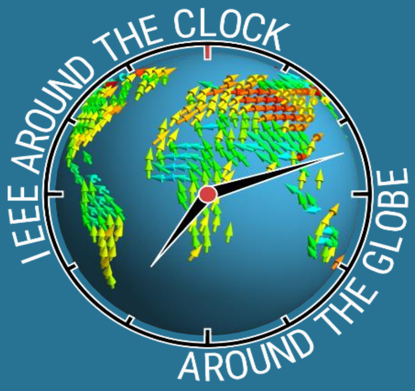

IEEE Around-the-Clock Around-the-Globe (AtC-AtG) 2022

Brought to you by IEEE Magnetics Society

PROGRAM BOOKLET

AUGUST 31, 2022

24-hour non-stop virtual conference on magnetism

IEEE
MAGNETICS

Contents

Program Overview

Welcome to the 2022 Around-the-Clock Around-the-Globe Magnetics Conference (AtC-AtG), which will be held online on the 31st of August 2022. AtC-AtG is a 24-hour non-stop virtual conference with speakers from all over the world passing the baton to each other. Join, interact, and network at any time – for free. The contributed talks are reserved for students and post-doctoral researchers only.

The scope of the conference is to bring together early-stage researchers through a series of oral and poster presentations and networking opportunities and provide an international platform to discuss recent progress and trends in the field of magnetism, ranging from fundamental to applied aspects.

The technical program includes 12 invited talks from senior scientists in the international magnetics community, 52 contributed oral presentations, and 70+ contributed poster presentations from graduate students and post-doc researchers worldwide. This conference is organized by the newest generation of magnetics professionals (featuring graduate students and postdocs from around the globe), aiming to provide an opportunity for worldwide participants to meet and discuss the development in key areas of magnetism research.

The AtC-AtG conference is divided into virtual sessions based around three geographic locations and time zones; they are 1) Asia / Pacific, 2) Europe / Middle East / Africa, and 3) Americas. Oral presentations will be hosted on the Zoom virtual conferencing platform by subcommittees located in different regions of the world. In parallel, interactive poster sessions and networking will be held in the Gather.Town virtual platform.

The AtC-AtG conference is sponsored by:

Poster Sessions / Networking in Gather.Town

We are very excited to add poster sessions and networking opportunities to this year's conference using gather.town, a proximity-based video conferencing tool. Every participant has a video-game like "avatar" which you use to walk around the map, and when you get close to people you can talk to them. The link will be shared with registrants only.

Conference Policies

Attendees should not record the talks given during this conference. All participants should act professionally, and will treat each other with respect at all times.

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AtC-AtG CONFERENCE PROGRAM

31 August 2022

Opening session

UTC	CEST	JST	PDT	EDT
-00:15	01:45	08:45	16:45	19:45

Session 1

UTC	CEST	JST	PDT	EDT
00:00	02:00	09:00	17:00	20:00

00:00	*Invited speaker:* *Fanny BÉRON*	*Tuning isolated zero-field skyrmions and spin spirals at room-temperature in synthetic ferrimagnetic multilayers*	Brasil
00:45	Ekaterina DENGINA	*Neural network prediction of nanodefects and magnetic anisotropy in FePt-X HAMR Media*	Japan
01:00	María Soledad APREA	*Magnetic properties of polycrystalline cylindrical $Fe_{65}Pd_{35}$ nanowires*	Argentina
01:15	Susant Kumar ACHARYA	*Ionic liquid gating control of magnetic anisotropy in magnetic tunneling junction stacks*	New Zealand
01:30	Adam G WHITNEY	*Damping in STT-MRAM free layers at elevated temperatures*	USA
01:45	McCoy Wei LIM	*Current-induced nucleation of magnetic skyrmions in multilayered devices*	Singapore

Session 2

UTC	CEST	JST	PDT	EDT
02:00	04:00	11:00	19:00	22:00

02:00	Sen YAN	*Extracellular magnetic labeling of mesenchymal stem cell spheroids with ferumoxytol for MRI tracking*	China
02:15	Yuhua REN	*Estimation of magnetic parameters from domain images with convolutional neural networks*	Singapore
02:30	Esita PANDEY	*Emergence of sizeable interfacial Dzyaloshinskii-Moriya interaction at Cobalt/Fullerene spinterface*	India
02:45	*Invited speaker:* *Max HIRSCHBERGER*	*Spin Dynamics and electronic transport: emergent inductance and chiral fluctuations*	Japan
03:15	**Poster session / Social activity** *(Gather.Town)*		

Session 3

UTC	CEST	JST	PDT	EDT
04:00	06:00	**13:00**	21:00	00:00

04:00	*Invited speaker:* Se Kwon KIM	*Topological spin transport in two-dimensional magnets*	South Korea
04:30	Ming Sheng Nicholas TEY	*Hardware accelerated spiking neural networks based on zero-field skyrmions*	Singapore
04:45	Koustuv ROY	*Spin Pumping and Inverse spin Hall effect in Co_3O_4*	India
05:00	Shaktiranjan MOHANTY	*Magnetization reversal and domain structures in perpendicular synthetic antiferromagnets prepared on rigid and flexible substrates*	India
05:15	Soumyaranjan RATHA	*Enhancement of magnetic properties by Lanthanides substitution in $(Bi,L)(Fe,Co)O_3$ (L = La, Nd, Sm, Gd, Dy, Er) multiferroic thin films*	Japan
05:30	Brindaban OJHA	*Excess velocity of domain walls in Pt/CoFeB thin films*	India
05:45	Michael DEREVYANKO	*Temperature dependence of electric impedance of the Cobalt-based soft magnetic wires near the ferromagnetic phase transition*	Russia

Session 4

UTC	CEST	JST	PDT	EDT
06:00	**08:00**	**15:00**	23:00	02:00

06:00	Rajeswari ROY CHOWDHURY	*An alternative route for tuning unconventional Hall effect in layered ferromagnet $Fe_3(Ge,As)Te_2$*	India
06:15	Ravindra MEENA	*Europium coated Mn doped Fe_2O_4 nanoparticle for Magnetic hyperthermia: Synergistic strategy for cancer treatment and imaging*	India
06:30	Jintao SHUAI	*Enhanced domain wall motion by surface acoustic waves*	UK
06:45	*Invited speaker:* Peng SONG	*Detection of 2D magnetic states with spin Hall effects*	Singapore
07:15	**Poster session / Social activity** *(Gather.Town)*		

Session 5

UTC	CEST	JST	PDT	EDT
08:00	10:00	17:00	01:00	04:00

08:00	*Invited speaker:* Xichao ZHANG	*Frustrated skyrmions and bimerons*	Japan
08:45	Mona BHUKTA	*Room-temperature stabilization of skyrmionic surface-magnetic textures in synthetic antiferromagnets*	Germany
09:00	Anastasiia Evgenievna DRIAGINA	*Synthesis and magnetic properties of nanowires in thin-film anodic alumina*	Russia
09:15	Aijaz Hamid LONE	*Skyrmion based neuromorphic device with short- and long-term synaptic plasticity*	Saudi Arabia
09:30	Zilu WANG	*Field-free spin orbit torque switching of synthetic antiferromagnet through interlayer Dzyaloshinskii-Moriya interaction*	China
09:45	Sumit GHOSH	*Ultrafast optical generation of magnetic texture pairs*	Germany

Session 6

UTC	CEST	JST	PDT	EDT
10:00	12:00	19:00	03:00	06:00

10:00	Luciano MAZZA	*Unconventional computing using spintronic oscillators*	Italy
10:15	Maarten Alexander BREMS	*Brownian reservoir computing realized using geometrically confined skyrmions*	Germany
10:30	Marta BRIOSCHI	*All-optical generation and time-resolved polarimetry of magneto-acoustic resonances via Transient Grating spectroscopy*	Italy
10:45	*Invited speaker:* Claire DONNELLY	*Visualising three-dimensional spin textures*	Germany
11:15	**Poster session / Social activity** *(Gather.Town)*		

Session 7

UTC	CEST	JST	PDT	EDT
12:00	14:00	21:00	05:00	08:00

12:00	*Invited speaker:* **Mariia EFREMOVA**	*Genetically controlled magnetic nanocompartments for cell manipulation - better than ferritin?*	Netherlands
12:30	Lin LUO	*Microstructure and magnetocaloric effect of $Mn_{1.3}Fe_{0.6}P_{0.5}Si_{0.5}$ microwires*	Spain
12:45	Gunasheel Kauwtilyaa KRISHNASWAMY	*Time-dependent multistate switching of topological antiferromagnetic order in Mn_3Sn*	Switzerland
13:00	Lionel PETIT	*Graphene Hall sensors for high performance magnetometry*	France
13:15	Javier HERMOSA	*3D magnetic structure of Py microstructures studied by vector tomography and micromagnetism*	Spain
13:30	Martín TESTA-ANTA	*Leveraging symmetry for an accurate spin-orbit torque quantification in ferrimagnetic insulators*	Spain
13:45	Sebastián Alejandro DÍAZ	*Steering Majorana braiding via skyrmion-vortex pairs: A scalable platform*	Germany

Session 8

UTC	CEST	JST	PDT	EDT
14:00	16:00	23:00	07:00	10:00

14:00	Juan Diego AGUILERA	*Gas sensors using magnetic nanoparticles and spin waves*	Spain
14:15	Oliver James AMIN	*Antiferromagnetic half-skyrmions electrically generated and controlled at room temperature*	UK
14:30	Joanna WOLFF	*Optomechanics of magnetic van der Waals heterostructures*	France
14:45	*Invited speaker:* Alexander MOOK	*Interacting Topological Magnons*	Germany
15:15	**Poster session / Social activity** *(Gather.Town)*		

Session 9

UTC	CEST	JST	PDT	EDT
16:00	18:00	01:00	09:00	12:00

16:00	*Invited speaker:* Miriam JAAFAR	*Advances in magnetic force microscopy*	Spain
16:45	Marco Antonio MORALES	*$Mn_xFe_{3-x}O_4$ Nanoparticles for Magnetic Hyperthermia*	Argentina
17:00	Alberto ANADÓN	*Spin conversion in epitaxial monolayer graphene structures*	France
17:15	César Leandro LONDOÑO CALDERÓN	*Magnetic vortex domain wall observation on iron-cobalt alloy nanowires growing on commercial aluminium*	Colombia
17:30	Meg SMITH	*Optimisation of perpendicular magnetic tunnel junction structures using scanning transmission electron microscopy*	UK
17:45	Cody Alexander TREVILLIAN	*Interferometry of Single Magnon Decoherence Mechanisms*	USA

Session 10

UTC	CEST	JST	PDT	EDT
18:00	20:00	03:00	11:00	14:00

18:00	Estela HERGUEDAS-ALONSO	*Recovering 3D magnetization of 2D structures and multilayers*	Spain
18:15	TBA	*TBA*	TBA
18:30	Matthew Ronald MCMASTER	*Tuneable low magnetostrictive NiFe multilayers for high-frequency application*	UK
18:45	*Invited speaker:* Jennifer SEARS	*Resonant X-ray Measurements of Magnetism in $RuCl_3$*	USA
19:15	**Poster session / Social activity** *(Gather.Town)*		

Session 11

UTC	CEST	JST	PDT	EDT
20:00	22:00	05:00	13:00	16:00

20:00	*Invited speaker:* Gabriel LAVORATO	*Hybrid magnetic nanoparticles: from synthesis to applications*	Argentina
20:30	Sebastian Eduardo PASSANANTE	*Magnetocaloric effect in nanocrystalline manganite bilayer thin films*	Argentina
20:45	Robin KLAUSE	*Magnetic droplet solutions from exotic spin-orbit torques*	USA
21:00	Petro ARTEMCHUK	*Stabilization of a nonlinear spin wave bullet mode in the presence of a hot magnon gas*	USA
21:15	Fabiana Nakary MORALES	*Magnetocaloric effect of* $La_{0.6}Sr_{0.4}CoO_3$ *nanoparticles*	Argentina
21:30	Hannah BRADLEY	*Neuromorphic pattern recognition using antiferromagnetic artificial neurons*	USA
21:45	Cristóbal Ríos VENEGAS	*Dynamic origin of conical helix magnetization textures stabilized by Dzyaloshinskii-Moriya interaction*	Chile

Session 12

UTC	CEST	JST	PDT	EDT
22:00	00:00	07:00	15:00	18:00

22:00	Josefina M SILVEYRA	*A new set of curves simplifies anhysteretic magnetization analysis*	Argentina
22:15	Santiago Antonio OSORIO	*Response of the chiral soliton lattice to spin polarized currents*	Argentina
22:30	Yeni Josefina SANCHEZ	*Magnetic and structural characterization of the* $FeIn_{2y}Cr_{2-2y}S_4$ $(0.6 \le y \le 1)$ *system*	Venezuela
22:45	Gilvania Lucia da Silva VILELA	*Magnon valves with perpendicular magnetic anisotropy*	Brazil
23:00	**Poster session / Social activity** *(Gather.Town)*		
23:30	*Invited speaker:* Jean Anne INCORVIA	*Using Magnetic Spin Textures for Cognitive Computing*	USA
24:00	**Parting words & Aftershow party** *(Gather.Town)*		

INVITED TALKS

Abstracts

List of Invited Talks

Tuning isolated zero-field skyrmions and spin spyrals at room-temperature in synthetic ferrimagnetic multilayers

Fanny Béron*[3], J. Brandño[1], D. A. Dugato[1,2],
M. V. Puydinger dos Santos[3], J. C. Cezar[1],

[1]Labratorio Nacional de Luz Śincrotron (LNLS),
Centro de Pesquisa em Energia e Materiais (CNPEM), Brazil
[2]Departamento de Física Universidade Federal de Santa
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[3]Institute of Physics “Gleb Wataghin”, University of
Campinas, Brazi

Antiferromagnetic spintronics is a promising alternative to ferromagnetic systems, mainly due to the absence of stray fields and possibilities of operating in the terahertz regime. However, AFM materials inherently difficult the magnetic spins control by currents and/or magnetic fields. Recently ferrimagnetic materials, which consist of anti-parallel yet uncompensated magnetic sublattices, emerged as a suitable solution. Here, the objective was to observe individual skyrmions at room-temperature and under null external magnetic field in ferrimagnetic multilayers. The study, performed in collaboration of the Brazilian Synchrotron Light Laboratory (LNLS), showed through element specific X-ray magnetic circular dichroism (XMCD) that uncompensated ferrimagnetic orientation between Co and Gd atoms remains in synthetic Pt/CoGd/Pt ferrimagnetic multilayers with sub-nanometer thick [1]. While spin spyrals were observed by magnetic force microscopy for thicker CoGd layers ≥ (1.2 nm), the tunable enhanced perpendicular magnetic anisotropy and remanent magnetization leads to isolated zero-field skyrmions for thinner CoGd ≥ (0.9 nm). The demonstration of stable skyrmions in perpendicularly magnetized materials with antiparallel exchange-coupling is a promising step towards future antiferromagnetic-based devices for spintronics applications.

References

[1] J. Brandao *et al.*, *Applied Surface Science*, vol. 585, p. 152598, 2022.

Speaker biography

Prof. Dr. Fanny Béron is an associate professor in physics and engineering physics at the University of Campinas (UNICAMP), in Brazil, where she completed her post-doctorate in 2012. She obtained her PhD in Engineering Physics in 2008 from École Polytechnique de Montreal (Canada). Her research interests encompass the development of novel magnetic nanostructures, mainly nanowires, focusing on spintronics and nanoelectronics applications. She is acting as Editor of the IEEE Magnetics Letter journal. She received the Carolina Nemes Award in 2018, for early-career female physicist in Brazil, and the Zeferino Vaz Academic Recognition Award in 2020, for her excellence in academic, research, and outreach activities.

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Spin Dynamics and electronic transport: emergent inductance and chiral fluctuations

Max Hirschberger*[1,2],
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Coming soon!

References

Speaker biography

Coming soon!

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Topological spin transport in two-dimensional magnets

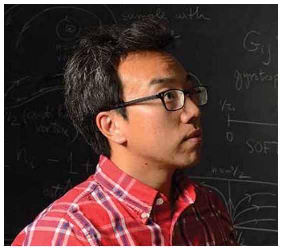
Se Kwon Kim*[1]
[1]Korea Advanced Institute of Science and Technology

Recently discovered two-dimensional magnets have been shown to support a variety of new spin-transport phenomena, which have not been found in bulk magnets. In this talk, we will discuss two illuminating examples in this research direction. The first topic is a magnonic topological insulator realized in an easy-axis two-dimensional ferromagnet such as $\mathrm{CrI_3}$, which is shown to give rise to the thermal Hall effect via the finite Berry curvature of magnons [1]. The second one is a magnetic Berezinskii-Kosterlitz-Thouless (BKT) transition in easy-plane 2D magnets [2]. The talk will be concluded with a future outlook on novel types of spin-transport phenomena in more general two-dimensional magnets.

References

[1] S. K. Kim *et al.*, *Phys. Rev. Lett.*, vol. 177, p. 227201, 2016.
[2] S. K. Kim and S. B. Chung, *SciPost Phys.*, vol. 10, p. 068, 2021.

Speaker biography



Se Kwon Kim obtained his Ph.D. from Johns Hopkins University in 2014 under the supervision of Oleg Tchernyshyov. After conducting research at the University of California, Los Angeles, as a Postdoctoral Research Fellow under the supervision of Yaroslav Tserkovnyak from 2014 to 2018, and working at the University of Missouri as an Assistant Professor, Vineyard Chair, from 2018 to 2020, he joined the Korea Advanced Institute of Science and Technology (KAIST) as an Assistant Professor in 2020. His research focuses on quantum spin dynamics, including the fundamental physics of magnetism and superconductivity.

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Detection of 2D magnetic states with spin Hall effects

Peng Song*[1]

[1]School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore

As an all-electrical scheme to generate, detect and manipulate spin current, the spin Hall effect (SHE) has been heavily investigated as a primary route towards next-generation spintronic devices. SHE-enabled readout of magnetic states (spin states) is central to the operation of energy efficient spin logic device. However, the spin readout signal of nanomagnets based on SHE in heavy metals, which is typically less than 10 mΩ, falls severely short of the operation standards in practical spin logic devices. In this talk, I will discuss our recent efforts of achieving highly efficient read out of 2D ferromagnetic states with topological semimetals. Our demonstration paves the way for integrating 2D ferromagnets into future memory and logic devices.

Speaker biography

Dr. Song Peng received his Bachelor degree in 2012 at Fudan University, and PhD degree in 2016 at National University of Singapore (NUS). From 2017 to 2021, he continued his postdoc research at NUS with Prof. Loh Kian Ping and then at Max Planck Institute of Microstructure Physics with Prof. Stuart Parkin. His research in two-dimensional materials and electronic devices has made several major breakthroughs and has led to publications in top scientific journals (Nature, Nature Materials etc). In May 2021, he was awarded the prestigious Nanyang Assistant Professorship at Nanyang Technological University, Singapore, with joint appointment in the School of Electrical & Electronic Engineering and School of Materials Science and Engineering.

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Frustrated Skyrmions and Bimerons

Xichao Zhang*[1]
[1]Department of Electrical and Computer Engineering, Shinshu University, Japan

Skyrmions and bimerons are typical topological spin textures that can be stabilized in frustrated magnetic systems with competing exchange interactions [1]–[3]. They have multiple degrees of freedom, which could be manipulated by external driving forces and thus, may lead to novel applications, such as the helicity-based information processing in nanoscale devices. Therefore, it is important to understand the fundamental physical properties of frustrated skyrmions and bimerons, and to explore their potential applications.In this talk, I will first briefly introduce topological spin textures in magnetic systems. [4] I will then talk about the static and dynamic properties of isolated skyrmions and bimerons in a magnetic monolayer with frustrated exchange interactions. [5], [6] I will focus on the discussion of the dynamic behaviors of isolated skyrmions and bimerons driven by spin torques, including linear motion, elliptical motion, and rotation. Besides, I will discuss the current-induced dynamics of a three-dimensional skyrmion string in a frustrated multilayer system. [7] Finally, at the end of the talk, I will share some views on possible future directions for the study of topological spin textures, which are not limited to the frustrated magnetic systems.

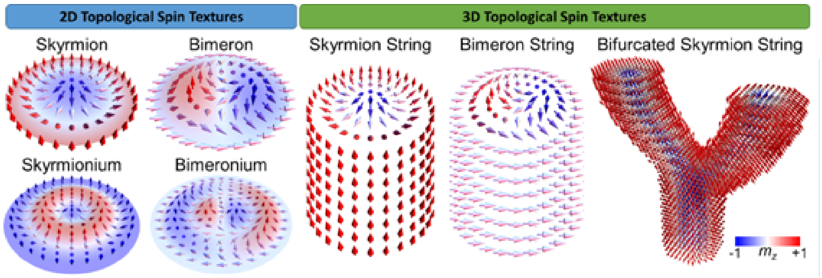

Figure 1. Different types of two-dimensional (2D) and three-dimensional (3D) topological spin textures, including skyrmion, bimeron, skyrmionium, bimeronium, skyrmion string, bimeron string, and bifurcated skyrmion string.

This work was done in collaboration with J. Xia, O. A. Tretiakov, H. T. Diep, L. Shen, Z. Hou, W. Wang, J. Yang, G. P. Zhao, M. Ezawa, Y. Zhou, and X. Liu. This work was supported by JSPS KAKENHI (Grant No. JP20F20363).

References

[1] A. O. Leonov and M. Mostovoy, *Nature Communications*, vol. 6, p. 8275, 2015.
[2] S.-Z. Lin and S. Hayami, *Physical Review B*, vol. 93, p. 064430, 2016.
[3] A. O. Leonov and M. Mostovoy, *Nature Communications*, vol. 8, p. 14394, 2017.
[4] X. Zhang *et al.*, *Journal of Physics: Condensed Matter*, vol. 32, p. 143001, 2020.
[5] X. Zhang *et al.*, *Nature Communications*, vol. 8, p. 1717, 2017.
[6] X. Zhang *et al.*, *Physical Review B*, vol. 101, p. 144435, 2020.
[7] J. Xia *et al.*, *Physical Review B*, vol. 105, p. 214402, 2022.

Speaker biography

Xichao Zhang is a JSPS Postdoctoral Fellow at the Department of Electrical and Computer Engineering at Shinshu University, Japan. He received his Ph.D. degree from Shinshu University in 2018. His research focuses on the theoretical study of topological spin textures and dynamics. He has coauthored more than 90 peer-reviewed papers, and his Google Scholar citations are over 5000 with an h-index of 33 in March 2022. He serves as a Guest Editor of Journal of Magnetism and Magnetic Materials, a Guest Editor of Magnetism, and a Guest Associate Editor of Frontiers in Physics. He is a member of the IEEE.

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Visualising three-dimensional spin textures

Claire Donnelly*[1]
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Three dimensional magnetic systems promise significant opportunities for applications, for example providing higher density devices and new functionalities associated with complex topology and greater degrees of freedom [1].

In this talk I will speak about our work making use of X-ray magnetic tomographic techniques to map the static configuration, and dynamic behaviour, of topological magnetic structures. As well as the spontaneous formation of Bloch point singularities and magnetic vortex rings in the bulk [2], [3], 3D spin textures can also be introduced via the patterning of complex 3D magnetic nanostructures [4], leading to the realisation of highly coupled curvilinear systems. These new experimental capabilities for 3D magnetic systems open the door to complex three-dimensional magnetic structures, and their dynamic behaviour.

References

[1] A. Fernández-Pacheo *et al.*, *Nature Communications*, vol. 8, p. 24, 2017.
[2] C. Donnelly *et al.*, *Nature*, vol. 547, p. 328, 2017.
[3] C. Donnelly *et al.*, *Nature Physics*, vol. 17, p. 316, 2020.
[4] C. Donnelly *et al.*, *Nature Nanotechnology*, vol. 17, p. 136, 2022.

Speaker biography

Following her Masters in Physics at the University of Oxford, Claire went to Switzerland to carry out her Ph.D. studies at the Paul Scherrer Institute and ETH Zurich. She was awarded her Ph.D. in 2017 for her work on 3D systems, which was recognized by a number of prizes including the APS Richard Greene Dissertation Award, the Werner Meyer-Ilse Memorial Award, the ETH Medal, and the SPS Award for Computational Physics. After a postdoc at the ETH Zurich, she moved to the University of Cambridge and the Cavendish Laboratory as a Leverhulme Early Career Research Fellow, where she was awarded the L'Oreal For Women In Science Fellowship, and the European Magnetism Association Young Scientist Award. Since September 2021 she is a Lise Meitner Group Leader of Spin3D at the Max Planck Institute for Chemical Physics of Solids in Dresden, Germany.

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Genetically controlled magnetic nanocompartments for cell manipulation - better than ferritin?

Maria V. Efremova*[1, 2, 3], F. Sigmund[1, 2], S.-V. Bodea[1, 2], I. Beer[1],
M. A. Abakumov[4, 5], T. Feggeler[6], H. Ohldag[6], R. Meckenstock[7],
N. Ivleva[1], U. Wiedwald[7], G. G. Westmeyer[1, 2]
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[4]Russian National Research Medical University, Moscow, Russia
[5]National University of Science and Technology «MISIS», Moscow, Russia
[6]Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, United States
[7]University of Duisburg-Essen, Duisburg, Germany

Using commercially available columns for magnet-assisted cell sorting, we isolated a small fraction of mammalian HEK293T cells grown in a Fe-rich medium and expressing spherical nanoreactors called encapsulins.[1], [2] The latter represent ginormous analogs of ferritins and naturally occur in bacteria, e.g., Quasibacillus thermotolerans. Encapsulins enable the biomineralization of up to 60000 iron atoms inside their cavity, which is ten times higher than ferritins. TEM and EDX revealed that each sorted cell contained 30±3 nm-sized iron oxide nanoparticles, while XAS and Raman microspectroscopy pointed towards Fe_2O_3 stoichiometry. VSM and FMR proved the ferrimagnetic response of the sorted cells at 5-250K, which corresponds to the maghemite-like (γ-Fe_2O_3) phase rather than to the antiferromagnetic ferrihydrite in ferritins. Finally, we demonstrated that the sorted cells could be manipulated by magnetic gradient fields, making encapsulins a modern tool for the magnetism-driven actuation and imaging of mammalian cells.

We acknowledge the support of an Alexander von Humboldt Research Fellowship for Postdoctoral Researchers, an Add-on Fellowship for Interdisciplinary Life Science by the Joachim Herz Foundation (M.E.), as well as an RSF grant number 19-45-06302 and the Helmholtz-RSF Joint Research Group (HRSF0064).

References

[1] F. Sigmund *et al.*, *ACS Nano*, vol. 13, pp. 8114 – 8123, 2019.
[2] M. V. Efremova *et al.*, *Pharmaceutics*, vol. 13, p. 397, 2021.

Speaker biography

Maria Efremova obtained her Ph.D. in Chemistry at the Department of Materials Science, Lomonosov Moscow State University, Russian Federation. In 2019, she was awarded a Long-Term Fellowship from the Federation of the European Biochemical Societies (FEBS) and then a Humboldt Research Fellowship for Postdoctoral Researchers from the Alexander von Humboldt Foundation. Thus, from 2019-to 2021, Maria was a Postdoctoral Fellow at the Technical University of Munich, Germany, with a project devoted to the bioengineering of genetically controlled magnetic nano compartments in living cells. In 2022, Maria received the EuroTechPostdoc2 Fellowship from the EuroTech Universities Alliance and joined Eindhoven University of Technology, Netherlands, to work on magneto-mechanical manipulation of ion channels with synthetic antiferromagnetic nanoparticles. Maria has authored or co-authored 25 peer-reviewed publications and has given oral talks at major international conferences including IV International Baltic Conference on Magnetism: focus on nanobiomedicine and smart materials (IBCM-2021), World Molecular Imaging Congress 2019, and others.

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Interacting Topological Magnons

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Topological magnets support magnetic excitations with a topologically nontrivial spectrum. As a result, they exhibit chiral edge states akin to those known from the quantum Hall effect. These edge states are envisioned to facilitate backscattering-free information channels for magnetic signals. Since spin excitations do not carry charge, they do not suffer from Joule heating and allow for ultra-low energy computation. However, in contrast to electrons, there is no conservation law for spin excitations. This gives rise to particle-number-nonconserving many-body interactions the influence of which on quasiparticle topology is an open issue of fundamental interest in the field of topological quantum materials.

I concentrate on magnons – the elementary spin excitations of ferromagnets – and demonstrate that interfacial Dzyaloshinskii-Moriya interaction (DMI) in chiral magnets leads to many-body effects without particle-number conservation. Selected implications are discussed: (i) interaction-stabilized topological gaps in the single-magnon spectrum (see Figure a, b) [1], and (ii) a topological hybridization of particle number sectors that results in exotic topological hybrids of single-magnon and two-magnon bound states (see Figure c, d) [2].

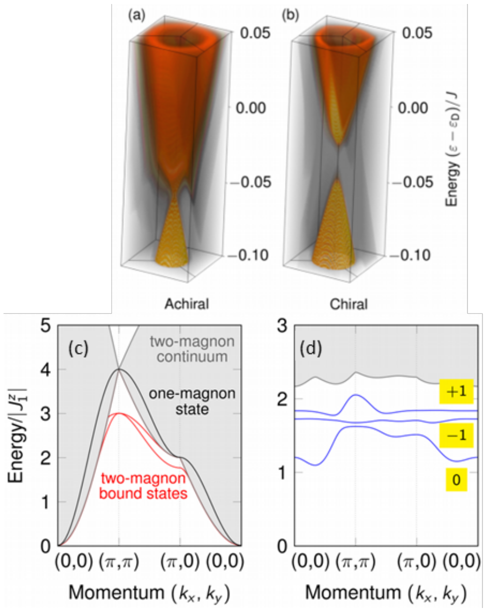

Figure 1. (a-b)Tomographic cut of the single-magnon spectral function showing interaction-renormalized magnonic Dirac cones in ferromagnets on the honeycomb lattice. (a) The Dirac magnons remain massless in achiral magnets. (b) The Dirac magnon acquires a mass gap due to nonconserving interactions in chiral magnets.(c-d) One and two-magnon spectrum in spin-1/2 quantum magnets on the square lattice along high-symmetry lines of the Brillouin zone. (c) For isotropic Heisenberg exchange and without DMI, the single-magnon state is buried by the two-magnon continuum, below which there are two-magnon bound states (red bands). (d) In the limit of strong Ising anisotropy and DMI, single-magnon states and two-magnon bound states hybridize and topological band gaps emerge (blue bands). Chern numbers are indicated by yellow labels.

References

[1] A. Mook *et al.*, *Physical Review X*, vol. 11, p. 021061, 2021.
[2] A. Mook *et al.*, *arXiv:2203.12374*, 2022.

Speaker biography

Dr. Alexander Mook did his Ph.D in Physics at the Max Planck Institute of Microstructure Physics in Halle, Germany, under the supervision of Prof. Ingrid Mertig. After completing his Ph.D., he became a postdoc in her group at the Martin Luther University of Halle-Wittenberg. In 2019, Alexander received the Georg H. Endress postdoctoral fellowship of the Center for Quantum Science and Quantum Computing and worked with Prof. Daniel Loss at the University of Basel, Switzerland. Currently, he is a Junior Group Leader in the group of Prof. Johannes Knolle at the Technical University of Munich, Germany.

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Advances in magnetic force microscopy

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Despite decades of advances in magnetic imaging, obtaining direct, quantitative information with high spatial resolution remains an outstanding challenge. The imaging technique most widely used for local characterization of magnetic nanostructures is the Magnetic Force Microscope (MFM), which is indeed a very active topic of investigation.[1] Advantages of MFM include relatively high spatial resolution, simplicity in operation as well as sample preparation, and the capability to applied in situ magnetic fields to study magnetization process.[2] The tip engineering, the quantitative measurements, the correct interpretation of the resulting MFM images, the possibility of operate in different environments including liquid media to investigate biological samples,[3] or the analysis of the loss of energy are subjects of ongoing research that will be reviewed in this talk

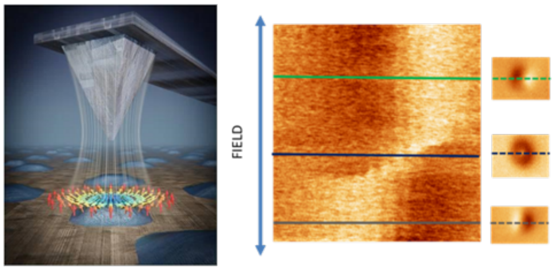

Figure 1. Nonstandard MFM image of a Py nanodot (height 30 nm). With this method, we can study the magnetization process of a single particle.

In particular, we will try to approach some of the challenges of MFM by following different routes. One route is the development of high-performance MFM probes with sub-10 nm (sub-25 nm) topographic (magnetic) lateral resolution by following different easy and quick low-cost approaches.[4] This allows one to not only customize the tip stray field, avoiding tip-induced changes in the sample magnetization, but also to optimize MFM imaging in vacuum (or liquid media [5]) by choosing tips mounted on hard (or soft) cantilevers, a technology that is currently not available on the market. On the other hand, the use of advanced MFM operation modes such as the combination of multifrequency modes [6] with the information obtained from the experimental dissipation of energy associated to tip-sample interactions [7] will be explored in order to improve the MFM capabilities.

References

[1] O. Kazakova *et al.*, *Journal of Applied Physics*, vol. 125, p. 060901, 2019.
[2] E. Berganza *et al.*, *Nanoscale*, vol. 12, pp. 18 646–18 653, 2020.
[3] M. Jaafar *et al.*, *ACS Appl. Mater. Interfaces*, vol. 6, p. 20936, 2014.
[4] M. Jaafar *et al.*, *Nanoscale*, vol. 12, p. 10090, 2020.
[5] P. Ares *et al.*, *Small*, vol. 11, pp. 4731 – 4736, 2015.
[6] V. G. Gisbert *et al.*, *Nanoscale*, vol. 13, pp. 2026 – 2033, 2021.
[7] M. Jaafar and A. Asenjo, *Applied Science*, vol. 11, p. 10507, 2021.

Speaker biography

Dr. Miriam Jaafar is an Associate Professor in the Department of Condensed Matter Physics at Universidad Autónoma de Madrid (UAM) (Spain) and a researcher at the IFIMAC Condensed Matter Physics Center. Her research focuses on Scanning Probe microscopy (SPM), with emphasis on developing new characterization methodologies based on Magnetic Force Microscopy (MFM) on new materials phenomena (e.g., low dimensional effects in particular nanoscale magnetic textures). She led several projects concerning the application of advanced MFM probes and methods for biological samples and low-dimensional systems. Dr. Jaafar has published 60 peer-reviewed papers, three licensed patents and has recently been awarded by the Spanish association of magnetism the Early Career Scientist Prize in the field of Magnetism (2021).

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Resonant X-ray Measurements of Magnetism in $RuCl_3$

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α-$RuCl_3$ is a layered honeycomb material that has emerged as a leading candidate in the search for Kitaev spin liquid physics. The exactly solved Kitaev model is a highly frustrated magnetic Hamiltonian, which supports a remarkable spin liquid ground state.[1] However, the picture in $RuCl_3$ is complicated by the presence of competing magnetic interactions allowed by symmetry in the real crystal. We present resonant x-ray scattering measurements that identify the magnetic moment direction [2], a quantity which is highly sensitive to the form of the magnetic Hamiltonian [3]. We determine that in α-$RuCl_3$ the Kitaev magnetic interaction is negative, while a competing interaction known as the Gamma term is positive. Further, the observed out-of-plane tilting angle of the magnetic moments constrains the ratio between these two interactions. These unambiguous experimental constraints on two of the leading magnetic interactions in α-$RuCl_3$ provide an important foundation for our understanding of this remarkable magnetic material.

References

[1] A. Kitaev, *Ann. Phys.*, vol. 321, pp. 2–11, 2006.
[2] J. A. Sears *et al.*, *Nat. Phys.*, vol. 16, pp. 837–840, 2020.
[3] J. Chaloupka and G. Khaliullinv, *Phys. Rev.B*, vol. 94, p. 064435, 2015.

Speaker biography

Jennifer is an experimental physicist, who specializes in using x-ray and neutron scattering techniques to investigate magnetism in condensed matter systems. She completed her Ph.D. at the University of Toronto in Canada, followed by postdoctoral studies at the resonant x-ray scattering beamline at the PETRA-III synchrotron at DESY in Hamburg, Germany. Jennifer is currently a member of the x-ray scattering group at the Brookhaven National Laboratory, researching exotic magnetism in a number of novel materials. She is particularly interested in materials with frustrated magnetism, multiple competing orders, or structural disorder.

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Hybrid magnetic nanoparticles: from synthesis to applications

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Modern chemical synthesis routes allow us to develop novel magnetic materials based on hybrid nanoparticles (NPs), i.e. formed by different inorganic or organic components combined in a single nanostructure [1]. Unlike single-phase materials, the magnetic properties of such systems are extremely sensitive to the interactions of their constituents at the nanoscale and to the characteristics of the interfaces between them, which often drive their technological applications and are still not fully understood.

In this talk, various magnetite (Fe_3O_4)-based hybrid materials will be described, including magnetic NPs functionalized with amphiphilic polymers and epitaxially grown exchange-coupled ferrites with core/shell morphology (Fig. 1). It will be discussed how the magnetic response can be precisely tuned by modulating the composition, morphology and dimensions of the NPs' components, and how a rational design of the hybrid NPs can provide innovative materials for environmental and biomedical applications.

References

[1] G. Lavorato *et al.*, *Nanoscale Advances*, vol. 3, no. 4, 2021.

Speaker biography

Gabriel Lavorato obtained his Engineering Sciences PhD degree in 2016 at the Balseiro Institute, National University of Cuyo, Argentina. Following a postdoctoral position at the Brazilian Center for Research in Physics and a Fulbright Visiting Scientist Scholarship at the University of South Florida, in 2018 he joined the National Scientific and Technical Research Council and National University of La Plata as Assistant Researcher. He was awarded the "Instituto Sábato" Prize in 2018 for his contribution to the field of Materials Science and Technology, and his current research is focused on the physical chemistry of metal oxide hybrid nanostructures and their technological applications.

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Using Magnetic Spin Textures for Cognitive Computing

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There are rich dynamical behaviors in magnetic materials that are bio-mimetic and highly applicable to cognitive computing. Here, we will present our recent results on understanding and leveraging the materials properties of magnetic domain walls (DWs), skyrmions, and magnetic tunnel junctions (MTJs) for energy efficient cognitive computing. We will show that DW motion in a magnetic track can be engineered to have highly linear position vs. time behavior, acting as an artificial synapse [1], [2]. We will show a brain-inspired "edgy-relaxed" behavior seen in biological neurons can be implemented inherently in the DW-MTJ device as an artificial neuron. [3] We will show results on designing a coupled skyrmions neuron that can be dynamically modulated based on context and environment [4].

References

[1] S. Liu *et al.*, *Applied Physics Letters*, vol. 118, p. 202405, 2021.
[2] T. Leonard *et al.*, *ArXiv: 2111.11516*, 2022.
[3] S. Liu *et al.*, *IEEE Magnetics Letters*, vol. 12, p. 4500805, 2021.
[4] P. Jadun *et al.*, *ArXiv: 2010.15748*, 2022.

Speaker biography

Jean Anne C. Incorvia is an Assistant Professor and holds the Fellow of Advanced Micro Devices (AMD) Chair in Computer Engineering in the Department of Electrical and Computer Engineering at The University of Texas at Austin, where she directs the Integrated Nano Computing (INC) Lab. Prof. Incorvia develops nanodevices using emerging physics and materials for the future of computing, including neuromorphic computing, in-memory computing, bio-inspired computing, and computing in extreme environments. Dr. Incorvia received her bachelor's in physics from UC Berkeley in 2008 and her Ph.D. in physics from Harvard University in 2015, cross-registered at MIT. She completed a postdoc at Stanford University before starting at UT Austin in 2017. She has received the 2020 IEEE Magnetics Society Early Career Award, a 2020 US National Science Foundation CAREER award, and is a 2021 Intel Rising Star.

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ORAL TALKS

Abstracts

List of Oral Presentations

Neural Network Prediction of Nanodefects and Magnetic Anisotropy in FePt-X HAMR Media

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High-anisotropy FePt-X nanogranular films with $L1_0$ ordered crystal structure are the media for heat-assisted magnetic recording (HAMR) [1], [2]. In order to reach the future industrial goal for the storage areal density of 4 Tb/in^2, an accurate control of the nanostructure is required. In this work, we propose and demonstrate a machine learning approach for evaluating micromagnetic and microstructural parameters from demagnetization curves of FePt-X granular media. The neural network was trained on a dataset of out-of-plane curves that were simulated using the TEM image based micromagnetic model that reproduced the actual nanostructure of the FePt-X HAMR medium [3]. Predicted nanodefects agree well with those estimated by synchrotron X-ray diffraction, and the demagnetization curve simulated with the predicted parameters accurately reproduces the experimental one (Fig. 1). This work paves the way for a high-throughput magnetometry-based characterization of FePt HAMR media for its structural optimization toward higher areal density of HAMR.

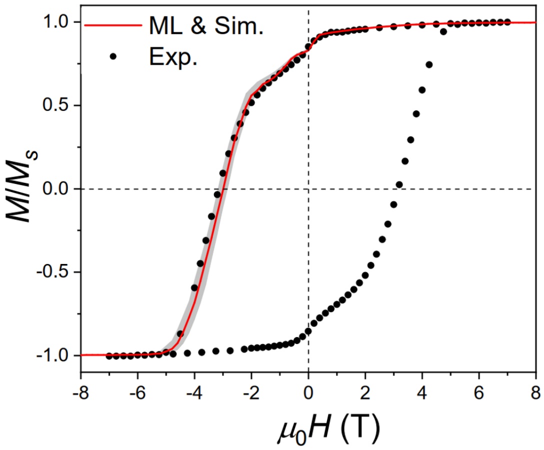

Figure 1. Experimental out-of-plane hysteresis loop of the FePt-X film (black dots) and the simulated one with parameters predicted by neural network (red line). The confidence interval for the simulated curve is shaded in gray.

References

[1] K. Hono *et al.*, *MRS Bulletin*, vol. 43, no. 2, pp. 93–99, 2018.
[2] D. Weller *et al.*, *Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena*, vol. 34, no. 6, p. 060801, 2016.
[3] A. Bolyachkin *et al.*, *Acta Materialia*, vol. 227, p. 117744, 2022.

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Magnetic properties of polycrystalline cylindrical Fe$_{65}$Pd$_{35}$ nanowires

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Iron-palladium alloys are studied because of their interest in different areas, depending on their chemical and physical properties [1]–[3]. In this work, Fe$_{65}$Pd$_{35}$ nanowires (NWs) were synthesized in commercial alumina porous templates by potentiostatic electrodeposition. The NWs morphology, composition, and crystalline structure were analyzed by SEM, TEM, EDS and XRD. Fe$_{65}$Pd$_{35}$ NWs are 10 μm long and 200 nm in diameter, with a polycrystalline microstructure (Fig. 1a). Magnetic properties were investigated by measuring hysteresis loops at different temperatures and ZFC-FC curves. The hysteresis loops were fitted using the law of approach to saturation, obtaining the values of the anisotropy field and the effective anisotropy constant at different temperatures (Fig. 1b). The blocking temperature dependence on the magnetic field was analysed using a modified random anisotropy model (Fig. 1c). The results indicate interactions between particles inside the NWs up to nearest neighbours.

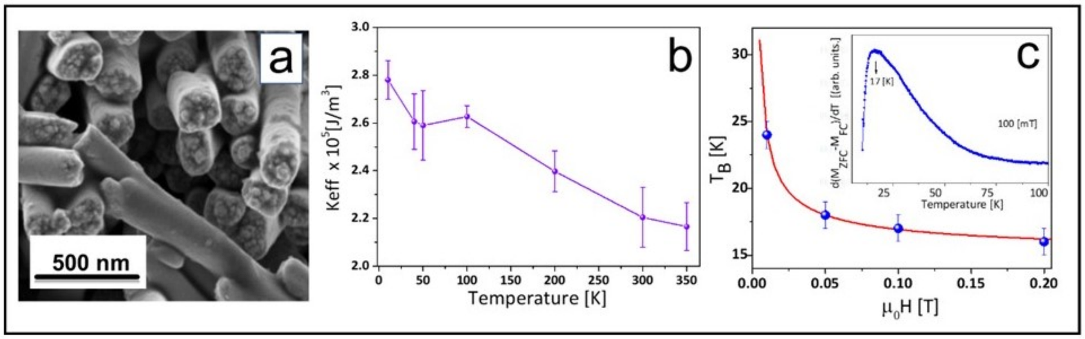

Figure 1. (a) SEM image of Fe65Pd35 NWs. (b) Effective anisotropy constant (Keff) values at different temperatures. (c) Blocking temperature (TB) as a function of the applied field (blue dots) and the best fit (red line) using the modified random anisotropy model. Inset: TB distribution is obtained from FC-ZFC curves measured with H=100 mT.

References

[1] K. Rozman *et al.*, *Smart Mater. Struct.*, vol. 27, no. 035018, 2018.
[2] K. Pondman *et al.*, *J. Magn. Magn. Mater.*, vol. 380, no. 299-306, 2015.
[3] E. Herrera *et al.*, *Catal. Sci. Technol.*, vol. 12, no. 2962-2971, 2022.

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Ionic Liquid Gating Control of Magnetic Anisotropy in Magnetic Tunneling Junction Stacks

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Magnetoresistive sensors have applications in non-destructive testing (NDT) for the detection of deterioration in pipes, re-enforcing bars in concrete, reliability monitoring, and sensing of faults in high voltage power lines.[1] A limitation of these sensors is their ability to sense on only one axis. This work aims to fabricate the magnetoresistive sensor with the ability to measure small magnetic field signals in three dimensions. The key step to obtaining a voltage tunable magnetic sensor is to modulate the magnetic anisotropy of the reference layer comprising the sensor stack through applied voltage. In this work, we will present the reversible tunability of anisotropy in CoFeB based magnetic tunneling junction stacks from out-of-plane to in-plane direction through ionic liquid gating.[2] Using magneto-optical Kerr effect (MOKE) microscopy we were able to observe the voltage-induced changes in the spatial magnetic anisotropy distribution. This work paves a way toward realizing voltage tunable magnetoresistive sensors.

References

[1] M. A. Khan *et al.*, *Engineering Research Express*, vol. 3, no. 2, p. 022005, 2021.
[2] U. Bauer *et al.*, *Nature materials*, vol. 14, no. 2, pp. 174–181, 2015.

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Damping in STT-MRAM Free Layers at Elevated Temperatures

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In spin-transfer torque magnetic random-access memory (STT-MRAM), both switching current and switching time depend on the free layer damping. It is known that magnetic damping varies with temperature; because STT-MRAM cells operate well above room temperature, there is an urgent need to clarify damping properties in MRAM free layers at elevated temperatures. We determined the Gilbert damping parameter (α) of a 1.38-nm-thick CoFe-based free layer sample [1], through high-temperature, frequency-dependent ferromagnetic resonance (FMR) measurements [2], [3]. The FMR data show $\alpha = (3.45 \pm 0.03) \times 10^{-3}$ at room temperature, very close to the intrinsic damping in Fe. The damping increases monotonically to $\alpha = (7.9 \pm 1.2) \times 10^{-3}$ when the temperature is increased to 520 K. The data also show a decrease in the effective anisotropy field from 2200 Oe to 200 Oe and a decrease in the inhomogeneity broadening of the FMR linewidth from 135 Oe to 40 Oe, within the same temperature range.

References

[1] T. S. Santos *et al.*, *J. Appl. Phys.*, vol. 128, no. 113904, 2020.
[2] D. Richardson *et al.*, *Physical Review Applied*, vol. 10, no. 054046, 2018.
[3] D. Richardson *et al.*, *Physical Review Applied*, vol. 11, no. 044016, 2019.

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Current-Induced Nucleation of Magnetic Skyrmions in Multilayered Devices

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Magnetic skyrmions are two-dimensional, topologically stable solitons comprised of winding spins [1]–[3]. In ferromagnetic multilayer thin films with broken inversion symmetry, their unique winding is stabilized due to the interfacial Dzyaloshinskii-Moriya interaction. Skyrmions find applications in racetrack memory and magnetic tunnel junctions, where they offer dense information storage and transfer using small currents. Skyrmions can be nucleated electrically using an energy-efficient spin-orbit torque (SOT) by injecting a lateral current into the device. Our work studies SOT nucleation of skyrmions in two-terminal wire and dot devices consisting of Ir/CoB/FeB/Pt and Ir/CoB/Pt multilayers respectively. In-situ imaging with a scanning transmission X-ray microscope was performed to explore the field and current density dependence of nucleated magnetic spin textures in these devices. We discovered that skyrmions are preferentially nucleated within a specific set of field and current density regimes for wire devices, while dot devices exhibit higher nucleation probabilities primarily at lower fields. The sizes of magnetic textures were also analyzed to shed light on the effects governing the stability of skyrmions in these devices. The insights from our work pave directions for the realization of viable skyrmionic devices.

References

[1] A. Fert *et al.*, *Nat. Rev. Mater.*, 2017.
[2] A. Soumyanarayanan *et al.*, *Nature Materials*, no. 9, p. 898–904, 2017.
[3] A. K. C. Tan *et al.*, *Nat. Commun.*, vol. 12, no. 1, pp. 6–13, 2021.

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Extracellular Magnetic Labeling of Mesenchymal Stem Cell Spheroids with Ferumoxytol for MRI Tracking

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Superparamagnetic iron oxide nanoparticles (SPIONs) have been used as mesenchymal stem cells (MSCs) labelling agents for various tissue repair studies and clinical trials [1]. However, clinically approved SPIONs (ferumoxytol) used for labeling of MSCs requires the use of transfection reagents, which largely limits their clinical application [2]. Here, we established a novel method for magnetic labelling of MSC spheroids using ferumoxytol. MSC spheroids are compact structures composed of MSCs and extracellular matrix (ECM) proteins. This 3D structure benefits ferumoxytol stably encapsulated into spheroid network instead of internalization by individual cells. Extracellular magnetic labeling of MSC spheroids minimized the cytotoxicity of ferumoxytol and showed effective magnetic properties under magnetic fields. Afterwards, we transplanted magnetic MSC spheroids and exhibited strong T2-MRI signal *in vivo*. This method showed the potential for posttransplantation MRI tracking in MSC-mediated regenerative medicine.

References

[1] K. Andreas *et al.*, *Biomaterials*, vol. 33, no. 18, pp. 4515–4525, 2012.
[2] M. S. Thu *et al.*, *Nature medicine*, vol. 18, no. 3, pp. 463–467, 2012.

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Estimation of Magnetic Parameters from Domain Images with Convolutional Neural Networks

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Magnetic multilayer films are known to host novel magnetic configurations with potential nano-electronic applications. However, characterizing these material systems typically involves laborious experiments. Therefore, it is crucial to maximize the information extracted from experiments that are more accessible, such as magnetic force microscopy. We show that convolutional neural networks can extract important magnetic parameters such as the exchange interaction, Dzyaloshinskii-Moriya interaction, and uniaxial anisotropy from domain images. Experimentally realistic training data were generated through micromagnetic simulations. The trained models were consistently able to achieve $R^2 \geq 0.85$ during validation. The intermediate feature maps of the neural network reveal that the network is able to learn features such as domain boundaries. Testing the models on experimental data yield values that were consistent with our knowledge of the material systems. Our work thus demonstrates the utility of developing machine models trained on simulation data to accelerate the characterization of magnetic systems.

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Emergence of Sizeable Interfacial Dzyaloshinskii-Moriya Interaction at Cobalt/Fullerene Spinterface

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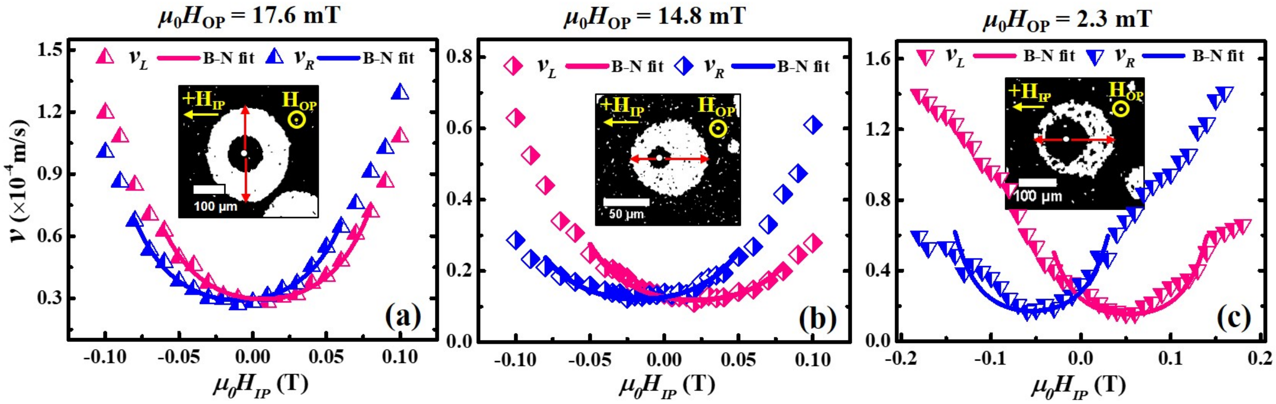

Figure 1. The left (pink) and right (blue) pointing symbols represents the velocities of the domain walls along the left and right sides of the domains and plotted against the in-plane bias field H_{IP} under a constant driving field H_{OP} for samples S1 in (a), S2 in (b) and S3 in (c). The solid lines represent the B-N fit of the curves by the modified creep law. The inset in each figure shows the direction of domain elongation w.r.t. the IP field (H_{IP}) direction.

Interfacial Dzyaloshinskii-Moriya interaction (iDMI) plays a crucial role in stabilizing chiral spin textures in magnetic multilayers [1]. Recently, a significant iDMI found to be originated from Co/graphene interface, owing to Rashba-SOC of graphene [2]. A sizeable DMI can also be expected from other C allotrope (C_{60}, CNT)/FM interface, due to their curvature enhanced SOC [3]. In this context, we have elucidated magnetization reversal, domain wall (DW) dynamics and iDMI in Pd(4.0nm)/Co(0.5nm)/C_{60}(t_{C60})/Pd(2.0nm) system with varied t_{C60}. A two order higher DW velocity has been found from the sample with 1.6nm thick C_{60}, due to lower depinning field and modified PMA. DMI measurements revealed a systematic increase in iDMI from -0.07 to -0.46 mJ/m^2 with increasing tC60 which turned the Bloch wall into chiral Neel wall. A finite DMI is found to be originating from the Co/fullerene interface ($D_{Co/C60} \sim$ -0.10 mJ/m^2), which makes C based materials promising for chiral DW based device applications.

References

[1] A. Fert *et al.*, *Nature Reviews Materials*, vol. 2, no. 7, pp. 1–15, 2017.
[2] F. Ajejas *et al.*, *Nano letters*, vol. 18, no. 9, pp. 5364–5372, 2018.
[3] D. Huertas-Hernando *et al.*, *Physical Review B*, vol. 74, no. 15, p. 155426, 2006.

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Hardware Accelerated Spiking Neural Networks Based on Zero-Field Skyrmions

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Hardware-accelerated spiking neural networks (SNN) are an active area of research that holds promise as a biologically-inspired, low powered solution to realise Edge Artificial Intelligence [1], [2]. Skyrmions - collective spin configurations with particle-like localisation and non-zero topological charge - has the potential to underpin these next-generation devices owing to their nanoscale size, energy efficient motion, and non-volatility at room temperature [3]. Here, we present a skyrmion-based SNN containing leaky-integrate-fire neurons and synapses with tuneable weights, using the spatial variance of interlayer exchange coupling (IEC) to enable device operability at zero fields, reduce skyrmion size and realise linear skyrmion motion with enhanced speeds. Associated neuronal dynamics and physical interpretations have been investigated using a blend of micromagnetic simulations and previously reported experimental evidence. Compatible with existing crossbar array architectures, our device is highly scalable and holds promise for the efficient and compact implementation of SNN-based neuromorphic computing.

References

[1] O. Krestinskaya *et al.*, *IEEE transactions on neural networks and learning systems*, vol. 31, no. 1, pp. 4–23, 2019.
[2] A. Tavanaei *et al.*, *Neural networks*, pp. 47–63, 2019.
[3] W. Kang *et al.*, *Proceedings of the IEEE*, no. 10, pp. 2040–2061, 2016.

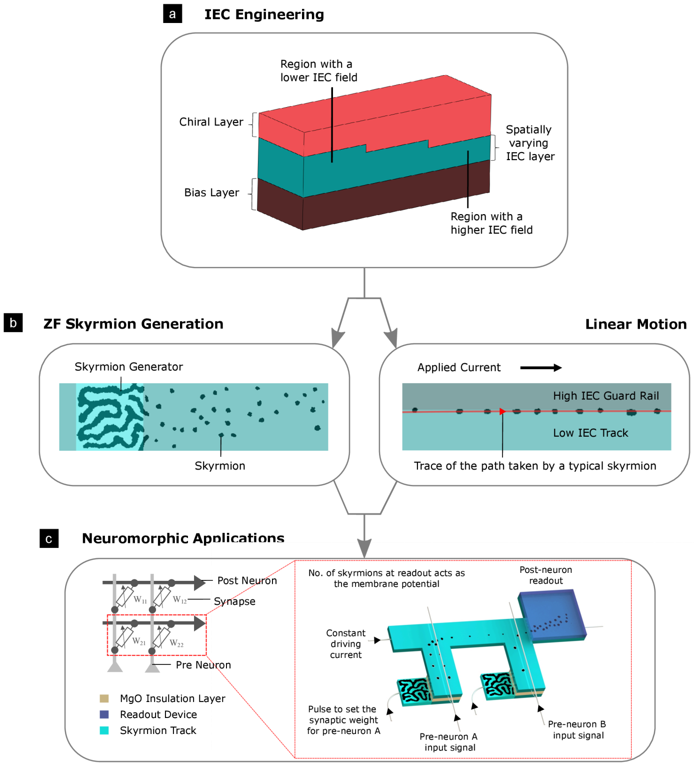

Figure 1. An overview of how IEC engineering is used to realise neuromorphic devices. (a) Illustration of how the IEC layer thickness is spatially varied to manipulate the IEC field strength. The chiral layer is a soft magnetic material with low magnetic anisotropy energy (Keff), the IEC layer is a spacer material, while the bias layer is a hard magnetic material with high Keff. (b) A spatially varying IEC layer is used to realise zero field skyrmion generation and the linear motion of skyrmions under an applied current. (c) These behaviours underpin our skyrmion-based, crossbar array compatible, zero-field (ZF) neuromorphic device that is capable of performing SNN computations. The illustration depicts the integration operation of the post neuron given a constant input signal, with the input signal of pre-neuron A being twice as frequent as that of pre-neuron B, and synapses A and B having weights of 2 and 1 respectively.

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Magnetization Reversal and Domain Structures in Perpendicular Synthetic Antiferromagnets Prepared on Rigid and Flexible Substrates

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Spintronics devices have shown potential application in data storage, non-volatile magnetic random access memories. Efficient spin current propagation across the ferromagnet (FM) and SOC material having high spin orbit coupling is the key requirement of such devices. Inverse spin Hall effect (ISHE) technique is used to probe the spin current efficiency of such FM/SOC heterostructures [1]. There are very few heavy metals in the periodic table which can be used as SOC material. Recently Antiferromagnets (AFM) are found to be a good SOC material for such heterostructures to provide high spin current efficiency [2]. In this work, systematic spin pumping and ISHE measurement was performed to evaluate the spin current efficiency in the Co_3O_4/ Co heterostructures. Here we have shown semi-conducting AFM Co_3O_4 do possess very high SOC as well as high spin diffusion length in comparison to the other heavy metals.

References

[1] E. Saitoh *et al.*, *Applied physics letters*, vol. 88, no. 18, p. 182509, 2006.
[2] W. Zhang *et al.*, *Physical review letters*, vol. 113, no. 19, p. 196602, 2014.

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Magnetization Reversal and Domain Structures in Perpendicular Synthetic Antiferromagnets Prepared on Rigid and Flexible Substrates

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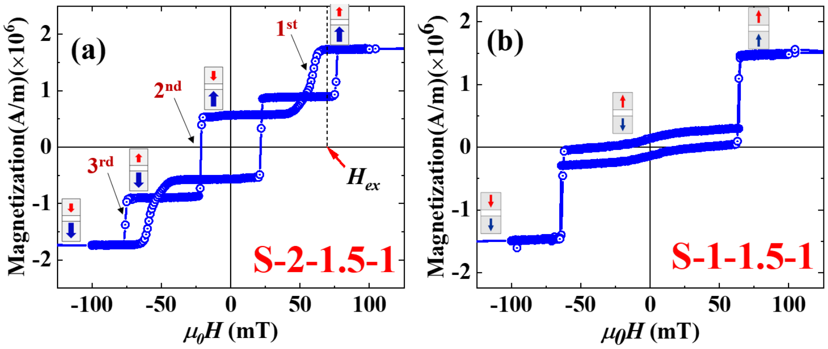

Figure 1. This figure shows the magnetic hysteresis loops of two SAF samples with Ir thickness 1.5nm, measured by SQUID-VSM. (a) SAF sample with 2 layers of [Pt/Co] below and 1 layer of [Pt/Co] above the Ir spacer. (b) SAF sample with layer of [Pt/Co] below and 1 layer of [Pt/Co] above the Ir spacer.

Synthetic antiferromagnets (SAF) are basically two ferromagnetic (FM) layers separated by a nonmagnetic spacer layer where both the FM layers are coupled antiferromagnetically. With metallic spacer, the coupling is dominated by Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction [1], [2]. Here, we have studied magnetization reversal by varying the number of bilayer stacks [Pt/Co] as well as thicknesses of Ir space layer t_{Ir} on rigid Si (100) and flexible polyimide substrates. The sample with t_{Ir} = 1.0 nm shows a FM coupling, whereas sample with t_{Ir} = 1.5 nm shows an antiferromagnetic (AFM) coupling between the FM layers. At t_{Ir} = 2.0 nm, a bow-tie shaped hysteresis loop is observed indicating a canting of magnetization at the reversal. We have also demonstrated the strain-induced modification of IEC as well as magnetization reversal phenomena. The IEC shows a slight decrease upon application of compressive strain and increase upon application of tensile strain, which indicates the potential of SAFs in flexible spintronics [3].

References

[1] R. Duine *et al.*, *Nat. Phys.*, p. 217, 2018.
[2] P. Bruno *et al.*, *Phys. Rev. Lett.*, p. 1602, 1991.
[3] S. Mohanty *et al.*, *JOM*, no. 6, 2022.

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Ionic Liquid Gating Control of Magnetic Anisotropy in Magnetic Tunneling Junction Stacks

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Bismuth Ferrite (BFO) is a promising material because of its multiferroic property in room temperature. The antiferromagnetic property of pure BFO needs to be changed to ferrimagnetic property by element substitution for application of this material to magnetic devices with low power consumption. In (Bi,Ba)FeO_3, relatively high saturation magnetization (Ms) (90 emu/cm^3) [1] was found, but the ratio of perpendicular coercivity against in-plane coercivity ($H_{c\perp}/H_{c//}$) (0.8) & magnetic Kerr rotation angle (θ_k) (0.03°) were not enough for device application. In our previous study, we found remarkable improvement of relatively high $H_{c\perp}/H_{c//}$ (1.6) [2] and very high θ_k (0.67°) in (Bi,La)(Fe,Co)$_3$ by substituting La in A-site and Co in B-site. In this study, we are going to investigate the improvement of magnetic properties of BFO based thin films by substituting other Lanthanides.

Table I
Magnetic properties (M_s, $H_{c\perp}$, $H_{c\perp}/H_{c//}$, θ_k) of (Bi,L)(Fe,Co)O_3 thin films.

Substitution element	Ba	La					Nd	Sm	Gd	Dy	Er
$Co^{2+}/(Fe^{3+}+Co^{2+})$	0	0	0.05	0.12	0.17	0.28	0.25	0.25	0.24	0.27	0.24
M_s (emu/cm^3)	90	15	25	50	70	80	140	110	65	75	135
$H_{c\perp}$ (kOe)	2.0	0	0	2.8	3.1	2.6	2.1	1.9	2.2	2.7	1.9
$H_{c\perp}/H_{c//}$	0.8	0	0	1.1	1.2	1.6	2.6	2.1	2.8	1.7	1.5
θ_k (°@750nm)	0.03	0		0.08	0.12	0.67	0.34	0.21	0.19	0.23	

References

[1] S. Yoshimura and M. Kuppan, *Japanese Journal of Applied Physics*, vol. 57, no. 9, p. 0902B7, 2018.
[2] M. Kuppan *et al.*, *Scientific Reports*, vol. 11, no. 1, pp. 1–8, 2021.

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Excess Velocity of Domain Walls in Pt/CoFeB Thin Films

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Domain wall (DW) dynamics have been immensely studied for the last few decades due to rich physics and spintronics applications [1]. The statics and dynamics of DW can be modified via interfacial Dzyaloshinskii-Moriya interaction (iDMI) which is significant in an inversion asymmetric system [2]. We have studied the DW dynamics in Pt/CoFeB/MgO multilayer thin films with perpendicular magnetic anisotropy. We have observed unusual behaviour in the DW dynamics which cannot be explained via universal creep or depinning law. At low driving force, the sample follows the universal creep law, however, near depinning field ($H_\mathrm{d} \approx$ 15.3 mT), excess velocity has been observed in DW dynamics instead of the usual creep law. Near H_d, due to additional relaxation events, the deterministic DW propagation length increased and hence velocity. The excess velocity has been demonstrated via modified creep law [3]. Further, iDMI value (~0.39 × 0.03 mJ/m^2) of the thin film has been quantified.

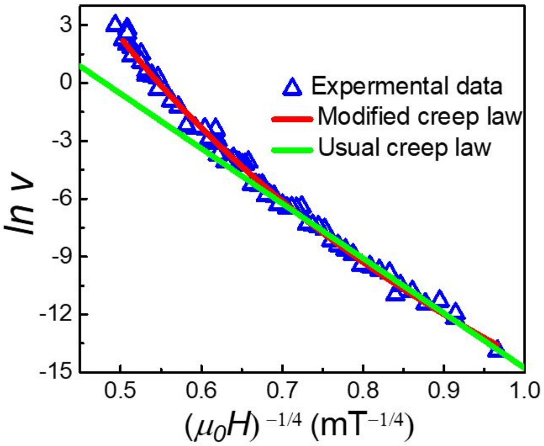

Figure 1. Plot of ln v vs $H^{-1/4}$. The logarithm of velocity did not follow the universal creep law (green line). It is demonstrated via the modified creep law (red line).

References

[1] S. S. P. Parkin *et al.*, *Science*, no. 5873, p. 190–194.
[2] A. Thiaville *et al.*, *EPL (Europhysics Letters)*, vol. 100, no. 5, p. 57002, 2012.
[3] N. B. Caballero *et al.*, *Phys. Rev. B*, no. 22, p. 224422.

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Temperature Dependence of Electric Impedance of the Cobalt-based Soft Magnetic Wires near the Ferromagnetic Phase Transition

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The studies of the amorphous alloy Co$_{66}$Fe$_4$Nb$_{2.5}$Si$_{12.5}$B$_{15}$ samples in the form of cylindrical wires 30 mm long and 180 μm in diameter are presented. The saturation magnetization, magnetostriction constant and Curie temperature were about 320 kA/m, 10-7 and 480 K, respectively. The impedance modulus of the samples was measured in an automated setup based on Agilent impedance analyzer [1]. The measurements were carried out with decreasing temperature from 510 to 295 K in the presence of the external magnetic field applied along the wire longitudinal direction. At frequency of 100 kHz, when the thickness of the skin depth is commensurate with the wire radius, the contribution to the impedance temperature change from the magnetization, of the entire wire volume will prevail, especially in the presence of H. Therefore, the inflection in the $Z(T)$ dependencies (Fig. 1) can be associated with the presence of two magnetic phases with different Curie temperatures.

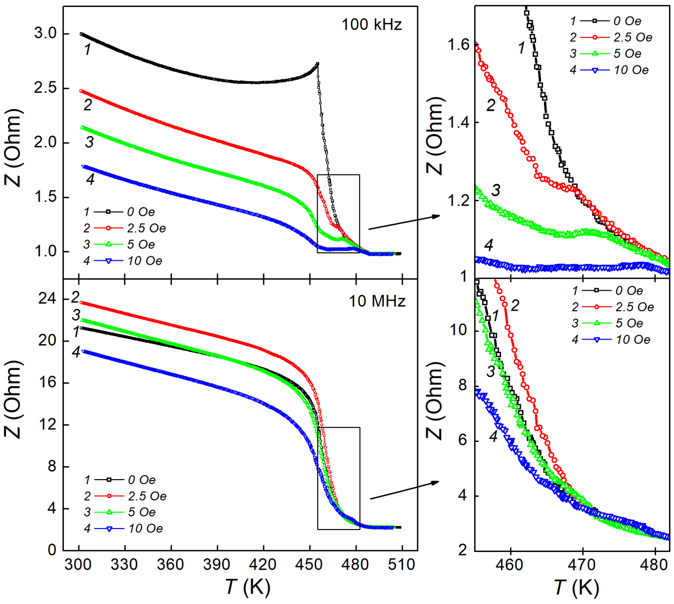

Figure 1. Temperature dependences of the impedance of Co$_{66}$Fe$_4$Nb$_{2,5}$Si$_{12.5}$B$_{15}$ wires obtained in the external magnetic field of 0, 2.5, 5, and 10 Oe at frequencies of 0.1 and 10 MHz.

References

[1] D. A. Bukreev *et al.*, *Materials*, vol. 13, no. 14, p. 3216, 2020.

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An Alternative Route for Tuning Unconventional Hall Effect in Layered Ferromagnet Fe_3(Ge,As)Te_2

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The discovery of two-dimensional (2D) magnetic van der Waals (vdW) materials and the stabilization of magnetic order down to the monolayer limit have ushered in a new venture, important from a fundamental viewpoint leading to development of novel spintronics devices [1]. Among 2D vdW ferromagnets (FMs), metallic Fe_3GeTe_2 (FGT) is an interesting candidate owing to high Curie temperature, uniaxial magnetic anisotropy, and realization of an unconventional chiral magnetic ground state [2]. Here, we investigate an unexplored route towards manipulation of the exotic ground state of FGT without affecting the magnetic site *i.e.*, by doping at the non-magnetic (Ge) site of Fe_3(Ge,As)Te_2. Interestingly, As doping results in an unconventional Hall effect whose strength was considerably modified by increasing concentration, arising from emergent electromagnetic behaviour from underlying complicated spin configurations [3]. Our results clarify the underlying factors responsible for stabilization of non-trivial spin texture magnetic ground state in a 2D vdW FM.

References

[1] K. S. Burch *et al.*, *Nature*, vol. 563, no. 7729, pp. 47–52, 2018.
[2] R. R. Chowdhury *et al.*, *Scientific reports*, vol. 11, no. 1, pp. 1–10, 2021.
[3] R. R. Chowdhury *et al.*, *Physical Review Materials*, vol. 6, no. 1, p. 014002, 2022.

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Europium Coated Mn Doped Fe_2O_4 Nanoparticle for Magnetic Hyperthermia: Synergistic Strategy for Cancer Treatment and Imaging

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Cancer has been major health problem for world since long time.Superparamagnetic nanoparticles used for magnetic hyperthermia for biomedical application like cancer therapy and detection. We have produced an innovative, theranostic hybrid nanocomposite (NC) of $EuMnFe_2O_4$ for radiofrequency hyperthermia therapy. A new approach by hydrothermal synthesis route for $EuMnFe_2O_4$ nanocomposite has been performed. For luminescence property outer shell of manganese ferrite was coated with europium chelate which is further coated by silica coating. Due to good colloidal stability, high SAR value of 312 W/gm and corresponding intrinsic loss power (ILP) value of 6.47 nHm^2kg^{-1} was achieved. The synthesized nanocomposite demonstrates good colloidal stability and low cytotoxicity in vitro. In vitro cytotoxicity studies demonstrated almost 70% cell viability at 200 μg/ml of $EuMnFe_2O_4$ nanocomposite, a comparable concentration for clinical use by FDA standard. We also demonstrate the magnetic hyperthermia on C6 cell line and cell death has been observed at 43°C for 60 minutes under alternating magnetic field (AMF) exposure. Thus, the developed nanocomposites have potential in the efficient treatment of cancer.[1]–[3]

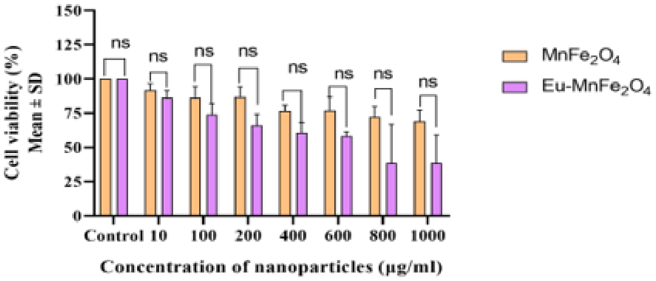

Figure 1. Cytotoxicity Assay of $EuMnFe_2O_4$

References

[1] A. Bettaieb *et al.*, *Rangel, L., Ed.; InTech.*, 2013.
[2] J. Mohapatra *et al.*, *Materials*, vol. 12, no. 19, p. 3208, 2019.
[3] A. Reisch and A. S. Klymchenko, *Small*, vol. 12, no. 15, pp. 1968–1992, 2016.

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Enhanced domain wall motion by surface acoustic waves

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We experimentally demonstrated an enhanced DW velocity in a PMA film using both standing and travelling surface acoustic waves (SAWs). Two interdigitated transducers (Fig.1a), centre frequency 47.93 MHz (Fig. 1b), were patterned on opposite side of a Ta(5)/Pt(2.5)/Co(0.5)/Ta(5) film (thicknesses in nm). Results showed that DW velocity increased from 7±1 to 34±1 μm/s with an increasing magnetic field from 10.9 to 14.8 Oe without SAWs (Fig.1c). An up to 24-fold DW velocity increase (870±10 μm/s at 14.8 Oe, Fig.1c) can be found in the presence of standing SAWs compared to that without SAW. A less significant DW increase (372±6 μm/s at 14.8 Oe) can also be observed with the application of travelling SAWs (Fig.1d). SAW-induced magneto-elastic coupling promotes DWs to overcome pinning energy barriers during its motion.[1], [2] This process is possibly an accumulative effect, which can explain the velocity difference between results for the travelling and standing SAW.

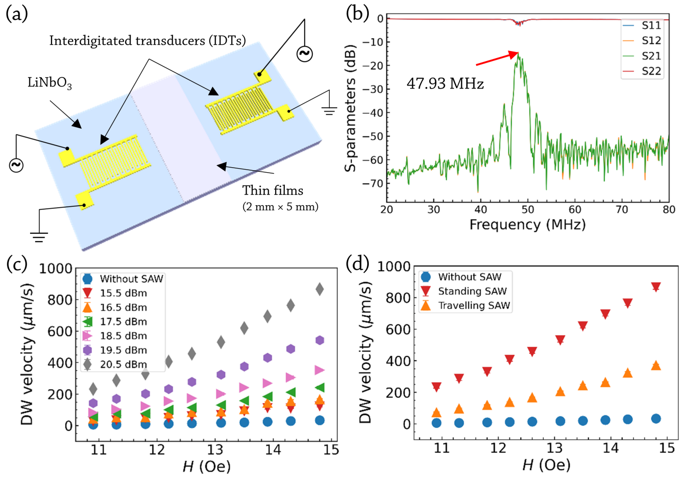

Figure 1. (a) Experimental set-up; (b) S-parameters of the SAW device; (c) Domain wall velocity against the applied field with standing SAWs (various applied SAW power) and without SAW. (d) Domain wall velocity against the applied field without SAW and with standing/travelling SAWs (applied SAW power of 20.5 dBm).

References

[1] Shepley, *Sci. Rep.*, vol. 5, p. 7921, 2015.
[2] Shuai *et al.*, *Appl. Phys. Lett.*, vol. 120, p. 252402, 2022.

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Room-Temperature Stabilization of Skyrmionic Surface-Magnetic Textures in Synthetic Antiferromagnets

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Magnetic skyrmions [1] are twisted spin configurations, which show a non-zero skyrmion Hall angle when driven by electrical currents due to their topological charge of ±1, which is detrimental for applications [2]. Skyrmions in synthetic antiferromagnets (SAFs), can suppress this effect owing to an overall zero topological charge [3].

Here, we investigate different, more exotic spin textures in a SAF consisting of $(CoFeB/Ir/CoFeB)_n$ using scanning electron microscopy with polarization analysis (SEMPA) and magnetic force microscopy (MFM). The unique high surface sensitivity of SEMPA is especially useful on SAFs enabling us to investigate the topological spin textures even at the fully compensated composition. We report high-resolved imaging of vortex-anti-vortex pairs in the SAF that are stable at room temperature. Micromagnetic simulations have been carried out to understand the mode of stabilization for these exotic spin textures as well as to explore the possible emergence of three-dimensional (3D) spin structures in the SAF multilayer system.

References

[1] K. Everschor-Sitte *et al.*, *J. Appl. Phys.*, vol. 124, no. 24, p. 240901, 2018.
[2] K. Litzius *et al.*, *Nat. Phys.*, vol. 13, no. 2, pp. 170–175, 2017.
[3] T. Dohi *et al.*, *Nat. Commun*, vol. 10, no. 1, pp. 1–6, 2019.

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Synthesis and Magnetic Properties of Nanowires in Thin-film Anodic Alumina

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Cylindrical magnetic nanowires offer unique flexibility in tunning their magnetic and electrical properties, which makes them one of the most promising class of magnetic nanomaterials for numerous applications [1], [2].

The main goal of our work was to offer a simple yet flexible way of producing a nanowires array embedded into a thin alumina layer synthesised on semiconducting or dielectric substrate with electrical contacts on both ends. Such a workflow could be useful for producing nanowires-based sensors or logic devices withing existing fabrication methods for integrated circuits or MEMS as well as for studying magnetoelectric properties of nanowires with alternating diameter or composition. The alumina template was synthesised using Al film deposited onto the glass substrates. Magnetic nanowires were obtained using AC or DC electrodeposition from aqueous electrolyte solutions [3]. To evaluate applicability of the synthesis method, magnetic properties and morphology of Fe-Ni and Fe-Co nanowires were studied and compared.

References

[1] L. Piraux, *Applied Sciences*, vol. 10, no. 5, 2020.
[2] J. Fernandez-Roldan, *Ph.D thesis*, 2019.
[3] A. Dryagina *et al.*, *IEEE Magnetics Letters*, vol. 13, pp. 1–4, 2021.

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Skyrmion-based Neuromorphic Device with Short- and Long-Term Synaptic Plasticity

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We propose a skyrmion-based neuromorphic magnetic tunnel junction (MTJ) device with both long- and short-term plasticity (LTP and STP) (mixed synaptic plasticity). We showed that plasticity could be controlled by magnetic field, spin-orbit torque (SOT), and the voltage-controlled magnetic anisotropy (VCMA) switching mechanism. LTP depends on the skyrmion density and is manipulated by the SOT and magnetic field while STP is controlled by the VCMA. The LTP property of the device was utilized for static image recognition. By incorporating the STP feature, the device gained additional temporal filtering ability and could adapt to a dynamic environment. The synapse device was trained and tested for emulating a deep neural network. We observed that when the skyrmion density was increased, the inference accuracy improved: 90% accuracy was achieved by the system at the highest density. We further demonstrated the dynamic environment learning and inference capabilities of the proposed device

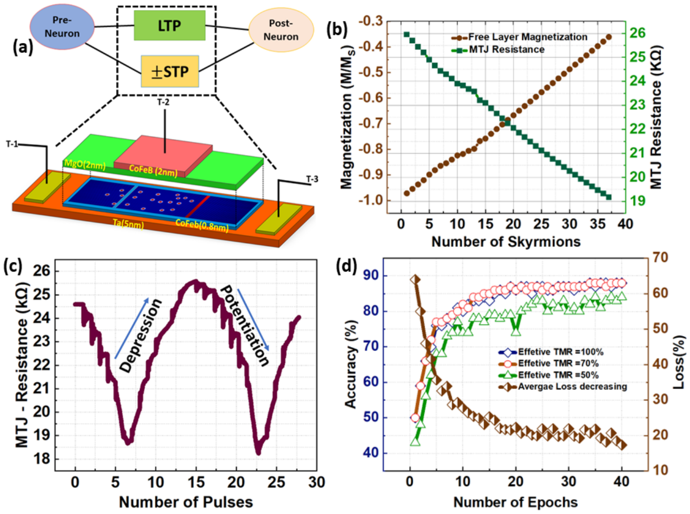

Figure 1. SOT and VCMA controlled skyrmion MTJ. (b) Skyrmion number vs synaptic resistance. (c) VCMA tuned STP (d) Recognition accuracy.

References

[1] S. Li *et al.*, pp. 539–544, 2018.
[2] K. M. Song *et al.*, *Nat. Electron.*, vol. 3, no. 3, p. 148, 2020.

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Field-free Spin Orbit Torque Switching of Synthetic Antiferromagnet through Interlayer Dzyaloshinskii-Moriya Interaction

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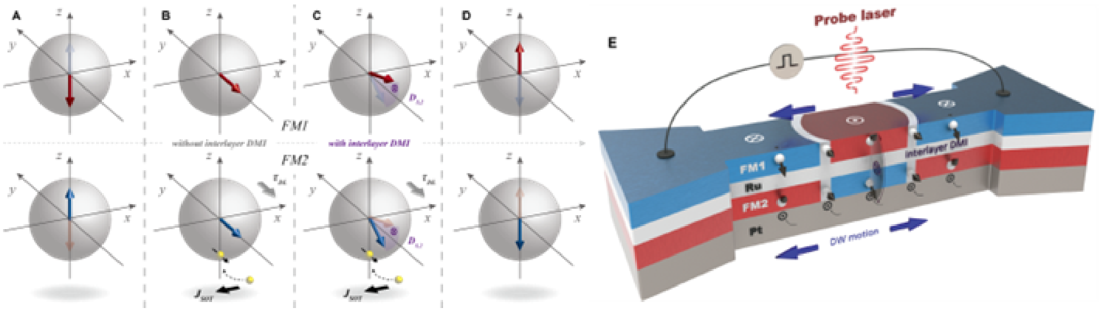

Figure 1. Schematic illustration of SAF field-free SOT switching through interlayer DMI. (A-D) Spin textures' evolution with time during the application of a SOT current pulse along -x. Magnetizations of the top and bottom magnetic layers in SAF are shown in the top and bottom spheres, respectively. (A) Initial magnetization state before SOT pulse. (B-C) Magnetization states during application of SOT in SAF with no interlayer DMI (B) and an interlayer DMI $D_{1,2}$ along +x (C). $_{DL}$ indicates the damping-like term of SOT. (D) Final state after application of SOT. (E) A sketch of the experimental setup where the switching mechanism under a domain nucleation and propagation regime is indicated. The probe laser is used to detect the MOKE signal in our experiment. The purple cross surrounded by a circle represents the interlayer DMI $D_{1,2}$ between two layers.

Perpendicular synthetic antiferromagnets (SAFs) are of interest for the next generation ultrafast, high density spintronic memory and logic devices [1]. However, to energy efficiently operate their magnetic order by current-induced spin orbit torques (SOTs), an unfavored high external field is conventionally required to break the symmetry. Here, we theoretically and experimentally demonstrate the field-free SOT switching of a perpendicular SAF through the introduction of interlayer Dzyaloshinskii–Moriya interaction (DMI) [2]. By macro-spin simulation, we show that the speed of field-free switching increases with the in-plane mirror asymmetry of injected spins. We experimentally observe the existence of interlayer DMI in our SAF sample by an azimuthal angular dependent anomalous Hall measurement. Field-free switching is accomplished in such a sample and the strength of the effective switching field demonstrates its origin from interlayer DMI. Our results provide a new strategy for SAF based high performance SOT devices. [3]

References

[1] Z. Guo *et al.*, *Proceedings of the IEEE*, no. 8, p. 190–194, 2021.
[2] D. Han *et al.*, *Nature Materials*, no. 703, 2019.
[3] Z. Wang *et al.*, *submitted to The Proceedings of the National Academy of Sciences*, 2022.

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Ultrafast Optical Generation of Magnetic Texture Pairs

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Optical generation of magnetic textures [1] is one of the most promising achievements is the quest for low power consuming and fast memory devices. The theoretical understanding of the underlying physics is, however, still not very clear. Recently we proposed a new mechanism to generate a new type of emergent chiral spin mixing interaction [2] with ultrafast laser which can lead to the quasi-stable nontrivial texture. In this presentation we extend this formalism and show that such emergent interaction can lead to more exotic phases like an antiferromagnetic meron-antimeron pair [3]. Such phase can survive for 100ps and is fairly robust against impurity scattering which makes suitable for experimental observation.

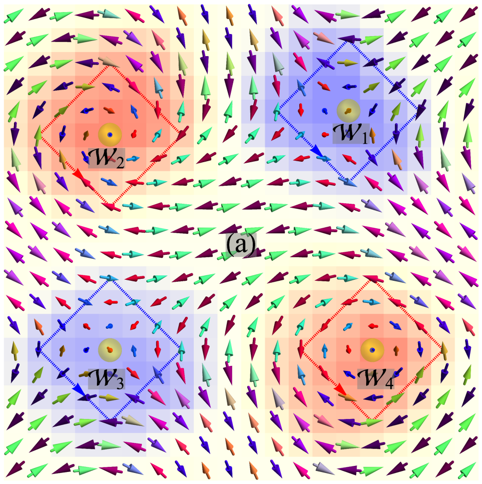

Figure 1. Laser excited meron-antimeron formation along with the magnetic charge centres [arXiv:2205.12100].

References

[1] F. Büttner *et al.*, *Nat. Mater.*, vol. 20, no. 1, pp. 30–37, 2021.
[2] S. Ghosh *et al.*, *Commun. Phys.*, vol. 5, no. 1, pp. 1–8, 2022.
[3] S. S. Ghosh *et al.*, *arXiv preprint arXiv:2205.12100*, 2022.

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Unconventional Computing Using Spintronic Oscillators

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The convolution operation is the accumulation of multiplications and is the key component of many neural networks. It is very computationally expensive and hard to optimize in both hardware and software domains. We define a new method [1] for the implementation of the convolution which implies the use of a parabolic function obtained with spin-torque diodes (STDs), that we named degree of rectification (DOR). The multiplication is obtained from three measures of the rectification curve of these devices. We prove the effectiveness of the system with micromagnetic simulations and experimental data taken from [2], a portion of which is shown in Fig. 1(a). As shown in Fig. 1(b), the obtained multiplication presents a small error which can be completely compensated by applying it in a convolutional neural network.

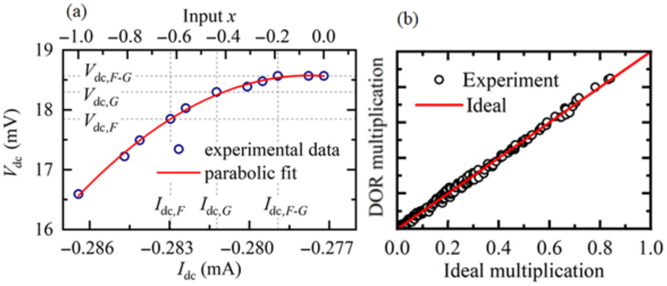

Figure 1. (a) Parabolic fit (red line) of the experimental data (blue dots) of the rectification curve of a STD [2]. (b) Comparison between 200 DOR-based multiplications (black dots) and ideal ones (red line).

References

[1] L. Mazza *et al.*, *Phys. Rev. Appl.*, vol. 17, no. 1, p. 014045, 2022.
[2] B. Fang *et al.*, *Nat. Commun*, vol. 7, no. 1, p. 11259, 2016.

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Brownian Reservoir Computing Realized Using Geometrically Confined Skyrmions

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Reservoir computing (RC) has been considered as one of the key computational principles beyond von-Neumann computing. Magnetic skyrmions, topological particle-like spin textures in magnetic films, are particularly promising for implementing RC [1] since they respond strongly nonlinear to external stimuli and feature inherent multiscale dynamics. We propose and experimentally demonstrate a conceptually new approach to skyrmion RC that exploits the thermally activated diffusive motion of skyrmions [2]. By confining the electrically gated and thermal skyrmion motion, we find that already a single skyrmion in a confined geometry suffices to realize non-linearly separable functions, which we demonstrate for the XOR gate along with all other Boolean logic gate operations [3]. Our proposed concept ensures low training costs as well as ultra-low power operation and can be readily extended by linking multiple confined geometries and/or by including more skyrmions in the reservoir, suggesting high potential for scalable and low-energy reservoir computing.

References

[1] D. Prychynenko *et al.*, *Phys. Rev. Appl.*, vol. 9, no. 1, p. 014034, 2018.
[2] J. Zázvorka *et al.*, *Nat. Nanotechnol.*, vol. 14, no. 7, pp. 658–661, 2019.
[3] K. Raab *et al.*, *arXiv preprint arXiv:2203.14720*, 2022.

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All-optical Generation and Time-resolved Polarimetry of Magneto-acoustic Resonances via Transient Grating Spectroscopy

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In the sub-micrometre range, Surface Acoustic Waves (SAWs) can be exploited to manipulate spin waves properties and implement desired functionalities, with appealing ramification in future energy-efficient spintronic devices.

By adopting a Four-Wave Mixing approach [1], we studied the magneto-elastic coupling in Ni thin films (14 nm, 8 nm) on crystalline (CaF_2) and amorphous (SiO_2) substrates. The output of PHAROS laser source (1030 nm, 300 fs) is split to obtain coherent pulses; their interference on sample generates the so-called Transient Grating (TG), which excite frequency-tuneable SAW. A third time-delayed beam is exploited to probe the acoustic (by TG spectroscopy) or magnetic dynamics (by time-resolved Faraday polarimetry). By tuning an in-plane applied magnetic field, it is possible to observe acoustically-driven ferromagnetic resonances (FMRs) [2], whose features allowed to quantify the effective magnetization and Gilbert damping of the samples. On the very same Ni/CaF_2 sample, we also performed standard FMR measurements, obtaining fully consistent results.

References

[1] J. Janušonis *et al.*, *Sci. Rep.*, vol. 6, no. 1, pp. 1–10, 2016.
[2] L. Dreher *et al.*, *Phys. Rev. B*, vol. 86, no. 13, p. 134415, 2012.

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Microstructure and magnetocaloric effect of $Mn_{1.3}Fe_{0.6}P_{0.5}Si_{0.5}$ microwires

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The family of Fe_2P magnetocaloric materials is highly regarded for their excellent magnetocaloric properties without any compositional reliance on critical elements. Their alloys, Mn-Fe-P-Si, are commonly fabricated through ball milling and arc induction melting followed by a subsequent thermal treatment to form the desired Fe_2P phase. In this work, polycrystalline $Mn_{1.3}Fe_{0.6}P_{0.5}Si_{0.5}$ microwires with the desired Fe_2P phase (Fig. 1(a)) were successfully fabricated by melt-extracted technique [1], and their microstructure and magnetocaloric effect (MCE) were investigated systematically. The microwires show a continuously variable solidification structure: near the contact zone with the Cu wheel, Fe_2P fine grains form and then grow into dendrites before resulting in the eutectic formation of Fe_2P+$(Mn,Fe)_5Si_3$ (Fig. 1(b)). The weight fraction of Fe_2P phase is detected as ∼82 %, leading to a maximum isothermal entropy change of ∼4.6 J kg^{-1} K^{-1} at a FM-PM transition temperature of ∼136 K (Fig. 1(c)).

References

[1] H. Wang *et al.*, *Metall Mater Trans A*, vol. 42, pp. 1103 – 1108, 2011.

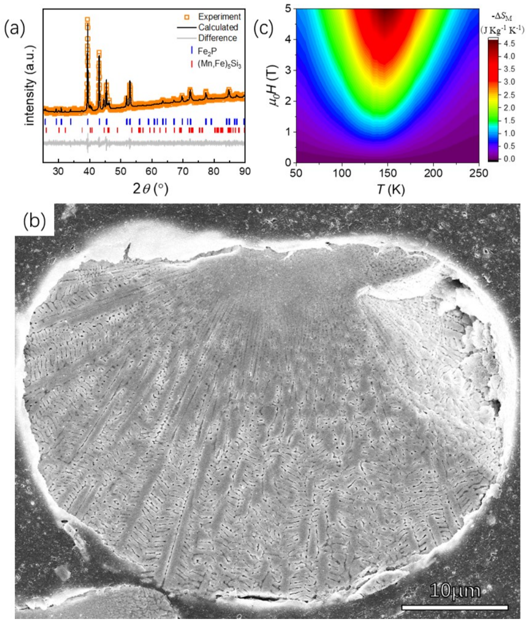

Figure 1. (a) Experimental XRD pattern and calculated Rietveld refinement, (b) SEM image of the radial cross section after etched and (c) temperature and magnetic field dependence of the isothermal entropy change.

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Time-dependent multistate switching of topological antiferromagnetic order in Mn_3Sn

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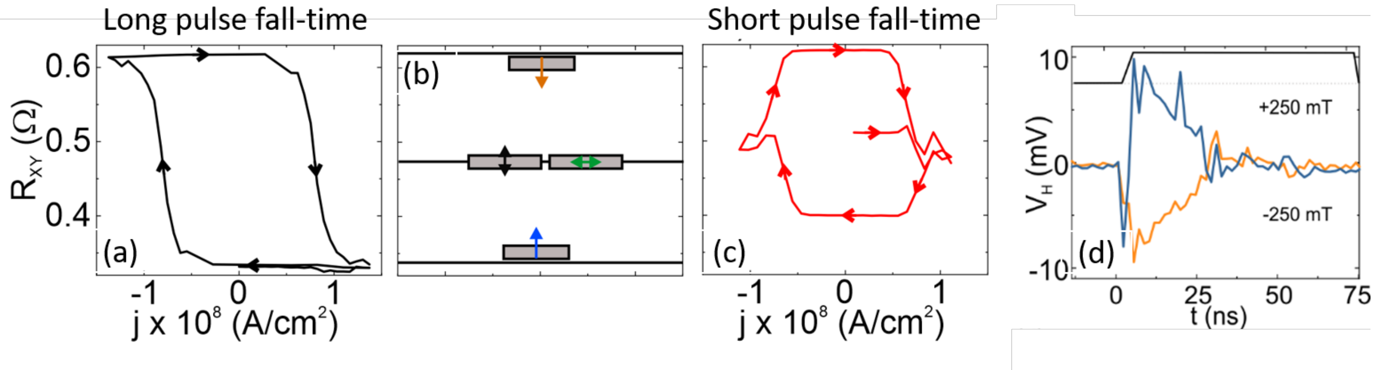

Figure 1. (a) Current induced switching of the AHE of Mn_3Sn with 10 μs pulses with 420 ns fall time. (b) Simplified magnetic configurations of the octupole vector. (c) Switching of AHE with 10 μs pulses with 35 ns fall time. (d) Time resolved switching of AHE during a 75 ns.

Antiferromagnets manipulated by spin-orbit torques offers a unique avenue to explain and exploit dynamics of antiferromagnets for spintronic device applications [1], [2]. We investigate the reversal of the magnetic octupole vector in the Weyl antiferromagnet Mn_3Sn by spin-orbit torques injected by Pt as a function of pulse shape, field, temperature and time [3]. The switching exhibits novel bi-stable or tri-stable [Fig. 1(b)] switching behaviour depending on the temporal evolution of current pulses [Fig. 1(a) and 1(c)]. Time resolved measurements reveal that switching occurs via a two-step demagnetization-remagnetization process. This is explained by self-heating over a timescale of tens of ns [Fig. 1(d)], followed by cooling in the presence of spin-orbit torques to deterministically set a magnetic state. These results offer a insight into the elusive switching dynamics of non-collinear antiferromagnets such as Mn_3Sn.

References

[1] H. Tsai *et al.*, *Nature*, vol. 580, pp. 608 – 613, 2020.
[2] Y. Takeuchi *et al.*, *Nature Materials*, vol. 20, pp. 1364 – 1370, 2021.
[3] G. K. Krishnaswamy *et al.*, *ArXiv*, 2022.

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Graphene Hall sensors for high performance magnetometry

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Graphene Hall sensors are a very promising devices for industrial applications but also for fundamental investigations [1]. In fact, the uncommon electronic properties of graphene and the physics of Hall effect allows to build high sensitivity sensors that can operate over a large range of magnetic field at ambient conditions. But such devices cannot be modelled by standard models used for semiconductor devices. We present here a model of galvanomagnetic effects in graphene devices that considers among other geometry effects, doping inhomogeneities, diffusion current and bias influence. The model is in good agreement with our experiments conducted on graphene devices encapsulated in boron nitride. We also conducted simulations on graphene Hall sensors subject to a non-uniform magnetic field in both diffusive and ballistic regime. Such simulations investigate the possibility to use sub-micrometer size Hall devices to detect and characterize magnetic nano-objects such as nanoparticles, ferromagnetic Van der Walls material or Spin-wave.

References

[1] H. Tsai *et al.*, *Nature*, vol. 580, pp. 608 – 613, 2020.

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3D magnetic structure of Py microstructures studied by vector tomography and micromagnetism

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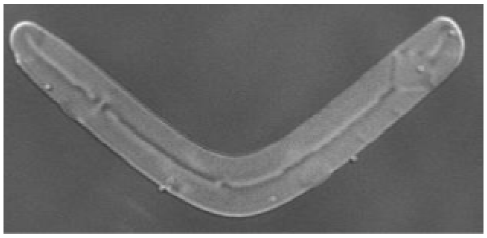

Figure 1. MTXM image of a 140 nm thick Py structure.

In the last years, the development of techniques like magnetic vector tomography [1], [2], or laminography [3] have provided the needed tools for a quantitative characterization of magnetization vector fields in thin films and nanostructures. Then, vector analysis methods can be applied to understand experimental 3D domain walls via emergent fields and topological charges. In this work we study the 3D magnetization vector field of a 140 nm thick permalloy microstructure in an arbitrary remanent state characterized by MTXM at MISTRAL beamline (ALBA synchrotron). A central asymmetric Bloch wall extends across the sample, dividing the structure into two domains with opposite magnetization direction in a closed-flux configuration. Emergent field lines, calculated from the experimental magnetization vector field using vector tomography, are concentrated in tubes connecting oppositely charged Bloch points. The interaction of emergent field tubes and domain walls and topological charge conservation rules will be discussed, comparing it with micromagnetic simulations.

References

[1] A. Hierro-Rodríguez *et al.*, *Nat. Comm.*, vol. 11, p. 6382, 2020.
[2] C. Donnelly *et al.*, *Nature*, vol. 547, pp. 328 – 331, 2017.
[3] C. Donnelly *et al.*, *Nat. Nanotechnol.*, vol. 15, pp. 356 – 360, 2020.

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Leveraging symmetry for an accurate spin-orbit torque quantification in ferrimagnetic insulators

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Spin transport across heavy metal (HM)/ferrimagnetic insulator (FI) interfaces has prompted an extensive research into the development of innovative spintronic concepts. In particular, spin-orbit torques (SOTs) have emerged as a highly efficient mean to electrically manipulate the magnetization, giving rise to ultrafast switching and domain wall motion in these insulating materials [1], [2]. Yet, there is an urgent need to appropriately account for the magnitude of these current-induced fields, without the influence of the spurious thermoelectric effects.

Herein, we propose a novel direct methodology based on combined harmonic Hall detection and macrospin simulations to accurately quantify SOTs in FIs with in-plane magnetic anisotropy. Based on angle-scan measurements and using symmetry arguments, we can accurately quantify the damping-like SOT, field-like SOT and thermoelectric contributions with an intrinsic error as low as a few % [3]. Our experimental results in Pt/Bi:YIG heterostructures further highlight the influence of in-plane temperature gradients induced by Joule heating, typically neglected in most studies up to date.

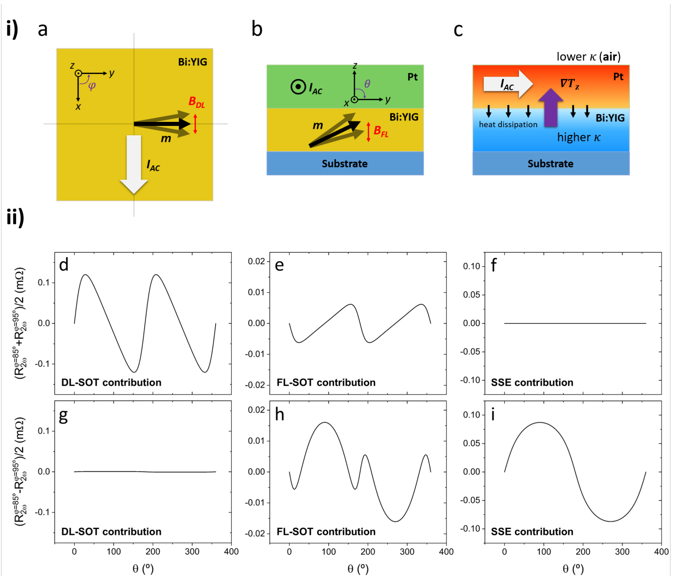

Figure 1. i) Schemes depicting the symmetry (at $\theta = 90°$) of the (a) damping-like (DL) and (b) field-like (FL) torques in a Pt/Bi:YIG bilayer; and (c) Joule heating-induced vertical temperature gradient, which contributes to the second harmonic response via the spin Seebeck effect (SSE). ii) Symmetry-based toolbox herein proposed to disentangle the interplay between the DL, FL and SSE components. Owing to their different symmetry with respect to $\theta = 90°$, the second harmonic oscillations originating from the previous individual contributions were simulated for an azimuthal angle of $\theta = 85°$ and 95°, and their sum (top panel, d-f) and difference (bottom panel, g-i) are taken as reference signals for SOT quantification.

References

[1] C. O. Avci *et al.*, *Appl. Phys. Lett.*, vol. 111, p. 072406, 2017.

[2] C. O. Avci *et al.*, *Nat. Nanotechnol.*, vol. 14, p. 561, 2019.

[3] M. Testa-Anta *et al.*, *Nat. Nanotechnol.*, in preparation (2022).

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Steering Majorana braiding via skyrmion-vortex pairs: A scalable platform

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Majorana zero modes are quasiparticles that hold promise as building blocks for topological quantum computing [1], [2]. However, the litmus test for their detection, the observation of exotic non-abelian statistics revealed by braiding, has so far eluded experimental efforts. Here we take advantage of the fact that skyrmion-vortex pairs in superconductor-ferromagnet heterostructures harboring Majorana zero modes can be easily manipulated in two spatial dimensions. We adiabatically braid the hybrid topological structures and explicitly confirm the non-abelian statistics of the Majorana zero modes numerically using a self-consistent calculation of the superconducting order parameter. Our proposal of controlling skyrmion-vortex pairs provides the necessary leeway toward a scalable topological quantum computing platform.

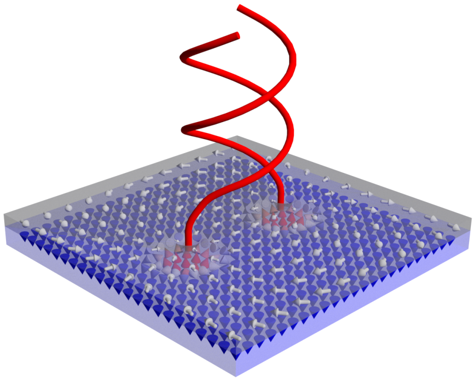

Figure 1. Braiding of two skyrmion-vortex pairs in a superconductor-ferromagnet heterostructure.

References

[1] J. Nothhelfer *et al.*, *Physical Review B*, vol. 105, no. 22, p. 224509, 2022.
[2] J. Nothhelfer *et al.*, *International Patent Application*, 2022.

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Gas sensors using magnetic nanoparticles and spin waves

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An innovative sensor based on the interaction between nanostructures and gases using spin waves to detect the induced magnetic changes was built (Fig. 1). The device is sensitive to low gas concentrations (under 50 ppm) of acetone, ammonia, carbon monoxide and benzene. The presence of these substances in breath is related to different metabolic mechanisms, so it could be used to diagnose complex diseases like cancer [1]. When traces of these gases diluted in air pass through magnetic nanoparticles (30 nm magnetite), the magnetic properties of the nanostructures are modified. This variation is detected by means of spin waves propagating along the surface of a YIG (Yttrium Iron Garnet) film: due to the known dependence of their propagation on the external field [2], their frequency will shift as the nanoparticles' properties change. The resonant frequency of the spin waves is measured with an oscillator circuit connected to a frequency counter.

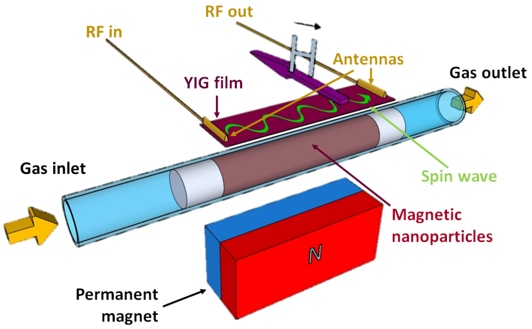

Figure 1. Scheme of the device.

References

[1] W. Miekisch *et al.*, *Clin. Chim. Acta*, vol. 347, pp. 25 – 29, 2004.
[2] J. R. Fragoso *et al.*, *Universidad Nacional Autónoma de Mexico*, 2016.

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Antiferromagnetic half-skyrmions electrically generated and controlled at room temperature

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Topologically protected spin textures, such as skyrmions, half-skyrmions (merons), and their antiparticles, are expected to play a pivotal role as information carriers in next generation magnetic memory devices [1]. Antiferromagnetic (AF) versions of these textures have gained significant interest due to their ultrafast dynamics, enhanced downsize scaling and deflection free current-driven motion. However, there has only been one example of their stabilization in a pure AF material [2], and evidence of their controlled movement is still lacking. We bridge the gap by showing that merons and antimerons can be electrically generated and moved at room temperature in thin film CuMnAs, a testbed material for AF spintronics [3].

References

[1] G. Finocchio *et al.*, *Journal of Physics D: Applied Physics*, vol. 49, no. 42, p. 423001, 2016.
[2] H. Jani *et al.*, *Nature*, vol. 590, no. 7844, pp. 74–79, 2021.
[3] P. Wadley *et al.*, *Science*, vol. 351, no. 6273, pp. 587–590, 2016.

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Optomechanics of magnetic van der Waals heterostructures

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The persistence of a magnetic order in a monolayer of van der Waals magnetic material has been established in 2016, offering the perspective to embed a magnetic degree of freedom in heterostructures made of other bidimensional materials such as graphene or transition metal dichalcogenides. The physical properties of van der Waals materials can be easily tuned by perturbations like strain or doping, inviting to the exploration of magnetism in two dimensions and its exploitation in novel ultrathin devices [1]. Our approach is to suspend these magnetic materials forming drum-like resonators and combine nano-optomechanics to a complementary method, Raman spectroscopy, on the same experimental setup [2], [3]. We probe the phase transition of a heterostructure encapsulating few-layer $FePS_3$, an Ising zigzag antiferromagnet, preluding an investigation of strain-tuned magnetism.

References

[1] B. Huang *et al.*, *Nature Materials*, vol. 19, no. 12, pp. 1276–1289, 2020.
[2] J.-U. Lee *et al.*, *Nano Letters*, vol. 16, no. 12, pp. 7433–7438, 2016.
[3] M. Šiškins *et al.*, *Nature Communications*, vol. 11, no. 1, 2020.

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$Mn_xFe_{3-x}O_4$ Nanoparticles for Magnetic Hyperthermia

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Magnetic nanoparticles (MNPs) have been studied for magnetic hyperthermia applications as co-adjuvant method for oncological treatments. Given its ability to transform the energy of an alternating magnetic field into heat, it raises the possibility of producing localized hyperthermia to induce tumor cell death [1]. Under this motivation, we synthesize, by thermal decomposition, $Mn_xFe_{3-x}O_4$ MNPs with a mean diameters of 12 and 28 nm and we study their properties. Both systems are superparamagnetic at room temperature with a blocking temperature lower than 18 K. The 12 and 28 nm MNPs systems present a saturation magnetization of 62 and 65 emu/g and magnetic anisotropy of $3.2 \cdot 10^4$ and $6.3 \cdot 10^4$ erg/cm^3 , respectively. The heating efficiency of the MNPs dispersed in different media, was evaluated by their specific loss power in presence of alternating magnetic fields obtaining values between 10-500 W/g. From cytotoxicity studies no significant dose-dependance on the cell viability for dose lower than 220 μg/ml of MNPs were found in HepG2 cell cultures. We will discuss the potential of these systems to generate magnetic hyperthermia as an oncological method.

References

[1] A. Jordan *et al.*, *Journal of Magnetism and Magnetic materials*, vol. 201, no. 1, pp. 413–419, 1999.

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Spin conversion in epitaxial monolayer graphene structures

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The search for materials with efficient spin-to-charge interconversion is currently a highly sought-after objective in spintronics. Spintronics devices allow functionalities like the manipulation of a magnetization by the spin Hall effect (SHE)[1] in the NM or thermal energy harvesting by means of its inverse counterpart the inverse spin Hall effect[2]. These effects can also be utilized for thermal management purposes, where a high efficiency of spin conversion is needed. In order to obtain more efficient devices based on thermo-spin phenomena, the role of interfaces is relevant. Here, we explore the effect of a graphene monolayer[3] between a FM and a NM layer and its interfacial spin transport properties by measuring the thermo-spin and spin pumping voltages.

We show that the gr monolayer plays an important role in the spin conversion process and its effect can be detected in both the thermo-spin and the spin pumping voltages.

References

[1] A. Anadon *et al.*, *ACS Applied Nano Materials*, vol. 4(1), pp. 487–492, 2020.
[2] R. Ramos *et al.*, *APL Mater.*, vol. 4, 2016.
[3] A. Anadon *et al.*, *APL Mater.*, vol. 9(6), p. 061113, 2021.

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Magnetic vortex domain wall observation on iron-cobalt alloy nanowires growing on commercial aluminium

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The magnetic vortex domain wall structure of polycrystalline imperfect iron-cobalt alloy nanowires (Nws) growing on 1050 aluminum by pulsed electrodeposition is reported. Nw arrays show homogeneous elemental composition and exhibit a structure composed of piled-up grains of small crystallites. Although the array of Nws on anodized aluminum grows both straight and within an inclination angle, in both cases, a high shape anisotropy is noticed, which is the most predominant contribution to the magnetic behavior. Misalignments and defects of the Nws in the array, as well as the wide distribution of lengths and diameters, do not contribute significantly to coercivity dispersion. A modified model is used to explain the changes in the magnetic behavior of the Nw's arrays, which accounts for structural imperfections and magnetostatic interactions. The reversal magnetization arising from the vortex domain wall propagation via localized curling is verified by off-axis electron holography.

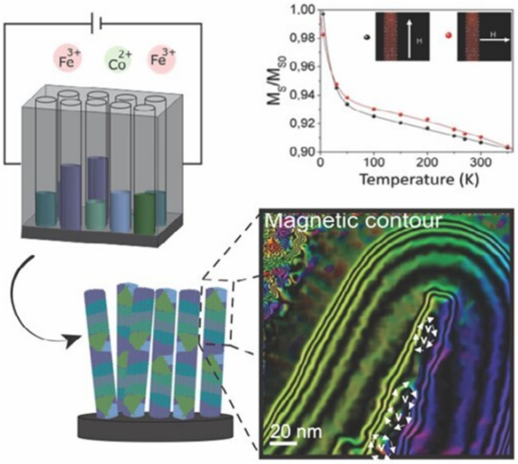

Figure 1. Polycrystalline, defective Fe67Co33 arrays of nanowires (Nws) are synthesized from low-purity anodized aluminum oxide by pulse electrodeposition. The magnetic properties are found to be dominated by shape anisotropy, despising the bending of the nanochannels forming hemispheric cavities. Off-axis electron holography confirms the magnetization reversal mechanism by vortex domain wall propagation via localized curling.

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Optimisation of perpendicular magnetic tunnel junction structures using scanning transmission electron microscopy

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The ability to fabricate high-quality magnetic tunnel junctions (MTJs) in a laboratory setting is essential if novel film structures and different switching mechanisms are to be explored [1], [2]. However, building successful structures for research remains a significant challenge even though CoFeB/MgO based MTJs have been commercially produced for many years [3]. Here, we report sputter deposited CoFeB/MgO/CoFeB MTJ stacks with thin continuous layers and CoFeB thickness ≤ 1.5 nm to obtain perpendicular magnetic anisotropy (PMA), essential for high-quality perpendicular MTJs.

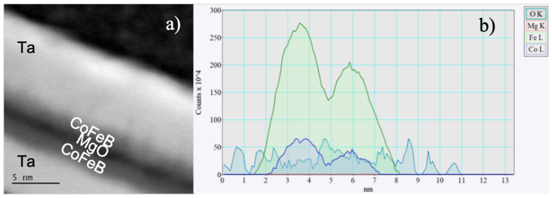

Figure 1. (a) STEM high-angle annular dark-field image showing the individual layers that form the MTJ, showing continuous CoFeB and discontinuous MgO layers (b) Integrated intensity of the electron energy loss spectroscopy core-loss edges taken from a line scan through the MTJ.

Scanning transmission electron microscopy (STEM) enabled a detailed investigation of prototype MTJ structures. Using the STEM data to optimise the Ta, CoFeB, and MgO deposition parameters produced enhanced, smoother interfaces. Resulting in MTJs with improved characteristics, which been grown at room temperature with a structure of (Pt(3nm)/Ta(6nm)/$Co_{20}Fe_{60}B_{20}$(0.8nm)/MgO(1nm)/$Co_{20}Fe_{60}B_{20}$(0.7nm)/Ta(6nm) on Si/SiO_2 (290nm) substrates. After annealing at $100°$C, the MTJs exhibit a strong interfacial PMA, demonstrating the importance of layer quality when growing MTJs.

References

[1] D. Apelkov *et al.*, *Proc. IEEE*, vol. 104, pp. 1796–1830, 2016.
[2] S. Ikeda *et al.*, *Appl. Phys. Lett.*, vol. 93, p. 082508, 2008.
[3] S. Ota *et al.*, *Appl. Phys. Express*, vol. 12, 2019.

Interferometry of Single Magnon Decoherence Mechanisms

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Finite magnon number state applications enabled by recent quantum magnonics advancements [1]–[3], such as, e.g., single magnon sources [2] and strong chip-integrated magnon-photon coupling [3], necessitate improved understanding of single magnon decoherence (SMD) mechanisms.

We propose a simple SMD measurement scheme (Fig. 1) using magnon and qubit (with much longer lifetime) states that evolve independently unless coupled temporarily under magnetic field pulses that entangle or unentangle them. The scheme (temporal-domain Mach-Zehnder interferometer) works as follows. Initially, the qubit is excited, and the system is unentangled. A magnetic pulse entangles the system. Then, after evolving freely for some time τ, it receives another "unentangling" pulse. When τ compares to the magnon lifetime, the final qubit population describes the SMD mechanisms.

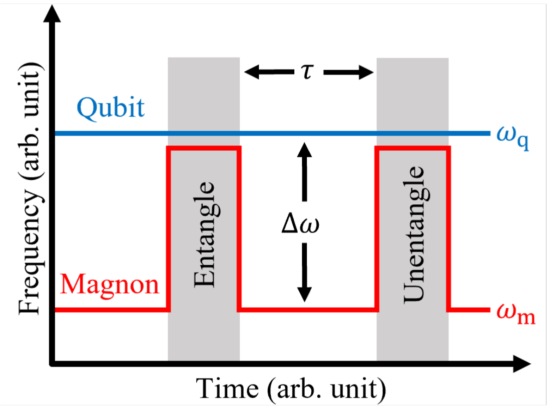

Figure 1. Proposed SMD measurement scheme.

In summary, we proposed a simple SMD measurement scheme that can be used to answer fundamental questions of quasi-particle decoherence at single quantum levels and is realizable using available technology.

References

[1] D. D. Awschalom *et al.*, *IEEE Trans. Quantum Eng.*, vol. 2, 2021.
[2] A. V. Chumak *et al.*, *IEEE Trans. Magn.*, vol. 58, 2022.
[3] P. G. Baity *et al.*, *Appl. Phys. Lett.*, vol. 119, 2021.

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Recovering 3D magnetization of 2D structures and multilayers

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The use of vector magnetic tomography has allowed the community to experimentally access the volume resolved vector magnetization field within arbitrary magnetic systems down to tens of nm resolution [1], [2]. However, these experiments usually require hundreds of different projections leading to very large acquisition times to be able to accurately reconstruct the magnetization.

Here we present a fast method to reduce dramatically the acquisition time. The method is specific for quasi two-dimensional magnetic structures, heterostructures and continuous films which are of interest for spintronics. The algorithm uses the Lambert-Beer equation to obtain the 3D magnetic configuration within the two-dimensional film [3].

We have validated our method with 40 nm thick Py microstructures. We have reconstructed the magnetization vector with just 30 projections measured where the acquisition time was about three hours. Work supported by Spanish MCI (PID2019-104604RB/AEI/10.13039/501100011033), Asturias FICYT (GRUPIN21 AYUD /2021/51185) and FEDER.

References

[1] C. Donnelly *et al.*, *Nature*, vol. 547, pp. 328–331, 2017.
[2] A. Hierro-Rodriguez *et al.*, *Nature Comm.*, vol. 11, p. 6382, 2022.
[3] A. E. Herguedas-Alonso *et al.*, *in preparation*.

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Tuneable Low Magnetostrictive NiFe Multilayers for High-Frequency Application

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Control of the electromagnetic properties of synthetic magnetic structures at gigahertz frequencies is advantageous for the simulation and design of components for high-frequency applications, such as shielding materials in magnetic recording. In such applications, it is desirable to have a high saturation magnetization, low coercivity, high permeability, and near-zero magnetostriction. A typical material is Ni$_x$Fe$_{100-x}$ alloys where $x \sim 80$ provides near-zero magnetostriction but also relatively low magnetization. However, multilayer structures such as Ni$_{80}$Fe$_{20}$/Ni$_{20}$Fe$_{80}$ may benefit some static properties such as magnetization while retaining low magnetostriction [1]. We present a study of the ferromagnetic resonance (FMR) [2] and microstructure of sputter-deposited thin-film NiFe bilayers of the form Ni$_x$Fe$_{100-x}$/Ni$_y$Fe$_{100-y}$. Of particular interest are layer combinations involving both fcc and bcc crystal structures, where FMR response was strong even when the bcc NiFe layer was the dominant layer (Fig. 1), a result not expected from the single-layer studies.

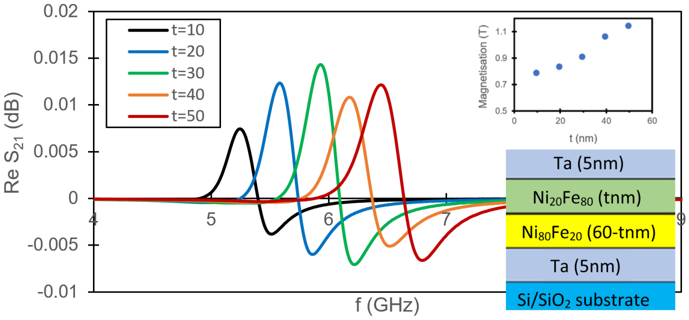

Figure 1. FMR spectra of Ni$_{80}$Fe$_{20}$ $(60 - t$ nm) / Ni$_{20}$Fe$_{80}$ (t nm) thin films with varying bcc layer thickness, t. Note that all measurements were performed at an applied field of 253Oe. Magnetization trend and structure schematic are inset.

References

[1] C. B. Hill *et al.*, *PhD Thesis, Queen's University Belfast*, 2013.
[2] Y. Ding *et al.*, *Journal of Applied Physics*, vol. 96, p. 2969, 2004.

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Magnetocaloric effect in nanocrystalline manganite bilayer thin films

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Due to their large surface-volume ratio, thin films are good candidates for magnetocaloric effect applications in refrigeration devices. With this aim, we studied the magnetic and magnetocaloric properties of the bilayers manganite thin films, La$_{0.88}$Sr$_{0.12}$MnO$_3$ / La$_{0.75}$Sr$_{0.25}$MnO$_3$ and La$_{0.75}$Sr$_{0.25}$MnO$_3$ / La$_{0.88}$Sr$_{0.12}$MnO$_3$, and their control single-layer films, La0.75Sr0.25MnO3 and La0.88Sr0.12MnO3. These films were grown by pulsed laser deposition on silicon substrates, resulting in polycrystalline films with average grain size of $\sim$35nm. We found that, for the bilayers, the temperature range of the magnetocaloric effect can be broadened without reducing the refrigerant capacity. Therefore, it is possible to combine the magnetocaloric effect qualities of nanocomposites and thin films to improve the performance and expand their potential use in refrigeration devices

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Magnetic Droplet Solutions from Exotic Spin-Orbit Torques

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Materials with large spin-orbit interactions can generate spin torques, that conventionally can only efficiently and deterministically switch materials with in-plane magnetizations. However, mirror symmetry breaking, such as in non-collinear antiferromagnets can generate exotic torques that can be used to manipulate magnetizations in materials with perpendicular magnetic anisotropy. Here, we investigate with micromagnetic simulations whether such exotic torques can generate magnetic droplet solitons in rectangular out-of-plane magnetized geometries. We show that a short high current pulse followed by a lower constant current can nucleate and stabilize magnetic droplet solitons. Due to the non-local injection of torque, that is different from the typical local nano-contact torque injection, we can control the number of droplets in our system through specific current pulse lengths and amplitudes. Additionally, we show that the nucleation current scales with the out-of-plane component of the spin polarization and is linear as a function of field strength.

This work was supported by NSF through the Illinois MRSEC (DMR-1720633). [1]

References

[1] A. H. R. Klause, *Appl. Phys. Lett.*, vol. 120, no. 242407, 2022.

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Stabilization of a Nonlinear Spin Wave Bullet Mode in the Presence of a Hot Magnon Gas

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One property of the nonlinear spin wave bullet mode is that it is unstable, and quickly vanishes if the excitation source is turned off [1]. The excitation source is usually a spin pumping, caused, for example, by the spin-Hall effect, and it would be useful to find means for a bullet mode stabilization.

It has been recently shown experimentally that a nonlinear spin wave bullet mode can be stabilized in the presence of a hot magnon gas [2] in a sample undergoing a rapid cooling process [3]. Here, we present a simple model for explanation of the observed nonlinear bullet mode stabilization. Our calculations show that the nonlinear bullet mode can be stabilized by a flow of magnons from the hot magnon gas, if the chemical potential of the hot magnons gas exceeds the frequency of the nonlinear spin wave bullet mode.

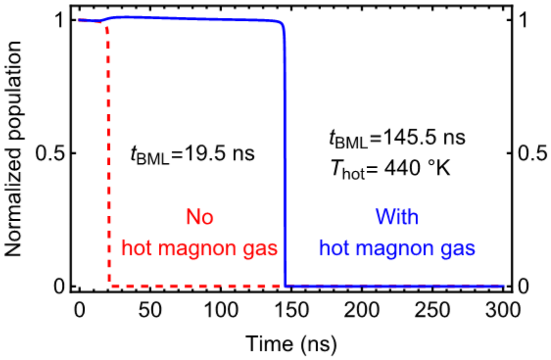

Figure 1. Calculated normalized population of a nonlinear bullet mode versus time after the excitation source is turned off. The bullet mode lifetime (BML) is significantly increased in the presence of a hot magnons gas. The hot magnons gas was considered to be created in the process of a rapid cooling of the sample after being heat up to 440 °K.

References

[1] V. E. Demidov *et al.*, *Sci. Rep.*, vol. 6, no. 32781, 2016.
[2] M. Schneider *et al.*, *Phys.Rev. B*, vol. 104, no. 14, 2021.
[3] M. Schneider *et al.*, *Nat. Nanotechnol.*, vol. 15, p. 457–461, 2020.

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Magnetocaloric effect of La$_{0.6}$Sr$_{0.4}$CoO$_3$ nanoparticles

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The study of the magnetocaloric effect (MCE) is defined as an isothermal change in magnetic entropy [1]. In this work we study the MCE, the structural, morphological and magnetic characterization of La$_{0.6}$Sr$_{0.4}$CoO$_3$ (LSCO) nanostructured powders. Samples were synthesized by the pore wetting method, using polycarbonate membranes with pores of 200nm (C2) and 800nm (C8) and treated with temperatures at 800°C (T1) and 1000°C (T2), obtaining C2T1, C2T2, C8T1 and C8T2 samples. All samples shown magnetic saturation larger than 11,5 emu/g and coercive fields less than 2500 Oe. The MCE values was obtained from the dependence of the entropy change (ΔS) with temperature. The maximum ΔS values were observed close to the transition temperature in all cases. The values of obtained for C2T1, C8T1, C2T2 and C8T2 was 0.38 J/kg/K, 0.32 J/kg/K, 0.77 J/kg/K, 1.13 J/kg/K respectively.

References

[1] H. Biswal *et al.*, *Ceram. Int.*, vol. 46, 2020.

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Neuromorphic pattern recognition using antiferromagnetic artificial neurons

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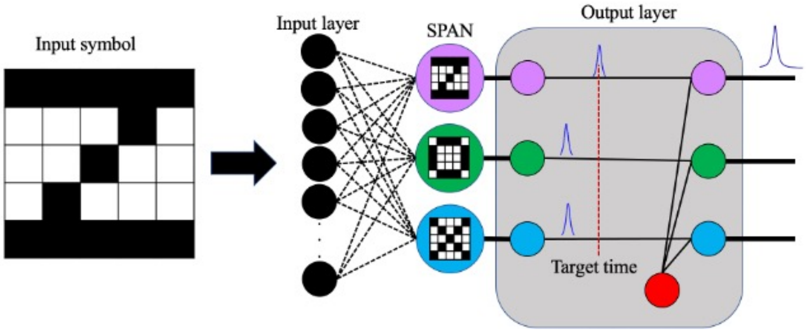

Figure 1. Architecture of a 3 SPAN neural network. The input symbol is encoded in the spiking pattern of the input layer neurons. The synaptic weights between the input layer and the SPANs are adjusted during training. The output layer ensures only the spike of the recognized symbol is outputted.

Neuromorphic computing using artificial spiking neurons outperforms traditional computation at recognition tasks. A promising design of an ultra-fast artificial neuron is based on antiferromagnetic (AFM) spin Hall oscillators driven by a sub-threshold spin current that produces ultra-short voltage spikes in response to a weak external stimulus [1]. A supervised machine learning algorithm based on the temporal position of the spikes, called spike pattern association neuron (SPAN) [2], is used during training. An AFM SPAN, trained to recognize a symbol made from a grid, produces a spike at a target time when the symbol is supplied as input. SPANs, trained to recognize different symbols, are connected to the same inputs. An output layer is created to ensure that only the spike corresponding to the recognized symbol is sent to the output. Using the SPAN algorithm, we develop a neural network with AFM artificial neurons capable of performing the pattern recognition tasks.

References

[1] R. Khymyn *et al.*, *Scientific reports*, vol. 8.1, pp. 1–9, 2018.
[2] A. Mohemmed *et al.*, *Neurocomputing*, vol. 107, pp. 3–10, 2013.

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A new set of curves simplifies anhysteretic magnetization analysis

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We present a recently developed magnetization interpretation method based on the analysis of both the semi-log and the linear magnetization derivative responses [1]. We discuss diverse scenarios of soft magnetic materials based on a law of partial magnetizations for magnetic mixtures and on the Langevin-Weiss model. An algorithm is proposed for fitting the physically based model parameters using a deterministic approach [1], [2]. We illustrate the proposed technique through a variety of well-motivated examples covering isotropic/anisotropic and homogeneous/non-homogeneous materials: an isotropic soft ferrite, a nanocrystalline alloy magnetized transverse to its preferred direction, a non-oriented electrical steel, and a highly grain-oriented electrical steel magnetized transverse to the rolling direction. Our method has demonstrated to simplify the analysis of soft magnets enabling an easier and more accurate modeling of anhysteretic magnetization curves.

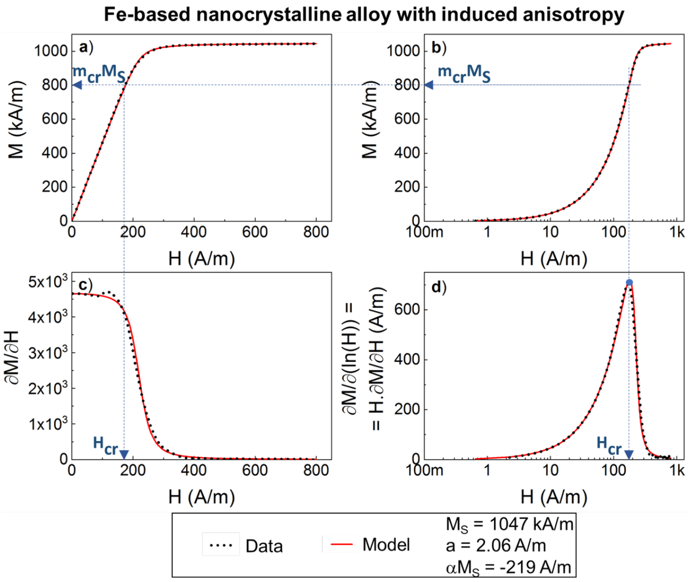

Figure 1. Anhysteretic magnetization of a nanocrystalline alloy with induced transverse anisotropy analyzed through the proposed set of plots: a) typical linear M vs H plot, b) same as a) but with a logarithmic scale for H, c) typical linear ∂M/∂H vs H plot, d) semi-log magnetization derivative vs H, with a logarithmic scale for H. The analysis allowed to identify the alloy as a magnetically homogenous material. The critical field and the corresponding magnetization are pointed out in the plots. Then, following our proposed algorithm, the magnetization response was fitted with a single Langevin-Weiss function. We obtained a negative molecular field constant, which describes the magnetic anisotropy of the material.

References

[1] J. M. Silveyra and J. C. Garrido, *AIP Advances*, vol. 12, no. 3, 2022.
[2] J. M. Silveyra and J. C. Garrido, *Journal of Magnetism and Magnetic Materials*, vol. 540, 2021.

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Response of the chiral soliton lattice to spin polarized currents

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Spin polarized currents originate a spin transfer torque that enables the manipulation of magnetic textures. In monoaxial chiral helimagnets the Dzyaloshinskii-Moriya interaction favors inhomogeneous distributions of the magnetization leading to the formation of a chiral soliton lattice (CSL) [1]. These objects present interesting properties, which make them good candidates for spintronic and electronic devices [2], [3]. Here we theoretically study the effect of a spin-polarized current on the magnetic texture corresponding to a CSL under a transverse magnetic field. At sufficiently small current density the CSL reaches a steady motion state with a velocity proportional to the intensity of the applied current which is independent of soliton density and the magnetic field. This motion is accompanied with a small conical distortion of the CSL. At large current density the spin transfer torque destabilizes the CSL, driving the system to a ferromagnetic state (FM) parallel to the magnetic field (Fig. 1).

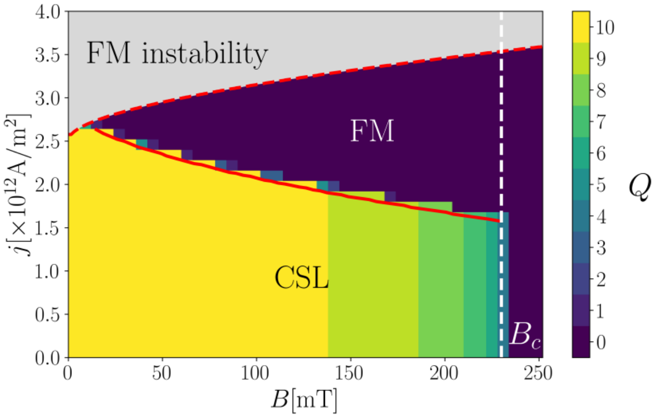

Figure 1. The j-B phase diagram for a chiral monoaxial helimagnet. In the yellow-green region the CSL is stable (Q>1). In the dark blue region the FM state is stable (Q=0).

References

[1] Y. Togawa *et al.*, *J. Phys. Soc. Jpn.*, vol. 85, no. 112001, 2016.
[2] C. Back *et al.*, *J. Phys. D: Appl. Phys.*, vol. 53, no. 363001, 2020.
[3] N. Nagaosa, *Jpn. J. Appl.*, vol. 58, no. 120909, 2019.

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Magnetic and Structural Characterization of the FeIn$_2$yCr$_{2-2y}$S$_4$ (0.6 $\leq$ y $\leq$ 1) system

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Ferromagnetic resonance (FMR) was used to study the temperature dependence of the FeIn$_2$yCr$_{2-2y}$S$_4$, 0.6 $\leq$ y $\leq$ 1, semiconductor system. The samples were synthesized using the Chemical Vapour Transport (CVT). X-Rays Diffraction (XRD), Scanning Electron Microscopy (SEM), Magnetization curves M(H), and FMR in the temperature range of 80<T<700 K were used for the structurally and magnetically characterization of the samples. Magnetization curves were measured in ZFC-FC conditions, observing the spin-glass behavior with freezing temperatures (T_{sg}) in the 130$\leq$T$\leq$150 K range, with Néel temperatures (T_N) in the 157$\leq$T$\leq$181 K range. At low temperatures, the magnetization curves show negative values, which increase with the Cr[1], [2]. The FMR spectra show a multiplet of signals for T<150K due to anisotropies, while for T> 150K a single quasi-symmetric signal is observed. In general, a non-monotonous increase in linewidth when the temperature decreases are observed.

References

[1] T. S. Santos *et al.*, *J. Appl. Phys.*, vol. 128, no. 113904, 2020.
[2] D. Richardson *et al.*, *Physical Review Applied*, vol. 10, no. 054046, 2018.

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POSTERS

Abstracts

List of Poster Presentations

Spin Splitting Torque Phenomenon: the Role of The Exchange Coupling in RuO_2/Py

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Recently, researchers have discovered that the combination of an anisotropic crystal field and strong antiferromagnetic exchange coupling between magnetic atoms leads to the anisotropic spin splitting effect (ASSE), which can be electrically used to generate a large noncollinear spin current and spin splitting torque (SST) on adjacent ferromagnetic layer [1], [2]. Bai et al. experimentally observed spin splitting torque in RuO_2, an antiferromagnetic material with ASSE, by spin torque-ferromagnetic resonance (ST-FMR) technique [3]. We further studied the SST in RuO_2/Py heterostructure by using the variable temperature ST-FMR measurements and proved that there exists a more efficient SST which is related to the electric field direction and Néel vector in RuO_2. Meanwhile, we use the exchange coupling between RuO_2 and Py to realize the control of the Néel vector by the ferromagnetic spin configuration, and then generate the adjustable SST by external magnetic field. These results reveal the features of SST and provide an opportunities to integrate exchange coupling with controls of spin torque in a single structure.

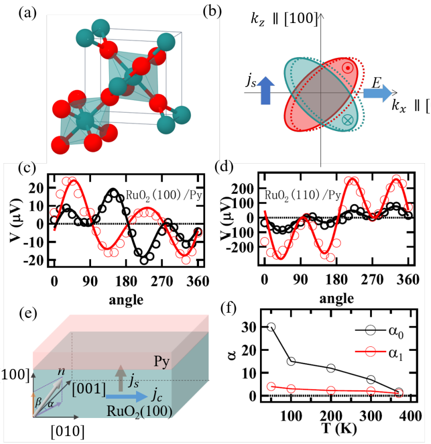

Figure 1. (a) Crystal of the rutile RuO_2. Green and red spheres represent O and Ru atoms, respectively. (b) Schematic of the anisotropic spin band splitting in RuO_2. When we apply the electric field E along the [010], the spin current JS flowing in the [100] direction can be generated via the spin-splitter effect. Angle-dependent voltage of ST-FMR data for (c) RuO_2(100)/Py and (d) RuO_2(110)/Py. (e) Schematic orientation of Néel vector in RuO_2 (Gray), the in-plane projection of the Néel vector n deviates from the easy axis [001] at the angle α. (f) The temperature dependence of α.

References

[1] R. González-Hernández *et al.*, *Physical Review Letters*, vol. 126, no. 12, p. 127701, 2021.
[2] H.-Y. Ma *et al.*, *Nature communications*, vol. 12, no. 1, pp. 1–8, 2021.
[3] H. Bai *et al.*, *Physical Review Letters*, vol. 128, no. 19, p. 197202, 2022.

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Electric control of topological defects in the stripe pattern of NiFe/NdCo$_5$ multilayers

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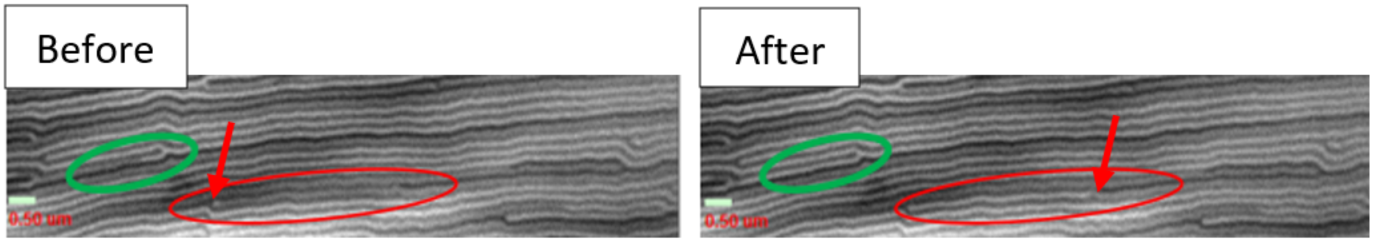

Figure 1. Figure 1: Magnetic TXM images before (left) and after (right) a 0.8 A pulse with 20 ns width is applied (j = $0.8{\cdot}10^{12}$ A/m^2). The areas where the movement of textures can be seen are marked in red and green.

The intense research done in spintronics, aiming to obtain low energy consumption memory devices, has led to the development of the magnetic racetrack concept [1]. Stripe domain patterns in $\mathrm{Ni_8Fe_2/NdCo_5}$ multilayers have been shown to act as natural racetracks for the motion of Bloch points and vortex-antivortex pairs under in-plane magnetic fields [2]. Here, using magnetic transmission X-ray microscopy, we have been able to observe the movement of both vortex-antivortex pairs and bifurcations within the stripe pattern in magnetic multilayers of Ni8Fe2/NdCo5 under current pulses with different amplitudes and widths (20-200 ns), as shown in Fig. 1. As a result of the geometry of the sample, these pulses correspond to current densities (j) between 0.1 and $3{\cdot}10^{12}$ A/m^2. This movement seems related to the spin-transfer torque effect, as it occurs when current densities of 1012 A/m2 are reached.

References

[1] S. S. Parkin *et al.*, *Science*, vol. 320, no. 5873, pp. 190–194, 2008.
[2] A. Hierro-Rodriguez *et al.*, *Applied Physics Letters*, vol. 110, no. 26, p. 262402, 2017.

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Skyrmion Pinning Energetics in Thin Film Systems

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Skyrmions are topologically stabilized magnetic quasi-particles, which are promising candidates for low-power applications in data storage and processing [1]. In order to realize reliable thin film skyrmion devices, a thorough understanding of pinning effects is required since pinning strongly influences skyrmion movement [2]. Our observations by Kerr microscopy show that a simple approach considering the skyrmion as a rigid particle in a static potential is not sufficient to capture such pinning effects [3]. Instead, we report that the pinning originates at the skyrmion boundary. As the skyrmions are not rigid but can be deformed, we conclude that an accurate energy description of skyrmion configurations is complex. Furthermore, we demonstrate a strong dependence of pinning on the skyrmion size. As the size can be tuned by an external magnetic field, this allows us to effectively switch pinning sites on and off [3].

References

- [1] J. Zázvorka *et al.*, *Nature nanotechnology*, vol. 14, no. 7, pp. 658–661, 2019.
- [2] C. Reichhardt *et al.*, *arXiv preprint arXiv:2102.10464*, 2021.
- [3] R. Gruber *et al.*, *Nature Communications*, vol. 13, no. 1, pp. 1–9, 2022.

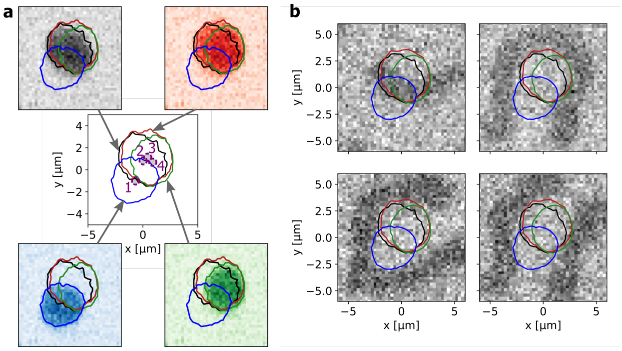

Figure 1. Pinning of skyrmion boundaries. (a) The central coordinate frame shows the observed skyrmion boundary positions for skyrmions centered at 1 (in blue), 2 (black), 3 (red) and 4 (green. The positions of the corresponding skyrmion center coordinates are visualized by the dashed purple circles, which are additionally filled in grey for better visibility. The surrounding plots depict the average intensity for each pinning site with a color scale matching to the boundary color. (b) Frame images of arbitrary stripe observations in the same sample area. The previously determined skyrmion boundaries are plotted additionally for comparison. The paths of the skyrmion boundaries fit the domain boundary position of the stripes in significant parts.

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Anomalous Spin Pumping and Thermal Stabilization in CFB/Mo Heterostructures for Spintronics Applications

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High temperature stability is a key requirement for better performance of spintronic devices [1], [2]. Here, we study the spin pumping in the as-grown and post-annealed (400°C) $Co_{60}Fe_{20}B_{20}$/Molybdenum (CoFeB/Mo) heterostructures. It is observed that the as-grown Mo layer, in the heterostructure, crystallizes as the mixed phase comprising of body centred cubic (*bcc*) and face centred cubic (*fcc*) phases, with *fcc* as the dominating phase. After the annealing at 400°C, although the Mo layer continues to exist in mixed phase, but *bcc* emerges as the dominating phase. The ferromagnetic resonance measurements reveal that the spin pumping efficiency is higher in annealed stack. The origin of large spin pumping lies at the structural modification in Mo. Thus, our results indicate that 4*d* transition metal such as Mo, even with a weak spin-orbit interaction, can be a suitable nonmagnetic material for spin orbit torque-based memory applications.

References

[1] P. Khanal *et al.*, *Applied Physics Letters*, vol. 119, no. 24, p. 242404, 2021.
[2] S.-W. Lee and K.-J. Lee, *Proceedings of the IEEE*, vol. 104, no. 10, pp. 1831–1843, 2016.

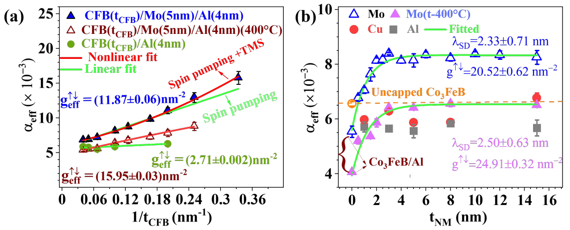

Figure 1. (a) shows the of effective Gilbert damping (α_{eff}) as a function of 1/tCFB for three different series Si/SiO2/CFB(tCFBnm)/Mo(5nm)/Al(4nm), Si/SiO2/CFB(tCFBnm)/Mo(5nm)/Al(4nm) (annealed at 400°C for 1 hour), and Si/SiO2/CFB(tCFBnm)/Al(4nm) heterostructure, respectively. The fitted lines are fitted with equation α_{eff}=α_{CFB}+$g^{\Updownarrow}_{eff}$ $(g\mu_B)/(4\pi M_S t_{CFB})$+ $\beta_{TMS}/(t_C FB^2)$ to extract the effective spin mixing conductance ($g^{\Updownarrow}_{eff}$). (b) Represent the α_{eff} as function of tNM for as grown (Si/SiO2/CFB(10nm)/Mo(tNMnm)/Al(4nm)) and (annealed sample Si/SiO2/CoFeB(10nm)/Mo(tNMnm)/Al(4nm)-400°C for 1hour), respectively. However, these data are fitted with equation $\alpha_{eff} - \alpha_{CFB} = g^{\Updownarrow}(g\mu_B)/(4\pi M_S)$ $1/t_C FB$ to extract the intrinsic spin mixing conductance $g^{\Updownarrow}_{Mo}$ and spin diffusion length (λ_{SD}) of Mo.

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Frequency Dependent Inverse Spin Hall Effect in $La_{0.67}Sr_{0.33}MnO_3$/Pt Bilayer System

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LSMO (20 nm)/Pt (t_{Pt} = 0, 4nm) bilayer samples have been prepared on $SrTiO_3$ (001) substrate using an oxygen plasma assisted molecular beam epitaxy system. ISHE measurements are performed using home modified coplanar wave-guide (CPW) based ferromagnetic resonance (FMR) spectroscopy [1] and microwave absorption spectra has been measured using Vector Network Analyzer (VNA). Here we have shown the relation between FMR absorption intensity to inverse spin Hall effect voltage. We have performed angle dependent spin pumping measurement for $La_{0.67}Sr_{0.33}MnO_3$/Pt bilayer system at different frequencies. It has been observed that spin Hall angle has a clear dependency on frequency [2]. We have shown that at higher frequency spin Hall angle is higher than that of at lower frequencies. The maximum value of spin pumping voltage at 14 GHz is 98 μV and its corresponding spin Hall angle is calculated to 0.06.

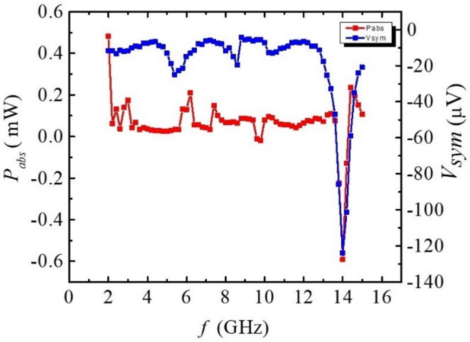

Figure 1. Microwave absorption (Pabs) and Vsym vs f plot.

References

[1] B. B. Singh *et al.*, *physica status solidi (RRL)–Rapid Research Letters*, vol. 13, no. 3, p. 1800492, 2019.
[2] P. Gupta *et al.*, *Nanoscale*, vol. 13, no. 4, pp. 2714–2719, 2021.

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Effect of Seed Layer on Ta Crystalline Phase and Spin Hall Angle

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Spin-orbit coupling (SOC) plays vital role in spin to charge interconversion for heavy metal (HM)-ferromagnet (FM) bilayer structure. Spin pumping is an efficient method to generate pure spin current by precessional motion of magnetization which transfers angular momentum to HM. The efficiency of conversion is quantified by spin Hall angle (θ_{SH}) and spin-mixing conductance (SMC) [1]. The need of low longitudinal resistivity with high θ_{SH} is challenging and the effect of seed layer on HMs phase is largely overlooked. Here, we report the effect of seed permalloy (Py or $Ni_{80}Fe_{20}$) layer thickness on Tantalum (Ta) crystalline phase and its θ_{SH}. In this work, we have investigated the effect of the permalloy seed layer and its thickness on the Ta crystalline phase. We have observed a structural phase transition in Ta as the thickness of the seed layer increases that affects the θ_{SH} of the Ta. Ta exhibits mixed phase (α+β) on seed permalloy layer above $t_{Py} > 12$ nm due to strain at the crystalline Py and Ta. However, Ta nucleates as α-Ta on $t_{Py} < 8$ nm where there is no prominent crystalline nature. This Ta phase transition is mainly attributed by strain at the Py/Ta interface. Ferromagnetic resonance (FMR) based spin pumping shows that effective damping is enhanced for all samples. We have quantified the θ_{SH} of (α+β)-Ta which is higher than α-Ta. The estimated □SH for (α+β)-Ta is 0.15±0.009 which is higher than α-Ta. Our systematic study provides an insight about Ta phase transition via seed layer thickness and gives an alternative route for tuning θ_{SH} [2].

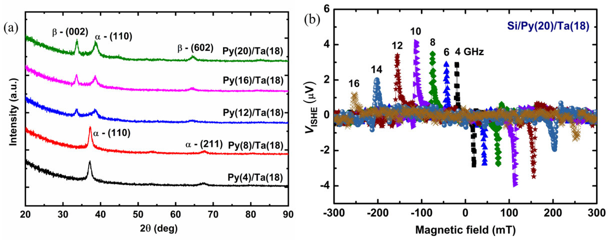

Figure 1. (a) Ta (18) Phase transition from α to (α+β) phase as a function of Py thickness (t_{Py}). (b) Inverse spin Hall voltage drop for Py(20)/(α+β)-Ta(18).

References

[1] Y. Tserkovnyak *et al.*, *Reviews of Modern Physics*, vol. 77, no. 4, p. 1375, 2005.
[2] K. Sriram *et al.*, *Nanoscale*, vol. 13, no. 47, pp. 19 985–19 992, 2021.

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Site Disorder Effects on Electronic and Magnetic Properties of Co_2MnAl Heusler Alloy

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Heusler alloys with high Spin Polarization (*P*) are the prerequisite for spintronics application. As, *P* is strongly influenced by the swap disorder present in the sample, DFT calculations have been carried out to find the Mn-Al and Co-Al swap disorder effect on electronic and magnetic properties of Co_2MnAl alloy [1]. Co-Al disordered structure has high relative energy with respect to the ground state ($L2_1$ ordered structure) compared to Mn-Al disordered structure; therefore, unlikely to be grown experimentally. The density of states calculations further reveals that Mn-Al disorder is accompanied by increased *P*, whereas Co-Al disorder shows the opposite effect. The change in *P* is due to the reconstruction of density of states near the Fermi level. The difference in saturation magnetization, from 4.02 μ_B/f.u. ($L2_1$ ordered structure) to 4.01 μ_B/f.u. (Mn-Al disordered structure) and 3.56 μ_B/f.u. (Co-Al disordered structure) can be attributed to the change in swap atom's magnetic moments.

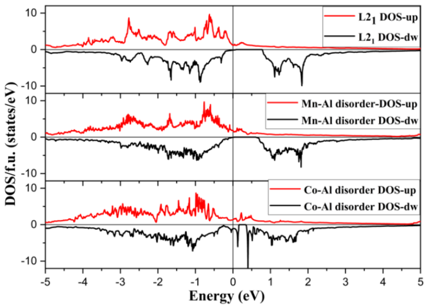

Figure 1. Density of states (DOS) of Co_2MnAl Heusler Alloy for $L2_1$, Mn-Al disorder and Co-Al disorder state.

References

[1] K. Seema, *Intermetallics*, vol. 110, p. 106478, 2019.

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Spinterface Modulated Magnetic Properties of $Co_{20}Fe_{60}B_{20}/Alq_3$ Hetero-structures

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Organic spintronics aims to combine organic electronics and spintronics by bringing the organic semiconductors (OSCs) to the close proximity of various inorganic materials [1]. When organic molecules are deposited on a ferromagnet, a few monolayers of organics acquire magnetism because of the orbital hybridization and charge transfer at the hybrid interface, popularly known as spinterface [2]. In this work, we have investigated the spinterface effect on the magnetization dynamics in CoFeB/Alq_3 hetero-structures. The Alq_3 molecules reduce the magnetic anisotropy and domain sizes of CoFeB upon the formation of the spinterface. Whereas, the ferromagnetic resonance study reveals that the Gilbert damping gets enhanced in the CoFeB/Alq_3 hetero-structures.

References

[1] S. Sanvito, *Nature Physics*, vol. 6, no. 8, pp. 562–564, 2010.
[2] M. Cinchetti *et al.*, *Nature materials*, vol. 16, no. 5, pp. 507–515, 2017.

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Spin Pumping in Sputtered MoS_2 /CoFeB Bilayers

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Transition metal dichalcogenides are known to have high spin-orbit coupling (SOC), an essential property for spintronic applications [1]. Large area fabrication of MoS_2 by chemical or exfoliation methods makes it difficult for spintronics applications. In this work, we demonstrate spin pumping and inverse spin Hall effect in sputtered MoS_2(t)/CoFeB(8 nm)/AlOx(4 nm) heterostructures where 't' varies from 5 to 28 nm.

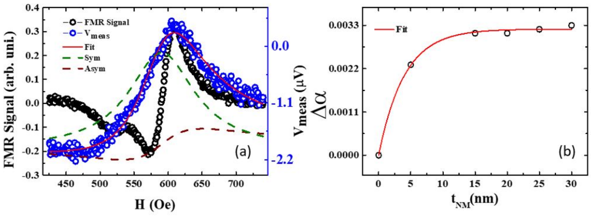

Figure 1. (a) Voltage (V_{meas}) measured across the sample with applied magnetic field along with FMR signal. (b). Change in damping constant as a function of thickness of MoS_2 (tNM).

The heterostructure was fabricated by RF and DC magnetron sputtering. Here the spin current was generated from CoFeB and injected into MoS_2 layer via spin pumping using ferromagnetic resonance (FMR) spectroscopy. Various spin rectification effects were separated by performing angle dependent FMR measurements [2]. The spin pumping voltage up to 4.4 μV was measured which was dominant over the rectification effects. The real part of spin mixing conductance, spin Hall angle and spin diffusion length were found to be $1.25\times10^{19} m^{-2}$, 0.19 and 8nm, respectively.

References

[1] Q. H. Wang *et al.*, *Nature nanotechnology*, vol. 7, no. 11, pp. 699–712, 2012.
[2] B. B. Singh and S. Bedanta, *Physical Review Applied*, vol. 13, no. 4, p. 044020, 2020.

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Room Temperature Nonlocal Detection of Charge-Spin Interconversion in a Topological Insulator

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Topological insulators (TIs) are emerging materials for next-generation nanoelectronic devices, thanks to the non-trivial spin-momentum locking of their topological surface states. Although charge-spin conversion (CSC) has previously been reported in TIs by potentiometric measurements [1], [2], reliable nonlocal detection has so far been observed only at cryogenic temperatures up to $T = 15$ K [3]. Here, we report nonlocal detection of CSC and its inverse effect in the TI compound $Bi_{1.5}Sb_{0.5}Te_{1.7}Se_{1.3}$ at room temperature using a van der Waals heterostructure with a graphene spin valve device. The lateral nonlocal device design with graphene allows observation of both spin switch and Hanle spin precession signals for generation, injection and detection of spin currents by the TI. Detailed bias- and gate-dependent measurements in different geometries prove the robustness of the CSC effects in the TI. These findings demonstrate the possibility of using topological materials to make all-electrical room-temperature spintronic devices.

References

[1] C. Li *et al.*, *Nature Nanotechnology*, vol. 9, 2014.
[2] A. Dankert *et al.*, *Physical Review B*, vol. 97, no. 12.
[3] K. Vaklinova *et al.*, *Nano Letters*, vol. 16, no. 4.

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Growth Conditions Optimization of Sputtered Yttrium Iron Garnet Thin Films

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Electronics devices are based on semiconductors transistors, and their improvement is mostly due to reducing its size, which is reaching its limit. The magnonic has appeared as an alternative solution for electronic devices to overcome this problem, with several advantages. Among these lower energy consumption, faster information exchange, and lower heating due to the absence of the Joule effect. The $Y_3Fe_5O_{12}$ (YIG) is a promising material for this application because it has low Gilbert damping and low coercivity, among other properties [1], [2]. In this work, we optimize the growth and annealing conditions of YIG thin films, seeking the lowest value of the Gilbert damping coefficient. The films were grown by magnetron sputtering on $Gd_3Ga_5O_{12}$ monocrystalline substrates with [111] orientation. We comprehensively analyzed the dynamic of magnetization using ferromagnetic resonance (FMR) and performed Spin Pumping (SP) and Inverse Spin Hall Effect experiments (iSHE).

References

[1] D. Zhang *et al.*, *Rare Met.*, 2019.
[2] H. Ucara *et al.*, *J. Magn. Magn. Mater.*, vol. 496, p. 165902, 2020.

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Electron Spin Resonance study of Anatase Ti$_{1-x}$ Fe$_x$O$_2$(0.03 ≤ x ≤ 0.12) Nanocrystalline as Dilute Magnetic Semiconductors:

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A simple sol gel approach technique was used to prepare Ti$_{1-x}$ Fe$_x$O$_2$ (0.03 ≤ x ≤ 0.12) of nano crystal. [1] The spin system of (i$_{1-x}$ Fe$_x$O$_2$) (0.03 ≤ x ≤ 0.12) nano-crystalline is examined using electron spin resonance (ESR) spectroscopy as a function of Fe doping concentration. We determined the spin parameters of ESR spectra of nano crystal to investigate the magnetic properties of nano crystalline materials. The ESR spectra consist of two strong (A) and weak (B) intense signals between 1.9951 and 1.9892 and 4.22 respectively [2]. These two signals are caused by Fe3+/Fe2+ replaced for Ti4+ in the TiO$_2$ lattice site and Fe^{3+} substituted in the lattice near to a charge-compensating oxide anion vacancy respectively [3]. The magneto crystals play a critical role in the formation of paramagnetic phase between 0.03 and 0.09 but at higher concentration (x=0.12) spin canting enhances the formation of paramagnetic phase our sample.

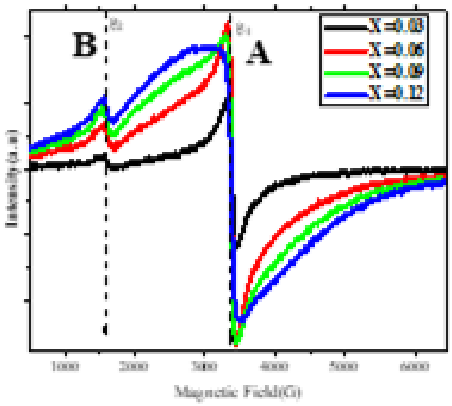

Figure 1. ESR Spectra (Ti$_{1-x}$ Fe$_x$O$_2$)(0 ≤ x ≤0.12) nano-crystalline taken at 25db and 3G

References

[1] V. R. Akshay *et al.*, *New J. Chem.*, vol. 43, pp. 6048—6062, 2019.
[2] B. Ranby *et al.*, *Springer Science and Business Media*, 2012.
[3] C. Fàbrega *et al.*, *J. Photochem. Photobiol. A Chem.*, vol. 211, pp. 170—175, 2010.

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Negative Magnetization Assisted Inverse Magnetocaloric Effect (MCE) in Bulk SmCaCoMnO_6

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The magnetic rare-earth(R=Sm,Pr,Nd, etc.) based antiferromagnetic RMnO_3 perovskites with canted magnetic moment produce an effective exchange field at the rare-earth sites which aligns the rare-earth ions anti-parallel to the canted moment giving rise to negative magnetization [1]. However, a negative magnetization with twisted isothermal magnetization(*MH*) curves has been found in SmCaCoMnO_6 double-perovskite which shows the Sm-exchange interaction(SEI) governed inverse MCE. The re-orientation of spins due to breaking of SEI at higher field(*H*) and hence twisting in MH-curves exhibits in two different temperature(*T*) regions - one starts at *T*=5K with *H*~6.5T and another at *T*=95K with *H*~1.8T field and both move towards low *H* under *T*-increment. The first spin-reorientation may be attributed to breaking of SEI with Co^{3+}—O^{2-}—Mn^{4+} ferrimagnetic moment [2], [3], responsible for negative magnetization and hence inverse MCE. The high *T* spin-reorientation may be attributed to the SEI with the Co^{2+}—O^{2-}—Mn^{4+} ferromagnetic moment which reduces the effective moment.

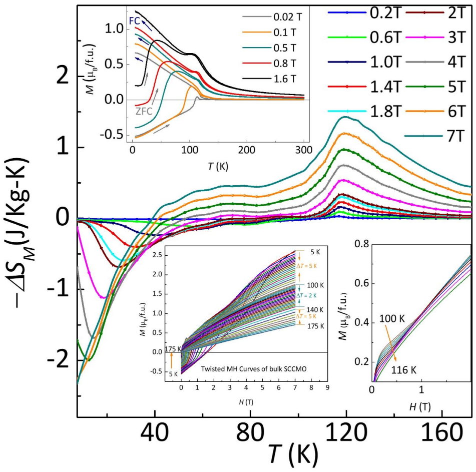

Figure 1. Entropy change (-DS_M) vs T curve showing inverse MCE at lower T region and direct MCE at higher T region. Upper inset shows the bifurcation between field cooled (FC) and zero-field cooled (ZFC) branch of Magnetization (M) vs T curve at different field. Bottom insets show the twisting of MH curves in different T ranges.

References

[1] J.-G. Cheng *et al.*, *Physical Review B*, vol. 84, no. 10, p. 104415, 2011.
[2] C. Macchiutti *et al.*, *Physical Review Materials*, vol. 5, no. 9, p. 094402, 2021.
[3] G. Tang *et al.*, *Physics Reports*, vol. 758, pp. 1–56, 2018.

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Large Spontaneous Exchange Bias in SmCaCoMnO_6

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Exchange bias (EB) is unarguably popular due to its industry oriented applicability in the future energy saving innovations. A low temperature (T) (<15 K) giant spontaneous EB of ≈4000 Oe is observed in our double perovskite system of SmCaCoMnO_6. indicating a complex spin glass (SG) behavior. A suppression of total magnetic moment is found (≈3 μB/f.u.) from the theoretically calculated moment (≈6.761 μB/f.u.) indicating antiferromagnetism (AFM), possibly due to the antiside disorder effect, emanated from the exchange of Mn and Co cations among B and B' sites [1]. The otherwise super-exchange (SE) ferromagnetic (FM) interactions will be suppressed by the SE AFM interactions between the cations of same valence states (e.g., Mn^{4+}-Mn^{4+}) [2]. A complex state of SG proven from the SG magnetic measurements due to the frustration between FM and antisite AFM may lead to the novel EB [3]. The interesting results will prompt a renewed interest to materialize energy-efficient devices.

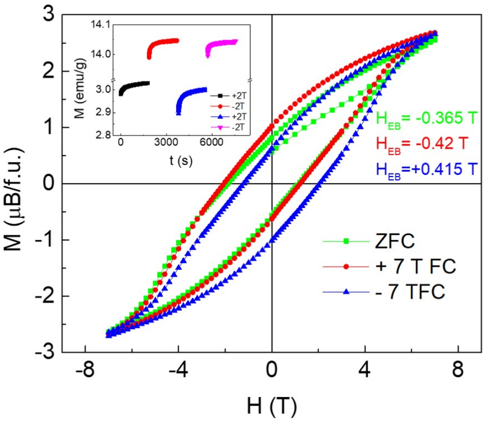

Figure 1. (a) Giant exchange bias of ≈4000 Oe for zero field cooling and positive (negative) field cooling; +7T (-7T). Inset: Memory delay measurements for opposite fields +2T and -2T confirming the spin glass behavior.

References

[1] V. Iurchuk *et al.*, *Physical Review Letters*, vol. 117, no. 10, p. 107403, 2016.
[2] X. Zhang *et al.*, *Applied Physics Letters*, vol. 116, no. 13, p. 132405, 2020.
[3] M. Zheng *et al.*, *Physical Review Applied*, vol. 9, no. 4, p. 044039, 2018.

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Visible Light Effects on Photostrictive/Magnetostrictive PMN-PT/Ni Heterostructure

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Optically exploited photostriction of ferroelectrics is an effective way of tuning the interfacial properties of a multiferroic heterostructure [1]–[3]. Here, we present the effects of 405 nm light illumination on the ferroelectric and ferromagnetic responses of PMN-PT/Ni heterostructure. By combining electrical, structural, magnetic and spectroscopic measurements, we show how light illumination above the ferroelectric bandgap energy induces the photostriction effect that reduces the coercive field of the magnetostrictive Ni layer. We firstly report a light-induced variation in the Ni orbital moment using sum-rule analysis of XMCD measurements. The change in orbital moment reveals a photogenerated strain field. The observed effect is strongly reduced when polarizing out-of-plane the PMN-PT substrate, showing a highly anisotropic photostrictive contribution from the in-plane domains. These results shed light on the delicate energy balance that leads to sizeable light-induced effects in multiferroic heterostructures, while confirming the need of spectroscopy for identifying the physical origin of interface.

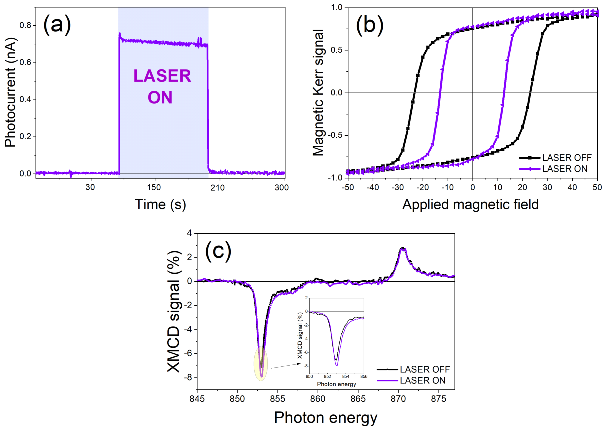

Figure 1. (a) Photocurrent evolution, (b) MOKE, and (c) XMCD measurement of PMN-PT/Ni heterostructure under 405 nm visible light illumination.

References

[1] V. Iurchuk *et al.*, *Physical Review Letters*, vol. 117, no. 10, p. 107403, 2016.
[2] X. Zhang *et al.*, *Applied Physics Letters*, vol. 116, no. 13, p. 132405, 2020.
[3] M. Zheng *et al.*, *Physical Review Applied*, vol. 9, no. 4, p. 044039, 2018.

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Self-similarity in magnetostrictive materials

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Magnetostrictive materials couple mechanical and magnetic quantities allowing a direct conversion of mechanical energy, normally associated to a tensional or deformation state, into electromagnetic energy [1]. This energy conversion could be normally exploited in both directions for sensing or actuation.

Despite the simple principle on which magnetostrictive materials rely on, the interaction between magnetization, magnetic field, mechanical stress and strain shows a complex hysteretic behaviour. Previous studies [2], however, have already shown that, assuming the stress as parameter, magnetic and magnetostrictive experimental curves exhibit a self-similar aspect.

In this work [3], we provide experimental evidences of self-similarity property in magnetostrictive materials illustrating the main results of measurements performed on a set of samples involving different magnetostrictive materials.

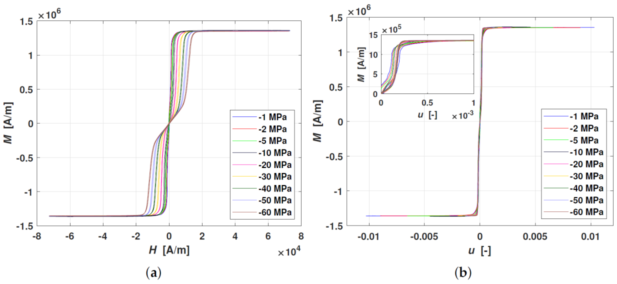

Figure 1. Magnetic characteristics (M-H) at different applied compressive stresses σ (a) and graphical representation of the self-similarity property (b) for NSA Galfenol. The inset represents a zoom of the figure in the 0–0.001 range of u. It is possible to note how the M-u curves almost collapse into a single one.

References

[1] G. Engdahl and I. D. Mayergoyz, *Handbook of giant magnetostrictive materials*. Elsevier, 2000, vol. 386.
[2] D. Davino *et al.*, *Smart Materials and Structures*, vol. 22, no. 9, p. 095009, 2013.
[3]

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Growth of Phase Controlled FeTe_x Thin Films and its Room Temperature Magnetic Properties

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The family of iron chalcogenides, e.g. Iron telluride (FeTe), possess interesting magnetic property, including changes in the long range magnetic ordering depending on the different structural phase; tetragonal phase is anti-Ferromagnetic (AFM) and hexagonal phase is ferromagnetic (FM) with large in plane magnetic anisotropy, etc. [1][2]. It is very challenging to grow uniform and continuous thin films. Here, we report intricate details on FeTe thin film growth conditions in salt assisted atmospheric pressure chemical vapor deposition (SAPCVD) to achieve desired phase. Magnetic property investigations using magnetometer and magnetic force microscopy on films grown under different conditions will be presented. Our study will highlight the importance of SAPCVD growth conditions to control the FeTe phase and emphasize on various control parameters to achieve uniform coating, specific magnetic ordering and stoichiometric control. The selective growth of FM and AFM FeTe thin film by SAPCVD provides a new opportunity for spintronics application.

References

[1] L. Kang *et al.*, *Nature communications*, vol. 11, no. 1, pp. 1–9, 2020.
[2] M. Cheng *et al.*, *ACS nano*, vol. 15, no. 12, pp. 19 089–19 097, 2021.

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Temperature-Dependent Optical Properties of Ferromagnetic BCC Fe: First-Principles Study

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The optical and magneto-optical properties have been widely exploited to characterize the magnetic features of ferromagnetic materials [1]. When the temperature changes, magneto-optical properties can provide additional information, such as magnetic phase transitions [2]. In this work, we use the first-principles method to describe the temperature dependence of optical and magneto-optical properties for ferromagnetic BCC Fe in terms of the electron, lattice, and magnetic temperatures up to 300 K. Both lattice and magnetic temperatures induce large imaginary dielectric function signals below 1.5 eV, indicating the capture of quasiparticle-assisted intraband transitions and originating from the dipole transition matrix change. Furthermore, we found a peak redshifting near 3 eV in an imaginary dielectric function with magnetic temperature. From unfolded band structure analysis, it originates from the thermal demagnetization of ferromagnetic BCC Fe. The method might be expanded to the paramagnetic phase at high temperatures in the future. **Illinois MRSEC NSF DMR-1720633

References

[1] T. Halder, *International Journal of Applied Electromagnetics and Mechanics*, vol. 7, no. 1.
[2] A. Balk *et al.*, *Applied Physics Letters*, vol. 114, p. 032401, 2019.

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Protein clIscA1/clCry4 Based MRI Contrast Material for T_2 Imaging

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Hitherto, many gene reporters have been described for MRI imaging, which rely on different underlying contrast mechanisms with most using exogenous contrast agents that alter T_2 transverse relaxation times.[1] Recently, Xie and his colleagues proposed that a magnetic biocompass clIscA1/clCry4, which integrated both iron-sulfur cluster assembly protein clIscA1 and cryptochrome protein clCry4.[2] Protein clIscA1 was polymerized into a linear protein complex and then wrapped helically by clCry4. Additionally, the biocompass possessed the characteristic of intrinsic magnetic moment. Here, we proposed clIscA1/clCry4 (in cell) as MRI contrast material under iron supplemented, and we introduce plasmid system for gene expression in prokaryotic E.coli. Experimental data provide evidence demonstrating that protein clIscA1/clCry4 in E.coli resulted in significant changes in the R_2 transverse relaxation rate and susceptibility MRI T_2 imaging contrast. However, further studies will be needed to investigate the most intricate details between clIscA1/clCry4 and MRI.

References

[1] F. Schilling *et al.*, *Nature biotechnology*, vol. 35, no. 1, pp. 75–80, 2017.
[2] S. Qin *et al.*, *Nature materials*, vol. 15, no. 2, pp. 217–226, 2016.

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Modular Assembly Method of Proteins on Iron-based Magnetic Nanoparticles

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Iron-based magnetic nanoparticles have great potential for application in the biomedical field. However, its surface energy is usually high, which is not conducive to direct coupling with biomolecules such as proteins, or the low binding efficiency of physical adsorption, which limits its application [1]. In this study, we utilized efficient Spy chemistry self-assembly to combine functional proteins with aminated iron-based magnetic nanomaterials for enhanced imaging. Spy chemistry provides abundant protein binding sites while maintaining excellent colloidal stability in solution. At the same time, Spy chemically protects the bound protein and reduces the loss of the protein's catalytic activity. This platform provides a simple and general method for modular self-assembly of functional proteins on iron-based magnetic nanoparticles, expanding the potential of iron-based magnetic nanoparticles for biomedical applications.

References

[1] R. O. M. Aboljadayel *et al.*, *https://arxiv.org/abs/2101.09946*, 2022.

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Sperimagnetic Nature of Phase Transitions in Amorphous Ferrimagnetic Alloys GdFeCo

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In this presentation we show numerical results for investigation of sperimagnetic phase transitions in "rare earth"-"transition metal" (RE-TM) amorphous ferrimagnetic alloys GdFeCo in presence of external magnetic field and for temperatures above 0 K. In our work we describe a body of amorphous RE-TM type ferrimagnet as a grid of interacting particles. The system of interacting ferrimagnetic particles can be described with the use of the Hamiltonian, which includes the d-d and f-d exchange Heisenberg-like interactions, stochastic uniaxial magnetic anisotropy for the f-sublattice, and the Zeeman interaction of f- and d-sublattices with the external magnetic field. The description of thermal properties is done by the use of the molecular field theory for d-sublattice. We calculated H-T phase diagrams for a variety of compositions of GdFeCo alloys. We show, that the sperimagnetic structure is almost completely limited to the tilted phase borders and is more pronounced around the phase transition lines.

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Determining the Induced Magnetic Moment in Graphene by Polarised Neutron Reflectivity and X-ray Magnetic Circular Dichroism

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We report the magnitude of the induced magnetic moment in CVD-grown epitaxial and rotated-domain graphene in proximity with a ferromagnetic Ni film, using polarized neutron reflectivity (PNR) and X-ray magnetic circular dichroism (XMCD). The XMCD spectra at the C K-edge confirm the presence of a magnetic signal in the graphene layer and the sum rules give a magnetic moment of up to □0.47 μB/C atom induced in the graphene layer. For a more precise estimation, we conducted PNR measurements. The 10 K PNR results indicate an induced magnetic moment of ≈0.53 μB/C atom for rotated graphene and ≈0.38 μB/C atom for epitaxial graphene. Additional PNR measurements on graphene grown on a non-magnetic $\mathrm{Ni_9Mo_1}$ substrate, where no magnetic moment in graphene is measured, suggest that the origin of the induced magnetic moment is due to the opening of the graphene's Dirac cone as a result of the strong C pz-3d hybridization [1].

References

[1] R. O. M. Aboljadayel *et al.*, *https://arxiv.org/abs/2101.09946*, 2022.

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Kerr Effect Magnetometer Optimization Using Ray Tracing Simulation

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The objective of this work is to present measurements of magneto-optical susceptibility and Giant Magnetoimpedance (GMI) [1], [2] and to study the performance of the Kerr magnetometer in TracePro software, to better understand the limitations of the equipment and modify it in the future [3]. Optical aberrations have already been identified through simulation and the spot formed in the photodiode has already shown significant improvements. It was even simulated the application of an anti-reflective film on the magnetometer lens to improve the transmittance of the optical system. There was a gain in light energy of 23.1% with the application of the anti-reflective layer. The application of a 33nm layer of ZnS on the CoFeSiB sample was also simulated, with ZnS passing 63.3% of the incident radiation, while reflecting 33.3%. At the measured frequency of 1MHz the GMI ratio and its field sensitivity reached the value of 75% and 7,5%/Oe.

References

[1] A. Santos *et al.*, *Journal of Applied Physics.*, vol. 79, 1996.
[2] A. Zhukov *et al.*, *Journal of Applied Physics.*, vol. 11725, 2015.
[3] S. Pavlovic *et al.*, *WIT Transactions on Information and Communication Technologies.*, vol. 57, pp. 211–218, 2014.

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Characterization of Ni-Nano Particles inserted in Carbonaceous Materials with Controlled Porosity and Morphology

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Carbonaceous materials that include metallic nanoparticles (NPs) have attracted extensive interest during the last decades, especially those of metals like Nickel organic frame works (NiOF), thanks to its importance in technological applications (i.e., catalysis, batteries, ceramics, etc) [1]. However, to control NiOF properties, a correlated analysis of its microstructure and magnetic properties should be done.

To achieve this purpose, we have prepared five samples of 2-methylimidazole Nickel NPs with carbonization temperatures between 400°C and 600°C [2]; characterized their crystal structure and microstructure by X-Ray diffraction (XRD) and high-resolution transmission electron microscopy (HRTEM). Additionally, their magnetic properties were studied by SQUID magnetometer through ZFC-FC and magnetization vs. magnetic field ($M(H)$) curves.

The samples exhibit two crystallographic phases of Ni: face centered cubic-FCC and hexagonal compact phase-HCP. Additionally, at the lowest carbonization temperature Ni3C was also detected. XRD peaks become narrower and symmetrical as the carbonization temperature raises, suggesting that the mean diameter of Ni-NPs increases. The interplanar distances were measured by analysing in detail HRTEM images. These studies corroborate XRD results and the existence of Ni_3C phase on samples synthesized at the lowest and the other carbonization temperatures.

The analysis of $M(H)$ curves recorded at room temperature reveals that saturation magnetization (M_S) is low on samples that contain antiferromagnetic Ni_3C compared to higher values obtained in the samples with FCC and HCP phases. Besides, M_S and mean blocking temperature values (T_B) increase as the carbonization temperature rises as a consequence of the increment of the average NP.

References

[1] M. Fernandez-Garcia *et al.*, *The Journal of Physical Chemistry C*, vol. 5.
[2] F. Martin-Jimeno, *uni. Oviedo*, 2018.

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Neutron diffraction study of magneto-volume effects in Tm_2Fe_{17} under hydrostatic pressure

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Binary R_2Fe_{17} (R = rare earth) intermetallic alloys show magneto-volume anomalies (i.e., abnormal reduction of cell parameters below the magnetic ordering and strong variations of the Curie temperature TC with pressure), related to the critical dependence of magnetic exchange interactions with the interatomic distances of the dumbbell Fe atoms [1], [2]. Among these alloys, Tm_2Fe_{17} exhibits a low-temperature spin-reorientation transition due to the competing anisotropies of the Tm- and Fe- sublattices, respectively [3]. We performed neutron diffraction measurements and DC magnetic measurements to study the evolution of the magnetic structure and properties as a function of the hydrostatic pressure. The fluctuation of the volume cell with the temperature (and its strong contraction as the pressure is increased), as shown in Fig. (Fig. 1), results in potential interest for applications such as stress sensors and key elements for vibrational/mechanical energy-harvesting.

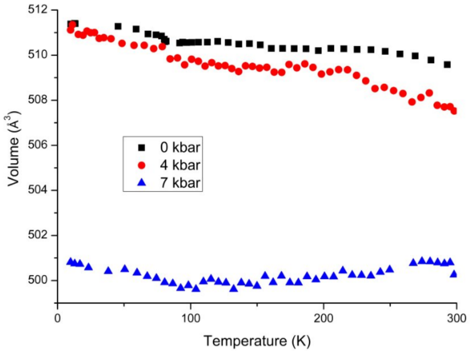

Figure 1. Volume cell as function of the temperature for different pressures.

References

[1] P. Gorria *et al.*, *Acta Materialia*, vol. 57, p. 1724, 2009.
[2] P. Álvarez Alonso *et al.*, *Acta Materialia*, vol. 61, p. 7931, 2013.
[3] J. Elemans *et al.*, *Physica Status Solidi (a)*, vol. 24, p. K125, 1974.

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Magnetic hyperthermia using superparamagnetic iron oxide nanoparticles

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Magnetic hyperthermia (MH) is a promising therapeutic modality for cancer treatment. MH is established on the concept that magnetic nanoparticles (MNPs) delivered to tumors can generate heat (temperatures between 42 °C and 46 °C) after exposure to a noninvasive external alternating magnetic field (AMF) [1], [2]. The heating efficacy is based on a more complex relationship between the intrinsic time-dependent relaxation processes of the nanoparticle magnetic moments and magnetic hysteresis losses. Therefore, it is essential that the surface of the nanoparticles be functionalized with organic molecules that guarantee their biocompatibility to reduce MNPs toxicity [3]. In this work the structural, morphological and heating properties of Iron Oxide Nanoparticles coated with Citric Acid were characterized in order to find the optimal concentration for use in MH. We found that the concentration of nanomaterials is proportional to the temperature, and that the MNPs should not be agglomerated, which could be viable for MH.

References

[1] H. Etemadi and P. G. Plieger, *Advanced Therapeutics*, vol. 3, no. 11, 2020.
[2] H. Albarqi *et al.*, *ACS nano*, vol. 13, no. 6, 2019.
[3] K. Mahmoudi *et al.*, *International Journal of Hyperthermia*, vol. 34, no. 8, 2018.

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Magnetocaloric effect in all-d-metal Ni(Co)-Mn(Fe)-Ti Heusler Alloys

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In contrast to most of the well-known first order magnetocaloric materials, all-d-metal Ni(Co)-Mn-Ti Heusler alloys show magnetocaloric properties together with good mechanical stability [1]. However, hysteresis reduction and improved response for moderate magnetic fields are still needed for real applications. In this work, a series of Ni$_{35}$Co$_{15}$Mn$_{35-x}$Fe$_{x}$Ti$_{15}$ (x = 0,3,5,7) samples with tuneable martensitic transition temperatures and magnetocaloric effect is investigated. The results indicate that the transformation temperatures and the latent heat decrease with increasing Fe content (Fig. 1 (a)). Moreover, Fe doping leads to the separation of martensitic and austenite Curie transitions and improves magnetization in both austenite and martensite states. These two combined effects lead to an increase in low-field isothermal entropy change (see 1-2 T in Fig. 1 (b)), improving the applicability of this system.

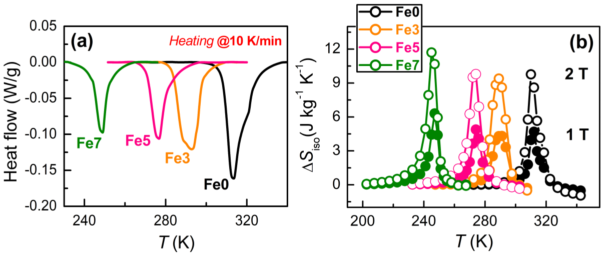

Figure 1. Fig. 1. (a) Differential Scanning Calorimetry (DSC) scans and (b) isothermal entropy change for the studied series. Arrows indicate the transition entropy change obtained from DSC.

References

[1] Z. Wei *et al.*, *Applied Physics Letters*, vol. 107, no. 2, p. 022406, 2015.

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Influence of Ferromagnetic Layer Thickness on The Gilbert Damping of CoFeB Thin Film Grown by Sputtering

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Thin films of CoFeB (4:4:2) with varying thicknesses (t_{CFB}=5-35nm) were deposited by RF sputtering on Si/SiO_2. The Gilbert damping constant (α) of the thin film measured from the ferromagnetic resonance (FMR) experiment show a direct dependency on the t_{CFB}. The α decrease monotonically with the increase in t_{CFB} up to 15 nm and thereafter saturate for large t_{CFB} (Fig.1). The observed trend in α with t_{CFB} is a direct indication of transition from ultra-thin to thick-film limit of deposited films ($\geq$ 15 nm). The observed behaviour of α and FMR linewidth is due to the effect of two magnon scattering process, which dominates and contribute as an extrinsic effect to the FMR linewidth at low t_{CFB} [1]. The effective magnetization (M_{eff}) also increase with t_{CFB} up to 15 nm, exhibiting the same transition from ultra-thin to thick-film limit. This investigation is crucial for the designing of efficient spintronic devices [2].

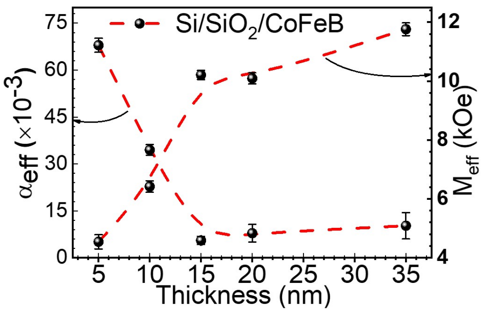

Figure 1. Thickness vs Gilbert Damping (α) and effective magnetization of CoFeB thin film

References

[1] R. Arias and D. Mills, *Physical review B*, vol. 60, no. 10, p. 7395, 1999.
[2] M. Savadkoohi *et al.*, *Organic Electronics*, vol. 102, p. 106429, 2022.

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Modification of Magnetic Properties in Tb–Fe/Gd–Fe/Tb–Fe Trilayer Using Ion Beam Irradiation

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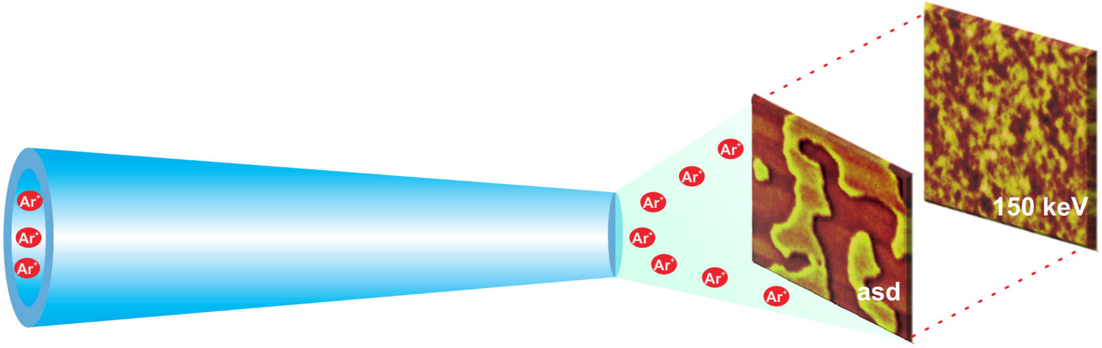

Figure 1. The above figure shows irradiation of as-deposited (asd) film with Ar+ ions. The asd film exhibits distinct features of the magnetic domain. Elongated magnetic domains disappeared after irradiation of the film with 150 keV.

Magnetic materials with perpendicular magnetic anisotropy (PMA) have ushered paramount importance in the data storage industry. Several techniques like thermal annealing, focused ion beam, laser-induced modification, etc., have been frequently used to tune the magnetic properties [1]–[3] However, tuning magnetic properties by the ion-irradiation technique in the heterostructures with PMA is not well explored. Here, we consider a Tb-Fe/Gd-Fe/Tb-Fe trilayer system exhibiting PMA in a pristine state. Irradiation with Ar^+ ions, with variable incident energies (50–150 keV), was employed to obtain the tunability in magnetic properties in the system. A spin reorientation transition from perpendicular to the film plane was observed even for the lowest energy of irradiation without any significant structural modification. The island-like magnetic domains have disappeared after irradiation. Micromagnetic simulations are performed to validate experimental observations. Our work shows a simple route to process anisotropy-engineered magnetic heterostructures using depth-sensitive external perturbation.

References

[1] K. Umadevi *et al.*, *Journal of Alloys and Compounds*, vol. 663, pp. 430–435, 2016.
[2] J. Franken *et al.*, *Journal of Applied Physics*, vol. 109, no. 7, p. 07D504, 2011.
[3] A. Talapatra and J. Mohanty, *Journal of Magnetism and Magnetic Materials*, vol. 418, pp. 224–230, 2016.

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Compensated ferrimagnetism of Mn-Co-V-Ga Heusler alloys

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Nowadays, Heusler alloys have attracted considerable attention as appropriate materials for the design of new fully compensated ferrimagnets. Fully compensated ferrimagnetism has been predicted theoretically in Heusler-based Mn-Co-V-Ga system. Melt spun ribbons of $Mn_{2-2x}Co_{0.5+x}V_{0.5+x}Ga$ Heusler alloys with 24 valence electrons were synthesized and their magnetic properties were investigated in order to detect fully compensated ferrimagnetic behaviour in these alloys. The lattice parameter decreases with decreasing Mn content from 5.8751 Åto 5.8118 Åfor the x = 0 and x = 5 compositions, respectively. Curie temperature decreases from 634 to 122 K with decreasing Mn content. The fully compensated ferrimagnetic state was achieved for the x = 0.2 and x = 0.4 samples. A feature of these alloys is a kink in the magnetization curves in a low-temperature region at T 70 K for all the alloys, expect MnCoVGa, which can presumably be explained as due to a spin-reorientation transition.

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Magnetotransport properties of Bi$_{100-x}$Sb$_x$ topological insulator thin films

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The temperature dependence of the resistance $R(T)$, and the magnetoresistance MR of Bi$_{80}$Sb$_{20}$, Bi$_{85}$Sb$_{15}$ and Bi$_{90}$Sb$_{10}$ topological insulator (TI) policrystalline thin films were measured. Samples were prepared by sequential flash-evaporation at room temperature and annealing at T=350 K. The $R(T)$ of the three investigated samples show metallic-like behavior at temperatures below 75 K, while at higher temperatures, $R(T)$ curves show a semiconducting-like behavior. The MR of all samples is positive with a small temperature dependence. The highest MR (B=7 T) was observed in Bi$_{85}$Sb$_{15}$ with a ≈600 % and ≈125 % change at 5 K and 300 K, respectively. Shubnikov de Haas oscillations are detected in the MR curve of sample Bi$_{85}$Sb$_{15}$ up to ∼21 K, these originate at the Fermi surface which has a 2D character. This is a clear evidence of a 2D metallic state in TI materials [1], [2].

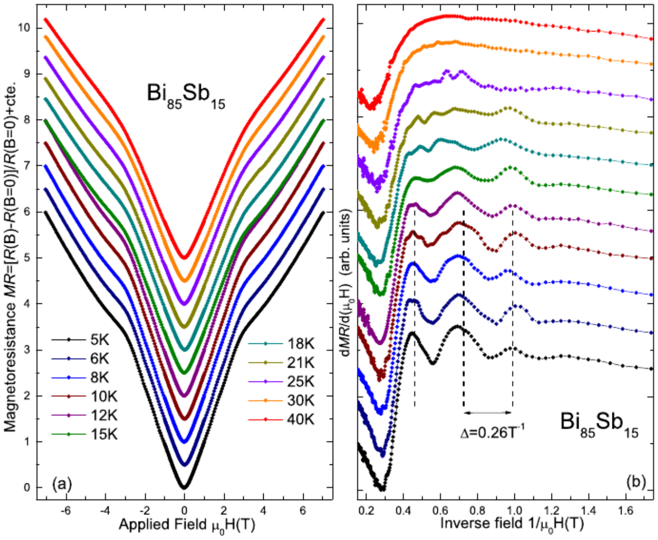

Figure 1. Magnetoresistance vs. applied magnetic field measured at temperatures below 50 K for sample Bi85Sb15 (a). First derivative of MR vs. the inverse applied magnetic field (b). The curves in (a) and (b) were shifted by an constant for the sake of clarity.

References

[1] A. Taskin and Y. Ando, *Physical Review B*, vol. 80, 2009.
[2] E. Osmic *et al.*, *Journal of Physics and Chemistry of Solids*, vol. 167, no. 110734, 2022.

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FeNi nanowires magnetic interactions study: FORC and magnetization reversal analysis

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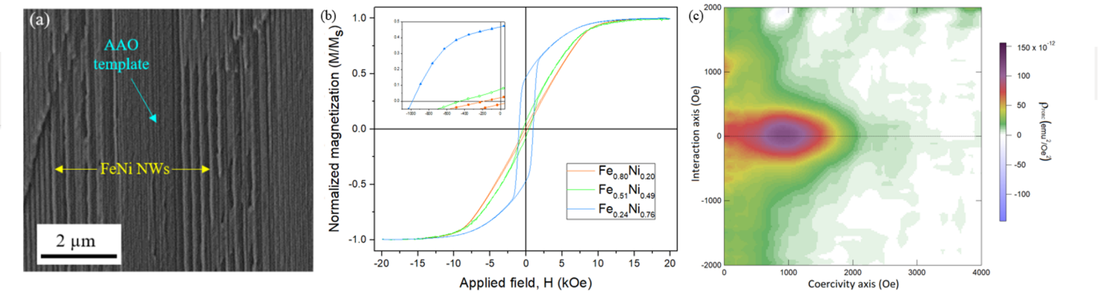

Figure 1. Figure 1: (a) SEM image of an array of FeNi NWs in an AAO membrane; (b) room temperature hysteresis loops measured for arrays of FeNi NWs with different compositions; and (c) FORC diagram for Fe$_{0.80}$Ni$_{0.20}$ NWs.

Tuning the parameters in the electrochemical synthesis of nanowires (NWs) allows to tailor their magnetic properties [1]. Herein, FeNi NWs (Fig. 1a) were synthesized under different conditions to correlate their geometry, crystallographic structure and magnetic properties.

Coercivities (Hc) ranging from 0.2 to 1.0 kOe were obtained (Fig. 1b), being higher for lower Fe content. The magnetization reversal (by transverse domain wall) indicated decreased magnetostatic interactions between NWs as the source of higher Hc. First-order reversal curves (FORCs) highlighted weak interactions in the arrays, except for Fe$_{0.80}$Ni$_{0.20}$ NWs (Fig. 1c).

This work thus explores the impact of magnetic interactions on FeNi NWs magnetic response, showing the possibility of tailoring the magnetic behaviour by tuning the synthesis parameters.

References

[1] E. M. Palmero *et al.*, *Journal of Applied Physics*, vol. 116, no. 3, p. 033908, 2014.

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Exploration of magnetic $Co_{(0.8-x)}Zr_xNa_{0.2}Fe_2O_4$ nanocomposites and their application as 4-aminophenol sensor

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Ferrite-based nanocomposites are significant for industry due to their elevated magnetic, electrical, and optical specifications paving routes for versatile technological applications. Herein, The sol-gel method is conducted for the preparation of $Co_{(0.8-x)}Zr_xNa_{0.2}Fe_2O_4$ magnetic nanocomposites. Structural, morphological and magnetic specification of nanocomposites were explored with altered ratio (0.1-0.4) of Zr in the matrix. The X-ray photoelectron spectroscopy (XPS) confirmed the chemical structure of the synthesized nanocomposites. Magnetic hysteresis loops reveal the soft magnetic nature of the composites. Furthermore, 4-aminophenol (4-AP) sensor is fabricated by covering a thin film of the composite on a glassy carbon electrode and subjected to electrochemical analysis. The results display an increased sensitivity of 10.5665 μA μM−1 cm−2 of the 4-AP sensor. The detection limit is 98.45±4.92 pM. Reproducibility, and stability of the sensor is also affirmed. The composite might enhance the development of the electrochemical sensing technologies worldwide.[1]–[3]

References

[1] A. M. El Nahrawy *et al.*, *Emergent Materials*, vol. 5, no. 2, pp. 431–443, 2022.
[2] A. M. El Nahrawy *et al.*, *Microchemical Journal*, vol. 163, p. 105881, 2021.
[3] A. B. Abou Hammad *et al.*, *New Journal of Chemistry*, vol. 44, no. 19, pp. 7941–7953, 2020.

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Eddy current brakes with permanent magnets: regulation of braking torque

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Eddy current brakes (ECBs) are widely used in industry, medicine and biology. The relative motion between the electrically conducting rotor and the magnetic field created by permanent magnets (PMs) will generate eddy currents (ECs). The EC magnetic field is opposite to the PM magnetic field, resulting in mechanical forces that retards relative movement. The PM ECBs adopt non-contact braking, and can effectively reduce the kinetic energy, while they do not require an external electrical source (ESS). The brakes with various types of speed controlling have been analyzed. The main way is the changing in the brake air gap, and consequently to regulate the magnetic flux. The reconfiguration of the magnetic circuit allow regulating the magnetic flux. Therefore, it is possible to control the speed without using ESS. In this paper, a review of PM ECBs is presented where different types of the reconfigurable brakes are compared from performance standpoints.

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Effect of MWCNTs Content on Microwave Absorption Characteristics of Co/MWCNTs Composites

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Morphological engineering can improve microwave absorption bandwidth by controlling multiple reflections and scattering, interfacial, dipole, and defect polarizations, as well as conductive losses. An attempt has been made to develop a broadband microwave absorber in 2 – 18 GHz frequency range with low coating thickness by analyzing morphological modifications. For this purpose, composites of flaky cobalt and multi-walled carbon nanotubes (Co/MWCNTs) were prepared using simple and scalable ball milling process. The addition of different wt% of MWCNTs enhances the dielectric losses in the composite by increasing the dipolar polarization, interfacial polarization, and conductive paths, which results in enhanced microwave absorption. Compared to typical Co absorbers, the Co/MWCNTs composite demonstrates significantly better microwave absorption performance. The composite of 5 hr milled Co and 3 wt% MWCNTs showed a minimum reflection loss value of – 37.48 dB at 8.38 GHz with 7.9 GHz (3.89 – 11.49) bandwidth and 2.5 mm coating thickness.

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Structural Transformations behind the Emergence and Disappearance of Exchange Bias in Nanocrystalline Ni-Mn/$Fe_{20}Ni_{80}$ Films

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Exchange bias manifesting itself as a shift of the hysteresis loop of the ferromagnetic $Fe_{20}Ni_{80}$ layer emerges in Ni-Mn/$Fe_{20}Ni_{80}$ films after annealing at 300 °C and disappears after annealing at 350 °C [1], [2]. In this work we show that this is due to the structural transformations that occur in Ni-Mn and involve the formation and consequential decomposition of the antiferromagnetic θ-NiMn phase. We use in situ high-temperature vibrating sample magnetometry and X-ray diffractometry to study structural and magnetic properties of magnetron-sputtered thin films and how they change upon annealing. Our findings explain the kinetics of the formation of this phase either from the nanocrystalline/amorphous state or from the disordered antiferromagnetic γ-Ni-Mn. These processes turn out to be sensitive to the presence of a buffer $Fe_{20}Ni_{80}$ and the composition of Ni-Mn. We find that the blocking temperature at which exchange bias irreversibly vanishes is the temperature of the decomposition of θ-NiMn.

References

[1] V. Vas'kovskiy *et al.*, *Journal of Alloys and Compounds*, vol. 777, 2019.
[2] M. Moskalev *et al.*, *IEEE Magnetics Letters*, vol. 10, 2019.

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Spherical and flower-like manganese ferrite nanostructures for enhancing chromium bio-reduction by *Shewanella oneidensis*

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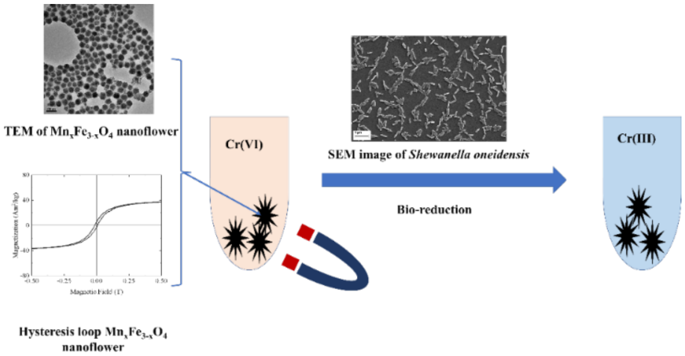

Figure 1. Representation of an integrated adsorption bio-reduction method for safe removal of hexavalent chromium.

Chromium is a common environmental pollutant deriving from several industries including plating, tanning and metal finishing. Human exposure to hexavalent chromium (Cr(VI)) can cause cancer and neurotoxicity. Leaking chrome from industrial sites into water can lead to soil and groundwater contamination which is a risk currently being considered in several industries. Integrating both adsorption and biological reduction of highly toxic Cr(VI) into the less toxic trivalent one (Cr(III)) together has been proposed as a promising strategy to tackle the aforementioned issue. In this context, nanoscale materials possess special features that make them promising candidates for such applications; nanoclusters have been gaining much attention due to their simple preparation, high surface to volume ratio, high stability and enhanced efficiency due to the complex interparticle interactions which depend on the single crystal particle size, orientation and spacing. Herein we report a simple route for the robust, single-step and scalable preparation of $Mn_xFe_{3-x}O_4$ nanoflowers via a polyol-assisted solvothermal method. Our results revealed that the one gram of nanoflowers (60 ± 12 nm diameters) can adsorb 12 mg of Cr(VI). The effect of nanoflowers on the Cr(VI) reduction and tolerance by *Shewanella oneidensis* have been explored as a safe an integrated way with good performance in heavy metal removal from water.

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Properties and Prospects of Magnetic Assemblies

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Magnetic nanoparticles are applied in different fields such as biomedicine, data storage, catalysis or hyperthermia [1] To the present day mostly isolated magnetic nanoparticles are used for applications while combining the magnetic properties with the high surface area and porous structure of aerogels [2] is beneficial. In this work magnetic aerogels were synthesized and characterized. The gelation was induced without a previous phase transfer to aqueous medium. Supercritical drying was used to obtain the porous aerogels. TEM, SEM and SQUID measurements were performed to analyze the structure and to investigate the influence of the gelation on the magnetic properties. The formation of highly porous structures out of connected particles was observed and confirmed through TEM and SEM measurements. The magnetism is present even after the formation of the gel networks. In case of FePt the gelation caused a change from paramagnetic behavior before gelation to ferromagnetic behavior afterwards at 300 K .

References

[1] A.-H. Lu *et al.*, *Angewandte Chemie International Edition*, vol. 46, no. 10, pp. 1222–1244.
[2] P. Rusch *et al.*, *Accounts of Chemical Research*, vol. 53, pp. 2414–2424.

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Modelling and Simulation of the Magnetostriction Effect in a Magneto-sensitive Material

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Magneto-sensitive elastomers are a class of smart materials that display certain behaviours when exposed to a magnetic field. More particularly, the deformation of such elastomers in the direction of the field, called magnetostriction, has been the focus of many research studies in the last decades [1], [2]. Here we present a recent numerical study using mesoscopic molecular dynamics to simulate the deformation of a non-magnetic matrix filled with randomly distributed iron microparticles. In the presence of a uniform uniaxial magnetic field, the system expands in the direction of the field, while contracting in the other two directions. Qualitatively, the obtained results are in agreement with past experimental work [3].

References

[1] D. Ivaneyko *et al.*, *Soft Matter*, vol. 10, no. 13, pp. 2213–2225, 2014.
[2] Y. L. Raikher *et al.*, *Tech. Phys. Lett.*, vol. 26, no. 2, pp. 156–158, 2000.
[3] L. Bodelot *et al.*, *Exp. Mech.*, vol. 58, no. 2, pp. 207–221, 2018.

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Conical and Traditional Geometries of Axial Flux Permanent Magnets Synchronous Machines

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High-speed radial flux machines have been largely investigated in terms of magnetic, thermal, and mechanical design. In contrast, few articles discuss high-speed axial flux machines. Engineers are facing many thermal, mechanical, and magnetic challenges when designing such structures at high rotating speeds. The produced torque is proportional to the square of the outer rotor radius for radial flux machines and the cube of the outer rotor radius for axial flux machines. Or, the outer rotor radius is strongly constrained by the centrifugal force at high speed for both radial and axial machines. Therefore, in this poster, a conical rotor-stator-rotor structure is proposed, which could help enhance the torque production capabilities while preserving the rotors mechanical integrity at a high rotational speed [1]–[3]. Conical structure is compared with a traditional axial machine, including electromagnetic torque, air-gap flux density, magnetic attraction forces, mechanical constraints, materials, and performances.

References

[1] S. Neethu *et al.*, *2018 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), IEEE*, pp. 1–4, 2018.

[2] K. Solmaz, *Doctoral thesis*, 2017.

[3] J. Petro, *Google Patents*, 2007.

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Consequence of Bi Doping on the Martensitic Transition Temperature and Refrigeration Capacity of $Ni_{45}Co_5Mn_{37}In_{12-x}Bi_xSi_1$ Heusler Alloy

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In this work, structural, microstructural and magnetocaloric properties of Bi-doped $Ni_{45}Co_5Mn_{37}In_{12}Si_1$ Heusler alloy have been studied through X-ray diffraction, FE-SEM and magnetization measurements. Presence of a high-temperature austenite phase and a low-temperature martensite phase is observed from room temperature XRD. The M-T curve illustrates the reduction in the martensitic transition temperature, T_M with higher magnetization upon Bi substitution. Isothermal M(H) curves with metamagnetic behaviour have examined for various temperatures with change in magnetic field. At H = 2 T, the maximum magnetic entropy change, ΔS_M, as well as refrigerant capacity (RC) are obtained as 11.4 J $kg^{-1}K^{-1}$, 430 Jkg^{-1}, respectively, which makes it to be a suitable candidate for magnetic refrigeration.

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Theoretical and Experimental Evaluation of Core-Shell Nanoparticles for Hyperthermia

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Recently, highly magnetic Fe and FeCo nanoparticles [1] up to 20 nm are obtained through instant chemical reduction that are suitable for magnetic nanoparticle hyperthermia (MNH) [2]. We present the theoretical and experimental evaluation of nanoparticles having (Fe, FeCo) core and Fe3O4 shell as potential materials for MNH. The experimental heating characteristics of the stable core-shell particles (CSPs) with average particle sizes of 46 (Fe) and 18 (FeCo) nm were probed using infrared thermography, and the effective magnetic anisotropy constants were determined from ferromagnetic resonance. The shell thickness of Fe nanoparticles was varied by annealing at various temperatures. The experimental temperature rise (ΔT) of Fe and FeCo CSPs were compared with magnetite (FeF) and Mn-doped Fe_3O_4 (Mn3) nanoparticles, as shown in Fig.1. A ΔT of 8 K was observed for the FeCo CSPs attributed to partial compliance with the linear response theory suggesting it as another promising candidate for MNH.

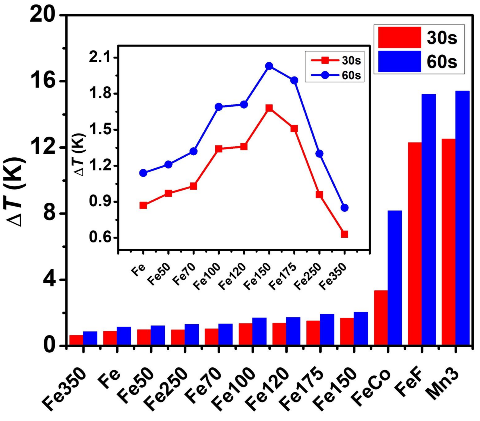

Figure 1. Experimental comparison of temperature rise (ΔT) of Fe, FeCo core-shell and ferrite (FeF, Mn3) nanoparticles at 30 and 60 s. The inset depicts the ΔT of Fe samples with annealing temperature.

References

[1] K. Sivaranjani *et al.*, *Journal of Magnetism and Magnetic Materials*, vol. 513, p. 167228, 2020.
[2] J. S. Anandhi *et al.*, *Journal of Magnetism and Magnetic Materials*, vol. 512, p. 166992, 2020.

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Comparative Study of Structural, Magnetic And Ferroelectric Properties of Polycrystalline Multiferroic $GaFeO_3$ Synthesized by Sol-gel and Hydrothermal Methods

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Multiferroic materials operating at RT are of great interest due to their usage in multifunctional devices. $GaFeO_3$ is a potential RT single-phase multiferroic [1]. In this work, polycrystalline $GaFeO_3$ samples are synthesized via both sol-gel (SG) and hydrothermal (HT) methods to study the effect of the synthesis routes on the structural, magnetic and dielectric properties. The SG sample is annealed at 1000°C to stabilize the orthorhombic structure, whereas HT technique lowers it to 800°C. Magnetization is measured as a function of temperature (fig 1) in the presence of 1000 Oe field in zero field cooled (ZFC) and field cooled (FC) mode. The T_C for SG sample is found to be 240±5 K and for the HT sample it is 260±5 K. The ferroelectric properties are established by measuring the polarization as a function of electric field at RT.

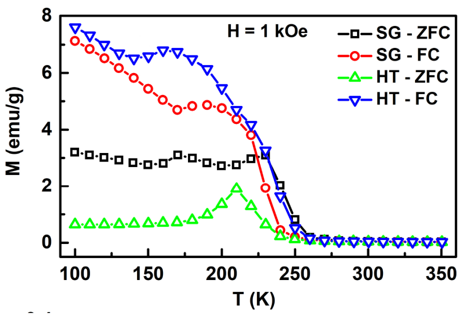

Figure 1. Magnetization as a function of temperature for the GaFeO3 sample synthesized by SG and HT methods.

References

[1] P. Pershan, *Journal of applied physics*, vol. 38, no. 3, pp. 1482–1490, 1967.
[2] D. Avery, *Proceedings of the Physical Society. Section B*, vol. 65, no. 6, p. 425, 1952.
[3] L. Kalandadze and O. Nakashidze, *Journal of Magnetism and Magnetic Materials*, vol. 500, p. 166355, 2020.

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Modified Maxwell-Garnett effective-medium theory for optical and magneto-optical properties of discontinuous Fe films

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This study reports the results of an experimental and theoretical investigation of the components of the tensor of dielectric permittivity of the discontinuous Fe films. For experimental investigation of the non-diagonal components of the tensor of dielectric permittivity we have chosen the equatorial Kerr effect [1]. The optical properties of discontinuous iron films were determined using Avery method [2]. The effective diagonal components of the tensor of dielectric permittivity of the Fe films are represented within the modified Maxwell-Garnett theory [3]. The non-diagonal tensor components were calculated using the framework of the theoretical model of an effective medium, extended to include the case of magnetic media. In this approach, optical and magneto-optical characteristics can be represented as a function of the matrix, volume fraction of the ferromagnetic particles and shape of particles. This theory gives a good opportunity to forecast the optical and magneto-optical properties of the ultrafine medium.

References

[1] P. Pershan, *Journal of applied physics*, vol. 38, no. 3, pp. 1482–1490, 1967.
[2] D. Avery, *Proceedings of the Physical Society. Section B*, vol. 65, no. 6, p. 425, 1952.
[3] L. Kalandadze and O. Nakashidze, *Journal of Magnetism and Magnetic Materials*, vol. 500, p. 166355, 2020.

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Magnetocaloric effect in canted ferromagnets

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The GdTSi (T = Fe, Co) intermetallic compounds crystallize in the tetragonal CeFeSi-type structure (*P4/nmm*). The hybridization between Si p and Fe or Co 3d states causes the absence of the magnetic moment of Fe or Co in the GdTSi compounds. The magnetic properties and the magnetocaloric effect MCE for the GdCo$_{1-x}$Cr$_x$Si, GdCo$_{1-x}$Ni$_x$Si, GdFe$_{1-x}$Ni$_x$Si systems have been studied. The transformation of a canted ferromagnetic structure into a collinear ferromagnetic structure for GdCo$_{1-x}$Cr$_x$Si, GdCo$_{1-x}$Ni$_x$Si and, conversely, a collinear ferromagnetic structure into a canted ferromagnetic structure for GdFe$_{1-x}$Ni$_x$Si, as x increases, is found. It has been established that the MCE noticeably increases in the GdCo$_{1-x}$Cr$_x$Si, GdCo$_{1-x}$Ni$_x$Si systems and drops sharply in GdFe$_{1-x}$Ni$_x$Si. Obviously, this character of the change of the MCE value is associated with the transformation of the canted structure into a collinear one for the GdCo$_{1-x}$Cr$_x$Si, GdCo$_{1-x}$Ni$_x$Si systems and, conversely, a collinear structure into a canted one for GdFe$_{1-x}$Ni$_x$Si.

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Nanorods array-based Co/Co_3O_4 exchange-bias composites

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The exchange interaction between nanostructured components is an effective way to enhance the magnetic properties of materials. The usage of cobalt for production of such composites is favourable, since its oxides are antiferromagnetic, hence it is possible to obtain the exchange-bias ferromagnetic/ antiferromagnetic (FM/AFM) nanocomposite by oxidizing the sample.

In their theoretical works, Patsopoulos et al investigated the physics behind crystallographic orientation of grains and exchange-bias properties of FM/AFM exchange-bias Co/CoO nanorods by Monte-Carlo simulations [1], [2]. However, the influence of the texture of the Co core on the magnetic properties of the resulting Co/CoO composites has not yet been studied in the literature experimentally, therefore it was the aim of this work. Nanorods array structure was investigated, as it is initially anisotropic, which can allow to further increase the magnetic properties of the material. Micromagnetic simulations using Mumax3 were performed in order to explain the obtained results.

References

[1] A. Patsopoulos and D. Kechrakos, *Journal of Magnetism and Magnetic Materials*, vol. 465, 2018.
[2] A. Patsopoulos *et al.*, *Journal of Magnetism and Magnetic Materials*, vol. 475, 2019.

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Thickness dependent transcritical state in sputtered Ni/GaN thin films

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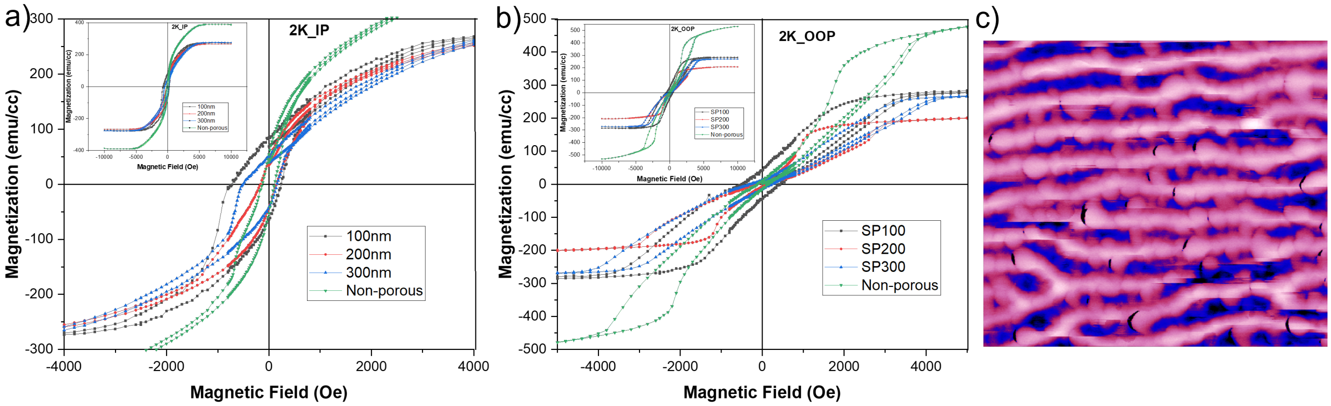

Figure 1. In plane (a) and out of plane (b) magnetization curves (original graphs are shown in the inset) at 2K of Ni/GaN sputtered thin films (c) 2 x 2 μm2 MFM image of 100 nm sputtered Ni/GaN thin film.

The engineering of low dimensional metallic or semiconductor thin films by controlled growth and tailorable physical properties has attracted significant attention for its importance in both fundamental research and potential applications. Here, we study ferromagnetic-semiconductor composites based on nickel and porous-GaN. Ni was sputtered onto porous GaN as a function of thickness. The films were found to have poor crystallinity and the temperature dependent magnetic measurements exhibited transcritical state of magnetic anisotropy. The transcritical state is a manifestation of weak perpendicular magnetic anisotropy resulting in peculiar hysteresis loop and stripe magnetic domains above a critical thickness of film. Signatures of transcritical state, corroborated by the formation of stripe domains, are observed from the VSM and MFM measurements of the Ni/GaN thin films. The properties like coercivity, saturation magnetization showed linearity with respect to the film thickness. In-depth investigation of tuning and magnetic property coupling with GaN is further explored.

References

[1] M. Coïsson *et al.*, *Journal of Applied Physics*, vol. 104, p. 033902.
[2] A. Masood *et al.*, *AIP Advances*, vol. 7, p. 055208.
[3] Y. Grishchenko *et al.*, *arXiv:2102.02904 [cond-mat.mtrl-sci]*, 2022.

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Limited Solubility of Rare Earth (Sm, Er) Co-substituted Nano-crystalline Cobalt Ferrite and their Effect on the Magnetic Properties

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Spinel ferrite with various elemental substitutions and co-substitutions are reported for different technological applications [1]–[3]. Nanocrystalline $\mathrm{CoSm}_x\mathrm{Er}_x\mathrm{Fe}_{2-2X}\mathrm{O}_4$ (0 ≤ x ≤ 0.10) synthesized by the sol-gel method have been discussed. The XRD patterns confirm the spinel structure along with secondary phase at higher concentrations. A non-systematic variation of lattice constant and crystallite size has been observed. FTIR spectra confirm the spinel lattice with two absorption peaks. The initial magnetization curve has been fitted to Law of Approach to Saturation. The saturation magnetization decreases with co-substitution, which is attributed to the weakening of the A-B, lattice distortion, the formation of secondary phase, and other factors such as the strong spin-orbit coupling effect in rare-earth ion and the variation of magnetocrystalline anisotropy and coercivity are found to be similar. The coercivity is affected by other factors such as the strong spin-orbit coupling, the nature of the cation distribution and the particle sizes.

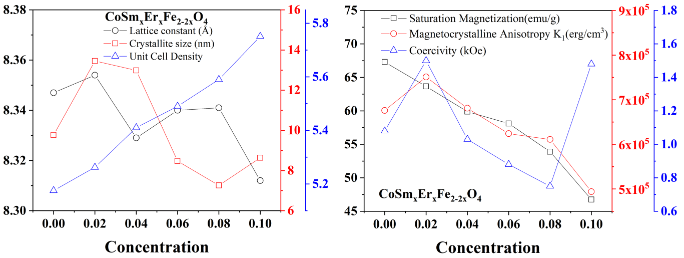

Figure 1. Variation of structural parameters and magnetic parameters of cobalt ferrite with increasing concentration of rare-earth (Sm, Er).

References

[1] A. Kuchin *et al.*, *Intermetallics*, vol. 133, p. 107183, 2021.

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Magnetic phase transitions in the GdRu$_{1-x}$M$_x$Si systems

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The Curie temperature TC in the GdRu$_{1-x}$Cr$_x$Si and GdRu$_{1-x}$Mo$_x$Si systems practically does not change. For the density of states N(E) calculated by us for the GdRuSi, the Fermi level EF is localized on the right slope of the N(E) peak for spin-up electrons and at the maximum of the peak for spin-down electrons. In the rigid band shift method, when Ru is replaced by Mo in GdRuSi, EF shifts to the left due to the smaller number of 4d electrons in the Mo atom (5) compared to the Ru atom (7). In this case, total N(EF) and TC N(EF) [1] practically do not change. Assuming hybridization of 4d electrons of Ru and 3d electrons of Cr, similar reasoning is also suitable for explaining the practical invariance of TC(x) in the GdRu$_{1-x}$Cr$_x$Si system, since the Cr atom (5) has fewer 3d electrons than the Ru atom (7) has 4d electrons.

References

[1] A. Kuchin *et al.*, *Intermetallics*, vol. 133, p. 107183, 2021.

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Structural and Magnetic Properties of Ni Substituted FeCo Alloy Synthesized through Polyol Process

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Fe alloy powders with optimum magnetic properties are in demand for the fabrication of soft magnetic composites that find applications in power electronics and more electric vehicles. Even though the superior magnetic properties make FeCo much preferred in soft magnetic composites, the presence of Co makes it expensive, and low corrosion resistance and brittleness make it unsuitable for practical devices. In this work, we try to circumvent these difficulties by adding Ni to the FeCo system. FeCoNi alloys with spherical morphology showing bcc structure are synthesized using a facile instant reduction polyol process. Reduction in Curie temperature has obtained with Ni substitution up to 14 at.%. The effective magnetic anisotropy realized using a modified law of approach to saturation [1] suggests better soft magnetic behavior with Ni substitution. The multidomain FeCoNi alloy particles have the potential for high-temperature applications as their effective magnetic anisotropy is lower than Fe and FeCo powders.

References

[1] K. S. Sivaranjani *et al.*, *physica status solidi (b)*, p. 2200050.

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Structural and local study of the alloy AL$_X$Fe$_{(1-x)}$ (x=0.25, 0.5 y 0.75) obtained by arc furnace

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Over the past three decades, it has provided much attention to the synthesis of nanoparticles: many routes have been developed to prepare magnetic nanoparticles well controlled. Thus, in the present work, the study structural and magnetic is carried out by X-ray diffraction and M̋ossbauer spectrocopy of the Al$_x$Fe$_{(1-x)}$ alloy with x = 0.25, 0.5 and 0.75. Samples were synthesized by the technique arc furnace (HA) and were subsequently treated at temperatures of 600C, 950C and 1000C for 48, 290 and 48 hours respectively. After the heat treatment corresponding to the temperature of 600C, is observed for the composition Al$_{25}$Fe$_{75}$ and Al$_{50}$Fe$_{50}$ ferromagnetic and paramagnetic; together to the solid solution Fe(Al) rich and poor in iron, for the composition Al$_{75}$Fe$_{25}$, the formation of the intermetallic Al$_{13}$Fe$_4$ and the solid solution Fe(Al), both paramagnetic, is observed [1].

References

[1] V. A. P. Rodríguez and other, *Hyperfine Interact.*, vol. 202, no. 145, 2011.

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Effect of Zr and Nd substitution on the structural and magnetic properties of the SmFe$_{11}$V

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Structural and magnetic behavior of polycrystalline alloys of Sm$_{1-x}$Y$_x$Fe$_1$1V (Y=Nd, Zr and 0 $\leq$ x $\leq$ 0.6) were studied. In case of Zr substitution, all the optimally heat-treated alloys crystallize into 1:12 with tetragonal ThMn12-type structure and α-(Fe,V) phases. For high content of Zr (x = 0.4 and 0.6), Laves phase ZrFe2 was also detected with T_C of 436 and 424°C, respectively. Oriented powder XRD patterns indicated that the easy magnetization direction was along (002) c-axis. As Zr content increased from x = 0 to 0.6, the $\mu_0 H_A$ decreased from 11 to 8.8 T and the T_C from 352 to 310°C, and the M_s increased from 115 to 138 Am^{2}kg^1. In case of Nd substitution, even small quantities of Nd promoted the formation of the 3:29 phase: Nd$_3$(Fe,Ti)$_{29}$ and Sm-oxides, which ruin the desired magnetic properties. The Zr-substituted alloys can be considered as potential candidates for permanent magnet applications. [1]–[3]

References

[1] K. P. Skokov *et al.*, *Scr. Mater.*, vol. 154, p. 289–294, 2018.
[2] A. Gabay *et al.*, *Scr. Mater.*, vol. 154, p. 284–288, 2018.
[3] A. Sch"onh"obel *et al.*, *J. Alloys Compd.*, vol. 786, p. 969–974, 2019.

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Ab-initio study of the magnetic properties of compounds based on Sm-Y-Co

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The magnets based on the isostructural RE-TM$_5$ compounds (RE: rare earth, TM: transition metal) are currently the best performing. Among these intermetallics, SmCo$_5$ has the largest known uniaxial magnetocrystalline anisotropy energy (MAE) of 17.2 MJ/m^3 as well as excellent magnetic performance at elevated temperatures. However, in an effort to reduce industrial costs, recent studies have focused on analyzing different doping elements that in turn maintain an efficient magnetic behavior of the compound [1], [2]. In this case, the YCo$_5$ alloys have emerged as promising intermediate-performance hard magnet, since on the one hand, Y costs about 50% less than Sm and, on the other hand, the absence of 4f electrons in Y allows to identify the TM network contribution to the overall MAE, magnetization and Curie temperature. We present the results of density functional theory calculations on the electronic structure, local and total magnetic moments, MAE, and density of states of Sm-Y-Co$_5$ compound.

References

[1] D. Zhang *et al.*, *Rare Met.*, 2019.
[2] H. Ucara *et al.*, *J. Magn. Magn. Mater.*, vol. 496, p. 165902, 2020.

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A linkage between major earthquakes, magnetic field and atmospheric pressure

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A current issue is trying to find seismic predictors in physical magnitudes [1], [2]. In this work, geomagnetic field and atmospheric pressure disturbances related to seismic events are studied. We analysed the great earthquakes of February 27, 2010, to 06:34 UTC, 150 km northwest of Concepción, Chile, and March 11, 2011, to 05:46 UTC off the coast of Tohoku, Japan, with the geomagnetic field difference (GMF) of the closest INTERMAGNET network observatories and the atmospheric pressure difference at sea surface level, evaluated in a period of 2 hours before and after the earthquakes. Evidence of disturbances in the atmospheric pressure (Fig. 1a, 1b) and in the GMF (Fig. 1c, 1d) can be observed moments before and during the occurrence of the earthquakes. It would be inferred that there is a connection between geomagnetic variations and seismic events, however some signals show signatures similar to those highlighted and not associated with earthquakes.

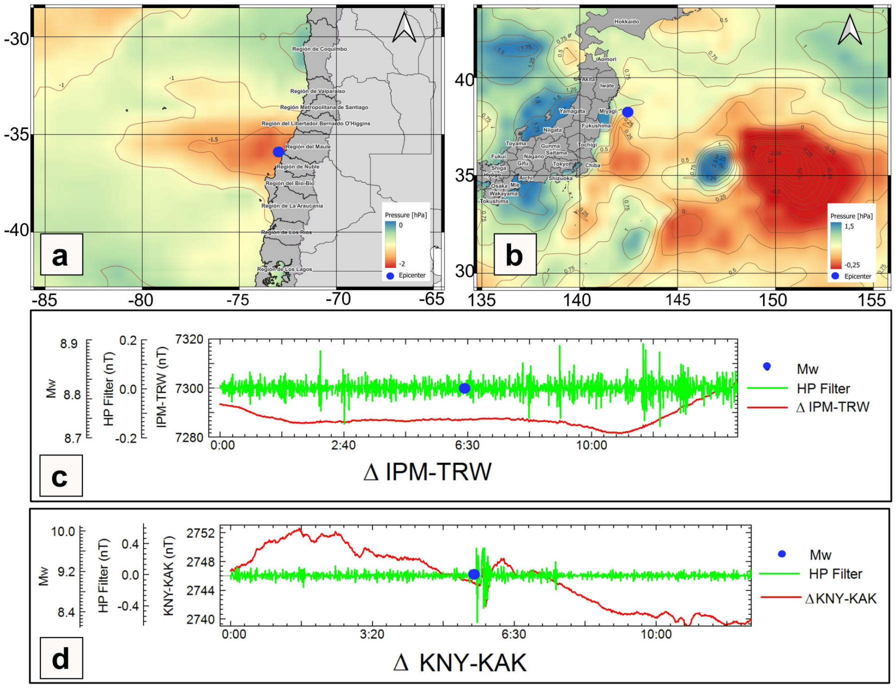

Figure 1. Difference of Sea level pressure, 2 hours before and after the earthquakes (0.5 x 0.625 deg) [MERRA-2 Model M2T1NXSLV v5.12.4] of February 27, 2010, Chile (a) and March 11, 2011, Japan (b). GMF difference between observatories (red line) and GMF filtered (green line) of Isla de Pascua-Trelew (c) and Kanoya-Kakioka (d). Earthquake (blue circle).

References

[1] N. Arai *et al.*, *Geophys. Res. Lett.*, vol. 38, p. L00G18, 2011.
[2] J. Zhao *et al.*, *Journal of Geophysical Research: Solid Earth*, vol. 126, p. e2021JB022102, 2021.

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Ultrafast Magnetization Dynamics in $Ni_{80}Fe_{20}$/Neodymium Bilayer Films

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Recently, as the most important physical quantity in spintronics, spin current has been extensively studied. The transmission of a spin current across the interface between materials is usually determined by the spin-mixing conductance at the interface. To improve the efficiency of spin transport or injection, control of the spin-mixing conductance at the interface is critically essential. Previous reports have proposed that an antiferromagnetic interface facilitates the spin transmission at the interface [1], [2] of ferromagnetic/nonmagnetic (FM/NM) bilayers. In ferromagnetic/rare earth (FM/RE) structures, the magnetic moment of the RE materials is induced by adjacent FM layer, such that they are antiparallel to each other, resulting in a spontaneous antiferromagnetic interface. The relationship between the spontaneous antiferromagnetic interface and the spin-mixing conductance in FM/RE systems lack thorough research.

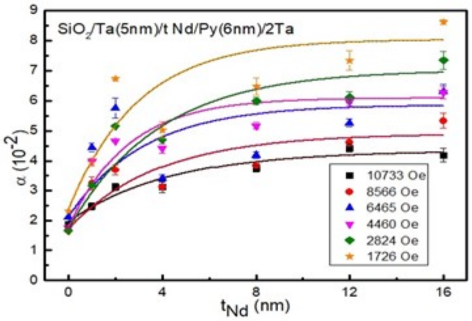

Figure 1. Dependence of the Nd layer thickness in relation to magnetic damping (α) at varying magnetic fields.

The ultrafast magnetization dynamics in $Ni_{80}Fe_{20}$/neodymium (Py/Nd) bilayer films were studied by using the time resolved magneto-optical Kerr effect (TRMOKE). Results show that the antiferromagnetic interface was suppressed by the increasing Zeeman field, which led to the decrease of interface spin-mixing conductance. This research demonstrates the key role that the antiferromagnetic interface plays in the spin transmission in FM/RE structures.

References

[1] W. Lin *et al.*, *Physical review letters*, vol. 116, no. 18, p. 186601, 2016.
[2] Y. Wang *et al.*, *Science*, vol. 366, no. 6469, pp. 1125–1128, 2019.

Exchange bias in polycrystalline films with antiferromagnetic Cr-Mn

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Antiferromagnet/ferromagnet systems are an important component of many functional media for spintronic devices due to the exchange bias effect present in them [1]. To limit the usage of platinum-group metals as critical raw materials, scientific community is searching for more affordable alternatives to currently used Ir-Mn and Pt-Mn antiferromagnets. In this regard, of a particular interest are the antiferromagnetic Cr-Mn alloys with Néel temperature TN as high as 500 °C [2]. This characteristic is especially important for technological applications: the temperature up to which exchange bias is present – a blocking temperature Tb – is closely related to TN.

In our work we systematically study how deposition conditions, buffer layers (Ta, Ta/Fe, Ta/Cr), composition and thickness of the Cr-Mn layer affect the exchange bias effect in polycrystalline Cr-Mn/Fe and Cr-Mn/$Fe_{20}Ni_{80}$ films, as well as their crystal structure. Our results show that antiferromagnetic Cr-Mn is a promising basis for further spintronics-oriented research.

References

[1] K. O'Grady *et al.*, *J. Appl. Phys.*, vol. 123, no. 4, 2020.
[2] Y. Hamaguchi and K. N., *Journal of the Physical Society of Japan*, vol. 19, no. 10, 1964.

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Micromagnetic modeling of domain wall dynamics under the Inverse Faraday Effect

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Domain wall (DW) motion can be achieved in a variety of ways: via fields, currents, thermal gradients etc. The application of ultrafast circularly-polarised laser pulses has also been demonstrated to produce DW motion with the Inverse-Faraday effect playing one of the most important roles.

Traditionally pictured as a field acting on the light propagation axis, recent ab-initio studies describe it both as a helicity-dependent magnetic moment or torque [1], [2]. To understand its role in DW dynamics, we employ high-temperature micromagnetics based on the Landau-Lifshitz-Bloch equation [3]. Inducing a magnetisation modulus gradient across an 1800 Néel wall, we show that pure longitudinal relaxation leads to DW displacement towards the reduced magnetisation region similarly to the Spin-Seebeck effect, but disregarding any additional field or thermal gradients. We compare this method with the field and torque actuation, investigating the DW displacement and velocity as a function of intrinsic damping and electron temperature.

References

[1] R. John *et al.*, *Scientific reports*, vol. 7, no. 1, pp. 1–8, 2017.
[2] F. Freimuth *et al.*, *Physical Review B*, vol. 94, no. 14, p. 144432, 2016.
[3] U. Atxitia *et al.*, *Applied physics letters*, vol. 91, no. 23, p. 232507, 2007.

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Hysteretic Resonances of Chiral Spin Textures in Multilayer Films

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Microwave resonances of ultrathin magnetic films are actively investigated for myriad applications in microwave computing, information processing, and transport. Of particular interest of late are chiral spin textures such as magnetic skyrmions, whose topological spin structures are expected to additionally host localized resonances. However, studies of chiral magnetic resonances have predominantly focused on bulk crystals at cryogenic temperatures. Their character, extent, and tunability in technologically relevant chiral multilayers is largely unexplored.

Here, we report a detailed investigation of the microwave resonance phenomenology of Co/Pt-based chiral multilayers hosting dense Neel textures. By combining microwave absorption spectroscopy, Lorentz transmission electron microscopy (L-TEM), and micromagnetic simulations on a tunable skyrmion platform, we establish the localized, confined, and extended modes of the resonances, and their hysteretic behavior with varying field. In particular, we find strong correlations between the hysteretic character of microwave resonances and the formation mechanism of the chiral spin textures as established by thermodynamic and microscopic techniques [1], [2]. Finally, the hysteretic resonances exhibited remarkable tunability with material parameters determining chiral domain stability, and field history, offering an intriguing approach to engineering magnonic bands for myriad applications.

References

[1] X. Chen *et al.*, *Physical Review Applied*, vol. 17, no. 4, p. 044039, 2022.
[2] X. Chen *et al.*, *Advanced Science*, vol. 9, no. 6, p. 2103978, 2022.

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Spin chirality produced by thermal fluctuations

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The term ”chirality” originates from ancient Greek word ”$\chi\epsilon\iota\rho$”, meaning ”hand”. It is used to describe objects which, similarly to the human hand, can be distinguished from their mirror reflections. In magnetic materials, this term is related to the geometrical non-coplanar spin arrangements. The resulting scalar spin chirality is defined as a mixed product of three neighboring spins $\chi = S_i \cdot (S_j \times S_k)$. This quantity affects the motion of quantum-mechanical electrons and thus translates the microscopic details of the electronic structure to the language of measurable off-diagonal transport responses such as Hall and Nernst effects. Apart from the materials with static spin-chiral textures, such as skyrmions, the finite χ can stem from the average arrangements of thermally fluctuating spins. This can be observed already in the paramagnetic state, as we demonstrate in metallic magnets with breathing kagomé lattice [1]. We also identify the geometrical precursors promoting the chiral spin fluctuations [2].

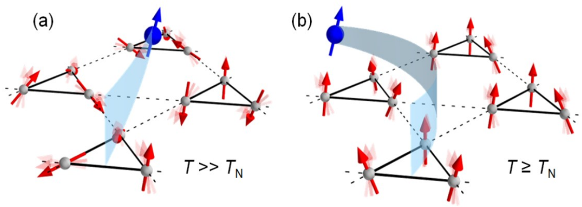

Figure 1. Spin chirality on a breathing kagomé lattice. At high temperature, as sketched in panel (a), the spin arrangement is entirely random. In this fully disordered state, the overall chirality, integrated over the whole material zero and the electron (blue) motion is unaffected. When temperature is lowered and approaches the magnetic ordering point T_N, as shown in panel (b), the thermally fluctuating spins carry a net chirality stemming from their average orientation. As a result, the conduction electron accumulates Berry phase and under the influence of the emergent magnetic field strays from its initial path.

References

[1] K. Kolincio *et al.*, *Proceedings of the National Academy of Sciences of the United States of America*, vol. 118, p. e2023588118, 2021.

[2] K. Kolincio *et al.*, *http://arxiv.org/abs/2206.05756*, 2022.

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Magnetic Anisotropy and Spin-Torque Modulation through Dead-Layer Reduction in Ta/CoFeB/MgO Trilayer

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Interfacial perpendicular magnetic anisotropy (i-PMA) offers technical advantages in terms of device scaling trends to keep up with the Dennard Scaling. Spin-orbit torque magnetic random-access memory (SOT-MRAM) is an emerging technology which offers better performance in terms of speed and endurance as compared to Spin-transfer torque technology[1]. However, i-PMA in Ta|CoFeB|MgO suffers damage during sputtering deposition due to the high-energy O^{2-} ions[1]. Here, we report our efforts in enhancing the SOT and i-PMA via modulating the O^{2-} concentration at CoFeB|MgO interface.

References

[1] K. Garello *et al.*, *Nature nanotechnology*, vol. 8, no. 8, pp. 587–593, 2013.
[2] Q. Ma *et al.*, *Physical review letters*, vol. 120, no. 11, p. 117703, 2018.

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Detection of Field-Free Magnetization Switching Through Thermoelectric Effect in Magnetic Heterostructures With Significant Spin-Orbit Torque and Competing Spin Currents

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In asymmetric Pt/Co/Pt heterostructures, antidamping (AD) SOT prevails [1]. Ta addition to this stack (Ta/Pt/Co/Pt) give rise to several compelling effects viz. competing spin currents, significant AD-SOT, thermoelectric effects (particularly, anomalous Nernst effect (ANE)) [1], and enhanced perpendicular magnetic anisotropy. For this Ta/Pt/Co/Pt stack, the AD-SOT values are stabilized to that of the Pt/Co/Pt stack, which is significant than what is expected for a stack with competing spin currents. Contrary to the reported literature [2], current-induced field-free magnetization switching (FFS) was absent in uniformly grown Ta/Pt/Co/Pt stack. It was observed that a thickness gradient is essential to assist the FFS. Further, the thermoelectric effects are utilized to develop a technique to detect the FFS. This technique detects the second harmonic ANE signal as a reading mechanism. Using ANE symmetry with the applied current, the switching can be detected in a single current sweep which was corroborated to the conventional DC Hall method.

References

[1] K. Garello *et al.*, *Nature nanotechnology*, vol. 8, no. 8, pp. 587–593, 2013.
[2] Q. Ma *et al.*, *Physical review letters*, vol. 120, no. 11, p. 117703, 2018.

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Dynamics of 3D topological spin textures

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In two dimensions, Skyrmions provide an optimal system to explore topology and magnetism. In three dimensions, the analogous topological spin texture is the recently observed magnetic Hopfion [1]. A Hopfion is a toroidal spin texture equivalent to a Skyrmion string twisted into closed into a torus (fig. 1). 3D magnetic systems are also predicted to host additional novel spin textures including target Skyrmions and Torons.

These 3D spin textures, which have so far only been observed statically, now hold promise for dynamical studies. I will present recent numerical calculations predicting that Hopfions and related 3D spin textures will exhibit dynamical behaviour coupled to their real-space topology [2]. This coupling of dynamics to topology has implications for experimental design and 3D spintronic device engineering.

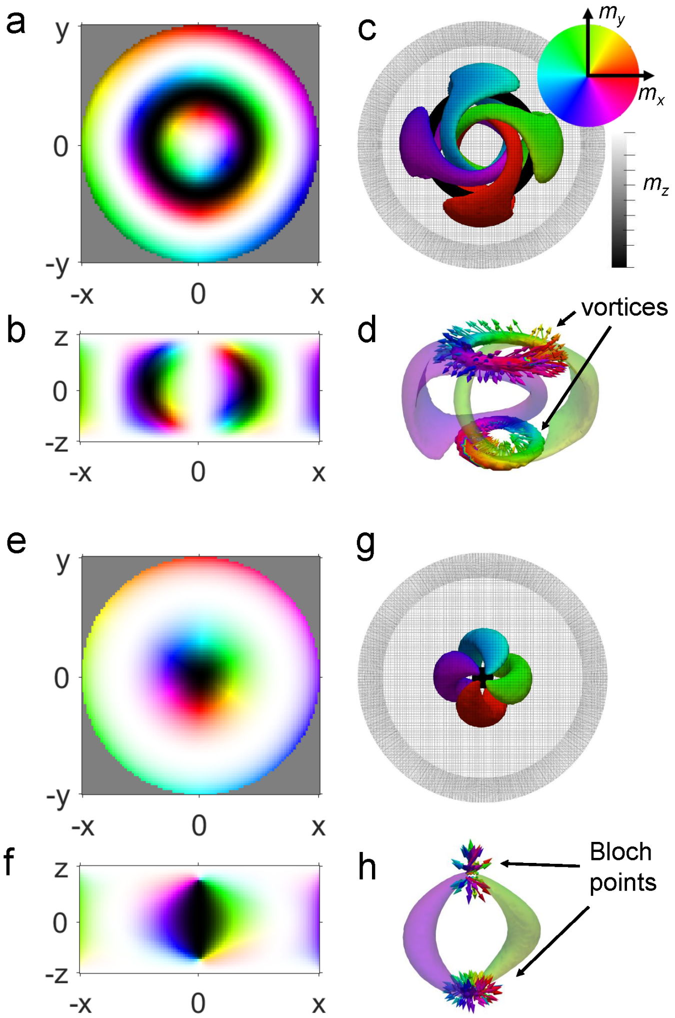

Figure 1. (a) Magnetization color map of a Hopfion at the z=0 plane. (b) Magnetization color map of Hopfion at the y=0 plane. (c) Hopfion spin textures with linked magnetization isosurfaces. The Hopf invariant or linking number, Q, is the number of times the isosurfaces are linked. (d) Detail of Hopfion vortex rings. (e) Magnetization color map of a toron at the z=0 plane. (f) Magnetization color map of toron at the y=0 plane. (g) Toron spin textures with unlinked isosurfaces. A toron has Q=0. (h) Detail of toron Bloch points (monopole antimonopole pair).

References

[1] N. K. 1 *et al.*, *Nat. commun.*, vol. 12, no. 1562, 2021.
[2] D. Raftrey and P. Fischer, *Phys. Rev. Let.*, vol. 127, no. 257201, 2022.

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Dynamic magnetic properties of Co$_2$FeAl/IrMn bilayers

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The exchange coupling between antiferromagnetic (AF) and ferromagnetic (FM) layers, coming from the interfacial AF/FM interaction, has received increasing attention due to its key role in spin valves, magnetic tunnel junctions, and a sort of electronic devices [1]–[3]. In the following study, we perform a systematic investigation of the static and dynamic magnetic properties of exchange-biased Co2FeAl/IrMn films. We analyse the evolution of the coercive field, exchange bias field, rotatable anisotropy and magnetic damping, using broadband ferromagnetic resonance, as a function of IrMn antiferromagnet film thickness. We observe an increase of exchange bias and rotatable anisotropy with the thickness of the IrMn layer. These anisotropies reach nearly constant values for thickness above 20 nm of IrMn, and surprisingly the rotatable anisotropy does not decrease as observed in other systems. We obtain magnetic damping parameters □ for the CoFeAl/IrMn systems, with no clear correlation with the thickness of the IrMn or the rotatable anisotropy.

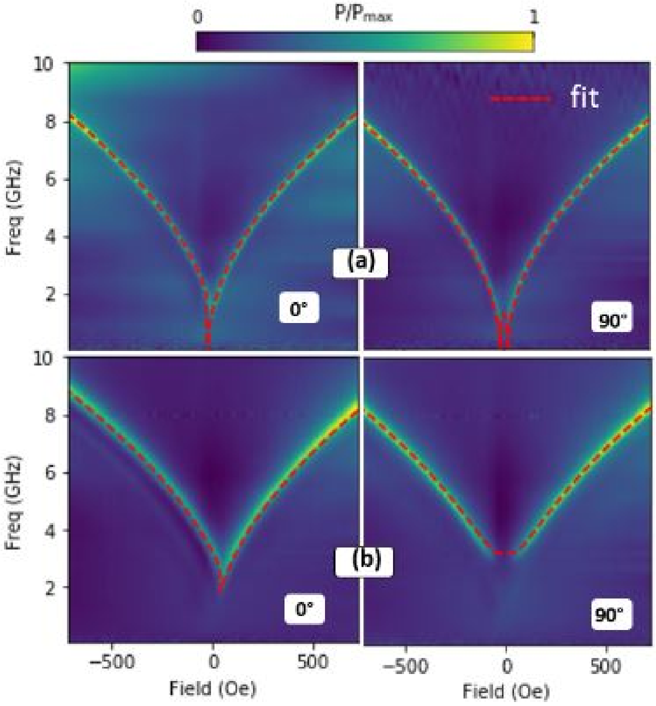

Figure 1. Representative broadband FMR spectra (two-dimensional color plots) and dispersion relation fits (dashed lines) for the (a) single CFA(10) film, and (b) CFA(10)/IrMn(15) sample, measured along (ϕ = 0°) and perpendicular (90°) to the direction defined by the field applied during deposition.

References

[1] A. Taskin and Y. Ando, *Physical Review B*, vol. 80, 2009.
[2] E. Osmic *et al.*, *Journal of Physics and Chemistry of Solids*, vol. 167, no. 110734, 2022.

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Universal Time conversion table

	UTC	AEST (+10)	JST (+9)	CST (+8)	IST (+5:30)	EEST (+3)	CEST (+2)	ART (-3)	EDT (-4)	MDT (-6)	PDT (-7)
	23:45	9:45	8:45	7:45	5:15	2:45	1:45	20:45	19:45	17:45	16:45
Session 1	0:00	10:00	9:00	8:00	5:30	3:00	2:00	21:00	20:00	19:00	18:00
	0:45	10:45	9:45	8:45	6:15	3:45	2:45	21:45	20:45	19:45	18:45
	1:00	11:00	10:00	9:00	6:30	4:00	3:00	22:00	21:00	20:00	19:00
	1:15	11:15	10:15	9:15	6:45	4:15	3:15	22:15	21:15	20:15	19:15
	1:30	11:30	10:30	9:30	7:00	4:30	3:30	22:30	21:30	20:30	19:30
	1:45	11:45	10:45	9:45	7:15	4:45	3:45	22:45	21:45	20:45	19:45
Session 2	2:00	12:00	11:00	10:00	7:30	5:00	4:00	23:00	22:00	21:00	20:00
	2:15	12:15	11:15	10:15	7:45	5:15	4:15	23:15	22:15	21:15	20:15
	2:30	12:30	11:30	10:30	8:00	5:30	4:30	23:30	22:30	21:30	20:30
	2:45	12:45	11:45	10:45	8:15	5:45	4:45	23:45	22:45	21:45	20:45
	3:15	13:15	12:15	11:15	8:45	6:15	5:15	0:15	23:15	22:15	21:15
Session 3	4:00	14:00	13:00	12:00	9:30	7:00	6:00	1:00	0:00	23:00	22:00
	4:45	14:45	13:45	12:45	10:15	7:45	6:45	1:45	0:45	23:45	22:45
	5:00	15:00	14:00	13:00	10:30	8:00	7:00	2:00	1:00	0:00	23:00
	5:15	15:15	14:15	13:15	10:45	8:15	7:15	2:15	1:15	0:15	23:15
	5:30	15:30	14:30	13:30	11:00	8:30	7:30	2:30	1:30	0:30	23:30
	5:45	15:45	14:45	13:45	11:15	8:45	7:45	2:45	1:45	0:45	23:45
Session 4	6:00	16:00	15:00	14:00	11:30	9:00	8:00	3:00	2:00	0:00	0:00
	6:15	16:15	15:15	14:15	11:45	9:15	8:15	3:15	2:15	0:15	0:15
	6:30	16:30	15:30	14:30	12:00	9:30	8:30	3:30	2:30	0:30	0:30
	6:45	16:45	15:45	14:45	12:15	9:45	8:45	3:45	2:45	0:45	0:45
	7:15	17:15	16:15	15:15	12:45	10:15	9:15	4:15	3:15	1:15	0:15
Session 5	8:00	18:00	17:00	16:00	13:30	11:00	10:00	5:00	4:00	2:00	1:00
	8:45	18:45	17:45	16:45	14:15	11:45	10:45	5:45	4:45	2:45	1:45
	9:00	19:00	18:00	17:00	14:30	12:00	11:00	6:00	5:00	3:00	2:00
	9:15	19:15	18:15	17:15	14:45	12:15	11:15	6:15	5:15	3:15	2:15
	9:30	19:30	18:30	17:30	15:00	12:30	11:30	6:30	5:30	3:30	2:30
	9:45	19:45	18:45	17:45	15:15	12:45	11:45	6:45	5:45	3:45	2:45
Session 6	10:00	20:00	19:00	18:00	15:30	13:00	12:00	7:00	6:00	4:00	3:00
	10:15	20:15	19:15	18:15	15:45	13:15	12:15	7:15	6:15	4:15	3:15
	10:30	20:30	19:30	18:30	16:00	13:30	12:30	7:30	6:30	4:30	3:30
	10:45	20:45	19:45	18:45	16:15	13:45	12:45	7:45	6:45	4:45	3:45
	11:15	21:15	20:15	19:15	16:45	14:15	13:15	8:15	7:15	5:15	4:15

	UTC	AEST (+10)	JST (+9)	CST (+8)	IST (+5:30)	EEST (+3)	CEST (+2)	ART (-3)	EDT (-4)	MDT (-6)	PDT (-7)
Session 7	12:00	22:00	21:00	20:00	17:30	15:00	14:00	9:00	8:00	6:00	5:00
	12:45	22:45	21:45	20:45	18:15	15:45	14:45	9:45	8:45	6:45	5:45
	13:00	23:00	22:00	21:00	18:30	16:00	15:00	10:00	9:00	7:00	6:00
	13:15	23:15	22:15	21:15	18:45	16:15	15:15	10:15	9:15	7:15	6:15
	13:30	23:30	22:30	21:30	19:00	16:30	15:30	10:30	9:30	7:30	6:30
	13:45	23:45	22:45	21:45	19:15	16:45	15:45	10:45	9:45	7:45	6:45
Session 8	14:00	0:00	23:00	22:00	19:30	17:00	16:00	11:00	10:00	8:00	7:00
	14:15	0:15	23:15	22:15	19:45	17:15	16:15	11:15	10:15	8:15	7:15
	14:30	0:30	23:30	22:30	20:00	17:30	16:30	11:30	10:30	8:30	7:30
	14:45	0:45	23:45	22:45	20:15	17:45	16:45	11:45	10:45	8:45	7:45
	15:15	1:15	0:15	23:15	20:45	18:15	17:15	12:15	11:15	9:15	8:15
Session 9	16:00	2:00	1:00	0:00	21:30	19:00	18:00	13:00	12:00	10:00	9:00
	16:45	2:45	1:45	0:45	22:15	19:45	18:45	13:45	12:45	10:45	9:45
	17:00	3:00	2:00	1:00	22:30	20:00	19:00	14:00	13:00	11:00	10:00
	17:15	3:15	2:15	1:15	22:45	20:15	19:15	14:15	13:15	11:15	10:15
	17:30	3:30	2:30	1:30	23:00	20:30	19:30	14:30	13:30	11:30	10:30
	17:45	3:45	2:45	1:45	23:15	20:45	19:45	14:45	13:45	11:45	10:45
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	18:15	4:15	3:15	2:15	23:45	21:15	20:15	15:15	14:15	12:15	11:15
	18:30	4:30	3:30	2:30	0:00	21:30	20:30	15:30	14:30	12:30	11:30
	18:45	4:45	3:45	2:45	0:15	21:45	20:45	15:45	14:45	12:45	11:45
	19:15	5:15	4:15	3:15	0:45	22:15	21:15	16:15	15:15	13:15	12:15
Session 11	20:00	6:00	5:00	4:00	1:30	23:00	22:00	17:00	16:00	14:00	13:00
	20:30	6:30	5:30	4:30	2:00	23:30	22:30	17:30	16:30	14:30	13:30
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	21:00	7:00	6:00	5:00	2:30	0:00	23:00	18:00	17:00	15:00	14:00
	21:15	7:15	6:15	5:15	2:45	0:15	23:15	18:15	17:15	15:15	14:15
	21:30	7:30	6:30	5:30	3:00	0:30	23:30	18:30	17:30	15:30	14:30
	21:45	7:45	6:45	5:45	3:15	0:45	23:45	18:45	17:45	15:45	14:45
Session 12	22:00	8:00	7:00	6:00	3:30	1:00	0:00	19:00	18:00	16:00	15:00
	22:15	8:15	7:15	6:15	3:45	1:15	0:15	19:15	18:15	16:15	15:15
	22:30	8:30	7:30	6:30	4:00	1:30	0:30	19:30	18:30	16:30	15:30
	22:45	8:45	7:45	6:45	4:15	1:45	0:45	19:45	18:45	16:45	15:45
	23:00	9:00	8:00	7:00	4:30	2:00	1:00	20:00	19:00	17:00	16:00
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