INTERNATIONAL WORKSHOP ON DYNAMICAL MAGNETIZATION PHENOMENA IN NANOMATERIALS:

FROM MAGNETIC LOSSES TO PARTICLE IMAGING

BOOK OF ABSTRACTS

SEGOVIA

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INTERNATIONAL WORKSHOP ON DYNAMICAL MAGNETIZATION PHENOMENA IN NANOMATERIALS:

FROM MAGNETIC LOSSES TO PARTICLE IMAGING

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- **Magnetic Particle Imaging (MPI)**
- **Magnetic heating** for biomedicine, catalysis and environmental applications
- **Magnetic sensing and transduction**
- **In silico modelling** of dynamical magnetization phenomena
- **Metrology and standardisation** in magnetic nanomaterials research

Participation in the workshop is free of charge upon registration.

Invited Speakers

- Lise Marie Lacroix (INSA Toulouse, France)
- Volker C. Behr (University of Würzburg, Germany)
- Pilar Marín (Universidad Complutense de Madrid, Spain)
- Aidin Lak (TU Braunschweig, Germany)
- Delphine Felder-Flesch (Superbranche, France)
- Álvaro Gallo-Córdova (ICMM-CSIC, Spain)

Important Dates and registration

- **Abstract submission:** 24/11–20/12 2025. Registration is free: **click here to register**.

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Venue: Hotel San Antonio el Real. **Google Maps**

Organising Committee: Francisco J. Teran (Nanotech Solutions/IMDEA Nanoscience), Daniel Ortega Ponce (Universidad de Cádiz), Helena Gavilán (Universidad Complutense de Madrid) and NexMPI COST Action.

INTERNATIONAL WORKSHOP ON DYNAMICAL MAGNETIZATION PHENOMENA IN NANOMATERIALS: FROM MAGNETIC LOSSES TO PARTICLE IMAGING

Table of contents

Understanding Magnetic Nanoparticles in Biological Systems: from theoretical foundations to hands-on experimental investigation

Lucía Gutiérrez

Type of abstract: Hands-on session

Magnetic nanoparticles (MNPs) are increasingly explored for biomedical applications, however, their successful translation from the laboratory to clinical practice requires a solid understanding of how nanoparticles interact with biological systems at multiple levels. This tutorial is designed for researchers from physics, chemistry, and materials science backgrounds who work with magnetic nanoparticles but may lack formal training in biology. The tutorial provides a comprehensive overview of nanoparticle biological interactions, from fluids to cells and the whole organism, emphasizing common pitfalls and often overlooked factors.

The first part of the tutorial focuses on interactions at the **fluid level,** introducing the concept of the protein corona and its central role in defining the biological identity of nanoparticles. We discuss the dynamic nature of protein adsorption, the distinction between hard and soft corona, and how nanoparticle properties such as size, surface charge, hydrophobicity, and coating influence corona composition. The implications of protein corona formation for biodistribution, circulation time, and cellular response are highlighted. In addition, nanoparticle sterility is addressed, with particular emphasis on endotoxin contamination, its biological consequences, regulatory limits, and best practices to prevent endotoxin-related artifacts in biological experiments.

The second part addresses interactions at the **cellular level**, covering cell culture models (2D vs. 3D), delivered dose versus nominal concentration, and the importance of dynamics and local concentration effects. Mechanisms of nanoparticle uptake, including phagocytosis, clathrin- and caveolin-mediated endocytosis, macropinocytosis, and pinocytosis, are presented in a comparative manner. The fate of nanoparticles, including exocytosis, degradation or accumulation, and its relevance for therapeutic timeframes is discussed. The tutorial also examines nanoparticle-induced toxicity.

The final part explores interactions at the **organism level,** addressing administration routes, biodistribution, clearance mechanisms, and accumulation in specific organs. Key concepts such as the enhanced permeability and retention (EPR) effect, heterogeneous nanoparticle distribution, and their implications for treatment efficacy are discussed. The tutorial further introduces commonly used animal models and reviews in vivo and ex vivo techniques for tracking nanoparticles, emphasizing the importance of combining complementary methods to obtain reliable global and local information.

Overall, this tutorial provides a practical and integrative framework to help non-biologists critically design, interpret, and troubleshoot biological experiments involving magnetic nanoparticles, bridging the gap between nanomaterials science and biology.

Hands-on session description: The two-hour hands-on session focuses on the magnetic characterization of magnetic nanoparticles interacting with biological systems (cells or proteins). Participants will perform dynamical magnetization measurements to investigate how key magnetic properties, such as magnetic moment, magnetic losses and dynamic response, change upon biological interaction. By comparing measurements before and after cellular association, the session will underline the influence of the biological environment on nanoparticle behavior and demonstrates how magnetic characterization can be used as a sensitive tool to probe nanoparticle–cell interactions and assess their implications for biomedical applications.

Thermal therapies with nanoparticles: magnetic hyperthermia, photothermia and their combination in multimodal strategies: from theoretical foundations to hands-on experimental investigation

Ana Espinosa

Type of abstract: Hands-on session

Thermal therapies based on nanoparticles have emerged as powerful strategies for localized cancer treatment. This talk introduces the physical and biological fundamentals of nanoparticle-mediated thermal therapies, focusing on magnetic hyperthermia and photothermal approaches. We discuss the mechanisms of heat generation, thermal effects at the nanoscale and key parameters governing therapeutic efficiency and safety. Finally, we outline the rationale for combining these modalities in multimodal strategies, highlighting their potential to enhance spatial control, therapeutic efficacy and integration with complementary therapeutic techniques.

Hands-on session Description: The two-hour hands-on session introduces participants to thermal therapies based on nanoparticles, with a focus on magnetic hyperthermia, photothermal heating, and their combination in multimodal treatment strategies. Participants will carry out calorimetric and dynamical magnetization measurements under alternating magnetic fields in different magnetic nanoparticle systems. SAR values will be determined and compared across nanoparticle systems and excitation conditions, the session illustrates how intrinsic material properties and external parameters govern thermal performance.

Exploiting the non-linear dynamic magnetic behavior of magnetic nanoparticles in biomedical imaging: from theoretical foundations to hands-on experimental investigation

Wiekhorst Frank

Type of abstract: Hands-on session

Magnetic nanoparticles (MNP) have emerged as versatile constituents in biomedical applications due to their unique magnetic behavior and tunable physicochemical properties.

Key particle characteristics such as core size, magnetic anisotropy, relaxation dynamics, and surface functionalization enable their use in applications such as biomolecule detection, targeted drug delivery, hyperthermia, biosensing, and imaging. However, the success of most of these MNP-based applications are crucially hampered by changes of their properties when exposed to physiological environments.

Magnetic Particle Imaging (MPI), a quantitative and highly sensitive imaging modality that detects the non-linear dynamic magnetic response of MNP relies in the same manner on the availability of tailored nanoparticles. MPI operates by spatially encoding the MNP response magnetic gradient fields (to saturate the dynamic MNP response) and dynamic drive fields, using concepts such as the field-free point, field-free line, and two different image reconstruction schemes including system-function and x-space approaches. Since its introduction in 2005, MPI has progressed from benchtop prototypes to advanced preclinical systems and is now moving toward human-scale applications. Throughout this development, MNP performance has proven to be a critical parameter determining the imaging quality and sensitivity, but very often ignoring the changes of MNP properties due to physiological environments.

Therefore, accurately characterizing MNP behavior for MPI requires dedicated measurement techniques probing the non-linear dynamic response of MNP with high sensitivity, examples are zero-dimensional Magnetic Particle Spectroscopy (MPS) systems or AC-hysteresis (ACH) systems. Each approach comes along with different frequency and field amplitude ranges and offers distinct advantages and limitations.

In this talk, I will introduce the fundamental principles of MPI and the corresponding measurement techniques MPS and ACH to determine the MPI performance of MNP emphasizing and demonstrating that conventional physical magnetic parameters (e.g., size, saturation magnetization) are often insufficient predictors of MPI performance in biomedical applications.

Hands-on session Description: During the two-hour hands-on session, participants will be introduced into the handling of an inductive magnetometer, measuring the magnetic moment and harmonic analysis of different magnetic nanoparticles. Demo will include the application of alternating magnetic field with varying field amplitude and frequency. By analyzing the resulting harmonics, participants will compare the nonlinear magnetic behavior of magnetic nanoparticles systems in different media, and discuss how biological entities (proteins or cells) influence the magnetization harmonics when interact with magnetic nanoparticles

Understanding Magnetic Nanoparticles in Biological Systems: from theoretical foundations to hands-on experimental investigation

Lucía Gutiérrez

Type of abstract: Hands-on session

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Coercivity-Size Map of Magnetic Nanoflowers: Elucidating the Hyperthermia Sweet Spot

Elizabeth M. Jefremovas, Lisa Calus, Jonathan Leliaert

Type of abstract: ORAL

Iron-oxide nanoflowers (NFs) are one of the most efficient nanoheaters for magnetic hyperthermia therapy. However, the physics underlying the dynamic response of realistic nanoparticles, containing disorder, beyond the single-domain limit remains poorly understood. Using large-scale micromagnetic simulations, the magnetization of biocompatible iron-oxide NFs ($d = 10–400$ nm) has been mapped, connecting their microstructure to their macroscopic magnetic response. Above the single-domain regime ($d > 50$ nm), the magnetization folds into a vortex state, within which the coercivity reaches a secondary maximum, not present for nondisordered nanoparticles. The dynamics of the vortex shows two distinct reversal modes: 1) a core-dominated one, with an increasing coercivity with d; 2) a flux-closure-domains dominated reversal mode, with a decreasing coercivity-size dependence. The coercivity maximum is located at the transition between both reversal modes and results from the combination of grain anisotropy and grain-boundary pinning. The results provide the first description of spin textures in iron oxide NFs beyond the macrospin framework, revealing how particles with identical static magnetization exhibit fundamentally distinct dynamics, which result in different macroscopic behavior. By adjusting the grain size, the coercivity “sweet spot” can be tailored, offering a practical route to next-generation, high-efficiency nanoheaters.

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Microwave-assisted synthesis of core-shell MNP@UiO-66 nanocomposites for magnetic hyperthermia

Samuel Funes-Hernando, Josef Kopp, Giulia Zampini, Sajid Fazal, Manuel Ceballos, Pablo Del Pino, Beatriz Pelaz

Type of abstract: ORAL

The reproducible synthesis of phase-pure magnetite magnetic nanoparticles (MNPs) remains challenging, often limited by factors such as reaction time, temperature control, and batch-to-batch variability. Microwave-assisted synthesis offers an effective solution to these issues, enabling rapid and facile nanoparticle preparation while improving reproducibility. In this approach, reactions are carried out in closed quartz vessels under direct microwave control, allowing precise temperature regulation and minimizing human intervention.

Herein, we report a straightforward microwave-assisted synthesis of phase-pure magnetite MNPs, yielding relatively homogeneous particles with excellent magnetic properties. In addition, a PEGylation protocol was developed to render the MNPs colloidally stable in polar solvents, enabling their subsequent use as cores for the preparation of core-shell MNP@MOF nanocomposites (NCs). UiO-66 was selected as the MOF shell owing to its well-established properties and exceptional chemical stability, including under cell culture conditions.

The resulting nanocomposites were evaluated for magnetic hyperthermia in A549 cells under exposure to an alternating magnetic field (AMF) within accepted physiological limits. Cell viability measurements revealed a pronounced decrease in the AMF + NCs condition compared to AMF-only or NCs-only controls. Notably, no significant bulk temperature increase was detected, suggesting the generation of highly localized intracellular heating without perturbing the extracellular environment.

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Temperature and Viscosity Mapping by Magnetic Particle Imaging

Simão Pinto

Type of abstract: ORAL

Magnetic Particle Imaging (MPI) is a non-ionizing imaging modality that offers high temporal resolution and exceptional sensitivity to the magnetic signatures of tracer particles. By employing temperature and viscosity-sensitive tracers, MPI has the potential to provide real-time temperature and viscosity imaging, offering a valuable tool for experimental research and eventually clinical applications.

Thus, the main aim of my research is to achieve sub-second 3D Temperature and Viscosity Image Reconstruction, with great accuracy, using MPI.

For viscosity mapping, a group of tracers comprised of samples with different viscosities were developed and subsequently tested in an MPI equipment, to construct a SM. The 5 ferrofluid sample's viscosity was tuned by adding different concentrations of dextran to each one, resulting in viscosities ranging from 0.80 cP to 1.43 cP. The 3 mm wide samples were scanned at 21 different positions, in a plane perpendicular to the bore's vertical axis – with 2mm steps. For this SM, a gradient of 3 T/m was used, with spectral information englobing harmonics from the 3rd to the 9th harmonic. The final reconstructions using the SM were spatially reliable, although noisy, specially for the highest viscosity samples.

For temperature mapping, a group of temperature-sensitive tracers were developed and subsequently tested in an MPI equipment, to construct a System Matrix (SM). Thus, a 2 mm wide powder sample was scanned at 25 different positions, in a 5x5 grid plane – parallel to the bore's vertical axis – with 2mm steps. For each position, it was measured the sample's signal in the temperature range of 45.50 ºC to 52.90 ºC with steps of 0.20 ºC. In order to achieve that, a pressurized air heating system was installed, with temperature control precision of 0.10 ºC. For this SM, a gradient of 3 T/m was used, with spectral information englobing harmonics from the 3rd to the 13th harmonic. This work resulted in a System Matrix based two-dimensional temperature reconstruction, achieving spatial resolution of 2 mm and maximum temperature resolution of 0.20 ºC, within the temperature range of 45.50 ºC to 52.90 ºC, with an acquisition time of 200 ms.

In conclusion, the use of temperature and viscosity-sensitive magnetic tracers in MPI systems can enable accurate image reconstruction of these parameters. These initial results represent an important step towards three-dimensional temperature and viscosity imaging, which holds significant potential for advancing biomedical applications.

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Exploiting the non-linear dynamic magnetic behavior of magnetic nanoparticles in biomedical imaging

Wiekhorst Frank

Type of abstract: ORAL

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Key particle characteristics such as core size, magnetic anisotropy, relaxation dynamics, and surface functionalization enable their use in applications such as biomolecule detection, targeted drug delivery, hyperthermia, biosensing, and imaging. However, the success of most of these MNP-based applications are crucially hampered by changes of their properties when exposed to physiological environments.

Magnetic Particle Imaging (MPI), a quantitative and highly sensitive imaging modality that detects the non-linear dynamic magnetic response of MNP relies in the same manner on the availability of tailored nanoparticles. MPI operates by spatially encoding the MNP response magnetic gradient fields (to saturate the dynamic MNP response) and dynamic drive fields, using concepts such as the field-free point, field-free line, and two different image reconstruction schemes including system-function and x-space approaches. Since its introduction in 2005, MPI has progressed from benchtop prototypes to advanced preclinical systems and is now moving toward human-scale applications. Throughout this development, MNP performance has proven to be a critical parameter determining the imaging quality and sensitivity, but very often ignoring the changes of MNP properties due to physiological environments.

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Non-spherical Fe3O4 Nanoparticles with Tunable Morphology and Magnetic Properties: From the Synthesis to their Theranostic Properties

Alejandro G. Roca, Aritz Lafuente, Javier Muro, Elvira Fantechi, Fatmahan Ozel, Miryana Hemadi, Alberto López-Ortega, Borja Sepúlveda, Josep Nogues

Type of abstract: ORAL

Most of the research performed in maghemite/magnetite nanoparticles has been carried out on isotropic spherical particles. [1] However, during the latest years, non-spherical morphologies such as nanorods and nanocubes have attracted the attention of the scientific community working on magnetic iron oxides due to their anisotropic properties and the potential wide range of applications. Here we present a rationally designed synthesis pathway based on the thermal decomposition to obtain high quality nanocubes [2] and on solvothermal strategies to reach magnetic iron oxide nanorods, both over a wide range of sizes. The nanocubes with an edge length below 17 nm show a great colloidal stability , even after transferring them to water. Moreover, the 17 nm nanocubes exhibit an excellent magnetic hyperthermia and NMR relaxivity performance (better than their spherical counterparts), making them excellent candidates for potential applications in nanotheranostics. In addition, the Fe3O4 nanocubes are outstanding heat mediators for photothermia in the near infrared biological windows (680-1350 nm), with heating efficiencies similar to, or better than, the best photothermal agents [3]. On the other hand, structural and magnetic properties of elongated IONPs between 25 and 400 nm (length) and aspect ratios between 4 and 8 are presented. The magnetic nanorods were synthesized by the solvothermal method using iron organic precursors. Different strategies for their transfer to water have been addressed. We will correlate their magnetic properties with the performance in hyperthermia and MRI applications as a function of the structural and colloidal properties, compared to their spherical equivalents

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Magnetically activated 4D drug-delivery implants

Alberto López

Type of abstract: ORAL

In this work, we present an innovative approach that combines magnetic nanoparticles with biodegradable polymers, commonly used in 3D printing, to fabricate smart (4D) implants designed for controlled, contactless drug delivery. This proposal is based on previous studies that demonstrated, on one hand, the feasibility of using magnetic nanoparticles to regulate drug release via external magnetic fields, and on the other, the fabrication of 3D-printable nanocomposites based on Fe3O4 nanoparticles capable of generating heat under magnetic stimulation.

It is noteworthy that while the nanoparticles act as intelligent elements enabling precise and adjustable drug release,[1] 3D printing simplifies the manufacturing process and significantly reduces production costs. The implants were fabricated using biodegradable polymers, such as polycaprolactone and polylactic acid, which serve as the base structure for incorporating Fe3O4 nanoparticles along with naproxen as a model drug.[2] The resulting devices exhibited a remarkable improvement in temporal and dosage control, demonstrating the ability to release the drug over prolonged periods, up to 200 minutes, with a release capacity 23 times greater than that of the passive material observed at 20 minutes. Moreover, these systems have proven capable of operating in an ON/OFF mode, depending on whether the external magnetic field is activated.

These results highlight the potential of magnetic nanoparticle-based platforms to develop intelligent drug delivery systems that can be tailored to the specific therapeutic needs of each patient.

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SLPcalculator: An Open-Access Tool for Determining Magnetic Nanoparticle Heating Capability by Combining Peak Analysis and F-Test Statistics

Iago López, Yilian Fernandez, Antonio Santana, Sergiu Ruta, Alfredo Amigo, Maria del Puerto Morales, Roy Chantrell, Lucía Gutierrez, David Serantes

Type of abstract: ORAL

The Specific Loss Power (SLP) is widely used to characterize the heating efficiency of magnetic nanoparticles (MNPs) subjected to alternating magnetic fields. Conventionally, SLP can be extracted from calorimetric measurements by analyzing the temporal evolution of the temperature variation curve ΔT(t), using approaches such as the Initial Slope, Box–Lucas or Corrected Slope methods. Nevertheless, it is well established that the SLP values obtained can differ significantly depending on the chosen methodology [1]. This dispersion arises from several experimental and physical factors, including spatial temperature gradients, the simultaneous presence of multiple heat dissipation pathways, and time-dependent colloidal changes during the measurement.

In order to reduce this strong dependence on the experimental setup, we previously introduced an alternative approach known as the Peak Analysis Method (PAM) [2]. This method estimates the SLP from the difference between the time derivatives of the ΔT(t) curve immediately before and after the field on/off maximum, a region where temperature inhomogeneities and competing dissipation mechanisms are largely suppressed. Since the PAM relies on the determination of linear slopes of ΔT(t), a rigorous identification of the time intervals exhibiting linear behavior is essential.

In the present work, we address this issue by defining “linearity” from a formal statistical perspective. Specifically, we implemented an F-test to compare linear and quadratic models, allowing for an objective determination of the temporal windows where the system behaves linearly. This analysis was applied to both the heating and cooling branches surrounding the ΔT(t) peak, using repeated measurements on aqueous suspensions of dextran-coated octahedral iron oxide nanoparticles. The results reveal a well-defined and relatively narrow linear regime, underscoring the necessity of accurately identifying this interval prior to any SLP evaluation.

For completeness, the same statistical treatment was applied to the conventional Initial Slope Method (ISM), which also assumes a linear fitting range. In all cases, the SLP values obtained via PAM were systematically higher than those derived from ISM, in agreement with previous reports indicating that the ISM tends to underestimate the true SLP [3]. Notably, the linear region identified by the F-test is located far from the time window typically selected for ISM fitting.

Finally, as a contribution to ongoing efforts toward the standardization of SLP determination, we have developed an open-access, user-friendly software tool, available online at SLPcalculator.com, which automatically computes the SLP using the PAM within the statistically validated linear range obtained from the F-test. The application is designed to avoid subjective hand-fitting procedures, providing a robust and reproducible estimation of the SLP. For reference and comparison, the software also reports the SLP obtained using the conventional ISM, given its widespread use in the field.

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Computational Insights into Nanoparticle Design for Safe and Effective Magnetic Hyperthermia

Necda CAM, Iago Lopez, Oscar Iglesias, David Serantes

Type of abstract: ORAL

Magnetic fluid hyperthermia (MFH) using magnetic nanoparticles (MNPs) has emerged as a promising approach for treating highly aggressive tumors, such as glioblastoma and pancreatic cancer, which are often resistant to conventional therapies. In MFH, an alternating magnetic field is applied to generate localized heating within the magnetic material. The field amplitude and frequency are carefully controlled to maximize therapeutic heating while minimizing undesired effects on surrounding healthy tissue. Biological safety thresholds, such as the Brezovich limit, set practical constraints for in-vivo applications, emphasizing the need for precise nanoparticle design [1].

In this work we use a computational model to study how particle shape (beyond the usual "spherical particles with uniaxial anisotropy" approach) defines heating performance under constrained field conditions. Based on a model previously reported [2], we simulate the behaviour of systems of magnetite nanoparticles in the framework of the macrospin approximation, in terms of their intrinsic magnetocrystalline anisotropy plus a uniaxial one (of shape origin). Dynamic hysteresis curves were generated using the OOMMF software [3] to evaluate heating efficiency under physiologically relevant magnetic field thresholds. This approach allows for the assessment of realistic particle geometries beyond the common idealization of perfect spheres. Our findings demonstrate that even small deviations from spherical shape can induce substantial changes in the specific loss power (SLP), highlighting the critical influence of particle shape and anisotropy on hyperthermia efficiency. These results provide practical guidance for the optimization of MNP design in clinical MFH treatments, suggesting that careful control of particle morphology could enhance therapeutic outcomes while respecting safety limits.

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COMPASS: New directions for the investigation of magnetic nanoparticle dynamics

Johanna Guenther, Thomas Kampf, Teresa Reichl, Martin Rückert, Volker Behr, Patrick Vogel

Type of abstract: ORAL

Magnetic nanoparticles (MNPs) have gained significant importance in biomedical research, since they enable many applications ranging from controlled drug release to magnetic hyperthermia and highly sensitive diagnostics [1]. However, their performance critically depends on well controlled and stable particle properties, emphasizing the need for advanced characterization techniques capable of resolving subtle changes in particle behavior.

Spectroscopic methods enable a detailed analysis of the magnetization response of magnetic nanoparticles to an external magnetic field, providing insights into particle properties and properties of the surrounding medium [1]. However, established methods like magnetic particle spectroscopy (MPS) or AC susceptometry are limited to either dynamic magnetic fields (HAC) only or a combination of a small range of static (HDC) and dynamic fields (HAC) for excitation. This leaves a previously unexplored range of possible HAC and HDC combinations, which may provide further insights into the properties and behavior of the particles. This is where the Critical Offset Magnetic Particle Spectroscopy (COMPASS) comes in, superimposing both HDC and HAC excitation amplitudes in a range from 0 to 25 mT [2].

For COMPASS, the magnetic response of each combination of a fixed HAC amplitude and a range of HDC amplitudes is measured, the complex spectrum is evaluated, and the course of each individual higher harmonic in dependency of HDC is analyzed. A dedicated data processing routine allows to extract Chebyshev-like polynomials for each higher harmonic from the complex spectra containing information-rich features about the MNPs [3]. The phase evolution in dependency of the HDC field for each individual higher harmonic exhibits a range of steep changes in the vicinity of distinct nodes in the curve, which are referred to as critical points (CPs). This measurement scheme can be extended by acquiring data for a whole range of discrete HAC amplitudes resulting in two-dimensional patterns for each higher harmonic, extending CPs to line structures. For better visualization, the derivative of the phase is calculated, displaying the critical points as peaks, which are characterized by their height, width and position.

It was shown previously that the position of these critical points is sensitive towards changes of the particle dynamics [2]. In this work, we introduce COMPASS as a novel tool for magnetic particle fingerprinting, which creates unique CP-patterns for different MNP systems. To categorize the measured differences of different particle types, various parameters were investigated to determine their influence on the fingerprints. These were amongst others: (1) viscosity of the surrounding medium, (2) sample temperature, and (3) particle size. Analyzing the CP characteristics, it becomes evident that the positions of the critical points exhibit a high sensitivity towards the variation of each of these parameters.

These results demonstrate good performance of COMPASS for analyzing the magnetic behavior of MNPS to static and dynamic magnetic fields providing access to previously unexplored excitation regimes and revealing highly sensitive features in the particle response that were not captured by established techniques yet. Thus, COMPASS is a powerful complementary tool for characterizing magnetic nanoparticle dynamics. Future work on this method aims towards quantitative interpretation of CP-features and investigate the applicability of this method in more complex, biologically relevant environments.

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AC magnetometry for monitoring conformational changes in proteins conjugated to magnetic nanoparticles

Alejandro Venegas Gómez, Cristina Sánchez Carrizo, Sara Hernández Mejías, Sebastián Thompson Parga, Francisco José Terán Garcinuño

Type of abstract: ORAL

Assessing conformational dynamics in proteins is a fundamental chapter in the understanding of their structural organization, functional behavior, and mechanisms of action within the biological environment. Nuclear magnetic resonance (NMR) [1], X-ray crystallography [2], and circular dichroism (CD) [3] are well-established techniques that are commonly used for this purpose. Nonetheless, when proteins are attached to nanoparticles, the resulting scattering and absorption background can hinder reliable signal readout. In this scenario, additional approaches are required to assess conformational transitions in these bioconjugated systems.

Here, we report the potential of AC magnetometry to track protein conformational changes induced by two separate methods: thermal heating and drug loading. In the first part of this study, we covalently bound bovine serum albumin (BSA) and fluorescein-labelled BSA to magnetic nanoparticles (MNPs), and subjected them to thermal denaturation through heating, holding, and cooling temperature dynamics. In the second part, BSA–MNPs were loaded with increasing amounts of paclitaxel (PTX) to induce conformational changes via drug loading. AC magnetization loops were measured under AC magnetic fields (30 kHz, 24 kA/m). In both cases, the AC magnetic hysteresis area was extremely sensitive to denaturation (thermal and drug-induced) and showed statistically significant discrimination of the protein–particle assemblies without being masked by the nanoparticle signal. Circular dichroism, fluorescence polarization anisotropy (FPA), and dynamic light scattering (DLS) were used as supporting techniques to corroborate these results.

Our experimental evidences underlineevidence underlines the potential of optical anisotropy and dynamical magnetization measurements for monitoring denaturation phenomena in conjugated magnetic nanoparticles. TheThese results offer a novel methodologiesmethodology to probe the physical and chemical stability and functionality of conjugated proteins.

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Investigation of magnetic nanoparticle's dynamic magnetization behavior with magnetorelaxometry and magnetoresistive sensors

Jaufenthaler Aaron, Baumgarten Daniel

Type of abstract: ORAL

Magnetic nanoparticles (MNP) offer promising biomedical applications like magnetic hyperthermia. Here, MNP are injected into tumor tissue and then locally heated by applying an alternating magnetic field. The design of biocompatible MNP with high intrinsic loss power and possible functionalization is challenging. It is especially important to stabilize MNP in different environments and to investigate immobilization and aggregation effects in tumor and non-tumor tissue. Whereas magnetic particle spectroscopy (MPS) and magnetic particle imaging (MPI) imaging usually address MNP with fast magnetization dynamics (kHz), magnetorelaxometry (MRX) and magnetorelaxometry imaging (MRXI) are well suited for slower magnetization dynamics (down to sub-Hz). In MRX(I), the MNP's magnetization behavior after pulsed DC magnetic field excitation is measured using highly sensitive but costly magnetometers like optically pumped magnetometers.
We developed a portable, low-cost and open-source MRX system using magnetoresistive sensors. It consists of an excitation coil and a bipolar excitation coil driver, which can magnetize the MNP with a magnetic flux density of up to 20 mT. Two magnetoresistive sensors in a gradiometric configuration are used to measure the MNP's relaxation signal and to suppress environmental noise, which can be orders of magnitude larger than the signal of interest. The sensor electronics features a set/reset ciruit to allow the sensors to recover within < 10 us after the excitation pulse, which exceeds the sensor's dynamic range. An offset circuitry allows to compensate for sensor offset and remanence effects. The sensor's analog bridge output voltage is amplified by 10k and is digitized using a 12 bit, 1 MSPS ADC.
The sensor's bandwidth is 100 kHz and the noise floor is about 30 pT/rtHz, limited by intrinsic sensor noise. With our system we were able to record MRX signals of liquid and immobilized samples of Perimag (Micromod Partikeltechnologie GmbH, Rostock, Germany), spanning relaxation times from single digit milliseconds to approx. 1 second. The limit of detection is currently investigated.
Our tool shows promising potential for the characterization of MNP dynamics during fabrication and for the analysis of immobilization and other effects in biological tissue.

Optimizing magnetic hyperthermia performance under safety limits: role of anisotropy, shape and interactions

Òscar Iglesias

Type of abstract: ORAL

A careful assessment of the heating performance of magnetic nanoparticles (MNPs) under alternating magnetic fields is critical for advancing magnetic hyperthermia as a viable clinical treatment, potentially replacing more invasive cancer therapies such as chemo and radiotherapy [1]. Despite numerous experimental studies, a consensus on standards regarding material properties, dosage, and field parameters remains elusive [2]. Moreover, many interpretations of experimental results rely on theoretical models that fail to capture the essentials of realistic NP ensembles or are based on oversimplified assumptions.

In this talk, we review recent progress in understanding the some of the key factors influencing magnetic hyperthermia performance, from a modeling and simulation perspective. We begin by highlighting the pivotal role of magnetic anisotropy and its relation to nanoparticle shape, in the understanding of the heating properties of MNPs. Our results show that even slight deviations from spherical shape can significantly influence the heating efficiency of MNPs [3]. We identify specific NP size ranges and aspect ratios that optimize heat delivery, constrained by the field amplitude and frequency safety limits required for clinical application. Finally, we address the impact of dipolar interactions in clustered NP ensembles. While such interactions are often considered detrimental, we demonstrate that proper control over spatial distribution and geometric arrangement can mitigate these effects, and that dipolar coupling can even be harnessed to enhance the heating efficiency for certain configurations.

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Wireless Magnetic Sensors in the Microwave Domain Enhanced by Functionalized Nanoparticles for Biomedical Applications

Pilar Marin, Enrique Conde, Daniel Matatagui

Type of abstract: ORAL

The integration of high-frequency electronics with functional magnetic materials has opened new frontiers in non-invasive medical diagnostics. This research proposes a sophisticated wireless sensing strategy centered on the Giant Magnetoimpedance (GMI) effect observed in amorphous magnetic microwires, operating specifically within the microwave domain (GHz range) [1]. The core of this technology lies in the extreme sensitivity of the microwire's complex impedance to external magnetic stimuli, a phenomenon significantly amplified at high frequencies due to the transverse skin effect. As the frequency increases into the microwave regime, the electromagnetic field penetration depth becomes restricted to a thin surface layer of the microwire, making the sensor exquisitely sensitive to the magnetic permeability and the electromagnetic properties of the immediate surrounding biological environment [2].

A distinctive feature of this strategy is the implementation of a low-frequency magnetic field modulation (typically in the Hz to kHz range) superimposed on the high-frequency microwave carrier. This dual-frequency modulation scheme serves as a "lock-in" mechanism to isolate the magnetic response of the microwire from the complex dielectric background of biological tissues. In clinical settings, tissues such as muscle and skin act as high-loss media due to their water and ionic content, which often masks subtle diagnostic signals. By modulating the microwire's state with a low-frequency field, the system can decouple the magnetic signature of interest from the static or slow-varying dielectric noise, drastically enhancing the Signal-to-Noise Ratio (SNR) and lowering the Limit of Detection (LoD) for wireless readouts [3].

The application of this platform is twofold. First, it is designed for the high-precision measurement of collagen density. Collagen is the primary structural protein in the extracellular matrix, and its density and spatial organization are critical indicators of tissue health, wound healing, and the progression of fibrotic diseases or malignant tumors. The microwire sensor detects variations in the effective permittivity and permeability induced by the collagen matrix's density [3], allowing for a structural "mapping" of the tissue without the need for invasive biopsies.

Secondly, the strategy incorporates the use of functionalized magnetic nanoparticles (MNPs) as a versatile possibility for molecular targeting. These nanoparticles can be engineered to bind to specific biomarkers, such as circulating tumor cells or inflammatory proteins. When these MNPs accumulate in the vicinity of the magnetic microwire, they perturb the local magnetic flux, which is immediately detected as a shift in the modulated GMI response. This dual-capability—measuring both the structural integrity of the collagen scaffold and the molecular presence of targeted nanoparticles—creates a comprehensive teranostic tool.

In conclusion, this wireless microwave GMI platform represents a significant leap forward in biosensing. By combining the geometric advantages of microwires, the sensitivity of the GMI effect, and the robustness of low-frequency modulation, the system provides a non-ionizing, non-invasive, and highly specific pathway for real-time monitoring of complex biological processes. This approach offers a scalable solution for future wearable or implantable diagnostic devices that require high sensitivity within the challenging electromagnetic environment of the human body.

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Actuation-Driven Reconfiguration of Magnetic Micropillars and Filaments Assembled from Nanoflowers

Caterina Landi, Rosa Pérez-Garrido, Julio Marco-Cuenca, Chantal Valeriani, Helena Gavilan, Fernando Martínez Pedrero

Type of abstract: ORAL

Magnetic nanoflowers enable the emergence of adaptive microstructures whose morphology and dynamics can be programmed by external fields. In this work, we introduce a scalable, template-free fabrication route for magnetic micropillars that relies exclusively on the interplay between field-induced forces, controllable interparticle interactions, and geometric confinement. We show that the reversibility and stability of the assembled structures are governed by ionic strength: low-salt conditions promote fully reversible assemblies, while intermediate ionic environments produce robust architectures that persist after removal of the magnetic field. Structural dimensions and aspect ratios are independently tuned by adjusting particle concentration and confinement during assembly. Beyond static structures, the resulting micropillars display rich field-driven dynamics, including cilia-like beating, rotational motion, and oscillatory responses. By applying magnetic torque, these pillars can be released from the substrate and transformed into autonomous microfilaments, which exhibit collective swarming behavior and can be extracted from the assembly chamber. Together, these results establish a low-cost, versatile platform for constructing biomimetic, magnetically active materials with strong magnetic response and efficient heating capabilities, opening new opportunities for microfluidic manipulation and bio-inspired microrobotic systems.

Impact of the Immobilization Method on the Magnetic Properties of Magnetic Nanoparticles

Baumgarten Daniel, Kerstin Pansegrau, Wiekhorst Frank, Patricia Radon, Aaron Jaufenthaler

Type of abstract: ORAL

The effective use of magnetic nanoparticles (MNPs) in clinical applications, e.g. magnetic drug targeting or magnetic hyperthermia, requires their characterization in the presence of blood or tissue. In preclinical phantom studies, the binding of MNPs to surrounding media has been mimicked with a wide range of immobilization methods. However, the influence of immobilization on the magnetic properties of such reference samples has not been investigated in detail.

In this study, we immobilized Perimag plain MNPs (micromod Partikeltechnologie GmbH, Germany) with five immobilization methods, namely freeze drying, gypsum, polyacrylamide, filter paper and cotton wool. Magnetic particle spectroscopy (MPS) and magnetorelaxometry (MRX) were used to characterize the magnetic properties of the reference samples in form of the normalized third-harmonic amplitude and the harmonic ratio of the corresponding spectra as well as the relaxation amplitude and relaxation time.

Immobilization methods based on the same underlying mechanism (crystallization for freeze drying and gypsum, polymerization for polyacrylamide, and evaporation for filter paper and cotton wool) exhibit more similar signal parameters, whereas the signal parameters of immobilization methods with different mechanisms differ more significantly from one another. This is more pronounced for MPS parameters than for MRX parameters. In both modalities, parameters that depend on the MNP quantity exhibit a stronger dependence on immobilization methods than parameters that are independent of the MNP quantity.

The results show that both MRX and MPS magnetic properties of reference samples are significantly impacted by the immobilization method used. On the one hand, this shows the importance of the choice of the immobilization method for obtaining relevant and reproducible results from preclinical studies. On the other hand, it implies that a direct comparison of study results with reference samples based on different immobilization methods is only recommended if the same immobilization mechanisms have been used.

Reducing Heat-Loss Variability through Field-Amplitude Tuning in Magnetic Hyperthermia

Necda CAM

Type of abstract: ORAL

Magnetic fluid hyperthermia (MFH) using magnetic nanoparticles (MNPs) has emerged as a promising approach for treating highly aggressive tumors, such as glioblastoma and pancreatic cancer, which are often resistant to conventional therapies [1].

We simulate the behaviour of systems of magnetite nanoparticles in the framework of the macrospin approximation, in terms of their intrinsic magnetocrystalline anisotropy plus a uniaxial one (of shape origin) [2]. Dynamic hysteresis curves were generated using the OOMMF software [3]. We present a theoretical analysis of the combined effects of nanoparticle size, shape-induced polydispersity, and AC magnetic field strength on the heating response of magnetite nanoparticles.

By varying the particle aspect ratio, we show that nearly spherical nanoparticles exhibit weak energy dissipation, while even slight deviations from sphericity strongly enhance specific loss power, especially at higher frequencies. Our results further highlight that for larger nanoparticles, heating is most uniform at intermediate AC field amplitudes, primarily governed by particle size and frequency, with shape polydispersity playing a minor role, providing guidance for achieving more homogeneous magnetic fluid hyperthermia.

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Toward Magnetoplasmonic Nanoparticles: Synthesis and Characterization of Magnetic Nanomaterials

Fernando Martín, Helena Gavilán, Guillermo González

Type of abstract: POSTER

Magnetic nanoparticles (MNPs) represent a highly adaptable class of nanomaterials with increasing significance in diverse areas such as biomedicine, catalysis, and environmental applications. Their magnetic response, together with the ability to finely adjust size, morphology, composition, and surface chemistry, provides precise control over both functionality and performance.[1] Recent progress in colloidal synthesis strategies includes seed-mediated approaches in solvothermal and thermal decomposition, which has enabled the creation of complex nanostructures such as core–shell, dumbbell, and alloy systems.[2] These architectures can integrate multiple elements to modulate magnetic behavior and allow multimodal functionalities. Characterizing MNPs requires a combination of physico-chemical techniques, including electron microscopy, light scattering, and magnetometry.[3] This step is crucial for establishing the relationship between material properties and their potential applications. Ongoing advancements in controlled synthesis and comprehensive characterization protocols are therefore vital to refine MNP performance and promote their implementation in next-generation technologies.

In this work, we synthesized different core–shell nanoparticles composed of various metals, including nickel, copper, zinc, and iron. We evaluated their potential for application in magnetic hyperthermia using an inductive magnetometer.

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Keywords: Magnetic nanoparticles, Colloidal, Characterization, Biomedical Applications.

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Influencing factors on the heating abilities of γ-Fe2O3 nanocrystals

Pauline Rooms, Patricia Radon, Frank Wiekhorst, Jonathan Leliaert, Klaartje De Buysser

Type of abstract: POSTER

Adhesive joining is increasingly used in industry due to its technical benefits compared to standard fastening or other welding alternatives. However, these adhesives have some drawbacks such as long curing times and difficult dismantling processes. To remedy this, magnetic nanoparticles (MNPs) can be included into the polymer-based adhesives, as these MNPs can operate as nano-heaters under the application of an alternating magnetic field, enabling on-demand bonding and debonding. Due to their local heating properties and their potential for tunability in size and chemistry, MNPs represent a promising strategy for smart adhesive systems. A thorough understanding of the factors influencing their heating performance is therefore essential.

Here, the influencing factors on the heating abilities (specific absorption rate, SAR) of y-Fe_2O_3 NPs are presented, ranging from synthesis methods to variations in physicochemical parameters. y-Fe_2O_3 NPs were synthesized by a polyol-based method and performed in different synthetic vessels (flask or autoclave). The nanoparticles were characterized using transmission electron microscopy (TEM), dynamic light scattering (DLS), X-ray diffraction (XRD), AC susceptometry, magnetic particle spectroscopy (MPS) and AC magnetometry. Post-synthesis, the influence of variations in physicochemical parameters (concentration, viscosity, and particle state) on the magnetic properties was investigated.

The results demonstrate that both the synthetic vessel and post-synthesis physicochemical parameters highly influence the magnetic properties. Changes in viscosity and particle state have shown to affect the heating behaviour of the nanoparticles: with increasing immobility of the nanoparticles, the ability to heat decreases. These findings highlight the important role of these factors in the design of the MNP-based smart adhesive systems.

Interactions of PEGylated iron oxide nanoparticles with male and female reproductive cells - a spectroscopic and toxicological study

Dominika Knapczyk, Natalia Janik-Olchawa, Dorota Lachowicz, Aleksandra Wilk, Jakub Cieslak, Katarzyna Berent, Patrycja Nacisk, Zuzanna Setkowicz, Małgorzata Duda, Joanna Chwiej

Type of abstract: POSTER

Magnetic iron oxide nanoparticles (IONPs) are extensively studied for their potential biomedical applications, including use as contrast agents in magnetic resonance imaging or as carriers in theranostic strategies. Despite the growing interest in these nanomaterials, knowledge regarding their interactions with cells, including those of the reproductive system, remains limited. In particular, the mechanisms of IONPs internalization and their possible effects on cell function are still under investigation, which is crucial for assessing the safety of their potential clinical applications.

The aim of this study was to evaluate the degree of internalization of magnetic iron oxide nanoparticles with a magnetite core and a diameter of 10 nm, coated with poly(ethylene glycol) (PEG), into selected reproductive system cells, as well as to assess their potential cytotoxic effects. In the first stage, a detailed physicochemical characterization of the IONPs was performed using transmission electron microscopy and dynamic light scattering to determine the core size and hydrodynamic diameter as well as Raman spectroscopy to analyze their chemical composition. Subsequently, the nanoparticles were administered at concentrations corresponding to clinically relevant doses to two immortalized cell lines: Sertoli cells (male reproductive system) and uterine smooth muscle cells (female reproductive system). Raman microscopy was used to assess the extent of IONPs internalization, their intracellular distribution, and potential changes in the distribution and accumulation of selected biomolecules induced by nanoparticle exposure. These results were correlated with cytotoxicity assays, including cell viability assessment and the level of induced apoptosis. The obtained data provide new insights into the interactions between PEGylated IONPs and reproductive system cells and may contribute to the evaluation of the safety of their potential biomedical applications.

Interactions of PEGylated iron oxide nanoparticles with male and female reproductive cells - a spectroscopic and toxicological study

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Mixed nanocrystalline ferrites for potential biomedical applications

Milena Georgieva, Peter Georgiev, Todor Karadimov

Type of abstract: POSTER

Growing global concern over antibiotic contamination of the environment and the rapid emergence of antibiotic-resistant bacteria has intensified research into novel, environmentally friendly inorganic nanomaterials that are effective against pathogenic microorganisms while remaining biocompatible. In this context, nanocrystalline copper/zinc- and manganese/zinc-substituted ferrites were synthesized via a solvothermal method at temperatures up to 200 °C and systematically investigated for their structural and magnetic properties. The crystalline phases, particle morphology, size distribution, and magnetic behavior at ambient temperature were characterized using powder X-ray diffraction (XRD), electron microscopy techniques, and vibrating sample magnetometry (VSM), respectively.

The copper-modified ferrite samples were found to consist of agglomerates of nanocrystalline magnetite (Fe_3O_4) containing metallic copper inclusions. In contrast, the zinc-substituted ferrites formed agglomerates of a superparamagnetic spinel phase, exemplified by compositions such as $Zn_{0.6}Fe_{0.4}Fe_2O_4$, with nanoscale copper particles uniformly dispersed within the matrix. These zinc-substituted samples exhibited a maximum magnetization of approximately 30 emu/g, indicating promising potential for practical magnetic applications.

Manganese ferrite samples were obtained as single-domain nanoparticles of non-stoichiometric manganese ferrite with varying Mn/Fe ratios. This material system was selected due to its favorable biocompatibility, relatively straightforward synthesis, and the tunability of both magnetic and structural properties through controlled synthesis conditions. All samples investigated were nanocrystalline, with crystallite sizes ranging from 5 to 15 nm. Key magnetic parameters, including the maximum magnetization (the magnetization measured at 6kOe max applied field) and coercive force, were determined for each composition. A nearly linear relationship was observed between the maximum magnetization and iron content, with magnetization increasing as the proportion of iron increased. Owing to the small particle size, nearly all samples exhibited superparamagnetic behavior at room temperature, as confirmed by magnetization curves showing negligible coercivity and near-zero remanent magnetization. Notably, nanocrystalline manganese ferrite particles exhibited significant magnetization values of up to 49 emu/g, while maintaining zero coercive force, making them particularly attractive for biomedical applications.

In addition, zinc-substituted manganese ferrites with various stoichiometries were synthesized and characterized. These materials also displayed superparamagnetic behavior, with maximum magnetization values reaching approximately 30 emu/g.

Overall, the results demonstrate that precise control over composition and synthesis conditions enables tailoring of the microstructure and magnetic properties of mixed nanocrystalline ferrites. Such superparamagnetic nanoparticles, combining high magnetization with zero coercivity at room temperature, are strong candidates for advanced biomedical applications, including magnetic hyperthermia, targeted drug delivery, and magnetic particle imaging (MPI).

Synthesis and characterization of different shapes of Superparamagnetic Iron Oxide Nanoparticles as dual-contrast agent for MRI

Hamza Yakubu

Type of abstract: POSTER

Accurate imaging of cancer cells is fundamental to early diagnosis, treatment planning, and therapeutic monitoring. Among available clinical imaging modalities, magnetic resonance imaging (MRI) is particularly advantageous due to its high spatial resolution and non-ionizing nature. The diagnostic performance of MRI is often enhanced through the use of contrast agents; however, the most widely used gadolinium-based contrast agents (GBCAs) have raised significant safety concerns. Clinical reports have linked GBCAs to nephrogenic systemic fibrosis in patients with impaired renal function, gadolinium deposition in brain tissue, and potential long-term nephrotoxicity. These limitations have intensified the demand for safer and more biocompatible MRI contrast agents that do not compromise image quality.

Superparamagnetic iron oxide nanoparticles (SPIONs) have emerged as a promising alternative to conventional GBCAs owing to their intrinsic biocompatibility, biodegradability, and favorable magnetic properties. Unlike gadolinium, iron can be metabolized through natural physiological pathways, reducing the risk of long-term accumulation and toxicity. In addition, SPIONs offer tunable magnetic behavior that can be optimized for both longitudinal (T1) and transverse (T2) relaxation, enabling enhanced MRI contrast. The ability to engineer SPIONs as dual-mode contrast agents holds particular promise for improving diagnostic accuracy by providing complementary bright and dark signal enhancements within a single imaging platform.

In this study, we report the synthesis and characterization of monodisperse SPIONs with controlled morphologies, including nanocubes, nanospheres, and nanostars, prepared via a solvothermal synthesis approach. This method enables precise control over particle size, shape, and crystallinity, all of which play critical roles in determining magnetic performance and relaxivity behavior. To further improve biocompatibility and functional versatility, the synthesized nanoparticles were surface-functionalized with dopamine. Dopamine provides strong anchoring to the iron oxide surface through catechol groups while introducing hydrophilicity and reactive sites for potential biological conjugation.

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Magnetic Nanoparticles as Dual Nanoheaters and Nanothermometers: From $Co_3Fe_{2.7}O_4$ to Synomag

Julieta Velasco Martínez-Pardo

Type of abstract: POSTER

In recent years, nanoscale systems capable of simultaneously generating and sensing heat have attracted growing interest [1]. Conventional dual-component constructs combining separate nanoheaters and fluorescent nanothermometers face major drawbacks in biological environments, including photobleaching, scattering, and biocompatibility issues.

To overcome these limitations, we previously demonstrated the label-free thermometric capability of magnetic nanoparticles (MNPs) functioning as both nanoheaters and nanothermometers. Specifically, commercial $Co_{0.3}Fe_{2.7}O_4$ nanoflowers [2] (Micromod Nanopartikels GmbH) with a crystal size of 30 nm and a dextran coating, resulting in a hydrodynamic diameter of ~50 nm and PDI < 0.1. These MNPs were employed for their efficient photothermal conversion and magnetic relaxation properties. Under 780 nm LED irradiation, heat generation was achieved, and temperature readout was performed via AC magnetometry (10–100 kHz, up to 32 kA/m), exploiting Brownian relaxation for temperature transduction.

This enabled label-free heat generation and self-sensing of temperature variations at the nanoscale. Comparisons with bulk thermometry revealed nanoparticle–solution temperature differences, and MNP performance was further evaluated in protein-conjugated forms and biological media, with experimental data supported by theoretical simulations.

Building on these findings, we now extend this approach to investigate the capacity of Synomag (Micromod Nanopartikels GmbH), a commercial iron oxide nanoparticle, to function as a nanothermometer. This next step aims to assess whether Synomag can replicate or improve upon the temperature-dependent magnetic behavior observed in $Co_{0.3}Fe_{2.7}O_4$ nanoflowers. This unified nanoheater/nanothermometer strategy provides a self-referenced and scalable platform for accurate magnetic nanothermometry, offering real-time thermal feedback and strong potential for biomedical applications such as magnetic hyperthermia and controlled drug delivery.

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Rigid-dipole magnetic nanoparticles for sub-second 3D viscosity imaging

João Miguel Lopes Costa Costa

Type of abstract: POSTER

Magnetic nanoparticles are widely explored in bio-related applications, as sensing probes, as localheat generators, and as contrast agents for imaging. The large majority of these nanoparticles areiron oxides and cubic ferrites with low to medium magnetic anisotropy, and thus a weak tomedium coupling between spins and crystal lattice. Here we present stable aqueous colloidalsuspensions made of a doped iron oxide (Al-doped ε-Fe2O3) with a strong coupling between themagnetic moment and the crystal lattice. We show that in stable aqueous suspensions, these highlyanisotropic nanoparticles are cell-compatible and follow a rigid dipole model, enabling viscositysensing, and viscosity imaging using a magnetic particle imaging (MPI) scanner. This opens newperspectives for bio-application of magnetic nanoparticles, such as 3D viscosity imaging withsub-second resolution using MPI, a tomographic technique with kHz imaging rates.1. IntroductionChanges in viscosity occur naturally across different parts of the body, during tissue formation, or due tomalign tissue formation, for instance [1, 2]. It is therefore a relevant parameter in biological processes, thatbenefits from being measured wireless. Magnetic nanoparticles emerge as a relevant tool in this context, sincetheir signal can be manipulated and read at a distance with time and space resolution. In fact, magneticnanoparticles can be rotated by an alternate magnetic field, being their response dependent on severalparameters including their surrounding viscosity. This response can be read with a magnetic susceptometer,or mapped in 3D with high time resolution using magnetic particle imaging (MPI)[3]. The importance ofviscosity and the possibility of its 3D mapping using MPI triggered the interest of developing magneticnanoparticles, ferrofluids and methods with this particular aim.To be effective in magneto-mechanical bio applications such as viscosity sensing, magnetic nanoparticlesshould have a strong coupling between their magnetic moment and their crystal lattice, such that themechanical torque exerted between the nanoparticle and its surrounding media is totally transmitted to themagnetic moment of the nanoparticle and vice-versa. In other words, the nanoparticles should havehigh coercivity, i.e. should be hard magnets. This is at odds with the usual requirements for magneticnanoparticles used in biological applications, which are designed to have a low coercivity as a way to preventaggregation by magnetic forces. The iron oxides magnetite and maghemite fit theabove requirements quite well with the added value of displaying suitable cytocompatibility.

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Tuning Magnetic Hyperthermia Efficiency of SPIONs via Post-Synthetic Surface Re-Functionalization

Adrian Radon, Dariusz Lukowiec, Agnieszka Ciuraszkiewicz, Lukasz Hawelek

Type of abstract: POSTER

Superparamagnetic iron oxide nanoparticles (SPIONs) are widely used in biomedical applications, including anaemia treatment, magnetic resonance imaging (MRI), magnetic particle imaging (MPI), magnetically induced hyperthermia, and blood filtration (haemofiltration) [1,2]. For most of these applications, SPION surfaces are modified with coatings such as dextran, carboxydextran, carboxymethyl dextran, or aminosilanes to enhance biocompatibility and colloidal stability and to reduce iron ion release. In some applications, including blood filtration and targeted anticancer therapies, SPIONs are additionally functionalized with antibodies to selectively bind inflammatory mediators or specific cellular antigens [1]. Recently, a surface functionalization strategy based on strain-promoted alkyne–azide cycloaddition (SPAAC) has been proposed for cancer treatment, enabling efficient targeting of cell membranes and their disruption via localized magnetic hyperthermia, thereby increasing membrane permeability [3].

Although established surface functionalization strategies significantly expand the biomedical applicability of SPIONs, nanoparticles synthesized via thermal decomposition of organic precursors often undergo spontaneous surface functionalization. The use of ligands such as oleic acid or sodium stearate typically yields hydrophobic particles that are unsuitable for direct biomedical use. Moreover, some organic species formed during high-temperature synthesis may exhibit cytotoxicity. Consequently, post-synthetic surface re-functionalization is required to improve biocompatibility and mitigate the adverse effects of residual surface species. Importantly, surface modification influences not only colloidal stability and biocompatibility but also the heating efficiency during magnetically induced hyperthermia by altering interparticle interactions.

In this study, we propose surface re-functionalization strategies for SPIONs that improve colloidal stability, reduce aggregation, and enhance heating efficiency. Nanoparticles synthesized by thermal decomposition of acetylacetonate precursors in different high-boiling solvents were characterized before and after re-functionalization using transmission electron microscopy, Fourier-transform infrared spectroscopy, X-ray photoelectron spectroscopy, and electron energy loss spectroscopy. Various re-functionalization agents were evaluated, with a particular focus on short-chain organic acids, including malonic and tartaric acids. The hyperthermia performance of the resulting SPIONs was assessed in terms of temperature increase and specific loss power (SLP) under low- and high-concentration regimes, where changes in interparticle interactions critically influence heating efficiency.

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Magnetic nanoparticles for theranostic: continuous flow micromixer synthesis and online monitoring with MPS

Christina Wenck, Nils Meier, Frank Wiekhorst, Regina Bleul

Type of abstract: POSTER

Magnetic nanoparticles (MNP) have a great potential for various biomedical applications such as magnetic particle imaging (MPI), Magnetic Fluid Hyperthermia (MFH), magnetic targeting and magnetic drug release. Thus, MNP represent a valuable constituent in a theranostic agent. For each specific application MNP must be designed and synthesized to achieve the desired function in a system. Here, we report an adaptable continuous synthesis for directly synthesizing hydrophilic and hydrophobic MNP within an aqueous synthesis using online analytics for monitoring and characterization of the MNP. Additionally, coating of the MNP with e.g. protein or by encapsulating can enable the possibility of simultaneously monitoring by MPI, drug delivery and MFH.

Iron oxide nanoparticles were synthesized in a continuous flow micromixer setup by precipitation from aqueous, alkaline solutions of iron salts, oxidation, and afterwards stabilization. Magnetic Particle Spectroscopy (MPS) was used as an online analytic tool to directly monitor the synthesis outcome and the purification of the MNP. Additionally, MPS was used to evaluate their potential MPI performance and to monitor changes due to MNP coating and their stability in different environments. AC-magnetometry was used to assess the MNP suitability for MFH. Further, size characterization was done using transmission electron microscopy.

In summary, we demonstrated a tunable, water-based and rapid continuous flow micromixer synthesis of MNP with MPS as a powerful online analytic tool to develop and produce tailored MNP for theranostic applications as well as for quality control of the synthesized MNP.

Mössbauer spectroscopy for of Fe57-labeled nanoparticles in biological systems.

Jakub Cieslak

Type of abstract: POSTER

In this study, we investigate the biodistribution and biotransformation of ^{57}Fe-labeled iron oxide nanoparticles (IONPs) in vivo using Mössbauer spectroscopy—a unique technique that enables selective detection of the ^{57}Fe isotope without interference from naturally occurring iron (natural abundance of ^{57}Fe ≈ 2.3%). ^{57}Fe-enriched Fe_3O_4-core nanoparticles (>95% ^{57}Fe) were synthesized, and their physicochemical and magnetic properties were thoroughly characterized. Following intravenous administration to Wistar rats, organ samples (blood, liver, spleen, brain, heart, and kidneys) were collected for analysis. Mössbauer measurements were performed at 80 K using transmission geometry. The Mössbauer spectra revealed distinct iron species and oxidation states, enabling differentiation between metabolized iron and nanoparticulate forms across the examined organs. Initial results indicate an unexpected mobility of the ^{57}Fe-labeled nanoparticles in solution, persisting even at cryogenic temperatures (8–240 K), as evidenced by preliminary Mössbauer data. Comparative analysis with spectra obtained from dried samples highlights substantial differences in iron speciation. In addition, analogous experiments are currently being conducted in plant models (Arabidopsis thaliana), with early results supporting the broader applicability of this isotopic labeling and Mössbauer-based approach. Overall, this work represents one of the first comprehensive studies to trace the in vivo fate of isotopically labeled magnetic nanoparticles using Mössbauer spectroscopy and provides a robust framework for elucidating nanoparticle behavior in biological systems.

Magnetic Anisotropy and Interaction Effects in Magnetite Nanorods for Hyperthermia Applications

Manuel Horcajo, José Alonso, Patricia de la Presa

Type of abstract: POSTER

Magnetic nanoparticles are widely investigated for biomedical technologies such as magnetic hyperthermia, contrast enhancement in imaging, and magnetically assisted actuation. Their performance is governed by intrinsic parameters including size, composition, and magnetic anisotropy, as well as by extrinsic factors such as colloidal stability and interparticle interactions[1]. Among the different morphologies, magnetite nanorods constitute a particularly attractive system because their elongated shape introduces a strong uniaxial anisotropy[2] that can significantly modify magnetization reversal processes and magnetic losses under alternating magnetic fields.

Although many studies have focused on optimizing the dimensions of isolated nanorods, the influence of their aggregation state and spatial arrangement has received comparatively less attention. In realistic environments, nanoparticles are rarely perfectly isolated: surface functionalization, encapsulation, or coating procedures required for stabilization and biocompatibility often modify interparticle distances and can induce clustering. These effects alter dipolar coupling and, consequently, the effective magnetic anisotropy and dynamic magnetic response, which are critical parameters for hyperthermia efficiency[3].

In this work, magnetite nanorods with two distinct aspect ratios are used as a model system to analyze the combined influence of shape anisotropy and magnetic interactions on both static and dynamic magnetic properties relevant for hyperthermia. The nanorods were synthesized using a solvothermal route, yielding highly crystalline Fe_3O_4 particles with narrow size distributions and excellent colloidal stability. By adjusting synthesis parameters, two populations were obtained: shorter nanorods of 38x6 nm, and longer nanorods of 66x7 nm. Both systems form stable dispersions in nonpolar solvents, showing no visible sedimentation over long periods.

Structural characterization by X-ray diffraction confirms that both samples have a magnetite structure. TEM images reveals well-defined rod-like morphologies and a high degree of uniformity within each population. Magnetic measurements performed using SQUID magnetometry show saturation magnetization values close to those of bulk magnetite.

AC hysteresis loops were recorded at 100 kHz and 8 kA/m. Clear differences are observed between short and long nanorods, reflecting distinct magnetization reversal mechanisms associated with their different anisotropy energies and magnetic moments. Longer nanorods exhibit narrower hysteresis loops, whereas shorter nanorods display broader loops under identical field conditions. These differences directly influence the energy dissipated per cycle and therefore the heating capability of the system.

Beyond the intrinsic behavior of isolated nanorods, this work also explores strategies to intentionally modify interparticle interactions. Silica coating is proposed as a versatile approach to control both magnetic dilution and aggregation. Thin silica shells deposited on individual nanorods can increase interparticle spacing, reducing dipolar coupling while preserving the magnetic core properties. Conversely, controlled aggregation of several nanorods followed by silica encapsulation can generate composite objects in which the number of interacting rods and their relative orientation are fixed within a confined volume. This architecture allows systematic tuning of collective magnetic effects without altering the chemical phase or individual particle morphology.

Such control over interactions is crucial because dipolar coupling can either enhance or suppress magnetic losses depending on particle arrangement, concentration, and anisotropy distribution. By adjusting coating thickness and aggregation degree, it becomes possible to tailor the effective anisotropy landscape experienced by the magnetic moments and to optimize the balance between thermal stability and dynamic response under alternating fields.

The results demonstrate that magnetite nanorods constitute a flexible platform for disentangling intrinsic shape effects from

extrinsic interaction-driven phenomena. While both nanorod populations exhibit bulk-like magnetization, their coercivity and AC hysteresis behavior depend sensitively on aspect ratio and on the magnetic environment created by neighboring particles. Surface modification and assembly therefore emerge as powerful design parameters, comparable in importance to particle size and shape.

Overall, this study highlights that magnetic hyperthermia efficiency is governed by a subtle interplay between intrinsic nanorod anisotropy and collective effects arising from particle interactions. Understanding and controlling both contributions is essential for the development of next-generation magnetic nanoheaters and other technologies based on AC-field-driven magnetic processes.

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Protein-conjugated magnetic nanosystems for methylated DNA detection

Beatriz Naranjo Martínez, Sedef Ozel-Okcu, Francisco J. Terán, Domenico Scionti, Marco Pierotti

Type of abstract: POSTER

Omics strategies and nanotechnology are advancing liquid biopsy approaches for cancer diagnostics, particularly by enabling the detection of genetic mutations and cancer-specific alterations in circulating tumor DNA (ctDNA) or circulating tumor cells (CTCs). Among these biomarkers, methylated DNA (mDNA) is particularly relevant, as it reflects key epigenetic changes associated with cancer development, early detection and therapeutic monitoring. More importantly, due to its tumor agnostic nature, mDNA can serve as a multiple cancer detection signature. To target the need for highly sensitive detection platforms that enable the capture and characterization of DNA methylation patterns, we developed a nanosystem based on functionalized magnetic nanoparticles for the detection of mDNA in liquid biopsy samples.

In this study, we evaluated the use of commercial dextran-coated cobalt ferrite magnetic nanoparticles (CoFeD MNPs), whose surface was conjugated with the methyl-CpG-binding domain (MBD) protein for the selective detection of mDNA. Protein conjugation onto the nanoparticle surface was performed, and the ability to capture mDNA was tested using commercially available reference methylated/unmethylated DNA. The conjugated CoFeD MNPs were physico-chemically characterized, and changes in their magnetic response induced by surface modifications associated with protein binding and DNA fishing were analyzed. Additionally, the experimental workflow was optimized to enhance specificity and reproducibility.

Physico-chemical characterization revealed a decrease in magnetization and an increase in hydrodynamic size after functionalization, indicating effective protein binding. Biomolecular recognition between mDNA and conjugated CoFeD MNPs leads to variation in MNP diffusion, which is sensitively reflected in the dynamic magnetization. Hence, DNA capture assays demonstrated that the conjugated CoFeD MNPs were capable of detecting mDNA at concentrations down to 100 picomolar (pM), based on the lowest concentration showing a measurable and reproducible magnetic signal change.

These results suggest that the conjugated CoFeD MNPs may represent a promising system to detect biomolecules in liquid biopsy for cancer diagnostics. Further analysis using patient-derived blood samples is needed for full validation.

Acknowledgements

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Effect of Oleate Based Precursors on the Magnetothermal Behavior of MAxMByFe3-x-yO4 nanoparticles (M = Mn2+, Co2+, Zn2+)

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Type of abstract: POSTER

The morphology and size-controlled magnetic ferrite nanoparticles have demonstrated remarkable versatility in achieving enhanced specific absorption rate (SAR) values during magnetic hyperthermia. Precise regulation of magnetic heat generation, relaxivity, and magnetically induced forces—both in aqueous environments and within cellular systems—confers significant potential for diverse biomedical applications. Incorporating small amounts of transition metals into the magnetite structure has been shown to be an effective strategy for producing mixed ferrites with tailored magnetic properties, adaptable to the requirements of clinical research [1].

In this work, we refine and extend a previously established chemical synthesis route to obtain monodisperse and monocrystalline nanoparticles doped with moderate concentrations of Mn^{2+}, Co^{2+} or Zn^{2+} ions. Furthermore, we investigated the influence of different oleate precursors (mono, bi and trimetallic precursors) on the magnetic response of the resulting samples. In this sense, Fe2.87Mn0.04Zn0.09O4, Fe2.90Mn0.05Co0.05O4 and Fe2.5Co0.25Zn0.25O4 nanoparticles were synthesized from three different precursor types: M(oleate)2, Fe3-xMx(oleate)6 and Fe3-x-yMxM'y(oleate)6, to elucidate their role in tuning the overall magnetic performance.

This synthetic approach yielded highly homogeneous nanoparticles with average sizes ranging from 16 to 32 nm and octahedral morphology. Analysis of the 57Fe Mössbauer spectra at room temperature enabled quantification of dopant site occupancy within the spinel lattice. All samples exhibited high saturation magnetization values, reaching 95–100 $A{\cdot}m^2{\cdot}kg^{-1}$ at 5 K and 86–96 $A{\cdot}m^2{\cdot}kg^{-1}$ at 300 K. The biomedical application of PEG coated nanoparticles was assessed through magnetothermal performance and cytotoxicity studies. Magnetic hyperthermia efficiency was evaluated under various alternating field conditions and clinically safe magnetic amplitudes and frequencies, achieving SAR values close to 1000 $W{\cdot}g^{-1}$. In addition, cytotoxicity assays confirmed that the applied doping levels do not induce cellular toxicity.

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AC Hysteresis as a powerful technique for magnetic nanoparticle and solvent characterization

Pablo Palacios Alonso, Mohamed M. Shams, Sedef Ozel-Okcu, Elena Sanz-de-Diego, Francisco Jose Teran, Rafael Delgado-Buscalioni

Type of abstract: POSTER

AC magnetometry is a technique that accurately probes changes in the magnetic relaxation times of nanoparticles. When applied to MNPs whose relaxation mechanism is predominantly Brownian, this technique is highly sensitive to any phenomenon that alters the particle's diffusion—whether due to modifications of its surface or of the surrounding medium. However, establishing a direct connection between changes in the environment and variations in the magnetic signal remains challenging, as no general analytical expressions exist that relate the magnetic response to the different influencing parameters (such as suspension viscosity, temperature, or particle size). Consequently, researchers often rely on computational algorithms that require significant computing time to extract accurate information [1].

In this work, we present a recently published method [2] that enables the determination of otherwise unknown system parameters from measurements of the magnetic hysteresis loop area of nanoparticles under varying field conditions (amplitude and frequency). The approach relies on a phenomenological expression—derived from extensive numerical simulations of nanoparticle magnetization loops over a wide range of field conditions—that links these parameters to the measured magnetic area. This algorithm is highly general and can be applied to diverse scenarios. In particular, we have used it to simultaneously determine the particle size and their magnetic moment; the viscosity and temperature of the suspension; as well as subtle changes in the hydrodynamic size occurring upon particle bioconjugation with a receptor and during its specific interaction with a target biomarker in suspension.

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Functionalized Magnetic Beads as Platforms for Methylated DNA Capture in Liquid Biopsy

Beatriz Naranjo Martínez, Ana Laura Coria Gutiérrez, Sedef Ozel-Okcu, Sunčica Sukur, Francisco J. Terán, Vaclav Ranc, Domenico Scionti, Marco Pierotti, Anna Piperno

Type of abstract: POSTER

Liquid biopsy has emerged as a minimally invasive approach for cancer diagnosis and prognosis, enabling longitudinal monitoring through analysis of tumor-derived DNA, RNA, and other biomarkers in biofluids (Yu et al., 2022). Recent advances in nanoparticle design have significantly enhanced the sensitivity, specificity, and reproducibility of biomarker detection (Goswami et al., 2024). Magnetic bead (MB)-based strategies represent a promising application in this field, enabling efficient isolation of biomarkers by exploiting their magnetic properties and functional features. Among them, superparamagnetic iron oxide nanoparticles (SPIONs) have gained considerable attention due to their nanoscale dimensions, surface functionalization potential, and responsiveness to external magnetic fields.

In this study, three MB systems were engineered for the selective capture of methylated DNA, a key epigenetic marker involved in early cancer detection. MB1 consisted of magnetic nanoparticles coated with poly(methacrylic acid) (MNP/PMAA) covalently functionalized with recombinant Methyl CpG Binding Domain Protein 2 via carbodiimide chemistry. MB2 is based on superparamagnetic iron oxide nanoparticles (SPIONs) coated with PMAA, functionalized with cystamine (Cys) and glutathione (GSH), where GSH mediated the interaction with glutathione S-transferase (GST) domains of the MethylCap protein, which in turn incorporated a MeCP2 domain for methylated DNA binding. MB3 was designed by assembling SPIONs coated with oleic acid (OA) into microspheres, followed by polyvinylpyrrolidone (PVP) and PMAA modification, and covalent attachment of recombinant MBD2. Comprehensive magnetic, physicochemical, and morphological characterization (AC magnetometry, TGA, FT-IR, ζ-potential, SEM, DLS) confirmed successful functionalization and stability of the MB systems.

Preliminary functional tests demonstrated the ability of all platforms to capture methylated DNA, with variations in binding affinity and reproducibility reflecting the influence of the different designs. In particular, MB3 showed improved reduction in non-specific binding, while MB2 displayed magnetic signatures consistent with preferential interaction with methylated DNA. MB3 was further evaluated by incubation with fragmented genomic DNA from the HeLa cancer cell line, showing a significant enrichment of methylated DNA compared with the non-conjugated MB3. The AC magnetic hysteresis loops of MB3 varied depending on the incubation conditions, exhibiting higher magnetization values in the presence of DNA and lower values in its absence. The magnetization loops obtained after incubation with methylated and unmethylated DNA showed an overlap, indicating similar magnetic responses under these conditions. Quantitatively, incubation with methylated and unmethylated DNA resulted in increases of approximately 8% and 11% in the magnetic area, respectively. These results demonstrate the functional capability of the synthesized beads to interact with DNA and provide an important foundation for further optimization of bead chemistry, protein conjugation, and elution protocols to enhance selectivity and stability in methylated DNA capture.

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Magnetic-Responsive Cyclodextrin Nanoplatforms for Controlled Drug Delivery in Osteosarcoma Therapy

Ana Laura Coria Gutiérrez, Joshua Mountford, Sedef Ozel-Okcu, Mohamed Saqawa, Sunčica Sukur, Dominique Heymann, Francisco J. Terán, Vaclav Ranc, Angela Scala, Angela Scala, István Puskás, Anna Piperno

Type of abstract: POSTER

Osteosarcoma (OS) is the most common primary malignant bone tumor in children and adolescents. Despite advances in chemotherapy and surgery, prognosis remains poor due to chemoresistance, relapse, and limited drug penetration. Nanomedicine offers promising strategies to overcome these barriers; however, challenges of stability, reproducibility, and translation have slowed clinical progress. Among candidate materials, iron oxide magnetic nanoparticles (MNPs) stand out for their superparamagnetic properties, biocompatibility, and responsiveness to external magnetic fields. Yet, their tendency to aggregate and oxidize requires tailored surface modifications to ensure stability and functionality [1, 2]. To address these limitations, we developed magnetosugammadex (MNP@SGX). Synthesized or commercial iron-oxide nanoparticles were coated with oleic acid, which allowed functionalization with the γ-cyclodextrin Sugammadex (SGX, BRIDION®). The resulting MNP@SGX assemblies enhance colloidal stability, reduce toxicity, enable drug loading, and magnetic properties allow localization.

We developed drug-loaded NanoTher (NT) systems by loading the anticancer therapeutics doxorubicin (DOX), docetaxel (DTX), or salinomycin (SAL) into the MNP@SGX platform, yielding a magnetically responsive treatment. Furthermore, to study cellular uptake, the fluorescent assembly FluoNanoTher (FNT) was prepared by entrapping adamantane rhodamine derivatives (Ada-Rhod) into MNP@SGX. The resulting nanoplatforms (MNP@SGX@DOX, MNP@SGX@DTX, MNP@SGX@SAL, and MNP@SGX@Ada-Rhod) were characterized by thermogravimetric analysis (TGA), FT-IR, ζ-potential, SEM, DLS, Raman spectroscopy, and AC magnetometry. The magnetic properties of DOX-loaded NTs were evaluated using a SENS AC Hyster Series magnetometry (10 kHz, 32 kA/m). The analysis suggests that the magnetic response of the superparamagnetic core is influenced by the diamagnetic contribution of the SGX shell and the encapsulated therapeutics. These preliminary results provide qualitative evidence of magnetic behavior and highlight the importance of standardizing iron concentration in future formulations to achieve the magnetic signal required for targeted drug delivery. The assemblies demonstrated kinetic and physiological stability across biological media, and the therapeutic effect is being tested in vitro via standard monolayer cultures and three-dimensional (3D) OS models that better mimic the tumor microenvironment. In parallel, ongoing studies are focused on monitoring the cellular uptake of FNTs using both fluorescence and brightfield microscopy.

The carrier alone (MNP@SGX) showed no significant decrease in cell viability in a healthy human fetal osteoblastic (hFOB) model after 3 days at the highest tested concentration (400 µg/mL). Biological activity of the DOX-, DTX-, and SAL-loaded NT formulations were evaluated by observing changes in metabolic activity in the osteosarcoma cell lines U-2 OS, MG63, 143B, MOS-J, and KHOS in vitro. The half maximal inhibitory concentration (IC50) values varied depending on the magnetite nanoparticle core used and among the investigated cell lines. Specifically, IC50 values of DOX-loaded NTs ranged from a 0.47-fold change in MOS-J to a 3.70-fold change in U-2 OS. Meanwhile, NTs loaded with DXT and SAL showed increases in IC50 values. Increases in IC50 may be due to unreleased drug from the NT; the hydrophobic nature of the chemotherapeutics likely results in a gradual release from the platform. Overall, in vitro IC50 values were comparable or slightly higher than free drug controls, indicating reduced potency in NT formulations. We believe that the magnetic properties of these NTs, allowing drug delivery and localization will more than compensate for the observed loss of therapeutic efficacy. Following on from this research, NTs will be evaluated in 3D models such as spheroid and scaffold systems, results of which will guide the design of an in vivo experiment using an animal model of osteosarcoma.

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Next-Generation Magnetic Bioassays Based on Engineered Magnetization Dynamics

Aidin Lak

Type of abstract: Speakers

Magnetic nanoparticles (MNPs) also offer a highly promising biosensing nanoplatform since their magnetic relaxation dynamics is highly sensitive to molecular interactions between receptors on MNPs and target in solution.1,2 Homogeneous magnetic assays (MAs) have merged based on this unique feature two decades ago. MAs are nonenzymatic and isothermal and can be performed on unprocessed biological samples without further purification, features that are indispensable for point-of-care (POC) detection of nucleic acids and proteins. Nevertheless, current magnetic bioassays are unbale to unlock these potentials, as they do not offer clinical sensitivity, specificity, and selectivity. Over the past few years, we have proposed a novel solution for bringing MAs with clinical sensitivity and selectivity to the POC settings. We have developed new declustering-based magnetic signal amplification biosensing circuits (MAC). Using MAC, we have detected complex RNA targets from biologically relevant samples. Since then, we have worked on different MAC generations by exploiting DNA nanotechnology design tools.3 Our current exponential amplification MAC enables dual model signal amplification, reaching the sensitivity of femtomolar. In my talk, I will discuss our journey through different design concepts and how custom MNPs with highly specific magnetization dynamics will take such cascades to the clinical settings in the few years. Last but not least, I will discuss what parameters in terms of magnetization dynamics of MNPs and DNA design have to be considered in order to adapt MAC cascades to the target of interest, providing a setting for exchange and interactions at the workshop, in particular with PhD students.

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Magnetic nanoalloys – fine tuning of the anisotropy

Lacroix Lise-Marie

Type of abstract: Speakers

Magnetic materials play a major role in the current energy and societal transitions. However, the development of sustainable yet performant materials, without critical elements such as rare-earths (RE), remains a challenge. The bottom-up approach opens great potentiality for the rational design of efficient RE free magnetic materials, by the fine tuning of the intrinsic properties of individual particles, through their chemical composition and their shape anisotropy, and their controlled assembly resulting in optimized collective properties [1].

We will present the chemical synthesis of nanoparticles (Figure 1-2) and the fine tuning of their magnetic properties thanks to size, shape and composition control [2]. Their applications as catalytic agents magnetically heated or as building blocks for integrated magnets will be discussed.

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Magnetic Nanoparticles as Tracers in Biomedical Application – Magnetic Particle Imaging

Volker Behr

Type of abstract: Speakers

Magnetic particle imaging (MPI) [1] uses magnetic nanoparticles (MNPs) as tracers detecting their spatial distribution as well as relaxation properties. While the former enables imaging the latter grants access to functional parameters of the MNPs' environment.

The fundamental principle of signal generation is the non-linear response of MNPs to time varying magnetic fields. This response will generate a signal containing higher harmonics to the basic frequency. The amplitudes of the higher harmonics are characteristic for the used MNPs as well as their environmental conditions. Additional offset fields can be used for spatial encoding.

A variety of MPI scanners have been implemented employing differently shaped field free regions for spatial encoding and ranging from large stationary to small handheld devices [2]. Even scanners combining MPI with other modalities have been presented.

To make MNPs biocompatible they are coated and can be further functionalised by adding groups to the coating that will exhibit specific bindings (e.g., to antibodies) giving access to diagnostic applications.

Preclinical tests visualized first-pass blood flow in the murine heart or agglomeration of particles in specific binding sites. First tests towards clinical application presented a head scanner to be used in stroke units or a leg scanner for use in interventional surgery [3]. An approach based primarily on the spectroscopic information determines the presence of an analyte (e.g., SARS-CoV2) with highest sensitivity and specificity but with results available within seconds.

MPI is a versatile tool that has the potential to complement or even substitute established techniques in medicine allowing to reduce radiation exposure connected with other modalities.

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Dendronized iron oxide: Superspio20® as MPI tracer and magnetic hyperthermia agent

Geoffrey Cotin

Type of abstract: Speakers

The rise of MPI technology has led to the growing development of equipment requiring the use of an optimized magnetic tracer
for increased sensitivity and resolution. In addition, MPI technology paves the way for truly targeted tumour treatment using the field free point approach for focused magnetic hyperthermia. The need for a theranostic tracer is therefore essential for further preclinical and clinical development. Among the many methods of synthesizing nanoparticles, thermal decomposition is the method of choice for perfect control of the size, distribution, shape and composition of nanoparticles. Mastery of this method has led to the development of SuperSpio20, a dendronised iron oxide nanoparticle whose 20 nm iron oxide core has a
first-order MPI signal and optimized heat release for focused mild hyperthermia. The controlled dendronized coating maintains
a hydrodynamic diameter of less than 35 nm, allowing intravenous injection. This design also allows the labelling of therapeutic
cells without the need for a transfection agent for the development of MPI-tracked cell therapies.

Magnetic Nanocatalysis: Precision Heating for Sustainable Processes

Alvaro Gallo Cordova

Type of abstract: Speakers

Magnetic hyperthermia, initially developed for cancer therapy, is now gaining attention as a powerful strategy in catalysis. When exposed to an alternating magnetic field (AMF), magnetic nanoparticles, especially iron oxide-based, generate localized heat at their surface, creating nanoscale “hot spots” without significantly increasing the bulk temperature [1]. This remote, contactless heating enables highly efficient, spatially controlled, and energy-saving chemical reactions.

In this lecture, I will discuss how this concept can be redirected toward sustainable chemical processes, particularly in water remediation and renewable fuel production. Rather than serving as passive additives, magnetic nanoparticles are used here as active catalytic nanoheaters that accelerate key reactions under AMF.

In the environmental domain, we have developed superparamagnetic iron oxide mesocrystals [2] with improved magnetic properties [3], that effectively degrade both model pollutants like methylene blue, acid orange 8 [4] and methyl orange and complex real samples such as landfill leachates and cosmetic-derived microplastics [5,6]. When activated by AMF, these systems achieved near-complete mineralization in shorter times compared to conventional heating, highlighting the benefits of magnetic activation in Fenton-based oxidation.

For energy applications, we addressed key limitations of conventional biodiesel synthesis, including inefficient heat distribution and catalyst recovery, by designing magnetically separable iron oxide/alumina nanocatalysts [7]. With the aid of bare nanoheaters to reach reaction temperatures, we obtained high-purity biodiesel with conversion rates above 98.6%, exceeding EU quality standards. This approach avoids large thermal gradients and simplifies downstream processing. Furthermore, we are extending this methodology to the hydrogen evolution reaction (HER), developing magnetic catalysts that reduce the need for precious metals like platinum while benefiting from induction-assisted thermal activation.

Altogether, our findings show that magnetic induction catalysis offers a versatile, sustainable, and scalable platform for green chemistry. By integrating nanotechnology, catalysis, and magnetic fields, we pave the way toward efficient and environmentally responsible chemical manufacturing.

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