

# Book of Abstracts

International Symposium on  
Integrated Magnetics 2026  
iSIM 2026



April 12–13, 2026

Manchester, U.K.

International Symposium on Integrated Magnetics 2026 (iSIM 2026)  
April 12–13, 2026, Manchester, U.K.

**Book of Abstracts**

<https://theisim.org/>



Web site

# Contents

List of supporters and sponsors . . . . .	2
General information . . . . .	8
Detailed schedule . . . . .	10
List of posters . . . . .	13
Invited talks . . . . .	15
Posters . . . . .	39

## List of supporters and sponsors

The iSIM 2026 is supported by the IEEE Magnetics Society.



The IEEE Magnetics Society (<https://ieemagnetics.org/>) is the leading international professional organization for magnetism and for related professionals. It promotes the advancement of science, technology, applications and training in magnetism. There are 2100 members and 45 chapters throughout the world (22 Americas, 9 Europe and 14 Asia). The Magnetics Society sponsors major conferences including Intermag, MMM, and Joint MMM/Intermag, organizes summer schools, and publishes the IEEE Transactions on Magnetics, IEEE Magnetics Letters, Special Magnetics Section in the IEEE eXplorer, and the Society Newsletter. Each of four Distinguished Lectures deliver 40-50 talks every year. Women in Magnetism (WiM), Young Professionals (YP) and Students in Magnetism (SiM) are getting more active in recent years. Please visit the [Society Web](#) for details, and join it!

## Gold sponsors

# Futek Furnace

Management owned and Yokohama based [Futek Furnace](#) has been developing, manufacturing and selling thermal processing equipment via an international dealer network for over 40 years. Their current thermal processing equipment line-up includes a broad range of magnetic annealing ovens that are integral to a variety of thin film applications including the development and production of non-volatile memory, sensors and thin film heads.



Analog Devices, Inc. (ADI) is a global semiconductor leader that bridges the physical and digital worlds to enable breakthroughs at the Intelligent Edge. ADI combines analog, digital, and software technologies into solutions that help drive advancements in digitized factories, mobility, and digital healthcare, combat climate change, and reliably connect humans and the world. With revenue of more than \$9 billion in FY24 and approximately 24,000 people globally, ADI ensures today's innovators stay Ahead of What's Possible. Learn more at [www.analog.com](http://www.analog.com) and on [LinkedIn](#) and [X](#).



The aim of [FuE-Zentrum FH Kiel GmbH](#) is to facilitate the transfer of technology between science and industry. Within the framework of clearly defined projects, we leverage outstanding research results, scientific expertise, and state-of-the-art technical facilities to give our clients a competitive advantage and a quick return on investment.

---

## Silver sponsors



The evico magnetics GmbH was founded in 2006 as spin-off of the Leibniz Institut for Solid State and Materials Research (IFW) Dresden. The main products are: (i) Advanced magneto-optical wide-field Kerr microscope systems for the visualization of magnetic domains and magnetization processes in all kinds of magnetic materials. The Kerr microscopes also serve as magneto-optical magnetometers for the sensitive and local measurement of hysteresis loops by MOKE magnetometry. (ii) High Pressure Milling Vials with a gas temperature monitoring system for the synthesis of magnetic powders and hydrogen storage materials. See [www.evicomagnetics.com](http://www.evicomagnetics.com) for information.

---



Texas Instruments ([www.ti.com](http://www.ti.com)) is a global semiconductor company that designs, manufactures, tests and sells analog and embedded processing chips. Our approximately 80,000 products help over 100,000 customers efficiently manage power, accurately sense and transmit data and provide the core control or processing in their designs, going into markets such as industrial, automotive, personal electronics, communications equipment and enterprise systems. Our passion to create a better world by making electronics more affordable through semiconductors is alive today as each generation of innovation builds upon the last to make our technology smaller, more efficient, more reliable and more affordable – opening new markets and making it possible for semiconductors to go into electronics everywhere.



Ion implantation, innovative products for high technical demands, know-how and state-of-the-art infrastructure for analysis and sample examinations: As a technology transfer company, [HZDR Innovation GmbH](#) offers innovations in high-tech environments. With our services and products you are one step ahead of the future. One example is our novel, high-performance magnetic field sensors on ultrathin, flexible substrates with high mechanical adaptability, which can also be used on curved surfaces.

---



**Magnaire**

[Magnaire](#) was established in April 2023 with the mission of developing, manufacturing, and commercializing GSR sensor products, primarily for medical applications. We believe this technology will become essential to future medical systems, enabling advanced high-precision catheter navigation and the detection of biomagnetic signals in everyday environments.



[MagneDesign Corporation](#) was founded by Yoshinobu Honkura in 2012. Our goal was to conduct research and development in magnetics and disseminate the results. In 2013, we started doing joint research with Nagoya University. In 2015, we discovered the GSR principle, which enables highly sensitive micromagnetic sensors. This discovery received significant attention. In 2016, we established a prototype center to serve as a development base where we successfully developed production technology for GSR sensor elements. In 2020, articles on GSR sensors with ASIC specifications were published. Currently, we are developing a magnetic gyrocompass for portable computers, a pT (picotesla) sensor for biomagnetic detection, and a GSR sensor for magnetic vehicle sensors. All of these projects are based on the GSR principle.

## General information

### Organizing Committee

**General Chair:** Prof. Jeffrey McCord,  
Kiel University, Germany

#### Program Chairs:

- Prof. Shin Yabukami,  
Tohoku University, Japan
- Prof. Amal El-Ghazaly,  
Cornell University, USA

#### Local Chairs:

- Dr. Liam O’Brien,  
University of Liverpool, UK
- Dr. Ranajit Sai,  
Tyndall National Institute, Ireland

#### Publications & Publicity Chairs:

- Dr. Denys Makarov,  
Helmholtz-Zentrum Dresden-Rossendorf e.V., Germany
- Prof. Runwei Li,  
Ningbo Institute of Materials Technology & Engineering, China

**Sponsorship:** Prof. Tianxiang Nan,  
Tsinghua University, China

**Web Admin:** Dr. Oleksandr Pylypovskiy,  
Helmholtz-Zentrum Dresden-Rossendorf e.V., Germany

### iSIM Advisory Board

Prof. Masahiro Yamaguchi,  
Tohoku University, Japan

Prof. Nian Sun,  
Northeastern University, USA

Dr. Dok Won Lee,  
Texas Instruments, USA

## Topics

1. Sensing  
Tunneling magnetoresistive (TMR) sensors, Magnetoelectric sensors, Giant magnetoimpedance sensors, Other magnetoresistive sensors
2. Integrated circuits for magnetics  
Power supply on chip (PwrSoP), Power supply in package (PwrSiP), Magnetics for advanced packaging, Communication circuits, etc
3. Disruptive technologies  
Flexible magnetoelectronics, Eco-sustainable magnetics, Quantum sensing, Machine learning for integrated magnetics

## Venue

The conference will be held at Manchester Central, Windmill St, Manchester M2 3GX, United Kingdom  
Tel.: +44 (0)161 834 2700



Google map

<https://maps.app.goo.gl/c4Jv4RMuoREDDyzEA>

# Schedule

Sunday, April 12		
8:30	Arrival	
9:00	Opening Remarks <i>Jeffrey McCord (iSIM) &amp; Ron Goldfarb (IEEE Mag.)</i>	
<b>Session 1: Power Magnetics</b>		
Session chair: Jeffrey McCord		
9:10	New power modules technology; MagPack <sup>TM</sup> increasing the power density <i>Kenji Kawano</i>	P. 16
9:35	MagNet Project: Data Driven Methods for Power Magnetics Modeling <i>Minjie Chen</i>	P. 17
10:00	Power Electronics Standards Sustaining Existing Technologies and Supporting the Development of New Technologies <i>Matt Wilkowski</i>	P. 18
10:25	Launching IEEE Technology Roadmap Program on Magnetic Passive Components for Power Electronics: Bridging Materials to Systems <i>Masahiro Yamaguchi</i>	P. 19
10:50	<b>Coffee Break</b>	
<b>Session 2: Materials Design</b>		
Session chair: Masahiro Yamaguchi		
11:15	Compensated ferrimagnets for emerging spintronics <i>WanJun Jiang</i>	P. 20
11:40	State of the Art on Magnetoelectrics <i>Nian Sun</i>	P. 21
12:05	Material Informatics for Magnetic Materials <i>Nicola Morley</i>	P. 22

12:30	Physically-Informed Neural Networks for the Estimation of Magnetization from External Measurements <i>Alessandro Formisano</i>	P. 23
12:55	<b>Lunch</b> + Mounting of contributed posters	
<b>Session 3: TMR/Spintronics</b>		
Session chair: Lee Dok Won		
14:25	TMR position and current sensors for industrial and automotive systems <i>Jeff Childress</i>	P. 24
14:50	Challenges in Tunneling Magnetoresistance Sensor Development <i>Simon Mendisch</i>	P. 25
15:15	Magnetic tunnel junction made of abundant materials for memory and dynamic applications <i>Witold Skowronski</i>	P. 26
15:40	Spintronics Innovation: The Art of Balancing Exploration (TRL < 4) and Exploitation (TRL > 4) <i>Bernard Dieny</i>	P. 27
16:05	From TMR Sensors to AI: integration of spintronics into devices <i>Jürgen Langer</i>	P. 28
16:30	<b>Coffee Break</b>	
16:30	<b>Poster session</b>	
18:30	<b>Dinner</b> Address: The Midland, 16 Peter St, Manchester <a href="https://maps.app.goo.gl/abfsoaHaMPxFfYLB8">https://maps.app.goo.gl/abfsoaHaMPxFfYLB8</a>	

<b>Monday, April 13</b>	
-------------------------	--

8:30	Arrival
------	---------

**Session 4: Sensors**

Session chair: Shin Yabukami

9:00	From magnetoresistive effects to sensing applications <i>Johannes Paul</i>	P. 29
9:25	Reducing Parasitic Output Signals in Magnetic Multiturn Counter Sensor <i>Jan Kubik</i>	P. 30
9:50	Development of an on-ASIC type GSR sensor <i>Yoshinobu Honkura</i>	P. 32
10:15	Magnetostrictive Multilayer SAW Sensors for Magnetic Field Detection <i>Dirk Meyners</i>	P. 33

10:40	<b>Coffee Break</b>
-------	---------------------

**Session 5: Interdisciplinary & Emerging Topics**

Session chair: Amal El-Ghazaly

11:10	Functional Magnetic Wires: Microstructure-Anisotropy Control for Miniaturized Sensors and Devices <i>Nicoleta Lupu</i>	P. 34
11:35	Design and Characterisation of Stimuli-Responsive Magnetic Composite Heterostructures for Multifunctional Smart Materials <i>Paola Tiberto</i>	P. 35
12:00	Novel Transcranial Magnetic Stimulation Coils and Validation Techniques for Human and Animal Studies <i>Ravi L. Hadimani</i>	P. 36
12:25	Energy efficient quantum control of spin qubits with classical nanomagnets for scalable quantum computing and sensing <i>Jayasimha Atulasimha</i>	P. 38

12:50	<b>Awards Ceremony &amp; Closing remarks</b>
-------	--

## List of posters

P01	A high-throughput experimental approach to the screening of hard magnet materials <i>Nora Dempsey</i>	P. 40
P02	Engineering NiFe-based sensing layers for xMR magnetic sensors <i>Diana Leitao</i>	P. 41
P03	Interfacial Hybrid States and Spinterface Effects in CoFeB/Alq <sub>3</sub> Magnetic Thin Films <i>Swayang Priya Mahanta</i>	P. 42
P04	Micro-fluxgate with Solenoid Coils based on Flip-chip Process <i>Jiri Maier</i>	P. 43
P05	Light Ion Beam process to enhance the performance of XMR sensors <i>Noël Montblanc</i>	P. 44
P06	MaMMoS: Ontology-linked FAIR Workflows from Magnetometry Data to Sensor Optimisation <i>Santa Pile</i>	P. 45
P07	Magnon mediated spin pumping by coupled ferrimagnetic garnets heterostructure <i>Kshitij Singh Rathore</i>	P. 47
P08	Planar by Print: Nanoparticle Ink-Bonded Magnetoelectric Antennas <i>Mahdieh Shojaei Baghini</i>	P. 48
P09	Sensitivity Enhancement of High-Frequency Driven Thin-Film Magnetic Sensor with Narrow Slit <i>Shin Yabukami</i>	P. 49
P10	Micro-patterned Fe <sub>65</sub> Co <sub>35</sub> Ferromagnetic Thin Film for High Frequency High-Q Integrated Inductors <i>Haosen Yin &amp; Amal El-Ghazaly</i>	P. 50

P11	Magnetoresistive Sensors on Flexible Substrates: From Thin Films to Printable Magnetoelectronics <i>Yevhen Zabala</i>	P. 51
P12	Magneto-optical Kerr Microscopy on Non-planar Geometries <i>Le Zhao</i>	P. 52

## Invited talks

## New power modules technology; MagPack™ increasing the power density

Kenji Kawano\*

*Kilby Labs, Texas Instruments Japan, 1 Chome-2-70 Konan, Minato City, Tokyo, 108-0075 Japan*

*\*kawano@ti.com*

In the presentation, TI's new power modules technology, MagPack™ is presented [1]. MagPack™ is TI's new proprietary integrated-magnetic packaging technology to increase power density, efficiency and thermal performance, offering ease of use and reducing electromagnetic interference (EMI) for industrial, enterprise and communications applications. MagPack™ technology helps achieve a higher power density and smaller overall solution size. These have been achieved through newly developed magnetic material which we can utilize with our common semiconductor packaging process. This can allow us to maximize the volume of magnetic component as well as module performance.

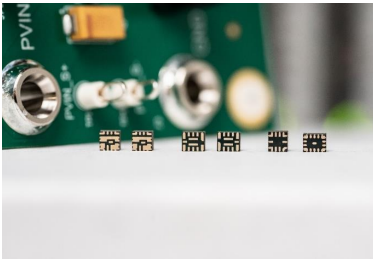


Fig. 1. TI's MagPack™ product portfolio

This MagPack™ technology can give us an initiative to design the magnetic component such as inductor and/or transformer, therefore new approach to design the magnetic component is also studied. For this new approach, active learning (AL) was introduced to accelerate the surrogate modeling for electromagnetic devices, requiring fewer samples to achieve higher accuracy. A 3D inductor model with nonlinear magnetic material is used for the prediction of the inductances, where random forest regressor (RFR) is employed as the surrogate model, trained via AL and random sampling (RS). The results indicate that the models trained by AL-selected samples outperform those trained by RS when data sets are limited. Meanwhile, AL demonstrates smoother learning curves, indicating enhanced robustness [3].

As a result, TI's latest modules; TPSM82866A, TPSM82866C and TPSM82816 all achieve a smaller size than any other 6A power module on the market. TI successfully launched 6 devices in 2024 and is trying to expand the boundary of this technology [2].

### References

- [1] Technical Article "MagPack technology: Four benefits of new power modules that can help you pack more power in less space" <https://www.ti.com/document-viewer/lit/html/SSZTD42>.
- [2] Technical Article "TI pioneers new magnetic packaging technology for power modules, cutting power solution size in half" <https://www.ti.com/about-ti/newsroom/news-releases/2024/2024-07-16-ti-pioneers-new-magnetic-packaging-technology-for-power-modules-cutting-power-solution-size-in-half.html>
- [3] Yunyi Gong; Kenji Kawano; Yuki Sato and Hajime Igarashi, "Accelerating Surrogate Modeling for Electromagnetic Device Using Active Learning," IEEE Transactions on Magnetics, 2025. accepted.

# MagNet Project: Data Driven Methods for Power Magnetics Modeling

Hyukjae Kwon<sup>1,2</sup>, Shukai Wang<sup>1,2</sup>, Davit Grigoryan<sup>1,2</sup>, Minjie Chen<sup>1,2\*</sup>,

<sup>1</sup>Department of Electrical and Computer Engineering, Princeton University, Princeton, NJ, 08540, USA

<sup>2</sup>Andlinger Center for Energy and the Environment, Princeton University, Princeton, NJ, 08540, USA

\*minjie@princeton.edu

The MagNet project (<https://mag-net.princeton.edu>) is a large-scale, open-source research platform developed by Princeton and Dartmouth to advance the modeling and design of power magnetic components through data-driven methods. Inspired by the impact of ImageNet on computer vision, its primary goal is to provide a common ground for the power electronics community to test, compare, and cross-validate different magnetic materials.

The project consists of several core pillars:

1. **Data Engineering:** The foundation of the project is its automated data acquisition system, which collects experimental excitation data for various materials. This data is stored in the MagNet Database, which currently contains over 1M data points for over 20 materials. To ensure accuracy, the project implements data quality control, including equipment calibration and automated outlier detection.
2. **Model Development:** MagNet moves beyond traditional physics-based and curve-fitting models by developing advanced Neural Network Models. These include: 1) Scalar-to-Scalar models for core loss prediction; 2) Sequence-to-Scalar models using LSTM networks to handle arbitrary waveforms; 3) Sequence-to-Sequence models (LSTM and Transformers) to predict entire loops, both in steady state and in transient; 4) Autoregressive neural network models for transient hysteresis modeling of the B-H loops.
3. **Magnetics Design Tools:** The final tier is the MagNet-AI platform, a website that provides data visualization, model deployment, and circuit simulation tools. A central concept here is the “Neural Network as Datasheet,” where a compact machine learning model replaces massive raw datasets, providing an efficient reference for designers. The infographic will also highlight the use of transfer learning to reduce data requirements for new materials and the project’s overarching goal to serve as a common research ground, much like ImageNet did for computer vision.

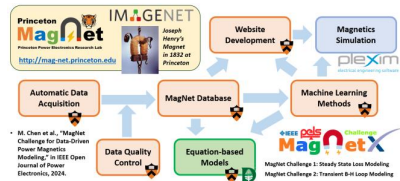


Fig. 1. The MagNet Project which aims at modernizing power magnetics modeling and design.

The MagNet project has a significant impact on power electronics by modernizing the way magnetic materials are modeled, analyzed, and integrated into designs. Its primary mission is to serve as the “ImageNet” for the power magnetics community, providing a common ground for researchers to test, compare, and cross-validate data-driven modeling techniques for power magnetic materials. Power electronics designers can precisely, and rapidly model magnetic components used in a variety of different operating conditions to maximize the system performances.

## References

- [1] D. Serrano, et al., “Why MagNet: Quantifying the Complexity of Modeling Power Magnetic Characteristics,” *IEEE Trans. on Power Electronics*, vol. 38, no. 11, pp. 14292-14316, Nov. 2023.
- [2] H. Li, et al., “How MagNet: Machine Learning Framework for Modeling Power Magnetic Material Characteristics,” *IEEE Trans. on Power Electron.*, vol. 38, no. 12, pp. 15829-15853, Dec. 2023.
- [3] H. Li, D. et al., “MagNet-AI: Neural Network as Datasheet for Magnetics Modeling and Material Recommendation,” *IEEE Trans. on Power Electronics*, vol. 38, no. 12, pp. 15854-15869, Dec. 2023.
- [4] S. Wang et al., “Unified Time Domain Foundation Models for Hysteretic Passive Components,” *IEEE Workshop on Control and Modeling for Power Electronics (COMPEL)*, Knoxville, TN, USA, 2025, pp. 1-8.

## Power Electronics Standards Sustaining Existing Technologies and Supporting the Development of New Technologies

Matthew Wilkowski<sup>1\*</sup>, Geroge Slama<sup>2</sup>

<sup>1</sup>Würth Elektronik, Plano, TX, 75075, USA

<sup>2</sup>Würth Elektronik, Watertown, SD, 57201, USA

*\*[matthew.wilkowski@we-online.com](mailto:matthew.wilkowski@we-online.com)*

Technological progress in power delivery systems and their components is accelerating to meet the demands of new market areas, such as smart power, high-performance computing, wearables, high-speed data transfer, handheld devices, and edge computing. Establishing standards, recommended practices, and guidelines is crucial for confirming and validating the performance and reliability of these developing systems, components, and materials. As innovative materials are created to help components satisfy strict technical requirements, having dependable and relevant technical performance data becomes vital for designing effective components and systems. For software modeling to be useful in design, it is necessary to have extensive, high-quality data from many types of materials covering the full spectrum of operating conditions.

This presentation will provide a brief overview of the standards development activity within IEEE Power Electronics Society (PELS) including past, current and future projects. It will cover the milestones and schedule of the standards development process and the methodology that drives open discussions to arrive at consensus to ensure that power delivery is sufficient and dependable to support evolving markets that meet consumer needs.

The presentation will cover important technical elements from ongoing projects, showcasing recent progress in validation methods that are crucial for new applications and changing markets. It will also include specific updates on test procedures, such as IEEE 388 (Recommended Practice for Testing Transformers and Inductors for Electronics Applications), IEEE 393 (Standard for Test Procedures for Magnetic Cores), and IEEE 2996 (Recommended Practice for Near Magnetic Field and Electric Field Characterization of Inductors). These standards have either been recently updated or are currently being revised to add new testing techniques and create methods for correlating different test procedures.

This presentation will also discuss the development of the Core Data eXchange database, which is supported by the Magnetics Committee of the Power Sources Manufacturer's Association. The goal of this database is to provide the magnetics design community with certified, unbiased magnetic core data. All information entered to the database is validated through four levels of uncertainty, each based on clearly documented test setups and procedures. These procedures include equipment specifications and consider their impact on accuracy, as well as calibration and compensation methods to reduce uncertainty. Additionally, a golden sample is used for comparison across different test systems, one of which must employ a calorimetric method.

### References

- [1] M. Wilkowski, "PELSC Sustaining Technology by Authenticating Technical Performance and Verifying Reliability of Current and Emerging Power Technologies," ECCE 2024 Asia, May 2024, DOI 10.17023/729z-bz45
- [2] M. Wilkowski and G. Slama, "Power Electronics Standards Sustaining Existing Technologies and Aiding Adoption of New Technologies," IEEE Power Electronics Magazine, September, 2024, 10.1109/MPEL.2024.3444150
- [3] G. Slama, "PSMA Core Loss Data Base" APEC 2025 Industry Session 24.4, March, 2025

# Launching IEEE Technology Roadmap Program on Magnetic Passive Components for Power Electronics: Bridging Materials to Systems

Masahiro Yamaguchi<sup>1\*</sup>, Satoshi Okamoto<sup>2</sup>, Luigi Solimene<sup>3</sup>, Matt Wilkowski<sup>4</sup>, Minjie Chen<sup>5</sup>, Keiji Wada<sup>6</sup>

<sup>1</sup>Graduate school of Biomedical Eng., Tohoku Univ., 6-6-05 Aoba, Aramaki, Aoba-ku, Sendai 980-8579, Japan

<sup>2</sup>Inst. Multidiscip. Res. Adv. Mater., Tohoku Univ. Katahira 2-1-1, Aoba-ku, Sendai 980-8577, Japan

<sup>3</sup>Politecnico di Torino, Corso Duca degli Abruzzi, 24, 10129 Torino, Italy

<sup>4</sup>Würth Elektronik, USA

<sup>5</sup>Department of Electrical and Computer Engineering, Eng. Quad., 41 Olden St., Princeton, NJ 08544, USA

<sup>6</sup>Dept. Elect. Electron. Eng., Tokyo Metropolitan Univ., 6-6 Asahigaoka, Hino, Tokyo 191-0065, Japan

\*masahiro.yamaguchi@ieee.org

**1. Introduction: The WBG Paradigm Shift and Roadmap Initiative** The rapid advancement of wide-bandgap (WBG) semiconductors has shifted the performance bottleneck of power electronics systems to magnetic passive components. To address this challenge, the IEEE Magnetics Society (MagSoc) and IEEE Power Electronics Society (PELS) have approved preparations to establish a joint Technology Roadmap program. A formal proposal is being submitted to the IEEE Technology Roadmaps Committee for official authorization. The roadmap aims to include integrated magnetics as an industry-driven roadmap context.

**2. Strategic Foundations: Academic Baseline and Application Framework** The roadmap initiative is established upon two critical pillars that ensure both academic depth and industrial relevance:

**Academic Baseline** (Japanese INNOPEL Project): This project provides a "common language" translating high-level circuit requirements into magnetic material parameters ( $\mu$ ,  $B_s$ ,  $P_{cv}$ ), facilitating vertical integration and inverse problem design, in which system-level targets guide material discovery [1].

**Application Framework** ("From Grid to Chip"): Championed by IEEE PELS leader, this framework defines four application stages: (1) Solid State Transformers (SST), (2) Rack Power (DAB, LLC), (3) Board Power (Vertical Power Delivery), and (4) Integrated Voltage Regulators (IVR/PwrSOC). These stages define requirements for magnetic materials, isolation, and integration processes across the power delivery network.

**3. Advanced Methodology: AI Paradigm and Materials Informatics (MI)** The program recognizes AI paradigms such as the MagNet platform [2] as frameworks for large-scale core loss machine learning and potentially Physics-Informed Modeling. The roadmap seeks to challenge the integration of data-driven Materials Informatics (MI) and AI to maximize utility for both Societies. A key methodological challenge is incorporating material parameters into MagNet-type modeling guidelines.

**4. Material Innovation and Sustainability** Rooted in IEEE MagSoc and INNOPEL expertise in magnetism and magnetic materials, the roadmap focuses on materials for the WBG era, including high- $B_s$  nanocrystalline alloys (e.g., NANOMET), iron-nitrogen ( $\alpha$ -Fe<sub>16</sub>N<sub>2</sub>) magnetic cores, and beyond-MHz composite materials. Advanced high frequency iron-loss measurements clarify magnetostriction-induced high frequency loss mechanism and enable clearer observation of moving magnetic domains (including soft ferrites) using time-resolved magneto-optical Kerr microscopy. The program also emphasizes sustainability through Life Cycle Assessment (LCA) and responses to the resource constraints of rare materials.

**5. Call for Participation at Intermag2026** Please participate in: (a) Session AA Invited Symposium: Advanced Soft Magnetic Materials and Devices Bridging Magnetics and Power Electronics, April 14, 8:30–12:00, (b) Magnetic Passive Components Roadmap General Meeting (open to everyone), April 14, 12:15–14:00, Room Exchange 4/5. Roadmap leaders and invited symposium speakers will discuss the roadmap concept and candidate topics with the community. Industry input is especially encouraged, as the purpose of an IEEE technology roadmap is to stimulate industry-wide dialogue on the development and implementation of emerging technologies [3]. Pre-registration for General Meeting encouraged (lunch provided for 30 participants): masahiro.yamaguchi@ieee.org

## References

- [1] Passive Component Technology Roadmap Working Group (Ed.), "Technology Roadmap for Passive Components (Version 1) (in Japanese)," MEXT INNOPEL Project, 2026. [Online]. Available: [https://www.mext.go.jp/b\\_menu/boshu/index.htm](https://www.mext.go.jp/b_menu/boshu/index.htm)
- [2] H. Li et al., "How MagNet: Machine Learning Framework for Modeling Power Magnetic Material Characteristics," IEEE Trans. Power Electronics, vol. 38, no. 12, pp. 15829–15853, 2023.
- [3] IEEE Roadmaps, 2026. [Online]. Available: <https://roadmaps.ieee.org/about/>

## Compensated ferrimagnets for emerging spintronics

Wanjun Jiang

*Department of Physics and State Key Laboratory of Low-Dimensional Quantum Physics, Tsinghua University,  
China, 100084,*

*email: [jiang\\_lab@tsinghua.edu.cn](mailto:jiang_lab@tsinghua.edu.cn)*

**Key Words:** (ferrimagnets, chiral magnon, spin torque, ionic liquid gating)

Compensated ferrimagnet is an interesting material system that exhibits both magnetization and angular momentum compensation, which results in the chiral magnon transport, the fast spin dynamics and the ability to display topological spin textures with fast motion, amongst many others [1,2].

In this talk, I will first review the chiral magnon dynamics in one of the insulating compensated ferrimagnets  $Gd_3Fe_5O_{12}$ , in which I will show the electrical excitation and detection of chiral magnon dynamics in a  $Gd_3Fe_5O_{12}/Pt$  bilayer, by using the spin-torque ferromagnetic resonance. The physics behind can be attributed to the different temperature-dependent evolution of magnetization and angular momentum of the Gd and Fe sublattices [3].

In the second part, I will unravel unconventional spintronic behaviors in metallic rare-earth transition-metal (RE-TM) ferrimagnets. In particular, I will present the fast motion of compensated domain walls in Pt/CoGd/Ta trilayer for the ultrafast neuromorphic spintronic performances [4], together with the unprecedented spin torque switching of the extremely thick ferrimagnets with thickness up to 200 nm in Pt/FeGd/Ta trilayers [5]. In the end, the ability to electrically switch magnetization of metallic ferrimagnets in Pt/FeTb/Pd trilayers, by applying gate voltage by using an ionic liquid technique will be shown [6].

### References

- [1] Yiqing Dong, et al., *Adv. Funct. Mater.*, 31, 2007485 (2021).
- [2] Teng Xu, et al., *Phys. Rev. Materials* 5, 084406 (2021).
- [3] Jiahao Liu, et al., *Advanced Functional Materials*, 32, 2107870 (2022).
- [4] Hao Bai, et al., *Phys. Rev. Mater.* 7, 094401 (2023).
- [5] Teng Xu, et al., *Phys. Rev. Applied* 19, 034088 (2023).
- [6] Le-Dong Wang, et al., *Phys. Rev. Lett.* 133, 166705 (2024).
- [7] Teng Xu, et al., *Phys. Rev. Lett.* 135, 126703 (2025).
- [8] Yang Chen, et al., *Phys. Rev. X*, 15, 011060 (2025).

## Magnetolectric Materials and Devices

Nian X. Sun

Midea Corporate Research Center, Midea Group, Foshan, China

&

W.M. Keck Laboratory for Integrated Ferroics, ECE Department, Northeastern University, Boston, MA

The coexistence of electric polarization and magnetization in multiferroic materials provides great opportunities for realizing magnetolectric coupling, including electric field control of magnetism, or vice versa, through a strain-mediated magnetolectric coupling in layered magnetic/ferroelectric multiferroic heterostructures. Strong magnetolectric coupling has been the enabling factor for different multiferroic devices, which, however, has been elusive, particularly at RF/microwave frequencies. In this presentation, I will cover the past, present, and future of magnetolectric materials and devices. I will focus on the most recent progress on new RF magnetolectric materials and microsystems [1-9]. Specifically, we will introduce magnetolectric materials and their applications in different devices, focusing on ultracompact magnetolectric mechanical antennas, which are immune from ground plane effect with ultra-compact size, self-biased operation, excellent impedance matching, ground plane immunity, etc. These magnetodielectric and magnetolectric antennas show great promise for applications in compact, lightweight, and power-efficient sensors, antennas, and tunable components for radars, communication systems, biomedical devices, IoT, etc.

### References

1. B. Luo, et al. *Nature Reviews Electrical Engineering*, 1, 317-334 (2024).
2. C. Dong, et al. *Materials Today Electronics* 11, 100135 (2025).
3. X. Liang, et al. *Advanced Engineering Materials*, 2300425 (2023).
4. C. Dong, et al., *Advanced Electronic Materials* 8 (6), 2200013 (2022).
5. M. Zaeimbashi, et al, *Nature Comm.* 12, 3141 (2021).
6. C. Dong, et al. *IEEE Antennas and Wireless Propagation Letters* 19 (3), 398-402 (2020).
7. M. Zeimbashi, *IEEE J-ERM*, 3, 206 (2019).
8. C. Dong, et al. *Applied Physics Letters* 113 (26), 262401 (2018).
9. T. Nan, et al. *Nature Comm.* 8, 296 (2017).

## Materials Informatics for Magnetic Materials

N. A. Morley<sup>\*1</sup>, E. Read<sup>1</sup>, R. M. Rowan-Robinson<sup>1</sup>, T. Wilkinson<sup>1</sup>, D. de Mouteney<sup>1</sup> and X. Liu<sup>2</sup>

<sup>1</sup>*School of Chemical, Materials and Biological Engineering, University of Sheffield, Sheffield, S1 3JD*

<sup>2</sup>*School of Computer Science, University of Sheffield, Sheffield, S1 3JD*

*\*n.a.morley@sheffield.ac.uk*

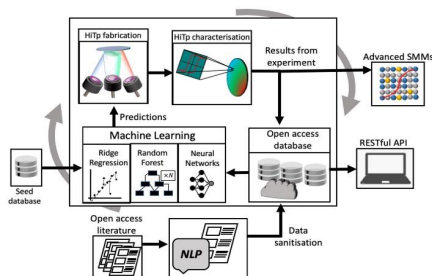


Fig. 1. Schematic of the methodology for Materials Informatics for Magnetic Materials

Global tensions over critical elements have established the need for sustainability within existing and new technologies, which is driving a demand for material innovation. New materials need to be economically sourced from abundant elements, whilst still obtaining the required functional characteristics for their applications. Functional Magnetic Materials are central to integrated magnetic devices. With soft magnets and magnetostrictive materials being important in a range of sensors and devices. Thus, by improving different functional magnetic material properties for their applications, industries can capitalize on engineering advances, saving money and the environment.

Traditional material discovery methods are too slow and costly. Material informatics overcome these existing problems, by using data-driven solutions to reduce the use of natural resources and expensive experiments [1]. Our research has focused on using Natural Language Processing (NLP), including large language models to data mine open access papers to create a bespoke database for different magnetic research fields. This has been achieved by combining the linear approach NLP, which searches for defined compositions and parameters, with semantic networks, to allow the compositions related parameters to be correctly linked together. Having created the bespoke database, machine learning (ML) algorithms are trained on it, which are then used to observe trends within the data, along with predicting compositions with specific magnetic parameters. We have investigated commonly used ML algorithms such as linear regression and random forest, along with the Microsoft Mattergen software [2], to predict new magnetic materials with useful parameters, along with the magnetic properties of promising materials. The promising compositions have been fabricated and characterized using high-throughput techniques, including combinatorial sputtering, XRD, FMR and MOKE. This has allowed us to verify the results from the ML, quickly and cheaply, along with discovering new magnetic materials that can be investigated further for sensor applications. Further the experimental results are then feedback into the database, allowing for a full circle discovery methodology.

### References

- [1] R. M. Rowan-Robinson, Z. Leong, S. Carpio, C. Oh and N. A. Morley, "Materials informatics for functional magnetic materials discovery", *AIP Advances*, vol. 14, pp. 015313, Jan 2024
- [2] C. Zeni, R. Pinsler, D. Zugner, A. Fowler, M. Horton, X. Fu, Z. Wang, et al, "A generative model for inorganic materials design", *Nature*, vol. 639, pp. 624-632, Jan 2025

# Physically-Informed Neural Networks for the Estimation of Magnetization from External Measurement

A. Formisano<sup>1\*</sup>, S. Barmada<sup>2</sup>, S. Dodge<sup>2</sup>, Z. Tang<sup>3</sup>

<sup>1</sup>Dept. of Engineering, Università della Campania “Luigi Vanvitelli”, Aversa (CE), 81031, Italy

<sup>2</sup>DESTEC, Università di Pisa, Pisa, Italy

<sup>3</sup>Univ. Lille, Arts et Métier Institute of Technology, Centrale Lille, Junia, F-59000 Lille, France

\*Alessandro.Formisano@UniCampania.it

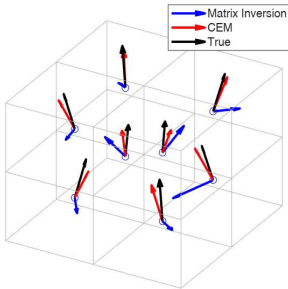


Fig. 1. Magnetization reconstruction with (red) and without (blue) CEM.

The proposed work is aimed at the estimation of the magnetization state in a ferromagnetic material from magnetic field measurements. The system is excited by a static current source, and the resulting magnetic flux density is measured at a sufficiently dense set of spatial locations using Hall probes distributed in the region of interest. This inverse problem is ill-posed in the sense of Hadamard, as the solution may not be unique and may exhibit strong sensitivity to measurement noise and modeling errors. Consequently, direct inversion approaches are unsuitable, and regularization is required to obtain physically meaningful and stable solutions.

In the present work, regularization is introduced through the Constitutive Error Minimization (CEM) [1], which enforces consistency between Maxwell’s magnetostatic equations and the constitutive relationship linking the magnetic field and the magnetization within the ferromagnetic material. The formulation

provides a natural way to balance data fidelity with physical admissibility, thereby stabilizing the inverse problem. The resulting constrained optimization problem is solved using Physics-Informed Neural Networks (PINN) [2-3]. Within this framework, the governing magnetostatic equations are embedded directly into the loss function using analytical expressions for the magnetic field from magnetized blocks [4], alongside the constitutive error and the mismatch with measured magnetic flux density data. A key advantage of the PINN-based formulation is its inherent ability to tolerate a certain level of measurement inaccuracies. In fact, by enforcing the physical laws as a constraint, the method reduces sensitivity to local noise and sparse measurement errors that typically affect Hall probe data. As a result, the reconstructed magnetization state remains physically consistent even in the presence of imperfect measurements.

The figure reports a representative example of magnetization reconstruction obtained with and without CEM, clearly illustrating the stabilizing effect of the proposed regularization strategy and its impact on the quality and physical plausibility of the estimated magnetization distribution.

## References

- [1] Alotto, P. (2000), “A field-based finite element method for magnetostatics derived from an error minimization approach”, *International Journal for Numerical Methods in Engineering*, Vol. 49 No. 4, pp. 573–593.
- [2] Formisano, A., Barmada, S., Dodge, S. (2026), “PINN-Based resolution of non-linear magnetostatic Problems”, to be published in *Compel*.
- [3] Gong, Z., Tang, Z. and Benabou, A. (2025), Physics-informed neural network for magnetization distribution estimation. *IET Electr. Power Appl.*, 19: e70047.
- [4] Fabri, M., (2008), Magnetic Flux Density and Vector Potential of Uniform Polyhedral Sources, *IEEE Trans. on Magnetics*, Vol. 44 n° 1, pp. 32-36.

## TMR position and current sensors for industrial and automotive systems

J. R. Childress<sup>1\*</sup>

<sup>1</sup>Allegro MicroSystems, 38000 Grenoble, France

\*[jchildress@allegromicro.com](mailto:jchildress@allegromicro.com)

Today's industrial megatrends are sharply focused on precise energy management, efficient transportation and advanced automation. Applications such as xEV powertrains, advanced driver-assist systems (ADAS), data center power management, and advanced automation and robotics require precision position and electrical current sensors to deliver safety, efficiency and reliability in these systems. Consequently, high performance in magnetic field (and hence position or current) sensing are essential to power these industrial and automotive trends.

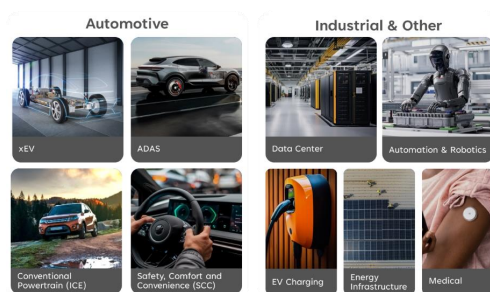


Fig. 1. Applications of magnetic sensors

reliability characteristics that they meet. The different TMR magnetic sensor technology approaches taken to meet the specific performance profiles of each product family will also be outlined. At the transducer-level, TMR sensors share a common technology base with specific variations to match the magnetic response characteristics needed in the application. The magnetic multilayer material which constitutes the TMR tunnel junctions, as well as the specific geometry chosen for the transducer design, offers the flexibility to design unique features and operating ranges that meet product needs with efficient overall chip design. Examples will be given across the product range.

TMR (tunneling magneto-resistive) sensors are ideally suited to meet the challenge of these increasing industrial and automotive requirements. TMR transducers achieve the performance needed in angular, position, speed and current transducers, and can be integrated with advanced application-specific integrated circuits (ASIC) to meet demanding specifications. I will describe the main applications where TMR sensors are being used at Allegro to address the needs of these markets, the advantages over conventional technology that these sensors provide, and the performance and

## Challenges in Tunneling Magnetoresistance Sensor Development

Simon Mendisch<sup>1\*</sup>, Giovanni Masciocchi<sup>2</sup>, Salim Dounia<sup>1</sup>, Wolfgang Raberg<sup>1</sup>, Jürgen Zimmer<sup>1</sup>,  
Apoorva Sharma<sup>1</sup>, and Florian Brandl<sup>2</sup>

<sup>1</sup>*Infineon Technologies AG, 85579 Neubiberg, Germany*

<sup>2</sup>*Infineon Technologies AG, Regensburg, Germany*

*\*Simon.Mendisch@infineon.com*

Tunnel magnetoresistance (TMR) sensors, compared to other magnetic sensors, offer intrinsic advantages such as large output signals, excellent signal-to-noise ratios, and wide bandwidth. Nevertheless, although first sensors entered the market more than a decade ago, their market share remains on the order of 10% [1]. The slow adoption rate reflects both the inertia of the market and the fact that significant obstacles remain to compete with mature technologies such as integrated silicon Hall sensors across all application ranges, and to enable applications not addressable by legacy sensor technologies.

This contribution addresses relevant device- and manufacturing-related challenges that currently limit the scalability, robustness, and cost competitiveness of TMR sensor technologies. After briefly reviewing the operating principle of MTJ-based sensors, including typical stack architectures, reference-system concepts, and bridge configurations, we discuss critical constraints in wafer-level integration, magnetic field range, non-linearities, noise, and reference-system design. The discussion emphasizes the interdependence between physical limitations and manufacturing constraints.

The analysis highlights why further progress requires coordinated advances in magnetic stack design, patterning, and integration concepts.

### References

- [1] "Magnetic Sensors 2024 Market & Technology Report," Yole Group, 2024. [Online]. Available: <https://www.yolegroup.com/product/report/magnetic-sensors-2024/>

## Magnetic tunnel junction made of abundant materials for memory and dynamic applications

W. Skowroński<sup>1\*</sup>, M. Cierpiał<sup>1</sup>, D. Maślanka<sup>1</sup>, K. Gubala<sup>1</sup>, J. Mojsiejuk<sup>1</sup>, K. Grochot<sup>1</sup>, J. Wrona<sup>2</sup>, J. Langer<sup>2</sup>, T. Nan<sup>3</sup>

<sup>1</sup>AGH University of Krakow, Institute of Electronics, Poland

<sup>2</sup>Singulus Technologies, Kahl am Main 63796, Germany

<sup>3</sup>School of Integrated Circuits, Tsinghua University, Beijing, China

\* skowron@agh.edu.pl

Magnetic tunnel junction (MTJ) are key building blocks of spintronic devices such as magnetic field sensors and magnetic random-access memory [1]. Modern MTJs employ perpendicular magnetic anisotropy to improve thermal stability and reduce the critical switching current density of the free layer. The reference layer is typically stabilized by a perpendicular synthetic antiferromagnetic (SAF) structure based on Pt- or Pd-containing materials to achieve anisotropy fields of several hundred mT [2]. Owing to the low abundance of Pt and Pd, alternative reference-layer designs are highly desirable. Here, we propose a full MTJ stack in which the reference layer is based on a Ni-Co superlattice [3].

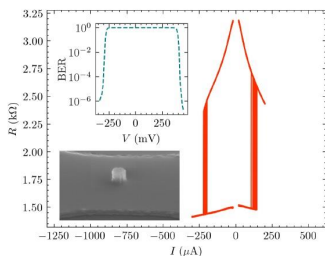


Fig. 1. Current-induced switching of the MTJ. Inset shows BER and micrograph of the device.

The MTJ is following (thicknesses in nm): buffer / SAF / FeCoB(1) / MgO(1) / FeCoB(1.3) / W(0.25)/ FeCoB(0.5)/ cap, which were deposited using a Singulus cluster tool sputtering system. SAF is made of two [Ni(0.6) / Co(0.25)] superlattices with Ru-based spacer. The magnetic anisotropy energies of each of the layers have been determined from the ferromagnetic resonance (FMR) measurements by modeling the resonance frequency vs. field dependence using *cMTJ* [4]. MTJ nanopillars with diameters down to 80 nm were fabricated, exhibiting tunneling magnetoresistance (TMR) exceeding 120% for the smallest devices. High-field TMR measurements show reference-layer switching above 250 mT. Resistance–current measurements display clear hysteresis, with an average switching current density of 2.6 MA/cm<sup>2</sup> and thermal stability  $D > 50$  - Fig. 1 [5]. Bit error

rate (BER) determined in a few MTJ pillars of the smallest diameter revealed values below  $10^{-7}$  for the switching voltages exceeding 0.5 V (inset of Fig. 1), without bifurcated effect.

**Acknowledgement:** The project is partially supported by the National Science Centre, Poland project no.2021/40/Q/ST5/00209 (Sheng), the Excellence initiative-research university (IDUB) programme of the AGH University of Krakow

### References

- [1] T. Kawahara, K. Ito, R. Takemura, and H. Ohno, "Spin-transfer torque ram technology: Review and prospect," *Microelectronics Reliability*, vol. 52, no. 4, pp. 613 – 627, 2012.
- [2] S. Mangin, et al. "Current-induced magnetization reversal in nanopillars with perpendicular anisotropy," *Nature Materials*, vol. 5, no. 3, pp. 210–215, 2006.
- [3] R. Jungblut, et al. "Orientational and structural dependence of magnetic anisotropy of Cu/Ni/Cu sandwiches: Misfit interface anisotropy," *Journal of Applied Physics*, vol. 75, no. 10, pp. 6424–6426, 1994.
- [4] J. Mojsiejuk, S. Zietek, K. Grochot, W. Skowroński, and T. Stobiecki, "emtj: Simulation package for analysis of multilayer spintronic devices," *npj Computational Materials*, vol. 9, no. 1, p. 54, 2023.
- [5] M. Cierpiał, et al. "Magnetic tunnel junction made of abundant materials for memory and dynamic applications," *Scientific Reports*, vol. 15, no. 1, p. 35227, 2025.

## Spintronics Innovation: The Art of Balancing Exploration (TRL<4) and Exploitation (TRL>4)

B. Dieny

Univ. Grenoble Alpes, CEA, CNRS, SPINTEC, 38000 Grenoble, France  
Corresponding: [bernard.dieny@cea.fr](mailto:bernard.dieny@cea.fr)

Since its inception, spin electronics has become a highly active field of research, driven by a strong synergy between fundamental science and applications in various areas of information and communication technologies. Historically, spintronics has achieved its greatest application success in hard disk drives (HDDs) and magnetic field sensors (automotive, robotics, magnetic imaging, etc.). Non-volatile magnetic memory (MRAM), enabling lower power consumption in electronic circuits, is now emerging as the next major application of spintronics, particularly in the context of AI, edge AI, and IoT.

On the fundamental research side, intense efforts over the past 15 years have focused on topics such as racetrack memories, skyrmions, and THz spin dynamics. In the early stages of a new research topic, a large amount of scientific knowledge is generated, which is essential for advancing the frontiers of understanding. After a few years, as research progresses along the technology readiness level (TRL) scale, costs tend to increase as more complex technologies must be integrated. Around TRL 2–3, it becomes important to consider potential applications and to initiate an honest benchmarking against competing technologies targeting similar use cases. At TRL 4, identifying a “killer application” becomes crucial—that is, an application significant enough to justify industrial investments of hundreds of millions of dollars toward commercialization. This step requires further benchmarking and careful consideration of industrial constraints such as cost, reliability, and operating conditions.

Ultimately, a limited number of technologies may prove worth advancing to higher TRL levels and be developed through to commercialization, as has been the case for HDD readers or MRAM. Other topics, however, may need to be discontinued, as continued funding may otherwise be spent on technologies unlikely to be deployed and no longer generating substantial new fundamental knowledge. This talk will provide recommendations on how to assess research directions in order to strike an optimal balance between maintaining broad exploratory capacity in fundamental research and efficiently advancing a few promising topics toward high TRL levels.

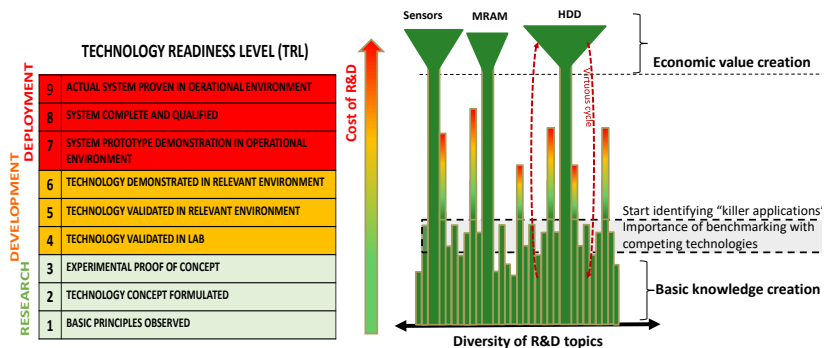


Fig. 1. TRL scale and schematic representation of the evolution of research and development topics along the TRL scale.

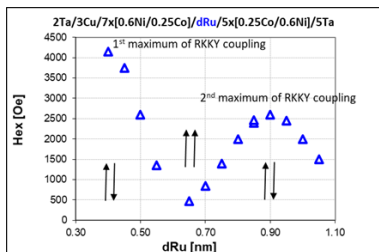
## From TMR sensors to AI: Integration of spintronics into devices

J. Langer<sup>1\*</sup>, M.-A. Syskaki<sup>1</sup>, J. Wrona<sup>1</sup>, B. Ocker<sup>1</sup>

<sup>1</sup>Singulus Technologies AG, Hanauer Landstr. 103, 63796 Kahl am Main, Germany

\*Corresponding: [juergen.langer@singulus.de](mailto:juergen.langer@singulus.de)

Devices based on spintronic building elements have a tremendous potential in a wide variety of applications from memory over sensors to artificial intelligent (AI). Besides the right material choice and intelligent design of layer-stacking based on a deep understanding of the underlying magnetic effects manufacturability is essential for the success in mass markets.



Common feature in design is the use of ultrathin multi-layers which utilizes effects which need to be controlled down to the sub-Å range. A well-established effective deposition method for mass production in the semi-conductor industry is physical vapor deposition (PVD).

We will discuss the different aspects and solutions to realize and integrate memory, sensor and AI enabling spintronic concepts from the view of a PVD tool vendor. Here we will present different magnetic sensor schemes based on TMR and topological structures (Skyrmions) as well as innovative AI devices using spin reorientation.

Fig. 1. Example of precise thickness control in an artificial antiferromagnet (AAF) based on sputtered Ni/Co multilayers

## From magnetoresistive effects to sensing applications

J. Paul<sup>†</sup>, A. Kehlberger

Sensitec GmbH, 55130 Mainz, Germany

Magnetoresistance is a material property whereby the electrical resistance of a material depends on an applied external magnetic field. Magnetoresistive effects occur in different classes of materials: single layers or bulk materials, in which anisotropic magnetoresistive (AMR) effects are observed; and thin-film multilayers, which are designed to measure giant magnetoresistive (GMR) or tunneling magnetoresistive (TMR) effects. All of these MR effects are easy to detect and demonstrate excellent temperature and lifetime stability. Consequently, they are ideal for use in consumer, industrial, medical, and automotive applications, and have experienced continuous market growth over the past decade.

Most applications can be covered by three types of measurement: a) field strength in the X-, Y- or Z-direction; b) field difference or gradient and c) the angle of the magnetic field with respect to a plane. Field measurements require a linear sensor signal output of the detected magnetic field. The three most dominant applications for linear sensors are switching, compass and current sensing. Gradient measurements detect differences in field strength or angles at two or more spatially separated locations. This is useful for detecting magnetic particles, pole rings or other structural differences within full bodies. Angle sensors are mainly used to detect rotary movements and absolute positions.

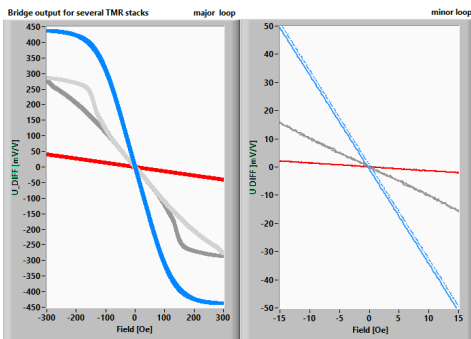


Fig. 1. Sensor bridge output for three different linear TMR stacks, ranging from high slope (blue) to high linearity (red). The right plot highlights a zoom in of  $\pm 15$  Oe of the left plot.

$\sim 200\%$ , it is possible to achieve a sensor output of up to 450 mV/V in a full bridge configuration. This results in a very high slope, but low linearity and a small linear range. At the other end of the scale, the linearity and saturation field are maximized (with no resolvable non-linearity or hysteresis in the  $\pm 300$  Oe field range), resulting in a low slope of 0.15 mV/V/mT and, consequently, a very high saturation field. This versatility of TMR sensors allows for application-specific optimization, making them suitable for a wide variety of industries.

### References

- [1] Ana V. Silva, D.C. Leitao, J. Valadeiro, J. Amaral, P.P. Freitas and S. Cardoso, "Linearization strategies for high sensitivity magnetoresistive sensors," *Eur. Phys. J. Appl. Phys.* (2015) 72: 10601, DOI: 10.1051/epjap/2015150214.

Linear sensors exhibit a linear output  $U$  as a function of the externally applied magnetic field  $H$ :

$$U = S \times H + \text{offset} \quad (1),$$

where  $S$  describes the sensor's sensitivity and  $H$  describes the magnetic field strength. However, this equation is only valid for small fields, since the TMR ratio is limited, leading to saturation. Other deviations from equation (1) include non-linearity, hysteresis and noise.

As can be seen in Fig. 1, the output signals of the various TMR designs (i.e. different TMR stacks combined with different tunneling junction geometries) differ greatly in terms of their slope, saturation field and hysteresis. See also [1]. With TMR values of

## Reducing Parasitic Output Signals in Magnetic Multiturn Counter Sensors

Jan Kubik<sup>1\*</sup>

<sup>1</sup>*Analog Devices, Inc., Global Operations & Technology, Limerick, V94RT99, Ireland*

\*Corresponding author: [jan.kubik@analog.com](mailto:jan.kubik@analog.com)

The ADMT4000 GMR-based magnetic multiturn counter sensor enables true-power-on operation without batteries, gears, or re-initialization after power cycling. The device relies on controlled magnetic domain wall (DW) propagation in nanowire spirals operating within a well-defined magnetic field window. However, when external magnetic fields are applied—typical in motor and actuator environments—significant parasitic distortion appears in the electrical readout due to magnetization tilting in the free layer of the GMR stack. This distortion causes reduction of resistor high/low state difference making turn count decoding difficult to impossible for the ASIC circuitry.

The distortion is modelled (Fig. 1) to explore and quantify impact of input parameters on the output signals. Several material and structural optimization paths were explored to mitigate distortion: increasing shape anisotropy, increasing free-layer thickness, adjusting saturation magnetization, and reducing nanowire width. While these approaches improve magnetic stiffness, they negatively impact domain wall reliability or GMR magnitude. A lamination strategy for the free layer—alternating NiFe and CoFeB films [1]—demonstrates significant suppression of parasitic AMR contributions while maintaining higher GMR ratios, reducing signal degradation under field and improving readout consistency. Measured devices show up to 160% improvement in useful signal amplitude relative to un laminated structures (Fig. 2).

A practical readout architecture is also presented, replacing half-bridge sensing with a matrix-addressed scheme [2]. Additionally, a ratio of resistances of spiral resistors and reference resistors is being used as output signal. This configuration significantly reduces output distortion in applied magnetic fields while enabling a major reduction in bond-pad count for ASIC interfacing. Together, the film-stack enhancements and matrix-based readout architecture provide a robust pathway toward high-accuracy, field-tolerant magnetic multiturn sensors for industrial motion-control applications.

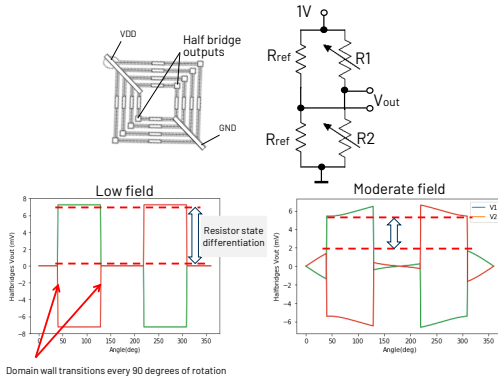


Fig. 1. Halfbridge readout electrical schematics (top); modelled signal output in small (left) and moderate field (right).

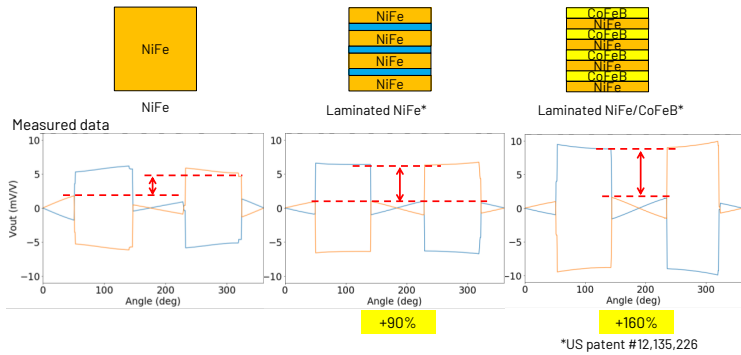


Fig. 2. Comparison of measured data under 35mT applied field using NiFe, laminated NiFe/Ta and laminated NiFe/CoFeB free layer.

## References

- [1] 'Magnetoresistive element with free-layer and method of manufacturing same,' U.S. Patent 12,135,226, Nov. 5, 2024.
- [2] 'Multiturn sensor arrangement and readout,' U.S. Patent 11,280,639, Mar. 22, 2022.

## The Development of an On-ASIC type GSR Sensor

Y. Honkura<sup>1\*</sup>, S.Honkura<sup>1</sup>, M.Hikishima<sup>1</sup>

<sup>1</sup>MagneDesign Corp.,

Kitahira2-4,Toyooka,Mihama-cho,Chita-gun,Aichi-ken,470-2414, Japan

\*Yoshinobu.honkura@magnedesign.co.jp

**1) Introduction:** GSR sensors [1] have the same element structure and signal processing circuitry as the well-known high-sensitivity magnetic sensors, Fluxgate sensors and MI sensors. However, they further reduce size by changing the pulse current frequency from kHz and MHz to GHz. By increasing the excitation current frequency from kHz/MHz to GHz, the magnetization change within the amorphous wire is driven by spin rotation rather than domain wall movement. While the magnitude of the magnetization change  $\Delta M$  becomes slightly smaller, the time change  $\Delta t$  becomes significantly shorter. Consequently, the coil voltage  $V = -\Delta M/\Delta t$  increases. The coil voltage's magnetic field dependence depends solely on spin rotation, resulting in a sinusoidal waveform. Furthermore, since it does not involve domain wall movement, hysteresis and Barkhausen noise are reduced. The authors propose this effect, dependent on spin rotation speed, as the GSR effect, or GHz-Spin-Rotation effect.

**2) Development of the GSR Sensor:** The coil voltage of the GSR sensor increases with rising pulse frequency and shows a saturation tendency above 3 GHz. Furthermore, the coil voltage increases with the number of coil turns and the wire's permeability, exhibiting a sensitivity of 10 mV/mT per turn. Sensitivity is primarily enhanced by refining the coil pitch to approximately 3 $\mu$ m. The number of turns N is adjusted from 50 to 500 depending on the application. Regarding signal quality, the magnetic field dependence follows a mathematical sine function, allowing excellent linearity to be achieved through inverse transformation. Hysteresis disappears and noise is low which mean the signal is of high quality. Development challenges included developing amorphous magnetic wire, micro coils, and GHz pulse circuits. For amorphous magnetic wire, optimizing alloy composition and removing impurities were critical. For micro coils, semiconductor processes were utilized to achieve a 3 $\mu$ m coil pitch. Furthermore, we successfully developed a GSR element formed directly on the ASIC circuit shown in Fig. 1, doubling sensitivity. Regarding the circuit, we struggled with eliminating ringing and noise generated in the coil when excited by GHz pulses.

**3) Fabrication of On-ASIC Type GSR Devices shown in Fig.2:** Coating the ASIC surface with a protective film and a positive photoresist for substrate formation. ① Forming microgrooves (width 18 $\mu$ m, depth 7 $\mu$ m) at predetermined positions. ② A bottom coil is formed. ③ A magnetic wire is inserted and positioned within the groove. ④ A positive resist is applied to fix the wire. ⑤ A top coil is formed. Note that the bonding between the ASIC surface's electrode terminals and the device's coil terminals or wire electrode terminals is performed simultaneously during step.

**4) Products Development:** Product development began with the commercialization of a 3D nT meter, which has been well received. The GSR sensor is currently in the prototype stage for an ASIC-type nT sensor, with anticipated applications including endoscope and catheter navigation within the body, magnetic microscopes, and biomagnetic observation devices. Applications for observing geomagnetic anomalies and micro-magnetic phenomena on the lunar surface are also anticipated. Development of the mass-production ASIC-type is anticipated for applications in current sensors, rotation sensors, and direction sensors.

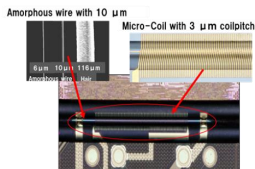


Fig. 1 Enlarged view of on-ASIC type GSR sensor element

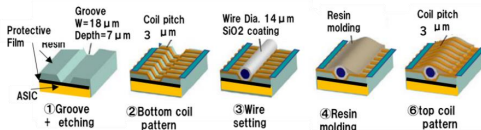


Fig. 2 Production process for a micro coil using 3 dimensional photolithography

### References

(1) Y.Honkura , S. Honkura: 'The development of a micro-coil-on-ASIC type GSR sensor driven by GHz pulse current,' J Magn. Magn. Mater. 513 (2020)

# Magnetostrictive Multilayer SAW Sensors for Magnetic Field Detection

D. Meyners<sup>1\*</sup>

<sup>1</sup>*Inorganic Functional Materials, Department of Materials Science, Faculty of Engineering, Kiel University, 24143 Kiel, Germany*  
 \*[dm@if.uni-kiel.de](mailto:dm@if.uni-kiel.de)

Successful implementation of a magnetic field sensor concept requires several criteria to be met. As well as high sensitivity, low intrinsic noise, linearity and a large signal bandwidth being important features, the operating point and directional characteristics of the sensor response must also be evaluated.

In this context, the contribution considers the design of magnetoelastic surface acoustic wave (SAW) sensors [1]. ST-cut quartz and 128° YX-cut LiNbO<sub>3</sub> are both used as piezoelectric sensor substrates. Shear horizontal acoustic waves are excited and detected by lithographically produced interdigital transducers (IDTs) arranged in a delay line configuration. A layer system based on amorphous FeCoSiB acts as the magnetically sensitive element. This is formed by magnetron sputter deposition and positioned between the transducers. The sensor principle is based on the magnetization-dependent change in the elastic shear modulus, accompanied by an alteration in the propagation velocity of the magnetoacoustic wave. An externally applied magnetic field is monitored by measuring the phase difference between the input and output IDT signals.

The presentation outlines methods for resolving the conflict between controlling magnetization processes and achieving high sensitivity using the thin-film approach. The starting point is a stack unit comprising the following layer sequence: Ta 5 nm | (Fe<sub>90</sub>Co<sub>10</sub>)<sub>78</sub>Si<sub>12</sub>B<sub>10</sub> 100 nm | Ni<sub>81</sub>Fe<sub>19</sub> 6 nm | Mn<sub>80</sub>Ir<sub>20</sub> 8 nm | Ta 5 nm. This stack unit is characterized by an exchange bias coupling mediated by NiFe. Selecting suitable deposition conditions allows the strength and direction of the unidirectional anisotropy to be adjusted. Combining several stack units permits the creation of magnetic multilayers with both parallel and angled magnetizations.

The presented data show that a scissor-type magnetization state is particularly suitable for achieving single-domain magnetic layers while simultaneously shifting the operating point of the sensor to zero magnetic field. Furthermore, the observed directivity in the sensor response is discussed as a basic requirement for vector magnetic field sensors.

In general, the sensitivity function of magnetic surface acoustic wave sensors can be factorized into magnetic, structural, and geometric components [2]. The presentation therefore considers the role of the center frequency of the acoustic wave. In a design variation involving different IDT periodicities, SAW sensors are compared in the frequency range from 100 MHz to 750 MHz. The best SAW sensors achieve detection limits of approximately 50 pT/Hz<sup>1/2</sup> for AC magnetic fields at 10 Hz and 9 pT/Hz<sup>1/2</sup> at 100 Hz.

## References

- [1] A. Kittmann, P. Durdaud, S. Zabel, J. Reermann, J. Schmalz, B. Spetzler, D. Meyners, N. X. Sun, J. McCord, M. Gerken, G. Schmidt, M. Höft, R. Knöchel, F. Faupel, and E. Quandt, "Wide Band Low Noise Love Wave Magnetic Field Sensor System", *Scientific Reports*, vol. 8, is. 1, 2018, Art no. 278, doi: 10.1038/s41598-017-18441-4
- [2] F. Weisheit, H. Wolfram, A. Malavé, M. Höft, E. Quandt, D. Meyners, "Frequency tuning and sensitivity enhancement of surface acoustic wave sensors for magnetic field detection", *Sensors and Actuators A: Physical*, vol 398, 2026, Art. no. 117316, doi: 10.1016/j.sna.2025.117316

## Functional Magnetic Wires: Microstructure–Anisotropy Control for Miniaturized Sensors and Devices

N. Lupu\*, S. Corodeanu, M. Lostun, L.-T. Mazilu, S.-I. Savin, T.-A. Óvári, H. Chiriac

<sup>1</sup>National Institute of Research and Development for Technical Physics, 700050 Iași, Romania

\*nicole@phys-iasi.ro

Amorphous and nanocrystalline magnetic wires are essential materials for advanced sensing technologies due to their unique cylindrical symmetry and highly tunable magnetic properties. This talk explores the precise control of magnetic anisotropy through thermal and stress-annealing treatments, emphasizing a recently discovered phenomenon: the full reversibility of induced magnetic states in both Co-Fe-based amorphous and Fe-based nanocrystalline (FINEMET) wires.

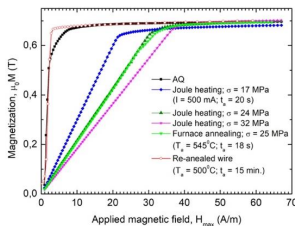


Fig. 1. Initial magnetization curves of Co-Fe-based amorphous wires (120  $\mu\text{m}$  diameter) under different annealing conditions.

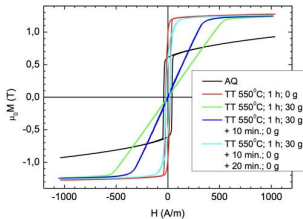


Fig. 2. Magnetic hysteresis of as-quenched and annealed amorphous FINEMET wire of 118  $\mu\text{m}$  in diameter. Subsequent stress-free relaxation annealing has been performed on the stress annealed sample.

miniaturized sensors with reconfigurable operation modes, in-situ recalibration, and enhanced long-term stability.

Financial support from the MEC NUCLEU Programme – Contract # 18N/01.01.2023 (Project PN 23 11 01 01) and UEFISCDI Project PN-IV-P1-PCE-2023-1896 – Contract # 12PCE/03.01.2025 is gratefully acknowledged.

In Co-Fe-Si-B amorphous wires, stress annealing at temperatures between 350°C and 550°C, conducted in furnace or by DC Joule heating, induces a strong helical magnetic anisotropy with a significant transverse component. This results in linear, inclined hysteresis loops and the formation of circumferential magnetic closure domains, which are ideal for linear field sensors and magneto-impedance (GMI) devices (Fig. 1). We attribute this behavior to anelastic microstructural rearrangements involving the orientational ordering of nanoscale clusters (~1–5 nm) within the amorphous matrix. Remarkably, subsequent stress-free thermal relaxation at 400–500°C for 30 min. restores the original as-cast magnetic behavior.

A similar level of control is demonstrated in Fe-based FINEMET nanocrystalline wires (Fig. 2). Stress annealing at 550°C–560°C induces a significant transverse anisotropy, which we attribute to creep-induced processes such as the directional ordering of atomic pairs (e.g., Fe-Si) within the  $\alpha$ -Fe(Si) nanograins. While the nanocrystalline grain structure remains stable, subsequent stress-free relaxation at the same temperature range erases the induced anisotropy, restoring the ultra-soft magnetic behavior characteristic of the standard nanocrystalline state.

By establishing the link between macroscopic magnetic response and microscale structural ordering, this work demonstrates that induced anisotropy is a reconfigurable state rather than a permanent one. This "tuning and resetting" capability offers a transformative route for developing smart

## Design and Characterisation of Stimuli-Responsive Magnetic Composite Heterostructures for Multifunctional Smart Materials

P. Tiberto<sup>1\*</sup>, F. Celegato<sup>1</sup>, G. Pradhan<sup>1</sup>, A. Magni<sup>1</sup>, M. Coisson<sup>1</sup>, D. Martella<sup>2</sup>, G. Barrera<sup>1</sup>

<sup>1</sup>Advanced Materials Metrology and Life Science, Istituto Nazionale di Ricerca Metrologica (INRiM), Strada delle Cacce, 91, 10135, Torino, Italy

<sup>2</sup>Department of Chemistry "Ugo Schiff", University of Florence, Via della Lastruccia 3-13, Sesto Fiorentino IT-50019, Italy

\*[p.tiberto@inrim.it](mailto:p.tiberto@inrim.it)

Composite magnetic heterostructures with multi-responsive behavior to environmental stimuli play a crucial role in various applications, particularly in sensing and actuation systems. The integration of magnetostrictive layers with both rigid piezoelectric (PMN-PT) and flexible (Kapton, soft photo-responsive polymer) substrates represents a significant advancement in multifunctional materials, offering unprecedented control over magnetic properties through strain-mediated interactions. The ability to tune magnetism via mechanical deformation and external stimuli (i.e. magnetic fields, light, and electric fields) opens new avenues for innovative device architectures and applications.

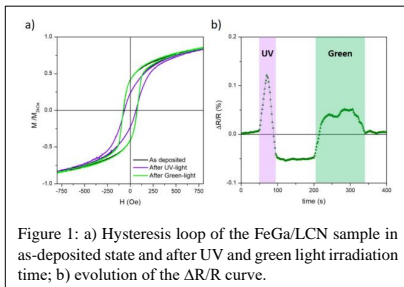


Figure 1: a) Hysteresis loop of the FeGa/LCN sample in as-deposited state and after UV and green light irradiation time; b) evolution of the  $\Delta R/R$  curve.

The photo-actuation mechanism induces mechanical stress to the magnetostrictive thin film, whose magnetic domains rearrange under the effect of uniaxial stress anisotropy with respect to the sign of the magnetostrictive coefficient (i.e. positive for FeGa and negative for Ni) [2]. The effect of light on magnetisation and electrical resistance are reported in Fig.1 a and b respectively.

This mechanically induced control over magnetism presents an alternative, energy-efficient approach for switching and modulating magnetic properties without relying on traditional magnetic components, addressing the growing demand for novel tuning mechanisms in advanced functional materials.

### References

- [1] G. Pradhan, Adv. Elect. Mat. Vol. 11 (20), p. e00558, 2025
- [2] G. Barrera, Adv. Sci., vol. 11, p. 2408273, 2024

## Novel Transcranial Magnetic Stimulation Coils and Validation Techniques for Human and Animal Studies

Ravi L. Hadimani,

Department of Mechanical and Nuclear Engineering Virginia Commonwealth University, Richmond, VA 23284 USA

**Abstract:** Transcranial Magnetic Stimulation (TMS) can tune brain functions non-invasively, safely, and effectively without the need for surgery or drugs. Thus, it can enable the treatment of several debilitating neurological and psychiatric disorders and enhance cognitive capabilities 1-3]. TMS coils suffer from lack of focal stimulation in the deeper parts of the brain due to rapid decay of magnetic field from the source. Focality on the cortical surface can be improved by using high magnetic permeability and high saturation

flux ferromagnetic cores. For deeper stimulation even the ferromagnetic cores suffer from the spread of the magnetic field. My lab has designed and fabricated several novel focal and deep brain stimulation coils based on novel soft ferromagnetic and diamagnetic materials as shown in Fig.1 [4-5]. We have experimentally verified some of the results from coil design in rats in collaboration with the Department of Neurology at VCU and Richmond Veteran Hospital. My team has also designed a TMS coil configuration that can stimulate multiple sites simultaneously and vary sites of stimulation without moving the coils physically. We have also investigated a feasibility study of combined TMS and DBS using brain phantom in collaboration with the VCU Department of Neurosurgery [6].

**We have successfully conducted human subject studies on healthy population and used a deep convolution neural network to predict the stimulation strengths in the brains of patients with mild traumatic brain injury in the form of induced electric fields as shown in Fig. 2.** We are currently working to predict TMS treatment responses in humans by using deep machine learning algorithms considering anatomical and functional variables using MRI, fMRI, DTI and EEG. These new machine-learning algorithms will enable prediction of the TMS treatment outcomes of patients and determine the dose-response curves before the treatment begins in the future.

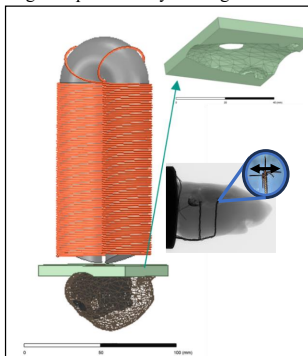


Fig. 1 Novel Parabolic Ferromagnetic Core (PFC) TMS coil with highly diamagnetic pyrolytic graphite shielding plate for a focused stimulation of primary motor cortex (M1) of a rat's brain.

### References:

- [1] D. Kumbhare, M. A. Azam, R. Hadimani, G. Weistroffer, J. Atulasimha, and M. S. Baron, "Healthy and pathological pallidum regulation of thalamic burst versus tonic mode firing: a computational simulation," *Neuro Report*, vol. 34, no. 16, p. 773, Nov. 2023.
- [2] L. M. Franke, G. T. Gitchel, R. A. Perera, R. L. Hadimani, K. L. Holloway, and W. C. Walker, "Randomized trial of rTMS in traumatic brain injury: improved subjective neurobehavioral symptoms and increases in EEG delta activity," *Brain Injury*, vol. 36, no. 5, pp. 683–692, Feb. 2022.
- [3] N. Mittal, B. Thakkar, C. B. Hodges, C. Lewis, R. L. Hadimani, and C. L. Peterson, "Effect of neuroanatomy on corticomotor excitability during and after transcranial magnetic stimulation and intermittent theta burst stimulation," *Human Brain Mapping*, vol. 43, no. 14, pp. 4492–4507, 2022.
- [4] I. C. Carmona, O. F. Afuwape, D. C. Jiles, and R. L. Hadimani, "Estimation of the Focality of Coils and Quality of Stimulation of Biological Tissues During Transcranial Magnetic Stimulation," *IEEE Trans. Magn.*, vol. 58, no. 2, pp. 2022.

- [5] M. Tashli, A. Mhaskar, G. Weistroffer, M. S. Baron, and R. L. Hadimani, "Novel multi-magnetic material transcranial magnetic stimulation coils for small animals application," *AIP Advances*, vol. 14, no. 1, p. 015324, Jan. 2024

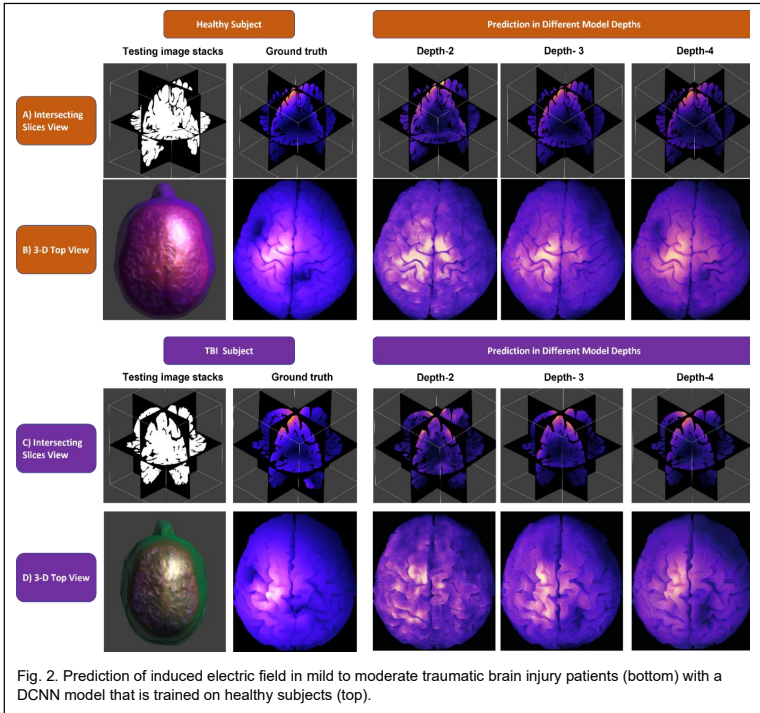


Fig. 2. Prediction of induced electric field in mild to moderate traumatic brain injury patients (bottom) with a DCNN model that is trained on healthy subjects (top).

## Energy efficient quantum control of spin qubits with classical nanomagnets for scalable quantum computing and sensing

Jayasimha Atulasimha<sup>1,2,3\*</sup>,

<sup>1</sup>Mechanical and Nuclear Engineering, <sup>2</sup>Electrical and Computer Engineering, <sup>3</sup>Physics  
Virginia Commonwealth University, Richmond, Virginia, USA 23284.

[jatulasimha@vcu.edu](mailto:jatulasimha@vcu.edu)

Our group has demonstrated energy efficient electrical control of nanoscale magnetization dynamics using strain mediated voltage control [1], and voltage control of magnetic anisotropy [2] in nanomagnets and skyrmions respectively. Such nanomagnets can generate highly confined microwaves to control the quantum state of proximally located spin qubits.

This talk will discuss the use of microwaves generated by voltage-controlled magnetization dynamics in nanomagnets to implement single-qubit quantum gates with fidelities approaching state-of-the-art [3] in a scalable manner. Further confinement of microwaves using convergent-divergent skyrmion devices can implement even lower footprint quantum control of spins [4]. Moreover, we show that using exchange-coupled spin ensemble as a qubit could offer intrinsic error mitigation by suppressing decoherence induced by thermal noise, enabling robust high temperature qubits [5].

This talk will also discuss experiment work demonstrating coherent quantum control of a single nitrogen vacancy (NV) center in diamond with microwave fields generated from proximally located shape anisotropic nanomagnets of lateral dimensions down to 200 nm x 180 nm, driven remotely by surface acoustic wave (SAW) excitation [6]. Specifically, high contrast Rabi oscillations have been demonstrated. Additionally, we report relaxometry using microwave pulses generated by such proximally located nanomagnets that can be orders of magnitude more efficient than using conventional antenna [6]. Such localized and energy efficient control has potential to lead to scalable quantum computing and sensing with NV-defects in diamond and other spin qubits.

### References

- [1] *Nano Letters*, **16**, 1069, 2016; *Nano Letters*, **16**, 5681, 2016.
- [2] *Nature Electronics* **3**, 539, 2020.
- [3] *Communication Physics* **5**, 284, 2022.
- [4] *Phys. Rev. Applied* **22**, 064077, 2024.
- [5] <https://arxiv.org/pdf/2503.12071>
- [6] <https://arxiv.org/abs/2407.14018>

**Acknowledgement:** This work was funded by the US National Science Foundation ExpandQISE grant # 2231356

## Posters

## **A high-throughput experimental approach to the screening of hard magnet materials**

W. Rigaut<sup>1</sup>, P. Le Berre<sup>1</sup>, H. Jaballah<sup>1</sup>, L. Fink<sup>1</sup>, V. Poline<sup>2</sup>, R.Haettel<sup>1</sup>, S. Grenier<sup>1</sup>, G. Chahine<sup>3</sup>, E. Bellec<sup>1</sup>,  
G. Buatier<sup>1</sup>, W. Hortschitz<sup>4</sup>, S. Pile<sup>4</sup>, T. Schrefl<sup>4</sup>, N. Blanc<sup>1</sup>, Y. Hong<sup>1</sup>, T. Devillers<sup>1</sup>, N. M. Dempsey<sup>1\*</sup>

<sup>1</sup>*Univ. Grenoble Alpes, Grenoble INP, CNRS, Institut Néel, Grenoble, France*

<sup>2</sup>*Univ. Grenoble Alpes, CEA, IRIG, MEM, NRX, Grenoble (France)*

<sup>3</sup>*SIMaP, Université Grenoble Alpes, CNRS, Grenoble INP, Grenoble, France*

<sup>4</sup>*Department for Integrated Sensor Systems, University for Continuing Education Krems, Wr. Neustadt, Austria*

*\*[nora.dempsey@neel.cnrs.fr](mailto:nora.dempsey@neel.cnrs.fr)*

This poster will outline a comprehensive workflow for the high-throughput characterization and analysis of compositionally graded hard magnetic films. Our combinatorial methodology is designed to accelerate the development of hard magnetic materials with reduced or no reliance on critical elements. Although combinatorial materials science is a well-established field, recent advancements in experimental instrumentation and software have made its practical application more accessible than ever. We outline the workflow—including characterization protocols, data management tools, and data analysis solutions—using test case films based on the hard magnetic  $\text{Sm}(\text{Fe},\text{V})_{12}$  phase. This system is just one of several hard magnetic materials we are currently studying with this approach. The integration of high-throughput experiments with advanced data analysis and machine learning techniques, as described here, holds potential for the study of different types of magnetic materials.

# Engineering NiFe-based sensing layers for xMR magnetic sensors

Bruno dos Santos<sup>1</sup>, Mahmoud Rasly<sup>1</sup>, Diana C Leitao<sup>1\*</sup>

<sup>1</sup>Department of Applied Physics, <sup>2</sup>Department of Electrical Engineering, Eindhoven University of Technology, 5612 AZ Eindhoven, The Netherlands,

\*[d.c.leitao@tue.nl](mailto:d.c.leitao@tue.nl)

Highly sensitive sensors capable of detecting ultra-low magnetic fields are central to address major technological challenges in biomedical monitoring, neural signal detection, or electrical grid monitoring [1]. State-of-the-art multilayered magnetoresistive (xMR) sensors require precise control over the thin film thicknesses, and their magnetic and crystalline structures to reach optimized performance [2]. In low noise tunnel-MR sensors, ensuring soft magnetic properties of the ferromagnetic sensing electrode is crucial to have both high field sensitivity and reduced magnetic noise contributions. This is usually obtained by combining CoFeB with NiFe or CoFe-based amorphous alloys [3]. However, the soft-magnetic character of NiFe often degrades above 300°C, a temperature required to crystallize the MgO barrier and the CoFeB electrodes to achieve the high tunnelling MR ratios, thus impairing the overall sensor performance.

In this work we investigate the design and optimization of NiFe-based sensing layers for incorporation into CoFeB/ MgO/ CoFeB magnetic tunnel junctions. We propose a  $(\text{Ni}_{80}\text{Fe}_{20})_{1-x}\text{Si}_x$  alloy engineered to withstand annealing above 300 °C while maintaining high saturation magnetization and showing a negligible increase in magnetic anisotropy after two annealing steps.

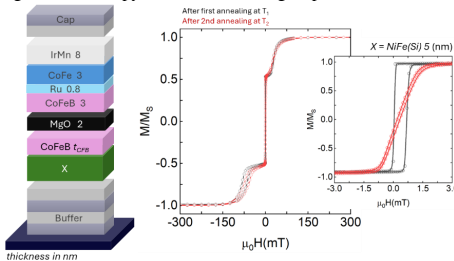


Fig. 1. Multilayer stack deposited with the engineered NiFe-based sensing layer and corresponding M(H) curve after two annealing steps.

These are used to achieve the crossed magnetization configuration for output linearization. We address the effect of Si doping on the structural and magnetic characteristics of the thin films, and demonstrate that an optimal Si concentration of 13 at. % retains competitive magnetic properties even after annealing at 400°C. Furthermore, we integrate the optimized alloy into TMR multilayer stacks with and without the use of dusting layers. The impact of incorporating such sensing layers is discussed, assessing the expected final magnetic performance. This approach paves the way toward the next-generation of highly sensitive

magnetic sensors for advanced applications.

This work is supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES)–Finance Code 001, CNPq (Grant 310795/2022-2), and HORIZON EUROPE Marie Skłodowska-Curie Actions Individual Fellowship Grant No. 101110716.

## References

- [1] Nakano et al, Applied Physics Letters 126 (2025).
- [2] Leitao et al., npj Spintronics 2, 54 (2024).
- [3] Rasly et al. Journal of Physics D: Applied Physics 54, 095002 (2020).

## Interfacial Hybrid States and Spinterface Effects in CoFeB/Alq<sub>3</sub> Magnetic Thin Films

Swayang Priya Mahanta<sup>1</sup>, Antarjami Sahoo<sup>1</sup>, Aritra Mukhopadhyaya<sup>2</sup>, Sagarika Nayak<sup>1</sup>, Thomas PA Hase<sup>3</sup>, Md Ehesan Ali<sup>2</sup>, Del Atkinson<sup>4</sup>, Subhankar Bedanta<sup>1,5</sup>

<sup>1</sup>Laboratory for Nanomagnetism and Magnetic Materials (LNMM), School of Physical Sciences, National Institute of Science Education and Research (NISER), An OCC of Homi Bhabha National Institute (HBNI), Jatni, Odisha 752050, India

<sup>2</sup>Institute of Nano Science and Technology, Mohali, Punjab 140306, India

<sup>3</sup>Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom

<sup>4</sup>Department of Physics, Durham University, Durham DH1 3LE, United Kingdom

<sup>5</sup>Center for interdisciplinary Sciences (CIS), National Institute of Science Education and Research (NISER), An OCC of Homi Bhabha National Institute (HBNI), Jatni, Odisha 752050, India

\*sbedanta@niser.cac.in

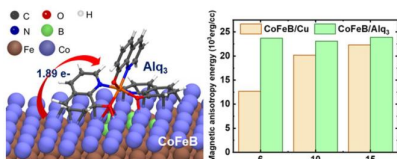


Fig. 1. Interfacial electronic hybridization at the CFB/Alq<sub>3</sub> interface. Charge transfer and  $\pi$ -d coupling between Alq<sub>3</sub> and CFB modify local magnetic anisotropies

reversal, spin polarization, and domain configurations in FM/OSC heterostructures as compared to the reference FM systems.

In this work, we have varied the thickness of ferromagnetic layer (6,10,15 nm) while keeping the Alq<sub>3</sub> thickness at 14 nm to understand the impact of spinterface of CFB/Alq<sub>3</sub> systems [3]. We performed a detailed investigation of magnetization reversal, magnetic domains, anisotropy, and magnetization dynamics in CFB/Alq<sub>3</sub> heterostructures. Our results show that Alq<sub>3</sub> deposition stabilizes the spinterface, leading to coercivity enhancement, domain modification, reduced damping, and significant increases in uniaxial anisotropy energy. Complementary DFT calculations further confirm that interfacial hybridization strongly alters the local magnetic environment. Together, these findings highlight Alq<sub>3</sub> as an effective material for tailoring magnetic interfaces and advancing organic spintronic device design.

### References

- [1] S. A. Wolf, D. D. Awschalom, R. A. Buhrman, J. M. Daughton, S. von Molnar, M. L. Roukes, A. Y. Chtchelkanova, and D. M. Treger, "Spintronics: a spin-based electronics vision for the future", *science*, Vol 294, pp 1488-1495, Nov 2001.
- [2] Stefano Sanvito, "Molecular Spintronics", *Chem. Soc. Rev.*, Vol 40, pp 3336-3355, May 2006.
- [3] Swayang Priya Mahanta, Antarjami Sahoo, Aritra Mukhopadhyaya, Sagarika Nayak, Thomas PA Hase, Md Ehesan Ali, Del Atkinson, Subhankar Bedanta, "Spinterface-Mediated Magnetic Properties of Nanoscale-Thick Co20Fe60B20/Alq3 Heterostructures for Spintronic Applications", *ACS appl. Nano mat.*, Vol 8, pp 12630-12638, June 2025.

## Micro-fluxgate with Solenoid Coils based on Flip-chip Process

J. Maier<sup>1\*</sup>, P. Ripka<sup>1</sup>, P. Chen<sup>2</sup>

<sup>1</sup>Faculty of Electrical Engineering, Czech Technical University in Prague, 166 27 Prague, Czech Republic

<sup>2</sup>National Taiwan University of Science and Technology, Taipei City 106, Taiwan

\*maierjir@fel.cvut.cz

Fluxgate sensors can reach better resolution compared to other types of magnetic sensors, but they are very difficult to miniaturize. Our goal is to create a miniaturized fluxgate with length of less than 1 cm using chip fabrication technology. In previous years, our team developed a CMOS-based micro-fluxgate [1] using a racetrack-shaped magnetic core and wire-bonded solenoid coils. The solenoid coils performed much better than flat coils and further improvements were made using custom thinned material for the core [2].

To overcome the placement imperfections and mass-production limitations of wire-bonded coils, we transitioned to a flip-chip design. It consists of two chips bonded together and the core placed in-between (Fig. 1). The coils are formed by metal layers and connections between the two chips (gold bumps). The chips were fabricated in TSMC T18 CMOS process, which will allow us to also include integrated electronics for pulse excitation and signal processing with non-trivial reference waveform in future versions. The design is symmetrical, meaning that the two chips have identical layout, which reduced the fabrication cost for prototyping. The chips are connected in a slightly offset way, so that one edge is accessible for wire bonding to a PCB, as shown in Fig. 2.

The sensor was tested using sinewave excitation with frequencies from 100 kHz to 2 MHz and amplitudes up to 70 mA. The maximum sensitivity is 9000 V/T at 2 MHz, 40 mA excitation current. While the maximum sensitivity is similar to the previous design (which is 8000 V/T), the required current is 30 % lower thanks to having more turns of the excitation coil, meaning lower power consumption. This is thanks to the flip-chip design being less restrictive in terms of pad placement and coil shape, allowing us to create denser and more optimized layout of the coils. The 1 Hz noise was measured to be around 70 pT/ $\sqrt{\text{Hz}}$  (at 2 MHz, 40 mA excitation). This is one order of magnitude lower than in the previous design.

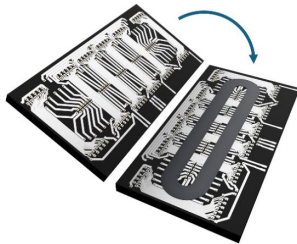


Fig. 1. Flip-chip micro-fluxgate design concept

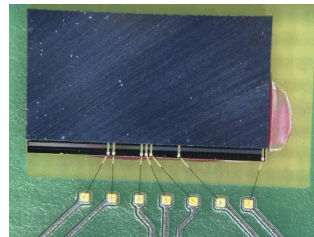


Fig. 2. Assembled device on a PCB

### References

- [1] J. Maier, P. Ripka, and P. Chen, "CMOS-based micro-fluxgate with racetrack core and solenoid coils," *Sensors and Actuators A: Physical*, vol. 379, p. 115886, 2024. doi: 10.1016/j.sna.2024.115886.
- [2] J. Maier, P. Ripka and P. Chen, "High-Frequency Low-Power Microfluxgate," in *IEEE Sensors Letters*, vol. 9, no. 8, pp. 1-4, Aug. 2025, Art no. 2503304, doi: 10.1109/LSENS.2025.3585367.

## Light Ion Beam process to enhance the performance of XMR sensors

N. Montblanc<sup>1,\*</sup>, Y. Sassi<sup>1</sup>, M. Deroo<sup>1</sup>, D. Gouéré<sup>1</sup>, M. Grelier<sup>1</sup>,  
D. Ravelosona<sup>1,2</sup>

<sup>1</sup>Spin-Ion Technologies, 91120 Palaiseau, France

<sup>2</sup>C2N & CNRS, 91120 Palaiseau, France

\*noel.montblanc@spin-ion.com

Light Ion beam process has emerged as a powerful approach for atomic-scale engineering of magnetic materials at the atomic scale, providing precise control over their magnetic properties. Building on years of development, we provide an advanced manufacturing process that significantly improves the performance of spintronic technologies, including XMR magnetic sensors, magnetic memories, and neuromorphic computing devices, enabling their deployment in next-generation edge AI systems. As the importance of XMR sensors increases in industries ranging from speed, position, and distance sensing to rotation and current detection, novel manufacturing processes are essential. In this context, light ion beam treatment enables targeted modification of material and interfacial properties at atomic scale, thereby overcoming intrinsic limitations in TMR and GMR devices.

In this presentation, we will highlight various aspects of the He<sup>+</sup> ion irradiation and several applications on TMR and GMR magnetic sensors, including the (i) reduction of edge damages in devices, (ii) tunability of sensitivity and linear range, (iii) tunability of exchange bias in AF/FM bilayers, (iv) tunability of magnetic anisotropy (H<sub>k</sub>), (v) improvement of CoFeB/MgO crystallization and (vi) the possibility to develop hybrid devices.

In summary, we will demonstrate that ion irradiation is a versatile tool for engineering magnetic properties at the nanoscale. By enabling precise tuning of interfacial and magnetic parameters, our results expand the design space of magnetic sensors and contribute to advancing their performance limits in spintronic devices.

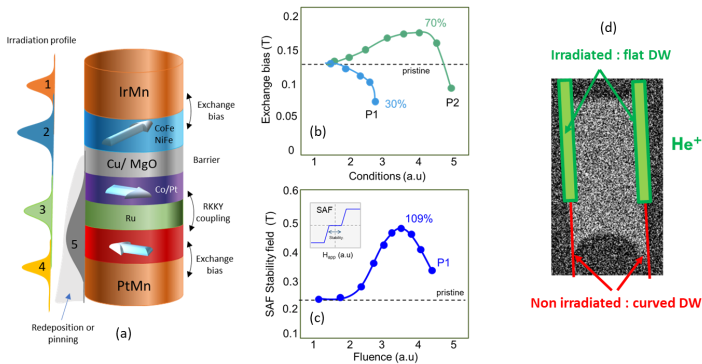


Fig. 1. (a) Schematic of the XMR stack architecture illustrating the spatial control of the ion irradiation profile for nanoscale modulation of magnetic properties. (b) Quantitative tuning of the exchange bias at the AF/FM interface, either at the top or bottom of the multilayer stack. (c) Up to 110% increase in SAF stability induced by controlled ion irradiation. (d) Significant reduction of the edge damages associated with domain wall (DW) motion following local irradiation.

## MaMMoS: Ontology-linked FAIR Workflows from Magnetometry Data to Sensor Optimisation

S. Pile<sup>1</sup>, W. Hortschitz<sup>1</sup>, T. Schrefl<sup>1</sup>, H. Fangohr<sup>2,3,4</sup>, A. Petrocchi<sup>2</sup>, S. A. Pathak<sup>2</sup>, M. Lang<sup>2</sup>, S. J. R. Holt<sup>2</sup>, T. G. Woodcock<sup>5</sup>, J. Winkler<sup>5</sup>

<sup>1</sup>*Department for Integrated Sensor Systems, University for Continuing Education Krems, Wiener Neustadt, Austria*

<sup>2</sup>*Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany*

<sup>3</sup>*University of Southampton, Southampton, United Kingdom*

<sup>4</sup>*European XFEL GmbH, Schenefeld, Hamburg, Germany*

<sup>5</sup>*Leibniz Institute for Solid State and Materials Research Dresden (IFW Dresden), Dresden, Germany*

*\*Corresponding: [santa.pile@donau-uni.ac.at](mailto:santa.pile@donau-uni.ac.at)*

Integrated magnetic microsystems demand rapid, traceable co-design of materials, process windows and device layouts. The Magnetic Multiscale Modelling Suite (MaMMoS [1,2]) addresses this need by providing an open-source, Python-first framework in which specialised components (packaged as small, composable libraries) are connected into end-to-end workflows implemented as scripts or Jupyter notebooks. A central design principle is that numerical values can carry both units and unambiguous semantics: MaMMoS ‘quantities’ represent values with units, while MaMMoS ‘entities’ additionally attach an ontology label compliant with EMMO, enabling machine-readable meaning alongside unit checking [3]. We highlight the ontology layer and its role in FAIR data exchange. MaMMoS provides an EMMO-based domain ontology for magnetic materials and properties, and practical tooling to serialise entity-rich datasets to CSV or YAML with embedded ontology labels, IRIs and units [4]. This allows experimental and simulation results to be archived with consistent semantics across length scales (DFT → spin dynamics → micromagnetics → device-level figures of merit), while remaining lightweight for daily use in Python. As a concrete data-sharing pathway, we consider vibrating sample magnetometry (VSM) data recorded on Quantum Design PPMS systems. Using the MaMMoS-supported magmeas package, raw VSM .DAT files can be imported and key extrinsic properties (e.g., coercivity, remanence, maximum energy product) can be derived and exported to YAML/CSV/HDF5 [5]. These outputs can be wrapped as MaMMoS entities and uploaded to the NOMAD platform, where parsers and schemas transform raw files into structured, searchable archives that support sharing and publication. The resulting NOMAD entries can be explored using MaMMoS companion visualisation notebooks, enabling reuse of experimental magnetometry data alongside simulation workflows. Finally, we connect data FAIRification to closed-loop design by referencing the MaMMoS sensor demonstrator: micromagnetic simulations (e.g., via Ubermag/OOMMF), hysteresis-loop analysis and Bayesian optimisation are combined to maximise the linear response region of a sensor element. Together, ontology-linked entities, NOMAD-based dissemination and optimisation workflows provide a reproducible route from measured data to integrated-magnetics design decisions [6].

## Acknowledgement

Funded by the European Union (Grant agreement ID: 101135546). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the EU or the European Health and Digital Executive Agency (HADEA). Neither the EU nor the granting authority can be held responsible for them.

## References

- [1] MaMMoS documentation: 'Design' (framework architecture, entities, and FAIR data principles). <https://mammos-project.github.io/mammos/design.html>.
- [2] MaMMoS Demonstrator: 'Sensor shape optimisation workflow' (hysteresis analysis and Bayesian optimisation). <https://mammos-project.github.io/mammos/demonstrator/sensor.html>.
- [3] MaMMoS mammos\_entity.io API (CSV/YAML serialisation with ontology metadata). [https://mammos-project.github.io/mammos/api/mammos\\_entity.io.html](https://mammos-project.github.io/mammos/api/mammos_entity.io.html).
- [4] MaMMoS-project/MagneticMaterialsOntology v0.0.3 (EMMO-compliant magnetic materials ontology). Zenodo: <https://doi.org/10.5281/zenodo.14547624>.
- [5] magmeas (VSM import from Quantum Design PPMS; export and property calculation). <https://doi.org/10.5281/zenodo.18350179>
- [6] nomad-vis (visualisation notebooks for MaMMoS data published on NOMAD). <https://github.com/MaMMoS-project/nomad-vis>.

## Magnon mediated spin pumping by coupled ferrimagnetic garnets heterostructure

Kshiti Singh Rathore<sup>1\*</sup>, Anupama Swain<sup>1</sup>, Pushpendra Gupta<sup>1</sup>, Abhisek Mishra<sup>1</sup>, Gary Lee<sup>2</sup>, Jinho Lim<sup>3</sup>, Ramanathan Mahendiran<sup>2</sup>, Axel Hoffmann<sup>3</sup> and Subhankar Bedanta<sup>1,4</sup>

<sup>1</sup>Laboratory for Nanomagnetism and Magnetic Materials (LNMM), School of Physical Sciences, National Institute of Science Education and Research (NISER), An OCC of Homi Bhabha National Institute (HBNI), Jatni-752050, Odisha, India

<sup>2</sup>Department of Physics, 2 Science Drive 3, National University of Singapore, 117551, Republic of Singapore

<sup>3</sup>Department of Materials Science and Engineering and Materials Research Laboratory, University of Illinois Urbana-Champaign, Urbana, Illinois 61801, USA

<sup>4</sup>Center for Interdisciplinary Sciences (CIS), NISER, An OCC of Homi Bhabha National Institute (HBNI), Jatni-752050, Odisha, India  
E-mail: [sbedanta@niser.ac.in](mailto:sbedanta@niser.ac.in)

Magnon-magnon coupling plays a pivotal role in advancing the field of magnonics by enabling the coherent interaction between spin excitations in magnetic materials. This phenomenon is particularly significant in designing energy-efficient magnonic devices for next-generation information processing [1]. In this study, we provide clear evidence of magnon-magnon coupling in an all-insulator garnet heterostructure composed of  $\text{Y}_3\text{Fe}_5\text{O}_{12}$  (YIG) and  $\text{Tm}_3\text{Fe}_5\text{O}_{12}$  (TmIG). The avoided crossing region between the ferromagnetic resonance (FMR) modes of YIG ( $n=0$ ) and TmIG ( $n=0$ ) demonstrates magnon-magnon coupling at 200 K. Notably, the mode crossing occurs at a resonance frequency of  $f = 6.88$  GHz, with a minimal resonance separation corresponding to a coupling strength of 2.8 mT shown in Fig. 1. [2] These findings not only validate the magnon-magnon coupling mechanism but also open avenues for exploring hybrid magnon physics essential for developing ultralow-power magnonic devices. We further investigate the spin pumping phenomenon in coupled YIG/TmIG bilayers with a heavy-metal layer (Pt) via the inverse spin Hall effect (ISHE). The spin pumping voltage ( $V_{\text{sp}}$ ) enhancement was observed in this system in compared to their reference single layer. This highlights the crucial role of interfacial exchange coupling [3]. The magnon transmission, occurring at the FMR positions of both ferrimagnetic (FiM) layers, emphasizes the effectiveness of magnon-mediated spin transport. The combination of a magnetic insulator with low damping and a heavy-metal interface also eliminates the complexities associated with conduction electrons, providing a simplified and accurate model to study spin-charge interconversion. These results underscore the importance of magnon coupling and its role in spin pumping, offering a pathway to optimize spin transport and manipulation for spintronic applications.

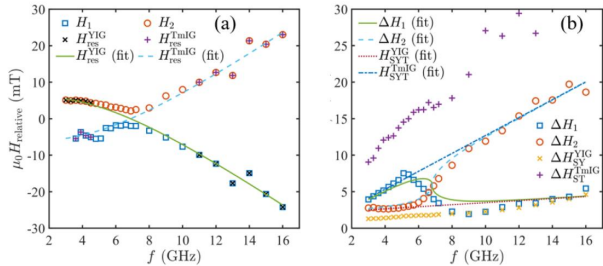


Fig.1: (a) The full range frequency vs resonance field plot at 200 K showing avoided crossing and (b) Linewidths of the two hybrid modes as a function of frequency

### References:

1. Yi Li et al., PHYSICAL REVIEW LETTERS 124, 117202 (2020)
2. K.S.Rathore et al., (Accepted in Phy. Rev. Applied)
3. A. Swain et al., Applied Physics Letters 125, 012406 (2024)

## Planar by Print: Nanoparticle Ink-Bonded Magnetoelectric Antennas

Mahdieh Shojaei Baghini<sup>\*</sup>, Kalina Gyoreva, Dayhim Nekoeian, Afesomesh Ofiare, Hadi Heidari

Microelectronics Laboratory, James Watt School of Engineering, University of Glasgow, G128QQ, UK

[\\*mahdieh.shojaeibaghini@glasgow.ac.uk](mailto:*mahdieh.shojaeibaghini@glasgow.ac.uk)

Magnetoelectric (ME) antennas are promising for mm-scale implantable and ingestible wireless systems because they can transduce magnetic fields into electrical signals with footprints far smaller than conventional RF radiators [1]. However, their practical translation into implantable platforms is increasingly limited not by device physics,

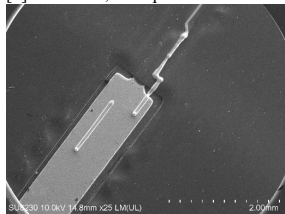


Fig. 1: Nanoparticle ink-based integration of magnetoelectric antennas.

but by packaging. Interconnects must be low-profile, mechanically robust, biocompatible, and scalable to wafer-level assembly of magnetoelectric and spin-based devices [2]. Traditional wire bonding introduces tall loops, localized stress concentrations, and stringent pad-height constraints that complicate hermetic encapsulation and miniaturized implant packaging. Ethylene glycol/silver nanoparticle (NP) ink-based bonding offers an attractive alternative by enabling planar, printed interconnects that inherently support planarization across topography, simplify encapsulation, and facilitate dense routing without bond-wire clearance requirements, capabilities that are particularly valuable for conformal, multilayer implantable packages as shown in Fig. 1. In this work, we compare the broadband input reflection ( $S_{11}$ ) response of microwave ME antenna implementations assembled using on-chip probing schemes versus packaged NP ink bonding. Across 3–4 GHz, a diced ME antenna baseline exhibits consistently low reflection, with  $S_{11}$  approximately -22 to -24 dB, and modest frequency-dependent ripple indicative of preserved resonance and overtone behavior. In contrast, the NP ink-bonded ME antenna shows a marked upward shift in  $S_{11}$  to roughly -11 to -9 dB over the same band, accompanied by a strong reduction in the observable dynamic range and a noticeably flatter frequency response. This ~12 dB degradation in reflection depth implies substantially higher reflected power at the feed and suggests that the ink-based interconnect and its associated package parasitics introduce additional loss and/or alter the effective impedance environment of the magnetoelectric antenna. Complementary measurements comparing mounting conditions (on-silicon versus on-PCB, and PCB assemblies incorporating printed/planarized bonding) further support that packaging and interconnect geometry can measurably shift the broadband match and suppress fine impedance features.

These results highlight a central tradeoff for implantable ME systems and packaged magnetoelectric devices as a whole. NP ink bonds are necessary enablers for manufacturable, planar and encapsulation-ready packaging. Hence, their electrical parasitics and process-dependent conductivity that can reduce apparent matching performance must be systematically addressed. Ongoing optimization of ink formulation, sintering/curing, pad geometry, and return-path design is therefore critical to retain ME antenna efficiency while realizing clinically and industrially relevant packaging form factors.

### References

- [1] D. Webb, D. Forester, A. Ganguly, and C. Vittoria, "Applications of amorphous magnetic-layers in surface-acoustic-wave devices," *IEEE Transactions on Magnetics*, vol. 15, no. 6, pp. 1410-1415, 1979, doi: 10.1109/TMAG.1979.1060442.
- [2] Y. Shao *et al.*, "Room-temperature high-precision printing of flexible wireless electronics based on MXene inks," *Nature Communications*, vol. 13, no. 1, p. 3223, 2022/06/09 2022, doi: 10.1038/s41467-022-30648-2.

## Sensitivity Enhancement of High-Frequency Driven Thin-Film Magnetic Sensor with Narrow Slit

N. Tazawa<sup>1</sup>, J. Honda<sup>2</sup>, Y. Okuyama<sup>2</sup>, L. Tonthat<sup>1</sup>, H. Aoki<sup>1</sup>, A. Kuwahata<sup>1,2</sup>, S. Yabukami<sup>1,2</sup>

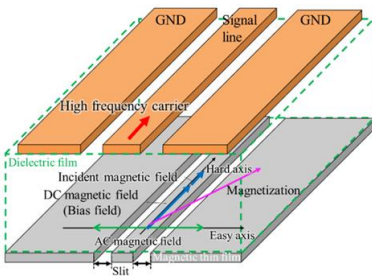
<sup>1</sup>Graduate School of Engineering, Tohoku Univ., 6-6-5 Aoba, Sendai 980-8579, Japan

<sup>2</sup>Graduate School of Biomedical Engineering, Tohoku Univ., 6-6-5 Aoba, Sendai 980-8579, Japan

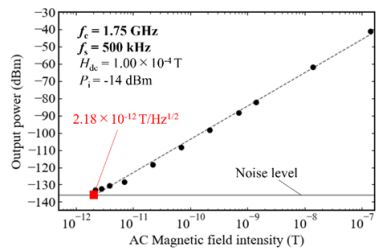
\*E-mail: [Shin.yabukami.e7@tohoku.ac.jp](mailto:Shin.yabukami.e7@tohoku.ac.jp)

The authors have been conducting research to improve the sensitivity of high-frequency driven thin-film magnetic sensors operating at room temperature. The sensor features an integrated structure consisting of a magnetic thin film and a transmission line. During operation, a DC bias magnetic field is applied to the magnetic thin film, and a carrier wave is passed through the transmission line. When an external magnetic field is applied to the sensor, its impedance changes due to the skin effect and resonance loss, enabling magnetic field detection. While these high-frequency driven thin-film magnetic sensors have successfully performed biomagnetic measurements, sensitivity degradation caused by impedance mismatch remains a challenge[1]. This mismatch is primarily due to the return loss of the carrier wave. In this report, we demonstrated improved impedance matching and enhanced sensitivity by incorporating slits into the magnetic thin film. This study presents an approach to enhance the sensitivity of high-frequency driven thin-film magnetic sensors by improving impedance matching through the introduction of a 10  $\mu\text{m}$  slit in the magnetic layer as shown in Fig. 1. The sensors with and without the slit were evaluated under weak AC magnetic fields at frequencies of 500 kHz and 109 Hz. Employing the carrier suppression circuit effectively reduced phase noise. When a 109 Hz,  $4.81 \times 10^{-6}$  T AC magnetic field was applied to the slit-patterned sensor, the carrier component was suppressed by approximately 60 dB, resulting in a signal-to-noise (SN) ratio improvement of 40 dB. The minimum detectable magnetic fields achieved with the slit-patterned sensor were  $2.18 \times 10^{-12}$  T/Hz<sup>1/2</sup> at 500 kHz and  $1.19 \times 10^{-10}$  T/Hz<sup>1/2</sup> at 109 Hz as shown in Fig. 2. These results demonstrate that improved impedance matching, combined with carrier suppression, significantly enhances the sensitivity of room-temperature-operating high-frequency driven thin-film magnetic sensors, thereby simplifying the measurement of weak magnetic fields.

**References** [1] M. Sakamoto, R. Suzuki, T. Ishihara, J. Honda, and S. Yabukami, *AIP Advances*, **13**, 2, 025321 (2023).



**Fig. 1** Structure of the fabricated sensor. The sensor has the slit in the magnetic thin film. The impedance matching and the high sensitivity were realized by employing the slit in the magnetic thin film.



**Fig. 2** Output power as a function of AC magnetic field intensity for the sensor with the slit. The minimum detectable magnetic field was  $2.18 \times 10^{-12}$  T/Hz<sup>1/2</sup> at 500 kHz.

# Micro-patterned Fe<sub>65</sub>Co<sub>35</sub> Ferromagnetic Thin Film for High Frequency High-Q Integrated Inductors

Haosen Yin<sup>1</sup>, Amal El-Ghazaly<sup>1\*</sup>

<sup>1</sup>Department of Electrical and Computer Engineering, Cornell University, USA

\*ase63@cornell.edu

Thin film magnetic materials have been integrated into multiple components of radio frequency (RF) front-end systems to improve performance or achieve versatile functionalities, such as enhancing inductance density, achieving wideband tunability, and realizing non-reciprocal signal transmission. Among these thin film materials, soft ferrites (especially YIG) exhibit low loss and excellent high frequency performance, but their low permeability and tedious growth processes severely limit the coupling with on-chip devices and integration with foundry processes. On the other hand, although soft metallic ferromagnets demonstrate high permeability and good soft magnetic properties, huge loss and limited ferromagnetic resonance (FMR) frequency hinder their application in microwave devices in mobile communication frequency bands. Therefore, magnetic materials with low loss, high FMR, and also high permeability are highly desirable for integrated RF passive devices [1].

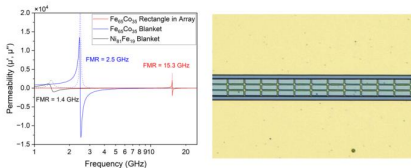


Fig. 1. CPW with Fe<sub>65</sub>Co<sub>35</sub> micropatterns and the frequency-dependent permeability of Fe<sub>65</sub>Co<sub>35</sub>

15.0 GHz was achieved without any external bias fields. To reduce the eddy current loss in this frequency range, Fe<sub>65</sub>Co<sub>35</sub> was deposited as thin film of 200 nm thick. Furthermore, studies have shown that Fe<sub>65</sub>Co<sub>35</sub> exhibits ultralow intrinsic damping [2]; thus, this choice of material ensures lower high frequency loss of the device near FMR. Through micromagnetic simulations, micro-patterns were designed with to reduce the number of domains nucleated and, therefore, reduce potential domain wall losses. High frequency low loss Fe<sub>65</sub>Co<sub>35</sub> micro-patterns were integrated onto coplanar waveguides (CPW) to demonstrate their ability to enhance inductance. A 3.7% increase in line inductance at 10 GHz was achieved while maintaining a high Q factor of 7.3 (compared to 9.9 for CPW without magnets). These results demonstrate great potential for high frequency application of Fe<sub>65</sub>Co<sub>35</sub> micro-patterns in RF passive devices.

## References

- [1] H. Chen *et al.*, "Integrated Tunable Magnetolectric RF Inductors," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 68, no. 3, pp. 951-963, March 2020, doi: 10.1109/TMTT.2019.2957472.
- [2] M. A. W. Schoen *et al.*, "Ultra-low magnetic damping of a metallic ferromagnet," *Nat Phys*, vol. 12, no. 9, pp. 839-842, 2016.

In this work, we designed and fabricated micro-patterned thin film Fe<sub>65</sub>Co<sub>35</sub> with low loss, high permeability (67) and ultra-high FMR (> 10 GHz). Due to Fe<sub>65</sub>Co<sub>35</sub> having the highest known saturation magnetization of 1904.93 emu/cc, the FMR limit of the thin film patterns was predicted to be much higher than those of commonly used ferromagnetic materials (e.g., permalloy). Shape anisotropy was introduced to further enhance the FMR of Fe<sub>65</sub>Co<sub>35</sub> micro-patterns, and an FMR of

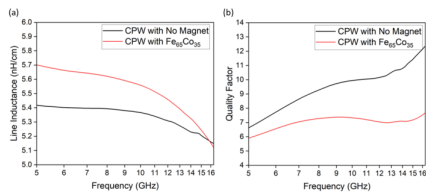


Fig. 2. Extracted line parameters of Fe<sub>65</sub>Co<sub>35</sub> patterned CPW.

# Magneto-resistive Sensors on Flexible Substrates: From Thin Films to Printable Magneto-electronics

Y. Zabala<sup>1,2\*</sup>

<sup>1</sup>HZDR Innovation GmbH, 01328 Dresden, Germany

<sup>2</sup>Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, 01328 Dresden, Germany

\*y.zabala@hzdr.de

The integration of magneto-resistive materials with flexible substrates and additive manufacturing enables compact, multifunctional sensor platforms tailored for advanced magnetic and robotic applications. We present our recent progress in magnetic field sensors operating from the nanotesla regime (<1 mT) up to several Tesla, together with strain and temperature sensors realized using both thin-film technology on polymer substrates and fully printable approaches.

For printable devices, we formulate inks with engineered AMR and GMR responses compatible with screen printing and dispensing. These materials enable conformal, transparent, stretchable, and recyclable magnetic sensors, including self-healable and large non-saturating magneto-resistive systems [1–5]. In parallel, we develop recyclable thermocouple-based temperature sensors and eco-compatible material platforms targeting sustainable and potentially biodegradable electronics [6,7].

For thin-film magneto-resistive sensors, we combine high-sensitivity architectures—including sub-micro-tesla-resolution planar Hall systems—with advanced modulation and digital signal processing [8]. A single functional element can thus simultaneously resolve magnetic field strength and mechanical deformation. This dual-readout concept enables robotic “smart skin” implementations, where magnetic sensing provides distance information while strain sensitivity delivers tactile feedback using one sensor element and a permanent magnet.

A central challenge in flexible resistive sensors is deformation-induced resistance drift. We address this through material-level optimization, cross-sensitivity suppression, and application-specific signal conditioning. The presented approach establishes a materials-driven framework for multifunctional, flexible, and sustainable magneto-electronic sensor systems.

## References

- [1] M. Ha *et al.*, “Printable and stretchable giant magneto-resistive sensors for highly compliant and skin-conformal electronics,” *Adv. Mater.*, vol. 33, 2005521, 2021, doi: [10.1002/adma.202005521](https://doi.org/10.1002/adma.202005521).
- [2] E. S. Oliveros Mata *et al.*, “Dispenser printed bismuth-based magnetic field sensors with non-saturating large magneto-resistance for touchless interactive surfaces,” *Adv. Mater. Technol.*, vol. 7, 2200227, 2022, doi: [10.1002/admt.202200227](https://doi.org/10.1002/admt.202200227).
- [3] R. Xu *et al.*, “Self-healable printed magnetic field sensors using alternating magnetic fields,” *Nat. Commun.*, vol. 13, Art. no. 6587, 2022, doi: [10.1038/s41467-022-34235-3](https://doi.org/10.1038/s41467-022-34235-3).
- [4] X. Wang *et al.*, “Printed magneto-resistive sensors for recyclable magneto-electronics,” *J. Mater. Chem. A*, vol. 12, pp. 24906–24915, 2024, doi: [10.1039/D4TA04567A](https://doi.org/10.1039/D4TA04567A).
- [5] R. Xu *et al.*, “Printed conformal and transparent magneto-resistive sensors for seamless integration and environment-resilient touchless interaction,” *ACS Nano*, vol. 19, pp. 21891–21903, 2025, doi: [10.1021/acsnano.5c07664](https://doi.org/10.1021/acsnano.5c07664).
- [6] X. Wang *et al.*, “Printed recyclable and flexible thermocouple temperature sensors,” *Adv. Sensor Res.*, 2400182, 2025, doi: [10.1002/adsr.202400182](https://doi.org/10.1002/adsr.202400182).
- [7] O. Bezsmerina *et al.*, “Versatile green transfer of magneto-electronics with loss-free performance and high adhesion for interactive electronics,” *Adv. Funct. Mater.*, 2502947, 2025, doi: [10.1002/adfm.202502947](https://doi.org/10.1002/adfm.202502947).
- [8] J. Schmidpeter *et al.*, “Exchange-biased multiring planar Hall magneto-resistive sensors with nanotesla resolution in nonshielded environments,” *IEEE Magn. Lett.*, vol. 15, Art. no. 4100205, 2024, doi: [10.1109/LMAG.2024.3490380](https://doi.org/10.1109/LMAG.2024.3490380).

## Magneto-optical Kerr Microscopy on Non-planar Geometries

Le Zhao<sup>1\*</sup>, Alexander Rabenstein<sup>1</sup>, Miguel Ángel Cascales-Sandoval<sup>1</sup>,  
Naëmi Leo<sup>1,2</sup>, Sabri Koraltan<sup>1</sup>, and Amalio Fernández-Pacheco<sup>1†</sup>

<sup>1</sup>Institute of Applied Physics, TU Wien, Wiedner Hauptstraße 8-10, 1040 Vienna, Austria

<sup>2</sup>Department of Physics, Loughborough University, Epinal Way, Loughborough LE11 3TU, United Kingdom

\*[le.zhao@tuwien.ac.at](mailto:le.zhao@tuwien.ac.at)

†[amalio.fernandez-pacheco@tuwien.ac.at](mailto:amalio.fernandez-pacheco@tuwien.ac.at)

Three-dimensional (3D) magnetic architectures are increasingly explored for next-generation spintronic and integrated magnetic microsystems [1-4]. Patterned and curved magnetic elements appear in applications ranging from advanced sensing to on-chip magnetic functionalities [5,6]. However, quantitative characterization of magnetization in such structures remains challenging as most laboratory techniques are optimized for planar samples. In particular, conventional magneto-optical Kerr effect (MOKE) microscopy, widely used for rapid magnetic imaging, suffers from a shallow depth of field that prevents reliable observation of magnetic domains on tilted or non-planar surfaces.

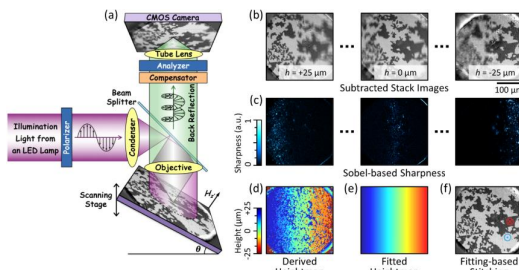


Fig. 1. (a) Schematic illustration of the MOKE microscope used for extended depth-of-field imaging. (b) Representative background-subtracted images acquired at different focal heights. (c) Sharpness evaluation of each subtracted image. (d) Heightmap obtained based on sharpness analysis. (e) Continuous two-dimensional height profile obtained by fitting the discrete height information in (d). (f) Final reconstructed all-in-focus domain image.

In this study, we integrate an extended depth-of-field (EDOF) approach into MOKE microscopy to enable sharp visualization of magnetic domains on 3D architectures. By acquiring multiple focal-plane images and applying focus stacking techniques, we construct a composite image with extended depth coverage, ensuring that all magnetic features remain well-resolved regardless of surface topography. Our approach effectively overcomes the depth-of-field constraints of conventional MOKE microscopy, providing a powerful tool for studying magnetization dynamics on non-planar and genuinely 3D nanostructures.

### References

- [1] A. Fernández-Pacheco et al., “Three-dimensional nanomagnetism,” *Nat. Commun.*, vol. 8, p. 15756, 2017.
- [2] P. Fischer et al., “Launching a new dimension with 3D magnetic nanostructures,” *APL Mater.*, vol. 8, p. 010701, 2020.
- [3] R. Streubel et al., “Magnetism in curved geometries,” *J. Appl. Phys.*, vol. 129, p. 210902, 2021.
- [4] G. Gubbiotti et al., “2025 roadmap on 3D nanomagnetism,” *J. Phys.: Condens. Matter*, vol. 37, p. 143502, 2025.
- [5] A. M. A. Farinha et al., “Interplay of geometrical and spin chiralities in 3D twisted magnetic ribbons,” *Nature*, vol. 639, pp. 67–72, 2025.
- [6] L. Skoric et al., “Domain wall automation in three-dimensional magnetic helical interconnectors,” *ACS Nano*, vol. 16, p. 8860, 2022.

# iSIM 2027

Jeju Island | 9-10 May 2027

International Symposium on Integrated Magnetics  
A satellite event to INTERMAG 2027

Join us for iSIM 2027 in Jeju Island before INTERMAG 2027

9-10 May 2027 in Jeju Island, South Korea, at Jeju International Convention Center (ICC) or Booyoung Hotel, prior INTERMAG 2027

iSIM 2027 covers integrated magnetic materials, devices, and microsystems for applications for use in sensing, integrated circuits, power supply integration, and magneto-electronics.

The symposium will feature invited talks and contributed posters.

We look forward to welcoming you to iSIM 2027!

