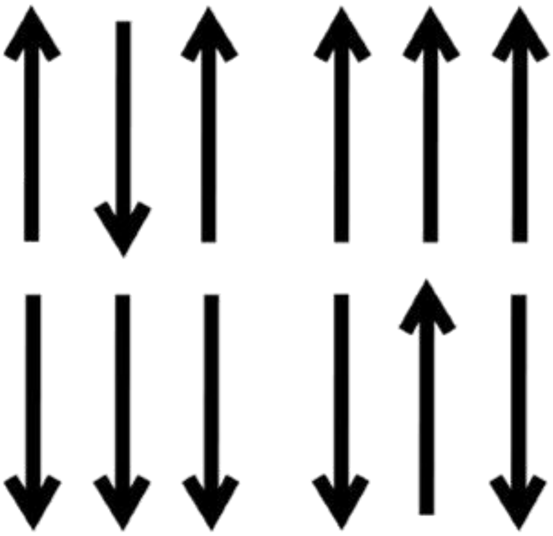
Magnetism in Portugal 2024

School of Metrology in Magnetism

IST-CTN, Bobadela
1-2 February



NPM

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PROGRAMME AND BOOK OF ABSTRACTS

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Welcome to School of Metrology in Magnetism

Dear colleagues,

On behalf of the Organizing Committee, we welcome you in CTN-IST, Bobadela, for the event of the Portuguese Magnetism Group (NPM): School of Metrology in Magnetism.

Since its creation in 2021 as part of the Condensed Matter Division of the Portuguese Physics Society (https://fisica-materia-condensada.spf.pt/npm), NPM has presented itself to the scientific community in various formats, bringing together renowned scientists and young researchers within the field of magnetism. The first event was a virtual meeting (Sep.2021) followed by the Magnetism in Portugal 2022 - Young Researchers, at the FCUP, Oporto Univ (Sep.2022). This time our aim was to prepare a school which includes plenary lectures, hands-on practical and tutorial sections and Poster presentations, thus giving participants the opportunity to learn about the state of the art and measurement challenges in different key topics related to magnetism, Magnetometry, Mössbauer Spectroscopy and Neutron Diffraction, while interacting with researchers from different Portuguese and abroad institutions.

Located in Bobadela, Loures, CTN – Campus Tecnológico e Nuclear from Instituto Superior Técnico, is one of the most important technology parks across the country, namely in areas related to nuclear sciences applied to advanced materials, cultural heritage, environment, and health, as well as in the field of radiological protection and nuclear safety. The Campus is easily connected to the nearby Lisbon modern area Parque das Nações, from where you can reach any part of our beautiful capital, and enjoy its magical life, culture, and light!

The local organization of Magnetism in Portugal 2024 – School of Metrology in Magnetism, welcomes you in Bobadela/Lisboa and wishes a pleasant and fruitful stay.

Laura Pereira
Chair, Magnetism in Portugal 2024: School of Metrology in Magnetism

SCHOOL ORGANIZATION

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João Amaral (CICECO/UA)
João H. Belo (IFIMUP/FCUP)
Laura C. J. Pereira (C2TN/IST)

SECRETARY

Patrícia Russo

*Instituto Superior Técnico (IST)

GENERAL INFORMATION

CHECK-IN

- The registration desk is in the lobby of CTN's library.
- Each participant will receive a school kit and an identification badge upon registration.
- The registration fee comprises:
  - Admission to all oral / *hands-on*/ poster sessions, registration kit and program.
  - Lunches, conference dinner (1st Feb), and coffee breaks

MEALS

The lunches and coffee breacks will be served at CTN's canteen.

The dinner will be at "D. Bacalhau", located at Parque das Nações (https://restaurantebacalhau.com/)

INTERNET ACCESS

Free wireless internet is available at Campus Tecnológico e Nuclear, including in the Auditorium.

ORAL SESSION GUIDELINES

- Time allocation for oral communications: 45 min= 35 min + 10 min (discussion)

POSTER SESSION GUIDELINES

- All poster materials must be confined to AO size (841 mm x 1189 mm) display board. Each presenter has one entire side of one poster board to use. Pushpins will be placed on each poster board.
- All posters must be set up at in the morning of the first day of the school and must remain up until its end, on Friday's afternoon.
- Poster Award Ceremony will be held on Friday, along with the Closing Ceremony.

Scientific Program – Schedule

Thursday, 1st February 2024

8:30		**Registration**
09:00 – 09:15		**Welcome reception**
Session 1		*Chaiperson: Célia Sousa*
09:15	**T-O1**	Metrology and Magnetism, **Isabel Godinho**
10:00	**T-O2**	Units in Magnetism, **Olivier Fruchart**
10:45		**Coffee Break**
Session 2		*Chaiperson: João Belo*
11:15	**T-O3**	Introduction to the Fundamentals of Nanomagnetism, **Cindi L. Dennis**
12:00	**T-O4**	Magnetometry: understanding the techniques behind the black box, **Victorino Franco**, Jia Yan Law
12:45		**Lunch**
Session 3		
14:00	*Hands - on*	*:* Magnetometry, **Carlos Amorim**
16:00		**Coffee Break**
16:30	**P**	*Poster Session*
20:00		*Dinner*

Friday, 2nd February 2024

Session 1		*Chaiperson : João Amaral*
09:15	**F-O1**	Magnetic ultrathin films and interface control, **Susana Freitas**
10:00	**F-O2**	Introduction to Mössbauer Spectroscopy, **Bruno J.C. Vieira**
10:45		**Coffee Break**
Session 2		*Chaiperson: Carlos Amorim*
11:15	**F-O3**	Neutron Scattering Techniques, **José António Paixão**
12:00		**Lunch**
Session 3		
14:00	*Hands - on*	*Mössbauer Spectroscopy, **Bruno J.C. Vieira***
15:30	**P**	Poster Session and Grupo Group formation
16:00	*Hands - on*	Putting It All Together: Quantitative Measurements in Nanomagnetism**, Cindi L. Dennis**
17:30		**Coffee Break**
18:30		**Closing Cerimony and Awards**

Poster Presentations

P01 A single Magnetometry Solution to Fully Characterize Magnetocaloric Material Thermodynamics, **C. Pereira**, R. Almeida, R. Kiefe, C. Amorim, J. S. Amaral, J. P. Araújo, J. H. Belo

P02 Strain-dependent magnetic and dielectric properties of $Ca_3Mn_2O_7$ thin films prepared by pulsed laser deposition, **B. M. Silva**, J. Oliveira, V. Lenzi, P. Rocha-Rodrigues, P. Neenu Lekshmi, L. S. Marques, A. M. L. Lopes, J. P. Araújo, B. G. Almeida

P03 Low-Consumption Logical Devices: Topological Insulator Spin Valve, **B. M. Fernandes**, M. S. Moreira, A. L. Pires, A. M. Pereira

P04 Control of Injected Spin Current into a Topological Insulator: Where Spintronics Meet Magnetoplasmonics, **Carlos E. Roque**, Mafalda Moreira, Ana L. Pires, André M. Pereira

P05 Optimizing magnetocaloric effect measurement in $Gd_5Si_2Ge_2$ using magnetometry, **D. Bastos**, C. Pereira, R. Almeida, C. Amorim, J.S. Amaral, J.P. Araújo, J.H. Belo

P06 Dimensional Dependence of Magnetocaloric Properties in ErCrO3Nanocrystals, **João P. F. Carvalho**, Venkata Ramana, Durairajan Arulmozhi, Manuel P. F. Graça

P07 Double perovskites for solar cells: Y_2NiMnO_6 a case study, **Francisco M. Melo**, João H. Belo, Gonçalo N.P. Oliveira

P08 Magnetic Signatures of Topological Surface States: A Roadmap for Optimizing Flexible Quantum Materials, **Mafalda Moreira**, André M. Pereira 1, Ana L. Pires, Eduardo V. Castro

P09 Magnetic ordering in the $Cu(Fe_{1-x}Ni_x)_2Ge_2$ system, **Phinifolo L.S. Cambalame**, José António Paixão

P10 COMSOL Magnetohydrodynamics Induction Heat Dissipator, **Ricardo M.C. Pinto**, João P. Araújo, Daniel.J. Silva, Ana L. Pires, João H. Belo

P11 Synthesis of cobalt-doped manganese ferrites through eco-friendly methods for thermo-therapeutic applications, **Sérgio R. S. Veloso**, Sara F. Nereu, Carlos O. Amorim, Vítor S. Amaral, Miguel A. Correa-Duarte, Elisabete M. S. Castanheira

P12 Magnetic properties of high aspect-ratio nanostructures for biomedical applications, **S. Caspani**, R. Magalhães, J. P. Araújo, A. Apolinário, C. T. Sousa

P13 Magnetic nanoparticles for cancer treatment through magnetic hyperthermia, **Bárbara Costa** , Sílvia Soreto, Manuel Graça, Sílvia Gavinho, João Carvalho, Tânia Vieira, Jorge Carvalho Silva, Paula I. P. Soares , Manuel Valente

P14 Synthesis of iron oxide particles by a biogenic sol-gel route for biomedical applications, **Juliana Jesus**, Joana Regadas, Bárbara Costa, João Carvalho, Sílvia Gavinho, Ana Pádua, Célia Henriques, Paula I. P. Soares, Manuel Graça, Sílvia Soreto

P15 Characterization and modelling of CoFeB films towards SOT magnetic sensors, **J. Francisco Moutinho**, Daniela N. Jordão, Diana C. Leitão, João P. Araújo

SCIENTIFIC PROGRAM - ABSTRACTS

ORAL COMMUNICATIONS

T-O1

Metrology and Magnetism

Isabel Godinho

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The definition, materialization and dissemination of units has always been related to the possibility and ease of measurement, conditioned by the available instrumentation. The development of measurement and the methods used has been determined by the increased demand for accuracy, sensitivity, greater reproducibility and repeatability, factors associated with growing competitiveness and the emergence of new areas in the scientific and technological domains. Fundamental physics has contributed to the development of the International System of Units (SI) and to the traceability of measurement, involving the award of several Nobel Prizes. The adoption of the new International System of Units made official at the 26th General Conference of Weights and Measures, in November 2018, came into force on May 20, 2019, as a universal and coherent system of units, with the primary objective of ensuring the traceability of measurement units to the highest level of rigor and accuracy, guaranteeing the improvement and needs of society. In this presentation, the contribution of Metrology to research and development in the field of magnetism and its applications will be emphasized.

T-O2

Units in Magnetism

Olivier Fruchart

SPINTEC (CNRS, CEA, University Grenoble Alpes), Grenoble, France

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I will propose a short review of units in magnetism, from concepts to their practical implementation and use. I will first question our vision of what physical dimensions and units are and recall the basics of the SI system of units (Système International). I will then focus on the quantities and units related to magnetism, related to the motion of electric charges, and illustrate practical concepts such as dimensional analysis and magnetic characteristic quantities. I cannot avoid giving a warning about the uneasy coexistence of the modern SI system with the persistent historical cgs-Gauss system, and the resulting pitfalls and apparent absurdities. This culminates with the emergence of modern metrology defining the mass from Planck's constant since 2019, so that the magnetic permeability of vacuum μ_0 is no more a constant but is to be measured experimentally, so that the SI and cgs-Gauss systems are no more formally consistent.

T-O3

Introduction to the Fundamentals of Nanomagnetism

Cindi L. Dennis

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This talk will offer a short introduction to the fundamentals of magnetism with a particular focus on the impact of reducing dimensions to the nanoscale.

T-O4

Magnetometry: understanding the techniques behind the black box

Victorino Franco, Jia Yan Law

University of Seville, Spain

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It is common that PhD students, at the start of their experimentation, blindly trust the expensive devices that their supervisor acquired. There is no doubt that these devices work perfectly well for the purpose they were made for, but that is not necessarily the use that the student wants to give it. In this talk we will demystify those expensive black boxes (which come in many different colors), classify the measurement techniques according to the magnitude that they measure, and explain the fundamentals of magnetometry. Understanding the way that systems measure is the way to obtain reliable results and to extend the capabilities of the technique to new applications.

[1] Victorino Franco, Brad Dodrill (Eds.), "Magnetic Measurement Techniques for Materials Characterization", Springer Nature (Switzerland), 2021. https://doi.org/10.1007/978-3-030-70443-8

F-O1

Magnetic ultrathin films and interface control

Susana Freitas

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The integration of magnetic materials in nanoelectronic devices requires accurate control of the thin film materials characteristics. Optimization of multilayers comprising different material thin films offer many challenges for the film deposition techniques, where accuracy of 0.01 nm is often required in the film thickness and the control of interfaces plays crucial role. In addition, uniformity in the film thickness and structure needs to be homogeneous in a large area substrate (200 mm), so to enable transfer to industry-relevant applications.

Here, we will illustrate how key physical characteristics and interfacial couplings are relevant in spintronic sensor design, while affecting sensor performance. Examples will be provided demonstrating the impact of materials and interfaces in device performance, such as noise, field detectivity and thermal stability.

F-O2

Introduction to Mössbauer Spectroscopy

Bruno J.C. Vieira

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Mössbauer spectroscopy stands as a remarkable technique that delves into the intricate world of materials, providing valuable insights into their structure, properties, and behavior. Its unique combination of sensitivity, specificity, and non-destructive nature makes it a versatile tool for a wide range of applications in material science, geology, biology, archaeology, and medical research.

This lecture will introduce the Mössbauer Spectroscopy technique. The uniqueness of the technique will be explained highlighting the features that set Mössbauer spectroscopy apart from other characterization methods. Some specific aspects of the technique will be underlined including the source of radiation used, sample preparation and characteristics, basic experimental apparatus, and spectra collection. A short introduction to the hyperfine interactions studied by this technique will be given: isomer shift, quadrupole splitting and hyperfine magnetic splitting.

F-O3

Neutron Scattering Techniques

José António Paixão

CFisUC – Centre for Physics, University of Coimbra, Portugal

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This lecture will introduce neutron scattering techniques, using both unpolarized and polarized beams, with an emphasis to its use in the determination and refinement of magnetic structures, magnetic form factors and magnetization densities. Advantages, disadvantages, and complementarity of neutron diffraction with other more commonly available techniques will be reviewed. A few examples using both polycrystalline and single crystalline samples will be presented and discussed.

SCIENTIFIC PROGRAM - ABSTRACTS

POSTER COMMUNICATIONS

P1-A single Magnetometry Solution to Fully Characterize Magnetocaloric Material Thermodynamics

C. Pereira [1], **R. Almeida** [1], **R. Kiefe** [2], **C. Amorim** [2], **J. S. Amaral** [2], **J. P. Araújo** [1], **J. H. Belo** [1]

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[2] *Departamento de Física and CICECO, Universidade de Aveiro, 3810-193 Aveiro, Portugal*

Measuring and comparing thermodynamic properties of near room-temperature magnetocaloric materials is a crucial tool for the continuous assessment and improvement of these materials' performance [1]. In this work, we present a new methodology that allows a complete characterization of a magnetocaloric material (ΔS_{iso}, ΔT_{ad}, C_p) as a function of temperature and magnetic field using a single equipment: SQUID MPMS3 magnetometer [2]. The temperature change induced by the application of the field H under adiabatic conditions, $\Delta T(T, H)$, can be obtained directly by measuring the temperature of the sample, however, it is very challenging to develop a setup for such measurements in adiabatic conditions [3]. Nevertheless, our group developed a technique capable of measuring ΔT_{ad} through time- dependent magnetometry using the SQUID [4]. With our approach, two $\Delta T_{ad}(T)$ curve profileswere obtained using Gadolinium under a directly and incrementally (using steps of 0.1 T) application of 1 T field change and the obtained values are within -12% and 2%, respectively, of the reported values for the $\Delta T_{ad}(T)$ peak amplitude of Gadolinium [5]. The temperature andfield dependent heat capacity of the material at a given temperature, (T, H) , can be obtainedby solving the ΔT_{ad} expression (derived from Maxwell relations) numerically using the direct measurement of $\Delta T_{ad}(T_i)_{\Delta H}$ through magnetometry for small incremental changes of ΔH up to1 T under adiabatic conditions. The estimate of the heat capacity of Gadolinium around its transition temperature is within 9% of the reported values [6]. The entropy change of the material upon the variation of the field H under isothermal conditions, $\Delta S_i(T, H)$, can be calculated indirectly using a standard well-known protocol on the magnetometer. Overall, we were able to completely characterize the major thermodynamic properties of the benchmark magnetocaloric material Gd using a worldwide available commercial device, enabling accelerated progress towards new, competitive, and industry-ready materials.

Acknowledgements: The authors acknowledge Fundação para a Ciência e a Tecnologia (FCT) for the IFIMUP projects UIDB/04968/2020, UIDP/04968/2020, NECL-NORTE-010145- FEDER-022096, CERN/FISTEC/0003/2019, PTDC/EME-TED/3099/2020.

[1] V. Franco et al., *Prog. Mater. Sci*. **93**, 112-232 (2018)

[2] Quantum Design North America, SQUID Magnetometer - Quantum Design MPMS

[3] F. Cugini et al., *J. Appl. Phys.* **127**, 123901 (2020)

[4] R. Almeida et al., *Phys. Rev. Appl.* **18**, 024081 (2022)

[5] M. D. Kuz'min et al., *Appl. Phys. Lett.* **99**, 012501 (2011)

[6] K. Wang et al., *J. Mater. Sci*. **56**, 2332–2340 (2021)

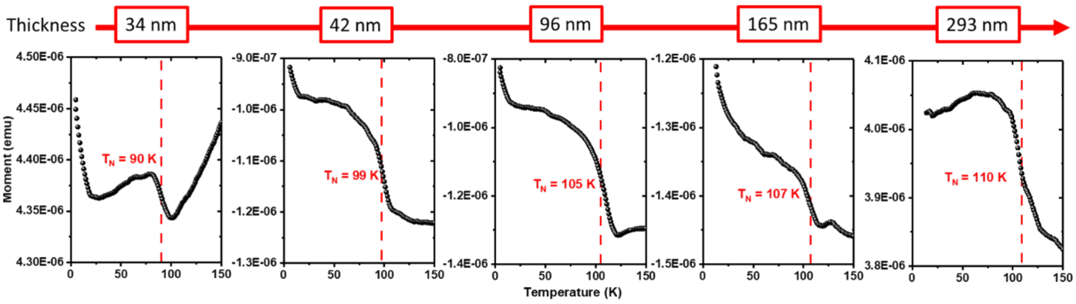
P2- Strain-dependent magnetic and dielectric properties of $Ca_3Mn_2O_7$ thin filmsprepared by pulsed laser deposition.

B. M. Silva[1], J. Oliveira[1], V. Lenzi[1], P.R. -Rodrigues[2], P. N. Lekshmi[2],L. S. Marques[1], A. M. L. Lopes[2], J. P. Araújo[2], B. G. Almeida[1]

[1] Center of Physics of the Universities of Minho and Porto, LAPMET, Dep. Física, Uni. Minho, 4710-057 Braga, Portugal; [2] Institute of Nanoscience and Nanotechnology and Photonics, LAPMET, Universidade do Porto, , 4169-007, Porto, Portugal

Naturally layered perovskite structures with improper ferroelectricity, such as the Ruddlesden-Popper calcium manganite compound $Ca_3Mn_2O_7$, offer an alternative to achieve non-expensive and high-performance room-temperature multiferroic magnetoelectricity. Theyallow exploring oxygen octahedra nonpolar rotations and cation site displacement to attain non-centrosymmetry. Additionally, their high sensitivity to lattice distortions allows for the manipulation of acentricity through preparation as thin films over crystalline substrates, whichenables the tuning of lattice, electric, and magnetic interactions [1]. As such, thin films of $Ca_3Mn_2O_7$ with variable thicknesses (~30-350 nm) were prepared by pulsed laser deposition over SrTiO3 substrates and their dielectric and magnetic properties were characterized [2]. The $A2_1am$ ferroelectric phase was observed in the films, along with the orthorhombic Acaaphase. The X-ray diffraction results show stronger strain in the thinner films that progressivelyrelaxed with increasing sample thickness. The magnetic properties show the presence of an antiferromagnetic (AFM) transition between 90 and 110 K. The dielectric characterization shows the presence of dispersion described by the Havriliak-Negami model function. From temperature-dependent fits show evidence of AFM transition between 85 and 112 K. Considering the results of magnetic and dielectric measurements, the AFM transition temperature was lower for more strained films and increased as the strain of the films decreased.For the thicker, less strained, film, an AFM transition at 110-112 K was found which is bulk $Ca_3Mn_2O_7$ Ruddlesden-Popper phase characteristic temperature. The magnetic/dielectric correlation results indicate the presence of magnetoelectric interactions and magneticallyinduced enhancement of dipolar correlations in the AFM phase. In this work, a study of the strain-dependent magnetic and dielectric properties of the films produced will be presented.

Figure 1: Temperature dependence of the magnetization measured in $Ca_3Mn_2O_7$ thin films with increasingthickness over $SrTiO_3$



substrates and their corresponding AFM transition temperatures.

1] P. Ghosez and J. M. Triscone, Nat. Mater. 10, 269 (2011).; [2] B. M. Silva, A. M. L. Lopes, J. P. Araújo, B. G. Almeida et al., Mater. Res. Bull. 158, (2023).

P3- Low-Consumption Logical Devices: Topological Insulator Spin Valve

B. M. Fernandes [1], M. S. Moreira [1], A. L. Pires[1], A. M. Pereira [1]

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The modern electronics industry is guided by the empirical observation made in 1965, by Gordon Moore [1], that predicts that the number of transistors in a integrate circuit will double every two years. Reciprocally, the size of semiconductor components used should reduce at thesame pace. This demand for improved devices has reached fundamental limitations, in terms ofsome core functionalities as power, weight and size. While the last two factors can be tackled by innovations in the lithography field, for power consumption it is still a required milestone, being only achievable with appearance of tailored materials. In this regard, a new class of quantum materials, that implied an extension of the Landau theory for phase transitions, since they did not break any symmetry state and could not be described by local order parameters [2],has gained the interest for their potential applications. These materials with topological phasesdue to band structure effects are named as topological insulators (TIs). Herein, we present an implementation of such materials in a spin-valve structure. Our aim is to study the transport dynamics of a multilayer system composed of a three-dimensional TI of Bi_2Te_3, intercalated with ferromagnetic layers of Ni, and to determine its potential as a low-consumption logical device. The production of such multilayer device will be attained by a DC sputtering technique.Also, characteristic voltage measurements will be done through an Inverse Spin Hall Effect set-up. The spin-momentum locking of the surface states in the TI will allow a spin-polarized current, at the surface, with the spin orientation (in-plane) perpendicular to the current direction[3]. The magnetization switching, at the spin valve, will be done by employing a train of currentpulses, with well-defined spin polarization. With this work we hope to contribute to the development of high-efficiency logical devices through the usage of topological materials.

Acknowledgement: This work was financially supported by Fundação para a Ciência e a Tecnologia (FCT)/MEC and FEDER under Program PT2020 through the projects UIDB/04968/2020 and UIDP/04968/2020, and NORTE-01-0145-FEDER022096 from NECL. The authors are thankful to IFIMUP.

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[2] B. A. Bernevig, Taylor L. Hughes, Topological insulators and topological superconductors,Princeton, University, Press, 2013.

[3] Tian et al., Topological insulator based spin valve devices: Evidence for spin polarized transportof spin-momentum-locked topological surface states, Solid State Communications, Volume 191, 2014.

P4- Control of Injected Spin Current into a Topological Insulator: Where Spintronics Meet Magnetoplasmonics

Carlos E. Roque [1], **Mafalda Moreira**[1], **Ana L. Pires**[1] **and André M. Pereira** [1]

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Non-magnetic semiconductors, the building blocks of the most common electronic devices, rely on electronics to process information. Although these served as the foundation for the technological advancements we have witnessed over the past few decades, we are experiencing an enormous demand for quicker, reliable and less energetically dissipative devices. Overheating, power dissipation, and the limitations of miniaturizing these materials are reasons that contribute to the current apparatus, resulting in a fundamental limitation of conventional electronic devices. A promising solution to all these issues is provided by spintronics, the branch of physics that investigateshow we can use the spin of electrons to acquire, transfer, and process information. Spintronic based devices are versatile and can make use of other branches of physics to enhance the response of magnetization in a more efficient way, taking the advantage, for example, of magnetoplasmonics. This field emerges from the interaction of light with dynamic magnetization in magnetic nanostructuresthat sustain plasmonic modes and studies not only the magneto-optical enhancement, linked to plasmonic resonances, but also how magnetic fields affect surface plasmon polaritons [1]. Furthermore, these emergent devices can incorporate quantum materials, such as Topological Insulators, which, in addition to having exotic properties such as surface states protected by time reversal symmetry, chiral symmetry, and spin-momentum locking, are potential candidates for carrying tuned plasmonic phenomena [2]. Taking this into consideration, the present work focuses firstly on the fabrication of plasmonic grating structures through thermal nanoimprint lithography, using polystyrene (PS) as a thermoplastic substrate.During this process, the grating period of these structures will be varied, in the range between 300 nm up to 1400 nm. Later, Magnetic material will be deposited on top of these structures using sputtering deposition, and the electric transport together with magnetic properties will be measured in response tothe incidence of a laser in this samples. In addition, the same characterization will be performed on similar structures, but deposited with Bi_2Te_3, a material which exhibits a topological phase. In a future stage of this work, these structures will be covered by both Bi_2Te_3 and magnetic materials to study whether we can achieve an efficient spin-current injection from a magnetic material into Bi_2Te_3, triggered by the spin waves tailored by magnetoplasmonics phenomena.

AcknowledgementsThis work was financially supported by Fundação para a Ciência e a Tecnologia (FCT)/MEC and FEDER under Program PT2020 through the projects UIDB/04968/2020 and UIDP/04968/2020, and NORTE-01-0145-FEDER022096 from NECL. The authors are thankful to IFIMUP.

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P5-Optimizing magnetocaloric effect measurement in $Gd_5Si_2Ge_2$ using magnetometry

D. Bastos[1], C. Pereira[1], R. Almeida[1], C. Amorim[2], J.S. Amaral[2], J.P. Araújo[1], J.H. Belo[1]

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Using a MPMS-3 Quantum Design superconducting quantum interference device (SQUID) magnetometer, we determined the adiabatic temperature change (ΔT_{ad}) in a sample of $Gd_5Si_2Ge_2$, subject to a magnetic field variation from 0 to 2 T. To establish the $\Delta T_{ad}(T_{initial})$ curve we compounded the (measured) curves magnetization vs temperature (M(T)) and the magnetization relaxation in time after applying a given magnetic field (M(t)). Our work is centered on optimizing this method, aiming to simplify the measurement of the magnetocaloric effect in first-order materials. We've developed an effective approach, which involves using the equilibrium magnetizations from the time relaxations to construct the M(T) curve. Additionally, we delved into the impact of conducting measurements under low chamber pressure on the $\Delta T_{ad}(T_{initial})$ curve.

Acknowledgements: The authors acknowledge Fundação para a Ciência e a Tecnologia (FCT) for the IFIMUP projects PTDC/EME-TED/3099/2020, UIDB/04968/2020 and UIDP/04968/2020

P6- Dimensional Dependence of Magnetocaloric Properties in $ErCrO_3$ Nanocrystals

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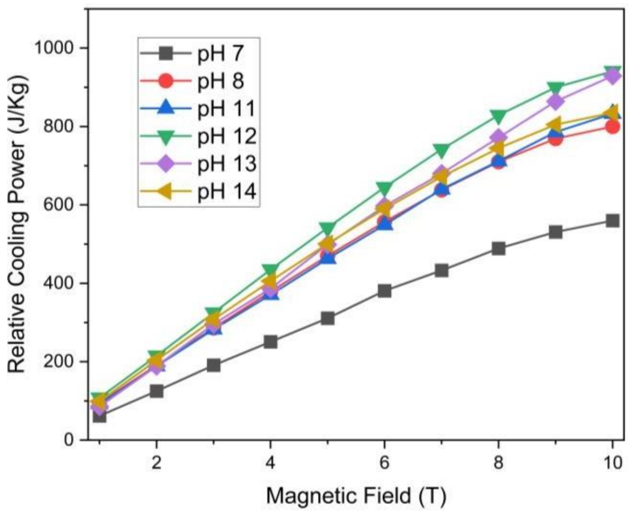
Solid-state refrigeration has attracted the attention of the scientific community for the past few years since it provides an efficient and sustainable alternative to vapour-based cooling. Magnetic field-induced cooling in materials, via the magnetocaloric effect, has environmental benefits since no greenhouse gases are used. Additionally, efficiency may be enhanced by altering material parameters. Considering this, erbium chromate ($ErCrO_3$, ECO) is investigatedin the current work as a potential material for low-temperature magnetic applications, by altering its nanoscale dimensions. ECO was synthesized via an hydrothermal process, where variables including the pH of the final solution (7–14), temperature, and heat treatmentprotocols were controlled to see how they affected the material's structure, morphology, and magnetic characteristics. X-ray diffraction and Rietveld refinements confirmed pure phases of varying pHs. TEM suggests that the pH has a stronger influence on the morphology of the particles, transforming ECO from vertical (rod) to semi-spherical dimensions. In magnetic characterization, temperature-dependent measurements, hysteresis loops, and magnetocaloric studies of all the synthesized samples were conducted. Magnetic transitions and magnetocaloric properties were estimated for all the synthesized samples. Magnetocaloric properties of the pH12 sample were found to be the best, amongst the synthesized samples, as shown in fig. 1, depicting the relative cooling power (RCP), as a function of the magnetic field. Compared to the bulk, these properties are also improved, showing an RCP of 941 J/Kg at 10 T, 742 J/Kg at7 T and 435 J/Kg at 4 T, demonstrating the potential for low-temperature magnetic refrigeration. Experimental results of this investigation indicate that hydrothermal conditions play a role in transforming the morphology of the particles, thereby influencing entropy and consequently, the relative cooling power.

Figure 1: RCP of all the synthesized samples as a function of the applied magnetic field.



P7- Double perovskites for solar cells: Y_2NiMnO_6 a case study

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Multiferroic materials that are both ferroelectric and magnetic have attracted much research interest due to their potential applications in multi-state data storage and electric-field controlled spintronics (e.g. sensors, novel circuits, microwave technology amongothers.). Among all the well-studied multi-ferroic systems, a large number of them are transition metal oxides, especially with perovskite-related structures. R_2NiMnO_6 (R = rare earth) with a double-perovskite structure has attracted much attention due to its unique properties, such as large magnetocapacitance, magnetoresistance, and relaxor ferroelectricity [1]. Y_2NiMnO_6, illustrated in figure 1, is a member of R_2NiMnO_6 with multiferroic character, which has been theoretically predicted with quantum mechanical calculations to be a ferroelectric material with an intrinsic polarization in the E-type ferromagneticground state. It also shows a giant dielectric effect at room temperature. Electrical conduction has been described by the polaron hopping mechanism [2,3]. In this communication, we identify some of the most important properties of the system Y_2NiMnO_6 currently under study, giving a general overview of the workflow, giving emphasis to the already performed work and results in addition to future work to be developed.

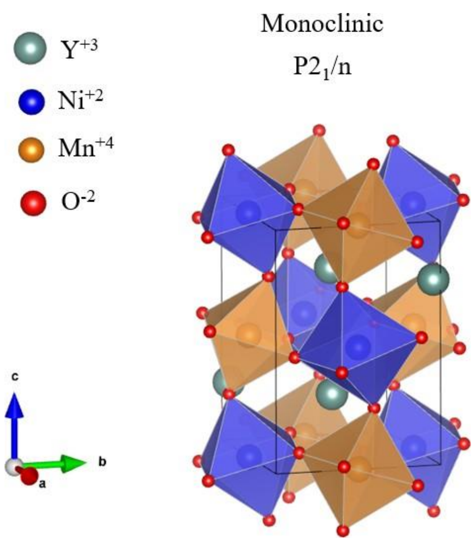

Figure 1: Crystal structure of Y2NiMnO6 (Vesta), with monoclinicsystem symmetry and $P2_1/n$ space group.

[1] Chakraborty, T., Nhalil, H., Yadav, R., Wagh, A. A. & Elizabeth, S. Magnetocaloric properties of R_2NiMnO_6 (R=Pr, Nd, Tb, Ho and Y) double perovskite family. *Journal of Magnetism and Magnetic Materials* **428**, 59–63 (2017).

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P8- Magnetic Signatures of Topological Surface States: A Roadmap for Optimizing Flexible Quantum Materials

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Finding alternative device concepts and materials to support the expansion of Information Technology (IT), in face of the anticipated breakdown of Moore's law for transistor evolution in the next years is one of the biggest ongoing challenges in material science. Topological Insulators (TI) are quantum materials with metallic surface states and an insulating bulk that are made possible by strong spin-orbit interactions [1], features that grant them exotic transport properties, sparking interest in their application to a variety of fields [2]. Still, experimental research into TI is in its infancy, and scalable approaches to both fabricate TI and gain control over the topological surface states (TSS) have yet to be defined [3]. Taking on this challenge, the present work focuses on the enhancement of sputtered Bi2Te3 thin films, a material with a well-documented topological phase, of varying thickness (13, 25, 49, 97 and 191 nm), and exploring the effects of annealing treatments on their structural and electronic properties. As a novelty, the samples are grown onto flexible polyimide substrates, in line with the rising trend in technological innovation of expanding towards wearable devices. A variety of experimental techniques are used to fully characterize the materials; their structure and morphology are studied through Scanning Electron Microscopy, X-Ray Diffraction and Reflectometry, and Raman Spectroscopy, and their transport characteristics by measuring their room temperature conductivity and Seebeck coefficient. However, the key to assessing TSS conduction lies in the magneto-resistive response, where the presence of these channels is revealed at cryogenic temperatures as a Weak Anti-localization Effect (WAL), modelled by a Hikami-Larkin-Nagaoka (HLN) description [4]. The competition between the bulk and surface conduction channels can be tracked by monitoring the model's parameters as the annealing temperature is increased, thus providing a roadmap to study the topological states. The present work depicts how, through thermal annealing treatments, it is possible to both mitigate structural defects arising from the sample's amorphous fabrication and control unwanted bulk contributions, unlocking their topological potential.

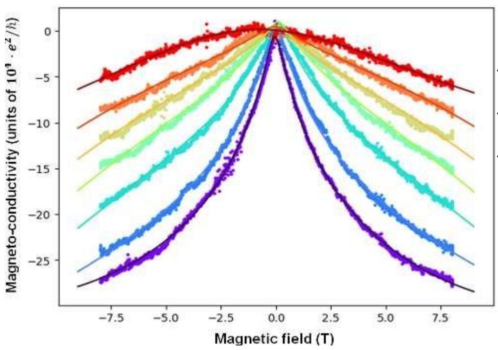

Figure 1: Weak Anti-localization Effect ofthe Magneto-conductance of a 97 nm Bi_2Te_3 thin film.

Acknowledgments: this work was financially supported by Fundação para a Ciência e a Tecnologia (FCT)/MEC and FEDER under Program PT2020 through the projects UIBD/04968/2020 and UIDP/04968/2020 and NORTE-01-0145-FEDER022096 from NECL. The authors are thankful to IFIMUP.

[1] Moore, J., Nature, 464, 194-198 (2010).; [2] Smejkal, L.; Yan, B; Mokrousov, Y.; et. al., Nature Physics, 14, 242-251, (2018).; [3] Teixeira, Sofia F.; Pereira, et. al., APS Applied Electronic Materials, 4, 5789-5798 (2022); [4] Salawu, Y.; Yun, J.; Rhyee, J.; et.al., Nature Scientific Reports, 12, 2845, (2022).

P9- Magnetic ordering in the $Cu(Fe_{1-x}Ni_x)_2Ge_2$ system

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$CuFe_2Ge_2$ is an intermetallic compound crystallizing in the orthorhombic system (space group 51, *Pmma*). Its crystal structure features sawtooth chains of Fe that lie within the *ac* plane. This compound has a complex magnetic behaviour, with a small ferromagnetic component appearing at T_C = 228 K, antiferromagnetic ordering developing at T_N ~175 K and an incommensurate spin-density wave (disclosed by neutron-scattering measurements) at ~125 K [1]. However, a recent Mossbauer spectroscopy study suggests that half of the Fe atoms behave paramagnetically in a large temperature scale (from 4.4 K to 296 K) while only the other half being magnetically ordered [2]. The possibility of near degeneracy of multiple magnetic orderings in these materials resembles that of iron-based superconductors [3]. Substitution studies are thus a perfect playground relevant to better understanding the magnetic ground states but also the mechanisms of unconventional superconductivity. We have succeeded in preparing single-phase samples of $Cu(Fe_{1-x}Ni_x)_2Ge_2$ by solid state synthesis up to 50% substitution of Fe by Ni. Preliminary studies of the evolution of magnetism, from low to half substituted samples, indicate a lowering of T_c as the Ni content increases. In the low temperature region distinct anomalies in the thermomagnetic curves show that the system is driven to the ground state through successive transitions of antiferromagnetic/ferrimagnetic character (Fig. 1). The preferential substitution of Fe by Ni, creating more than one magnetic sublattice, adds to the complexity of the magnetic behaviour of the parent compound.

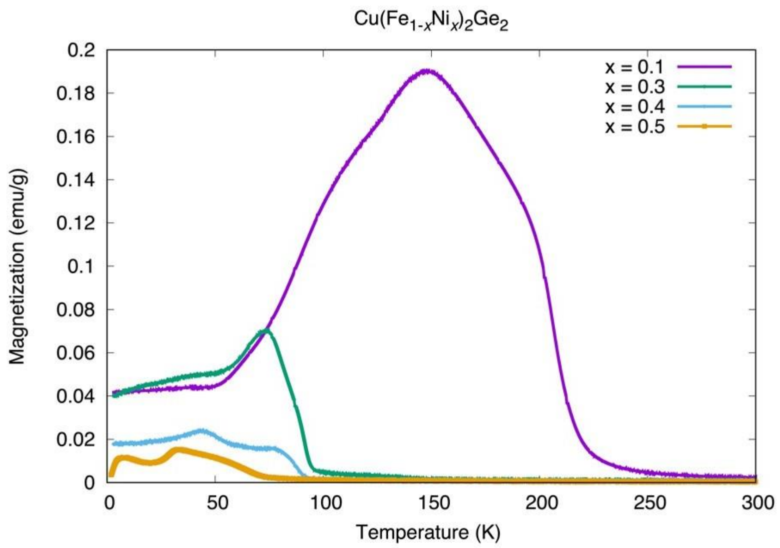

Fig 1 – ZFC thermomagnetic curves (*H* = 100 Oe) of $CuFe_{1-x}Ni_xGe_2$ (*x* = 0,2; 0.3; 0.5).

[1] May, A. F. et al, *Sci. Rep.* **6**, 35325 (2016)

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P10- COMSOL Magnetohydrodynamics Induction Heat Dissipator

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Power electronics play a crucial role in vital sectors such as transportation, renewable energy, and artificial intelligence (AI). As the need for more compact and small devices with higher power densities continues to increase, the challenge of efficiently dissipating higher heat flows becomes more significant. Traditional cooling methods namely, air and water cooling, face limitations in handling high heat fluxes. Thus, in this study, we employed COMSOL simulations to investigate a magnetohydrodynamics (MHD) induction heat dissipator with Galinstan, a liquid metal at room temperature, as the working fluid. Galinstan [1] boasts both high electrical and thermal conductivity. Despite its relatively modest heat capacity, the synergistic effect of these properties results in a 42% reduction in the overall thermal resistance compared to water [2]. Our simulated system comprises a circular channel filled with Galinstan, and a rotor embedded with NdFeB permanent magnets. The simulations involve rotating magnetic fields, induced currents, and the Lorentz force arising from their combination. Additionally, we conducted a detailed examination of Galinstan velocity as a function of rotor frequency. To evaluate the system's performance, we placed a heat source and a heat sink on opposite sides of our geometry and conducted a time-dependent study of the system'stemperature.

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[1] Castro, I. A. et al, *Nano Lett.* 2017, 17, 12, 7831–7838

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P11- Synthesis of cobalt-doped manganese ferrites through eco-friendly methodsfor thermo-therapeutic applications

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Biomedical applications require high-quality magnetic nanoparticles. However, the synthesis through environmentally friendly methods is a major challenging task. In this work, multi- and single-core citrate-stabilized cobalt and/or manganese-doped ferrite ($Co_xMn_{1-x}Fe_2O_4$, $0 \leq x \leq 1$) nanoparticles were synthesized through eco-friendly methods: oxidative precipitation and oxidative hydrothermal synthesis. The nanoparticles morphology and structure were found to be influenced by the Co^{2+}/Mn^{2+} ratio and synthesis method. Particularly, the oxidative precipitation afforded multicore nanoparticles (crystallite size in the2 - 10 nm range), while the oxidative hydrothermal synthesis provided single-core nanoparticles (crystallite size in the 4 - 11 nm range). The mixed ferrites displayed superparamagnetism at room temperature and improved saturation magnetization than stoichiometric cobalt and manganese ferrites. Besides, the nanoparticles exhibited great colloidal stability at physiological pH and intrinsic fluorescence emission in the violet-green range. The heat generation through magnetic hyperthermia and photothermia effects was assessed. High heating efficiencies were obtained for several alternating magnetic field conditions (up to ~2.5 nHm^2/kg) compatible with biological applications. The nanoparticles also exhibited high light-to-heat conversion efficiency (up to ~53%) with near infrared (NIR) laser irradiation at 808 nm. Hence, the oxidative precipitation and oxidative hydrothermal synthesis are promising methods for the development of nanoparticles. Besides, the synthesised cobalt and/or manganese-doped ferrites displayed suitable properties for biomedical applications, such as magnetic hyperthermia, photothermia and as prospective fluorescent probes for bioimaging.

Acknowledgements: **: t**his work was funded by the Portuguese Foundation for Science and Technology (FCT) in the framework of the Strategic Funding of CF-UM-UP (UIDB/04650/2020, UIDP/04650/2020), CICECO Aveiro Institute of Materials (UIDB/50011/2020, UIDP/50011/2020 and LA/P/0006/2020). S.R.S. Veloso acknowledges FCT for a PhD grant (SFRH/BD/144017/2019). Support from MAP-Fis Doctoral Programme is also acknowledged.

P12- Magnetic properties of high aspect-ratio nanostructures for biomedical applications

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Progress in nanotechnology, particularly in the nanoparticles research field, has allowed the synthesis of nanostructures with precise morphologies and to suitably modify particles' surfaces, manipulating their characteristics for precise applications. Extensive studies have been carried out, and protocols have been developed, aiming the optimization ofnanoparticles' characteristics such as composition, surface charge, shape, size, size distribution, and magnetic properties. With the latest evolution and demands in nanomedicine, magnetic nanostructures (MNNs) are attracting increasing attention due to their potential to improve conventional therapeutic procedures and traditional clinical diagnostic, as well as to introduce novel approaches in biomedicine and tissue engineering. Among several MNNs that have been developed, the ones that exhibit fast change of themagnetic state with the application of an external field, negligible remanence (magnetizationat zero field) and coercivity (the field required to bring the magnetization to zero), are usually desired. These features are essential in biomedicine, as they prevent particles' agglomeration when dispersed in solution. Thus, this specific type of NS must combine high susceptibility and/or loss of magnetization after removal of the magnetic field, which make Superparamagnetic nanoparticles (SP-NPs), vortex state nanodiscs, high aspect-ratio nanowires (NWs), and ellipse/needle-like magnetic nanostructures very suitable in biomedicalapplications because of their unique magnetic properties and spin configurations. In this framework, high aspect-ratio Fe NWs and ellipse/needle-like magnetite nanoparticles with different sizes and shapes have been successfully fabricated through two different bottom-up approaches, namely electrodeposition into porous anodic alumina templates and hydrothermal synthesis, respectively. Such magnetic nanostructures, after the appropriate surface functionalization, have found applications in several areas in the fight against cancer disease owing to their exclusive capability in magnetic targeting, magnetic resonance imaging, and hyperthermia.

P13- Magnetic nanoparticles for cancer treatment through magnetic hyperthermia

Bárbara Costa [1], Sílvia Soreto[1], Manuel Graça[1] Sílvia Gavinho [1], João Carvalho[1], Tânia Vieira[2], Jorge Carvalho Silva[2], Paula I. P. Soares [2], Manuel Valente[1]

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Cancer is a major worldwide public health problem. Since 1957[1] Magnetic Hyperthermia (MH) is described in the literature as a promising therapy for cancer treatment. Consisting of heating the tumour cells to a temperature of 40-46 °C through the different mechanisms of relaxation of Magnetic Nanoparticles (MNPs), it is responsible for selectively kill cancer cells through mechanisms of apoptosis without causing severe side effects on the surrounding tissues [2],[3]. Biocompatibility, good heating efficiency and non-toxicity are some of the essential requirements for the use of MNPs in MH[4]. The objective of this work is to develop a new nanocomposite of Gadolinium Ferrite ($Gd3Fe5O12$) and Zinc Ferrite ($ZnFe2O4$) to be used in magnetic hyperthermia through a proteic sol-gel method with powder coconut water. A nanocomposite with a constitution of 65% $Gd3Fe_5O_{12}$ and 10% $ZnFe_2O4$ was synthesized. After the production of the nanocomposite, a structural, morphological, magnetic and biological analysis was performed. For the synthesis of the nanocomposite, $Gd_3Fe_5O_{12}$ samples heat-treated at 1200 °C for 24h, and $ZnFe_2O_4$ heat-treated at 1200 °C for 4h. To reduce their size, a planetary ball mill was used during a total of 96h. The performed structural analysis identified a phase of SiO_2, a contamination that resulted from the agate balls used for the milling process. Morphological (SEM) characterization revealed a diameter of 155 nm for the synthetized nanocomposite. Magnetic analysis revealed that at room temperature the nanocomposite exhibits a saturation magnetization of 11.56 emu/g and assumes ferromagnetic behaviour. A low specific absorption rate (SAR) of 0.5 ± 0.2 (W/g) was registered. In terms of cytotoxicity, for concentrations below 10 mg/mL, the composite does not appear to have cytotoxic behaviour. Despite the results obtained, this innovative nanocomposite presents interesting features. However, its low SAR denotes a limitation to be used for magnetic hyperthermia.

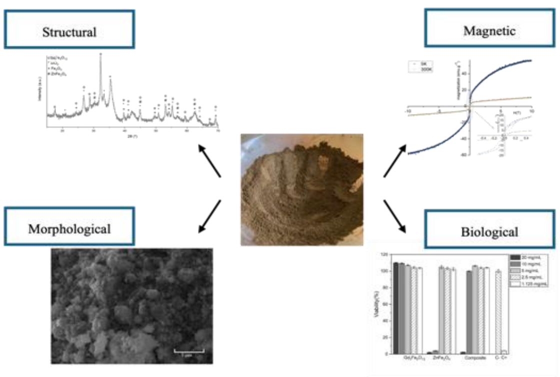

Figure 1: Characterization of the nanocomposite: structural, magnetic, morphological, and biological

Acknowledge funding: This research was funded by national funds (OE), through FCT— Fundação para a Ciência e a Tecnologia, I.P., in the scope of the framework contract foreseen in the numbers 4, 5 and 6 of the article 23, of the Decree-Law 57/2016, of 29 August, changed by Law 57/2017, of 19 July.

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P14- Synthesis of iron oxide particles by a biogenic sol-gel route for biomedicalapplications

Juliana Jesus [1], Joana Regadas [1], Bárbara Costa [1], João Carvalho [1], Sílvia Gavinho [1], Ana Pádua [2], Célia Henriques [2], Paula I. P. Soares [3], Manuel Graça [1], and Sílvia Soreto [1]

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This research focuses on the synthesis and characterization of magnetite particles for magnetic hyperthermia. The particles were synthesized using a protein-based sol-gel method, employing a solution of powdered coconut water as the solvent and iron chlorides as the reagents. The resulting samples were subjected to structural, morphological, magnetic, and biological characterization techniques (Figure 1). X-ray diffraction analysis confirmed the presence of pure-phase magnetite in samples treated at 700 °C and 400 °C (washed powder) for 4 h under an argon atmosphere. Morphological analysis revealed the presence of micrometer-sized grains in the samples. Magnetic characterization demonstrated that samples treated at 350 °C for 48 h, and 700 °C and 400 °C (washed powder) for 4 h, exhibited saturation magnetization values of 37, 76, and 10 emu/g, respectively, at 300 K. Additionally, specific absorption rate (SAR) values were determined, indicating the heat generation capability of the particles when exposed a magneticfield of with an amplitude of 300 G (~24 KA/m) and a frequency of 338.4 KHz for 10 min. TheSAR values obtained were 27.1, 19.9, and 14.1 W/g for the samples mentioned above. All samples exhibited ferrimagnetic behavior [1]. Finally, biological characterization demonstratedthat for concentrations below 10 mg/mL all samples were not cytotoxic, indicating their biocompatibility and potential suitability for biomedical applications.

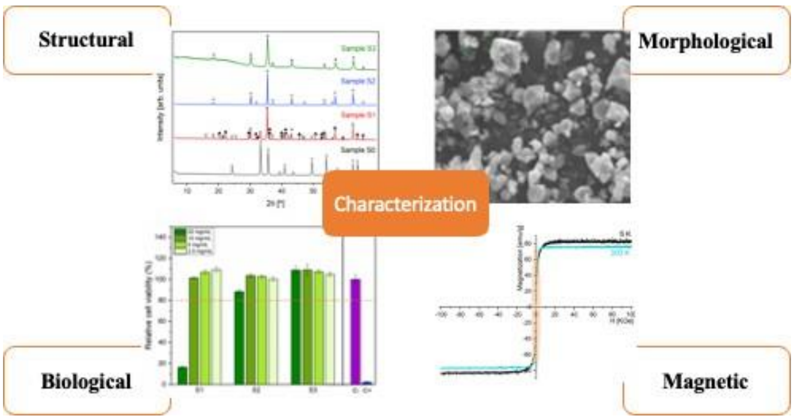

Figure 1 Characterization methods.

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P15- Characterization and modelling of CoFeB films towards SOT magnetic sensors

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This work represents the starting point of an investigation towards the development of a 3D magnetic sensor using only a single element. These sensors take advantage of the spin-orbit interaction that arises at the interface of a heavy metal and a ferromagnet [2]. Previous work [1] shows a linear output that depends on the current density and the ability to measure the 3 components of the external magnetic field. Different multilayers are characterized magnetically, namely Ta (10)/ Co60Fe20B20 (1.2)/MgO (1.6)/Ta (20) and another of Ta (5)/Ir (5)/Co60Fe20B20 (1.2)/MgO (1.6)/Ta (20), all thicknesses in nanometres. The first acts as a reference, following [1], while the second one has an Iridium layer to study changes in magnetic properties, expecting the ability to detect higher magnetic fields. All these measurements were possible due to the development of a dedicated measurement protocol for the SQUID MPMS®3 to measure magnetization *vs* magnetic field ((H)) loops in plane and out of the plane. Every step of the protocol and some recent improvements will be detailed in this work. With these measurements we can obtain magnetic characteristics such as anisotropy field, saturation magnetization, and the coercive field of the different samples. Alongside experimental characterization, a macro-spin model was developed, that accounts for the perpendicular anisotropy, the demagnetizing field and the external magnetic field [3]. As a first approximation, it also includes an effective magnetic field to mimic the effect of the spin orbit torque in the thin film magnetization. Using our experimental data as input to the model we are able to predict the necessary critical current to linearize the hysteresis loop and obtain the expected linear range.

Funding: IFIMUP, Departamento de Física e Astronomia da Faculdade de Ciências da Universidade do Porto, Rua do Campo Alegre s/n, Porto 4169-007, Portugal

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Scientific Program – Schedule

Magnetism in Portugal 2024 – School of Metrology in Magnetism,
1-2 February, IST-CTN, Bobadela

Day 1

	Thursday Feb. 1st
08:30	Registration
09:00	**Welcome Reception**
09:15	**Isabel Godinho** Metrology and Magnetism
10:00	**Olivier Fruchart** Units in Magnetism
10:45	Coffee Break
11:15	**Cindi Dennis** Introduction to the Fundamentals of Nanomagnetism
12:00	**Victorino Franco** Magnetometry: understanding the techniques behind the black box
12:45	Lunch
14:00	**Carlos Amorim** Hands - on: Magnetometry
16:00	Coffee Break
16h30	Poster Session
20:00	Dinner

Day 2

	Friday Feb. 2nd
09:15	**Susana Freitas** Magnetic ultrathin films and interface control
10:00	**Bruno Vieira** Mössbauer Spectroscopy
10:45	Coffee Break
11:15	**António Paixão** Neutron scattering techniques
12:00	Lunch
14:00	**Bruno Vieira** Hands - on: Mössbauer Spectroscopy
15:30	Poster Session + Group Formation
16:00	**Cindi Dennis** Hands - on: Putting It All Together: Quantitative Measurements in Nanomagnetism
17:30	Coffee Break
18:00	Closing Ceremony + Award