# MA 49: Magnetic Information Technology, Recording, Sensing

Time: Friday 9:30–11:45 Location: HSZ 403

MA 49.1 Fri 9:30 HSZ 403

**Spin revolution breaks time reversal symmetry of rolling magnets** — •Elena Vedmedenko and Roland Wiesendanger — University of Hamburg

The classical laws of physics are usually invariant under time reversal. Here, we reveal a novel class of magnetomechanical effects rigorously breaking time-reversal symmetry. These effects are based on the mechanical rotation of a hard magnet around its magnetization axis in the presence of friction and an external magnetic field, which we call spin revolution. The spin revolution leads to a variety of symmetry breaking phenomena including upward propulsion on vertical surfaces defying gravity as well as magnetic gyroscopic motion that is perpendicular to the applied force. The angular momentum of spin revolution differs from those of the magnetic field, the magnetic torque, the rolling axis, and the net torque about the rolling axis. The spin revolution emerges spontaneously, without external rotations, and offers various applications in areas such as magnetism, robotics and energy harvesting.

E. Y. Vedmedenko and R. Wiesendanger, Spin revolution breaks time reversal symmetry of rolling magnets, Sci. Rep. 12, 13608 (2022).

MA 49.2 Fri 9:45 HSZ 403

**Improved Planar Hall Effect sensors for fluid measurement techniques** — •Jan Schmidtpeter, Thomas Wondrak, Denys Makarov, and Yevhen Zabila — Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden Germany

Inductive flow measurement techniques such as the Contactless Inductive Flow Tomography require sensors that provide a magnetic field resolution of 1 nT while operating in magnetic fields of several mT. With advancements in state-of-the-art magnetoresistive thin-film sensors the required behavior regarding sensitivity, precision and hysteresis can be achieved [1]. Planar Hall Effect sensor have been shown to be one of the leading sensor types in this area. Therefore we present a detailed study on the effect of different sensor layouts, geometries, magnetic flux concentrators and other parameters on the characteristics of single layer Permalloy Planar Hall Effect sensors.

[1] Granell, Pablo Nicolás, et al. npj Flexible Electronics 3.1 (2019): 1-6.

MA 49.3 Fri 10:00 HSZ 403

**Towards nanomechanical detection of fT magnetic fields** — Dhavalkumar Mungpara, Torben Hänke, and •Alexander Schwarz — Institute of Nanostructure and Solid State Physics, University of Hamburg, Jungiusstr. 11, 20355 Hamburg

This work has been conducted in the framework of the OXiNEMS project that aims to establish etching protocols for oxides similar to those nowadays available for silicon and to develop a novel all-oxide nano-mechanical sensor to detect bio-magnetic field in the fT-regime required for magnetoencephalography (MEG).

Our envisaged hybrid sensor consists of a superconducting loop with a constriction that functions as field-to-gradient converter and a magnetically sensitive mechanical resonator that detects the Oersted field above the constriction. To increase the signal above the thermal noise limit we present an optimized constriction-resonator arrangement that encompasses a spiral geometry instead of a single constriction. This optimized geometry, can be fabricated using up-to date technology and should be able reach a sensitivity of 10 $\mathrm{fT}/\sqrt{Hz}$ at 77 K.

The OXiNEMS project (www.oxinems.eu) has received funding from the European Union‘s Horizon 2020 research and innovation program under Grant Agreement No. 828784. The author gratefully acknowledges the fruitful discussions with all members of the consortium, particularly Luca Pellegrino, Stefania Della Penna, Alexei Kalaboukhov, Federico Maspero, Nicola Manca, Simone Cuccurullo, Warner Venstra, Daniele Marré and Riccardo Bertacco.

MA 49.4 Fri 10:15 HSZ 403

**Magnetic noise theory of magnetoelastic magnetic field sensors** — •Elizaveta Spetzler[1], Benjamin Spetzler[2], and Jeffrey McCord[1] — [1]Institute for Materials Science, Kiel University, Kiel, Germany — [2]Department of electrical engineering and information technology, Technical University Ilmenau, Ilmenau, Germany

Intrinsic magnetic noise currently limits the performance of many magnetoelastic magnetic field sensors. Therefore, understanding and estimating the magnetic noise level is crucial for further sensor improvement. This work reviews the theory of thermal-magnetic noise in general and discusses additional magnetic noise sources relevant to magnetoelastic magnetic field sensors. We highlight the limitations and assumptions of previous approaches and develop important model extensions. We demonstrate and quantify the strong connection between magnetic sensitivity, loss, and noise by implementing the magnetic noise description in a multilevel model of a magnetoelastic magnetic field sensor based on the $\Delta$E effect. The excellent match of simulations and measurements reveals a significant influence of the fundamental nonlinearity of the $\Delta$E effect on the sensor performance. While the model is applied to $\Delta$E effect sensors, many of the results are also valid for other magnetic field sensors and magnetoelastic modulated devices.

This work was funded by the German Research Foundation (DFG) through the Collaborative Research Centre CRC 1261 ”Magnetoelectric Sensors - From Composite Materials to Biomagnetic Diagnostics” and the Carl-Zeiss Foundation via the Project MemWerk.

**15 min. break**

MA 49.5 Fri 10:45 HSZ 403

**Transfer printing of GMR sensing elements for curved electronics** — •Bezsmertna Olha[1], Rui Xu[1], Eduardo Sergio Oliveros-Mata[1], Clemens Voigt[2], Sindy Mosch[2], Jürgen Fassbender[1], Mykola Vinnichenko[2], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., 01328 Dresden, Germany — [2]Fraunhofer Institute for Ceramic Technologies and Systems IKTS, 01277 Dresden, Germany

In the post-covid era, touchless interaction between human beings and environments is attracting more and more attentions. Sensors based on giant magnetoresistance (GMR) effect are widely considered as a workhorse to address this demand. However, the fabrication of GMR multi-layer elements face many limitations (e.g., inappropriate to substrates with curved and/or rough surfaces) due to the layer thickness dependence of performance. Here, we propose a transfer technique to overcome the aforementioned limitations. With the assistance of two sacrificial layers, a large scale and wrinkle-free coverage is realized on various substrates (of different materials, roughness, and curvatures) with little loss of GMR performance. Notably, such technique is easy processing, without the need of any substrate deformation, temporary carriers or high-temperature processing. The transferred sensors are integrated into skin-mountable electronics, successfully functioning as a human-machine interface.

MA 49.6 Fri 11:00 HSZ 403

**Printed Giant Magnetoresistive Sensors** — •Yevhen Zabila, Eduardo Sergio Oliveros Mata, Minjeong Ha, Gilbert Santiago Cañón Bermúdez, Rico Illing, Ingolf Mönch, Jürgen Fassbender, and Denys Makarov — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Printing is an affordable and high-throughput method to process electronics in soft substrates. Printable magnetoresistive pastes have been developed as an alternative single-step fabrication method to obtain magnetic field sensors. Until now, there were no examples of magnetic printed sensors that deliver steady sensing behavior upon mechanical stretching. Here, we will present low-noise printable magnetic field sensors sensitive down to sub-mT, which are mechanically stretchable after printing. The pastes are composites of poly(styrene-butadiene-styrene) copolymer (SBS) with embedded magnetoresistive microflakes. Our printed sensors were demonstrated to be used as electronic skin interfaces.[1]

[1] M. Ha, Y. Zabila, et. al. Adv. Mater. 33 (12), 2005521 (2021)

MA 49.7 Fri 11:15 HSZ 403

**Printed magnetic field sensors based on bismuth showing large non-saturating magnetoresistance** — •Eduardo Sergio Oliveros-Mata[1], Clemens Voigt[2], Gilbert Santiago Cañón Bermúdez[1], Zevhen Zabila[1], Rico Illing[1], Marco Fritsch[2], Sindy Mosch[2], Mihails Kusnezoff[2], Jürgen Fassbender[1], Mykola Vinnichenko[2], and Denys Makarov[1] — [1]Helmholtz-

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The development of functional inks allows to create novel printed electronics with unconventional form factors. Here, we show the fabrication of printed magnetic field sensors based on bismuth microparticles. Sensors showed non-saturating large magnetoresistance (146%, 5T, at room temperature), and resilience to mechanical bending (2000 cycles). We demonstrated large area magnetically sensitive interfaces such as smart locks and interactive wallpapers.[1]

[1] E.S. Oliveros-Mata, C. Voigt, et al. Adv. Mater. Technol. 2200227 (2022)

MA 49.8 Fri 11:30 HSZ 403

**Self-healable printed magnetic field sensors using alternating magnetic fields** — •Rui Xu[1], Gilbert Santiago Cañón Bermúdez[1], Oleksandr V. Pylypovskyi[1], Oleksii M. Volkov[1], Eduardo Sergio Oliveros Mata[1], Yevhen Zabila[1], Rico Illing[1], Pavlo Makushko[1], Pavel Milkin[2], Leonid Ionov[2], Jürgen Fassbender[1], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]University of Bayreuth, Ludwig Thoma Str 36a, 95447 Bayreuth, Germany

Percolation network of fillers plays a critical role in rendering printable electronics functionality and durability1. We employ alternating magnetic fields (AMF) to drive magnetic fillers actively and guide the formation and self-healing of percolation networks2. Relying on AMF, we fabricate printable magnetoresistive sensors revealing an enhancement in sensitivity and figure of merit of more than one and two orders of magnitude relative to previous reports. These sensors display low noise, high resolution, and are readily processable using various printing techniques that can be applied to different substrates. The AMF-mediated self-healing has six characteristics: 100% performance recovery; repeatable healing over multiple cycles; room-temperature operation; healing in seconds; no need for manual reassembly; humidity insensitivity. By virtue of these advantages, the AMF-mediated sensors are used in safety application, medical therapy, and human-machine interfaces for augmented reality. 1 Nat. Electron. 2, 144-150 (2019); 2 Nat. Commun. 13, 6587 (2022).