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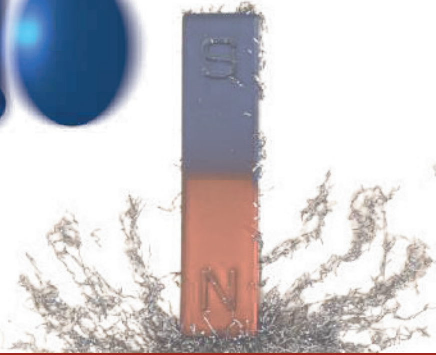

NEUMOSENSOR
AND OTHER APPLICATIONS OF NANOMAGNETISM TO BRIDGE SCIENCE, INDUSTRY, AND SOCIETY

BOOK OF ABSTRACTS

JULY 12, 2024

NEUMO SENSOR

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NEUMOSENSOR AND OTHER APPLICATIONS OF NANOMAGNETISM TO BRIDGE SCIENCE, INDUSTRY, AND SOCIETY

Start Time	Program		
10:00	Opening		
	Chair: Margo Hauwaert		
10:02	**NEUMOSENSOR project: A general overview**	Montserrat Rivas	Universidad de Oviedo (Spain)
10:10	**Magnetic Nano- and Microstructures for Unambiguous MRI Contrast Generation and Sensing**	Samuel Oberdick	University of Colorado (USA)
10:40	**Antibodies, Antigens, and Nanoparticles: Beyond a Simple Affinity Union**	María Dolores Cima Cabal	Universidad Internacional de la Rioja (Spain)
10:55			
	Chair: María Salvador		
11:15	**Low-Anisotropy Magnetic Nanoparticles for Inductive Detection in Lateral Flow Assays**	Vanessa Pilati	Universidad de Oviedo (Spain)
11:45	**Sensors for food technology**	José Manuel Costa Fernández	Universidad de Oviedo (Spain)
12:00	**Key design features in magnetoresistive sensors for bio applications**	Diana C. Leitao	Eindhoven University of Technology (The Netherlands)
12:30			
	Chair: Vanessa Pilati		
14:00	**High precision quantification of magnetic nanoparticles using inductive sensors**	José Luis Marqués-Fernández	Universidad de Oviedo (Spain)
14:15	**Magnetic Nanocatalysis: from Environmental Remediation to Alternative Energies**	Álvaro Gallo-Cordova	Instituto de Ciencia de Materiales de Madrid CSIC (Spain)
14:45	**NanoGap: The view from a company**	David Buceta	NanoGap SL (Spain)
15:00	**Táctica SL: An entrepeuner journey**	Buba	Táctica Industrial SL Spain)
15:15	Closing remarks	Montserrat Rivas & María Salvador	
15:20			
16:30	Pneumosensor Meeting *Only for NEUMOSENSOR CONSORTIUM PARTICIPANTS		
17:30			

IEEE NANO24 - Workshops Day

LABORAL CIUDAD DE LA CULTURA, GIJÓN

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Magnetic Nano- and Microstructures for Unambiguous MRI Contrast Generation and Sensing

Samuel Oberdick (samuel.oberdick@nist.gov), Kalina Jordanova, John Lundstrom, Giacomo Parigi, Megan Poorman, Kathryn Keenan, Stephen Dodd, Alan Koretsky, Gary Zabow

University of Colorado Boulder, USA

Magnetic resonance imaging (MRI) is a non-invasive biomagnetic imaging technique that produces three-dimensional images of human anatomy. MR images can be enhanced using contrast agents, which are exogenous magnetic materials that interact with resonant protons in tissue and modify image characteristics. Iron oxide-based magnetic nanoparticles (MNPs) have long been researched as MRI contrast agents and are usually thought of as negative contrast agents. That is, MNPs dephase signal from water protons and result in a region of decreased signal on an MR image. However, new technological advancements related to low-field MRI scanners and, separately, microfabrication of magnetic nanoparticle constructs have created new opportunities for contrast generation that move beyond negative contrast. In this talk, I will describe new pathways for magnetic nanoparticle-based MRI contrast using low-field MRI and also "color" contrast with magnetic microstructures.

First, I will describe possibilities for using MNPs as positive contrast agents with low-field MRI (LF-MRI). While MNPs can be used as positive contrast agents for clinical and high field MRI, the MNPs need to be specially synthesized with sizes of 3 nm or smaller. Here, I will discuss using FDA-approved contrast agents, like Ferumoxytol, as well as commercially available iron oxide MNPs with sizes of 5 nm to 16 nm for positive contrast at low field. LF-MRI scanners require less infrastructure than clinical MRI scanners and can be wheeled next to a patient's bedside, creating revolutionary possibilities for point-of-care diagnostics. I will present experiments using an FDA-approved, 64 mT MRI scanner to evaluate the potential of MNPs as contrast agents for LF-MRI. At 64 mT, MNPs show enhanced longitudinal relaxivity (r_1) and reduced transverse relaxivity (r_2) compared to 3 T. Moreover, MNPs have a size-dependent r_1 that is up to 8x larger than a common Gd-based contrast agent (Gd-BOPTA), suggesting that MNPs may outperform traditional positive contrast agents at lower fields [1].

Secondly, I will describe how specially shaped MNP-polymer microparticles can be used as RF-addressable, "color" MRI contrast agents at high magnetic fields (9.4 T). "Color" contrast is a unique form of contrast that uses three-dimensional magnetic microstructures to produce a distinct frequency readout [2]. I will describe a new way for producing MNP-polymer microparticles that generate spectral shifts that are tens of times larger than familiar NMR chemical shifts, providing an RF-identifier that is spectrally distinct from the environment. I will also show that the particles can be made of environmentally sensitive "smart" polymers for use as sensors [3].

[1] S. D. Oberdick et al., Scientific Reports, 13, 2023.
[2] G. Zabow et al., Nature, 453, 2008.
[3] S. D. Oberdick et al., ACS Sensors, 9, 2024.

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I am an experimental physicist and a research associate at the National Institute of Standards and Technology (NIST) where I work with the Magnetic Imaging Group (MIG). I am also a research associate with the Department of Physics at CU Boulder. My research is focused on the intersection of magnetic nanotechnology, biosensing and medical imaging.

I received my BA in Physics (with honors) from The University of Chicago in 2010 and a PhD in Physics from Carnegie Mellon University in 2016. At Carnegie Mellon, I performed my PhD work in Professor Sara Majetich's group and wrote my dissertation on patterned magnetic nanostructures.

Following my PhD, I was awarded a National Research Council (NRC) Postdoctoral Fellowship. I performed my NRC fellowship at NIST, Boulder, where I was advised by Dr. Gary Zabow. During my postdoc, I researched novel MRI contrast agents and magnetic signal transduction in magnetic nanoparticle/polymer composites.

Currently, I am interested in using magnetic signals to learn about biological and soft matter systems.

Antibodies, Antigens, and Nanoparticles: Beyond a Simple Affinity Union

María Dolores Cima Cabal (dolores.cima@unir.net), Mar García Suarez
ESIT, Universidad Internacional de La Rioja

This talk is about the interplay between antibodies, antigens, and nanoparticles. We often think of antibodies and antigens in terms of their basic biological interactions, but when we introduce nanoparticles into the mix, we open up a whole new world of possibilities. In fact, Nanoparticle-antibody conjugates hold significant promise in enhancing the specificity and efficacy of cancer treatments. While several candidates are in clinical phases, ongoing research and clinical trials will determine their potential to become standard therapeutic options in the future. These innovative therapies represent a significant step towards personalized and precision medicine in oncology.

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Low-Anisotropy Magnetic Nanoparticles for Inductive Detection in Lateral Flow Assays

Vanessa Pilati (pilativanessa@uniovi.es), Maria Salvador, Leyre B. Fraile, José Luis Marqués-Fernández, José Carlos Martínez-García, Montserrat Rivas

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Laboratório de Nanociência Ambiental e Aplicada - Universidade de Brasília, Brasília, Brazil

Rapid diagnostic tests using lateral flow immunoassays (LFIAs) are commonly used as point-of-care devices for detecting various diseases. These paper-based tests rely on microfluidics and biorecognition to deliver quick and qualitative results. Commercial LFIAs use colloidal gold labels, which produce a visible positive/negative test line. Quantifying the bio-analyte is sometimes crucial, but it remains a challenging task.
Magnetic nanoparticles can also be used as nanolabels in LFIA, offering optical and magnetic signals. They are detectable and quantifiable by magnetic sensors and can be utilized for sample pre-treatment to enhance the sensitivity and specificity of the immunoassay. Iron oxide nanoparticles and nanoclusters have been investigated as magnetic labels to detect and quantify histamine in wine[2], Streptococcus pneumoniae[3], and cancer biomarkers[4], among others.
In this talk, we will discuss the role of magnetic properties in magnetic detection using inductive sensors and the impact of the magnetic anisotropy of nanoparticles on detection sensitivity and resolution. We will explore how low magnetic anisotropy nanoparticles and their assemblies can enhance the magnetic signal and present some results using manganese ferrites, magnetite, and maghemite nanoparticles. This would be useful for further developing LFIAs to detect and quantify several biomarkers with high sensitivity.

Acknowledgments
This work was partially founded by the Ministry of Science and Innovation of the Spanish Government through grant PLEC2022-009490, the University Technological Institute of Asturias (IUTA) under grant SV-22-GIJON-18, and the Government of the Principality of Asturias under projects FICYT/IDI/2021/000100 and FICYT/IDI/2021/00027 3.
M.S. was supported by a "Severo Ochoa" fellowship (Consejería de Educación y Cultura del Gobierno del Principado de Asturias, grant BP19-141) and by the Margarita Salas fellowship financed by the European Union-NextGenerationEU and the Plan for Recovery, Transformation and Resilience.

[1] Liu Y. et al. ACS Nano 15 (2021), 3593
[2] Moyano, A. et al. Analytical and Bioanalytical Chemistry 411 (2019) 6615
[3] Salvador, M. et al. Nanomaterials 12 (2022) 2044
[4] Moyano, A et al. Sensors 21 (2021), 3756.
[5] Lago-Cachón, D. et al. Journal of Magnetism and Magnetic Materials 423 (2017) 436–440

Sensors for food technology

José Manuel Costa Fernández (jcostafe@uniovi.es)
Departamento de Química Física y Analítica - Universidad de Oviedo, Gijón, Spain

Food-borne illnesses remain a significant global health concern, particularly in low-income countries and rural areas. While traditional methods for detecting food-borne bacteria are accurate, they are time-consuming and require trained personnel. In recent years, nanotechnology-based approaches have gained popularity for rapid food pathogen detection. Specifically, metal nanoparticles with surface plasmonic properties and semiconducting nanoparticles with photo-luminescence properties, along with their hybrids, have been explored for point-of-care testing (POCT)–based food biosensors.
In this presentation an overview will be provided on the use of metal nanoparticles, surface functionalized with genetic material, for decentralized targeted pathogen identification. Special emphasis will be given regarding the need of an appropriate characterization of the bioconjugated nanomaterials to ensure an efficient application.

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Key design features in magnetoresistive sensors for bioapplications

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Department of Applied Physics, Eindhoven University of Technology, The Netherlands

Magnetoresistive sensors can deliver high sensitivity and spatial resolution in magnetic field detection [1]. These advantages make them competitive actors for developing portable and compact biomedical platforms targeting, for example, imaging of bio-magnetic fields or detecting magnetically tagged entities. Still, the requirements that the sensing devices have to meet are highly specific to the final applications and, in some cases, pose exciting challenges from the nanomaterials and device design perspectives. In this presentation, I will address successful strategies to (1) push the limits of detections towards the measurements of brain signals and (2) design large area sensors for magnetic signal quantification, which have to be compatible with the media where the magnetic particles are flowing.

[1] C Zheng et al. IEEE Transactions on Magnetics 55 (2019) 1-30

Diana Leitao graduated in Applied Physics from University of Porto, and has a PhD in Physics from University of Porto and Materials Science Institute of Madrid ICMM-CSIC. She then joined INESC Microsystems and Nanotechnologies in Lisbon, first as a postdoctoral researcher, and later as a FCT Investigator Starting Grantee to lead her research line in magnetic nanodevices. Since September 2021 she has been an Assistant Professor at Eindhoven University of Technology. Her research focus is on exploring novel thin-film stackings, designs, and hybrid technology integration to improve the performance of magnetoresistive sensing devices and provide added functionalities. Diana Leitao actively contributes to the international magnetism community via IEEE Magnetics Society and European Magnetism Association (EMA). She is also involved in the organization of main conferences in her research area.

High Precision Quantification of Magnetic Nanoparticles Using Inductive Sensors

J.L. Marqués, J.Martínez-García, V.Pilati, M.Salvador, M. Rivas
Department of Physics, University of Oviedo.Spain

Experimental magnetic rapid diagnostic test (MRDT) requires quantification of magnetic nanoparticles (MNP) in the range of nanograms [1]. For years numerous research groups have tried to provide an affordable and compact solution to quantify these MNPs. A recent aproach in the usage of inductive sensor for quantify disperse materials called inductive radiofrequency refractometry, can breach the sensitivity gap and realize affordable MRDT.

Radiofrequency refractometry uses the inductive sensor's self-resonant frequency (SRF) to quantify magnetic nanoparticles [2]. The sensor's SRF measure is the technology's main roadblock. In previous work [2] this measurement was performed with a vector network analyzer. Many developments have used oscillators as a cost effective solution to measure the self-inductance of inductive sensors. The cost-effectiveness comes from the ease of measurement of frequency-type signals using common digital electronics. However, there is no practical solution for measuring the pure SRF of an inductor.

To provide an ultra-sensitive sensor for quantifying MNPs, we have developed our own oscillator design to obtain the inductive sensor SRF. To achieve this, we have modified an astable oscillator tuned to the sensor's SRF. This design enables us to leverage the full sensitivity of inductive sensors for quantifying MNPs. Our oscillator uses common and recent components in a compact package with high stability while providing differential signaling.

We have built various prototypes, achieving quantification abilities in the order of 100 ng of MNPs. Based on this technology, we have developed a new generation of sensors with improved capabilities targeting the measurement of MRDT.

[1] Salvador, M. et al. "Biological and Medical Applications of Magnetic Nanoparticles" Springer: Cham, Switzerland,
2021; pp. 771–804.
[2] J.L. Marqués-Fernández et al. "New Perspective on Planar Inductive Sensors: Radio-Frequency Refractometry for Highly Sensitive Quantification of Magnetic Nanoparticles", Sensors 2023. 23, 2372.

Fig. 1A Linear model of the astable tuned oscillator.

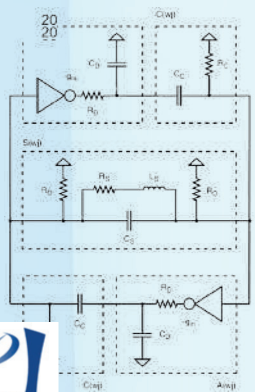
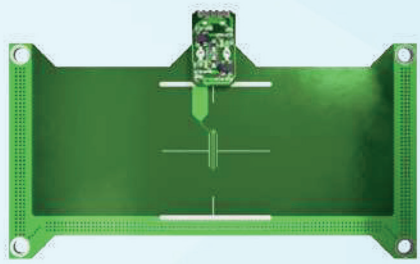


Fig 1B Oscillator and inductive sensor



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Magnetic Nanocatalysis: from Environmental Remediation to Alternative Energies

Álvaro Gallo-Córdova (alvaro.gallo@csic.es)
Department of Nanoscience and Nanotechnology, Institute of Materials Science of Madrid ICMM/CSIC (Spain)

This talk explores the development of efficient magnetic nanocatalysts designed to enhance reaction rates through magnetic induction heating. In this sense, the main focus is on synthesizing iron oxide nanoparticle-based nanocatalysts using a sustainable method that combines microwave irradiation with the polyol procedure.
This approach allows precise control over the size, shape, anisotropy, and aggregation of the nanoparticles. The synthesized nanocatalysts were rigorously tested for their effectiveness in various applications, including the degradation of real wastewater and emergent contaminants, the efficient production of biodiesel, and carbon capture and conversion. The results demonstrate the potential of these magnetic nanocatalysts to address critical environmental and energy challenges through innovative catalytic processes.

Alvaro Gallo Cordova is a postdoctoral researcher at the Institute of Materials Science of Madrid in the Materials for Medicine and Biotechnology group. His principal research focuses in the advancement of magnetic nanoparticles for environmental and catalytic purposes assisted by magnetic fields. In March of 2022, he earned his doctoral degree in Advanced Materials and Nanotechnology and has garnered recognition with awards from the Autonomous University of Madrid, IEEE Magnetics Society, Madrid City Council, and most recently, the Young Researcher Award from the European Magnetism Association.
His recent investigations notably include unraveling the formation process and scalability of multinuclear nanostructures. These endeavors have led to breakthroughs in applications such as biodiesel production assisted by magnetic induction heating and the magnetic extraction and degradation of microplastics.

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