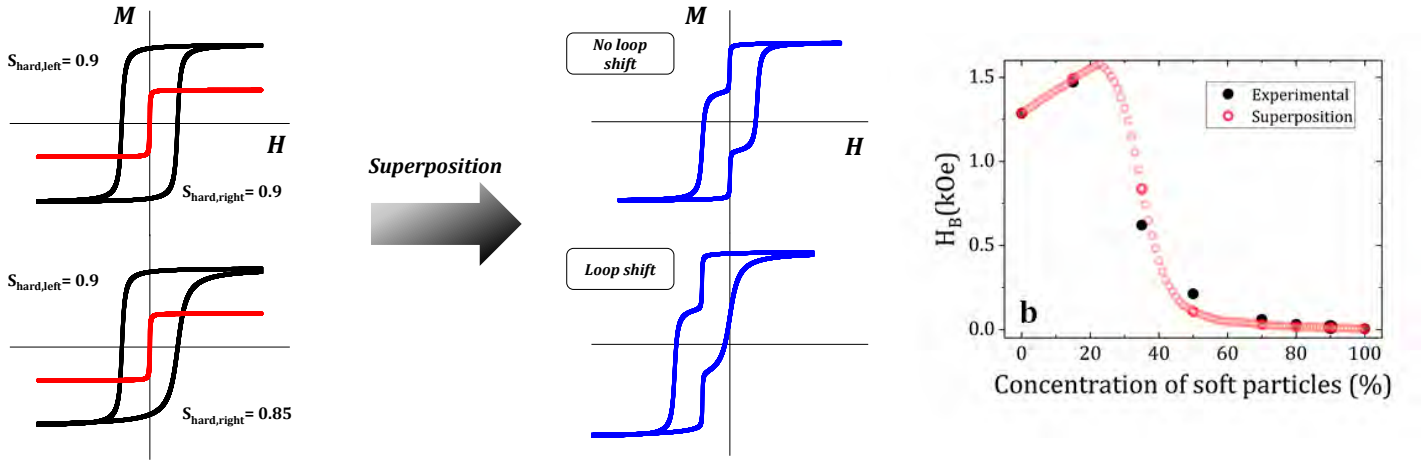

Figure 1. Sketch of asymmetric reversal induced bias (left) and Bias enhancement (right) in binary dense systems.

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Anomalies in a Magnetostrictive Sensor based on Love Surface Acoustic Waves

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There is a wide range of high-performance, small, low cost and low consumption sensors based on the variation of parameters that characterize surface acoustic waves (SAW) propagating through piezoelectric substrates [1]. In this work, the response of a SAW device sensitive to magnetic fields due to a magnetostrictive nanofilm is investigated. It is considered a novel study as there is a few literatures on the topic of the study [2-3]. The device (Fig. 1) is based on a ST-cut quartz substrate on which there are two interdigitated electrodes (IDT) and a 3,6µm film of amorphous SiO_2, which excite and guide the shear horizontal SAW near to the interface (Love Wave). A 100 nm thick polycrystalline galfenol ($Fe_{72}Ga_{28}$) layer is deposited by sputtering into the area between the IDTs. A feedback loop circuit provides a resonant SAW frequency, f_R, around 160 MHz that can be tracked in real time. When a magnetic field is applied, f_R varies with the applied field.

Fig 2a shows the frequency shift due to applied magnetic field sweeps from -40 to 40 mT forming an angle of 45º or 0º with the SAW propagation. In the case of orientation at 45º, f_R follows a hysteretic behaviour induced by the strain linked to the nanofilm magnetization M, where f_R increases as |M| increases. Apparently, the saturation is reached for higher fields and the coercive field corresponds to the two central minima. In the case of 0º, the saturation is not reached but a relative maximum appears when the applied field reverses. So f_R cannot be directly related to magnetization in a simple way. In addition, a sudden drop in f_R is shown (Fig. 2b) that occurs after the peak, with a slope so high that the available equipment could not resolve it, despite having a sensitivity of around 3 Hz/nT. This fact has not been visualized in the literature, and it is assumed due to a more complex magnetization process interacting with the acoustic waves. This phenomenon can lead to high resolution magnetic measurements, a necessary quality in different branches of study such as biomagnetism.

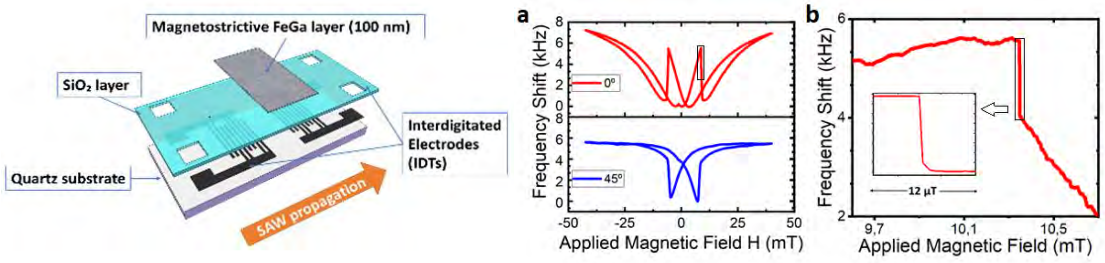

Figure 1: Schematics of the fabricated device. *Figure 2*: Frequency shift versus field for 0º (red) and 45º (blue) configuration (a). Zoom at the highlighted area of Fig.2a, including another zoom at the abrupt fall of the frequency (b).

Acknowledgements

This research has been funded by Ministerio de Ciencia, Innovación y Universidades (grant number PID2021-123112OB-C21 and PDC2022-133039I00) and supported with the contracts RYC2021-031166-I and Programa Investigo 96-UCM-INV.

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Magnetization reversal processes in ferromagnetic nanowires modulated in geometry and composition

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The development of three-dimensional (3D) network architectures based on arrays of magnetic nanowires (NWs) and nanotubes (NTs) has unlocked new possibilities for a wide range of applications due to the arise of singular features and novel phenomena. Furthermore, the ability to modulate both the diameter and composition of the aforementioned nanowires has emerged as a promising avenue for tailoring their magnetic properties. This approach allows for a more precise control over the magnetic domain wall (DW) motion and offers the potential to manipulate the DW displacement under external applied magnetic fields or electrical currents. These advancements hold significant promise for integrating such magnetic nanowires into next-generation devices, encompassing information storage, logic systems, and sensors. Metallic NWs can be efficiently synthesized through different techniques, with the electrochemical deposition being one of the most versatile methods, using nanoporous alumina membranes as meticulously patterned templates. Moreover, atomic layer deposition (ALD) stands as a reliable physicochemical deposition technique, known for its ability to offer extensive coverage and impeccable uniformity of coatings, often comprising metallic oxides applied to 3D nanostructured surfaces. Many studies employ ALD method to craft tailored 3D nanostructured networks via template-assisted procedures, including the fabrication of intricately designed geometrically segmented arrays of NWs and the production of multilayered NTs or thin films [1]. Here we present our latest progress made on magnetic NWs forming building blocks of complex 3D nanostructures with modulated geometry and composition. To make significant advancements in these research areas, it is imperative to gain a comprehensive understanding of the magnetic properties displayed by these complex 3D nanostructures. This encompasses a thorough study of their magnetization reversal processes and the ability to control the movement of magnetic DWs [2]. The magnetic properties of these 3D modulated nanostructures, along with their magnetostatic interactions, are explored through a combination of techniques, including vibrating sample magnetometry (VSM), magneto-optical Kerr effect (MOKE) measurements, and the analysis of first-order reversal curves (FORC). Additionally, micromagnetic simulations carried out with mumax[3] has played a pivotal role in identifying the primary mechanisms governing their magnetization reversal process. These findings display an attractive approach for crafting novel and innovative 3D magnetic storage and spintronic devices based on the controlled design of both, geometrical and compositional modulation, of magnetic nanowire arrays.

Acknowledgements

Spanish MCINN under research grant No. PID2019-108075RB-C32/AEI/10.13039/501100011033 is gratefully acknowledged for financial support.

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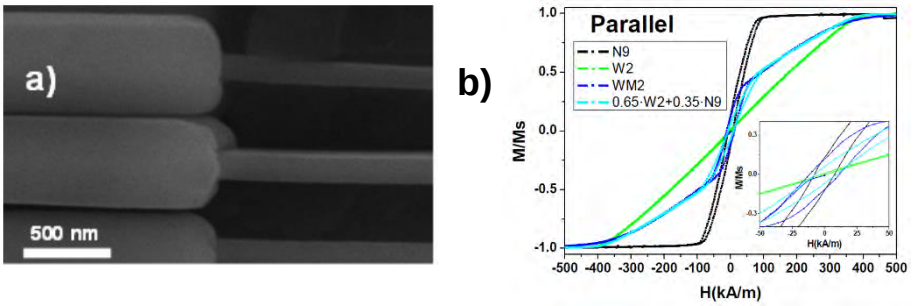

Figure 1: a) SEM image of diameter modulated FeNi nanowires. b) Hysteresis loops measured with VSM of the NWs in a).

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Investigating the complex coexistence of magnetic interactions in Ni-doped $TbCu_2$ nanostructured alloys

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Size reduction of materials to the nanoscale leads to the change of its properties, which has a fundamental research interest and often exciting applications. In this sense, we aim to study nanostructured intermetallic 4f-Rare-Earths - 3d-transition metals compounds, whose complex magnetic structure make them suitable materials for a wide variety of research fields. When performing studies in $TbCu_2$ nanoparticles (NPs), an evolution on its magnetic properties with milling time (t) was observed, evolving from antiferromagnetic (AFM) on bulk [1], to AFM + Spin-Glass (SG) on its NP state [2,3]. AC- susceptibility measurements showed an unexpected hump in the imaginary susceptibility $\chi''(T)$ for $t \geq 5h$ (see Figure 1) which can be associated with the presence of ferromagnetic (FM) coupled moments. With the aim of increasing this FM character and, therefore, its applications in magnetic refrigeration via the magnetocaloric effect, we substitute some Cu atoms by Ni (FM). Bulk $Tb(Cu,Ni)_2$ properties are well known [4], which is not the case for its nano counterpart.

For this very reason, samples of $Tb(Cu_{1-x}Ni_x)_2$ with (x=0, 0.08, 0.11, 0.15 and 0.25) were prepared by arc melting followed by a subsequent ball milling. This allows us to study how the magnetic properties evolve not only with Ni composition but also with particle size reduction. Samples were characterised both structurally and magnetically, observing peculiar features (see Figure 2) which will be presented.

Figures

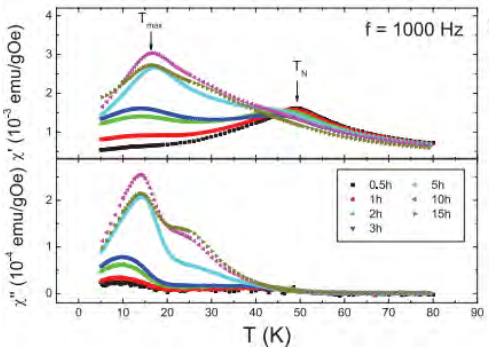

Figure 1: AC-susceptibility of $TbCu_2$ for different milling times for f=1000Hz. The out-phase component (χ'') shows a contribution at T≈25K when $t \geq 5h$

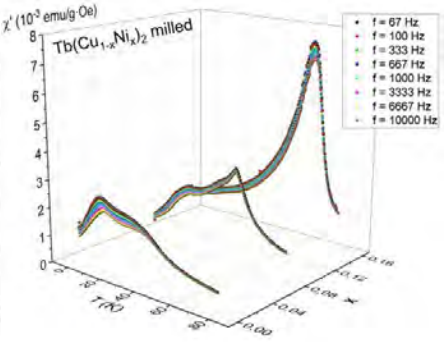

Figure 2: Real component of the AC susceptibility of the nanostructured Tb(Cu1-xNix)2 alloys (x=0, 0.08, 0.15) at different frequencies.

Acknowledgements

This study was funded by the Principado de Asturias SV-PA-21-AYUD/2021/51822 proyect.

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Index Terms — Magnetic Nanoparticles, Tb(Cu,Ni), Spin-Glass, Magnetocaloric Effect

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Understanding the Magnetic Behaviour of a $Fe_{65}Co_{35}$ Soft Magnetic Alloy by Means of its Structural, Thermal and Magnetic Analysis

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Spring magnet demand is rapidly increasing due to the wide range of applicability. These magnets are used in fields such as microwave absorption, magnetic recording media and in many biomedical applications [1]. A spring magnet is a composite material where a soft magnetic alloy, in low weight percentage, is added to a hard magnetic alloy to enhance the hard magnetic alloy. The applicability of spring magnets depends mainly on selecting the most suitable soft and/or hard magnetic alloys.

This study focuses on understanding how the manufacturing conditions alter the $Fe_{65}Co_{35}$ alloy and their effect on the overall magnetic behaviour of the alloy. Six samples of the same alloy were prepared in a Fritsch Pulverisette P7 planetary ball mill spinning at 400 rpm with a ball-to-powder ratio of 5:1. Three milling times (10, 25 and 50 h) were chosen to manufacture the samples. Two samples were manufactured for each milling time: one only had the elemental powders while the other had 1 mL of cyclohexane added to it acting as a process control agent (PCA). The magnetic characterization was performed by Vibrating Sample Magnetometry (VSM) and by Mössbauer Spectroscopy. X-Ray Diffraction (XRD) provided the structural analysis while Differential Scanning Calorimetry (DSC) provided the thermal analysis. Scanning Electron Microscopy (SEM) equipped with an EDX detector allowed for the observation of the powders and the confirmation of the chemical composition of the samples. The principal aim of the study was to analyse the magnetic, structural and thermal properties according to the different milling times and the use of a PCA.

The manufacturing conditions had a clear effect on all the properties of the samples. VSM proved that longer milling times increase magnetic parameters (coercivity, remanent and saturation magnetization) while the PCA caused the samples to be less soft magnetic (higher coercivity and remanent magnetization and lower saturation magnetization). Mössbauer Spectroscopy determined that the atomic positions in the sample produced with PCA was different to the sample without it. This is also confirmed by structural analysis in which two different stable phases were present in the samples: the A2 phase (or α-Fe(Co)) and the B2 phase (Fe nucleus surrounded by Co). The quantity of B2 phase was higher for samples produced without PCA. This would justify why Mössbauer Spectroscopy was different for the two analysed samples. DSC scans showed a clear structural ordering at 680 °C for all samples related to the transition between B2 and A2 [2]. Also, an additional peak for the samples produced with PCA was detected at 519°C. This process was associated with the non-reversible transformation of a metastable pattern of anti-phase domains of a tetragonal Fe_3Co structure [3]. It is believed that the use of a PCA, which contains carbon, favoured the formation of this tetragonal structure (similar to steels) [4]. This tetragonal structure presents a hard magnetic behaviour. Therefore, as the samples with PCA present this structure, it is expected that the magnetic behaviour of the samples should be less soft magnetic. Finally, SEM-EDX observations confirmed the chemical composition of the samples.

Acknowledgements

This project was funded by the coordinated project NEXUS (PID2020-115215RB-C22 and PID2020-115215RB-C21). E.M.P. acknowledges support from AEI through the Juan de la Cierva Incorporación program (IJC2020-043011-I/MCIN/AEI/10.13039/501100011033) and EU by NextGeneration EU/PRTR.

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Magnetic Shape Memory Heuslers for Low-grade Heat Harvesting

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A considerable amount of waste heat is generated by manufacturing and industrial processes, most of which is emitted at temperatures under one hundred Celsius degrees. The conversion of this large amount of untapped heat into useful energy could contribute significantly to the energy transition in our society [1]. To date, the harvesting of low-grade heat is only based on thermoelectric materials. These are, however, too expensive for industrial use, and not suitable for thermal sinks near room temperature. One the over hand, magnetic materials, exploiting the thermomagnetic cycle for the conversion of low-grade heat, introduce a promising technology for fully sustainable energy production. Such materials must have high magnetic moment change and thermal diffusivity in the working temperature range of their applications. In addition, they should, preferably, be free of critical elements and cost-effective [2].

Desirable materials for this application are characterized by a second-order Curie magnetic transition between 40–80 °C to maximize the change of magnetic moment in the typical working temperature range of a thermomagnetic generator for low-grade heat harvesting. For that purpose, we synthesized and characterized a set of Ni-Mn-Z Heusler alloys (with Z = Sn, In, Cu-Ga). We chose to work around the second order transition because, even if a first-order magnetostructural martensitic transition would lead to a sharper change of magnetic moment, the thermal hysteresis of such transition could lower the efficiency of the thermomagnetic cycle. Finally, we reduced the compounds to powders and we realized some rotor-shape functionalized graphene-based composites [3] to test them directly on a thermomagnetic generator developed in situ.

The wide tunability of the magnetic interactions and critical temperatures of the synthesized Heuslers have been investigated, revealing the potential of this class of materials for thermomagnetic energy harvesting. The thermomagnetic characterization of the different synthesized compounds has been conducted measuring the mechanical power generated by the thermomagnetic generator varying the temperature of the hot thermal sources and the load output of the generator. The obtained tunability of the Curie temperature of the compounds opens the possibility to find the most appropriate material for every temperature working range of the heat conversion thermomagnetic device. The strict correlation between the magnetic moment change across the transition temperature and the efficiency of the thermomagnetic generator will be also discussed.

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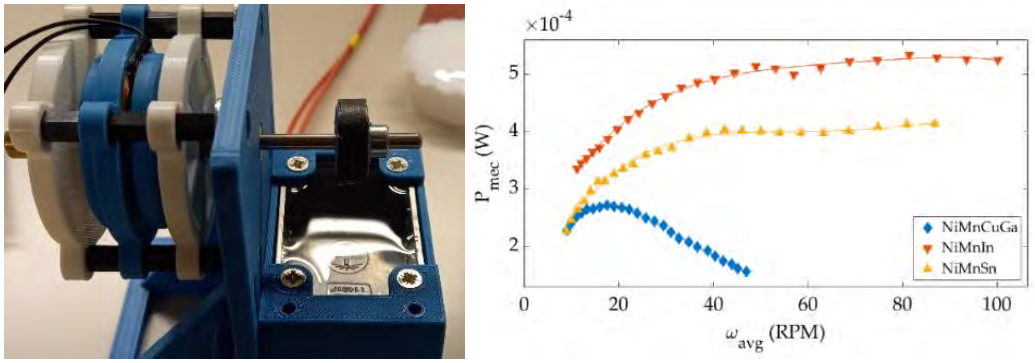

Figure: (left) The thermomagnetic generator developed in situ as thermomagnetic materials tester. (right) Comparison between different Heusler compounds of mechanical power generated by the thermomagnetic generator over the rotors average angular speed. Measurements are carried out maintaining constant temperatures of the thermal sources at T_{cold}=25°C and T_{hot}=55°C.

All-optically driven domain-wall dynamics in an antiferromagnetic system

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Antiferromagnets appeal as ideal candidates for the next generation of magnetic memory and logic devices due to their exchange enhanced dynamics in the THz regime and low dimensional potential on account of their negligible stray fields [1,2]. The state-of-the-art mechanism employed to control the AFM order relies on specific crystal symmetries which allow the appearance of current-induced, staggered, spin-orbit fields [3] previously shown capable of driving 180^0 domain-wall (DW) dynamics [4]. At the other end, laser pulse excitation displays the fastest and least dissipative control of any magnetic system observed so far. Here, we report on the theoretical prediction of all-optically driven DW motion in an AFM material, based on previous *ab-initio* results which showed that a linearly polarised laser can induce a torque on the Néel order parameter of Mn_2Au in the range of several mT [5]. We demonstrate via atomistic spin dynamics simulations [6] that the optical torque can drive 90^0 DWs but interestingly its intrinsic spatial symmetry forbids the motion of 180^0 walls. In the steady-state regime, the kinematics display special relativity signatures with the increase of the strength of the optical torque: the propagation velocity saturates up to a given magnonic limit equivalent to an effective "speed of light", whilst the wall-width exhibits a decrease in length, well described by a Lorentz contraction factor. Interestingly, near the magnonic limit, the AFM DW enters a proliferation regime in which part of its relativistic energy is invested towards the nucleation of novel magnetic textures. We believe our investigation contributes towards the fundamental understanding of magneto-optical effects as well as supports the development of next generation, all-optically controlled AFM spintronics.

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie International Training Program COMRAD, grant agreement No 861300.

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magnetisation dynamics, antiferromagnetic spintronics, multi-scale modelling, domain-wall dynamics

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Fe tips Grown by Focused Electron Beam Induced Deposition for high-resolution Magnetic Force Microscopy

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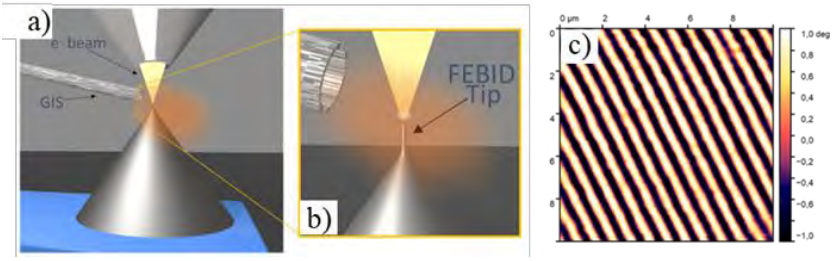
Magnetic Force Microscopy (MFM) is a Scanning Probe Microscopy (SPM) technique used to study magnetic structures at the nanoscale. A magnetized tip scans the sample and detects magnetic tip-sample interactions providing qualitative information about the magnetic configuration of the sample. The sensitivity of the MFM is directly proportional to the amount of magnetic material present in the MFM tip [1]. To improve the magnetic sensitivity, several methods were developed, such as sputter deposition of magnetic material on the SPM tip [2] or coating the tip with a ferromagnetic film by evaporation [3]. However, these strategies have some limitations such as the increased tip radius and the weak control of the magnetic coating, factors that can reduce the resolution and may influence over the magnetic state of the sample, respectively.

Here, we present the fabrication of magnetic tips grown by Focused Electron Beam Induced Deposition (FEBID) as an alternative to conventional magnetic coating for application to Magnetic Force Microscopy to overcome the limitations outlined above. It has been reported that FEBID growth allows one to tune the geometry and composition of the magnetic tip, enabling control and enhancement of the magnetic sensitivity, resolution (10 nm final tip radius) and magnetic stray field (900 Oe) created by the probe [4-6]. This tip configuration achieved by FEBID, featuring a high aspect-ratio and good magnetic behaviour, yields a better performance of the FEBID-tips compared to the conventional tips. This leads to high-resolution imaging and relatively low tip-sample interaction and its potential use in the study of magnetic biological samples [7]. Since FEBID is a versatile and reproducible technique, it is possible to adjust the shape, length and diameter of the tip according to the specific requirements of the samples. Furthermore, we have recently demonstrated the robustness and long-term performance of FEBID-grown Fe tips [8].



Schematic FEBID-tip growth process (a, b). MFM image obtained using FEBID-grown Fe-magnetic tip (c).

Acknowledgements

The authors acknowledge the grant PDC2021-120852-C21 funded by MCIN/AEI/10.13039/501100011033 and by the European Union NextGenerationEU.

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Index Terms — Magnetic Force Microscopy, Focused Electron Beam Induced Deposition, 3D Magnetic Nanowires.

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Soft magnetic actuators based on the pre-alignment of magnetic particles

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Soft magnetic actuators are soft materials able to respond to an external magnetic field by locomotion, by changing their temperature or some of their dimensions, or even by bending or twisting. Magnetic field is an attractive stimulus due to the ease of its application, the fast response of magnetic actuators, and the safe penetration in biological environments [1, 2]. In this work, we studied the role of the structural organization of magnetic particles within the three-dimensional structure of an alginate hydrogel in the response of the actuators when an external magnetic field was applied. To be precise, the magnetic particles were aggregated into chains of magnetic particles, which programmed the response of the actuator. Firstly, we studied the microstructure of the different actuators using microCT techniques, obtaining structures that ranged from chains of particles with different orientational angles, to randomly distributed particles. Secondly, we studied the response of actuators with the same shape but different particle distribution using a mold-casting technique to prepare the actuators, such that the actuators cured in the presence of the field with a particular shape returned to this shape when the actuation field was applied. In addition, following this technique, we developed an actuator that imitated the flapping of a butterfly's wings, with the wings having a fast response to the magnetic field of less than one second. Finally, torsion in response to the applied magnetic field was also studied for different structures formed by the particle chains within the polymeric network of the actuators, differentiating in this work between two types of structures: i) circular structures and ii) helical structures. The experimental torsional response agreed with the prediction of a theoretical model that we also developed.

Acknowledgements

This study was supported by grant PID2020-118498GB-I00 funded by MCIN/AEI/10.13 039/501100011033, Spain. CGV and ALC acknowledge respectively grants FPU17/00491 and FPU19/01801 funded by MCIN/AEI/10.13039/501100011033 and by "ESF Investing in your future", Spain.

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Low frequency vibration harvester based on the levitation force between permanent magnets

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Deploying wired sensors on structures such as bridges costs thousands of euros per node [1]. Thus, providing power to these devices has become an interesting application for vibration energy harvesting. Magnetic levitation-based harvesters display high lifespan and low maintenance requirements [2]. However, structural vibrations often feature very low frequencies (< 4 Hz) [3], whereas vertical harvesters of this kind have 3 Hz resonant frequency at best [4]. On addition, virtually every reported harvester is comprised of rare earth magnets only, which makes costs uncertain.

In this work, a non-stochastic algorithm is implemented to design a resonant low frequency vibration energy harvester, based on the magnetic levitation between a ferrite and a NdFeB magnet. The design is checked by 3D Finite Element Analysis. A prototype is built, including a pick-up coil to collect the induced electromotive force. Experimental tests under vertical vibration confirm 1.7 Hz resonant frequency.

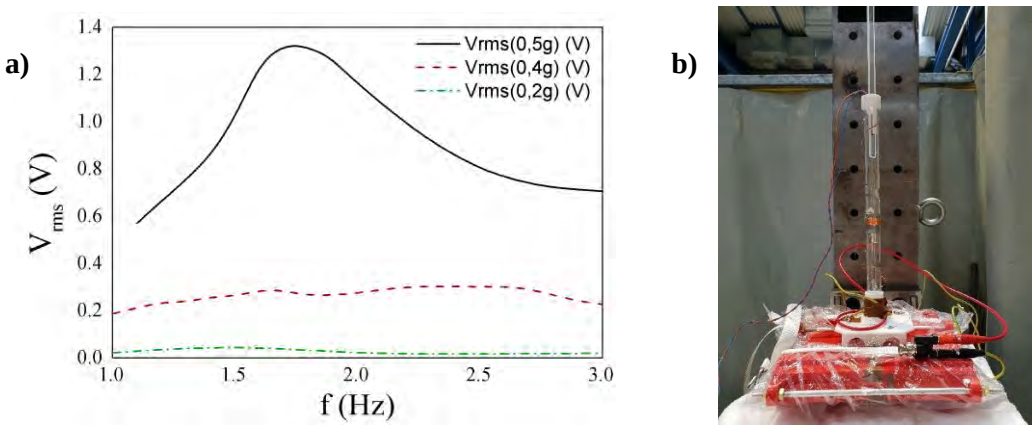

Figure 1: (a) Measured open circuit rms voltage, V_{rms}, at different vibration accelerations and frequencies. **(b)** Prototype over shaker.

Acknowledgements

This work is funded by Spanish Agencia Estatal de Investigación and Ministerio de Ciencia e Innovación MCIN/AEI/ 10.13039/501100011033 and by "European Union NextGenerationEU/PRTR", project TED2021-130884B-I00.

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Index Terms — Vibration Energy Harvesting, Low-frequency Vibration, magnetic spring

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Manganese ferrite nanoparticles for the detection of biomolecules in lateral flow assays.

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Magnetic nanoparticles are excellent candidates to label and detect biomarkers in rapid diagnostic tests as, for example, the lateral flow immunoassays [1]. A paradigmatic case is the detection of antibodies generated in the body in response to a disease, such as SARS-Cov-2. It is known that, in antigen and antibody tests, a positive result is very reliable (demonstrating its good specificity), but a negative result is not (low sensitivity) since sometimes the amount of biomarker immobilized in the test is not enough to be perceived. Magnetic nanoparticles can be functionalized with chemical groups that selectively bind to said target antibodies, and their magnetic signal can be quantified to determine the concentration of the molecule of interest [2]. In this work, we synthesized magnetic biofunctional nanoparticles based on manganese ferrites using the hydrothermal coprecipitation method, followed by their bioconjugation to neutravidin. The goal of the work is to study their capability to improve the performance of previous results using magnetite superparamagnetic labels. For this purpose, we immobilized a line of biotin across the lateral flow membrane and used the neutravidin–biotin affinity to determine and study their potential application in the detection of biotinylated antibodies, as those of COVID-19 (IgG and IgM).

The magnetic lateral flow strips were measured with an *ad-hoc* sensor based on impedance spectroscopy [3]. The results were positive, thus confirming the promising use of the synthesized nanoparticles as detection markers.

Acknowledgements

This work has been partially supported by the Ministry of Science and Innovation of Spain under grant PLEC2022-009490, the Government of Asturias (SV-PA-21-AYUD/2021/51822) and the University Institute of Technology of Asturias (SV-22-GIJON-18).

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Multifunctional platform for photothermal hyperthermia combined with luminescence nanothermometry probes.

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The design of multifunctional magnetic nanoparticles (NPs) that can generate and monitor heat exchange, in real-time during thermal therapy is a major challenge in nanomedicine. In this work, a trimodal system that combines magnetic hyperthermia (MH), photothermal therapy (PT) and luminescence nanothermometry (LT) has been set up in a single platform. Magnetite NPs were optimized focusing on MH and PT, then, the NPs have been coated with embedded Nd^{3+} cations in order to enhance the PT and also to act as LT probe.

Neodymium is an interesting luminescent probe, with excitation around 800 nm and emission at the second biological window. Such hybrid system could act as heat mediator and imaging probe for in-vitro and in-vivo experiments, since these wavelengths belong to the biological windows, as well as an in-situ thermometer during the PT.

The samples were prepared by a modified hydrothermal method [1], the multifunctional system is composed of magnetite NPs as core funcionalized with citrate for colloidal stability (Fe_3O_4/cit), then coated with a silica shell containing Nd^{3+} (Fe_3O_4/cit@SiO_2:Nd^{3+}). The structure and morphology have been investigated by XRD and HRTEM, and the magnetic properties by SQUID magnetometry. The heating efficiency has been measured under laser irradiation at 808 nm as in Ref. 2. Table 1 shows the Specific Absorption Rate (SAR) obtained in PT, and, as it can be seen, are higher than 200 W/g and are independent of the coating. On the other side, the SAR measured with MH at 300 kHz and 100 Oe is around 20 W/g for uncoated NPs and almost negligible for the coated ones. High frequency magnetometry characterizations allows us to understand this behavior. The luminescent characteristics of the multifunctional platform have been examined using a polarized continuous-wave laser operating at 800 nm. Figure **1** displays the resulting spectrum, revealing a sharp atomic emission line at the anticipated 1064 nm wavelength. This spectrum was acquired with a silica coating containing a 6% concentration of Nd^{3+}.

Table 1. SAR obtained through PT and MH for the various NPs studied.

NP species	PT / Wg^{-1}	MH / Wg^{-1}
Fe_3O_4/cit	270 ± 30	20 ± 3
Fe_3O_4/cit@SiO_2	250 ± 30	-
Fe_3O_4/cit@SiO_2:Nd^{3+}	260 ± 20	-

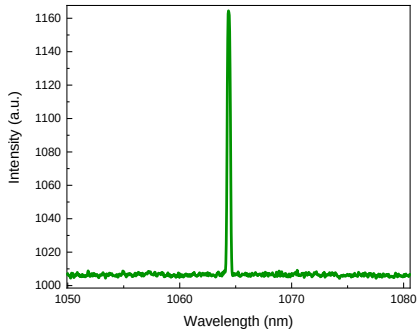

Figure 1: photoluminescence spectrum of Fe_3O_4/cit@SiO_2:Nd^{3+} (~6% Nd^{3+}).

Acknowledgements

This work was supported by PID2021-123112OB-C21 and TED2021-129688B-C21.

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Influence of nanoparticle diffusion on AC magnetization cycles : potential for sensing tranduction

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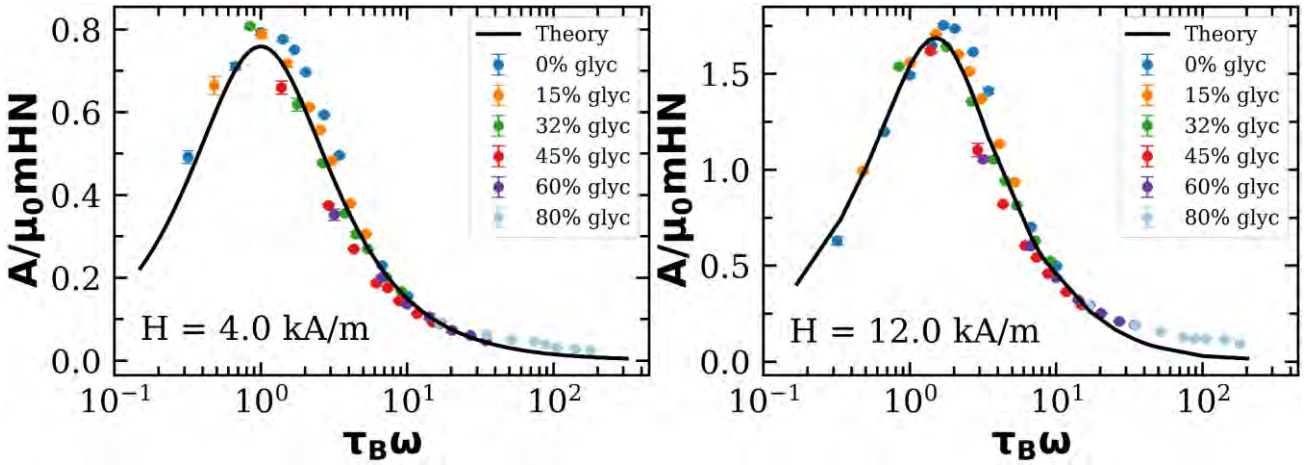
Magnetic nanoparticles (MNPs) have gained substantial attention in recent years due to their applications in life sciences. Their unique properties and versatility have cemented their role in a range of biomedical areas, from drug delivery to medical imaging. As their significance grows, it becomes increasingly important to understand how these nanoparticles respond to different stimuli. Such understanding is pivotal for enhancing their existing uses and for paving the way for innovative applications in the constantly evolving field of health sciences. Here, we present an experimental and theoretical work to deeply delve into how the diffusion of MNPs dispersed on liquid solutions influences their magnetization cycles under alternating magnetic field. This response is analysed in the context of the dominant relaxation mechanisms (Brown, and/or Neel procees). Through rigorous experimental and theoretical scrutiny, we identify the specific field parameters where the magnetic signal is acutely sensitive to changes in hydrodynamic size. Stochastic Landau Lifshitz Gilbert equation is solved combined with Brownian motion to fully describe the experimental AC magnetization cycles obtained from individual cobalt ferrite MNPs dispersed in liquid media of different viscosities and under AC magnetic fields up to 300 kHz and 24 kA/m. Our results underscore that the dynamical magnetic response, contingent on size, can be harnessed as a potent transducer mechanism, presenting vast opportunities for biotechnological interventions such as protein detection and conformational change sensing when subjected to denaturing agents.



Acknowledgements

Authors acknowledges financial support from PEJ-2020-AI/IND-19394, M-ERANET 2018 (PCI2019-103600), PID-2020-117080RB-C51, PID-2020- 117080RB-C53 and PDC2021-121441-C21

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Formation of Micropatterned Hydrogels based on Magnetic Pickering Emulsions

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The construction of hybrid microstructured complexes based on hydrogels and functional micro-compartments (such as micro-sized droplets or capsules) is expected to lead to a new generation of materials, which could find applications in fields such as soft robotics or micro-actuators [1]. Controlling the spatial distribution of micro-compartments within hydrogels is particularly interesting, because it would enable spatial modulation of the functions provided by the compartments (e.g., chemical reactions). In this regard, the use of Pickering emulsion droplets (i.e., stabilized by solid particles that adsorb at the oil/water interface) as microcompartments is especially relevant, because the particles can be chosen to guide the droplet spatial positioning. In particular, magnetic Pickering emulsion droplets (MPED) can respond to magnetic force fields [2]. Here, we demonstrate the formation of hydrogel drops equipped with MPED as integral compartments of their microstructure, which can be organized according to pre-set patterns by using magnetic fields. For this purpose, oil-in-water MPED stabilized by magnetite nanoparticles functionalized with oleic acid have been used. We employed a gel precursor as the external phase of the MPED, which allows crosslinking of the MPED-containing hydrogel. Before gelation is completed, the arrangement of the MPED within the hydrogel is achieved thanks to spatially modulated magnetic fields generated by microstructured stamps [3]. In this way, depending on the stamp pattern, we can produce microstructured hydrogels with different geometries, which would enable their use as smart materials in applications like those listed above.

Index terms: functional hydrogels, Pickering emulsion, magnetic stamps.

Acknowledgements

This study was supported by grants PID2019-105930GA-I00/AEI/10.13 039/501100011033 and A-FQM-258-UGR20 (Fondos FEDER, Junta de Andalucía).

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Efficient Production of Printable Magnetic Filaments with Recycled Ferrite Cores

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Soft ferrites are the most widely traded magnetic material in the world [1] and are mainly used as protective mitigators of electromagnetic noise. Every year a large amount of waste is generated that requires a considerable economic investment for its treatment. To solve this problem, an efficient ferrite recycling method is proposed, based on the production of 3D printer polymeric filaments with ferrite particles inside. The recycling process begins by grinding the ferrite cores in a ball mill to obtain particles with a size below 100 µm. Different grinding conditions are studied to produce recycled ferrite particles (RFPs) [2]. Its structural and magnetic characteristics are characterized by VSM, AC Magnetometer, XRF and XRD. Once the RFPs are obtained, a composite fabrication is performed starting from a solution of polymer and RFP. To obtain the printable filament, the fabricated compound is extruded and characterized by SEM in order to obtain an adequate dispersion of the RFPs (Figure 1). Finally, the extruded filaments are fed into a 3D printer to obtain simple, ecological and economical devices. The goal is that once the devices are printed they have suitable properties for different applications.

Acknowledgements

This work has been carried out with the financial support of the Navarra Government (project number PC003-04 3D-MAGNET).

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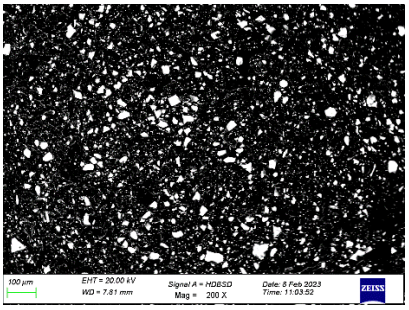

Figure 1. SEM image of RFPs dispersion into synthesized RFP-PCL composite filament.

Index Terms — Magnetism, Recycling process, Ball milling, Ferrite cores, 3D printer, Composites.

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Fast and Reproducible Synthesis of Iron Oxide Nanoflowers by Microwave-assisted Heating

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Recently, iron oxide nanoflowers (NFs) have proven to be of great interest in a wide range of applications (e.g. biomedicine, catalysis, remediation, etc.) because of their unique structure (high surface area) and magnetic properties [1]. These nanoparticles exhibit a magnetic cooperative behaviour due to their crystallographycally aligned cores, resulting in impressive heating capabilities and rapid magnetic separation, which can significantly improve various processes. The polyol method is one of the most commonly employed techniques for NFs synthesis, but their reproducibility remains to be further studied. Moreover, this method stands out as a great synthetic procedure as the solvent used (polyol) can serve as surfactant, as well as reducing agent with high polarity which proves advantageous for microwave-assisted heating techniques. Microwaves allow an "in situ" heating by the vibration of the molecules in the solvent which reduces dramatically the temperature gradients and the synthesis can be performed in reduced times with high reproducibility [2,3].

In this study we have optimized the synthesis of NFs via microwave-assisted heating and have deeply analyzed its reproducibility by the synthesis of several batches (*Z*=21). In this regard, the reproducibility of structural and colloidal parameters was assessed through the characterization of all samples by TEM, XRD and DLS, while their magnetic properties by VSM. The characterization revealed the formation of multicore structures of 40 nm (Fig 1, NFs from first batch) with a mean core size of 14 nm, crystal size of 14 nm and hydrodynamic size of 140 nm. Impressively, by analysing all samples, an average reproducibility rate of 91% was obtained (Fig 1). This result demonstrates a promising alternative to produce NFs and marks a good start for potential large-scale production that could hold considerable appeal for the industrial sector. Overall, analyzing reproducibility is a critical step to ensure large-scale production for industrial application and eventual commercialization.

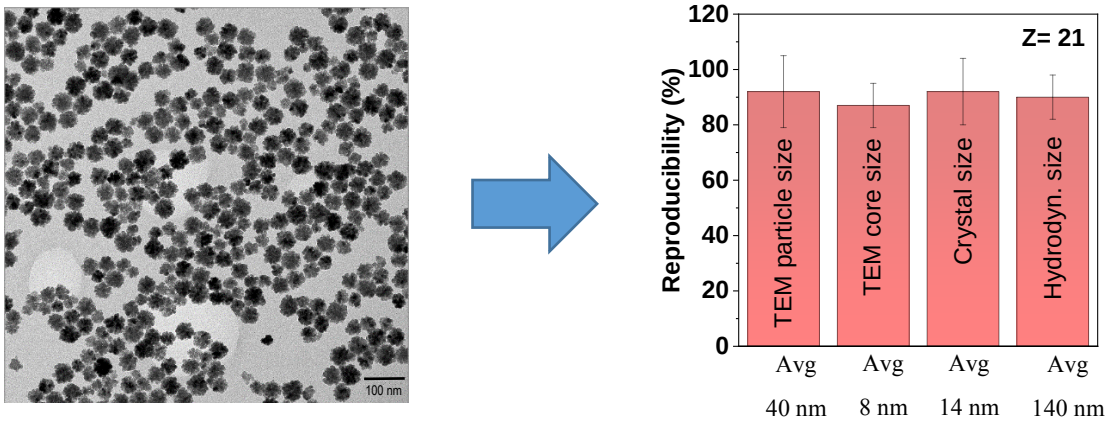

Fig.1. TEM image of the nanoflowers obtained by microwave-assisted heating and reproducibility of core and particle average size measurements obtained by TEM, XRD, and DLS, ensuring reliability and validity of the synthesis method.

Acknowledgements

EU Marie Sklodowska-Curie grant No. 101007629 and RHA acknowledges CONAHCYT for his PhD grant.

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Innovations in Strontium Ferrite: Nanostructuring Permanent Magnet Materials for a Sustainable Future

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Due to the new achievements with hard ferrite magnets, this material could soon see expanded utilization within the field of electromobility. Their enhanced magnetic properties and the potential of reengineering to fully exploit these recent advancements [1] are the key factors for success. As such, this is an opportunity to help alleviating the scenario of Europe's dependence on critical raw materials in the permanent magnet industry.

This research shows the feasibility of producing high-coercivity strontium ferrite (Sr-ferrite) powder that exhibits exceptional performance at low temperatures, all without the need for critical raw materials like lanthanum and cobalt. This achievement was made possible by starting with a commercial ferrite and applying a nanostructuring process (Figs. 1a,b) using our self-developed "flash milling" method [2,3]. The formation of Sr-ferrite/hematite nanocomposite has resulted in a room temperature coercivity exceeding 475 kA/m, and the coercivity further increasing with longer milling times as illustrated in Figure 1c. By introducing hematite (Fe_2O_3) powder prior to milling, we have managed to reduce the processing time and obtain a high-coercivity nanocomposite that performs exceptionally well at low temperatures, measuring 430 kA/m at -100 ºC (Figure 1d). This breakthrough paves the way for prospective applications in the electromobility sector.

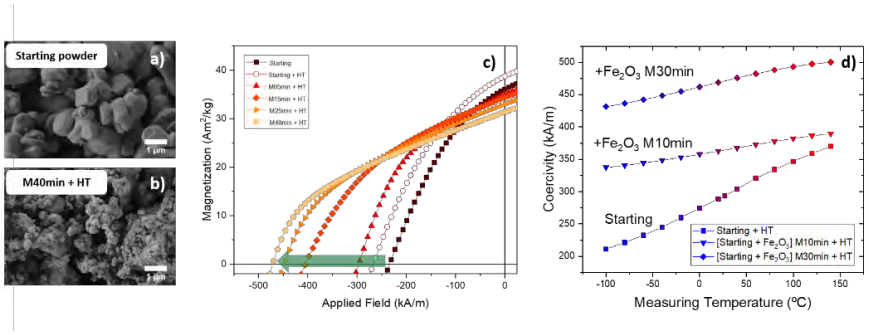

Figure 1: Scanning Electron Microscopy (SEM) images of (a) starting (commercial) powder and (b) the same powder after milling for 40 min and followed by a thermal treatment. (c) Second quadrant of the room temperature hysteresis loops measured by Vibrating Sample Magnetometry (VSM) for the precursor powder and that after milling (different durations) and heat treatment (1000ºC). (d) Evolution of coercivity between -100 ºC and 140 ºC for the starting (commercial) precursor and the synthesized Sr-ferrite/hematite nanocomposites.

Acknowledgements

Authors acknowledge support from EU H2020 research and innovation program through the project PASSENGER (GA Nº101003914). IMDEA thanks support from MICINN through the RETAIN project (TED2021-132490BI00). E.M.P. acknowledges support from AEI through the Juan de la Cierva Incorporación program (IJC2020-043011-I/MCIN/AEI/10.13039/501100011033) and EU by NextGeneration EU/PRTR.

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Index Terms — Sr-ferrite, Permanent magnets, Electromobility, Sustainability.

Exploring the magnetocaloric effect on nanocrystalline melt spun R_2Fe_{17} (R= Pr, Nd) ribbons

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R_2Fe_{17} (R = Pr and Nd) ribbons with the rhombohedral Th_2Zn_{17}-type crystalline structure (space group $R\bar{3}m$) have been fabricated by melt-spinning [1]. The polycrystalline ribbons are composed of nanograins that consist of agglomerated nanocrystalline entities with a size of approximately 15 nm. The nanocrystallites are separated by disordered boundaries, where the crystalline order disappears, leading to the existence of two successive ferro-to-paramagnetic phase transitions shown in the low-field thermomagnetic analysis curves. The low-temperature transition coincides with that of the parent bulk alloy (290 and 326 K for R = Pr and Nd, respectively [2]), while the other one can be ascribed to the disordered boundaries (323 and 350 K for R = Pr and Nd, respectively). The contribution of the disordered phase to the magnetocaloric effect results in a remarkable broadening of the magnetic entropy change curve $|\Delta S_M|(T)$ and a "table-like" behaviour (see Fig. 1), providing a wide temperature range with a moderate and constant magnetocaloric effect. Additionally, an enhanced refrigerant capacity (RC > 200 J·kg^{-1} for R = Pr at $\mu_0\Delta H$ = 5 T) was observed in comparison with the parental bulk alloy [3,4].

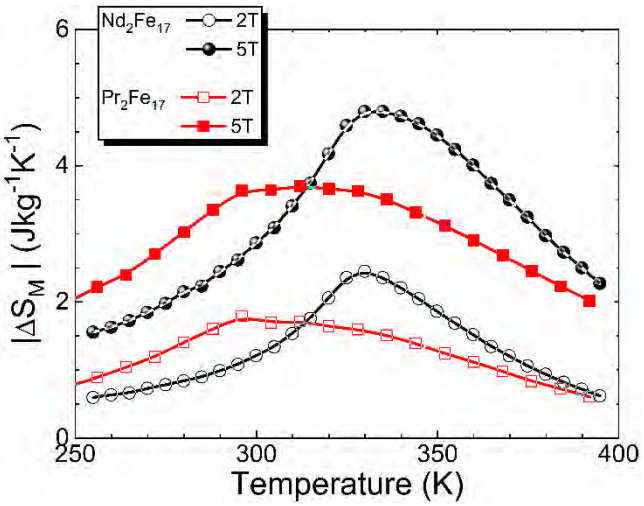

Figure 1. Temperature dependence of the magnetic entropy changes for magnetic field changes of 2 and 5 T for Pr_2Fe_{17} and Nd_2Fe_{17} melt-spun ribbons.

Acknowledgements

Work supported by MCIU, AEI, European FEDER (MCIU-19-RTI2018- 094683-B-C52), and Principado de Asturias (SV-PA-21-AYUD/2021/51822). J.L.S.LL. acknowledges the support received from the EU-NGEU, MIU, and Plan de Recuperación, Transformación y Resiliencia (Maria Zambrano program; Ref: MU-21-UP2021-030 71741542).

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Index Terms — nanostructured R_2Fe_{17} intermetallic compounds (R= Pr, Nd); melt-spun ribbons; structure and magnetic properties; magnetic entropy change.

Synthesis of permalloy nanoclusters using microwave-assisted aqueous method

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Magnetically soft materials hold significant importance due to their extensive range of applications, spanning from radio frequency systems to electromagnetic signal shielding. Permalloy, an alloy composed of iron and nickel, with iron content reaching up to 35% of the alloy, is commonly employed in these applications [1,2]. However, a notable challenge with the use of permalloy arises from its susceptibility to oxidation, owing to its metallic nature. This concern becomes more pronounced as the material is scaled down in size, where an increase in surface area amplifies the potential for oxidation. This issue becomes even more pronounced in nanomaterials.

Here, we have devised an aqueous synthesis method that enables the production of permalloy nanoclusters across a range from 0% to 35% [3]. This synthetic process involves a microwave-assisted water-based method that yields iron-nickel nanoclusters in ten minutes. To prevent the oxidation of permalloy nanoclusters, we have applied a surfactant, 1,12-dodecanediol, which serves as antioxidant by coating the particles and imparts a high resistance to oxidation. In long-term storage experiments, samples have been kept for a year without showing any sign of oxidation or alteration in the alloy's lattice parameters.

Acknowledgements

We acknowledge support under grants PID2020-117544RB-I00, CEX2020-001039-S, RED2018-102626-T and MAT2017-85617-R funded by MCIN/AEI/ 10.13039/501100011033, and grant RYC2018-025253-I funded by MCIN/AEI/10.13039/501100011033 and by "FEDER A way of making Europe". A.S-O and D.O. acknowledge financial support from the Community of Madrid under Contract No. PEJ-2018-AI/IND11069. This research was also funded by the CSIC Intramural project 201960E062 (MPM).

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Production of Magnetic Nanoparticles by Recycling Industrial Steel Manufacturing Residues

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Ensuring the reutilization of residues generated during the manufacturing of products has become a pressing concern in order to reduce the environmental impact and enhance the efficient utilization of resources [1,2]. The steel industry stands out as one of the rapidly expanding sectors, and Europe plays a major role in its growth. Fostering a circular economy within this industry not only ensures its sustainable development but also unlocks fresh market opportunities. Magnetic nanoparticles (NPs) hold significant technological potential across various fields such as energy, transportation, and medicine. Their versatile magnetic properties make them a subject of considerable interest, also in view of developing advanced fabrication techniques for tuning their magnetic properties.

This research presents the outcomes achieved through the implementation of an innovative procedure designed to convert residues produced by the steel industry into iron oxide NPs. The initial material was supplied by CELSA Group in the form of powder, containing micrometer-sized particles in the framework of a collaboration project. In view of the potential for industrial scalability of the process, a physical method was employed, which involved remarkably brief milling times ranging from 5 to 25 minutes (utilizing IMDEA's self-developed "flash-milling" method [2,3]), followed by an optimized heat treatment.

This approach has enabled to transform a residue with a saturation magnetization of 23 emu/g to iron oxide NPs (25 nm mean particle size) with a saturation magnetization close to 165 emu/g accompanied by a coercivity of 240 Oe after milling for 10 min and annealing (Fig. 1). Further optimization of the process allows reducing the milling time to a total duration of 5 min, achieving an outstanding saturation magnetization close to 200 emu/g (and a coercivity below 100 Oe). These achievements pave the way for exciting new applications of this industrial residue in the form of iron oxide NPs.

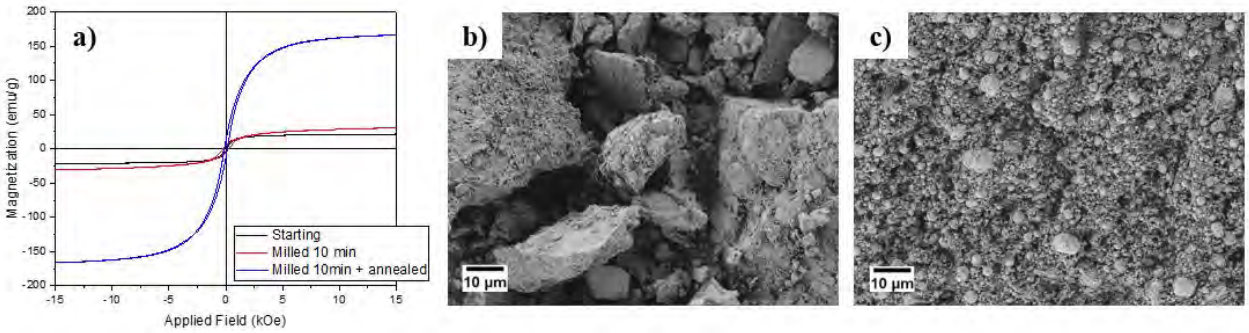

Figure 1: (a) Room temperature hysteresis loops measured by Vibrating Sample Magnetometer (VSM) for the precursor powder and that after milling for 10 min before and after annealing. Scanning Electron Microscopy (SEM) images of (b) the starting powder and (c) the powder milled for 10 min.

Acknowledgements

Authors acknowledge provision of the precursor material by CELSA Group and financial support through a CELSA-IMDEA Nanociencia collaboration project. IMDEA Nanociencia thanks support from the ‘‘Severo Ochoa’’ Programme for Centers of Excellence in R&D (MICINN, Grant CEX2020-001039-S) and Comunidad de Madrid through NANOMAGCOST project (Ref. S2018/NMT-4321).

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Carbon-supported magnetic nanoparticles for combined water decontamination purposes: Fabrication and Characterization

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The motivation for this work is to find an effective method for decontaminating wastewater from industries. Water is a fundamental life-giving resource, and industrial activities frequently jeopardize it. A promising idea is to use magnetic nanoparticles that can achieve, simultaneously, photocatalysis, adsorption, and magnetic removal. Nickel nanoparticles have an excellent catalytic activity and a large saturation magnetization [1], necessary for efficient magnetic separation. A carbon coating is ideal for this purpose thanks to its low density and large porosity.

This study focuses on producing and studying carbon-supported nickel nanoparticles derived from nickel-organic frameworks (see Fig. 1). Their magnetic and structural properties were studied in particles of various sizes obtained at different carbonization temperatures [2]. Our findings indicate the fabrication conditions yielding the most promising particles for noble metal and dye elimination from water. In this presentation, I will explain which are the best candidates and why.

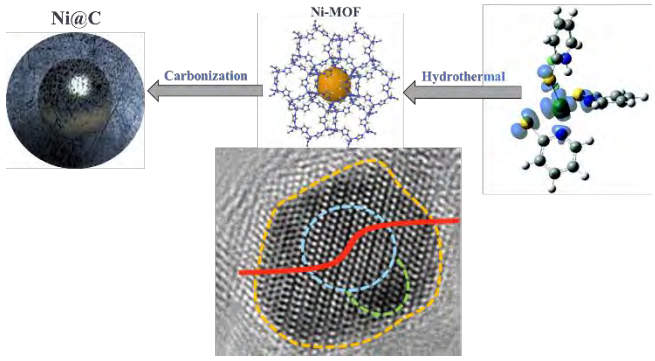

Fig. 1: Schematic of the MOF-derived fabrication of the carbon-coated Ni nanoparticles of this work.

Acknowledgements

This work was financially supported by the research projects PID2022-138256NB-C21 (AEI, Spain &FEDER, EU) and AYUD/2021/51822 (Gobierno del Principado de Asturias, Spain). The authors would like to acknowledge the technical support provided by Scientific-Technical Services of the University of Oviedo, Spain.

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Enhancing the Particle Content in 3D-printed Ferromagnetic Objects by tuning the MnAlC / Hydrogel Precursor Inks

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Additive manufacturing technologies, compared to traditional methods, offer fast and precise fabrication of objects with complex geometries and a reduced waste generation [1]. Additionally, the use of composites materials is attracting much interest in many sectors (electronics, aerospace, medicine…) due to the possibility of fabricating functional objects with complex designs, tailored properties and high-performance [2]. The potential of 3D-printing using metallic/polymer composites with different filler content has been successfully proved for providing certain required properties depending on the final application, while preserving the properties of the filler along the process [3, 4]. Particularly, hydrogel-based composites have been used in 3D-printing for applications like flexible and soft electronics or biomedicine [2, 5] due to their interesting and tunable structural properties, combined with the possibility of using a broad range of materials.

Direct Ink Writing (DIW) 3D-printing has been used in this work to fabricate objects with self-synthesized composite inks (Fig. 1a). Gas-atomized τ-phase MnAlC particles were used as filler and a hydrogel as matrix. Homogeneous and highly loaded inks were synthesized up to 80 wt.% of MnAlC particles (Fig. 1b) by tuning and optimizing the required additives [5]. Vibrating Sample Magnetometry (VSM) characterization showed that coercivity (H_c) is kept constant after the composite ink synthesis in comparison to the precursor τ-MnAlC particles, while the magnetization scales according to the particles content (Fig. 1c). Objects of diverse sizes and shapes have been fabricated by DIW (Fig. 1d), exhibiting structural flexibility and mechanical strength. After 3D-printing and post-processing, VSM measurements show that the magnetic properties of the τ-MnAlC particles are preserved (Fig. 1d). This outcome paves the way for future advancements in this additive manufacturing technology, enabling its application in high-tech sectors demanding complex-shaped and tailored components made of magnetic/metallic composites.

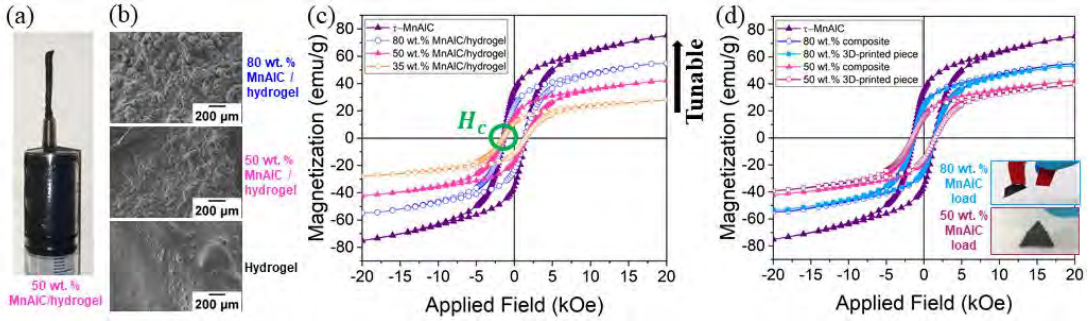

Figure 1: (a) Composite ink with 50 wt.% MnAlC particles load; (b) SEM images of composite inks with different MnAlC particles load; room temperature hysteresis loops measured for (c) MnAlC/hydrogel composites and (d) 3D-printed pieces up to 80 wt.% MnAlC load, compared to the starting MnAlC particles. Insets in (d) show images of 3D-printed magnetic objects.

Acknowledgements

Authors acknowledge Höganäs AB (Sweden) for providing the gas-atomized MnAlC particles through an industrial IMDEA-Höganäs collaboration, and the financial support from MICINN by NEXUS project (PID2020-115215RB-C21). IMDEA Nanociencia thanks support from the ‘‘Severo Ochoa’’ Programme for Centers of Excellence in R&D (MICINN, Grant CEX2020-001039-S). E.M.P. acknowledges support from AEI by the JdC-I program (IJC2020-043011-I/MCIN/AEI/10.13039/501100011033) and EU by NextGenerationEU/PRTR.

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From lab to industry: Industrial development of coercivity in MnAlC alloys

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The τ-MnAlC compound is as a promising candidate for a rare-earth-free permanent magnet applications [1], owing to its excellent properties, including an estimated (BH)max of 12 MGOe [2] at ambient temperature, coupled with a density of 5.2 g/cm^3 (in contrast to $Nd_2Fe_{14}B$'s 7.6 g/cm^3) and an expected good corrosion behaviour.

In this study, Less Common Metals (LCM) employed "casting" and "hammer milling" techniques in an industrial environment to produce powder with particle sizes below 90 µm and 300 µm, respectively. Analysis using VSM and XRD confirmed that these powders were made of almost pure τ-MnAlC. Initial experiments were carried out using IMDEA's "flash-milling" method [3] on powder under 90 µm with milling durations ranging from 30 to 840 seconds. This process led to a twofold enhancement in coercivity compared to the precursor material while maintaining a remanence of 34 Am^2kg^{-1}. Subsequently, High-Energy Ball Milling (HEBM) trials were conducted on a pilot scale using a proprietary process by MBN (restricted to 0.5 kg per test). These experiments demonstrated the feasibility of up-scaling the process and enlarging precursor particle sizes up to 300 µm. This approach yielded a maximum coercivity of 0.35 T, representing a 4.4-fold increase over the starting material, achieved within a timeframe of less than 1 hour. Following prior findings [4, 5], powders were further subjected to annealing at a moderate temperature of 550ºC for 10 minutes under a nitrogen (N_2) atmosphere. This treatment served to recrystallize the τ-phase and promote the development of the β-phase, ultimately optimizing the magnetic properties of the material.

The corrosion resistance of the material was evaluated under two distinct conditions: immersion in distilled water at ambient temperature and exposure to elevated temperatures in air at 550ºC. Encouraging findings were observed, demonstrating notable resistance to corrosion after more than 190 days of immersion in water and 10 minutes of exposure to processing temperature in air.

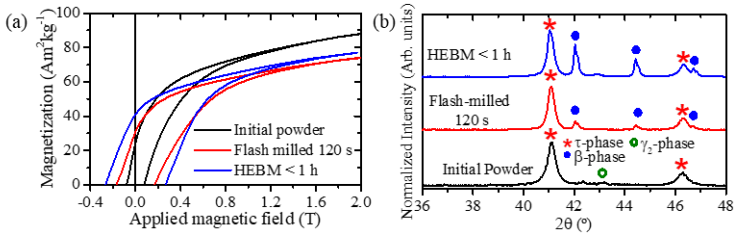

Figure 1: (a) First and second quadrants of the VSM hysteresis loop; (b) XRD patterns for the initial powder, powder flash-milled for 120 seconds, and powder HEBM for less than 1h. Milled samples after annealing at 550ºC.

Acknowledgements

Authors acknowledge support from EU Horizon 2020 research and innovation programme through the project PASSENGER (grant agreement Nº 101003914). IMDEA thanks support from MICINN through NEXUS project (PID2020-11521RB-C21). E.M.P. acknowledges support from AEI - Juan de la Cierva - Incorporación program (IJC2020-043011-I/MCIN/AEI/10.13039/501100011033) and NextGeneration EU/PRTR.

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Index Terms — Permanent Magnets, MnAlC, Alloys, Rare-earth-free.

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Exploring Cobalt Ferrite Nanoparticles as Sustainable Alternatives to Rare-Earth-Based Permanent Magnets

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The exceptional magnetic properties of rare-earth-based permanent magnets (PM) are the reason they are chosen for applications such as electric car batteries, solar panels, and wind turbines. However, the widespread use of rare-earth (RE) elements has led to a shortage, posing a challenge to the growth of renewable energy technologies. At present, strong research activity is focused on finding novel nanomaterials that can replace currently used RE PM in a wide part of the spectrum of industrial necessities [1]. In this context, the reduction of the size of traditional RE-free magnetic materials to the nanoscale can be a promising approach. Among spinel ferrites, the cobalt ferrite ($Co_xFe_{3-x}O_4$) nanoparticles are receiving considerable attention owing to their interesting properties (larger saturation magnetization and high magnetic anisotropy), and their cheap and easy manufacturing [1, 2, 3].

However, the origin of how magnetic anisotropy in cobalt ferrite nanoparticles depends on both their size and composition (Co/Fe ratio and occupancy), as well as their pronounced temperature dependence, is still not well understood. Therefore, a series of cobalt ferrite nanoparticles with different Co/Fe ratios were synthesized by thermal decomposition of $Fe(acac)_3$ and $CoCl_2$ in high boiling point solvents using oleic acid and oleylamine as surfactants. The as-prepared nanoparticles are monodisperse and depict the characteristic orthorhombic shape associated with large particle sizes (particle length = 30 nm). On the other hand, the magnetization curves exhibit the expected open hysteresis loop, indicating the PM properties of cobalt ferrite.

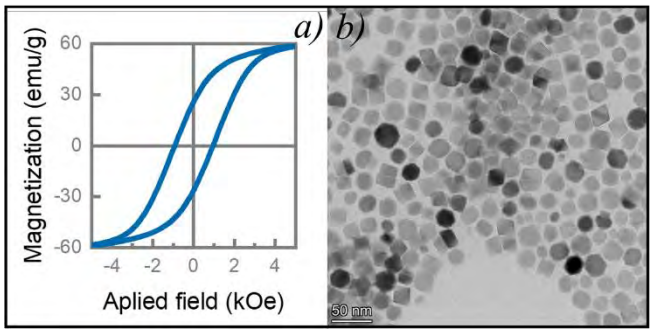

Figure 1: a) Room temperature hysteresis loop and b) transmission electron microscopy image of as-synthesized cobalt ferrites NPs.

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Marie-Sklodowska Curie grant agreement No 101034285.

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

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Potential of AC Magnetometry to Display Protein Conformational Changes

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Nowadays, magnetic nanoparticles (MNPs) are active agents in a broad range of research lines and biomedical applications, such as hyperthermia, drug delivery, imaging, or diagnosis. The latest application benefits from the variation of colloidal and magnetic features, after biomolecular recognition in liquids between target proteins and recognition ligands, which are present in bioconjugated MNPs (b-MNPs). AC magnetometry has shown to be a quick, reliable, and accurate technique to display variations of MNP magnetic relaxation processes, when proteins are attached onto MNP surface. Conformational changes of proteins alter their diffusion in liquids, altering MNP Brownian motion in liquids, which strongly influence AC magnetization cycles.

In this work, we report on the transduction potential of cobalt ferrite MNPs to detect protein conformational changes, based on variations of dynamic magnetization cycles in a field frequency range from 10 up to 100 kHz, for field intensities up to 24 kA/m. We studied two protein families covalently bonded onto commercial cobalt ferrite MNPs, with different chemical affinity and molecular mass. Proteins undergo conformational changes when exposed to temperature or denaturing agents (guanidine hydrochloride or urea) as corroborated by standard techniques (*i.e.* circular dichroism). Consequently, protein unfolding leads to conformational changes resulting in variation of MNP diffusion coefficient, quantified by nanoparticle tracking analysis and variations of the AC hysteresis area. The comparison of AC hysteresis area values, obtained from distinct controls subjected to similar denaturing conditions, allows probing reversible and irreversible changes depending on the employed denaturation method (temperature or chemical agents), in agreement with circular dichroism. This novel magnetic methodology is sensitive to protein conformational changes depending on their molecular mass, and affinity, requiring 20-fold less protein mass and providing quick and more accurate results (errors < 1%) than circular dichroism. Indeed, AC magnetometry has a novel technological biosensing potential beyond its use as a magnetic characterization technique.

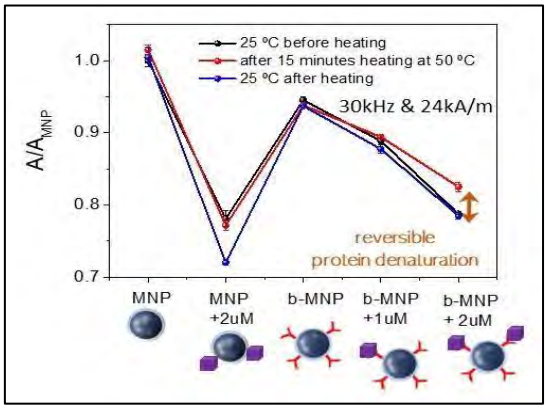

Figure 1: Normalized AC hysteresis area values obtained from different samples at 30 kHz & 24 kA/m at different temperatures.

Acknowledgements

Authors acknowledges financial support from PEJ-2017-AI/BMD-7517, M-ERANET 2018 (PCI2019-103600) and PID- 2020-117080RB-C53.

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Towards the Standardization of Photothermal Measurements of Iron Oxide Nanoparticles in Two Biological Windows

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Research into the photothermal responses of iron oxides, when exposed to infrared laser irradiation, is presently a dynamic and ongoing field of investigation. Substantial advancements are being made through the manipulation of nanoparticle sizes, the exploration of diverse morphologies, and the evaluation of various organic and inorganic coatings [1, 2]. These breakthroughs are steadily advancing our prospects for future biomedical applications [3]. Nevertheless, it is worth noting that several crucial factors essential for accurate measurements are often overlooked when detailing experimental configurations.

A comprehensive examination of laser-induced heating within two distinct biological windows (800 nm and 1053 nm) for Fe_3O_4 nanoparticles suspended in water has unveiled compelling evidence regarding the pronounced influence of extrinsic factors on the specific absorption rate (SAR). Notably, parameters like vessel volume and laser spot size exert a substantial impact on SAR. The findings indicate that a minimum vessel size of 100 µL is necessary to achieve SAR values independent of vessel size. Furthermore, under constant intensity but varying laser powers and spot size ratios, SAR values may vary by a factor of three, underscoring the profound effect of laser power and irradiated area on heating curves at both wavelengths.

The infrared molecular absorber IRA 980B underwent characterization under identical experimental conditions, reinforcing the universality of SAR dependence on these extrinsic parameters. Given these findings, we propose employing solutions of IRA 980B as a standardized probe for SAR measurements and utilizing the ratio $SAR_{iron\text{-}oxide}/SAR_{IRA980B}$ as a benchmark to compare measurements conducted in diverse laboratories. This standardization of measurements enhances the precision of information extracted regarding the heating performance of various nanoparticles.

Acknowledgments

This work was supported by Projects FIS2017-87360P and RTI2018-095856-BC21. We also acknowledge the Sistema Nacional de Garantía Juvenil for providing the predoctoral contract through the Comunidad Autónoma de Madrid (PEJ-2020-AI/IND-17711).

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Index Terms — iron oxide nanoparticles; laser-induced photothermia; specific absorption rate

Preparation of conductive nano-inks for sustainable electronics

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In recent years, there has been a great interest in the use of printed electronics due to its numerous advantages and potential applications of this type of technology, allowing the use of a wide range of substrates and the production of smaller, more flexible, and portable components [1]. In this context, conductive nano-inks have been developed, which are materials that conduct at a nanoscale level and possess unique properties due to their tiny size, making them ideal for implementation in next-generation electronic devices [2]. Biodegradable and economically accessible metallic materials such as iron, nickel, copper and zinc are interesting alternatives to silver with much lower environmental impact.

The main objective of this research is to establish manufacturing processes of the metallic nanoparticles that composed the inks that are environmentally sustainable, increasing energy efficiency and reducing the carbon footprint. With this purpose in mind, the plan is to substitute toxic reagents with safer alternatives and optimize synthesis processes to decrease resource consumption and waste generation. Up to now, we have developed a method to coat and reduce commercial nanopowders by microwave-assisted polyol method. Particle size is preserved after the coating process, as followed by SEM, while the oxide content has been diminished, what is expected to improve the conductivity of the inks and the magnetic behaviour in the case of Fe nanoparticles.

In the future, the synthesis, coating and reduction of these nanomaterials will be carried out in a single step, using the microwave-assisted polyol method [3], and the process will be scaled up to a continuous microwave system for gram-level production of the material. Thanks to this type of progress, a socially-fair green transition is getting closer and closer.

Acknowledgements

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Design of Magnetic Metal Organic Frameworks for the CO_2 Capture and Conversion under Magnetic Induction Heating

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The issue of global warming, driven by the release of greenhouse gases, has garnered significant global awareness. Of these gases, carbon dioxide (CO_2) is the most significant contributor, accounting for over 60% of global warming due to its substantial emissions. Consequently, there is considerable scientific interest in mitigating CO_2 emissions and reducing its concentration in the Earth's atmosphere [1]. Many researchers have gathered efforts to develop highly efficient materials for the CO_2 capture that also serve as catalysts for its conversion [2].

In this sense, the present study is centered on the design and development of innovative catalytic systems based on magnetic metal organic frameworks (MOFs) to support the combined process of CO_2 capture and conversion. Here, different sized and shaped iron oxide nanoparticles were integrated into MOF structures with a core-shell architecture, leading to suitable physicochemical properties for the efficient generation of heat through magnetic induction irradiation. This induced heat will drive catalytic chemical reactions and help reduce energy consumption.

Figure 1 displays the micrograph (Fig.1c) of one of the magnetic MOFs synthesized in the presence of cobalt ferrite nanoparticles ($CoFe_2O_4$, Fig.1b) with high heating capabilities (Fig.1c) for the hydrogenation reaction of the captured CO_2 to produce valuable molecules like methanol (Fig.1d). The obtained magnetic MOFs were structurally characterized by X-ray diffraction (XRD) and Scanning Electron Microscopy (SEM) coupled with Energy-dispersed X-ray spectroscopy (EDX) exhibiting great coupling of the magnetic nanoparticles.

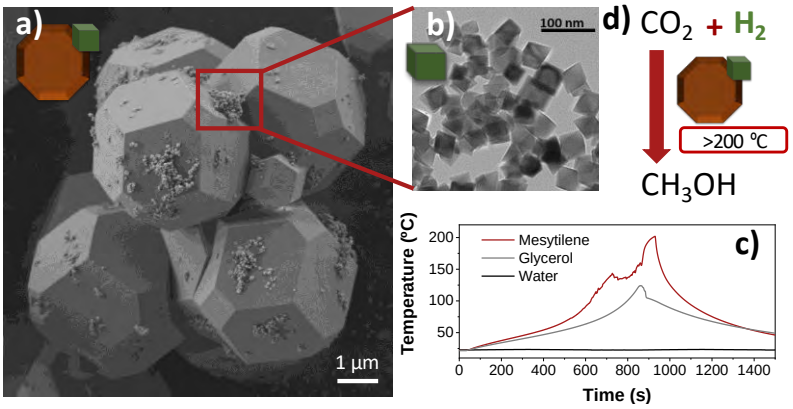

Figure 1 Magnetic MOF (a), $CoFe_2O_4$ nanoparticles (b), heating efficiency of $CoFe_2O_4$ nanoparticles (c) and schematic representation of the application (d).

The synthesized nanocatalysts play a crucial role in the effective capture and conversion of CO_2, ultimately yielding valuable chemical compounds through hydrogen mediated-reaction which could be previously obtained from the water splitting process catalysed by non-magnetic MOFs. In general, the synthesized catalyst stands as a great alternative for environmental remediation and catalytic processes assisted by magnetic induction heating.

Acknowledgements

This research was funded by the Spanish Ministry of Science and Innovation (AEI/FEDER, UE), project reference: TED2021-130191B-C43.

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Theoretical analysis of the interaction between surface acoustic waves and deposited magnetostrictive layer in magnetic Love wave devices

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Love wave-based sensors stand out among other surface acoustic waves (SAW) sensors due to the high sensitivities reached by exploiting the confinement of the mechanical energy associated to shear stress into a very thin volume close to the interface of the substrate and the guiding layer. Few Love wave devices have been made magnetic by including a magnetostrictive element in the design, generally a thin amorphous layer deposited on top. When a material with a higher coercivity is used, a rich phenomenology can be observed.

The studied sensor was fabricated by sputtering a 100 nm layer of polycrystalline galfenol on the area between the interdigitated transducers (IDTs) of the Love wave device, then inserted as a delay line into a feedback loop circuit [3] to track the resonant frequency shift when a magnetic field H is applied using a coil. While the resonant frequency figure (f_r vs H) measured when H and k (wave vector) form an angle of 45º (Figure 1) is similar to a usual magnetization hysteresis cycle, the behaviour is more complex when H and k are collinear (Figure 2). Two new peaks appear, and the frequency does not stabilise with the higher fields. A theoretical model is proposed to explain the observed differences. The effective Young modulus of magnetostrictive materials depends on the capability of the applied strain to rotate the magnetization. Therefore, the interaction between the applied field and the anisotropies generated by the deformation will vary with the angle. By decomposing the stress in compression and traction components, this can be modelled satisfactorily: for 45º, the anisotropy and the applied fields are collinear or perpendicular, so the competition is simple. For 0º, there is a rotation of the magnetization even for the higher fields applied. The peaks can be explained by the annulation of the magnetization at the coercive field, so the Young modulus returns to its constant magnetization value (the same as when H is high enough), only diminished by a small microscopic crystalline anisotropy. Understanding this phenomenon is a necessary step towards developing high performance hybrid sensors with enough sensitivity and resolution for biomagnetic applications.

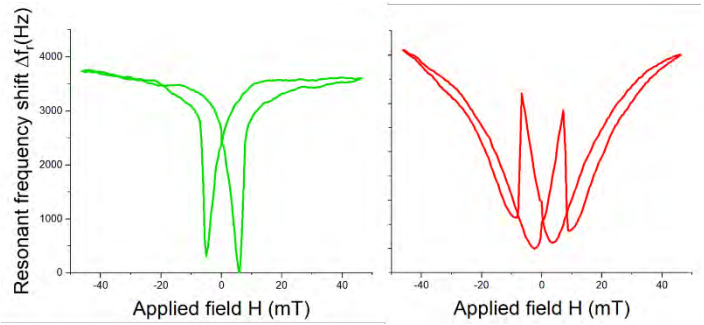

Figure 1:Resonant frequency graph for 45º configuration.
Figure 2: Idem for 0º configuration.

Acknowledgements

The authors acknowledge the Spanish Ministry of Science and Innovation for financing the projects PID2021-123112OB-C21 (AEI/FEDER), PDC2022-133039-I00 (AEI/FEDER), PID2021-122980OB-C51 (AEI/FEDER) and Comunidad de Madrid (NANOMAGCOST-CM S2018/NMT-4321). J.D.A received funding from Programa Investigo from grant 96-UCM-INV. D. M. acknowledges financial support from the Spanish Ministry of Science and Innovation through the Ramón y Cajal grant RYC2021-031166-I.

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Index Terms — Surface Acoustic Waves, Love waves, magnetostriction, theoretical model

Magnetoelastic resonators functionalized with Metal Organic Frameworks for humidity detection

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We propose a relative humidity (% RH) sensor based on magnetoelastic resonators functionalized with Metal Organic Framework (MOF) active layers. Different MOF materials were used in the sensor coating: MOF-801, MOF-808 and UIO66-NH_2, and their capacity to enhance the sensor response to humidity was analysed.

Among other gases, the detection of relative humidity (RH) is crucial in air quality monitoring and processing industries. We propose the use of magnetoelastic resonance (MER) sensors as a cheap, fast and sensitive method of detecting humidity. MER sensors are usually made of ribbons of amorphous ferromagnetic alloys. Due to magnetostriction, these ribbons can be driven to mechanical resonance by the application of external magnetic fields. As their resonance frequency is highly sensitive to external factors, they have been used to design different sensing devices, among them, those related to a change of the resonator mass $\Delta f/f_0 = -\Delta m/2m_0$ [1]. One of the strategies used to improve the performance and applicability of these sensors is the functionalization of its surface with an active layer that is able to provide them with absorption capacity (mass gain Δm) and tailored selectivity. Metal-organic framework (MOF) materials, which are highly porous materials, can be excellent candidates for this purpose [2], [3], as they have a high surface area and tunable pore volume. We propose the use of magnetoelastic ribbons with active layers of MOF materials to monitor humidity.

Three different MOFs were prepared by solvothermal synthesis: MOF-801, MOF-808 and UIO66-NH_2, and then deposited on the resonator ($Fe_{73}Cr_5Si_{10}B_{12}$) surface by spray coating technique. The response of the functionalized sensor (MER sensor + MOF coating) to humidity was assessed over controlled N_2/H_2O flows. MOF materials have proven to be highly moisture-sensitive materials, which produce a fast and sensitive response of the sensor to H_2O. The combined MOF-MER sensors were able to detect relative humidities in a range of 6-76 %. The humidity absorbance per mg, response time, sensitivity and stability of the sensors were evaluated for the different MOF materials and different MOF layers.

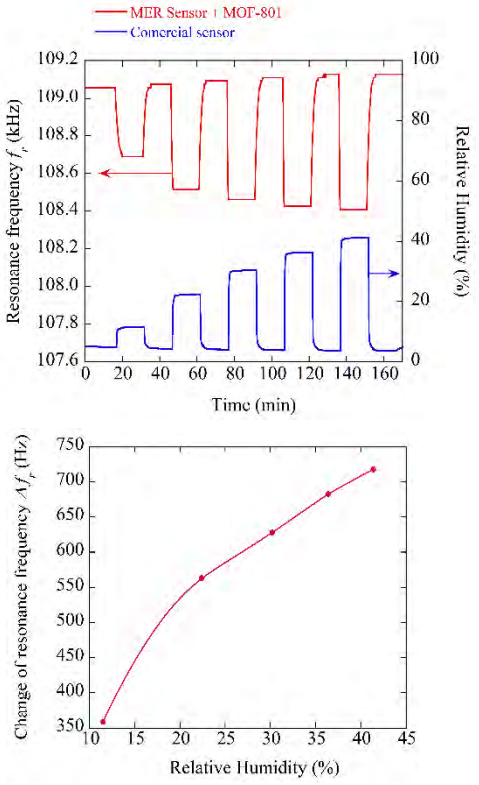

Figure 1 : a) Monitorization of the response of the sensor with MOF-801 layer to cycles of adsorption and desorption of H_2O at different humidity levels (% RH), and comparison with a commercial sensor (Sensirion SHT45). b) Response of the sensor.

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Index Terms — Magnetoelastic sensor, MOF, Gas sensor, Humidity sensor

Exchange Bias Effect of Ni@(NiO, $Ni(OH)_2$) Core/Shell Nanowires Electrodeposited in Nanoporous Alumina Membranes

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The development of groundbreaking technologies is increasingly dependent on our ability to precisely control the magnetic properties of materials at the nanoscale. In addition to refining alloy compositions, crystalline structures, and the geometries of nanomaterials, magnetic heterostructures are being explored as key systems for fine-tuning functional magnetic properties. Specifically, the combination of ferromagnetic (FM) and antiferromagnetic (AFM) layers has gained significant attention for the purpose of altering or generating one-way magnetic anisotropies. This is of particular interest in the design of novel read heads for magnetic recording media that rely on giant magnetoresistance [1]. Even though the magnetic properties and exchange bias effect have been examined in stacked thin films and core/shell nanoparticles, core (FM)/shell (AFM) cylindrical nanowires have not been the primary focus of researchers [2]. In this work, we employed a purely electrochemical method to create arrays of core (FM) /shell (AFM) Ni@(NiO, $Ni(OH)_2$) nanowires, avoiding the use of thermal oxidation processes that are not compatible with integrated semiconductor technologies. We conducted morphological and compositional analyses using SEM, HR-TEM techniques, and XPS analysis. Temperature dependent magnetic hysteresis loops, thermomagnetic curves and FORC analysis, have also been used to determine the influence of the electrochemical modification of Ni nanowires' surface on their magnetic properties. First of all, a magnetic hardening of these FM/AFM nanowires along the parallel direction of applied magnetic field with respect their long axis (easy magnetization axis) has been found to be around 17% (43%) at 300K (50K). On the other hand, as the temperature drops below 100K while field cooling the nanowires under a 3T applied magnetic field along their easy magnetization axis, an increasing exchange bias effect becomes evident.

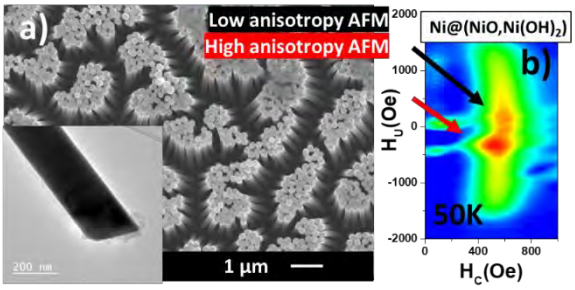

Figure 1: a) SEM image of electrochemical surface modified for Ni@(NiO,$Ni(OH)_2$) nanowires. The inset shows a high magnification HRTEM image of a single nanowire. b) FORC distribution obtained at 50K showing two different magnetic behaviours ascribed to the different magnetic interactions between the core and the shell of the Ni@(NiO, $Ni(OH)_2$) nanowires.

Acknowledgements

Spanish MCINN under research grant No. PID2019-108075RB-C32/AEI/10.13039/501100011033 is gratefully acknowledged for financial support.

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Index Terms — Nanoporous alumina membranes, nanowires, core/shell, antiferromagnetism, exchange bias, FORC.

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Magnetization Reversal Process of Bi-modulated FeCo Cylindrical Nanowires

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The understanding and control of magnetic structures is essential for the development of novel applications in several areas such as biomedicine, data storage, microwave technology [1]. Cylindrical nanowires offer an alternative to nanostripes due to geometry induced effects such as the suppression of the Walker breakdown [2]. Cylindrical geometry stabilizes a number of novel magnetic textures such as Bloch Point Domain Walls (BPDW) and vortex tubes. Especially interesting are the modulated cylindrical nanowires with variation in magnetization or diameter since complex configuration can be found [3].

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Pressure-tuned interactions in magnetically driven $Nd_xCe_{1-x}CoIn_5$ superconductor

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Heavy-fermion metals are intermetallic compounds with partially filled *f* orbitals. The complex interplay between localized magnetic moments and their hybridization with itinerant conduction electrons gives rise to rich phase diagrams and novel phases such as unconventional superconductivity and non-Fermi liquid behavior [1]. The small energy scales of the relevant interactions compared to typical solids place them in the vicinity of quantum critical point, at which the ground state is driven by quantum fluctuations even at finite temperatures. Thus, these materials are highly susceptible to external tunning parameters such as magnetic field, chemical substitution or hydrostatic pressure and an ideal platform to investigate the interplay of magnetism and superconductivity. $CeCoIn_5$ is an ultraclean unconventional superconductor [2] near a magnetic quantum critical point on which superconductivity and magnetism coexist at large fields [3]. The cooperative superconducting **Q** phase with an amplitude modulated incommensurate magnetic phase is attributed to collective magnetic excitations within superconductors. On the other hand, a competing and localized magnetic order can be promoted by implanting Nd ions in Ce sites beyond the Kondo breakdown [4]. However, the onset of a zero-low field incommensurate spin density wave (SDW) inside the superconducting condensate is very surprising. This is even more so as this ordered state shows identical magnetic symmetry than the **Q** phase. Yet, it remains unclear the origin of the magnetic order within the superconducting dome, its correlation with the cooperative phase and the occurrence of SDW in other members of the $CeTIn_5$ (T=Rh, Ir and Co) family. In this work, we have investigated the role of chemical implantation and hydrostatic pressure in the $Nd_xCe_{1-x}CoIn_5$ series by muon spin relaxation. We found clear signature of magnetic order down to the minimum concentration of Nd dopants investigated (%10) where both phases coexist. From the muon ensemble relaxation, we determined a volume fraction of muons with an oscillatory behavior equal to the Nd impurities. Moreover, we observed a suppression of the magnetic order by hydrostatic pressure while the superconducting condensate exhibit a similar trend than the pristine compound. Those results rule out chemical pressure from the dopant as a driven source of the magnetism or the cooperative origin of the low-field magnetic phase unlike previously suggested [5]. Instead, the results strongly support a scenario given by an incommensurate SDW governed by localized 4f Nd electrons via Ruderman-Kittel-Kasuya-Yosida (RKKY) interactions, while highly hybridized Ce electrons contribute to the condensate.

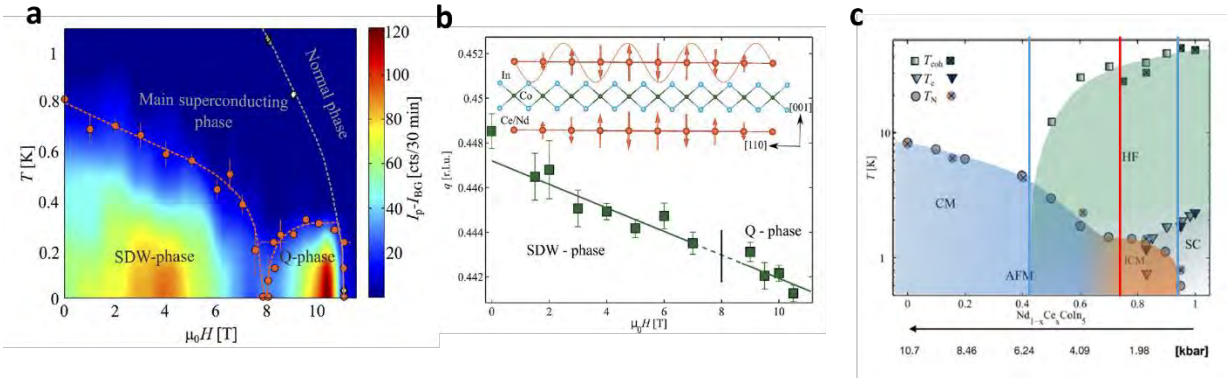

Figure 1 a) T-H phase diagram and b) magnetic structure $Nd_{0.05}Ce_{0.95}CoIn_5$ from [4], c) $Nd_{1-x}Ce_xCoIn_5$ xT-phase diagram

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Synthesis, characterization, and study of the spin-polarization in 2-dimensional chiral hybrid organic-inorganic metal halides

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Two-dimensional hybrid organic-inorganic metal halides (2D-HMHs) are interesting materials in which layers of inorganic octahedra are connected by organic spacers through van der Waals interaction, forming a kind of natural multiple quantum well structures. Their special architecture allows for great flexibility in their design, due to the possibility to play with the immense variety of organic chemical compounds. Inversion symmetry can be broken by using homochiral organic molecules as spacers, giving rise to the appearance of spin polarization in the electron currents generated in or transmitted through them thanks to the chirality-induced spin selectivity (CISS) effect. [1] Due to their strong optical absorption, these 2D-HMHs are also excellent candidates to obtain spin-polarized photo-generated charges. The goal of this research is to develop a range of semiconductor materials with tunable magnetic characteristics for spintronics applications.

Our strategy consists in introducing homochiral organic ligands in the composition of the 2D-HMHs in such a way that they can impart a chiral structure to the whole crystal lattice. The use of different metallic atoms in the halides also allows to customize the electronic and magnetic properties of the resulting materials. Within this approach, diverse compounds have been synthesized and characterized by a combination of structural, chemical, and electronic spectroscopy techniques. In $(MBA)_2PbI_4$ the organic cation is homochiral (either R or S) methylbenzylamine (MBA); its crystal structure, as determined from X ray diffraction measurements, is displayed in Fig. 1. Spin-resolved photoemission experiments carried out at the Soleil synchrotron have revealed sizeable spin polarization in the photoelectrons emitted from this compound, in spite of the relatively small size of MBA that results in a flat (i.e., non-chiral) arrangement of the PbI_4 octahedra, so that the chiral symmetry is limited to the organic layers. A larger molecule such as naphthyl-ethylamine (NEA) induces further distortion in the lattice of $(NEA)_2Pb_2Br_6$ causing a chiral buckling also in the inorganic sublattice, which is expected to result in a stronger spin polarization. Finally, $(PEA)_4Bi_2Br_{10}$ where PEA stands for phenylethylamine, is interesting for the effect that the strong spin-orbit coupling of a heavy metal such as Bi can have in the material's electronic and magnetic properties.

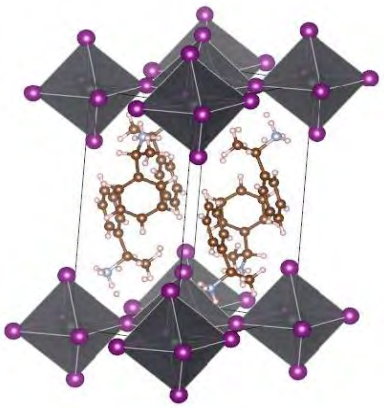

Figure 1: *Crystal structure of $(MBA)_2PbI_4$ as determined from X ray diffraction measurements.*

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

Acknowledgements

This work has been funded by the Spanish Ministry of Science and Innovation through Grants Nos. TED2021-131042B-I00 and PID2021-123295NB-I00.

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High-Precision Magnetic Characterization with the Cryogenic S700XR SQUID Magnetometer

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Abstract:

The Superconducting Quantum Interference Device (SQUID) magnetometer represents a vital tool for investigating magnetic properties with high sensitivity. It allows to determine the bulk magnetic moment of a sample in absolute units of $A \cdot m^2$. The Cryogenic S700XR SQUID Magnetometer is suitable for the measurement of magnetic properties as a function of magnetic field and temperature with a range of 1.6–400 K. A variety of magnetic materials can be measured using this unique instrument.

The SQUID S700XR consists of two parallel Josephson junctions. When the sample is moved up and down it produces an alternating magnetic flux in the pick-up coil. The magnetic signal of the sample is obtained via a superconducting pick-up coil. This coil is, together with a SQUID antenna, part of a whole superconducting circuit transferring the magnetic flux from the sample to SQUID loop which is located away from the sample in the liquid helium bath. SQUID magnetometer acts as a magnetic flux-to-voltage converter, with the resulting voltage signal being further amplified and recorded by the magnetometer's electronics. Accurate placement of a sample within the detection coil is of a great importance, directly influencing the reliability of magnetic moment measurements. A series of measurements conducted at various temperatures and magnetic field strengths offer a comprehensive view of the sample's magnetic characteristics. The one constraint imposed on the samples is their size, with a maximum length of approximately 8 mm along one of the axes. The Cryogenic S700XR SQUID Magnetometer, with its precision and versatility, stands as an indispensable tool for an array of experimental investigations in the field of magnetism.

This SQUID Magnetometer was employed in our recent study to conduct thermomagnetic measurements on a dysprosium single crystal, encompassing tasks such as measuring the remanent magnetization and identifying various magnetic phases and transitions within the dysprosium element.

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Manual of “Cryogenics S700XR” SQUID magnetometer.

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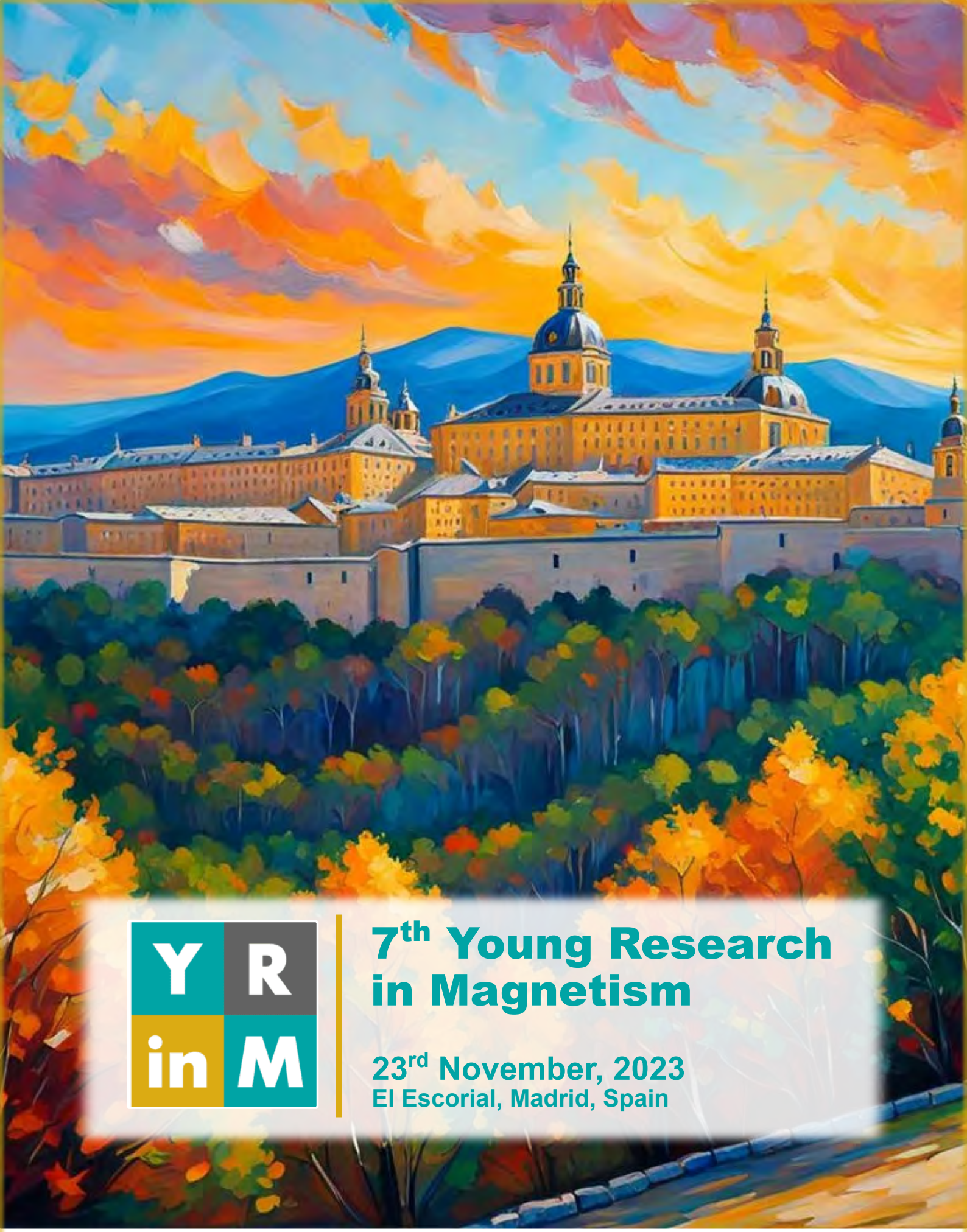

7th Young Research in Magnetism

23rd November, 2023

El Escorial, Madrid, Spain

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