AIMagn Associazione Italiana di Magnetismo

UNIVERSITÀ DI PARMA

DEPARTMENT OF MATHEMATICAL, PHYSICAL AND COMPUTER SCIENCES

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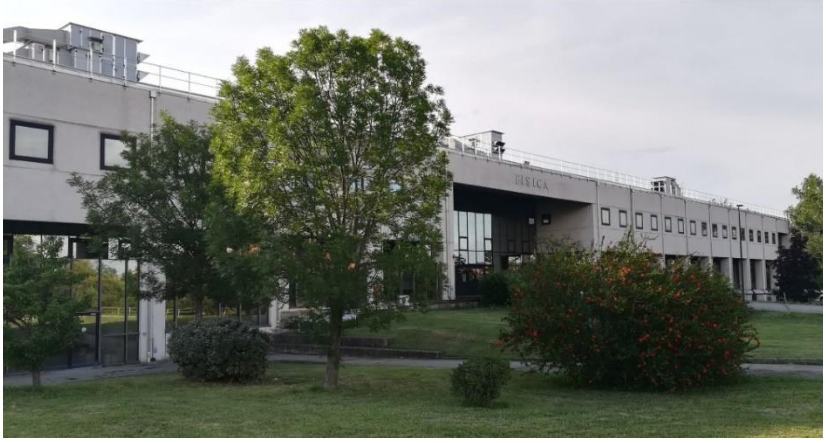
AIMagn Colloquia

Magnetic Materials for Energy



Thursday
May 26th 2022 | 14.30-18.00
Parma University Campus

Dipartimento di Scienze Matematiche,
Fisiche e Informatiche,
Parco Area delle Scienze 7/A, Parma

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P. Tiberto, INRIM Torino

Keynote speaker

Oliver Gutfleisch TU Darmstadt (Germany)
'Magnetic materials for energy conversion - state of the art'

Invited speakers

Vittorio Basso, INRIM Torino
Mario Carpentieri, Politecnico Bari
Francesca Casoli, CNR-IMEM
Francesco Cugini, Università di Parma
Claudio Sangregorio, CNR-ICCOM

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Book of Abstracts

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May 26th 2022

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The event belongs to a series of scientific talks, the AIMagn COLLOQUIA, organized by the Italian Association of Magnetism, aimed at promoting the dialogue and exchange between renowned international researchers in the field of Magnetism and the Italian community of Magnetism.

PROGRAM

Parma, May 26th, 2022 – 14:30-18:00

14:30-14:40	*Opening remarks* **Paola Tiberto** – INRIM, Torino – AIMagn President **Massimo Solzi** – Università di Parma
14:40-15:30	*Magnetic materials for energy conversion - state of the art* **Oliver Gutfleisch** – Technische Universität Darmstadt, Germany
15:30-15:50	*Magnetic tunnel junctions for energy harvesting* **Mario Carpentieri** – Politecnico di Bari
15:50-16:10	*Exploring the versatility of ferromagnetic shape memory thin films* **Francesca Casoli** – CNR-IMEM, Parma
16:10-16:50	*Coffee break*
16:50-17:10	*Magnetocaloric and electrocaloric refrigeration: methods and materials* **Vittorio Basso** – INRIM, Torino
17:10-17:30	*Tuning the properties of spinel ferrite nanoparticles for energy applications* **Claudio Sangregorio** – CNR-ICCOM, Firenze
17:30-17:50	*Functional composites for thermomagnetic energy conversion* **Francesco Cugini** – Università di Parma
17:50-18:00	*Closing remarks*

Please register at: **https://forms.gle/Aw2u3Zy2DK7xCVsN9**

Abstracts

Magnetic materials for energy conversion - state of the art

Oliver Gutfleisch

TU Darmstadt, Material Science, Germany

High performance permanent magnets are key components of energy-related technologies, such as direct drive wind turbines and e-mobility. They are also important in robotics and automatization, sensors, actuators, and information technology. The magnetocaloric effect (MCE) is the key for new and disruptive solid state-based refrigeration. Magnetic hysteresis – and its inherent energy product - characterises the performance of all magnetic materials. Despite considerable progress in the modelling, characterisation and synthesis of magnetic materials, hysteresis is a long-studied phenomenon that is still far from being completely understood. Discrepancies between intrinsic and extrinsic magnetic properties remain an open challenge and magnets do not operate yet at their physical limits. Basic material requirements, figure of merits, demand and supply, criticality of strategic elements are explained for both permanent magnets and magnetocalorics referring to the benchmark materials NdFeB and LaFeSi. The search for perfect defects is driving the material design strategy.

[1] O. Gutfleisch, M. A. Willard, E. Brück, C. H. Chen, S. G. Sankar, and J. P. Liu, Magnetic materials and devices for the 21st century: stronger, lighter, and more energy efficient. Adv. Mater. 23 (2011) 82.

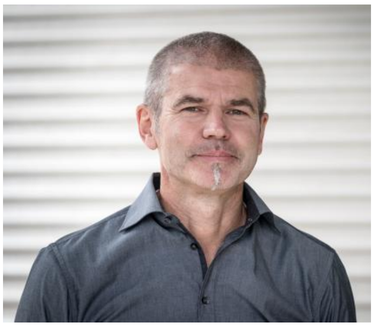
[2] K.P. Skokov and O. Gutfleisch, Heavy rare earth free, free rare earth and rare earth free magnets - vision and reality, Scripta Materialia View Point Set, 154 (2018) 289-294.

[3] M. Duerrschnabel, M. Yi, K. Uestuener, M. Liesegang, M. Katter, H.-J. Kleebe, B. Xu, O. Gutfleisch, L. Molina-Luna, Atomic structure and domain wall pinning in samarium -cobalt based permanent magnets, Nature Communications 8:54 (2017).

[4] T. Gottschall, K.P. Skokov, M. Fries, A. Taubel, I. Radulov, F. Scheibel, D. Benke, S. Riegg, O. Gutfleisch, Making a cool choice: the materials library of magnetic refrigeration, Progress Report in Advanced Energy Materials 9 no. 34 (2019) 1901322.

[5] T. Gottschall, A. Gracia-Condal, M. Fries, A. Taubel, L. Pfeuffer, L. Manosa, A. Planes, K.P. Skokov, O. Gutfleisch, A multicaloric cooling cycle that exploits thermal hysteresis, Nature Materials (2018).

[6] O. Gutfleisch, T. Gottschall, M. Fries, D. Benke, I. Radulov, K. P. Skokov, H. Wende, M. Gruner, M. Acet, P. Entel and M. Farle, Mastering hysteresis in magnetocaloric materials, Phil. Trans. R. Soc. A 374 (2016) 20150308.



Oliver Gutfleisch is a full Professor for Functional Materials at TU Darmstadt, a scientific consultant at Fraunhofer IWKS Hanau Materials Recycling and Resource Strategies and is running the external Max-Planck Research Group De Magnete at MPI for Iron Research Düsseldorf. His scientific interests span from permanent magnets for power applications to solid state energy efficient caloric cooling, ferromagnetic shape memory alloys, magnetic nanoparticles for biomedicine, with emphasis on tailoring structural and chemical properties on the nanoscale. He has published more than 460 papers, was awarded an EU ERC Advanced Grant (Cool Innov), is an IEEE Fellow and is the speaker of the DFG Cooperate Research Center 270 Hysteresis Design of Magnetic Materials for Efficient Energy Conversion.

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Magnetic tunnel junctions for energy harvesting

Mario Carpentieri

Politecnico di Bari, Italy

In the internet of things is fundamental to connect sensors and a key challenge is the development of products with low cost, low energy, very low physics scale, and very fast. In this scenario spintronics can be a great candidate to develop sensors with low energy dissipation, at nanoscale size, and with high performance. In particular, magnetic tunnel junction (MTJ) can be used for different purposes and applications beyond memory applications. In a recent joint project with the Italy Space Agency, we have developed and optimized MTJs for their use as high sensitive and radiational hardness detectors (spintronic diodes) in space applications. In this talk, I will review the state of the art of spintronic diodes focusing on high-detection sensitivity at room temperature, without any external bias fields, and for low-input power (micro-Watts or lower) [1]. In addition, spintronic detectors with broadband response can be used for energy harvesting applications [2]. In this talk, the possibility to use these MTJs for electromagnetic energy harvesters will be presented.

[1] L. Zhang, B. Fang, et al., *"Ultrahigh detection sensitivity exceeding 105 V/W in spin-torque diode"* Applied Physics Letters, Vol. 113(10), pp. 102401-1-4 (2018).

[2] B. Fang, M. Carpentieri, et al., *"Experimental Demonstration of Spintronic Broadband Microwave Detectors and Their Capability for Powering Nanodevices"* Physical Review Applied, Vol. 11(1), pp. 014022-1-7 (2019). d

Mario Carpentieri received the M.S. degree in electronic engineering and the Ph.D. degree in advanced technologies for the optoelectronic and photonic and electromagnetic modeling from the University of Messina, Italy, in 1999 and 2004, respectively. During 2003–2005, he was a Visiting Researcher in the Department of Applied Physics, University of Salamanca, Spain. From 2005 to 2011, he was an Assistant Researcher at the University of Perugia and University of Calabria, Italy. Since 2012, he has been with the Department of Electrical and Information Engineering, Politecnico di Bari, where he was an Assistant Professor, became an Associate Professor in 2015 and since May 2019 he is full professor. His current research interests include micromagnetic modeling of a variety of spintronic nanostructured materials and devices, including microwave nano-oscillators and diodes based on the spin-torque and spin-orbit effects. He is authors of more than 130 articles published in well-established international. He is founders of one start-up company for the development of parallel computation. Prof. Carpentieri is currently a member of the Editorial board and Associate Editor of the IEEE Transactions on Magnetics and Associate Editor of Scientific Reports (Nature).

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Exploring the versatility of ferromagnetic shape memory thin films

F. Casoli[1], M. Takhsha Ghahfarokhi[1], L. Nasi[1], S. Fabbrici[1], R. Cabassi[1], G. Trevisi[1], F. Albertini[1]
Alisa Chirkova[2], Fernando Maccari[2], Semih Ener[2], Konstantin P. Skokov[2], Oliver Gutfleisch[2]
Jon Ander Arregi[3], Michal Horký[3], Vojtěch Uhlíř[3]

[1]IMEM – CNR, Parma, Italy
[2]Functional Materials, Materials Science, Technical University of Darmstadt, Darmstadt, Germany
[3] CEITEC BUT, Brno University of Technology, Brno, Czech Republic

Ferromagnetic shape memory (FSM) compounds show multifunctional properties arising from a strong coupling between magnetic, thermal, and mechanical degrees of freedom. They are among the most promising classes of materials for multiple-stimuli actuation and energy harvesting from heat and vibrations. Ni_2MnGa is a model system within this class of compounds; it shows a martensitic phase transformation from a cubic phase (austenite) to a lower symmetry phase (martensite) by decreasing temperature.
We have grown Ni-Mn-Ga films with thickness up to 200 nm by RF sputtering on MgO(100) or Cr/MgO(100). The $L2_1$ austenitic phase grows epitaxial at high temperature. The martensitic phase, which is stable at room temperature, has a monoclinic 7M incommensurate structure and shows a complex microstructure made of arrays of twin lamellae with different alignment respect to the substrate symmetry directions and different martensitic cell orientations. These are X-type and Y-type families of twins.
We have explored the versatility of the system by modifying the martensitic microstructural patterns in different ways: through growth conditions, applying a stress during or after growth, annealing the films and patterning the films with different shapes and sizes on the nanometer and micron scale. The occurrence of specific microstructural patterns (X-type or Y-type) and their spatial organization strongly influence the magnetic properties, a correlation which we have studied by comparing magnetometry measurements on films with different martensitic patterns with micromagnetic simulations. We have also studied how the specific microstructural patterns influence the martensitic phase transformation, and particularly the thermal hysteresis and sharpness of the transition.

Francesca Casoli is a researcher at CNR - IMEM. In 2005 she received her PhD in Physics from the University of Parma with a thesis on magnetic thin films and multilayers with perpendicular anisotropy and exchange-spring properties. Her main interest is in the design and study of magnetic thin films, nanostructures and nanocomposites with new functional properties. She has published around 80 peer-reviewed papers and edited 1 book on magnetic materials for data storage, energy, sensors/actuators and biomedicine. She has been involved in several editorial activities and is currently member of the editorial board of *JPhys Materials*.

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Magnetocaloric and electrocaloric refrigeration: methods and materials

V. Basso, M. Kuepferling, E. Olivetti, A. Sola

Istituto Nazionale di Ricerca Metrologica (INRIM), Torino, Italy.

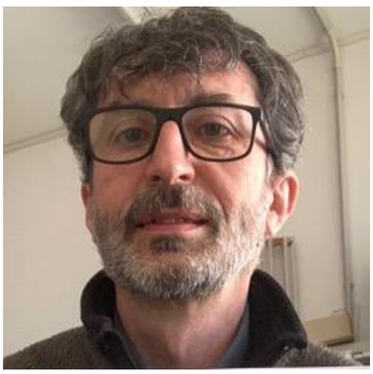
The growing demand for environmentally friendly refrigeration methods has stimulated the search for alternatives to the vapor compression technique currently used in most applications. Among the several methods proposed, the magnetic refrigeration has been widely investigated in the last twenty years [1]. This technique exploits the magnetocaloric effect of magnetic materials in which the magnetic field is able to produce an ordering at the microscopic scale and a corresponding decrease of the entropy [2,3]. More recently also the electrocaloric and elastocaloric effects have been considered as potentially useful active materials. In the talk, after a brief introduction on the engineering techniques used in the prototypes, the main magnetocaloric and electro-caloric materials will be illustrated with particular attention to their properties relevant for refrigeration and their characterization [4].

[1] A. Kitanovski et al. *"Magnetocaloric energy conversion"*, Springer (2016).

[2] V. Basso, *"Basics of the magnetocaloric effect"*, in Magnetic Cooling: From Fundamentals to High Efficiency Refrigeration (O. Gutfleisch and K. Sandeman, eds.) Wiley, in preparation, arXiv:1702.08347

[3] J. Lyubina, *"Magnetocaloric materials for energy efficient cooling"* Journal of Physics D: Applied Physics 50, 053002 (2017)

[4] V. Basso, et al. *"Specific heat and entropy change at the first order phase transition of La(Fe-Mn-Si)13-H compounds"*, J. Appl. Phys. 118 053907 (2015); V. Basso et al. *"Direct measurement of the electrocaloric effect in poly(vinylidene fluoride- trifluoroethylene-chlorotrifluoroethylene) terpolymer films"* , Appl. Phys. Lett. 103, 202904 (2013);



Dr. Vittorio Basso is research scientist at the Italian National Institute for research on metrology (INRIM) where he is responsible of the magnetic measurement laboratory. His research fields include: magnetic characterization and modeling, magnetocaloric effect and thermodynamics, spintronics effects in ferromagnets. He is co-author of 150 scientific publications in the field of magnetism.

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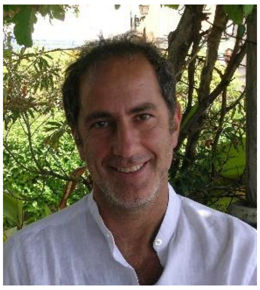
Tailoring the properties of spinel ferrite magnetic nanoparticle towards applications

Beatrice Muzzi[1,2], Alberto López-Ortega[3], Martin Albino[1,2], Claudia Innocenti[1,2] Giovanni Bertoni[4], César de Julián Fernandez[4] **Claudio Sangregorio[1,2]**

[1] ICCOM – CNR and INSTM, Sesto F.no, 50019 Italy
[2] INSTM and Dept. of Chemistry "U. Schiff", Univ. of Florence, 50019 Sesto. F.no, 50109, Italy
[3] Dept. de Física Aplicada, Universidad de Castilla-La Mancha, 45071 Toledo, Spain
[4] IMEM - CNR, Parco Area delle Scienze, 37/A, Parma, 43124, Italy

Spinel ferrite magnetic nanoparticles are expected to have a tremendous impact on several technological fields, ranging from electronics, to spintronics and clinical applications, one of the most prominent reasons being the possibility of fine tuning over a wide spectrum their unique physical properties to match the required optimal values. Indeed, their properties can be drastically modified not only through the control of the size and shape, but also by simply replacing, either completely or partially, the metal ions, or by modifying their distribution into the tetrahedral and octahedral cavitites without affecting the crystal structure.
In this contribution, we will provide few examples to show how this unique feature can be exploited for optimizing the nanomaterial's properties for different applications. In particular, we will focus on core-shell magnetic hybrid nanostructures displaying exchange bias behavior. We will demonstrate how 3d metal doping is an effective strategy to tune the chemical-physical properties of this new material provindg core@shell nanoparticles with high coercivity and increased antiferromagnetic ordering transition temperature, close to room temperature.

This research was supported by KIC- EIT Raw Materials INSPIRES project (n.20090).



Claudio Sangregorio graduated in Chemistry and obtained the Ph. D degree in Material Science at the Univ. of Florence. At present he has a position as Research Director at the Institue of Chemistry of OrganoMetallic Compounds at the Italian National Research Council. His scientific interests are in the field of nanomagnetism, and particularly in the synthesis and characterization of novel nanomaterials based on metal transition oxide or metal particles. In the recent years the activity has been mainly focused on the development of biocompatible magnetic nanomaterials for theranostic applications, magnetic-plasmonic nanostructures for high-sensitivity sensors and optimized ferrite nanoparticles for the realization of rare-earth free permanent magnets and high frequency low losses materials. Large part of his activity has also been devoted to the field of molecular magnetism. He has co-authored ca. 240 scientific articles on peer-reviewed international journals of chemistry, physics and material science and his work has been presented to several international conferences.

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Functional composites for thermomagnetic energy conversion

F. Cugini[1,2], C. Coppi[1,2], L. Gallo[1,2], G. Magnani[1], D. Pontiroli[1], M. Solzi[1,2]

[1]Department of Mathematical, Physical and Computer Sciences, University of Parma,
[2]IMEM-CNR, Parma, Italy

The magnetic refrigeration and the thermomagnetic harvesting of waste heat are two promising technologies that might contribute to the transition to a fully sustainable society. The fulfilment of their potentiality and their mass-market uptake still need the development of performant, critical-elements free and cost-effective active magnetic materials, with excellent thermomagnetic properties in the working temperature range. [1,2] Moreover, the implementation of materials in thermomagnetic devices requires improved thermal properties, easy machinability and long-term mechanical and chemical stability. In particular, the thermal diffusivity of active magnetic materials and their shaping in structures with a large surface area play a key role in defining the maximum operating frequency, the efficiency and the power of magnetic refrigerators and generators.[3] The preparation of functional composites offers the chance to improve thermal and mechanical properties of thermomagnetic materials and to design complex structures to promote a fast heat exchange. In this talk, the main advantages and drawbacks of thermomagnetic composites will be discussed, with a focus on the control and direct evaluation of their thermal diffusivity.[4-6] Furthermore, a versatile and cost-effective method to prepare high-conductive functional composites, enriched with carbon nanostructures, will be presented.[7]

[1] T. Gottschall, et al., "*Making a cool choice: the materials library of magnetic refrigeration*", Adv. Energy Mater. 34 (2019) 1901322.
[2] D. Dzekan, et al., "*Efficient and affordable thermomagnetic materials for harvesting low grade waste heat*" APL Mater. 9 (2021) 011105.
[3] A. Kitanovski, et al., "*Magnetocaloric energy conversion: from theory to applications*", Springer (2016).
[4] G. Porcari, et al., "*Influence of thermal conductivity on the dynamic response of magnetocaloric materials*", Int. J. Refrig. 59 (2015) 29.
[5] K. Sellschopp, et al., "*Interfacial thermal resistance in magnetocaloric epoxy-bonded La-Fe-Co-Si composites*", Energy Techno. 6 (2018) 1.
[6] F. Cugini, M. Solzi, "*On the direct measurement of the adiabatic temperature change of magnetocaloric materials*", J. Appl. Phys. 127 (2020) 123901.
[7] C. Coppi, et al., "*Graphene-based magnetocaloric composites for energy conversion*" (2022) submitted.

Francesco Cugini obtained his degree in Physics in 2013 and his PhD in Science and Technology of Materials in 2018 at the University of Parma. Actually, he is Assistant Professor in Experimental Physics the Department of Mathematical, Physical and Computer Sciences of the University of Parma and he is affiliated to the Institute of Materials for Electronics and Magnetism of the National Research Council (IMEM-CNR). His research activity, carried out in the frame of the Parma Research on Magnetism Laboratory (PaRMa), is focused on magnetocaloric materials for energy conversion, molecular nanomagnets for quantum computing, magnetic nanoparticles and metallorganic frameworks, ferroelectric materials. He has developed two innovative experimental setups for the direct characterization of the magnetocaloric effect in thin samples and under pulsed magnetic fields. He was involved in the POR-FESR FRIMAG project on the magnetic refrigeration. He is author of 38 papers and over 50 conferences contributions.

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Practical Information

Colloquium venue

The Colloquium will be held at the Physics department of the University of Parma. The address is:

Plesso di Fisica (Pad.03)

Parco Area delle Scienze 7/a (Campus), 43124 PARMA

GPS: Latitude N 44.767236 - Longitude E 10.315338

How to reach the Department of Mathematical, Physical and Computer Sciences (Physics building) of the University of Parma

How to reach University Campus "Parco Area delle Scienze":

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Coming from Bologna or from Verona (A1 motorway): take 'Parma Nord' exit, turn right onto Tangenziale Nord, then follow the indications to La Spezia/Campus/Langhirano.

From Tangenziale take exit n. 15 (Langhirano/Campus). This exit leads to a large round-about, take its first exit, marked “Campus”. Go straight on, across a small round-about, and enter the University gate.

Physics Building: after Univ. gate take the first turn on the right and follow for 200 m, the Physics building is on the right.

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Each line has a frequency of about 7 min, between 7:00 and 19:45, less frequent in August and September. Bus timetables from station to Campus available here: http://www.tep.pr.it/servizi_speciali/campus_express/default.aspx

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By Train

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