# AGNET 2015

## Bologna 17-19 February 2015

# BOOK OF ABSTRACTS

AIMagn Associazione Italiana di Magnetismo

CNR ISMN ISTITUTO PER LO STUDIO DEI MATERIALI NANOSTRUTTURATI

Dipartimento di Fisica e Astronomia
Università di Bologna

Dipartimento di Fisica e Astronomia
Università di Bologna

4th Conference of the Italian Magnetism Association (AIMagn)

# MAGNET 2015

## Bologna, February 17-19, 2015

## CNR Research Area - Via Gobetti 101

### Conference Chairs

**Alek Dediu (ISMN CNR, Bologna)**
**Lucia Del Bianco (University of Bologna)**

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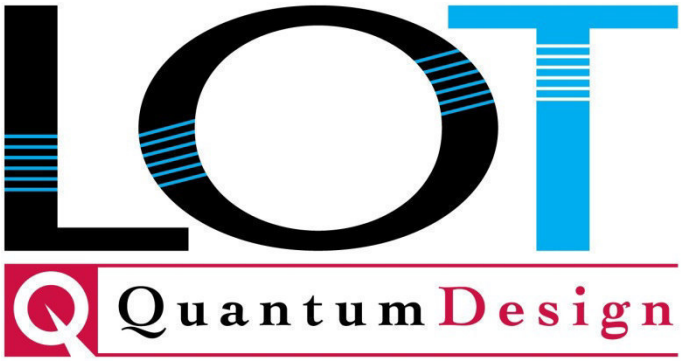



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# PROGRAM

# AGNET 2015

## Bologna 17-19 February 2015

### Tuesday – February 17th

| | |
|---|---|
| 9.00-10.00 | **REGISTRATION** |
| 10.00-10.20 | **Opening and Welcome** |
| 10.20-11.00 | Invited talk: **P. Vavassori**<br>Chair: D. Fiorani |
| | **MAGNETIC NANOSTRUCTURES**<br>Chair: P. Allia |
| 11.00-11.20 | **G. Varvaro** |
| 11.20-11.40 | **A. Brambilla** |
| 11.40-12.00 | **F. Spizzo** |
| 12.00-12.20 | **R.Vaia** |
| 12.20-12.40 | **R. Bertacco** |
| 12.40-13.00 | **R. Moroni** |
| 13.00-14.10 | LUNCH |
| | **THIN FILMS, SURFACES AND INTERFACES**<br>Chair: E. Agostinelli |
| 14.10-14.30 | **A. Barla** |
| 14.30-14.50 | **A. Vianelli** |
| 14.50-15.10 | **S. Laureti** |
| 15.10-15.30 | **F. Casoli** |
| 15.30-16.00 | COFFEE BREAK |
| | **SUPERCONDUCTIVITY AND MAGNETISM**<br>Chair: R. De Renzi |
| 16.00-16.20 | **A.Continenza** |
| 16.20-16.40 | **F. Bobba** |
| 16.40-17.00 | **S. Sanna** |
| 17.00-18.30 | **POSTER SESSION AP1-AP2-AP3-AP4**<br>Chairs: G. Panaccione F. Spizzo<br>**including Carnival happy hour** |

### Wednesday – February 18th

| | |
|---|---|
| | **MICROMAGNETICS, MAGNETIZATION DYNAMICS, SPIN DYNAMICS**<br>Chair: G. Carlotti |
| 9.00- 9.20 | **S. Perna** |
| 9.20-9.40 | **S. Tacchi** |
| 9.40-10.00 | **F. Montoncello** |
| 10.00-10.20 | **A. Meda** |
| 10.20-10.40 | **H. Hedayat** |
| 10.40-11.10 | COFFEE BREAK |
| | **NANOPARTICLES**<br>Chair: V. Iannotti |
| 11.10-11.30 | **G. Barrera** |
| 11.30-11.50 | **A. López-Ortega** |
| 11.50-12.10 | **G. Muscas** |
| 12.10-12.50 | Invited talk: **F. Gazeau**<br>Chair: R. Bertacco |
| 12.50 14. 10 | LUNCH |
| | **MAGNETISM AND BIOAPPLICATIONS**<br>Chair: C. Sangregorio |
| 14.10-14.30 | **C. de Julián Fernández** |
| 14.30-14.50 | **E. Fantechi** |
| 14.50-15.10 | **V. Iannotti** |
| 15.10-15.30 | **M. Fittipaldi** |
| 15.30-15.50 | **M. Coisson** |
| 15.50-17.00 | **POSTER SESSION BP1-BP2-BP3-BP4-CP1-CP2-CP3-CP4**<br>Chairs: M. Coisson S. Tacchi<br>**including Coffee Break** |
| 17.00-18.30 | MEETING OF THE ITALIAN MAGNETISM ASSOCIATION |
| 20.30 | **Conference Dinner**<br>**Circolo Ufficiali, via Marsala 12** |

### Thursday - February19th

| | |
|---|---|
| | **QUANTUM SPIN SYSTEMS AND MOLECULAR MAGNETISM**<br>Chair: P. Carretta |
| 9- 9.20 | **A. Cornia** |
| 9.20-9.40 | **M. Scarrozza** |
| 9.40-10 | **S. Bordignon** |
| 10-10.20 | **A. Candini** |
| 10.20-10.50 | COFFEE BREAK |
| 10.50-11. 30 | Invited talk: **S. Sanvito**<br>Chair: R. Sessoli |
| | **SPINTRONICS**<br>Chair:I.Bergenti |
| 11.30-11.50 | **A.Riminucci** |
| 11.50-12.10 | **C.Rinaldi** |
| 12.10-12.30 | **M.Madami** |
| 12.30-12.50 | **M. Carpentieri** |
| 12.50-13.10 | **A. Sola** |
| 13.10 14. 10 | LUNCH |
| | **MULTIFUNCTIONAL MAGNETIC MATERIALS**<br>Chair: M. Solzi |
| 14.10-14.30 | **D.Delmonte** |
| 14.30-14.50 | **P.Torelli** |
| 14.50-15.10 | **D.Di Sante** |
| 15.10-15.30 | **A.G.Monteduro** |
| 15.30-15.50 | **J. Lorenzana** |
| 15.50-16.10 | **AIMagn Best poster prize**<br>**CLOSING REMARKS** |

AIMagn Associazione Italiana di Magnetismo

CNR ISMN ISTITUTO PER LO STUDIO DEI MATERIALI NANOSTRUTTURATI

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA A.D. 1088

Dipartimento di Fisica e Astronomia
Università di Bologna

Tuesday

# February 17th

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**9.00 – 10.00 REGISTRATION OPEN**

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**10.00 – 10.20 OPENING and WELCOME**

**10.20 – 11.00 I-01 INVITED TALK - Magneto-plasmonic nanoantennas: news and views**

Paolo Vavassori
*CIC nanoGUNE, 20018 San Sebastian and IKERBASQUE Basque Foundation for Science, 48011 Bilbao (Spain)*
***Chair**: Dino Fiorani*

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**11.00 – 13.00 AO1 - Magnetic nanostructures**

***Session Chair**: Paolo Allia*

**11.00 – AO1-01 Ledge-type Co/$L1_0$-FePt exchange-coupled composites**

Th. Speliotis[1], G. Giannopoulos[1], D. Niarchos[1], W.F. Li[2], G. Hadjipanayis[2], G. Barucca[3], E. Agostinelli[4], S. Laureti[4], D. Peddis[4], A. M. Testa[4], and G. Varvaro[4]
[1] *Institute of Materials Science, NCSR Demokritos, Athens, Greece*
[2] *Department of Physics, University of Delaware, Newark, DE 19716, USA*
[3] *SIMAU, Università Politecnica delle Marche, via Brecce Bianche, Ancona, Italy*
[4] *ISM-CNR, Area della Ricerca RM1, Via Salaria Km 29,300, P.B. 10-00015, Monterotondo Scalo, Roma, Italy*

**11.20 – AO1-02 Magnetic properties of ordered CoO nanostructures on Co/Fe(001)**

A. Brambilla[1], A. Picone[1], D. Giannotti[1], M. Riva[1], G. Berti[1], A. Calloni[1], F. Boschini[1], H. Hedayat[1], E. Carpene[2], C. Dallera[1], G. Vinai[3], P. Torelli[3], M. Finazzi[1], L. Duò[1] and F. Ciccacci[1],
[1]*Dipartimento di Fisica, Politecnico di Milano, piazza Leonardo da Vinci, 32 – 20133 Milano (Italy)*
[2]*IFN-CNR, Dipartimento di Fisica, Politecnico di Milano, piazza Leonardo da Vinci, 32 – 20133 Milano (Italy)*
[3]*Laboratorio TASC, IOM-CNR, S.S. 14 km 163.5, Basovizza, I-34149 Trieste, Italy*

**11.40 – AO1-03 Exchange coupling and spatial confinement in IrMn/NiFe films and dot arrays**

F. Spizzo[1], E. Bonfiglioli[1], M. Tamisari[1], A. Gerardino[2], G. Barucca[3], A. Notargiacomo[2], F. Chinni[1], L. Del Bianco[4]
[1]*Dipartimento di Fisica e Scienze della Terra, Università di Ferrara, I-44122 Ferrara, Italy*
[2]*Istituto di Fotonica e Nanotecnologie, CNR, I-00156 Roma, Italy*
[3]*Dipartimento SIMAU, Università Politecnica delle Marche, I-60131 Ancona, Italy*
[4]*Dipartimento di Fisica e Astronomia, Università di Bologna, I-40127 Bologna, Italy*

**12.00 – AO1-04 Reentrant spin-flop transition in nanomagnets**

Ruggero Vaia[1,2], Mattia Crescioli[2,3], Paolo Politi[1,2]
[1]*Istituto dei Sistemi Complessi - CNR, via Madonna del Piano 10, I-50019 Sesto Fiorentino, Italy*
[2]*Istituto Nazionale di Fisica Nucleare, Sezione di Firenze via G. Sansone 1, I-50019 Sesto Fiorentino, Italy*
[3]*Dipartimento di Fisica e Astronomia, Università di Firenze, via G. Sansone 1, I-50019 Sesto Fiorentino, Italy*

**12.20 – AO1-05 Nanopatterning reconfigurable magnetic landscapes via thermally assisted scanning probe lithography**

E. Albisetti[1], D. Petti[1], M. Pancaldi[2], J. Curtis[3], W.P. King[4], P. Vavassori[2], E. Riedo[3], R. Bertacco[1]
[1]*PoliFab-Dipartimento di Fisica-Politecnico di Milano, Via Giuseppe Colombo, 81 20133 Milan, Italy*
[2]*CIC nanoGUNE Consolider, E-20009 San Sebastian, Spain.*
[3]*School of Physics, Georgia Institute of Technology, Atlanta, GA 30332, USA.*
[4]*Department of Mechanical Science and Engineering, University of Illinois Urbana-Champaign, Urbana IL, USA.*

**12.40 – AO1-06 Reentrant surface anisotropy in the antiferromagnetic/ferromagnetic bilayer Mn/Co/Cu(001)**

R. Moroni[1], F. Bisio[1], M. Caminale[2], P. Torelli[3], W-C Lin[4], M.Canepa[5] and L. Mattera[5]
[1]*CNR-SPIN, Genova, Italy*
[2]*Max-Planck Institut für Mikrostrukturphysik, Halle (Saale), Germany*

[3]*CNR-IOM, Trieste, Italy*
[4]*National Taiwan Normal University, Taipei, Taiwan*
[5]*Dipartimento di Fisica, Università di Genova, Genova, Italy*

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**13:00 - 14:10 LUNCH**

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**14.10 - 15.30 AO2 - Thin films, surfaces and interfaces**
***Session Chair**: Elisabetta Agostinelli*

**14.10 - AO2-01 Magnetic exchange coupling across a graphene layer**
A. Barla[1], V. Bellini[2], S. Rusponi[3], F. Donati[3], M. Pivetta[3], S. K. Mahatha[4], M. Papagno[5], L. Persichetti[6], C. Piamonteze[7], S. Fichtner[8], P. Ferriani[8], S. Heinze[8], P. Gambardella[6], H. Brune[3], and C. Carbone[1]
[1]*Istituto di Struttura della Materia (ISM), Consiglio Nazionale delle Ricerche (CNR), I-34149 Trieste, Italy*
[2]*S3-Istituto di Nanoscienze-CNR, Via Campi 213/A, I-41125 Modena, Italy*
[3]*Institute of Condensed Matter Physics (ICMP), Ecole Polytechnique Fédérale de Lausanne (EPFL), Station 3, CH-1015, Switzerland*
[4]*International Center for Theoretical Physics (ICTP), I-34014 Trieste, Italy*
[5]*Dipartimento di Fisica, Università della Calabria, I-87036 Arcavacata di Rende (Cs), Italy*
[6]*Department of Materials, ETH Zurich, CH-8093 Zurich, Switzerland*
[7]*Swiss Light Source, Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland*
[8]*Institute of Theoretical Physics and Astrophysics, University of Kiel, D-24098 Kiel, Germany*

**14.30 - AO2-02 Observation of large magnetoresistance in graphene oxide layers**
A. Vianelli [1,2], A. Candini[2], E. Treossi[3], V. Palermo[3], M. Affronte[1,2].
[1] *Dipartimento di Scienze Fisiche, Informatiche e Matematiche, Università di Modena e Reggio Emilia, Via G.Campi 213/a – 41125 Modena – Italy*
[2] *Centro S3 - Istituto di Nanoscienze - CNR, Via G. Campi 213/a - 41125 Modena - Italy*
[3] *ISOF - Istituto per la Sintesi Organica e la Fotoreattività - CNR Area della Ricerca di Bologna, Via P. Gobetti 101 - 40129 Bologna - Italy*

**14.50 - AO2-03 Chemical order and lattice distortion in $L1_0$ FePtCu thin films studied by EXAFS**
S. Laureti[1], C. Brombacher[2], D. Makarov[2,3], M. Albrecht[2,4], D. Peddis[1], G. Varvaro[1], and F. D'Acapito[5]
[1]*ISM - CNR, Area della Ricerca, Via Salaria km 29.500, 00016 Monterotondo Scalo, Italy*
[2]*Institute of Physics, Chemnitz University of Technology, D-09107 Chemnitz, Germany;*
[3]*Present address: Institute for Integrative Nanosciences, Leibniz Institute for Solid State and Materials Research (IFW Dresden), Helmholtzstr. 20, D-01069 Dresden, Germany*
[4]*Present address: Institute of Physics, Augsburg University, Universitätstrasse 1, D-86135 Augsburg, Germany*
[5]*CNR-IOM-OGG c/o ESRF, GILDA CRG, C/o ESRF BP220, F-38043 Grenoble, France*

**15.10 - AO2-04 Epitaxial films of tetragonal $Mn_{3-x}Ga$: magnetism, morphology and microstructure**
F. Casoli[1], J. Karel[2], P. Lupo[3], S. Fabbrici[1], L. Nasi[1], M. Campanini[1], P. Tiberto[4], F. Celegato[4], F. Albertini[1], C. Felser[2]
[1]*IMEM-CNR, Parco Area delle Scienze 37/A, 43124 Parma, Italy*
[2]*Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Str. 40, 01187 Dresden, Germany*
[3]*Information Storage Materials Laboratory, Department of Electrical and Computer Engineering, National University of Singapore, 1 Engineering Drive 3, Singapore 1175766, Singapore*
[4]*INRIM, Strada delle Cacce 91, 10135 Torino, Italy*

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**15.30 -16.00 COFFEE BREAK**

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**16.00 - 17.00 AO3 - Superconductivity and magnetism**
***Session Chair**: Roberto De Renzi*

**16.00 - AO3-01 Electronic properties of 42214 Fe-based superconductors**
Frederic Bucci[1], Gianni Profeta[1,2], Alessandra Continenza[1]

[1]*Diparimento di Scienze Fisiche e Chimiche, Università dell'Aquila,, L'Aquila (Italy)*
[2]*Cnr-Spin, Università dell'Aquila,, L'Aquila (Italy)*

**16.20 - AO3-02 Vortex-Antivortex coexistence in Nb based Superconductor/Ferromagnet heterostructures**

Bobba Fabrizio[1], Di Giorgio Cinzia[1], D'Agostino Domenico[1], Cucolo Anna M. [1], Iavarone Maria[3], Moore Steven A.[3], Karapetrov Goran[4], Novosad Valentyn[5], Yefremenko Volodymyr[5]
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[2] *Department of Condensed Matter Physics, University of Geneva, Geneva, Switzerland*
[3] *Temple University, Philadelphia , PA, United States*
[4]*Drexel University, Philadelphia, PA, United States*
[5]*Argonne National Laboratory, Argonne, IL, United States*

**16.40 - AO3-03 Investigation of the magnetic character of oxy-pnictides via Spin Dilution**

S. Sanna[1], P. Carretta[1], P. Bonfà[2], R. De Renzi[2], Y.Yiu[3], M. A. McGuire[4], A. Huq[5], S. E. Nagler[6], G. Lamura[7], A. Palenzona[7], A. Martinelli[7], M. Putti[7]
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[3] *Department of Physics and Astronomy, University of Tennessee Tennessee, USA*
[4] *Materials Science and Technology Division, Oak Ridge National Laboratory, Tennessee*
[5] *Chemical and Engineering Materials Division, Oak Ridge National Laboratory, Tennessee*
[6] *CIRE, University of Tennessee, Tennessee,USA*
[7]*CNR-SPIN and University of Genova, Genova, Italy*

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**17:00 - 18:30 POSTER SESSION I (including Carnival happy hour)**

**AP1, AP2, AP3, AP4**

***Session Chairs**: Giancarlo Panaccione, Federico Spizzo*

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Wednesday

# February 18th

**9.00 -10.40 BO1 - Micromagnetics, magnetization dynamics, spin dynamics**
***Session Chair**: Giovanni Carlotti*

**9.00 – BO1-01 Noise induced drift in magnetization dynamics of nanomagnets**
G. Bertotti[1], I.D. Mayergoyz[2], M. d'Aquino[3], S. Perna[4], A. Quercia[4], C. Serpico[4]
[1]*INRIM, Torino, Italy*
[2]*ECE Dept. and UMIACS, University of Maryland, College Park, MD, United States*
[3]*Engineering Dept., University of Naples 'Parthenope', Napoli, Napoli, Italy*
[4]*DIETI, University of Naples Federico II, Napoli, Napoli, Italy*

**9.20 – BO1-02 Thickness dependence of the spin wave dispersion in square antidot lattices**
S. Tacchi[1], P. Gruszecki,[2] M. Madami,[3] G. Gubbiotti,[1] G. Carlotti,[3] J. W. Klos,[2] M. Krawczyk,[2] A. Adeyeye[4]
[1]*Istituto Officina dei Materiali del CNR (CNR-IOM), Unità di Perugia, c/o Dipartimento di Fisica e Geologia, Via A. Pascoli, I-06123 Perugia, Italy*
[2]*Faculty of Physics, Adam Mickiewicz University in Poznan, Umultowska 85, Poznan 61-614, Poland*
[3]*Dipartimento di Fisica e Geologia, Università di Perugia, Italy*
[4]*Information Storage Materials Laboratory, Department of Electrical and Computer Engineering, National University of Singapore, 117576 Singapore*

**9.40 – BO1-03 Bandwidth variation of collective spin waves at the edge of magnetic transitions**
Federico Montoncello, Loris Giovannini
*Dipartimento di Fisica e Scienze della Terra – CNISM – Università di Ferrara, Ferrara (Italy)*

**10.00 – BO1-04 Ghost imaging for magneto optics applications**
Alice Meda, Ambra Caprile, Ivano Ruo Berchera, Ivo Pietro Degiovanni, Alessio Avella, Alessandro Magni, Giorgio Brida, Marco Genovese
*Istituto Nazionale di Ricerca Metrologica, Torino, Italy*

**10.20 – BO1-05 Ultrafast demagnetization of metals: single-particle vs collective excitations**
H. Hedayat[1], F. Boschini[1], D. Bugini[1], C. Dallera[1], E. Carpene[2]
[1]*Dipartimento di Fisica, Politecnico di Milano, piazza L. da Vinci 32, Milano*
[2]*IFN-CNR, Dipartimento di Fisica, Politecnico di Milano, piazza L. da Vinci 32, Milano*

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**10.40 - 11.10 COFFEE BREAK**

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**11.10 - 12.10 BO2- Nanoparticles**
***Session Chair**: Vincenzo Iannotti*

**11.10 - BO2-01 $Fe_3O_4$ nanoparticles and nanocomposites for applications in biomedicine and the ICTs: nanoparticle aggregation, interaction and effective magnetic anisotropy**
P. Allia,[1] G. Barrera,[2,3] P. Tiberto,[3] T. Nardi,[4] Y. Leterrier,[4] and M. Sangermano[1]
[1]*DISAT, Politecnico di Torino, Torino, I-1029, Italy*
[2]*Chemistry Dept,.Università di Torino, Torino, I-10125, Italy*
[3]*INRiM, Electromagnetism Division, Strada delle Cacce 91, I-10135 Torino, Italy*
[4] *EPFL- STI IMX LTC, CH-1015 Lausanne, Switzerland*

**11.30 - BO2-02 Tailoring magnetic size-dependent properties of Co-ferrite nanoparticles for permanent magnet applications**
A. López-Ortega[1], E. Lottini[1], C. de Julian Fernandez[2] and C. Sangregorio[3]
[1]*INSTM and Università degli Studi di Firenze, Sesto Fiorentino (Firenze), Italy.*
[2]*INSTM and CNR-IMEM, I-43124 Parma, Italy.*
[3]*INSTM and CNR-ICCOM, I-50019 Sesto Fiorentino (Firenze), Italy*

**11.50 - BO2-03 Advanced Multiferroic Nanocomposites**
G. Muscas[1,2,3], R. Mathieu[3], P. Anil Kumar[3], G. Concas[2], G. Varvaro[1], C. Cannas[4], A Musinu[4], and D. Peddis[1]
[1]*Istituto di Struttura della Materia - CNR, 00016 Monterotondo Scalo (RM), Italy*

[2]*Dipartimento di Fisica, Università di Cagliari, S.P. Monserrato-Sestu km 0.700, 09042, Monserrato, Italy*
[3]*Department of Engineering Sciences, Uppsala University, Box 534, SE-751 21, Uppsala, Sweden*
[4]*Dipartimento di Scienze Chimiche e Geologiche, Università di Cagliari, S.P. Monserrato-Sestu km 0.700, 09042, Monserrato, Italy*

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**12.10 - 12.50 I-02 INVITED TALK - Nanomagnets in the Organism: Therapeutic Opportunities and Long Term Fate**

Florence Gazeau
*Matière et Systèmes Complexes, CNRS / Université Paris Diderot, 75205 Paris Cedex 13, France*
***Chair**: Riccardo Bertacco*

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**12:50 - 14:10 LUNCH**

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**14.10 – 15.50 BO3 - Magnetism and bioapplications**
***Session Chair**: Claudio Sangregorio*

**14.10 – BO3-01 Magneto-plasmonic films for biosensing applications**

C.de Julián Fernández[1], M.G. Manera[2], A. Colombelli[2,3], P Lupo[1], F. Casoli[1], F. Albertini[1], R. Rella[2]
[1]*Institute of Materials for Electronics and Magnetism - CNR Parma, Parco Aree delle Scienze 37/A, 43123, Parma*
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[2] *Department of Innovation Engineering, University of Salento, Strada prov. per Monteroni 73100, Lecce*

**14.30 – BO3-02 Ferritin-based Hybrid Nanoparticles for Theranostic Applications**

Elvira Fantechi[1], Claudia Innocenti[1], Andrea Guerrini[1], Manuela Fornara[2], Elisabetta Falvo[2], Pierpaolo Ceci[2], Matteo Zanardelli[3], Lorenzo Di Cesare Mannelli[3], Carla Ghelardini[3], Dante Gatteschi[1], Claudio Sangregorio[4]
[1] *INSTM-LaMM, Department. of Chemistry, University of Florence, Firenze, Italy*
[2]*National Research Council of Italy, Institute of Molecular Biology and Pathology, Roma, Italy*
[3] *Department NEUROFARBA, University of Florence, Firenze, Italy*
[4] *National Research Council of Italy, ICCOM, Firenze, Italy*

**14.50 – BO3-03 Novel Fe-doped hydroxyapatite nanoparticles with high-spin ground states**

Vincenzo Iannotti[1], Giovanni Ausanio[1], Luciano Lanotte[1], Kalliopi N. Trohidou[2], Monica Sandri[3], and Anna Tampieri[3]
[1]*CNR-SPIN and Department of Physics, University of Naples "Federico II", P.le V. Tecchio 80, I-80125 Napoli, Italy*
[2]*IAMPPNM, Department of Materials Science, NCSR 'Demokritos', Aghia Paraskevi, 15310 Athens, Greece*
[3]*Institute of Science and Technology for Ceramics—National Research Council, Faenza (RA) 48018, Italy*

**15.10 – BO3-04 Magnetic Nanoparticles in Bioreactors: host-guest characterization by EPR and Mössbauer Spectroscopies**

M. Fittipaldi[1], R. Mercatelli[1], S.Sottini[2], E. Falvo[3], P. Ceci[3], D.Gatteschi[2], M. Ardini[4], B.D. Howes[2], D. Rovai[2], A. Ilari[3], A. Fiorillo[3], M. Lantieri[5], G. Spina[1], S. Stefanini[3]
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[5] *Istituto dei Sistemi Complessi, Consiglio Nazionale delle Ricerche, Via Madonna del Piano 10, 50019 Sesto Fiorentino (FI) Italy*

**15.30 – BO3-05 $Ni_{80}Fe_{20}$ nanodisks by nanosphere lithography for biomedical applications**

Paola Tiberto[1], Federica Celegato[1], Gabriele Barrera[1,2], Gianluca Conta[1], Marco Coïsson[1], Franco Vinai[1]
[1]*INRIM, Electromagnetics Division, Torino (TO), Italy*
[2]*Università degli Studi di Torino, Chemistry Department, Torino (TO), Italy*

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**15.50 – 17.00 POSTER SESSION II (including Coffee break)**

**BP1, BP2, BP3, BP4, CP1, CP2, CP3, CP4**

***Session Chairs**: Marco* Coïsson *, Silvia Tacchi*

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**17.00 – 18.30 MEETING OF THE ITALIAN MAGNETISM SOCIETY**

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**20.30 CONFERENCE DINNER**

Thursday

# February 19th

**9.00 - 10.20 CO1 - Quantum spin systems and molecular magnetism**
***Session Chair**: Pietro Carretta*

**9.00 - CO1-01 Mapping single-site magnetic anisotropy tensors by torque magnetometry**
Andrea Cornia[1], Luca Rigamonti[1], Andrea Nava[1,2], Mauro Perfetti[3], Marie-Emmanuelle Boulon[3], Anne-Laure Barra[4], Xiaoliang Zhong[5], Kyungwha Park[5], Roberta Sessoli[3]
[1]*Dipartimento di Scienze Chimiche e Geologiche, Università degli Studi di Modena e Reggio Emilia (UniMORE) & INSTM RU of Modena and Reggio Emilia, via G. Campi 183, 41125 Modena, Italy*
[2]*Dipartimento di Scienze Fisiche, Informatiche e Matematiche, UniMORE, via G. Campi 213/a, 41125 Modena, Italy*
[3]*Laboratory of Molecular Magnetism (LaMM), Dipartimento di Chimica 'Ugo Schiff', Università degli Studi di Firenze & INSTM RU of Firenze, via della Lastruccia 3-13, 50019 Sesto Fiorentino (FI), Italy*
[4]*LNCMI–CNRS, BP166, 25 Avenue des Martyrs, 38042 Grenoble Cedex 9, France*
[5]*Department of Physics, Virginia Tech, Blacksburg, Virginia 24060, USA*

**9.20 - CO1-02 Magnetic properties and magneto-electric effects in molecular spin helices: Insights from theory and simulations**
M. Scarrozza[1], A. Vindigni[2], P. Barone[1], A. Caneschi[3], R. Sessoli[3], S. Picozzi[1]
[1]*CNR SPIN, UOS L'Aquila, via Vetoio 10, 67100 Coppito, L'Aquila, Italy*
[2]*Laboratorium für Festkörperphysik, ETH Zürich, CH-8093 Zürich, Switzerland*
[3]*Laboratory of Molecular Magnetism (LaMM), Dip.to di Chimica 'Ugo Schiff', Università degli Studi di Firenze & INSTM RU, via della Lastruccia 3-13, 50019 Sesto Fiorentino (FI), Italy*

**9.40 - CO1-03 Relaxation Dynamics of the Dy6 Molecular Ring**
S. Bordignon[a], P. Arosio[b], S. Sanna[c], L. Bordonali[c], C. Pernechele[a], G. Allodi[a], R. De Renzi[a], E. Garlatti[a], S. Carretta[a], P. Santini[a], G. Amoretti[a], R. Inglis[d], S.Langley[e] ,K.S. Murray[e], E.K. Brechin[d], A. Lascialfari[b,c]
[a]*Parma University, Dept. of Physics and Earth Sciences, Parma, Italy*
[b]*Milan University, Dept. of Physics, Milano Italy*
[c]*Pavia University, Dept. of Physics, 27100, Pavia, Italy*
[d] *School of Chemistry, The University of Edinburgh, Edinburgh, EH9 3JJ, U.K.*
[e] *School of Chemistry, Monash University, , Clayton, Victoria 3168, Australia*

**10.00 - CO1-04 Understanding and controlling the magnetic interaction between Ln(III) bis-(phthalocyanine)s "double decker" molecular nanomagnets and a magnetic substrate**
A. Candini[1], D. Klar[2], S. Marocchi[1], V. Corradini[1], R. Biagi[3,1], V. de Renzi[3,1], U. del Pennino[3,1], F. Troiani[1], V. Bellini[1], S. Klyatskaya[4], M. Ruben[4,5], K. Kummer[6], N. B. Brookes[6], H. Wende[2], M. Affronte[3,1]
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[5]*Institut de Physique et Chimie des Matériaux de Strasbourg, UMR 7504 UdS-CNRS, 67034 Strasbourg Cedex 2, France*
[6]*European Synchrotron Radiation Facility (ESRF), Avenue des Martyrs 71, 38043 Grenoble, France*

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**10.20 - 10.50 COFFEE BREAK**

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**10.50 – 11.30 I-03 INVITED TALK - Charge and spin transport in organic single crystals from first principles**
Stefano Sanvito
*School of Physics and CRANN, Trinity College, Dublin 2, Ireland*
***Chair**: Roberta Sessoli*

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**11.30- 13.10 CO2 - Spintronics: materials and devices**
***Session Chair**: Ilaria Bergenti*

**11.30 - CO2-01 Organic spintronics: state of the art and recent results**
Alberto Riminucci[1], Ilaria Bergenti[1], Patrizio Graziosi[1], Marco Calbucci[1], Raimondo Cecchini[1], Francesco Borgatti[1], Alessandro Gambardella[1], V.Alek Dediu[1]
[1] *Istituto per lo studio dei materiali nanostrutturati, CNR, Via Gobetti 101, 40129 Bologna*

**11.50 - CO2-02 Bulk Rashba effect driven by ferroelectric polarization in GeTe**
C. Rinaldi[1], D. Di Sante[2], A. Giussani[3], R.-N. Wang[3], S. Bertoli[1], M. Cantoni[1], L. Baldrati[1], I. Vobornik[4], G. Panaccione[4], R. Calarco[3], S Picozzi[2], R. Bertacco[1]
[1]*Department of Physics, Politecnico di Milano, P.zza l. da Vinci 32, 20133 Milano, Italy*
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[3]*Department of Epitaxy, Paul Drude Institute for Festkörperelektronik, Berlin, Germany*
[4]*TASC Laboratory, Elettra Synchrotron IOM-CNR, Trieste, Italy*

**12.10 - CO2-03 Micro-focused Brillouin light scattering study of the magnetization dynamics driven by Spin Hall effect in a transversely magnetized NiFe nanowire**
M. Madami,[1] G. Gubbiotti,[2] T. Moriyama,[3] K. Tanaka[3], G. Siracusano,[4] M. Carpentieri,[5] G. Finocchio,[4] T. Ono,[3] S. Tacchi,[2] G. Carlotti[1]
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[3]*Institute for Chemical Research, Kyoto University, Japan*
[4]*Department of Electronic Engineering, Industrial Chemistry and Engineering University of Messina, Italy*
[5]*Department of Electrical and Information Engineering, Politecnico of Bari, Italy*

**12.30 - CO2-04 Skyrmion racetrack memory driven by spin-Hall effect**
R. Tomasello[1], E. Martinez[2], R. Zivieri[3], L. Torres[2], M. Carpentieri[4], G. Finocchio[5]
[1]*Department of Computer Science, Modelling, Electronics and System Science, University of Calabria, Via P. Bucci I-87036, Rende (CS), Italy*
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[5]*Department of Electronic Engineering, Industrial Chemistry and Engineering, University of Messina, C.da di Dio, I-98166, Messina, Italy*

**12.50 - CO2-05 Evaluation of thermal gradients by heat flux detection in longitudinal spin Seebeck effect samples**
Alessandro Sola[1], Michaela Kuepferling[1], Elena Ferraro[1], Vittorio Basso[1], Massimo Pasquale[1]
[1] *Istituto Nazionale di Ricerca Metrologica (INRIM), Strada delle Cacce 91, 10135, Turin, Italy*

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**13.10 – 14.10 LUNCH**

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**14.10- 15.50 CO3- Multifunctional magnetic materials**
***Session Chair**: Massimo Solzi*

**14.10 - CO3-01 A new effective strategy for the study of magnetic disordered systems: how to investigate the field effects on spontaneous magnetization reversal of bulk $BiFe_{0.5}Mn_{0.5}O_3$**
D. Delmonte[1,2], F. Mezzadri,[3] C. Pernechele,[1] E. Gilioli,[2] G. Calestani,[3] R. Cabassi,[2] F. Bolzoni,[2] G. Spina,[4] M. Lantieri,[5] and M. Solzi[1]
[1]*Dipartimento di Fisica e Scienze della Terra, Università di Parma, Italy*
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[4]*Dipartimento di Fisica, Università di Firenze, Sesto Fiorentino (FI), Italy*
[5]*ISC-CNR, Sesto Fiorentino (FI), Italy*

**14.30 - CO3-02 Spectroscopy investigation of magnetic memory device *in-operando***

Piero Torelli[1], Benoit Gobaout[1], Giovanni Vinai[1], Roberta Ciprian[1], Damjan Krizmancic[1], Alexander Petrov[1], Bruce Davidson[1], Ivana Vobornik[1], Jun Fujii[1], Pasquale Orgiani[1,2], Tommaso Pincelli[3], Giancarlo Panaccione[1] and Giorgio Rossi[1,3]
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[3] *Dipartimento di Fisica dell'Università di Milano, via Celoria 16, 20133 Milano, Italy*

**14.50 - CO3-03 Topological tuning in three dimensional Dirac semimetals**

Awadhesh Narayan[1], Domenico Di Sante[2], Silvia Picozzi[2] and Stefano Sanvito[1]
[1]*School of Physics and CRANN, Trinity College, Dublin 2, Ireland*
[2]*Consiglio Nazionale delle Ricerche (CNR-SPIN), Via Vetoio, L'Aquila, Italy*

**15.10 - CO3-04 Optimization of $BiFeO_3$ thin films for spintronic applications**

Anna G. Monteduro[a,b], Chiara Leo[a], Shilpi Karmakar[a], Zoobia Ameer[a,b], Vittorianna Tasco[a], Silvia Rizzato[a,b], Anna P. Caricato[b], Maurizio Martino[b], Ross Rinaldi[a,b], Giuseppe Maruccio[a,b]
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[b] *Department of Mathematics and Physics ''Ennio De Giorgi'', University of Salento, Lecce, 73100, Italy*

**15.30 - CO3-05 Tuning order-by-disorder multiferroicity in CuO by doping**

J. Lorenzana[1]
[1]*Istituto dei Sistemi Complessi, Consiglio Nazionale delle Ricerche, Dipartimento di Fisica, Università di Roma "La Sapienza", P. Aldo Moro 2, 00185 Roma, Italy*

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**15:50 – 16:10 AIMagn BEST POSTER PRIZE and CLOSING REMARKS**

# List of POSTERS

## AP1 - Magnetic nanostructures

### AP1-01 Magnetic circular dichroism in magnetoplasmonic systems: from gold to alloy nanoparticles

V. Bonanni[1], F. Pineider[1], G. Campo[1,2], C. de Julián Fernández[1,3], G. Mattei[4], V. Amendola[5], C. Sangregorio[1,6]
[1] *Department of Chemistry, University of Florence & INSTM, 50019 Florence, Italy*
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[3] *CNR-IMEM, 43124 Parma, Italy*
[4] *Department of Physics, University of Padova, 35131 Padova, Italy*
[5] *Department of Chemical Sciences, University of Padova, 35131 Padova, Italy*
[6] *ICCOM-CNR Sesto Fiorentino, 50019 Florence, Italy*

### AP1-02 Revealing the chemical composition of Fe oxide nanoparticles by magneto-optical spectroscopy

G. Campo[1,2], F. Pineider[2], V. Bonanni[2], M. Albino[2], A. Caneschi[2], C. de Julià Fernàndez[3], C. Innocenti[2], C. Sangregorio[4]
[1]*CNR-INO-UOS Firenze LENS, Via N. Carrara 1, 50019 Sesto Fiorentino (FI), ITALY*
[2]*INSTM and La.M.M, Department of Chemistry U. Schiff, Università di Firenze, Via della Lastruccia 3, 50019 Sesto Fiorentino (FI), ITALY*
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[4]*CNR-ICCOM and INSTM, Via Madonna del Piano 10, 50019 Sesto Fiorentino (FI), ITALY*

### AP1-03 Understanding the magnetism of Co thin films from the local scale anisotropies

Ilaria Carlomagno[1], C. Meneghini[1], K.V. Sarathlal[2] and A. Gupta[2]
[1]*Università di Roma Tre, Dipartimento di scienze, via della Vasca Navale, 84 00146 Roma, Italia*
[2]*UGC-DAE Consortium for Scientific Research, University Campus, Khandwa Road, Indore 452017, India*

### AP1-04 Exchange bias in $Co_xFe_{1-x}O$(AFM)|$Co_xFe_{3-x}O_4$(FiM) Core|Shell nanoparticles

E. Lottini[1,2], A. López-Ortega[1,2], G. Bertoni[3] , S. Turner[4], C. de Julián Fernandez[2,3], G. Salviati[3], C. Sangregorio[2,5]
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[2]*INSTM, Sesto Fiorentino (Firenze), Italy*
[3]*CNR-IMEM, Parma, Italy.*
[4]*EMAT, University of Antwerp, Belgium.*
[5]*CNR-ICCOM, Sesto Fiorentino (Firenze), Italy*

### AP1-05 Zn-doped cobalt ferrite nanoparticles: the effect of zinc doping on the magnetic properties

Valentina Mameli[1], Anna Musinu[1,2], Andrea Ardu[1,2], Guido Ennas[1,2], Davide Peddis[3], Daniel Niznansky[4], Nguyen T. K. Thanh[5], Carla Cannas[1,2]
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[2]*Consorzio Interuniversitario Nazionale per la Scienza e Tecnologia dei Materiali (INSTM), Italy*
[3]*Institute of Structure of Matter, National Research Council (CNR), Italy*
[4]*Department of Inorganic Chemistry, Charles University of Prague, Czech Republic*
[5]*University College London (UCL), London, United Kingdom*

### AP1-06 Magnetic Properties of Nanoparticles Investigated by Niobium NanoSQUIDs

R. Russo[1], E. Esposito[1], D. Fiorani[2], C. Granata[3], A. Vettoliere[3] and D. Peddis[2]
[1] *Istituto per la Microelettronica e i Microsistemi, Unità di Napoli, 80128 Napoli, Italy*
[2] *CNR, Istituto di Struttura della Materia, 00015 Monterotondo Scalo (RM), Italy*
[3]*CNR, Istituto di Cibernetica "E.Caianiello" , 80078 Pozzuoli (NA), Italy*

### AP1-07 Effect of the oxygen content in the reaction environment on size and shape of $CoFe_2O_4$ nanoparticles: morphological analysis by aspect maps

G. Muscas[3,4,5], G. Singh[1], W. R. Glomm[2], R. Mathieu[5], P. Anil. Kumar[5], G. Concas[4], E. Agostinelli[3] and D. Peddis[3]
[1]*Ugelstad Laboratory, Department of Chemical Engineering, Norwegian University of Science and Technology (NTNU), NO-7491, Trondheim, Norway*
[2]*SINTEF Materials and Chemistry, Biotechnology and Nanomedicine Sector, Trondheim, NO-7491, Norway*
[3]*Istituto di Struttura della Materia - CNR, 00016 Monterotondo Scalo (RM), Italy*
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[5]*Department of Engineering Sciences, Uppsala University, Box 534, SE-751 21, Uppsala, Sweden*

**AP1-08 Charge transport in self assembled Fe4 single molecular magnet-gold nanoparticle multilayers**

Zoobia Ameer[a], Mauro Perfetti[b], Giuseppe Cucinotta[b], Andrea Cornia[c], Roberta Sessoli[b], Giuseppe Maruccio[a]
[a] *NNL Istituto Nanoscienze - CNR and Department Of Mathematics and Physics, University Of Salento, Via per Arnesano, 73100 Lecce, Italy*
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[c] *Dipartimento di Chimica—Centro SCS, Universita di Modena e Reggio Emilia, UdR INSTM, Via G. Campi 183, 41100 Modena (Italy)*

**AP1-09 Study of the size, shape and solvent effects on longitudinal and transverse relaxometry of ferrite-based MNP**

M. Basini[a], P. Arosio[a], M. F. Casula[b], A. Barbaglia[a], E. Fantechi[d], C. Sangregorio[d,e], and A. Lascialfari[a, c]
[a]*Dipartimento di Fisica and INSTM, Università degli Studi di Milano, Milano, Italy*
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[e]*ICCOM-CNR, Sesto F.no, Italy*

**AP1-10 A facile and fast one step bottom-up approach for developing iron oxides magnetic nanoparticles**

M. Bellusci[1], P. Guglielmi[1], A. La Barbera[1], A. Masi[1, 2], F. Padella[1], D. Peddis[3], D. Secci[4]
[1]*ENEA, CR Casaccia, via Anguillarese 301, 00123 Roma, Italy*
[2]*Università degli Studi della Tuscia, via S. Camillo de Lellis snc, 01100 Viterbo, Italy*
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[4]*Università di Roma La Sapienza, Piazzale Aldo Moro 5, 00185 Roma, Italy*

**AP1-11 One-step synthesis of magnetic zeolites from waste materials**

Claudia Belviso[1], Elisabetta Agostinelli[2], S. Belviso[3], F. Cavalcante[1], G. Diego Gatta[4], Davide Peddis[2], Gaspare Varvaro[2], S. Fiore[1]
[1]*IMAA–CNR, Tito Scalo (PZ), 85050, Italy*
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[4]*Università degli Studi di Milano, Dipartimento di Scienze della Terra, I-20133 Milano*

**AP1-12 A Low-temperature Solvent-free Chemical Strategy for the Direct Synthesis of L10 FePt Nanoparticles from Layered Precursor**

A. Capobianchi [1], E. Agostinelli [1], X. C. Hu[2], C. Ni[2], G. C. Hadjipanayis[3]
[1] *ISM-CNR AdR Roma1, Via Salaria Km 29.3, Monterotondo 00015, Rome (Italy)*
[2] *Department of Materials Science and Engineering, University of Delaware, DE, USA*
[3] *Department of Physics and Astronomy, University of Delaware, DE, USA*

**AP1-13 Spin wave eigenmodes in single and coupled sub-150 nm rectangular permalloy dots**

G. Carlotti[1], S. Tacchi[2], G. Gubbiotti[2], M. Madami[1], H. Dey[3] , G. Csaba[3] and W. Porod[3]
[1] *Dipartimento di Fisica e Geologia, Università di Perugia, Perugia, Italy*
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[3] *Center for Nano Science and Technology, Department of Electrical Engineering, University of Notre Dame, Notre Dame, Indiana 46556, USA*

**AP1-14 An alternative route to synthesize large area magnetic nanostructure by block copolymers**

F. Celegato[1], P. Tiberto[1], G. Barrera[1,2], M. Coïsson[1], G. Aprile[1,3], L. Boarino[1], G. Seguini[4], F. Ferrarese Lupi[4], T. J. Giammaria[4], M. Perego[4]
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[3]*Università del Piemonte Orientale, Alessandria, Italy*
[4]*MDM, IMM - CNR, Agrate Brianza, Italy.*

**AP1-15 Magnetization reversal in finite size dot arrays: Global Configurational Anisotropy**

Samuele Fin[1], Ben Van de Wiele[2], Anandakumar Sarella[3], Paolo Vavassori[1,3,4] and Diego Bisero[1,5]
[1]*Dipartimento di Fisica e Scienze della Terra, Università degli Studi di Ferrara, 44122 Ferrara, Italy*
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[3]*CIC nanoGUNE Consolider, Donostia-San Sebastian, Spain*
[4]*IKERBASQUE, Basque Foundation for Science, 48011 Bilbao, Spain*
[5]*CNISM, Unità di Ferrara, 44122 Ferrara, Italy*

**AP1-16 Spin Dynamics in Hybrid Iron Oxide-Gold Nanostructures**

T. Orlando[1], A. Capozzi[2], E. Umut[3,4], L. Bordonali[1], M. Mariani[5], P. Galinetto[1], F. Pineider[6], C. Innocenti[6], P. Masala[7], F. Tabak[3], M. Scavini[7,8], P. Santini[9], M. Corti[1], C. Sangregorio[6,10], P. Ghigna[11], and A. Lascialfari[12,1]
[1]*Department of Physics, Università di Pavia, and Consorzio INSTM, Pavia, I-27100, Italy*
[2]*Institute of Physics of Biological Systems, EPFL, Lausanne, CH-1015, Switzerland*
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**AP1-17 Beyond the Effect of Particle Size: Influence of $CoFe_2O_4$ Nanoparticle Arrangements on Magnetic Properties**

D. Peddis[1], C. Cannas[2], A. Musinu[2], A. Ardu[2], F. Orrù[2], D. Fiorani[1], S. Laureti[1], D. Rinaldi[1,4,5], G. Muscas[1,3], G. Concas[3], and G. Piccaluga[2]
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[5]*Consorzio Nazionale Interuniversitario per le Scienze Fisiche della Materia (CNISM), Roma, Italy*

**AP1-18 Structure and Magnetic Properties of Fe nanoparticles embedded in a Cr matrix**

T Qureshi[1], S Baker[1] , C Binns[1], M. Roy[1], S. Laureti[2], D. Fiorani[2] and D Peddis[2]
[1]*Department of Physics and Astronomy, University of Leicester, Leicester LE1 7RH, UK*
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**AP1-19 Magnetic Properties of Small Magnetite Nanocrystals**

G. Muscas[1,3], G. Concas[3], C. Cannas[2], A. Musinu[2], A. Ardu[2], F. Orrù[2], D. Fiorani[1], S. Laureti[1], D. Rinaldi[1,4,5], G. Piccaluga[2], and D. Peddis[1]
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**AP1-20 Magnetic properties in magnetite nano-crystals by ac magnetic measurements**

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## AP2 - Thin films, surfaces and interfaces

### AP2-01 Analysis of perpendicular magnetic anisotropy in [Pt/Co] multilayers

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### AP2-02 The First SPIN and ANGLE-resolved Photoemission Setup at Elettra at APE Low Energy End-station within NFFA Demonstrator

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### AP2-03 XAS/XMCD investigation of the Au/LSMO interface

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### AP2-04 Surface Nanostructures in Manganite Films studied by Scanning Tunneling Microscopy

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### AP2-05 Magnetic Bistability in a submonolayer of sublimated Fe4 Single-Molecule Magnets

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### AP2-06 Co/Pt multilayers for perpendicular exchange coupled dots: experimental characterization and *ab initio* calculations of magnetic anisotropy features

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**AP2-07 Magnetothermal behavior of the antiferromagnet in exchange-coupled NiFe/IrMn bilayers**

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**AP2-08 Sheding light on Gr-intercalation processes in hybrid magnetic systems**

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**AP2-09 Magnetic anisotropy of $La_{0.7}Sr_{0.3}MnO_3$ thin films**

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**AP2-10 Synthesis and characterization of PLD CoFe thin films as a function of composition and deposition conditions**

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**AP2-11 Novel chiral metastable states in the discrete finite-size classical one-dimensional planar spin model with competing exchange interactions**

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**AP2-12 Magnetic properties of (ultra)thin LaSrMnO films**

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**AP2-13 Synthesis by self-assembling of polystyrene nanospheres and static magnetic properties of Co dot arrays embedded in a $Ni_{80}Fe_{20}$ antidot matrix for magnonic applications**

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**AP2-14 Selective electrochemical decomposition of outgrowths and nanopatterning in $La_{0.7}Sr_{0.3}MnO_3$ perovskite thin films**

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## AP3 - Superconductivity and magnetism

### AP3-01 Modeling experimental magnetization cycles of type II superconductors by finite element simulations

Gerardo Iannone[1], Stefania Farinon[2], Gianluca De Marzi[3], Pasquale Fabbricatore[2], Umberto Gambardella[1]
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### AP3-02 Microwave determination of the superfluid density in S/F/S heterostructures: indications of a $0$-$\pi$ phase transition

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### AP3-03 Metal-to-superconductor transition, mesoscopic disorder and intrinsic charge instability in oxide heterostructures

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### AP3-04 First principles analysis of magnetic and elastic properties of hexagonal perovskite-type $LaCrGe_3$

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### AP3-05 AC losses measurements of a trapezoidal shaped HTS coil with a capacity compensation technique

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### AP3-06 Enhancement of low-frequency magnetic fluctuations driven by Mn in $(La,Y)FeAsO_{0.89}F_{0.11}$ superconductors

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## AP4 - Soft and hard magnetic materials

### AP4-01 Skin effect in magnetic steel sheets under rotating induction

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### AP4-02 Temperature dependence of coercivity in Ti substituted MnBi

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### AP4-03 Rotatable magnetic anisotropy in anisotropy-graded FePt films induced by ion irradiation at low incidence angle

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## BP1 - Magnetism and bioapplications

### BP1-01 Iron oxide magnetic nanoparticles for magnetic fluid hyperthermia therapy: synthesis and characterization

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### BP1-02 Magnetite nanoparticles: hyperthermia and Lorentz microscopy

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### BP1-03 Development and utility of magnetic nanoparticles production by mammalian cells

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### BP1-04 On-chip investigation of cellular functions via magnetic nanoparticles: a novel tool in mechanobiology

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### BP1-05 MTJ-based platform for the detection of DNA pathogens in agrifood industries

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### BP1-06 Synthesis and characterization of magnetic nanogranular $Fe_3O_4$/biomimetic hydroxyapatite for potential applications in nanomedicine

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### BP1-07 A scanning probe investigation of hydroxyapatite thin films enriched with magnetic nanoparticles for bone tissue engineering

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## BP2 - Applications

### BP2-01 Direct measurement of the magnetocaloric effect in micrometric sheets

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### BP2-02 Co and In doped $Ni_2MnGa$ multifunctional alloys for energy applications: a structural, magnetic and magnetocaloric study

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### BP2-03 Magnetic and dielectric properties of cobalt ferrite/titania composites

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### BP2-04 Energy dissipation during Landauer erasure in sub-micrometric permalloy switches: magneto-optical measurements vs micromagnetic simulations

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### BP2-05 Magnetic properties of granular CoCrPt:$SiO_2$ thin films deposited on GaSb nanocones

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## BP3 - Micromagnetics, magnetization dynamics, spin dynamics

### BP3-01 The magnetic history of an assembly of Stoner-Wohlfarth particles

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### BP3-02 Spin-wave properties of IrMn/NiFe based spin-valves

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**BP3-03 Two regimes of magnetization relaxation dynamics in $La_{0.66}Sr_{0.33}MnO_3$ films**

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**BP3-04 Heteroclinic tangle phenomena in nanomagnets subject to time-harmonic excitations**

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**BP3-05 Static and Dynamic Properties of Magnetic Antivortices in Asteroid-Shaped Permalloy Nanomagnets**

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**BP3-06 Resonant spin-wave modes in trilayered magnetic nanowires studied in the parallel and antiparallel ground state**

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**BP3-07 On the energy concentration factor in a binary magnonic crystal**

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**BP3-08 Metamaterial description of perpendicularly magnetized 2D antidot lattices**

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**BP3-09 A micromagnetic study of spin wave eigenmodes excited by spin transfer torque in circular nanopillars: influence of Oersted field and lateral size**

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## BP4 - Interdisciplinary topics

### BP4-01 Chemical Physical and Magnetic Characterization of iron-rich fired clays

D. Peddis[1], D. Capitani[2], N. Proietti[2], V. Di Tullio[2], E. Agostinelli[1]
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### BP4-02 Teaching Nanomagnetism: Peer Education By E- learning Platform

G. Righini[1], V. Abiuso[2], S. Laureti[1], G. Varvaro[1], E. Agostinelli[1], S. Rossignoli[2], L. Saccoccio[2], A. Tiscioni[2], B. Tonetto[2], R. Moncado[2] and D. Peddis[1]
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### BP4-03 Finite element simulation to investigate the effects of the ferromagnetic materials characteristics in linear magnetic actuator

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## CP1 - Quantum spin systems and molecular magnetism

### CP1-01 Quantum effects and spin dynamics in open antiferromagnetic rings: A $^{1}$H NMR study of Cr8Zn

F. Adelnia[1,2], L. Bordonali[3], S. Bordignon[4], E. Garlatti[4], P. Santini[4], S. Carretta[4], R. De Renzi[4], G. Timco[5], R. Winpenny[5], M. Corti[2], F. Borsa[2] and A. Lascialfari[1,2,6]
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### CP1-02 Spin dynamics in highly processable Lanthanide Single-Molecule Magnets with tetraazaporphyrin ligands

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### CP1-03 NMR investigation of Er(III)-polyoxometalate single molecule magnet

M. Mariani[1], S. Sanna[2], M. Filibian[2], K.P.V. Sabareesh[2], M. Graf[3], S. Cardona[4], E. Coronado[4], M. Corti[2], F. Borsa[2], P. Carretta[2] , B. Z. Malkin[5] and A. Lascialfari[6]
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### CP1-04 Effective magnetic moment in cyclodextrin-polynytroxides

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**CP1-05 Dipolar ordering in a molecular nanomagnet detected using muon spin relaxation**

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**CP1-06 Local spin dynamics at low temperature in the slowly relaxing molecular chain [Dy(hfac)3{NIT(C6H4OPh)}]: a $\mu^+$SR study**

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**CP1-07 Study of Quantum Decoherence and Relaxation of $Cr_8Zn$ Molecular Rings by means of High Field/High Frequency Pulsed EPR Spectroscopy**

A. Ghirri[1], S. Carretta[2], A. Chiesa[2], F. Troiani[1], J. Van Tol[3], S. Hill[3], G. Timco[4], R. E. P. Winpenny[4] and M. Affronte[1,5]

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## CP2 – Spintronics: materials and devices

**CP2-01 Towards room temperature antiferromagnetic memories: investigation of the MgO influence on the IrMn properties in IrMn/MgO-based devices without ferromagnetic elements**

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**CP2-02 Synchronization of spin-Hall nano oscillators**

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**CP2-03 Power Behaviour of Vortex Oscillations in Co-Fe-B Magnetic Tunnel Junctions in Presence of Defects**

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**CP2-04 Analysis of reliable ultra-fast spin-torque switching under transverse bias magnetic fields**
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**CP2-05 Topological modes driven by spin-transfer torque**
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**CP2-06 Integrating magnetic molecules in spin valves**
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**CP2-07 A joint research project on molecular nanomagnets on metallic and magnetic surfaces for applications in molecular spintronics**
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**CP2-08 Multifunctional organic spintronic device acting as a magnetically enhanced memristor**
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## CP3 - Multifunctional magnetic materials

**CP3-01 Efficient scheme for *ab initio* muon site assignment based on the double adiabatic approximation**
Pietro Bonfà[1], Roberto De Renzi[1]
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**CP3-02 Effects of strain and size reduction on structural and magnetic properties of NiMnGa 2D and 1D systems**
Marco Campanini[1], P. Ranzieri[1], S. Fabbrici[1,2], V. Chiesi[1], F. Casoli[1], L.Nasi[1], F. Celegato[3], G.Barrera[3], P. Tiberto[3], V. Grillo[1,4], C. Magen[5], F.Albertini[1]
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**CP3-03 Magnetic characterisation and phase diagram of join CaCo-$CoCoSi_2O_6$ pyroxenes**

Erica Lambruschi[1], Chiara Pernechele[1], Luciana Mantovani[1], Irene Aliatis[1], Danilo Bersani[1], Pier Paolo Lottici[1], Mario Tribaudino[1], Massimo Solzi[1], Gunther Redhammer[2]
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**CP3-04 Magnetocaloric effect at the exchange-inversion in antiferromagnetic systems with magnetoelastic coupling**

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**CP3-05 Influence of thermal conductivity on the Dynamic Response of MCE materials**

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**CP3-06 Electrical and calorimetric properties at the transition of the magneto-caloric compound $LaFe_{11.41}Mn_{0.3}Si_{0.29}$-$H_{1.65}$**

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**CP3-07 Magnetocaloric effect at single molecule level: a spectroscopic investigation on Fe14 and Gd4M8 on surfaces**

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**CP3-08 The polaronic framework fully accounts for transport properties in metallic ferromagnetic manganites**

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**CP3-09 Amorphous ferromagnetism and re-entrant magnetic glassiness in single-crystalline $Sm_2Mo_2O_7$**

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**CP3-10 Magnetoelectric composite bilayer film by electrophoretic deposition**
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## CP4 - Advanced techniques

**CP4-01 Recent advances in X-Ray Magnetic Circular Dichroism experiments at the BACH beamline**
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**CP4-02 Detection of vortex chirality via local hysteresis loops measured by Magnetic Force Microscopy**
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**CP4-03 Detecting magnetic anisotropy by using torque magnetometry: from single crystals to thin films**
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# ABSTRACTS

## Invited talks

# Magneto-plasmonic nanoantennas: news and views

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The rapidly developing field of magneto-plasmonics merges the concepts from plasmonics and magnetism to realize novel and unexpected phenomena and functionalities for the manipulation of light at the nanoscale. In this talk I will show recent advances in the field of magneto-plasmonic nanoantennas, which contributed to broaden the understanding and control of optics at the nanoscale in ferromagnetic nanostrucutres owing to the intertwined optical and magneto-optical properties. The fundamentals aspects of the physics underlying the optical behavior of magneto-plasmonic nanoantennas are introduced [1-3].
Metamaterials based on magneto-plasmonics nanoantennas open a clear path towards applications to variety of emerging technologies as, e.g., ultrasensitive molecular sensing and ultrathin optical metadevices (flat nano-optics). Here, three relevant applications are presented as an example of the broad scientific and technological perspectives enabled by such multifunctional optical metamaterials.

- Systems allowing label-free molecular detection are expected to have enormous impact on biochemistry and biomedicine, and are therefore subject to intense investigation. We propose an innovative and alternative route based on magneto-plasmonic nanoantennas, which enables radically improved sensitivity, clearly outperforming recently reported plasmon based sensors [4,5]. Most remarkably, we achieved a local raw surface sensitivity of two orders of magnitude higher than the best values reported for nanoplasmonic sensors. Such sensitivity corresponds to a mass of ~0.8 attog/nanoantenna of polyamide-6.6 (n=1.51), which is representative for a large variety of polymers, peptides and proteins.

- Light polarization rotators and non-reciprocal optical isolators are essential building blocks in photonics technology. The control of the non-reciprocal light propagation displayed by magnetoplasmonic nanoantennas offer a promising route to bring these devices to the nanoscale. Here we introduce the design rules necessary for highly tunable active nanoscale magnetoplasmonic elements [6]. That is, the ability to tailor at will the amplitude and sign over a broad spectral range. We are able to achieve this over the entire visible and near-infrared wavelength range by tuning the combination of nanoplasmonic axes in our magnetoplasmonic nanoantennas.

- Plasmon ruler is an emerging concept where strong near-field coupling of plasmon nanoantenna elements is employed to obtain the structural information at a nanoscale. We combined nanoplasmonics and nanomagnetism to conceptualize the magnetoplasmonic dimer nanoantenna that would be able to report the nanoscale distances while optimizing its own spatial orientation [7].

[1] J. Chen et al. Small 7 (2011) 2341
[2] N. Maccaferri et al., Phys. Rev. Lett. 111 (2013) 167401
[3] N. Maccaferri et al. Opt. Express 21 (2013) 9875
[4] V. Bonanni et al. Nano Lett. 11 (2011) 5333
[5] N. Maccaferri et al. Nature Commun. in press
[6] K. Lodewijks et al., Nano Lett. 14 (2014) 77
[7] I. Zubritskaya et al. submitted to Nano Lett.

# Nanomagnets in the Organism: Therapeutic Opportunities and Long Term Fate

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Interactions of magnetic nanoparticles with the biological environment determine both their biomedical promises and their safety profile. The bio-nano-interface is where nanoparticles engineered by chemists meet biological components such as blood proteins, cells, and interstitial tissue which determine their biological fate. Many research efforts focus on the life cycle and toxicity of nano-sized materials. While most toxicology studies warn about the effects of nanomaterials on biological functions, the physical transformations inflicted by the living environment on the nano-objects and their subsequent impact on nanoparticle physical properties are still unclear.

We have developed a multiscale methodology to examine the influence of biological environment on the structure and physical properties of magnetic nanoparticles that show outstanding properties for magnetothermal therapy and MRI detection.

We combined *nanoscale* electron microscopy observations of nanoparticle structure with the follow-up of magnetic properties in biological environment to investigate the long term of nanomagnets in the body. This multiscale methodology opens up a new way to evaluate the life cycle of nanoparticles in the organism up to one year after their administration and to identify their byproducts of degradation. We will present several examples of magnetic nanostructures – iron oxide nanospheres, nanocubes, cooperative nanoflowers and iron oxide/gold dimers with different coating – and examine how cell-induced morphological degradation critically alters their magnetic properties, heating power and Magnetic Resonance relaxivity over time. Hence, for magnetothermal therapy of tumors, it might be more advantageous to maintain nanoparticles in the extracellular matrix of the tumor environment than to favor uptake by tumor cells. By contrast, specific internalization by the monocyte/macrophage system warrants the long term degradation of nanoparticles and iron recycling by endogenous proteins. Generally the fate of nanoparticles appears to be strongly dependent on their composition, architecture as well as surface coating.

In the quest for efficient and safe nanomedicines based on nanomagnets, one should tightly control the balance between short term efficacy in the relevant biological context and long term degradability or elimination from the body.

L. Lartigue et al., ACS Nano 6 (2012) 2665-2678
M. Lévy et al., Nanoscale 3 (2011) 4402-4410
M. Lévy et al., Phys Rev B 84 (2011) 075480-070754
M. Lévy et al., Contrast Media & Molecular Imaging 7 (2012) 373-383
M. Levy et al., Biomaterials 32 (2011) 3988-3999
P. Guardia et al., ACS Nano 6 (2012) 3080-3091
L. Lartigue et al., ACS Nano 7 (2013) 3939-3952
L. Lartigue et al., ACS Nano 6 (2012) 10935-10949
J. Kolosnjaj-Tabi et al., ACS Nano 8 (2014) 4268-83
Javed Y et al., Small 10 (2014) 3325-37

# Charge and spin transport in organic single crystals from first principles

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Charge and spin transport in organic single crystals is a complex problem, where the computation of accurate structural and vibrational properties needs to be coupled to ways of determining the charge mobility and the spin-diffusion characteristics. Here we will present a rigorous computational scheme for evaluating the charge carrier mobility of pure organic crystals at finite temperature, which is material-specific, it accounts for van der Waals interactions and it includes vibrational contributions from the entire phonon spectrum of the crystal. Such an approach is based on the *ab initio* framework provided by density functional theory and the construction of a tight-binding effective model via Wannier transformation. The final Hamiltonian includes coupling of the charge carriers to the crystals phonons, which are also calculated from density functional theory. Furthermore, in the case of spin transport both spin-orbit and hyperfine interaction complete the picture [1]. We apply this methodology to a range of molecular crystals, and here we will present in detail the case of durene [2], a small π-conjugated molecule, which forms a high-mobility herringbone-stacked crystal. We show that accounting correctly for dispersive forces is fundamental for obtaining a high-quality phonon spectrum, in agreement with experiments. Then the mobility as a function of temperature is calculated along different crystallographic directions and the phonons most responsible for the scattering are identified.

[1] Akinlolu Akande, Sandip Bhattacharya, Thomas Cathcart and Stefano Sanvito, J. Chem. Phys. 140, (2014) 074301
[2] Carlo Motta and Stefano Sanvito, J. Chem. Theory Comput. 10, (2014) 4624

# ORAL SESSIONS

## February 17th

# Ledge-type Co/L1$_0$-FePt exchange-coupled composites

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FePt-based exchange-coupled composite (ECC) systems, consisting of a magnetically hard L1$_0$-FePt phase exchange coupled to a soft ferromagnetic material, are one of the most promising candidates for future ultra-high density (> 1 Tbit/in$^2$) perpendicular magnetic recording media. Tuning both intrinsic and extrinsic properties of the two components allows simultaneously achieving high thermal stability and low switching fields [1,2]. The phase boundary between the two materials can be sharp or graded, and the cross-sectional shape of the magnetic phases is identical in conventional ECC, while in the *ledge-type* ECC the soft component is more extended along the recording direction [3].

In this communication, the effect of the thickness of a soft Co layer ($th_{Co}$) on the magnetic behavior of *ledge-type* Co/L1$_0$-FePt nanocomposites deposited on an MgO (100) substrate (Fig. 1a) is systematically studied by combining angular magnetic measurements (vector VSM) and morpho-structural analyses (XRD, SAED, HRTEM). Magnetic measurements revealed a significant reduction of the switching field, which is well below the writing field of currently available write heads ($\mu_0 H_w < B_s$ with $B_{s,max}$ = 2.4 T) for $th_{Co} \geq 6.5$ nm (Fig. 1b). The relationship between the structure and the angular magnetic properties is also discussed (Fig. 1c,d).

[1] G. Varvaro et al., JMMM 368 (2014) 415

[2] D. Goll et al., Phys. Status Solidi A 210 (2013) 1261

[3] D. Goll et al., APL 93 (2008) 152512

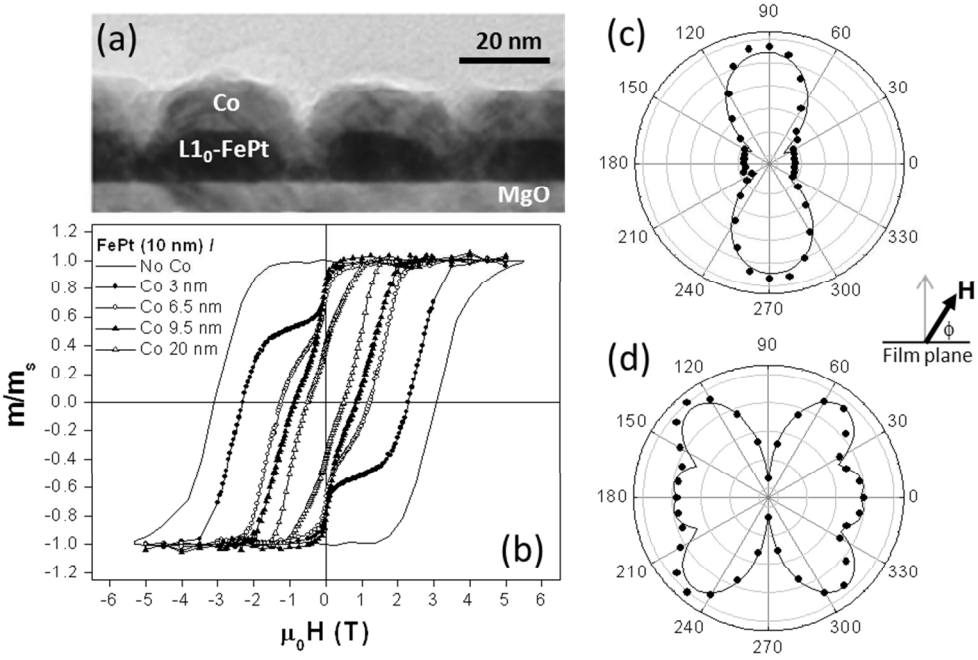


Figure 1: (a) Cross-sectional TEM image of sample with $th_{Co}$ ~ 9.5 nm. (b) Room temperature out-of-plane hysteresis loops as a function of Co thickness. (c,d) Room temperature angular remanence curves for $th_{Co}$ = 9.6 (c) and 20 nm (d); the curve's fit allowed determining the easy axes arrangement in the two phases, which resulted in agreement with the morpho-structural analysis.

# Magnetic properties of ordered CoO nanostructures on Co/Fe(001)

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Intriguing magnetic properties can be obtained in systems containing antiferromagnetic (AF) transition metal oxides both by low-dimensionality and by proximity to ferromagnetic (F) layers, the latter giving rise to well-known exchange coupling phenomena. Hybridization, strain, or chemical interdiffusion, to give some examples, can dramatically alter the interface properties of such systems. So far, we have investigated both chemical [1,2] and magnetic [3,4] properties of a rich record of Fe/AF (where AF is either NiO or CoO) layered structures [5].
One of the most critical issues concerning the interfaces between transition metal mono-oxides (such as CoO) and a reactive transition metal (such as Fe) is the high degree of chemical mixing at the interfaces [2]. We have observed, through a combined Scanning Tunneling Microscopy (STM) and Auger Electron Spectroscopy (AES) investigation, that the layer-by-layer growth of an ultrathin Co buffer layer (thickness about 1 nm) prior to CoO deposition prevents, in particular growth conditions, the different elements to react and mix at the interface. In such a special case, we also observed a dislocation-driven self-organized nanostructuration of CoO, which grows in three-dimensional square islands, whose lateral sizes increase with CoO coverage, up to some tens of nanometers. One example of the CoO nanostructures is provided in Fig.1a).

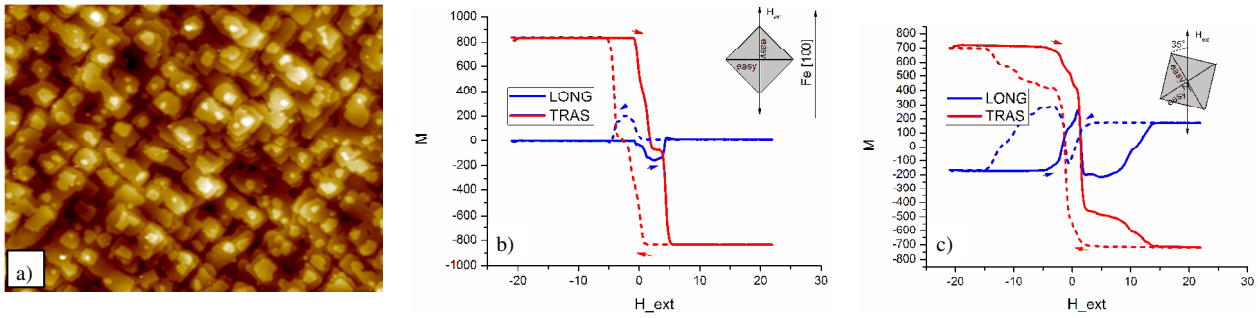


Figure 1: a) STM image (about 150 nm x 100 nm) of 7 ML CoO/Co/Fe; b) In-plane MOKE hysteresis loops on 27 ML CoO/Co/Fe either b) measured along a Fe [100] easy axis or c) 35° away from the axis.

When the mentioned growth conditions are met, Magneto-Optical Kerr Effect (MOKE) measurements taken on a 5 nm CoO/1 nm Co/Fe(001) sample show very peculiar hysteresis loops characterized by the presence of magnetic moments perpendicular to the magnetic field, when the latter is applied along one of the Fe easy axes, as shown in Fig.1b). When the field is not parallel to one of the easy axes, as shown in Fig.1c), jumps in the loops are seen, which interestingly resemble those observed on exchange spring multilayers [6], thus suggesting the presence of different magnetically active components. When performing element specific hysteresis loops by XMCD, it is revealed that the transverse component observed in the loop arise only upon CoO formation and that it can be attributed to both Fe and Co magnetic moments close to the interface. These results will be discussed in the light of recent experimental findings.

[1] M. Finazzi, A. Brambilla, L. Duò, et al., Phys. Rev. B 70, 235420 (2004).
[2] A. Brambilla, P. Sessi, M. Cantoni, et al., Thin Solid Films 516, 7519 (2008).
[3] A. Brambilla, P. Biagioni, M. Portalupi, et al., Phys. Rev. B. 72, 174402 (2005).
[4] M. Finazzi, A. Brambilla, P. Biagioni, et al., Phys. Rev. Lett. 97, 097202 (2006).
[5] M. Finazzi, L. Duò, and F. Ciccacci, Surf. Sci. Rep. 64, 139 (2009).
[6] K. Dumesnil, C. Dufour, Ph. Mangin, A. Rogalev, Phys. Rev. B 65, 094401 (2002).

# Exchange coupling and spatial confinement in IrMn/NiFe films and dot arrays

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Nowadays, the exchange coupling at the interface between antiferromagnetic (AF) and ferromagnetic (FM) phases plays a crucial role in the technology of magnetoresistive spin-valves and tunnel junctions and, due to the increasing demand for the miniaturization of magnetic devices, a large interest is devoted to the investigation of confinement effects on this phenomenon.
In this context, we present a comprehensive study of the exchange bias phenomenon in an AF/FM IrMn[10 nm]/NiFe[5 nm] (IrMn = $Ir_{25}Mn_{75}$, NiFe = $Ni_{80}Fe_{20}$) continuous film and in arrays of square dots with different size (1000 nm, 500 nm and 300 nm), aimed at elucidating the temperature dependence of the exchange field $H_{ex}$ and coercivity $H_C$, in conjunction with spatial confinement effects.
To achieve this goal, samples prepared by electron beam lithography and lift-off using dc-magnetron sputtering were subjected to structural investigations by electron microscopy techniques and to magnetic study, through SQUID and magneto-optic magnetometry measurements coupled to micromagnetic calculations. In particular, we have observed that at T = 300 K $H_{ex}$ decreases with reducing the size of the dots and it is absent in the smallest ones, whereas the opposite trend is visible at T = 10 K ($H_{ex}$ ~ 1140 Oe in the dots of 300 nm and $H_{ex}$ ~ 750 Oe for the continuous film).
The exchange bias mechanism and its thermal evolution have been explained through an exhaustive phenomenological model, which joins spatial confinement effects with other crucial items concerning the pinning AF phase: the magnetothermal stability of the nanograins forming the IrMn layer (mean size ~ 10 nm), assumed as essentially non-interacting from the magnetic point of view; the proven existence of a structurally disordered IrMn region at the interface between the NiFe phase and the bulk of the IrMn layer, with a magnetic glassy nature; the stabilization of a low-temperature (T < 100 K) frozen collective regime of the IrMn interfacial spins, implying the appearance of a length of magnetic correlation among them.
This research work has been carried out in the framework of the project FIRB2010 “Tailoring the magnetic anisotropy of nanostructures for enhancing the magnetic stability of magnetoresistive devices” – NANOREST.

# Reentrant spin-flop transition in nanomagnets

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An antiferromagnetic spin chain is known to undergo a transition from an anti-parallel to a spin-flop configuration when subjected to an increasing magnetic field. The transition arises from the competition between antiferromagnetic coupling and magnetic field, and connects an antiferromagnetic configuration with spins aligned along the field to a configuration where they are almost perpendicular to the field, with a small tilting angle producing a nonvanishing magnetization. In the thermodynamic limit, the spin-flop phase already occurs at infinitesimal field in the isotropic case, while a finite field is required in the presence of an easy-axis anisotropy favoring the field direction. If the spin chain is finite, a parity effect comes into play: if the number of spins is odd the antiferromagnetic configuration is favored because of the Zeeman energy gain from one unbalanced spin, and only beyond a finite field the spin-flop state appears, still in the isotropic case [1]. Moreover, in the presence of an anisotropy perpendicular to the field, the spin-flop state appears for both weak and strong field, the anti-parallel state appearing for intermediate fields [2]. In both transitions the configuration varies continuously with the field intensity. Such re-entrant transition is robust with respect to quantum fluctuations and it might be observed in atomic chains deposited on suitable substrates or in layered systems.

[1] P. Politi and M. G. Pini, Phys. Rev. B 79 (2009) 012405
[2] M. Crescioli, P. Politi, and R.Vaia. Phys. Rev. B 90 (2014) 100401 (R)

# Nanopatterning reconfigurable magnetic landscapes via thermally assisted scanning probe lithography

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The search for novel nanotechnological tools for controlling and manipulating magnetism at the nanoscale is crucial for the development of next-generation devices. So far, the patterning of magnetic nanostructures has been mainly achieved via structural or chemical irreversible modifications.[1-2] We propose a new concept, that we call 'thermally assisted magnetic scanning probe lithography' (tam-SPL), for creating reconfigurable magnetic nanopatterns, by crafting at the nanoscale the anisotropy landscape of an exchange-biased magnetic system. By performing a highly localized field-cooling with the heated tip of an atomic force microscope, we demonstrate that it is possible to pattern magnetic domains with arbitrarily oriented magnetization and tunable unidirectional anisotropy. In Fig. 1a-c the MFM image of squares, diamonds and triangular-shaped structures patterned on a IrMn/CoFeB/Ru trilayer, is presented. Fig. 1d-e show 250 nm lines patterned with a single SPL scan. This technique is straightforward and combines the full reversibility and stability of exchange bias, as the same pattern can be written and reset many times, with the resolution and versatility of scanning probe lithography.

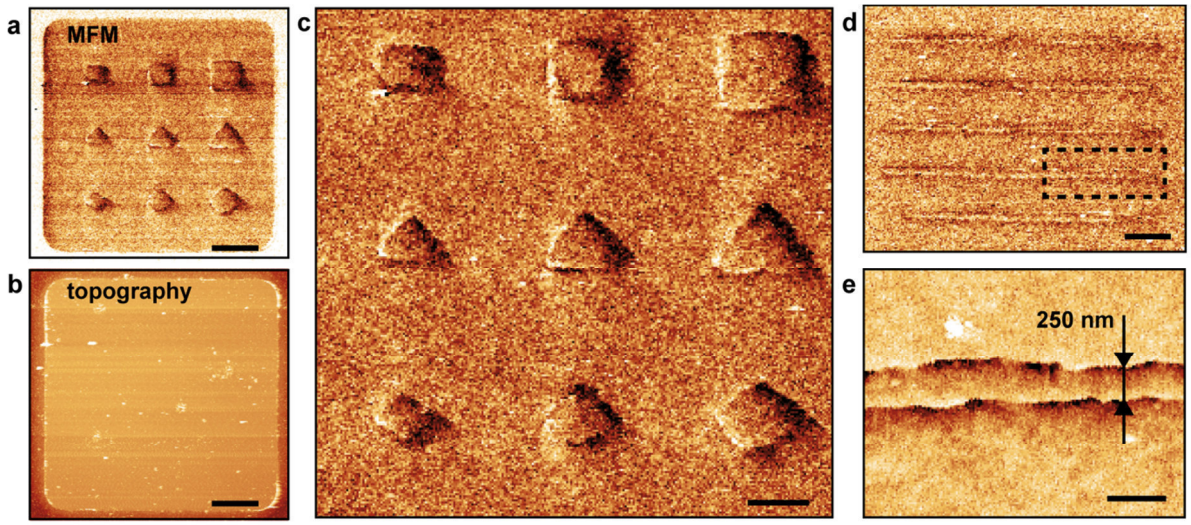


Figure 2: MFM image (a) and topography (b) of a 20 µm x 20 µm IrMn 7/CoFeB 5/Ru 2 trilayer where squares, triangles and diamond structures were patternd by tam-SPL. (c) zoomed-in MFM image of square- (top row), triangular- (center row) and diamond- (bottom row) shaped magnetic domains with size 2.5 µm (right column), 2 µm (center column) and 1.5 µm (left column). The magnetic contrast marks the domain boundaries. (d) MFM of single lines 12 µm long. (e), High-resolution MFM image of the dashed rectangle in d, showing a minimum width of 250 nm.

[1] Nagpal, P., Lindquist, N. C., Oh, S.-H. & Norris, D. J. Science 325, 594–7 (2009).
[2] Chappert, C. Planar Patterned Magnetic Media Obtained by Ion Irradiation. Science 280, 1919–1922 (1998).

# Reentrant surface anisotropy in the antiferromagnetic/ferromagnetic bilayer Mn/Co/Cu(001)

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The magnetic anisotropy in exchange-coupled antiferromagnetic/ferromagnetic (AF/FM) systems is at the root of some of some their most intriguing properties, like exchange bias, yet the microscopic understanding of how the magnetic anisotropy arises at AF/FM interfaces is largely lacking.
We investigated the magnetic anisotropy energy of monatomic surface-step atoms in the model epitaxial AF/FM bilayer system Mn/Co grown on vicinal Cu(001) surfaces. The Mn/Co/Cu(001) system is of utmost interest, since manganese films undergo a Mn-thickness-dependent transition from FM to AF in the 1–2 Mn monolayer thickness range, which entails the coexistence of FM and AF Mn phases in the film.
We observed that, for increasing Mn thickness, the step-induced anisotropy of the Co/Cu(001) films was quenched in the submonolayer-Mn regime, re-entered for Mn thickness between 1 and 2 monolayers, and disappeared for Mn thickness above 2 monolayers.
The observation of a sizeable uniaxial anisotropy exclusively in the Mn-thickness range of coexistence of the FM and AF phases points out the crucial role of the boundaries between FM and AF regions within the Mn film in inducing the anisotropic spin arrangement. A symmetry-breaking mechanism of a magnetic type, rather than a purely geometric one, is therefore proposed as the origin of the re-entrant anisotropy, which may reproduce general magnetic configurations occurring at AF/FM interfaces.

[1] M. Caminale et al., Phys. Rev. Lett. 112, 037201 (2014)

# Magnetic exchange coupling across a graphene layer

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The peculiar properties of graphene, such as an extraordinary in-plane charge carrier mobility and a long electron mean free path [1,2], coupled with a low spin-orbit interaction, make graphene attractive for planar spin transport [3,4]. In order to exploit graphene's remarkable properties also in the direction perpendicular to the planes, its ability to transmit magnetic interactions has to be assessed. Exchange coupling with magnetic substrates across graphene was recently found in molecular spin systems [5-9] where, however, competing coupling pathways coexist.
A more straightforward assessment of the M/G/M (M=transition metal or rare-earth, G=graphene) exchange coupling may be obtained by replacing the complex molecular unit by individual M atoms. Here we present the results of our investigations of the magnetic coupling of isolated adatoms and small clusters of transition metals (V, Fe, Co) and rare-earths (Dy) to a Ni crystal across a graphene monolayer in systems of the type M/G/Ni(111).

[1] K. S. Novoselov et al., Science 306, 666 (2004)
[2] Y. Zhang et al., Nature 438, 201 (2005)
[3] N. Tombros et al., Nature 448, 571 (2007)
[4] W. Han, R. Kawakami, Phys. Rev. Lett. 107, 047207 (2011)
[5] C. F. Hermanns et al., Adv. Mater. 25, 3473 (2013)
[6] S. Bhandary et al., Sci. Rep. 3, 3405 (2013)
[7] S. Marocchi et al., Phys. Rev. B 88, 144407 (2013)
[8] D. Klar et al., Phys. Rev. B 89, 144411 (2014)
[9] A. Candini et al., J. Phys. Chem. C 118, 17670 (2014)

# OBSERVATION OF LARGE MAGNETORESISTANCE IN GRAPHENE OXIDE LAYERS.

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Thanks to its peculiarities, Graphene Oxide (GO) has been proposed as novel material in many fields and applications. In order to fully exploit its potentialities, a deeper understanding of its properties is still necessary. Here we present a systematic study of magneto-transport properties of thin films of thermally reduced graphene oxide (rGO), from room temperature to 2 K, in presence of magnetic fields up to 7 Tesla.
GO was deposited on silicon wafers by spin coating. The film thickness is ~10 nm for all our measured devices. Typical lateral dimensions of our samples are 0.8 x 3 mm. Reduction of GO was obtained by thermal annealing in high vacuum at temperatures ranging between 200°C and 940°C for 1 hour.
The most conductive rGO sheets exhibit different transport regimes: at room temperature they have an Arrhenius-like behavior; at lower temperature they exhibits a thermally activated behavior with resistance $R$ following a $R = R_0 exp(T_0/T)^p$ law with $p = 1/3$, consistent with 2D Mott Variable Range Hopping (VRH) transport mechanism. Below a critical temperature $T_c$, we observe a crossover from VHR to another regime, probably due to a decrease of the characteristic lengths of the disordered 2D system. The temperature $T_c$ depends on the reduction grade of the rGO.
For all of our samples we find a room temperature negative magnetoresistance ΔR/R, the intensity of which usually increases by reducing the temperature and without any signature of saturation up to a field of 7 T. The observed magnetoresistance strongly depends on the degree of reduction of the material. For the intermediate reduction samples, we observe a crossover to positive magnetoresistance at a temperature comparable with $T_c$. For the most reduced sample, ΔR/R is always negative, reaching values as high as -63% at 2 K, which are surprisingly high for a -nominally- non magnetic material. These results show that the magneto-transport properties of GO can be controlled by changing the degree of annealing. [1]

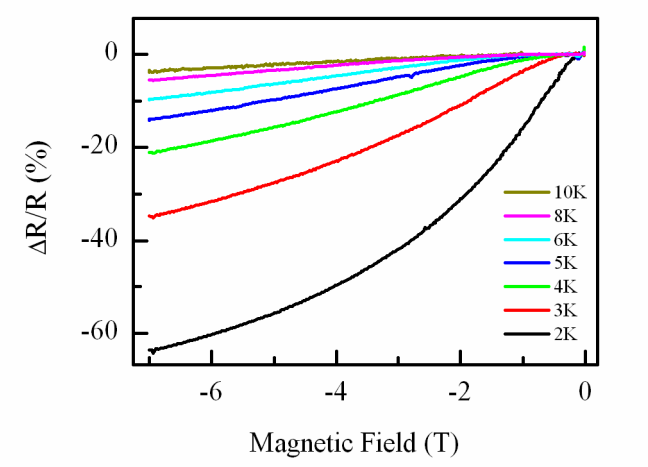


Figure 1: Magnetoresistance ΔR/R of GO thin film annealed at 900°C, at different temperatures.

[1] A. Vianelli et al., *submitted* (2014)

# Chemical order and lattice distortion in $L1_0$ FePtCu thin films studied by EXAFS

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Nowadays, magnetic recording is a central technology in information storage, and a large part of the interest in nanoscaled magnetic films has been stimulated by their application to data storage [1, 2]. Significant progresses in this field can be achieved by developing new materials, architectures and technologies, which allow overcoming the limits imposed by thermally stability and writability requirements. In this contest, the FePt in the chemically ordered $L1_0$ phase is a material with a very high uniaxial magnetic anisotropy of $K_u \sim 10^8$ ergs/cm$^3$ which provides the thermal stability for high density magnetic recording [3]. Furthermore, the addition of third elements allows tailoring the magnetic properties like Curie temperature or magnetic anisotropy, but also the onset annealing temperature for chemical ordering from the as deposited disordered FePt phase is strongly affected [4-6].

In this work we present an Extended X-ray Absorption Fine Structure (EXAFS) characterization of ternary FePtCu alloys with different Cu content [7]. The EXAFS measurements have been carried out at the Cu-K and Pt-$L_{III}$ edges in order to describe the local environment around these elements in the FePtCu samples and to compare the structural evolution as a function of the Cu content. The EXAFS study, based on a substitutional model where the Cu atoms occupy Fe or Pt sites in the tetragonal structure, has been performed by using linear dichroism to enhance the sensitivity to differently oriented bonds and to gain a detailed description of the atomic environment. The study allowed to distinguish experimentally the effects on the chemical order and lattice distortion induced by the Cu atoms. We correlated the determined positions of the Cu atoms in the chemically $L1_0$ ordered fct lattice with the magnetic properties of FePtCu ternary alloys. In particular, the main effect of Cu atoms in the alloy is a linear reduction of the c/a ratio, while the non-monotonic behaviour of the chemical order is consistent with the variation of the magnetocrystalline anisotropy.

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[1] C. A. Ross, Annu. Rev. Mater. Res. 31 (2001) 203
[2] D. Makarov et al. IEEE Trans. Magn. 45 (2009) 3515
[3] D. Weller and M. F. Doerner, Annu. Rev. Mater. Sci. 30 (2000) 611
[4] J.-I. Ikemoto et al. IEEE Trans. Magn. 44 (2008) 3543
[5] S. D. Willoughby, J. Appl. Phys. 95 (2004) 6583
[6] C. Feng et al. Appl. Phys. Lett. 93 (2008) 152513
[7] S. Laureti et al. J. Appl. Cryst. 47, (2014) 1722

# Epitaxial films of tetragonal $Mn_{3-x}Ga$: magnetism, morphology and microstructure

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Tetragonal $Mn_3Ga$ films show exceptional magnetic and electronic properties, i.e., a unique combination of low magnetization, high uniaxial anisotropy, high Curie temperature, high spin polarization and low Gilbert damping, which make them very promising as ferromagnetic electrodes in Spin-Transfer-Torque Magnetic RAMs [1]. A few recent works have demonstrated epitaxial growth of this phase on MgO, $SrTiO_3$ or Cr, Pt underlayers [2,3].

We have epitaxially grown $Mn_{3-x}Ga$ ($0<x<1$) films by RF sputtering on two different substrates, i.e., $SrTiO_3(100)$ and $(LaAlO_3)_{0.3}$-$(Sr_2AlTaO_6)_{0.7}(100)$ (LSAT), exploiting alternate layer deposition from two different targets to obtain specific and variable compositions. We have fully characterized the films by structural and magnetometric techniques (X-Ray Diffraction – XRD; High Resolution Transmission Electron Microscopy – HRTEM; Atomic and Magnetic Force Microscopy - AFM and MFM; SQUID Magnetometry). After optimizing the growth conditions (growth temperature, Ar pressure) to obtain the epitaxial growth, we have varied the film thickness in the range 10 to 40 nm for both the compositions $Mn_{75}Ga_{25}$ and $Mn_{70}Ga_{30}$.

At growth temperatures $T_g$ in the range 300 °C $\leq T_g <$ 350 °C XRD and HRTEM demonstrate that the tetragonal phase grows epitaxially on STO and LSAT with easy magnetization c-axis oriented perpendicular to the substrate plane. The AFM investigation of the surface of the epitaxial films ($T_g$= 300 and 325 °C) shows a maze-like island morphology; island size increases with increasing thickness. Islands are faceted and exhibit a quite flat surface (roughness below 1.5 nm). The variation in island height is of several nanometers and increases with film thickness. A substantially different morphology has been found in the films grown at the highest temperature ($T_g$=350 °C). Islands are smaller and clearly separated. HRTEM measurements indicate a partial loss of epitaxy at the same $T_g$. This result confirms the challenges, as already reported by other authors, in obtaining a single-phase $D0_{22}$ epitaxial film, especially due to the complexity of the Mn-Ga phase diagram and instability of the $D0_{22}$ phase.

The epitaxial films show perpendicular magnetic anisotropy, due to the highly anisotropic $D0_{22}$ phase. Compared to the existing literature, we have obtained very high coercivity values in the perpendicular direction on $Mn_{75}Ga_{25}$ films, i.e., from 2 to 2.5 T. At this composition typical saturation magnetization values range from 50 to 100 kA/m. Consistent with the previous report of Kurt and co-workers [2], decreasing the Mn concentration, i.e., for $Mn_{70}Ga_{30}$ films, leads to a decrease in coercivity and an increase in saturation magnetization. Typical values on our films are $\mu_0 H_C$=1 – 1.5 T and $M_S$=120 - 250 kA/m.

[1] B. Balke, H.F. Fecher, J. Winterlik, C. Felser, Appl. Phys. Lett. 90 (2007) 152504
[2] H. Kurt, K. Rode, M. Venkatesan, P. Stamenov, J.M.D. Coey, Phys. Status Solidi B 248 (2011) 2338
[3] M. Li, X. Jiang, M.G. Samant, C. Felser, S.S.P. Parkin, Appl. Phys. Lett. 103, 032410 (2013)

# Electronic properties of 42214 Fe-based superconductors

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We present a detailed ab-initio study of the newly discovered[1] $L_4Fe_2As_2Te_{1-x}O_4$ superconductors, where L is a Rare earth element (RE) (namely, RE= Pr, Sm, and Gd). This compound family represents a new entry on the Fe-based superconductor scenery, showing similar features to the other 1111 family and critical temperatures that have been shown to reach the order of 40K. As the crystal structures is an essentially layered structure with Fe-As planes intercalated by RE-O and Te planes there are new possible tools that could be optimally adjusted to possibly push the critical temperature towards higher values. To this end, we provide a detailed first principles study of the structural, electronic and magnetic properties of the 42214 family as a function of the RE involved and pressure. In order to give insights on the possible role of Te-vacancies we also considered the effect of Te-vacancies on the Fermi surface features. A careful comparison with experiments available shows that the ab-initio results give a reliable representation of the real material, even taking into account the non-perfect stoichiometry of the compounds; moreover, analyzing properties such as magnetic stability of the compounds, As-height, and electronic states at the Fermi level we are able to draw a consistent picture of this compound family and to give predictions on how to improve the material properties.

[1] S. Katrych et al., Phys. Rev. B 87 (2013) 180508(R) and Phys. Rev. B 89 (2014) 024518

# Vortex-Antivortex coexistence in Nb based Superconductor/Ferromagnet heterostructures

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We used low temperature Magnetic Force Microscopy to investigate the vortex dynamics in Superconductor/Ferromagnet (S/F) heterostructures realized by Py/Nb thin films. By tuning the magnetic state of the ferromagnet new physical phenomena can be observed due to the interaction between the Abrikosov vortex lattice in the Nb layer and the periodic, stripe-like, Py magnetic domains. The analysis of the different behaviors of these systems is of great importance for applications, allowing to predict and control the electronic properties of the S/F hybrids. In our samples Nb thickness ($d_s$) varied in the range 100÷360 nm and Py thickness ($d_{Py}$) in the range 1÷4 μm. To ensure that the F and S layers were only magnetically coupled a 10 nm $SiO_2$ was deposited on top of the Py film. The behavior above and below the Nb superconducting critical temperature was analyzed by means of a cryogenic Scanning Force Microscope. Low temperature MFM allowed us to collect topographic and magnetic force maps in the same area of the sample at different tip-sample heights varying in the range of 50÷280 nm. We used commercial Si cantilevers with magnetic coating, resonance frequency *f*o of about 75 kHz, magnetic moment $0.3\times10^{-16}$ $Am^2$ and coercivity $<3\times10^4$ A/m. Before measuring the tip was magnetized in the upward direction. In our experiments a variety of different behaviors were observed [1-3], depending on the intensity of the out of plane magnetization component $M_0$ of the Py layer as well as on the interrelations among some "geometrical" parameters of the hybrids, i.e., the Nb penetration depth $\lambda$ and thickness $d_s$ and the Py stripe half period width $w$. When $w > \lambda$, in zero external applied field, depending on $d_s$, the samples showed "spontaneous" Vortices-Antivortices (V-AV) formation in a chain-like configuration along the magnetic stripes due to the alternating out of plane component $M_0$ of the Py stray field (Fig.1). We have analyzed the observed experimental results within a theoretical model which deals with $M_0$ intensity threshold, causing spontaneous V-AV formation [4], finding the estimates $M_0$>17G for the Py-4μm, $M_0$>21G for the Py-2μm and, finally, 15G<$M_0$<25G for the Py-1μm [5].

[1] M.Iavarone et al. IEEE Magnetics Society 48, 11 (2012)
[2]A.M. Cucolo et al., Journal of Superconductivity and Novel Magnetism, 25, 2167-2171 (2012)
[3] M.Iavarone, et al. Phys. Rev. B 84, 024506 (2011)
[4] R. Laiho, et al, Phys. Rev. B 67, 144522 (2003)
[5]F. Bobba, et al. Phys. Rev. B 89, 214502 (2014)

# Investigation of the magnetic character of oxy-pnictides via Spin Dilution

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Parent compounds of many iron-based high-temperature superconductors are metallic and magnetic, with a spin density wave character. Although it is commonly believed that here magnetic interactions might be the glue for superconductivity, the microscopic origin of the magnetic state is not fully clarified yet. At first sight, the metallic ground state suggests that magnetism originates from the Fermi surface nesting of itinerant electrons, consistently with band structure calculations. However there are several indications that electron correlations could be important and local moments might play a significant role together with itinerant electrons for magnetic, transport and superconducting properties [1].

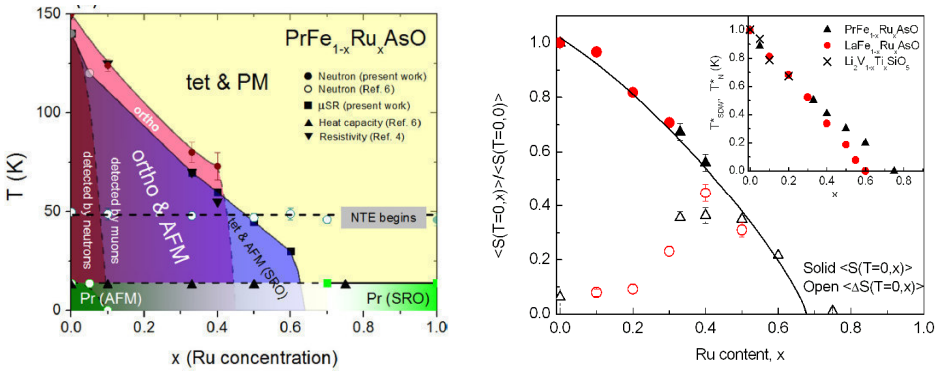


Figure 1. Phase diagram of $PrFe_{1-x}Ru_xAsO$ (left) and staggered magnetization as a function of Ru/Fe spin dilution, *x* (right). Inset: Comparison of magnetic transitions *vs x* for the $Li_2V_{1-x}Ti_xSiO_5$ J1-J2 prototype.

Here we discuss the evolution of the magnetic and structural phase diagram of $LnFe_{1-x}Ru_xAsO$ for *Ln* = La, Pr via diamagnetic Ru for Fe spin dilution. The substitution of Ru for Fe is isoelectronic [2,3], hence allows for investigations of the underlying physics without the complication of extrinsic modifications of the Fermi surface.

Muon spin relaxation measurements show that the Ru/Fe spin dilution directly produces a gradual disruption of magnetism which eventually disappears at the dilution threshold $x$=0.6, significantly higher than plain square bond dilution, and coinciding with the threshold for the J1-J2 frustrated square-lattice, localized spin model [2]. Neutron diffraction measurements show that the structural tetragonal-to-orthorhombic transition $T_S$, detectable up to $x\approx0.4$, is always a close precursor of the magnetic transition $T_{SDW}$, thus indicating the relevance of magneto-elastic coupling within the FeAs layers [3,4]. These results can be described in the framework of the Ising-nematic scenario predicted for localized spins in the J1-J2 model, indicating that a model of localized degrees of freedom is a proper framework to describe the magnetic character of oxy-pnictides.

[1] e.g. see : P. Dai, J.Hu, E.Dagotto Nature Physics 8, 709 (2012)
[2] P. Bonfà et al., Phys. Rev. B 85, 054518 (2012); M. Mazzani et al., Phys. Status Solidi B 251, 974 (2014)
[3] A. Martinelli et al., J. Phys.: Condens. Matter 25, 395701 (2013).
[4] Y. Yiu, S. Sanna et al., Phys. Rev. B 90, 064515 (2014)

# February 18th

# Noise induced drift in magnetization dynamics of nanomagnets

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Magnetization dynamics in magnetic micro and nanosystems relevant to magnetic recording and spintronics technologies are essentially stochastic phenomena due to the presence of thermal fluctuations. The stochastic nature of the magnetization dynamics manifests itself in the random transitions among coexisting steady states such as metastable magnetic equilibria or self-oscillatory regimes driven by spin-polarized currents. In this respect, the traditional Neel-Brown theory of thermal stability of magnetic particles [1], has to be properly generalized to take into account the broader class of magnetization dynamics observable in these systems. In this work, we propose a generalization of the classic approach by using the concept of noise-induced drift [2]. The starting point of our analysis is the stochastic Landau-Lifshitz equation, properly generalized to include spin-transfer torque effects, and in which thermal fluctuations are taken into account by including a white noise field term. The Fokker-Planck equation associated with this stochastic differential equation is averaged along trajectories of constant free energy and from that, by using separation of time scales, a stochastic differential equation for energy is derived [3]. In this equation, the drift part can be interpreted as the derivative of an effective potential which has two terms: the first term is of deterministic origin and the second term is due to the noise-induced drift. In this second term, the temperature appears explicitly through the fluctuations-dissipation relation. By using this machinery and analyzing the bifurcations of this generalized potential as a function of the temperature, we are able to determine critical temperatures which correspond to the transitions between different stochastic behaviors. This enables to study superparamagnetic-like transitions in a much broader settings. The analytical findings are finally compared with numerical simulations of stochastic Landau-Lifshitz equation.

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[1] W. F. Brown, Phys. Rev. 130, 1677 (1963)
[2] S. Hottovy, J. Stat. Phys. 146, 762 (2012)
[3] R. Bonin et al., Eur. Phys. J. B 59, 435 (2007)

**Thickness dependence of the spin wave dispersion in square antidot lattices**

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Magnonic crystals (MCs) have attracted considerable interest during recent years due to possibility of engineering the spin wave bands structure. In the present work we investigate two-dimensional MCs, consisting of Py antidot lattices (ADLs), as a function of thickness, *t*, in the range between 12 and 30 nm. The samples are composed by circular holes having a diameter of 240 nm arranged in square lattice with a period of 440 nm. Brillouin light scattering (BLS) has been exploited to measure the spin wave frequency as a function of the wave vector (*q*) along the ΓY direction, applying a magnetic field H=1kOe parallel to the side of the ADL. Several peaks have been detected in the whole wave vector range investigated and some of them showed a marked dispersive character. The experimental data have been interpreted by means of the plane wave method that enabled us also to calculate the BLS intensity as a function of *q*. As it can be seen in Fig.1, the frequency of the edge (E) mode, confined close to the holes edge in the direction of H, and the fundamental (F) mode, characterized by a quasi-uniform spin precession amplitude extending in the vertical channels comprised between rows of holes, increases on decreasing *t*. On the contrary, the fundamental localized ($F_{loc}$) mode, having the maximum amplitude in the horizontal channels between rows of holes, follows an opposite trend. These findings have been explained taking into account the thickness evolution of the demagnetizing field in the regions where the modes are located.

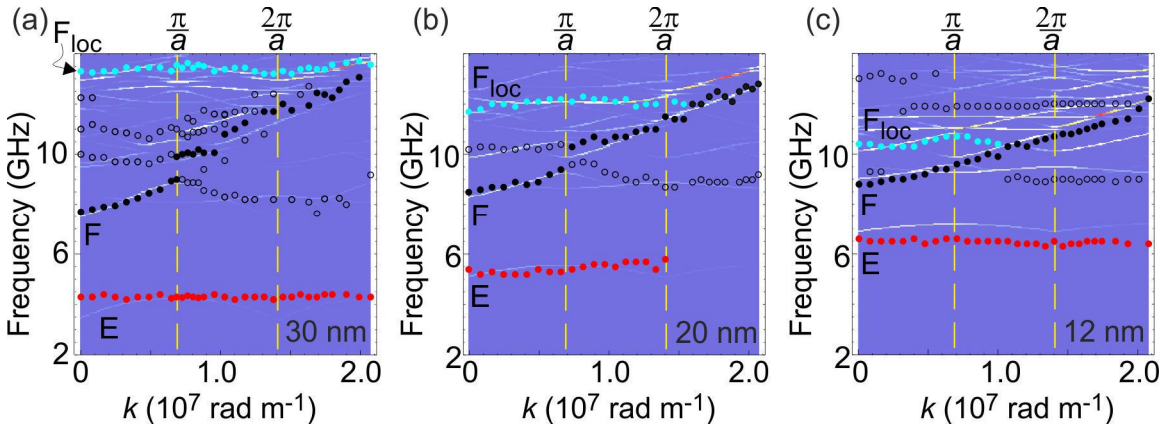


Figure 1: BLS data (points) and PWM results (color plot), where the largest cross-section modes have been emphasized, for the sample (a) 30 nm, (b) 20 nm, and (c) 12 nm thick. Vertical lines denote the edges of the Brillouin zones of the ADL.

[1] J. W. Klos, D. Kumar, J. Romero-Vivas, H. Fangohr, M. Franchin, M. Krawczyk, and A. Barman, Phys. Rev. B 86, 184433 (2012).

# Bandwidth variation of collective spin waves at the edge of magnetic transitions

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Similarly to other magnetic systems, even **magnonic crystals** are characterized by **soft modes** with a vanishing frequency at the critical field of any given magnetic transition. The profile of these modes has a symmetry that depends on the symmetry change between the initial and final magnetic configurations [1]. The knowledge of the soft mode is not a theoretical-only issue, but can have **technological implications**, especially in the field of magnonic- and spin-logic devices, where collective spin waves are used for information storage and delivery [2]. Actually, it has been recently demonstrated [3] that the bandwidth of the mode that softens at the critical transition field, undergoes dramatic variations even when just approaching this critical field. This fact can result in a band broadening also for modes usually non-dispersive (like some end modes). In some cases, it is possible to design the magnonic crystal to be characterized by a soft mode with the desired symmetry, in order to use its bandwidth variation close to the transition field for a specific purpose. We show this concept as emerging from calculations within the dynamical matrix method: first, for square arrays of disks in the saturated and also in the vortex state, then for rectangular arrays of interacting elliptical dots, magnetized along the minor and also major axis, and find out the behavior of the **soft mode dispersion close to different magnetic transitions**. We discuss the correlation among: the magnetization curve, the soft mode frequency vs. field curve, and the frequency vs. wavevector curve. In the vortex-to-saturated transition the soft mode is characterized by a bandwidth that goes to zero at a magnetic field quite distinct from the critical transition field, and we call this field **stopping field**, because at this field the collective soft mode turns into non-dispersive (stationary). We believe that this features might be used to design versatile devices, in which information can be stored or delivered at the energy costs of a small magnetic field variation.

[1] F. Montoncello, L. Giovannini, F. Nizzoli, P. Vavassori, and M. Grimsditch, Phys. Rev. B 77, 214402 (2008).
[2] A. V. Chumak, V. I. Vasyuchka, A. A. Serga, M. P. Kostylev, V. S. Tiberkevich, and B. Hillebrands, Phys. Rev. Lett. 108, 257207 (2012).
[3] F. Montoncello and L. Giovannini, Applied Physics Letters 104, 242407 (2014).

# Ghost imaging for magneto optics applications

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In this work, we develop a new approach to perform magneto-optical investigations, applying for the first time a high resolution Ghost Imaging (GI) protocol to reconstruct the image of Weiss domains within a ferromagnetic sample. As a matter of fact, imaging techniques for domain analysis are still one of the most important research topic in magnetic materials field [1].
Thermal light GI is a technique that exploits correlations between light beams to reconstruct the image of an object [2,3,4]. Considering two intensity-correlated multi-speckles light beams, the first one illuminating an object and observed with a "bucket" detector (i.e. without any spatial resolution such as e.g. a pigtailed photodiode), the other one, that has never interacted with the object, addressed to a spatial resolving detector (like a CCD camera), the image of the object can be retrieved by correlating the outputs of the two detectors.
The sample used here is a film of yttrium iron garnet (YIG), of chemical composition $(YSmCa)_3(FeGe)_5O_{12}$ grown on gadolinium gallium garnet substrate. The outstanding magneto-optical properties of YIG [5], which possesses one of the highest Faraday rotation angle, make it the perfect material for a feasibility investigation of the technique.
We report our experimental setup and ghost image reconstruction of domains of average size of 60 µm with opposite magnetization, exploiting Faraday effect [6]. In Figure 1 the real image of Weiss domains in YIG and their preliminary reconstruction are shown.
The investigated approach opens to the development of interesting innovative setups for magneto-optics, allowing operations in small volumes such as e.g. in cryostats since no actuators to scan the sample or CCD close to the sample are needed, where, in perspective, the image of the domains can be obtained just inserting a tiny bundle of optical fibers in the proximity of the sample.

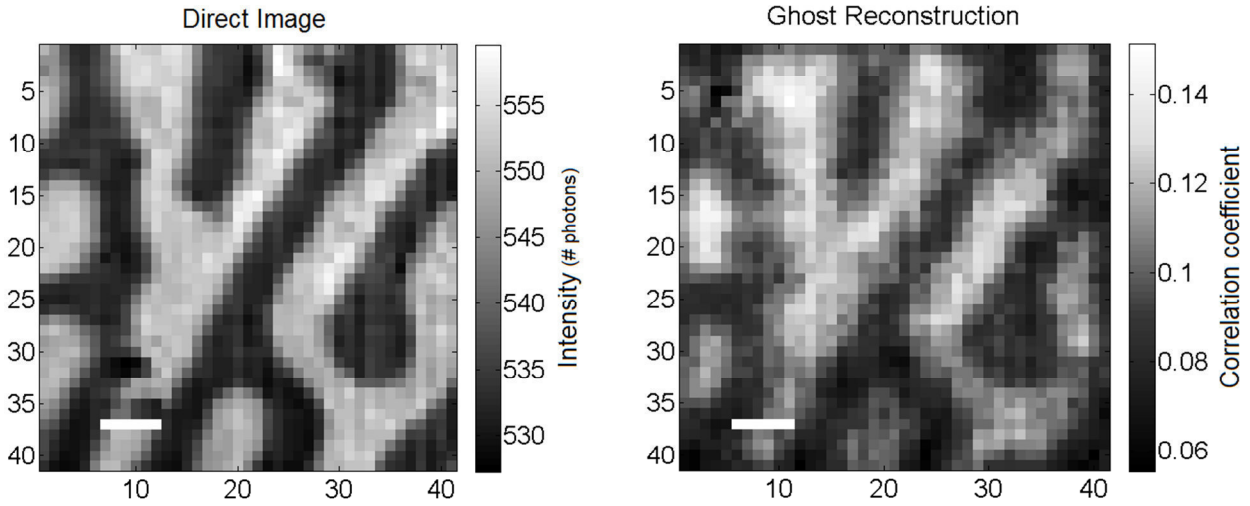


*Figure 1: Direct image of YIG Weiss domains (left) and their ghost reconstruction (right). The images are 350µm × 350µm and the white bars indicated are 50 µm long .The x and y axis report the number of pixels.*

[1] I. Manke,et al., Nature Communications 1, 125 (2010)
[1] A. Gatti et al., Phys. Rev. Lett. 70 013802 (2004)
[3] D. V. Strekalov, et al., Phys. Rev. Lett. 74, 3600 (1995).
[4] G. Brida et al. , Phys. Rev. A, 83, 063807 (2011)
[5] A. A. Serga, et al., Journal Of Physics D: Applied Physics, Vol. 43 264002 (2010)
[6] H.S. Bennett and E.A. Stern, Phys. Rev. 137 A448 (1965)

# Ultrafast demagnetization of metals: single-particle vs collective excitations

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The ultrafast loss of spin order upon femtosecond laser irradiation is a well-established experimental fact since its discovery in 1996 [1]. Theoretical explanations of this phenomenon have been attempted, but the underlying mechanism is not fully understood to date. Models such as phonon-assisted Elliot-Yafet spin flip [2], electron-magnon scattering processes [3], superdiffusive transport [4] and, more recently, dynamic exchange splitting [5] have been proposed. Although the scattering of particles (or quasi-particles such as phonons and magnons) is the established candidate to explain ultrafast demagnetization, different models lead to incomplete results.

We have investigated the magneto-optical response of Fe epitaxial films by femtosecond pump-probe polarimetry in a broad probe spectral region (1.8-2.6 eV) in order to extrapolate the photo-induced variation of the conductivity tensor disclosing spin and charge dynamics. In particular, the analysis of the off-diagonal tensor element – sensitive to the magnetization - reveals negligible dependence of its relative pump-induced variation on the photon energy. In other words the ultrafast demagnetization is independent on the probe wavelength.

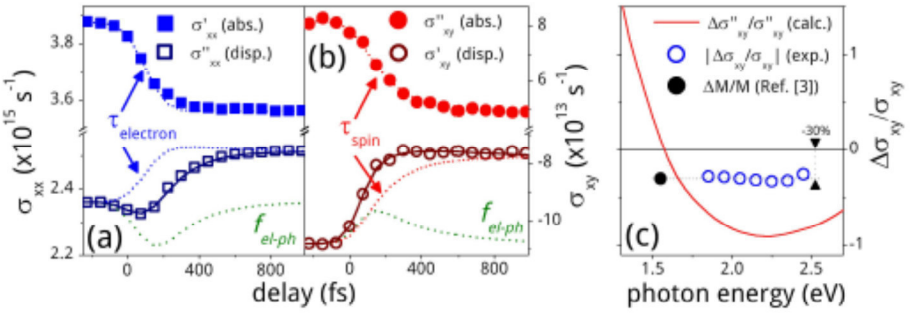


Figure 1: Real and imaginary parts of diagonal (a) and off-diagonal (b) elements of the transient conductivity tensor ($f_{el\text{-}ph}$ is the electron-phonon contribution). (c) Comparison between experimental (dots) and calculated (line) variation $\Delta\sigma_{xy}/\sigma_{xy}$. The calculation assumes a photo-induced collapse of the exchange interaction.

This observation rules out any significant modification of the electronic band structure (including the exchange interaction) upon laser excitation since a strong dependence on the photon energy would be expected (as shown in Fig. 1c). Our results suggest that ultrafast demagnetization is determined by collective excitations (i.e. spin fluctuations) which do not involve any major modification of the electronic structure.

[1] E. Beaurepaire, J.-C. Merle, A. Daunois and J.-Y. Bigot, Phys. Rev. Lett. **0**, 4250 (1996).
[2] B. Koopmans, J. J. M. Ruigrok, F. Dalla Longa, and W. J. M. de Jonge, Phys. Rev. Lett. **95**, 267207 (2005).
[3] E. Carpene, E. Mancini, C. Dallera, M. Brenna, E. Puppin, and S. De Silvestri, Phys. Rev. B **78**, 174422 (2008).
[4] M. Battiato, K. Carva, and P. M. Oppeneer, Phys. Rev. Lett. **105**, 027203 (2010).
[5] B. Y. Mueller, A. Baral, S. Vollmar, M. Cinchetti, M. Aeschlimann, H. C. Schneider, and B. Rethfeld, Phys. Rev. Lett. **111**, 167204 (2013).

# $Fe_3O_4$ nanoparticles and nanocomposites for applications in biomedicine and the ICTs: nanoparticle aggregation, interaction and effective magnetic anisotropy

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Magnetite nanoparticles with a size of 5-6 nm with potential impact on biomedicine and the ICTs were synthesized by thermal decomposition of $Fe(acac)_3$ and subsequently coated with a silica shell exploiting a water-in-oil synthetic procedure [1]. The as-produced powders (comprised of either $Fe_3O_4$ or $Fe_3O_4$@silica nanoparticles) were mixed with a photocurable resin obtaining two magnetic nanocomposites with the same nominal amount of magnetic material. The static magnetic properties of the two nanopowders and the corresponding nanocomposites were measured in the 10 K - 300 K temperature range. Both coating with silica and dissolution in the polymer result in a decrease of the spontaneous magnetization of the bare $Fe_3O_4$ particles. The FC/ZFC curves reveal a high degree of particle aggregation in the $Fe_3O_4$ nanopowder, which is partially reduced by silica coating and strongly decreased by dissolution in the host polymer. A comparison between the size distribution function obtained from magnetic measurements and from TEM images indicate that static magnetic measurements are a valuable tool to obtain detailed information on the nanoparticle size distribution, allowing one to determine the value of the effective magnetic anisotropy of the particles and to estimate the anisotropy contribution from the surface. In all considered materials the nanoparticles are magnetically interacting, the interaction strength being a function of nanoparticle environment and being the lowest in the nanocomposite containing bare, well-separate $Fe_3O_4$ particles. All samples behave as interacting superparamagnetic materials instead of ideal superparamagnets and follow the corresponding scaling law[2].

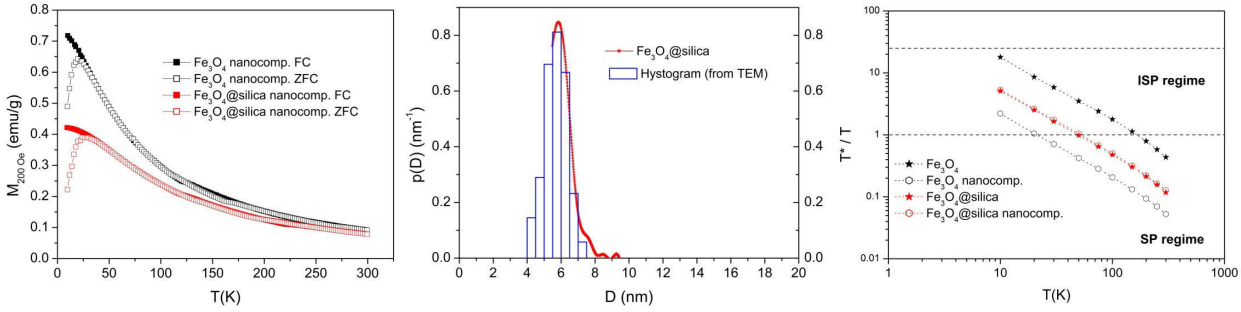


Figure 1: FC/ZFC magnetization curves obtained at H = 200 Oe in polymer nanocomposites (left). Matching between the size distribution function p(D) from the FC/ZFC curves (red line) and the p(D) distribution histogram from TEM image analysis (center). Ratio T*/T (T* being the effective interaction temperature [2]) in a diagram depicting the different magnetic regimes of nanopowders and nanocomposites (right).

[1] T. Nardi et al. Polymer 54 (2013) 4472
[2] P. Allia et al. Phys. Rev. B. 64 (2001) 144420

# Tailoring magnetic size-dependent properties of Co-ferrite nanoparticles for permanent magnet applications

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Magnetic nanoparticles (NPs) have attracted a great interest in the last decades thanks to their novel fundamental properties emerging from their extremely reduced size. Special attention has been devoted to Co-ferrite ($Co_xFe_{3-x}O_4$) NPs due to their cheap manufacturing and high magnetic anisotropy. [1, 2] In particular, the application of Co-ferrite in the realization of permanent magnet has attracted a renewed interest as an alternative to rare-earth base materials. Many works have been focused on the correlation between magnetic properties and stoichiometry, [2,5] particle size [3,4,6–8] and structural defects, [9,10] demonstrating Co-ferrite NPs are a promising candidate for permanent magnet application, although a global picture of the effect of each parameter on the final properties is still missing. Indeed, all these investigations have been limited to a short range of particle sizes and to confined temperatures. Therefore, a deeper understanding in structural, size-dependent and morphological effects on final physical properties appears necessary. Herein, we present the synthesis and investigation of a series of Co-ferrite NPs with average size covering a broad range (from 4 to 60 nm), with narrow size distributions and controlled shape and stoichiometry (see Fig. 1). Structural, morphological and magnetic characterizations were carried out using several techniques, including transmission electron and helium ion microscopy, X-ray diffraction analysis and magnetometric measurements. The evolution of the magnetic properties was studied as a function of particle size and shape. In addition, we evaluated the $(BH)_{max}$ product, the figure of merit of permanent magnets, obtaining the maximum values ever reported in the literature for Co-ferrite NPs (i.e., 2.1 MGOe (18 $MJm^{-3}$) for 40 nm NPs) (see Fig. 1(i)). Finally, this study allowed us to settle the limits of Co-ferrites for permanent magnet applications in base of the definition of the $(BH)_{max}$ product. (*This research was supported by EU-FP7 NANOPYME Project (No. 310516)).*

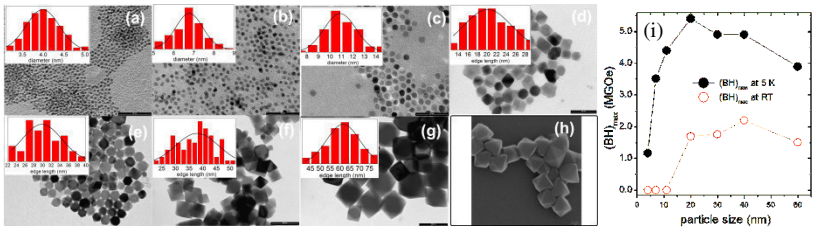


Figure 1. Transmission electron microscopy images and particle size histogram for (a) 4 nm, (b) 7 nm, (c) 11 nm, (d) 20 nm, (e) 30 nm, (f) 40 nm, (g) 60 nm. (h) Scanning Helium Ion Microscope image for 60 nm particles. (i) $(BH)_{max}$ product as function of particle size at 5 K (black symbols) and 300 K (red symbols)

1. Falk, R. *et al.* J. Appl. Phys. 1961, 32, S190.
2. Fantechi, E. et al. J. Phys. Chem. C 2012, 116, 8261–8270.
3. Song, Q *et al.* J. Am. Chem. Soc. 2004, 126, 6164–6168.
4. Chinnasamy, C. N. *et al.* Appl. Phys. Lett. 2003, 83, 2862.
5. Salazar-Alvarez, G. *et al.* Chem. Mater. 2007, 19, 4957–4963.
6. Jian, G. *et al.* J. Magn. Magn. Mater. 2012, 324, 671–676.
7. Liu, C. *et al.* J. Am. Chem. Soc. 2000, 122, 6263–6267.
8. Maaz, K. *et al.* J. Magn. Magn. Mater. 2007, 308, 289–295.
9. Ponce, A. S.e*Et al*. J. Magn. Magn. Mater. 2013, 344, 182–187.
10. Liu, B. H. *et al*. Appl. Phys. Lett. 2006, 88, 042506.

# Advanced Multiferroic Nanocomposites

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Entering the nanometer scale regime, the magnetic behavior changes dramatically with respect to the bulk state and new phenomena appear, such as Supermagnetism [1]. Nanostructured strongly electron correlated magnetic oxides represent a very interesting class of materials due to their electronic and magnetic properties and for their important technological applications (in magnetic recording, biomedicine, ferrofluid technology, catalysis, etc.). Among them, magnetoelectric multiferroics appear very promising from a technological point of view due to the presence and coupling of ferroelectric with ferromagnetic behavior, permitting the control of magnetic states using a simple electric field (and conversely inducing an electric polarization by a magnetic field) [2]. In order to improve this coupling, an interesting way is to develop new nanocomposites of Colossal Magneto-Resistance (CMR) manganites (i.e., $La_{1+x}Ca_{1-x}MnO_3$, LCMO) with a hard magnetic material as ferrites (i.e.$CoFe_2O_4$, CFO). This class of composites has already attracted a great interest for the Tunnel Magneto-Resistance effect (TMR) [3], employed in actual hard drives, We propose a new approach to synthesize nanocomposites $CoFe_2O_4/La_{0.67}Ca_{0.33}MnO_3$, in order to maximize interphase interactions,. A comparison between the nanocomposite (NC) and a

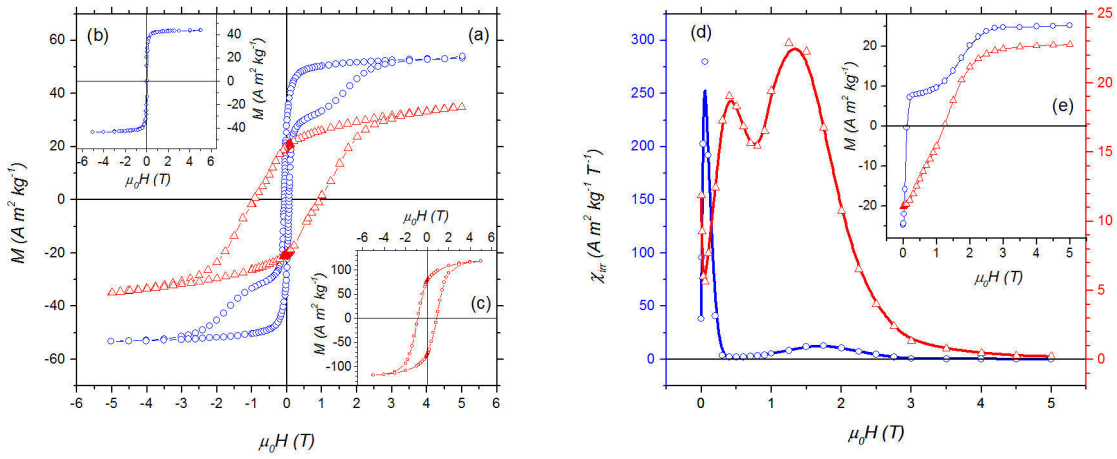


Figure 1: M Vs H curve of N-MIX (blue circles) and NC (red triangles) are reported in panel a. The single nanocrystalline phases N-LCMO (b) and N-CFO (c) are reported for comparison. For N-MIX (blue circles) and NC (red triangles) the switching field distributions are reported in panel (d), while the original DCD curves are reported in inset (e).

mechanical mixing (N-MIX) of the same two phases is carried out by a complete structural and morphological characterization, together with a deep magnetometry studies. All the results suggest that a strong coupling only occurs for the NC sample, whose magnetic behavior resembles that of an exchange-spring system [4] as clearly indicated by both the M(H) curve and the switching field distribution measured at 5 K (Figure 1).

[1] S. Bedanta and W. Kleemann J. Phys. D: Appl. Phys. 42 (2009) 1–28
[2] Eerenstein et al. Nature 442 (2006) 759–65
[3] P. Anil Kumar and D.D. Sarma Appl. Phys. Lett. 100 (2012) 262407
[4] H. Fukunaga et al. IEEE Trans. Magn. 49 (2013) 3240–3243

# Magneto-plasmonic films for biosensing applications

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Surface Plasmon Resonance (SPR) is known as a leading technology for label-free biosensing [1]. It is based on the optical detection of refractive index changes occurring at a metal/dielectric interface upon a proper choice of the metal layer, its thickness as well as on the excitation light beam. Biological and chemical analysis are achieved by functionalizing the gold surface with surface bioreceptors and measuring the shift of corresponding optical signals when a biomolecular reaction occurs.

In this work a proper combination of metal and ferromagnetic multilayers tailored on the nanoscale is used as novel transducer in propagating SPR-based biosensor coupled with an external magnetic field. The modulation of plasmon moment by an external magnetic field has been demonstrated in literature [2,3]. The coupling between the incident light and the surface plasma waves is determined by the magneto-optical (MO) properties of the magnetic layer that can be modulated using an external magnetic field. Moreover, such a combination of materials can produce a great enhancement of the MO effects when the Plasmon resonant condition is satisfied. The MO enhancement is strongly localized in the plasmon resonance conditions and critically depends on the refractive index of the dielectric medium. As a consequence, small variations of the refractive index will induce large changes in the MO response, allowing using the proposed platform as novel transducer for optical sensi1ng .

Proper combination of Au and Co metals films with total thickness of 50 nm are prepared on glass substrates by sputtering technique. Atomic Force microscopy demonstrates the high quality of the surface. On the other hand Magnetic Force microscopy and magnetic measurements show that magnetization is easy-plane and can be modulated by small magnetic fields.

Functional characterization of the prepared transducers is carried out by recording refractive index changes of ethanol solutions in order to get relative calibration curves. Therefore, the realized transducers are properly functionalized by thiol chemistry and investigated for antigen-antibody interactions recording. The sensing performances in terms of sensitivity, limit of detection, specificity are taken into account. Finally, a comparison between of "standard" plasmonic detection techniques and the proposed magneto-plasmonic detection demonstrates a significant increase in the sensing performance of the investigated materials with respect to standard plasmonic transducers.

This study was supported by the Italian MIUR through FIRB project RBFR10OAI0 Nanoplasmag.

[1] Schuck, P.,1997, Annu. Rev. Biophys. Biomol. Struct. 26, 541-566.
[2] González-Díaz, J. B., García-Martín, A., Armelles, G., García-Martín, J. M., Clavero, C., Cebollada, A., Lukaszew, R. A., Skuza, J. R., Kumah, D. P., Clarke, R., 2007, Phys. Rev. B 76, 153402.
[3] Manera, M. G., Montagna, G., Ferreiro-Vila, E., González-García, L., Sánchez-Valencia, J. R., González-Elipe, A. R., Cebollada, A., Garcia-Martin, J. M., Garcia-Martin, A., Armelles, G., et al., 2011, J. Mater. Chem., 21, 16049−16056

# Ferritin-based Hybrid Nanoparticles for Theranostic Applications

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Magnetic nanoparticles (NPs) for biomedical applications require a proper functionalization of the magnetic core in order to ensure biocompatibility, stability and targeting properties. In this framework, iron oxide NPs mineralized within the internal cavity of the human protein ferritin (NPs@HFt) represent a viable platform, thanks to the high biocompatibility of HFt and the large possibility of functionalization. However, the size constraint imposed by the proteic shell limits the use of this system for Magnetic Fluid Hyperthermia, since a mean size of 8 nm is not sufficient for iron oxide NPs to provide a sizable temperature increase under an alternating magnetic field.

In order to overcome this drawback while still exploiting the advantages provided by HFt, we develop two different approaches for the improvement of the hyperthermic efficiency. In the first strategy we increased the magnetic anisotropy of 6-7 nm NPs@HFt by doping the core with $Co^{2+}$ (**Co-NPs@HFt**, **Fig. 1a**).[1] The second approach was based on **HFt-NPs** constructs (**Fig. 1b**), obtained by conjugation of larger magnetite NPs (15-18 nm) from chemical synthesis with *apo*-HFt.

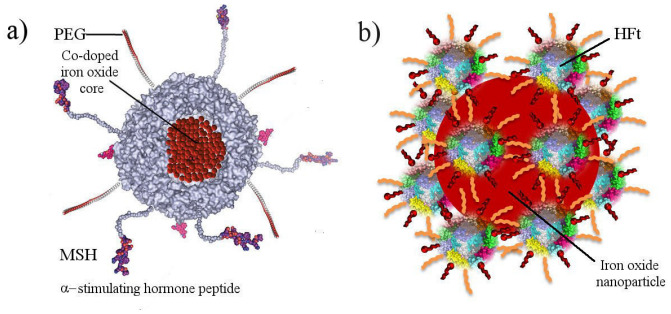


Figure 1: Schematic representation of Co-NPs@HFt (a) and HFt-MSH-NPs (b).

The hyperthermic properties of **Co-NPs@HFt** and **HFt-NPs** were investigated through calorimetric techniques and correlated with structural features and magnetic properties. A doping of 5% was found to enhance the hyperthermic efficiency of **Co-NPs@HFt** with respect to NPs@HFt, while a larger doping was detrimental, since it affected the crystal quality of the NPs. *In vitro* tests showed that both constructs were highly biocompatible. A significant reduction of the viability was observed in cells incubated with **Co-NPs@HFt** and exposed to the field, with clear indications of an advanced stage of apoptotic process. On the other hand, the same treatment performed with **HFt-NPs** had no effect on cell viability, despite its larger hyperthermic performances with respect to **Co-NPs@HFt**. Confocal microscopy measurements, performed on **HFt-NPs** labeled with rhodamine, showed that this construct is poorly internalized inside cells, unlike **NPs@HFt** which was found to be completely internalized in melanoma cells, thanks to a specific targeting peptide.[2] Therefore the differences observed in hyperthermic efficiency on cell lines should be ascribed to the different level of cell internalization. These results point out that research must be mostly focused on systems able to be efficiently internalized in tumor cells, rather than being limited in a compulsive research of heat mediators with the highest possible SAR.

*Work funded by projects **RINAME** (MIUR FIRB), **MAGNANO** (INSTM-Regione Lombardia 2012) and **BaTMAN** (CARIPLO n. 2013-0752).*

[1] E. Fantechi *et al.*, *ACS Nano* 8 (2014) 4705.
[2] L. Vannucci *et al. Int. J. of Nanomed.*, **7** (2012) 1489 and L. Vannucci *et al., J. Biomed. Nanotechnol.* 11 (2015) 81.

# Novel Fe-doped hydroxyapatite nanoparticles with high-spin ground states

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Nanoparticles (NPs) of synthetic hydroxyapatite (HAP) are rendered magnetic by treatment with iron ions using a wet-chemical process [1]. The composition analysis of the Fe-doped hydroxyapatite (Fe-HAP) NPs by an inductively coupled plasma–optical emission spectroscopy indicated that most of the iron had been substituted for calcium, in a ratio Fe : Ca equal to 22.15 %. Morphology and size of as-prepared NPs were checked by AFM and TEM. X-ray diffraction confirmed the hydroxyapatite structure of the crystallites comprising the Fe-HAP NPs, and the presence of secondary additional peaks identified as magnetite or maghemite.
The magnetic properties of Fe-HAP NPs have been studied by means of a vibrating sample magnetometer (Oxford Instruments Maglab 9T). The results show that the as-produced Fe-HAP NPs dried powder cannot be simply described as containing superparamagnetic particles undergoing an anisotropy-driven blocking and that collective magnetic interactions play a non-negligible role. The magnetization cycles identify the investigated material as an "interacting superparamagnet" ISP. The Monte Carlo simulations reproduce very well the experimental behavior of the remanence ratio and coercive field versus temperature, supposing that the magnetic crystals are single-domain and representing them as three-dimensional classical unit spin vectors that interact through dipole-dipole interaction. Low temperature hysteretic properties indicate that the Fe-HAP NPs have a high spin ground state, with a magnetization of about 35 emu/g for a magnetic field applied of 3 Tesla. The electronic structure calculations confirm the value detected in the material with a ferromagnetic moment of about 4.0 $\mu_B$ for ordered iron. The ordered magnetic moment for 3d cation at low concentration is greater than in any simple iron oxide with superexchange interactions ($Fe_3O_4$ or $Y_3Fe_5O_{12}$) or alloy, including the pure metal, and inexplicable in terms of possible known ferromagnetic phases.
The biocompatible and bioresorbable Fe-HAP NPs represent in perspective a valid alternative to replace iron oxide particles (primarily magnetite and maghemite) or at least reduce their amount used for bio-applications, considering the uncertainties regarding the safety profile of iron oxides.

[1] A. Tampieri et al. Acta Biomaterialia 8 (2012) 843

# Magnetic Nanoparticles in Bioreactors: host-guest characterization by EPR and Mössbauer Spectroscopies

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We investigated MNPs of spinel type iron oxide of approximately 8 nm mineralized in the internal cavity of the bioreactor ferritin. In particular, we used Electron Magnetic Resonance, EMR, spectroscopy and took advantage of the capacity of the protein shells (host) to control the size of the MNP (guest). EMR measurements in perpendicular and parallel configurations have been recorded at variable temperature. A model based on the giant spin is used to interpret the experimental results in an effort to describe the quantum behavior of the system, which is observed.

The host reactors contain 24 ferroxidase centers, where the mineralization initiates, each constituted by two metal binding sites. These have been characterized by a combination of Mössbauer and EPR experiments that have clearly unveiled iron and manganese binding and their involvement into the protein function. In particular, the Fe affinities of both sites are found to be similar, while the Mn ion shows higher affinity for one of the sites. Moreover, Mn binding does not have an active influence into the catalytic activity of the protein.

# $Ni_{80}Fe_{20}$ nanodisks by nanosphere lithography for biomedical applications

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Magnetic nanoparticles have been intensively studied for applications in data storage, contrast enhancement agents in magnetic resonance imaging, drug delivery and magnetic hyperthermia. The typical synthesis methods are chemical routes. The intrinsic difficulty of controlling nanoparticle dimension leads to not easily tunable magnetic properties. The production of nanodisks having controlled diameter and ferromagnetic properties can be achieved by a bottom up nanolithography process. In this work, the fabrication process of $Ni_{80}Fe_{20}$ nanodisks suspended in ethanol solution is presented. Arrays of nanodisks were obtained by polystyrene nanospheres nanolithography [1], as shown in the scheme reported in Fig. 1a together with the corresponding SEM images. Such a process is based on the self-assembling of polystyrene nanospheres (starting diameter 800 nm) on continuous thin films (thickness 30 nm) sputtered on a layer of optical resist. After depositing a monolayer of nanopsheres on the film surface, their diameter is reduced in an Ar plasma. Subsequently, magnetic material among the nanospheres is removed by sputter-etching. The removal of the remaining spheres is performed by sonication. At this stage, the resist underlayer is dissolved in aceton resulting in free-standing nanodisks. After the complete removal of the polymer by several washing, the nanodisks are dispersed in ethanol. AFM/MFM images have been measured on all samples before the removal process. Magnetic vortex magnetisation process has been observed. Room temperature magnetic hysteresis curves have been recorded at several stages of the process, as shown in Fig. 1b. The continuous film displays a typical soft magnetic behaviour while nanodisks array are characterised by magnetisation process typical of vortex nucleation with a higher coercive field, as observed in MFM image. Free-standing nanodisks are characterised by an unsaturating magnetisation curve together with a non-zero coercivity.

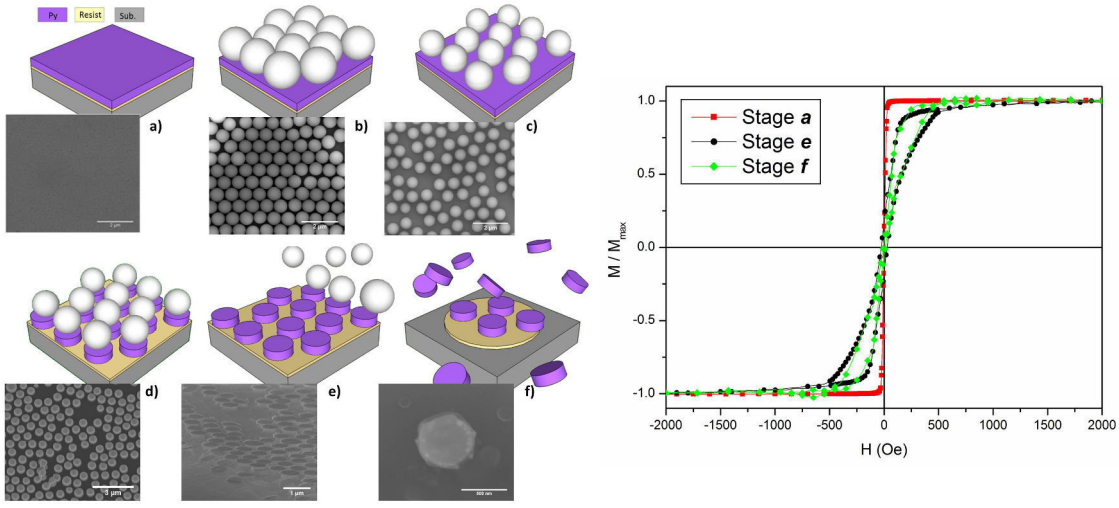


Figure 1: (Left) Sketch of the nanolithography process by self-assembling together with corresponding SEM images. (Right) Room temperature hysteresis loops recorded at selected stages of the process to obtain $Ni_{80}Fe_{20}$ nanodisks.

[1] P. Tiberto, L. Boarino, F. Celegato, G. Barrera, N. De Leo, M. Coïsson, F. Albertini, F. Casoli, P. Ranzieri, J. Appl. Phys. 113 (2013) 17B516

# February 19th

# Mapping single-site magnetic anisotropy tensors by torque magnetometry

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Weakly-interacting magnetic centers with noncollinear anisotropies, like nonparallel molecules in a crystal [1] or lanthanide polynuclears [2], are of great relevance in molecular magnetism. When such systems are probed in the low-temperature ($T$) limit, departures from simple tensorial response (i.e. from the law $\mathbf{M} = \boldsymbol{\chi}\cdot\mathbf{H}$, where $\boldsymbol{\chi}$ is the $T$-dependent susceptibility tensor) allow to map local anisotropies. These deviations can be most easily measured by torque magnetometry (TM), a popular technique for the characterization of magnetically-anisotropic samples [3,4].

We used TM to investigate a single crystal of $[Fe_3La(tea)_2(dpm)_6]$ (**$Fe_3La$**), where $H_3tea$ is triethanolamine and Hdpm is dipivaloylmethane. **$Fe_3La$** is a lanthanum(III)-centred variant of tetrairon(III) ($Fe_4$) single-molecule magnets (SMMs) [5] and features an equilateral triangle of iron(III) ions. Superexchange interactions between iron(III) sites are one order of magnitude smaller than single-ion anisotropies and angle-resolved TM allowed to fully reconstruct the iron(III) anisotropy tensors in both magnitude and orientation.

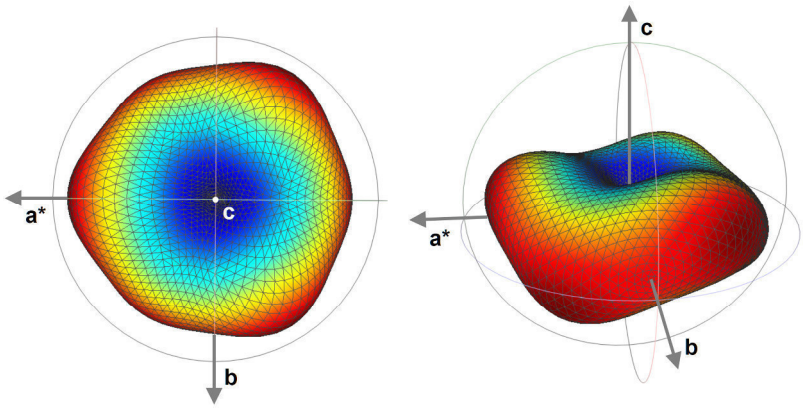


Figure 1: Free energy of **$Fe_3La$** as a function of field orientation at 30 kOe and 2.3 K. Departures from cylindrical symmetry reveal the arrangement of single-ion anisotropy tensors.

The tensors were found to be quasi-axial ($|E/D| \sim 0.05$) and of the hard-axis type ($D > 0$). The local hard directions form an angle of about 70° with the threefold molecular axis (**c** in Figure 1), which therefore corresponds to an *easy* magnetic direction for the whole molecule. The resulting picture was confirmed by high frequency EPR and DFT calculations [6] and definitively demonstrates the occurrence of strongly noncollinear anisotropies in $Fe_4$ SMMs.

[1] M. Perfetti et al. Chem. Eur. J. 20 (2014) 14051
[2] J. Luzon et al. Phys. Rev. Lett. 100 (2008) 247205
[3] F. El Hallak et al. Europhys. Lett. 95 (2011) 57002
[4] F. El Hallak et al. J. Magn. Reson. 223 (2012) 55
[5] M. Mannini et al. Nature 468 (2010) 417
[6] L. Rigamonti et al. Phys. Chem. Chem. Phys. 16 (2014) 17220

# Magnetic properties and magneto-electric effects in molecular spin helices: Insights from theory and simulations

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Single chain magnets (SCMs) are an interesting class of molecular polymeric chains displaying slow relaxation of the magnetization, *i.e.* magnetic bistability due to short-range magnetic correlation [1]. The archetype of SCMs is the so-called CoPhOMe [2], composed of alternating $Co(hfac)_2$ moieties and NITPhOMe organic radicals arranged in 1D arrays with helical structure [2]. Recently, this Co-based noncollinear spin chain has shown an interesting interplay between structural chirality and magnetism, as evidenced by a giant magneto-chiral dichroism in the hard X-ray range [3]. In this work, we present a theoretical investigation of CoPhOMe and its Mn-congener (MnPhOMe) by a combined *first-principles* and thermodynamic modelling approach. Their peculiar and distinctive magnetic behaviour is here elucidated through a microscopic description of their magnetic, electronic, and anisotropy properties. A key-result pertains the Co-helix: the microscopic picture resulting from density-functional calculations allows us to propose a spin Hamiltonian of increased complexity, suitable to study the finite-temperature behaviour, and that seems to clarify the long-debated scenario of experimental observation of multiple characteristic energy scales.

We also report on theoretical findings about novel magneto-electric effects in these helices: by modelling spin-spiral magnetic structures for different polar angles (as mimicking an applied magnetic field along the helices-axis), we find a clear modulation of the electric polarization that varies with the relative alignment of neighbouring metal and radical spins. This theoretical prediction of spin-spiral induced ferroelectricity and associated magneto-electric coupling opens, for these compounds, new possibilities in terms of multifunctionality.

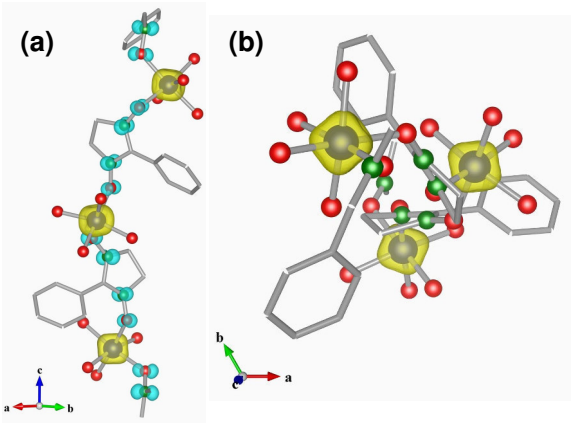


Figure 1: Isosurface plots of the spin density in CoPhOMe, showing the magnetic building units of the helix: high-spin Co(II) ions (yellow lobes) antiferromagnetically coupled with the bridging organic radicals containing a free-electron localized on O and N *p*-states (cyan lobes). (a) side and (b) top view of the crystal unit cell.

[1] L. Bogani et al., J. Mater. Chem. 18, (2008) 4750
[2] A. Caneschi et al., Angew. Chem. Int. Ed. 40, (2001) 1760
[3] R. Sessoli et al., Nat. Phys., DOI: 10.1038/NPHYS3152.

# Relaxation Dynamics of the $Dy_6$ Molecular Ring

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Molecular nanomagnets are good candidates to study quantum effects in finite systems, such as level crossings or quantum tunneling of the magnetization, and are promising components for emergent technologies in spintronics and quantum information processing.
Recently, the first rare-earth based ring has been synthesized: [Dy(Htea) (NO3)]6·8MeOH, where $H_3$tea refers to triethanolamine (in short $Dy_6$). $Dy_6$ is predicted to have a non-magnetic ground doublet with a net toroidal magnetic moment, which makes it very interesting for fundamental issues and for the possible applications in quantum computing and information storage [1]. In this work we present an investigation of $Dy_6$ by means of Muon Spin Relaxation (μSR), proton Nuclear Magnetic Resonance ($^1$H-NMR) and AC-susceptibility. AC-susceptibility measurements as a function of temperature and frequency, have been performed in zero and applied field. This allowed us to study the relaxation of the spin system and to evince that, at low temperature, the magnetization is characterized by more than one characteristic relaxation time, whose values depend strongly on the applied field. NMR and μSR techniques have been used as they are powerful tools for studying the "local" spin dynamics. In particular the nuclear spin–lattice relaxation rate ($1/T_1$) and the muon longitudinal field relaxation rate ($\lambda$ ) can probe the fluctuations of molecular observables thus eventually providing information on the electronic relaxation dynamics [2]. The $^1$H-NMR and μSR measurements have been carried out as a function of temperature for different applied magnetic fields. The $^1$H NMR spin-lattice relaxation rate $1/T_1$ by lowering T shows, at all applied fields in the range 0.5-6 Tesla, a strong increase which produces a considerable loss of the echo signal (wipeout effect) below 50-70 K, hampering the study of the low-temperature spin dynamics. To overcome this limitation, μSR measurements as a function of temperature in zero and in different applied fields have been performed, with the aim of extracting the temperature- and field-dependence of the dominant electronic relaxation time. The μSR longitudinal field relaxation rate $\lambda$ displays a sizeable peak in the range 20-30 K, whose position depends on the applied field. Theoretical studies to understand the origin of such anomaly are in progress. We present in addition the AC-susceptibility measurements as a function of temperature and frequency of Y5Dy for understand the relaxation dynamics of single Dy-ion.
*Acknowledgements*: This work was financially supported by the Italian FIRB project "New challenges in molecular nanomagnetism: from spin dynamics to quantum-information processing".

[1] L. Ungur et al, *J. Am. Chem. Soc*. 2012, 134, 18554.
[2] P. Santini et al, *Phys. Rev. Lett.* 94, 077203 (2005).

# Understanding and controlling the magnetic interaction between Ln(III) bis-(phthalocyanine)s "double decker" molecular nanomagnets and a magnetic substrate

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Understanding and controlling the interaction between molecules and metallic substrate is of crucial importance for the realization and implementation of future devices where molecules are employed as the active units. Here the magnetic coupling between a molecular spin center and magnetic substrate is studied on prototypical $LnPc_2$ "Double Decker" (Ln = Tb, Dy, Er) molecules on top of a Ni(111) single crystal.

$LnPc_2$ molecules are deposited *in situ* by sublimation on a freshly prepared Ni(111) surface. The morphological, electrical and magnetic properties of the metallic-organic magnetic system are studied by STM, XPS and UPS and by means of X-ray Absorption Spectroscopy (XAS) and element-selective X-ray Magnetic Circular Dichroism (XMCD) at synchrotron facilities. We observe that the molecules graft intact and oriented with the Pc plane flat on the substrate and do not form 3D aggregation for the employed submonolayer coverage. We find that the molecules are not altered by the deposition on the surface: in particular the microscopic parameters of the ligand field and the magnetic anisotropy are the same as measured in the bulk.

Our low temperature (8K) magnetic characterization by field dependent XMCD evidence the existence of an antiferromagnetic exchange coupling between the Ln magnetic moment and the magnetic substrate, whose strength and features depend on the specific Ln ion in the molecules. This dependence is explained by the analysis of the Ln spin-polarized density of states as calculated by Density Functional Theory. This allows us to identify the microscopic origin of the magnetic interaction between the Ln ions and the substrate which happens by the mediation of the organic part of the molecule[1].

We also address the general problem of how to describe the magnetic coupling between an isolated magnetic moment and a macroscopic object such as the magnetic substrate. Finally, we show how this interaction can be further tuned by the insertion of a graphene layer between the molecules and the Ni(111) surface. Our results will be of interest also for the investigation of recently demonstrated molecular spincontrics devices employing TbPc2 molecules[2]. Here the exchange of information between the Tb magnetic center and the electronic environment is known to play a crucial role, however its origin was not yet fully understood so far.

[1] A. Candini et al. *paper submitted* (2014).

[2] M. Urdampilleta et al. Nature Mater. 10 (2011) 502; A. Candini et al. Nano Lett. 11 (2011) 2634; R. Vincent et al. Nature 488 (2012) 357; J. Schwöbel et al. Nat. Comm. 3 (2012) 953.

# Organic spintronics: state of the art and recent results

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After the demonstration of the first organic spintronic device [1], numerous lines of investigation were followed in order to understand spin injection and transport into an organic semiconductor. The possibility of spin injection and transport was confirmed by muon spin rotation [2] and by two-photon-photoemission[3]. Both nanoindentation [4] and two-photon photoemission [5] were used to demonstrate the crucial role played by the interface.
The hallmark of spin injection is spin precession [6] which has not been observed in organic semiconductors [7, 8]. Despite some attempts at explaining this result in terms of exchange coupling among carriers [9], there is no consensus on why spin precession is not observed in organic semiconductors. An analysis of the transport characteristics of organic spintronic devices reveals the existence of two regimes of transport, only one of which gives rise to spintronic effects. A better understanding of the difference between these two regimes can shed light on their injection and transport processes.

1. Dediu, V., et al., *Room temperature spin polarized injection in organic semiconductor.* Solid State Communications, 2002. **122**(3-4): p. 181-184.
2. Drew, A.J., et al., *Direct measurement of the electronic spin diffusion length in a fully functional organic spin valve by low-energy muon spin rotation.* Nature Materials, 2009. **8**(2): p. 109-114.
3. Cinchetti, M., et al., *Determination of spin injection and transport in a ferromagnet/organic semiconductor heterojunction by two-photon photoemission.* Nature Materials, 2009. **8**(2): p. 115-119.
4. Barraud, C., et al., *Unravelling the role of the interface for spin injection into organic semiconductors.* Nature Physics, 2010. **6**(8): p. 615-620.
5. Steil, S., et al., *Spin-dependent trapping of electrons at spinterfaces.* Nature Physics, 2013. **9**(4): p. 242-247.
6. Monzon, F.G., H.X. Tang, and M.L. Roukes, *Magnetoelectronic Phenomena at a Ferromagnet-Semiconductor Interface.* Physical Review Letters, 2000. **84**(21): p. 5022-5022.
7. Gruenewald, M., et al., *Vertical organic spin valves in perpendicular magnetic fields.* Physical Review B, 2013. **88**(8).
8. Riminucci, A., et al., *Hanle effect missing in a prototypical organic spintronic device.* Applied Physics Letters, 2013. **102**.
9. Yu, Z.G., *Suppression of the Hanle Effect in Organic Spintronic Devices.* Physical Review Letters, 2013. **111**(1): p. 016601.

# Bulk Rashba effect driven by ferroelectric polarization in GeTe

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Germanium telluride (GeTe) belongs to the new class of materials called FerroElectric Rashba SemiConductors (FERSCs) [1]. The remanent ferroelectric polarization vector breaks the inversion symmetry in GeTe and leads to a giant bulk Rashba spin splitting of the bands [2], which can be controlled via external electric field, providing a unique way to modulate the spin transport properties in novel spintronic devices with non-volatile logic functions associated with remanent ferroelectric states.
In this work, by piezo-force microscopy measurements we demonstrate the presence of an intrinsic remanent outward ferroelectric polarization, which provides the inversion symmetry breaking needed to observe a net Rashba effect.
By angular resolved photoemission spectroscopy we provide evidence for a huge Rashba splitting of the valence band in GeTe(111) thin films [3]. The bands map and the k-splitting are in nice agreement with DFT calculations both for surface states and bulk bands (Fig. 1) [2].
This work provides the experimental proof of the existence of FERSC materials displaying bulk Rashba and paves the way to their use in novel spin-orbitronics devices.

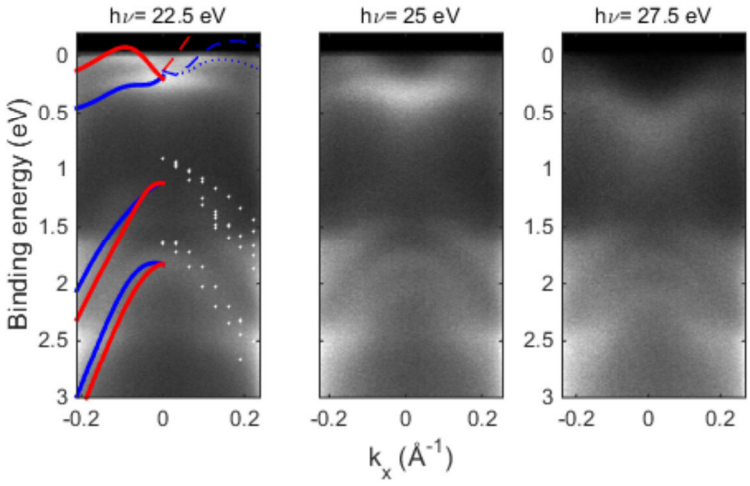


**Figure 1.** Band dispersion for 22.5, 25 and 27.5 eV photon energy (h$\nu$). Red and blue solid lines represent calculated bulk bands, while dashed lines and dots indicates surface states. We have found a clear downwards dispersion with h$\nu$ of the Rashba bands close to the valence band maximum, thus indicating the bulk nature of these states.

[1] S. Picozzi et al., Frontiers in Physics 2 (2014) 10
[2] D. Di Sante et al., Adv. Mat. 25, 509-513 (2013) 509
[3] A. Giussani et al., Phys. Status Solidi B 249 (2012) 1939

# Micro-focused Brillouin light scattering study of the magnetization dynamics driven by Spin Hall effect in a transversely magnetized NiFe nanowire

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Recent studies have demonstrated the possibility to reduce (or increase) the effective magnetic damping in ferromagnetic materials by means of a pure spin current, generated by the spin Hall effect (SHE).[1,2,3,4] This discovery opened a new range of opportunities in the field of spintronic envisioning new ways to exploit spin waves (SWs) for high-frequency signal transmission and processing.

In the present work we employed micro-focused Brillouin light scattering (micro-BLS) to study the amplification of thermal SWs by means of a pure spin current, generated by SHE, in a Pt(4nm)/NiFe(4nm)/$SiO_2$(5nm) layered nanowire of dimensions 500×2750 $nm^2$. Measurements have been performed by applying an external field H=500 Oe, at an angle of about θ=20° away from the direction normal to the sample surface. In this geometry, the in-plane component of the field is perpendicular to the direct current ($I_{DC}$) which flows along nanowire. The frequency of both the center (fundamental) and the edge SW modes has been measured by micro-BLS as a function of $I_{DC}$ and the results are shown in Fig.1. The frequency of both modes exhibits a clear redshift on increasing $I_{DC}$. The inset of Fig.1 shows the inverse of the SW intensity integrated in the whole frequency range as a function of $I_{DC}$; a linear extrapolation of the data accounts for a threshold value of about 2.9 mA. Interestingly, just above the threshold value a third mode, localized in the central part of the rectangle appears at higher frequency values (blue points in Fig. 1). Micromagnetic simulations were used to quantitatively reproduce the experimental results and to investigate the appearance of this extra mode above the $I_{DC}$ threshold.

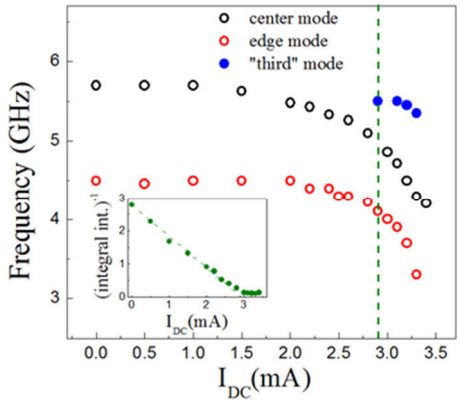


Figure 1. (points) SW frequency as a function of $I_{DC}$ for the center (open black), edge (open red) and the "third" (full blue) mode. The vertical dashed green line represents the value of the $I_{DC}$ threshold (2.9 mA) as extracted from the SWs intensity data. (inset) inverse of the SWs intensity integrated in the whole frequency range as a function of $I_{DC}$.

1) K. Ando, *et al. Phys Rev. Lett.* **101**, 036601 (2008).
2) R. Liu, *et al. Phys. Rev. Lett.* **110**, 147601 (2013).
3) V.E. Demidov, *et al. Nature Mater.* **11**, 1028 (2012).
4) V.E. Demidov, *et al. Appl. Phys. Lett.* **104**, 152402 (2014).

# Skyrmion racetrack memory driven by spin-Hall effect

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Magnetic skyrmions are attracting a growing interest from both a fundamental and a technological point of view. A promising application concerns the racetrack memory, where skyrmions (moved by spin-transfer torque (STT) or spin-Hall effect (SHE)) can be used to carry the information bit, replacing domain walls [1,2,3]. Skyrmions are nucleated in out-of-plane materials, where the Dzyaloshinskii–Moriya interaction (DMI) arises: Bloch skyrmions are stabilized in the case of bulk DMI, whereas Néel skyrmions are obtained in the case of interfacial DMI.
Here, we show that a skyrmion racetrack memory can be obtained in four scenarios, by combining the skyrmion type and the motion source [4]. In particular, the Néel skyrmion motion driven by the SHE (fig. 1a), exhibits a large velocity-current tunability, as well as a good robustness towards surface roughness and thermal fluctuations at room temperature. Moreover, we micromagnetically prove that the motion of the Néel skyrmion is mainly along the direction perpendicular to the electrical current flow (*y*-axis if the current is along the *x*-axis). This outcome is confirmed by analytical results (fig. 1b), obtained from an analytical formulation based on the Thiele's equation:

$$\begin{cases} v_x = \dfrac{\alpha_G \mathcal{D} B}{1+\alpha_G^{\,2}\mathcal{D}^2}\, j_{HM} \\ v_y = \dfrac{B}{1+\alpha_G^{\,2}\mathcal{D}^2}\, j_{HM} \end{cases} \qquad (1)$$

where $v_x$ and $v_y$ are the skyrmion velocity components in the *x*- and *y*-direction respectively. $\alpha_G$ is the Gilbert damping, $\mathcal{D}$ is the dissipative tensor, $B$ is a coefficient linked to the SHE and $j_{HM}$ is the electrical current flowing through the heavy metal. Both velocity components are proportional to $j_{HM}$. However, being $v_x$ also proportional to the $\alpha_G$<<1, it follows that $v_x << v_y$.

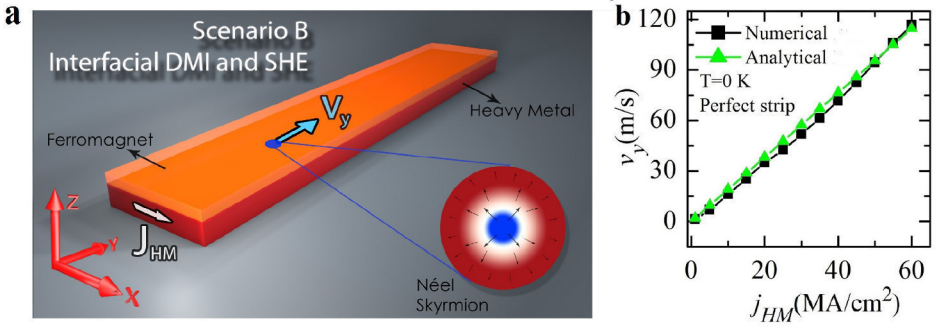


Figure 1: **a**. Sketch of the Néel skyrmion racetrack memory driven by SHE. **b**. comparison between the numerical and analytical velocity-current relations.

[1] A. Fert et al. Nat. Nanotech. 8, (2013) 152.
[2] J.Iwasaki et al. Nat. Nanotech. 8, (2013) 742.
[3] J. Sampaio et al. Nat. Nanotech. 8, (2013) 839.
[4] R.Tomasello et al. Sci. Rep. 4, (2014) 6784.

# Evaluation of thermal gradients by heat flux detection in longitudinal spin Seebeck effect samples

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The research on spintronics has gained a renewed interest thanks to the recently discovered spin Seebeck effect. This spin analogue of Seebeck effect has a promising role for the thermal generation of a spin current [1-3]. The longitudinal spin Seebeck effect (LSSE) rises when a temperature gradient is generated in the out of plane direction of a ferrimagnetic layer, typically yttrium iron garnet $Y_3Fe_5O_{12}$ (YIG) grown on a gadolinium gallium garnet (GGG) substrate. Because of the LSSE, the YIG layer generates a spin current along the direction of temperature gradient; this spin current is detected by inverse spin Hall effect (ISHE) [4,5] by means of a paramagnetic metal film deposited over the YIG layer. For the characterization of a LSSE device it is necessary to know the temperature profile inside the Pt-YIG-GGG layered structure. In particular, the measurement of the temperature difference between the two surfaces of the YIG layer is not trivial because of the value of the contact thermal resistance between a thermometer and the LSSE sample. The contact thermal resistance is hardly reproducible and much bigger than the thermal resistance of the YIG layer that is usually a few micrometers thick. To overcome this issue, we have developed an experimental setup for the measurement of the heat flux through the sample [6]. This system is based on detection of the heat flux by means of a calibrated Peltier cell that allows the indirect measurement of the temperature difference between the YIG surfaces, once known the thermal conductivity of the YIG. This procedure makes it possible to disregard the values of the thermal resistance of the contacts and the interfaces between each layer of the LSSE sample. In order to test this technique, a standard LSSE device produced at Tohoku University was measured and we find a spin Seebeck coefficient of $2.8 \cdot 10^{-7}$ V/K. LSSE has been theoretically investigated by an Hamiltonian model that describes the thermal non-equilibrium between magnons in ferrimagnets [7], that is responsible for the spin accumulation in the Pt layer.

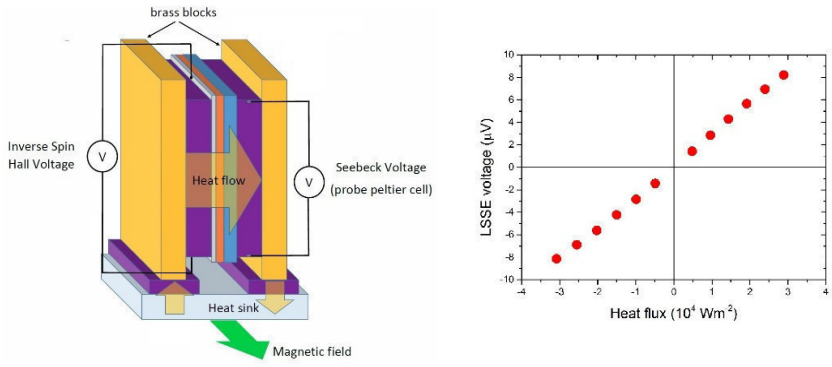


Figure 1: Left: measurement system for the characterization of a LSSE device as function of the heat flux. Right: LSSE voltage as function of the heat flux trough the sample.

[1] G. Siegel et al. Scientific reports 4 (2014)
[2] A. Kirihara et al. Nat. Mater. 11 (2012) 686
[3] K. Uchida et al. J. Appl. Phys. 111 (2012) 103903
[4] E. Saitoh et al. Appl. Phys. Lett. 88 (2006)
[5] H. Adachi et al. Appl. Phys. Lett. 97 (2010) 252506
[6] A. Sola et al. J. Appl. Phys. in press
[7] Y. Ohnuma et al. Phys. Rev. B 87 (2013) 014423

# A new effective strategy for the study of magnetic disordered systems: how to investigate the field effects on spontaneous magnetization reversal of bulk $BiFe_{0.5}Mn_{0.5}O_3$

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We show a thorough study on the external field effects in the magnetic complex properties observed in the polycrystalline solid solution $BiFe_{0.5}Mn_{0.5}O_3$, an intriguing compound synthesized in high pressure-high temperature conditions and candidate to high temperature multiferroism and magnetoelectricity. In analogy to what observed in other perovskites presenting cationic disorder on the B-site, the intrinsic inhomogeneity of $BiFe_{0.5}Mn_{0.5}O_3$ [1][2] determines the presence of distinct mesoscopic regions (clusters) with different concentrations of iron or manganese. Their coexistence and interplay are likely responsible for a spontaneous magnetization reversal (MRV) occurring below the Neél temperature that is always observed in absence of applied magnetic field. SQuID magnetometry allowed to individuate two critical fields of the system (650 Oe and 2200 Oe), related to the presence of two independent magnetic phases. These phases result to be magnetically competitive for H < 650 Oe, while for an intermediate field regime the energy of this weak interaction becomes comparable to the energy of the system under field application. As a result, in the latter case, Zero Field Cooled magnetization thermal evolution depends on the sample degree of inhomogeneity. In the same conditions, applied field Mössbauer spectroscopy shows that the room temperature iron rich clusters are highly polarized by the field while the largest part of the material appears to consist of AFM clusters characterized by axial anisotropy and uncompensated moments. Moreover, anomalous T-dependence of the iron ions mean-square displacements suggests the presence of low temperature anhamornicities. Above the higher critical field the M(T) measurements denotes the trend expected for a typical antiferromagnetic material. The MRV phenomenon results to be highly sensitive on both the thermal and magnetic measurement conditions. Herein we propose a specific characterization strategy that takes into account this criticalities and in principle has a large applicability in the study of disordered perovskites showing similar phenomenology.

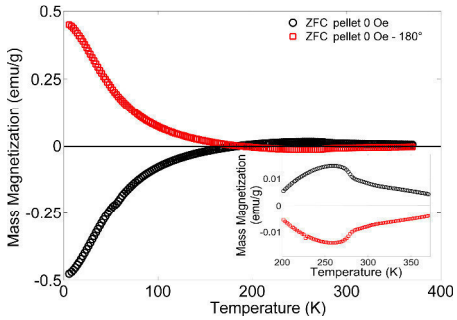


Figure 1. BiFe0.5Mn0.5O3 spontaneous magnetization collected in absence of an applied external magnetic field for two different orientations of the RT resultant magnetization, parallel (black circles) and anti-parallel (red squares) with respect to the positive magnetic field direction.

[1] D. Delmonte et al., Phys. Rev. B 88(2013) 014431.
[2] A.A. Belik, Inorg. Chem. 52 (2013) 2015.

# Spectroscopy investigation of magnetic memory device *in-operando*

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Controlling the magnetism of materials by means of electric field is the key for the development of fast and low power-consumption electronics. Recent years have witnessed many attempts to achieve such goal and significant progress have been made in the electric control of both the magnetic anisotropy and the Curie temperature of magnetic films and interfaces. Despite the great interest the current research is mainly based on transport measurements and magnetic measurements such as SQUID and MOKE which can address the magnetic response but do not the electronic structure of the materials. Here I will present an experimental set-up and the experimental procedure to perform the investigation of the magnetic and electronic structure of materials by performing XMCD under applied bias voltage.
The High Energy branch (APE-HE) is optimized for Near Edge X-ray absorption Fine Structure (NEXAFS) and magnetic circular dichroism (XMCD) and in the framework of the NFFA demonstrator project, we recently developed a set-up for the investigation of the magnetic properties of thin films and nanostructures *in-operando* conditions. Within this framework I will present few examples of *in-operando* experiments: at first I will show the variation of the magnetic properties of a ferromagnet when is subjected to an electric field in a ferromagnetic/ferroelectric junction [1], successively I will present how the same set-up can be exploited for the investigation of other interesting effects such as bistability in resistive switching devices. Moreover in the new set up we have the possibility of investigate the electric properties of magneto tunnel junctions relating them to the magnetic properties of the different layers[2].

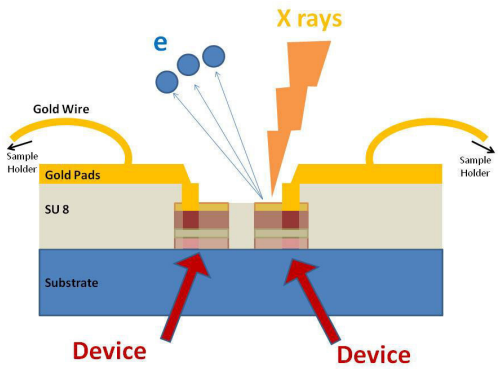


Figure 1: Schematic configuration of the in-operando XMCD experiment @ APE

[1] G. Radaelli et al. Nature Commun. 5, 3404 (2014)
[2] B. Gobaut et al. JMMM in press.

# Topological tuning in three dimensional Dirac semimetals

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In recent years an ever growing attention has been devoted to Dirac fermions, both in two as well as in three dimensions, and a big step in this field was brought when several theoretical studies have predicted the existence of three dimensional (3D) topological Dirac semimetals. In this work, we have studied the interplay between bulk and surface Dirac fermions in prototypical 3D Dirac semimetals (see Figure 1), by using first-principles-based tight-binding calculations. Furthermore, by means of density functional theory with coherent potential approximation simulations, we have revealed a topological phase transition in $Na_3Bi_{1-x}Sb_x$ and $Cd_3[As_{1-x}P_x]_2$ alloys. The change of Sb or P concentration provides an efficient way to engineer the reciprocal space position of the three

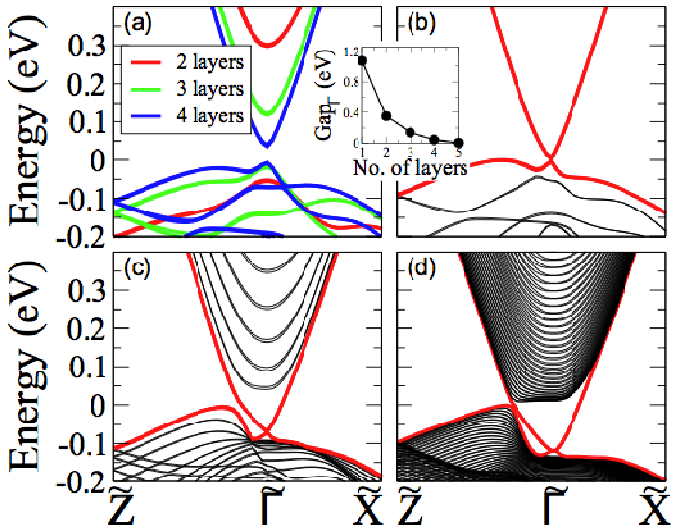


Figure 1: Band evolution and interplay between bulk and surface Dirac fermions in three dimensional Dirac semimetals $Na_3Bi_{1-x}Sb_x$ films.

dimensional Dirac cone, with potential implications for technological devices benefiting from this additional degree of freedom. Intriguingly, we show that the phase transition from a Dirac semimetal to an insulator is accompanied by a change in the bulk band ordering. This can be related, via the bulk-boundary correspondence, to a concomitant transition in the surface state spectrum.

[1] A. Narayan, D. Di Sante, S. Picozzi and S. Sanvito, arXiv:1408.3509 (2014) (accepted for publication in Phys. Rev. Lett.)

# Optimization of $BiFeO_3$ thin films for spintronic applications

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Complex transition metal oxides represent a vast class of materials with fascinating and interesting physical phenomena, such as high dielectric permittivities, ferroelectricity and multiferroicity.
Among multiferroic materials the perovskite $BiFeO_3$ [1] has attracted a lot of attention, since it is one of the few robust materials with ferroelectric and antiferromagnetic order well above room temperature (Néel temperature $T_N$ = 643K and a ferroelectric ordering below $T_c$=1103K).
Recently, a robust and large exchange bias effect has been demonstrated at room temperature in $BiFeO_3$/CoFeB heterostructures [2]. The exchange bias and magnetoelectric coupling [3, 4] at a BFO/ferromagnet interface can play a key role in the development of electrically controlled spin devices. Here we report on our activity on $BiFeO_3$, which range from target preparation and optimization to a systematic study and characterization of thin films deposited by PLD. The realization of targets with phase and stoichiometry control still represents a significant task, since the quality of the BFO film strongly depends from target characteristics. Structural, dielectric and ferroelectric characterizations of both bulk and thin films were performed using X-Ray Diffraction, impedance spectroscopy and piezoresponse force microscopy (PFM).

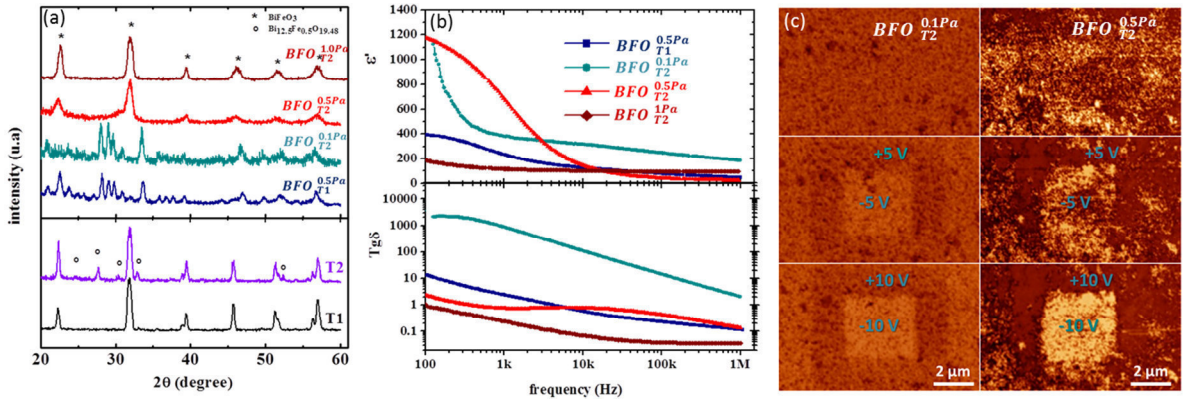


Figure 1 (a) XRD spectra of target and BFO thin films; (b) dielectric characterization; (b) PFM measurements carried out on two films deposited at two different oxygen pressure (0.1Pa and 0.5Pa) varying the polarization bias.

A systematic study was then performed in order to understand the role of each deposition parameter, such as substrate temperature, oxygen pressure, fluency, number of pulses, on the structure and impure phase formation during BFO film growth. It was found that a non-stoichiometric target is preferable to limit the effect of bismuth losses and contain the impure phase formation. On the other hand increasing the oxygen pressure from 0.5Pa to 1Pa, improved dielectric properties have been observed, due to the decreasing number of the oxygen vacancies (figure 1).

1. Catalan, G. and J.F. Scott, *Physics and applications of bismuth ferrite.* Advanced Materials, 2009. **21**(24): p. 2463-2485.
2. Béa, H., et al., *Tunnel magnetoresistance and robust room temperature exchange bias with multiferroic $BiFeO_3$ epitaxial thin films.* Applied physics letters, 2006. **89**(24): p. 242114-242114-3.
3. Chu, Y.-H., et al., *Electric-field control of local ferromagnetism using a magnetoelectric multiferroic.* Nature materials, 2008. **7**(6): p. 478-482.
4. Zhao, T., et al., *Electrical control of antiferromagnetic domains in multiferroic $BiFeO_3$ films at room temperature.* Nature materials, 2006. **5**(10): p. 823-829.

# Tuning order-by-disorder multiferroicity in CuO by doping

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CuO exhibits strong coupling among ferroelectric and magnetic orders at temperatures much higher than other strongly coupled multiferroics but short of room temperature which would enable practical spintronic devices. To achieve such a goal it would be desirable to find design principles which could guide the search for new materials. Here we show that CuO allows to validate two such principles i) It contains two weakly coupled sublattices with robust magnetic order within each sublattice so that the relative orientation among the magnetic order parameter in different sublattices is determined by small perturbations and the canted magnetic state, required to have ferroelectricity, can be stabilized without sacrificing the ordering temperature. ii) Isovalent doping allows to stabilize the multiferroic phase, in non-ferroelectric regions of the pristine material phase-diagram by the so called ``order-by-disorder" mechanism[1]. We demonstrate experimentally that doping with 5\% of Zn indeed widens the multiferroic temperature window by 250\%[2].

Work done in collaboration with: G. Giovannetti, S. Kumar, A. Stroppa, J. van den Brink, S. Picozzi, J. Hellsvik., M. Balestieri, T. Usui, A. Bergman, L. Bergqvist, D. Prabhakaran, O. Eriksson,T. Kimura

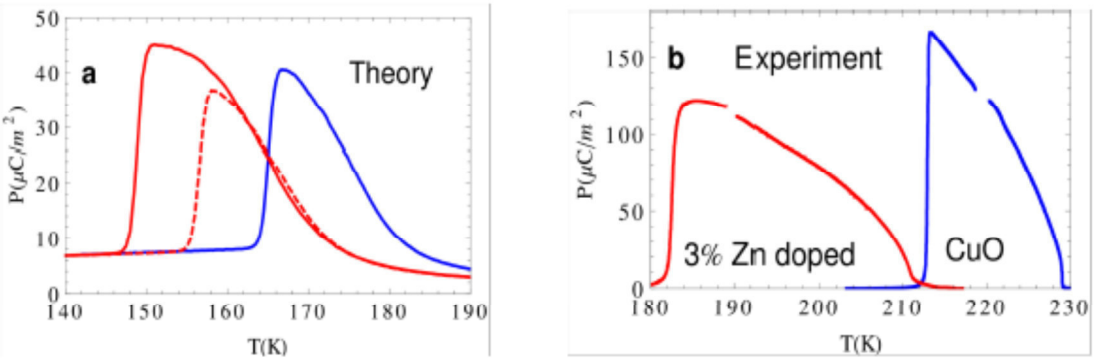


Figure 1: Theoretical and experimental polarization as a function of temperature. In (a) the dashed line is neglecting order-by-disorder effects.

[1] G. Giovannetti, S. Kumar, A. Stroppa, J. van den Brink, S. Picozzi, and J. Lorenzana, Phys. Rev. Lett.106, 026401 (2011).
[2]J. Hellsvik., M. Balestieri, T. Usui, A. Stroppa, A. Bergman, L. Bergqvist, D. Prabhakaran, O. Eriksson,S. Picozzi, T. Kimura and J. Lorenzana Phys. Rev. B 90, 014437 (2014).

# POSTER SESSION I

## February 17th

# Magnetic circular dichroism in magnetoplasmonic systems: from gold to alloy nanoparticles

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Magnetoplasmonics [1] –intertwined effects of surface plasmon resonances and magnetic fields – represents an expanding and promising research field whose principal aim is the control of the plasmonic resonance by means of an external magnetic stimulus.
The magneto optical technique with its extreme sensitivity to both optical and magnetic response in materials is a powerful tool to investigate magnetoplasmonic phenomena. In particular the magnetoplasmonic modes of both pure noble metal and alloy nanoparticles (NPs) can be studied by the spectral MCD (magnetic circular dichroism).
In this contribution we firstly show the modulation of the plasmonic resonance in non-magnetic Au NPs due to the application of a relatively weak magnetic field (~1T). The experimental observation of this phenomenon through the spectral MCD response is explained and theoretically rationalized [2].
Subsequently, we show how the same phenomenon can be studied in the case of a hybrid system of AuFe alloy NPs where a non-magnetic noble metal like Au is coupled to a ferromagnetic metal like Fe. A surprising coexistence of plasmonic and magnetic properties can be found and most importantly, new magnetic and optical behaviors can be observed in the hybrid NPs compared to the single components [3]. In particular, the MCD lineshape of the AuFe NPs mimics the Au NPs response (Fig. 1), confirming a plasmonic resonance also in the alloy nanosystem.
Unlike the simple Au, the magnetization of the AuFe NPs shows a non-linear response at low temperatures. This makes the class of noble-ferromagnetic metals alloys a promising candidate in magnetoplasmonics.

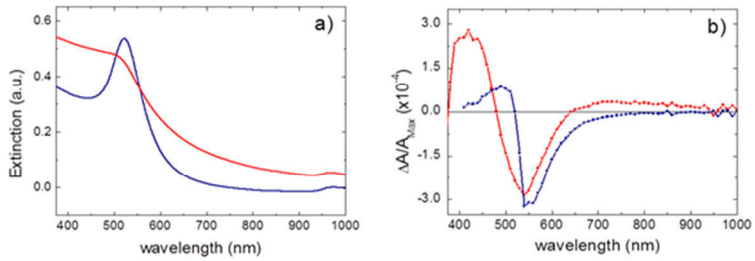


Figure 1: Panel a): UV-vis absorption of 30 nm AuFe (red) and Au (blue) nanoparticles in water. Panel b): MCD spectra of 30 nm AuFe (red ) and Au (blue) nanoparticles in water.

In addition to the interest from the point of view of the fundamental research, our findings can be relevant also for plasmonic applications in sensing. The peculiar features in the MCD spectrum of the magnetically modulated plasmonic resonance could critically improve the sensitivity to the refractive index changes using simple noble metal structures.
This research was supported by the Cariplo Fundation (project n.2010-0612) and FIRB Futuro in Ricerca 2010 Project “NanoPlasMag” (Contract MIUR RBFR10OAI0).

[1] G. Armelles et al. Adv. Optical Mater. 1 (2013) 10.
[2] F. Pineider et al. Nano Letters 13 (2013) 4785.
[3] V. Amendola et al. Nanoscale 5 (2013) 5611.

# Revealing the chemical composition of Fe oxide nanoparticles by magneto-optical spectroscopy

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Spinel ferrites magnetic nanoparticles show great applicative potential in different areas as magnetic recording, spintronics, sensoristics and biomedicine. Due to the increased surface/volume ratio, nanosized magnetic ferrites are more affected by oxidation processes compared to the bulk state[1]. The compositional purity becomes thus a critical aspect for the full understanding of the physical properties of the system.

A particularly interesting case for technological applications is the conversion of $Fe^{2+}$ ions of the metastable magnetite phase into $Fe^{3+}$ ions of maghemite. Conventional techniques for magnetic and structural characterization are often not able to completely discriminate between nanosized magnetite and maghemite and thus different strategies are requested.

Here we present the magnetic circular dichroism (MCD) spectroscopy as a viable and complementary tool to overcome this issue. Being able to detect specific electronic transitions[2], magneto-optics can be exploited as a magnetic element-sensitive technique.

In this work the time evolution of spherical Fe oxide nanoparticles with different size has been monitored by MCD characterization in the nUV-ViS-nIR range for a long period after the samples have been synthesized. MCD spectra show a complex lineshape which can be deconvolved through the analysis of the related MCD hysteresis loops (Fig. 1). As a result, our method indicates the presence of two distinct contributions in the nanoparticles, most likely originating from magnetite and maghemite domains[3]. Our MCD analysis has also been applied to mixed samples of pure maghemite and magnetite nanoparticles, showing its potentiality towards a quantitative magneto-optical composition analysis of magnetic nanosystems.

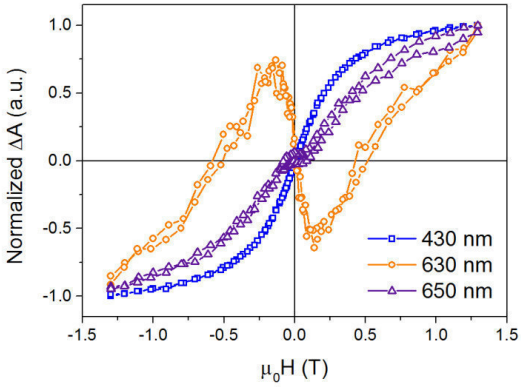


Figure 1: MCD loops recorded at different wavelengths for 5 nm Fe oxide NPs.

[1] J. Santoyo Salazar et al. Chem. Mater. 23(2011) 1379
[2] W.F.J. Fontijn et al. J. Appl. Phys. 85 (1999) 5100
[3] F. Bentivegna et al., J. Appl. Phys. 85 (1999) 2270

# Understanding the magnetism of Co thin films from the local scale anisotropies

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The structural anisotropy in thin ferromagnetic films and nanoparticles is tightly related to the magnetic response of the system itself. In nanostructured metallic systems, many factors such as shape anisotropy, atomic scale distortions or chemical anisotropy contribute in determining the direction of the easy axis of magnetization. Therefore accurately characterizing the structure of the magnetic nano-phases down to the atomic scale is a prerequisite to reliably understand their magnetic behavior and to tailor the magnetic response of novel systems for applicative purposes.

The phenomena which take place at the atomic scale during a film growth can be exploited for self-assembling nanostructures which present peculiar magnetic properties. For instance, it has been proved that a nanostructured substrate can affect the morphology of a thin layer on its surface through self-organization [1]. Furthermore a deep influence on crystalline orientation and magnetic easy axis direction has been found in Co thin films deposited onto nanorippled Si substrates [2,3].

Here we present a work which aims to unravel the relation between magnetic and structural anisotropy in Co films (thickness from 10 to 40 nm) grown on nanorippled Si substrates: this system exhibits a magnetic easy axis lying along the direction of the ripples. Synchrotron radiation was exploited to carry out Co K-edge polarized XAFS measurements in order to finely explore the local atomic structure around Co atoms along and perpendicularly to the ripples. The analysis of polarized XAFS spectra allows us to reveal and quantify the local distortions around Co atoms related to the magnetic anisotropy. From a comparative analysis of the data acquired using two different polarization, we are able to identify anisotropies down to few tenths of Å. Such ability leads to the understanding and then to the to the control of the anisotropies behavior. With them, one is given the capability of tailoring the easy axis at wish and to optimize the system for a certain application.

A fine control on the Co film morphology at an atomic level (Co film thickness, oxidation, features of the ripples etc.) can have dramatic effects on the overall magnetic behavior of a whole device: its achievement is fundamental to optimize magnetic-based devices.

[1] S. Facsko et al., Science 285 (1999) 1551
[2] Sarathlal K.V. et al., Appl. Phys. Lett. 98 (2011) 123111
[3] Sarathlal K.V. et al., Appl. Surf. Sc. 258 (2012) 4116

# Exchange bias in $Co_xFe_{1-x}O$(AFM)|$Co_xFe_{3-x}O_4$(FiM) Core|Shell nanoparticles

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The exchange bias effect, firstly reported by Meiklejohn and Bean in Co|CoO ferromagnetic(FM)|antiferromagnetic(AFM) core-shell (CS) nanoparticles [1], manifests as a horizontal hysteresis loop shift and coercivity increase due to interface coupling between AFM and FM or ferrimagnetic (FiM) materials. Interestingly, being an interface effect, exchange bias is only observed at the nanoscale. In the last decades main efforts have been devoted to study exchange bias in thin films. However, with the increased capability of controlling the synthesis of CS nanoparticles, in terms of particle size distribution, morphology and chemical composition, the interest is extended in studying exchange bias effect in these kinds of structures. Here, an investigation on inverted AFM|FiM CS nanoparticles of formula $Co_xFe_{1-x}O|Co_xFe_{3-x}O_4$, is presented. The samples were characterized by X-ray- Diffraction (XRD), Transmission and Scanning Electron Microscopy (TEM and STEM), Electron Energy Loss Spectroscopy (EELS) and magnetometric measurements.
Narrowly size distributed CS nanoparticles with mean diameter from 7 to 20 nm have been synthesized by thermal decomposition of mixed iron and cobalt metal-oleate (($Co^{2+}$,$Fe^{3+}$)-oleate), leading to the formation of an AFM-core ($Co_xFe_{1-x}O$) which is passivated under air yielding the corresponding FiM-shell ($Co_xFe_{3-x}O_4$). The presence of a $Co_xFe_{1-x}O|Co_xFe_{3-x}O_4$ CS structure has been confirmed by both XRD and EELS analyses; interestingly, all the samples are characterized by the presence of a constant FiM shell thickness ($t_{Shell}$ = 2 nm) and a variable AFM core diameter ($d_{Core}$ = 7, 11 and 16 nm). Low temperature hysteresis loops revealed the presence of exchange bias and increased coercivities as indeed expected for a good exchange coupling between core and shell phases. Since the exchange bias effect is affected in an entangled way by the core and shell size [2-4], the synthesized NPs have been used to systematically address the effect of the size of AFM counterpart which has been less studied than the FM size dependent properties. [5] (*This research was supported by EU-FP7 NANOPYME Project (No. 310516) and EU-FP7 ESTEEM2 Project (No. 312483)*).

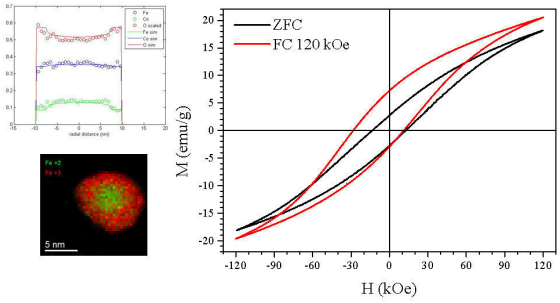


**Figure 1:** Left side: EELS elemental distribution (top) and $Fe^{2+}$/$Fe^{3+}$ mapping (bottom) into nanoparticles. Right: Hysteresis loops at LT (10K) measured in a field range of ±12 T after a ZFC (black) and 120 kOe FC (red) process.

[1] Skumryev, V. et al. Nature 2003, 423, 850.
[2] Salazar-Alvarez, G. et al. J. Am. Chem. Soc. 2007, 129, 9102.
[3] Golosovsky, I. V. et al. Phys. Rev. Lett. 2009, 102, 247201.
[4] López-Ortega, A. et al. J. Am. Chem. Soc. 2010, 132, 9398.
[5] Nogués, J. et al. Phys. Rep. 2005, 422, 65.

# Zn-doped cobalt ferrite nanoparticles: the effect of zinc doping on the magnetic properties

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Nanostructured iron oxides with cubic spinel structure ($M(II)Fe_2O_4$ , $M(II)=Fe^{2+}$, $Co^{2+}$, $Mn^{2+}$, $Ni^{2+}$, etc.) are very interesting for both fundamental studies and applications (e.g. gas-sensing, pollutant removal, biomedicine) [1]. The ferrite spinel structure is based on a closed-packed oxygen lattice, in which tetrahedral (A sites) and octahedral (B sites) interstices are occupied by the cations. The physical behaviour and, in particular, the magnetic properties depend on the cationic distribution in the A and B sites and on the chemical composition.

In this view, doping ferrites by diamagnetic divalent ions has become a good strategy to modify the magnetic properties of these compounds [2].

In this communication, magnetic properties of Zn-doped cobalt ferrite nanoparticles ($Zn_xCo_{1-x}Fe_2O_4$, $0<x<0.6$) synthesized by thermal decomposition of metal acetylacetonates in the presence of surfactants have been discussed [3]. X-Ray Diffraction (XRD) shows the presence of a unique spinel cubic phase ($CoFe_2O_4$, PdF card # 221086) for all the samples with a mean crystallite size of ~6 nm. The Transmission Electron Microscopy (TEM) images show *log normal*-distributed spherical-like nanoparticles with a mean diameter of ~7 nm and a polidispersity of ~20%. Due to the structural and morphological similarities between the samples, the effect of the Zn-doping on the magnetic properties was investigated beyond the effect of particle size. *M versus H* at 5K shows that the saturation magnetisation ($M_s$) increases up to x=0.5 and decreases for higher Zn concentration. On the other hand, both coercive field ($H_c$) and irreversibility field ($H_K$) have similar values when $x>0$, suggesting a similar value of magnetic anisotropy despite the increase of Zn content and, consequently, the reduction of Co concentration. This behaviour can be ascribed to a modification of the cationic distribution induced by Zn doping. In fact, the strong difference of single ion magnetic anisotropy of $Co^{2+}$ located in A and B sites can compensate for the deficiency of $Co^{2+}$.

To confirm this idea, Mössbauer experiments under intense magnetic field are in progress. Thermal dependence of magnetization by Zero Field Cooled (ZFC), Field Cooled (FC) and ThermoRemanent Magnetization (TRM) protocols have been also studied.

[1] C. S. S. R. Kumar, Ed., Magnetic Nanomaterials. Wiley-VCH Verlag GmbH & Co. KGaA (2009)
[2] J. Jang et al. Angew. Chem. Int. Ed. Engl. 48 (2009) 1234
[3] S. Sun et al. J. Am. Chem. Soc. 126 (2004) 273

# Magnetic Properties of Nanoparticles Investigated by Niobium NanoSQUIDs

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Magnetization measurements of $Fe_3O_4$ nanoparticles have been performed by using a nanosized Superconducting Quantum Interference Device (nanoSQUID). The nanosensor consists of a niobium loop interrupted by two Dayem nanobridges (60nm large, 150nm long and 20nm thick). The characterization of the nanodevice in the temperature range from 1.2K to 4.2 K includes measurements of current-voltage, critical current vs. magnetic flux characteristic and flux noise[1-3]. A proper feedback circuit has been employed to increase the dynamic range of the nanosensor and to measure the M(H) curve, whereas the sensors are employed in the small signal mode regime for the magnetic relaxation measurements[4,5].
The magnetic nanoparticles under investigation have a diameter of 4 nm and 8 nm and were synthesized by thermal decomposition of metallorganic precursors in the presence of oleic acid and oleylamine as surfactants and organic solvent with high boiling point. Measurements of magnetization as a function of the external magnetic field for both nanoparticle diameters are reported at liquid helium temperature in magnetic field up to 100mT. In both case it can be observed magnetic histeresis (Fig. 1b) indicating a blocking temperature above 4.2 K. The sigmoid shape of the virgin curves (Fig. 1a) indicates the presence of dipole–dipole interparticle interactions which tend to resist to the magnetization process. Magnetic relaxation measurements with a time resolution below 0.1s have also been performed and they will be reported.
We will also present measurements of niobium films (5, 10 and 15 nm) in magnetic field up to 8Tesla in parallel and perpendicular configuration showing that, in order to operate, the nanoSQUID in magnetic field up to 5 Tesla the niobium thickness should be 10nm or less.

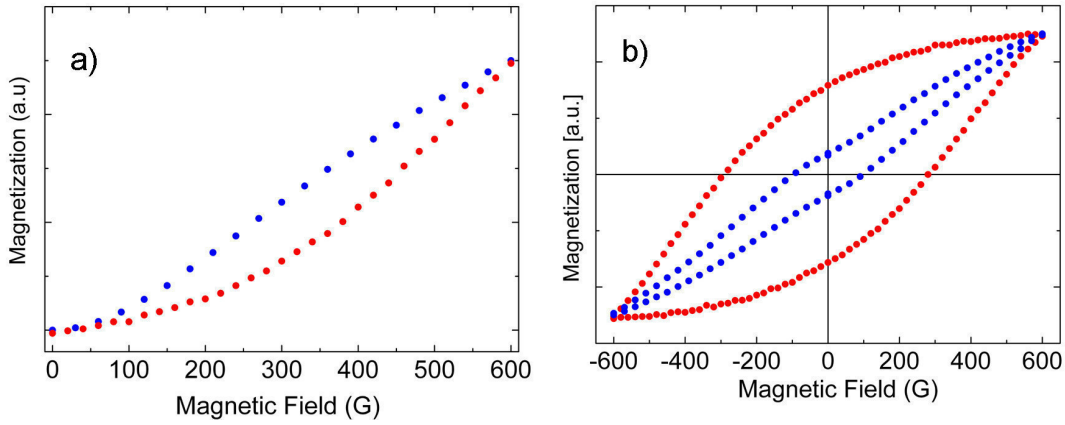


Figure 1: Field dependence of magnetization for MNP 4nm (blue dots) and MNP nm8 (red dots) nanoparticles measured at T=4.2 K by using a nanoSQUID. a) Virgin curves; b) hysteresis cycles

[1] R. Russo et al. Journal of Nanoparticle Research 13, 5661-5668 (2011)
[2] R. Russo et al Appl. Phys. Lett. 101, (2012) 122601; doi: 10.1063/1.4751036
[3] R.Russo et al (2014) SUST 27 (4), 044028
[4] C. Granata, et al. (2013) EPJ B, , vol. 86, 272, doi: 10.1140/epjb/e2013-40051-2
[5] C. Granata, et al. (2013) Appl. Phys. Lett, vol. 103, 102602

# Effect of the oxygen content in the reaction environment on size and shape of $CoFe_2O_4$ nanoparticles: morphological analysis by aspect maps.

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Advanced synthesis approaches, necessary to achieve a strict control of the structural, morphological and chemical properties of nanomaterials, are at the basis of a reproducible manipulation of their unique physical behavior. Nowadays, this is one of the most difficult problems faced by nanotechnology. In fact, any advanced application that takes advantage of nanoparticle (NP) systems will also rely on the achievement of such control. This is true in particular for magnetic nanoparticles that are unique complex physical objects whose properties, being particularly sensitive to the particle size [1], differ greatly from their parent massive material.
Within this context, the synthesis of spinel ferrite nanoparticles ($MeFe_2O_4$, Me = $Fe^{2+}$, $Co^{2+}$, $Ni^{2+}$, $Zn^{2+}$, …) with controlled morpho-structural features represents an important issue due to the strong interest in these materials from both a fundamental and a technological point of view (e.g., MRI, hyperthermia, drug delivery, catalysis, microwave applications).
Crystalline cobalt ferrite nanoparticles were prepared by a modified high thermal decomposition (HTD) synthesis of acetylacetonate precursors [1,2]. This widely employed synthetic approach has been improved introducing a strict control on the residual oxygen in the reaction environment. A detailed analysis of the effect of the oxygen content was carried out analyzing TEM images through a statistical approach and using aspect maps [3].

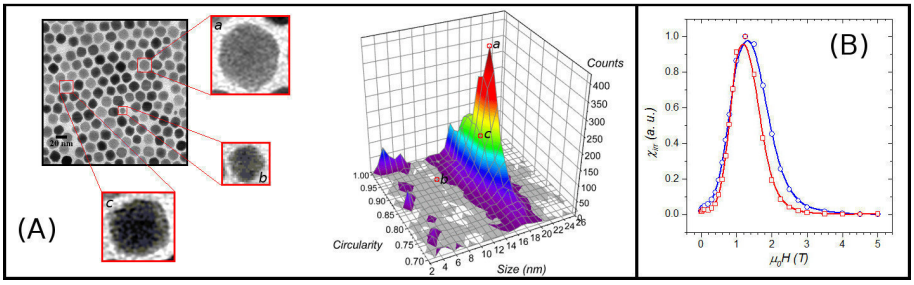


Figure 1: (A) The aspect map analysis is graphically summarized in sketch (A). The switching field distribution (SFD) of a classical HTD synthesis is reported in panel (B) (blu line), and compared with the 20 % narrower SFD obtained by the reduced oxygen improved synthesis approach (red curve).

The aspect maps have allowed to follow the growth process of nanoparticles and to select the optimal value of $O_2$ pressure to produce particles size of ~ 19 nm with a sharp size distribution (polydispersity 0.4 %). The magnetic properties were analyzed, showing an improvement of the switching field distribution, which is a key parameter for technological applications. In addition, our results suggest that particles with larger sizes can be also stabilized.

[1] D. Peddis et al. Chem. Mater. 25 (2013) 2–10
[2] S. Sun, et al. J. Am. Chem. Soc. 4 (2004) 126–132
[3] G. Muscas et al. Chem mater. *submitted*

# Charge transport in self assembled Fe4 single molecular magnet-gold nanoparticle multilayers

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Advancing towards molecular spintronics, single molecular magnets (SMM) are very promising candidate building blocks because of their high spin ground state and large easy axis magnetic anisotropy. Many SMMs were attempted to incorporate in electronic devices like Mn12. However, both of these molecules have shown a change in structural and magnetic dynamics when grafted on a conducting surface. Some $Fe_4$ derivatives were recently demonstrated to have the good stability and structural robustness to be immobilized while maintaining their SMM properties opening up a doorway to address SMM electrically and to implement them in device architectures. For example, Zyazin et al. showed the possibility for electrical control of the magnetic anisotropy in $Fe_4$ derivatives using electromigrated junctions. However, such nanojunctions are very difficult to prepare reproducibly. Thus, in this work, we investigated different techniques to produce simple optically lithographed device architectures to electrically address SMM from the micro- to the nanoscale. The devices are functionalized in a layer-by-layer process and an increase in current was observed as a function of the number of layers. A comparison with other non magnetic molecules was also carried out. A temperature dependent study was then performed from room temperature to 1.5K on these devices however, the amount of current was reduced significantly at low temperature, and hence no magnetic field study was performed. Currently experiments on nano-gapped devices are in progress in order increase the current and to study magnetoresistance response at low temperature.

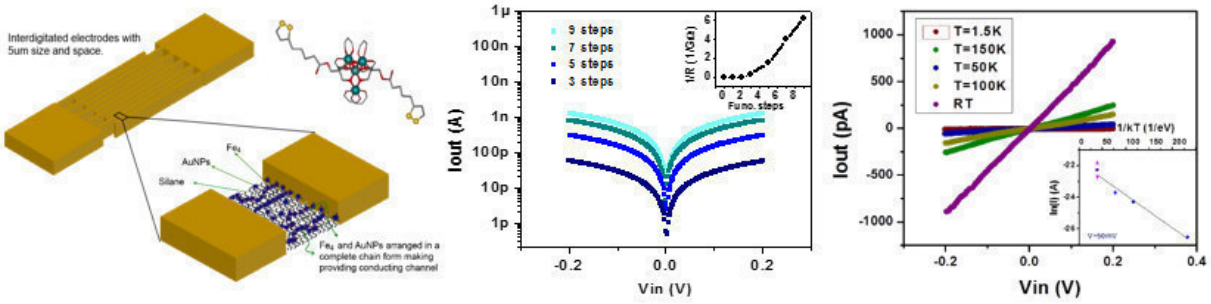


*Figure 1 (a) Device architecture demonstrating the formation of conducting channel by layer-by-layer deposition. (b) IV curve of these devices as a function of functionalization steps. Inset: Current increase strongly after some threshold value. (c) Temperature dependence of the IV curves measured at 1.5K, 50K, 100K, 150K and room temperature. Inset: the logarithm of the current at 50 mV is plotted as a function of the temperature in order to calculate barrier height for transport.*

# STUDY OF THE SIZE, SHAPE AND SOLVENT EFFECTS ON LONGITUDINAL AND TRANSVERSE RELAXOMETRY OF FERRITE-BASED MNP

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The spin dynamics of novel superparamagnetic systems based on colloidal Iron-Oxide magnetic nanoparticles (MNP), has been investigated by means of NMR relaxometry as a function of magnetic core diameter. Two differently shaped systems with similar size have been also studied.
The nanostructures contain a surfactant-capped magnetite ($Fe_3O_4$) inorganic core, with different controlled size ranging from 4 to 20 nm [1]. The as-synthesized nanostructures are passivated by hydrophobic surfactants (oleic acid) and fully dispersed both in hexane and in acqueous media by means of a microemulsion. These magnetic nanocrystals are potentially useful as contrast agents (CA) for magnetic resonance imaging (MRI) because of the high values of transverse relaxivity, which gives rise to a proper negative contrast in the MR images. For studying the fundamental physical mechanisms of nuclear relaxation, the complete NMR-D profile of $r_1$ (longitudinal) and $r_2$ (transversal) have been measured, until frequencies as low as 10 kHz, a not usual occurrence especially for $r_2$. The NMR-D curves have been qualitatively compared with those predicted by theoretical models [2] describing the dependence of relaxivity on the size of the magnetic spheres, and confirm the hints on the nature of the involved physical mechanism: at low frequencies (<1 MHz about) the nuclear relaxation enhancement is led by the Neel correlation time while at higher frequencies the Curie relaxation mechanism dominates. Moreover, the comparison between experimental curves and theoretical models allowed to conclude that, for both $r_1$ and $r_2$, our data can be explained in the framework of the model of superparamagnetic relaxation for small magnetic spheres.

**Acknowledgements**
The Italian projects INSTM-Regione lombardia "Mag-NANO" and FIRB "Riname" are acknowledged. Tomas Orlando is gratefully acknowledged for help in experimental measurements and data analysis.

**References**
[1] M.F.Casula, A.Lascialfari et al. *Chem. Mater.* ***2010****, 22, 1739-1748*
[2] A.Roch, R.N.Muller, P.Gills *J. of Chem. Phys.* ***1999****, VOL 110, No. 11 pag 5403-5411*

# A facile and fast one step bottom-up approach for developing iron oxides magnetic nanoparticles

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Although a large body of data is available on the synthesis of metal-oxides nanoparticles, the need of a clean, low-cost and easy scalable process that assures strict control over nanoparticles size, chemical composition and colloidal stability remains a synthetic challenge [1]. In this work, a novel, facile and unconventional bottom-up mechanochemical approach for the synthesis of iron-oxides nanoparticles is reported. For the purpose hydrated metal chlorides were induced to react with stoichiometric NaOH using NaCl as dispersing agent.
After 1h milling, proposed approach offers single crystalline domains iron oxides nanoparticles (mean XRD diameter about 8 nm) with good control over size and oxydril groups on the particles surface. The oxydril groups can be readily adapted to specific application by further functionalization. The successful achievement of desired materials was investigated by X-Ray diffraction, Mössbauer analysis, thermal analysis, infrared spectroscopy, surface area analysis and scanning electronic microscopy (figure 1 left side). Field dependence of magnetization measured at 300 K (figure 1 right side) shows zero remanence and coercivity, suggesting a superparamagnetic behavior of the nanoparticles.
Potential perspectives of obtained nanoparticles include a wide range of applications in biomedical and energy fields.

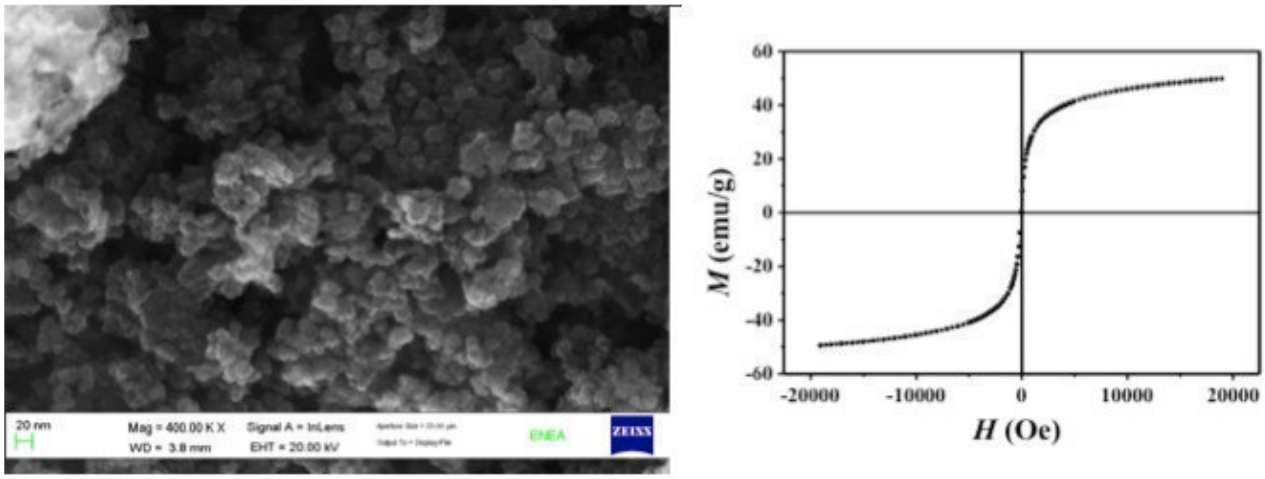


Figure 1. SEM micrograph (Left) and magnetization curve at 300K (Right) for 1h milled sample

[1] J. Park et al. Angew. Chem. Int. Ed. 46 (2007) 4630

# One-step synthesis of magnetic zeolites from waste materials

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Magnetic zeolites can be successfully used for removing contaminants from polluted water, as they can be easily separated by the solution using an external magnetic field. In such a way, the wastewater treatment becomes simpler than conventional processes, which imply time and energy consuming centrifugation or filtration steps [1,2].
In this study, a low temperature environmentally friendly synthesis of magnetic zeolites by hydrothermal activation is presented [3]. The major novelty of the process is the use of a mixture of waste materials namely, fly ash (FA) and red mud (RM), as precursors to synthesize zeolites with good magnetic properties in a *one step process*, i.e. without passing through the additional synthesis of magnetic nanoparticles, which is commonly used for the preparation of the magnetic zeolites. The structural properties were investigated by SEM, XRD and TEM and showed that different types of zeolites (A, X and ZK-5) were obtained for different FA/RM percentages and incubation temperature. All of them possess sufficiently high magnetic moment to allow their easy separation by the solution using an external magnet (Fig. 1). The magnetic investigation was carried out by SQUID and VSM magnetometry. The global magnetic properties of the newly formed minerals were discussed on the basis of magnetic properties of precursors, where different magnetic behavior was observed (Fig.1). Good adsorbance properties of the final synthetic products were confirmed.

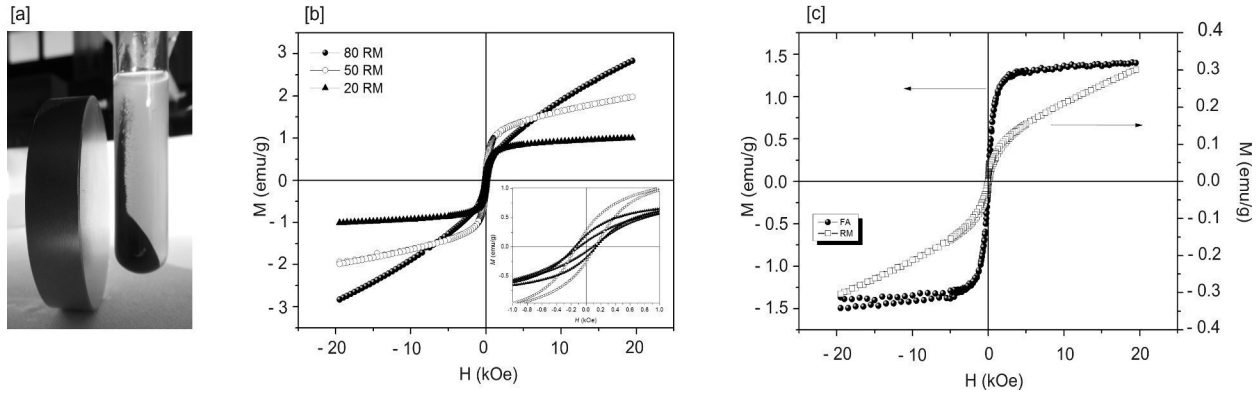


Figure 1. [a] magnetic separation for sample 20%RM; [b] Room temperature hysteresis cycles of the mixtures containing 20, 50 and 80 %RM, respectively;[c] Room temperature hysteresis for RM and FA samples (modified from Belviso et al. [3])

[1] K. Barquist, S.C. Larsen, Micropor. Mesopor. Mat. 130 (2010) 197-202.
[2] J. H. Faghihian, M. Moayed, A. Firooz, M. Iravani, J. Colloid Interf. Sci. 393 (2013) 445-451.
[3] C. Belviso, E. Agostinelli, S. Belviso, F. Cavalcante, S. Pascucci, D. Peddis, G. Varvaro, S. Fiore, Micropor. Mesopor. Mat. 202 (2015) 208-216.

# A Low-temperature Solvent-free Chemical Strategy for the Direct Synthesis of L10 FePt Nanoparticles from Layered Precursor

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The binary FePt alloy in the high magnetic anisotropy $L1_0$ phase is one of the most promising magnetic materials for applications in the field of magnetic recording for media capable to sustain areal density larger than 1 Tbit/in2. This is due to the large magnetic anisotropy energy of $7\times10^7$ erg/cc [1], which allows stable ferromagnetic particles with size as small as 2.8 nm, its resistance to oxidation and its stability at room temperature.
In this work, a new green chemical approach to synthesize magnetically hard $L1_0$ FePt nanoparticles is described by using a crystalline saline complex hexaaquairon(II)hexachloroplatinate, [Fe(H2O)6]PtCl6 as the precursor. [2] The crystal structure of this complex is chemically ordered [3], and it shows alternate layers of Fe and Pt atoms, resembling the chemical order of the $L1_0$ phase.
The precursor was mixed with NaCl in different proportion (50mg/20g, 25mg/20g, 10mg/20g) and milled in a planetary milling for 5 h at 250 rpm. After milling, the powder was heated (heating rate = 5 K/min) up to 400 °C in a horizontal furnace under a reducing atmosphere of 0.1 L/min flow of 5% H2 and 95% Ar. Then, after annealing at the final temperature for 2 h, the formation of FePt nanoparticles in the highly ordered $L1_0$ phase was obtained as confirmed by XRD and HRTEM investigations. This method is a green synthesis due to the low temperature used to induce the phase transformation, and the absence of organic solvents or surfactants in the reaction. Indeed only non-hazardous materials were used in the synthesis, the milling step being performed using NaCl as media and water as solvent. By varying the precursor/NaCl ratio, particles with size in the range of 6.2 – 13.2 nm were obtained. With the decrease of particle size, the room temperature coercivity of FePt nanoparticles also decreased from 10.9 kOe to 4.7 kOe.

[1] K. Inomata, T. Sawa and S. Hashimoto, J Appl Phys, 1988, 64, 2537-2540; J. P. Wang, P Ieee, 2008, 96, 1847-1863.
[2] X. C. Hu, E. Agostinelli, C. Ni, G. C. Hadjipanayis, and A. Capobianchi. Green Chemistry in press
[3] A. Capobianchi, G. Campi, M. Camalli and C. Veroli, Z Kristallogr, 2009, 224, 384-388.

# Spin wave eigenmodes in single and coupled sub-150 nm rectangular permalloy dots

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We present the results of a Brillouin light scattering investigation of thermally excited spin wave eigenmodes in square arrays of either isolated rectangular dots of permalloy or twins of dipolarly coupled elements, placed side-by-side or head-to-tail. The nanodots, fabricated by e-beam lithography and lift-off, are 20 nm thick and have the major size D in the range between 90 nm and 150 nm. The experimental spectra show the presence of two main peaks, corresponding to modes localized either at the edges or in the center of the dots. Their frequency dependence on the dot size and on the interaction with adjacent elements has been measured and successfully interpreted on the basis of dynamical micromagnetic simulations. The latter enabled us also to describe the spatial profile of the eigenmodes, putting in evidence the effects induced by the dipolar interaction between coupled dots. In particular, in twinned dots the demagnetizing field is appreciably modified in proximity of the "internal edges" if compared to the "external" ones, leading to a splitting of the edge mode. These results can be relevant for the exploitation of sub-150 nm magnetic dots in new applications, such as magnonic metamaterials, bit-patterned storage media and nano-magnetic logic devices.

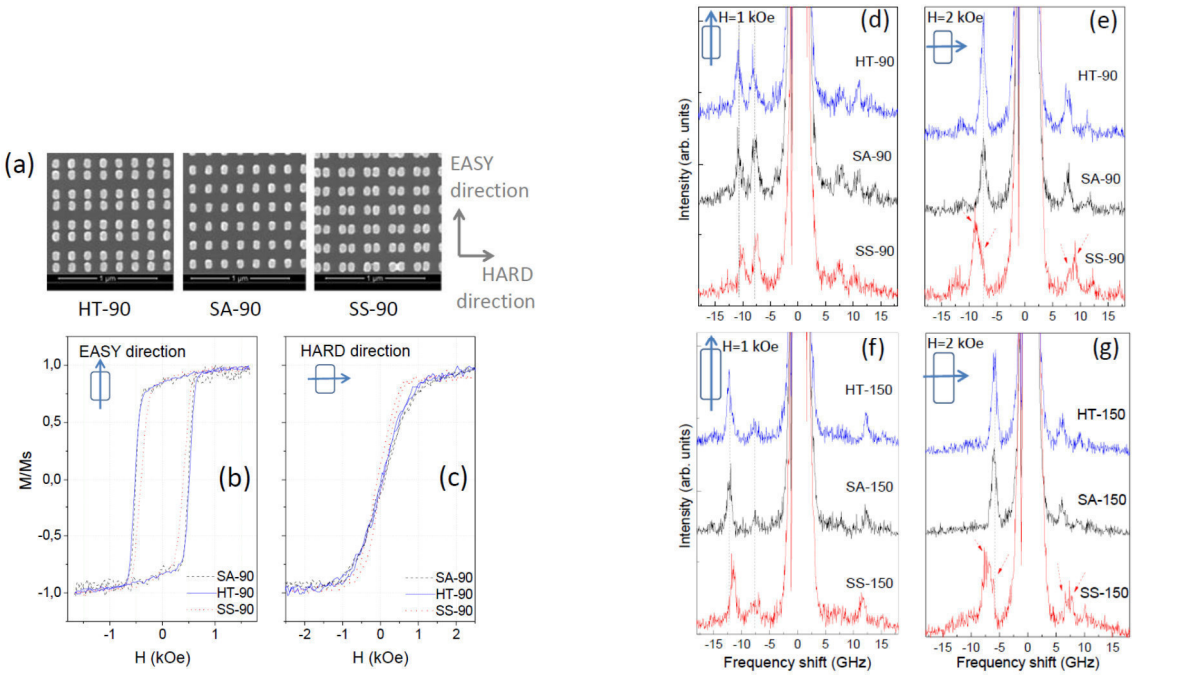


**Figure 1**: LEFT PANEL: a) Scanning electron microscopy of a portion of the three arrays relative to the dots with D=90, placed head-to-tail (HT-90), stand-alone (SA-90) and side-by-side (SS-90). The hysteresis cycles measured along either the easy or the hard direction are shown in b) and c), respectively. RIGHT PANEL: Measured BLS spectra for an external magnetic field H applied either along the easy, (d)-(f), or the hard direction, (e)-(g), for the samples with D=90 nm, (d)-(e), or D=150 nm, (f)-(g).

# An alternative route to synthesize large area magnetic nanostructure by block copolymers

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Synthesis of nanopatterned magnetic materials offers advanced capabilities in tailoring material structures and opens up new opportunities for engineering innovative devices (i.e. electronic and biomedical). In the frame of magnetic materials, the most demanding application consists in fabricating high-density arrays for use in data storage and magnetic sensors for spintronics [1]. In the last decade, many routes for the reliable fabrication of magnetic nanostructures have been extensively investigated, including top-down lithography and bottom-up self-assembly processes. Conventional electron beam lithography (EBL) soon turned out to be limited by low--speed and high costs while self--assembling emerged as a viable and handy alternative technique for designing nanostructures over a wide area on magnetic thin films. The capability of soft materials such as block copolymers (BC) to form a rich variety of low-dimensional, uniform periodic patterns offers unique opportunities to develop large area nanometer scale features. The domain spacing typically depends on molecular weight, segment size, and the strength of interaction between the blocks.
In this work, block-copolymer (BCP) – based lithography has been exploited to fabricate uniform, densely spaced nanometer – scaled on $Ni_{80}Fe_{20}$ and Co sputtered thin film with thickness ranging in the interval 10 - 30 nm.
A Random Copolymer (RCP) brush layer was grafted on the Si substrate in order to obtain the surface neutralization. A PS-b-PMMA Block Copolymer (BCP) film was subsequently deposited on the RCP, obtaining cylindrical features perpendicularly oriented with respect to the substrate. In this way, a patterned nanostructure having cylindrical features has been realized. The self-organization is promoted by means of a thermal annealing higher than the glass transition temperature of the BCP [2]. The magn etic layer is then deposited by RF sputtering. A careful evaluation of the propagation effect of the nanometric pattern to the magnetic thin film has been performed with the aim to optimise nanostructures and preserve the magnetic properties of the continuous film. A systematic morphological study has been made by Scanning Electron (SEM) microscopy. Room-temperature magnetic behavior has been studied by magnetisation measurements by means of ultra-sensitive magnetometry measurements following the hysteresis loop changes during all the step process. Hysteresis loops of patterned films have been measured as a function of temperature in the interval 5 – 300 K.

[1] C. A. Ross, Annu. Rev. Mater. Res. 31, 203 (2001).
[2] F.Ferrarese Lupi at al, *Nanotechnology,*2013, 24, 315601

# Magnetization reversal in finite size dot arrays: Global Configurational Anisotropy

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We analyzed with MFM and MOKE finite squared (rectangular) arrays of circular (elliptical) magnetic dots and performed simulations with MuMax, a GPU-based software [1]. We showed as for limited size of the periodic arrays the transition of the magnetization during the reversal starts at the edges and corners of the array and propagates inside the pattern, so that in a restricted field range the magnetization results to be not uniformly distributed.
While the shape of the dots (circular, elliptical, etc.) introduces a *Configurational Anisotropy* [2], we find that the finite array dimensions introduce an additional *Global Configurational Anisotropy* [3]. Both effects originate at the demagnetizing interactions playing at different space scales: the dot and total array space scale, respectively.
Simulations of dot arrays are often restricted to one dot assuming isolated non-interacting magnetization processes. Periodic boundary conditions are often used to incorporate interdot interactions, still limiting computations to a restricted number of dots and assuming infinite lattice periodicity. Then, configurational anisotropy is accounted for, but global configurational anisotropy is not. We show that mutual dot interactions together with finite array dimensions have a non-negligible impact on the magnetization reversal of a dot array. We numerically and experimentally study the hysteresis properties of Permalloy (Py) arrays of 16x16 circular and elliptical dots, with thickness ranging between 10 and 25 nm and lateral size between 300 and 500 nm. In magneto-optical Kerr effect (MOKE) measurements, in-field magnetic force microscope (MFM) measurements and simulations, we find that global shape anisotropy steers the magnetization reversal of the array: the dots run through different magnetization states depending on the dot location and collective magnetization processes occur, leading to transition avalanches and formation of magnetization chains. Moreover, we find that imperfections as edge roughness and external perturbations, as the MFM measurement itself, anticipate the dots reversal path set by the global configurational anisotropy and promote field induced magnetization state changes. These findings are important in the development of applications that rely on a robust control of dot magnetization states in dot arrays.

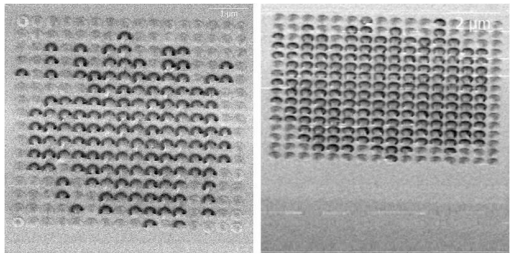

Fig 1: MFM images of Py circular and elliptical dot arrays performed in a 60 Oe external field.

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[1] A. Vansteenkiste and B. Van de Wiele, J. Magn. Magn. Mater. 323, 2585 (2011)
[2] P. Vavassori, D. Bisero, F. Carace, A. di Bona, G.C. Gazzadi, M. Liberati and S. Valeri, Phys. Rev. B 72, 054405 (2005)
[3] B. Van de Wiele, S. Fin, A. Sarella, P. Vavassori and D. Bisero, Appl. Phys. Lett. 105, 162407 (2014)

# Spin Dynamics in Hybrid Iron Oxide-Gold Nanostructures

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We report a broadband $^1$H-NMR study of the spin dynamics of coated maghemite and gold-maghemite hybrid nanostructures with two different geometries, namely dimmers and coreshells. All the samples have a superparamagnetic behaviour, displaying a blocking temperature $T_B \sim 80$ K (maghemite), ~ 105 K (dimer), ~ 150 K (core-shell) and the magnetization reversal time follows the Vogel-Fulcher law. We observed three different anomalies in $^1$H-NMR $T^{-1}_1$ vs. T that decrease in amplitude when increasing the applied magnetic field. We suggest that the anomalies are related to three distinct system dynamics: molecular rotations of the organic groups ($240 < T < 270$ K), superparamagnetic spin blockage ($100 < T < 150$ K) and surface-core spins dynamics ($T < 25$ K). By fitting the $T^{-1}_1$ data with a heuristic model, we achieved a good agreement with magnetic relaxation data and literature values for methyl groups rotation frequencies.

# Beyond the Effect of Particle Size: Influence of $CoFe_2O_4$ Nanoparticle Arrangements on Magnetic Properties

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This paper focus on assemblies of $CoFe_2O_4$ nanoparticles, analyzing the influence of the synthesis method on nanoparticles arrangement and magnetic properties. Using synthesis procedures based on direct micelle (DM) and high thermal decomposition (HTD) of metalorganic precursors, three samples of $CoFe_2O_4$ nanoparticles with the same average particles size of about 5 nm have been prepared. The HTD method allows obtaining high crystalline nanoparticles coated by oleic acid and self-assembled in hexagonal close packing (H-$CoFe_{HTD}$) [1]. On the other hand, the DM method results appropriate to prepare either individual irregular arrangements of $CoFe_2O_4$ nanoparticles (I-$CoFe_{DM}$) or secondary spherical iso-oriented nanoporous assemblies with a high surface area (S-$CoFe_{DM}$) [1].

Despite the same particle size, magnetization measurements of the HTD samples show tendency towards cubic anisotropy (MR/MS ~ 0.7), while in DM samples a uniaxial anisotropy (MR/MS ~ 0.4) is observed. The comparison between I-$CoFe_{DM}$ and S-$CoFe_{DM}$ samples indicates that the ordering of nanocrystals at the mesoscopic scale induces an increase of the coercive field ( $\mu_0 Hc$ = ~1.17 T → ~ 1.45 T) and of the reduced remanent magnetization (MR/MS: ~ 0.4→ ~ 0.5). The reason for these differences is discussed. In particular, a detailed study on interparticle interactions is carried out, highlighting the influence of the molecular coating and of the formation of spherical iso-oriented assemblies [2].

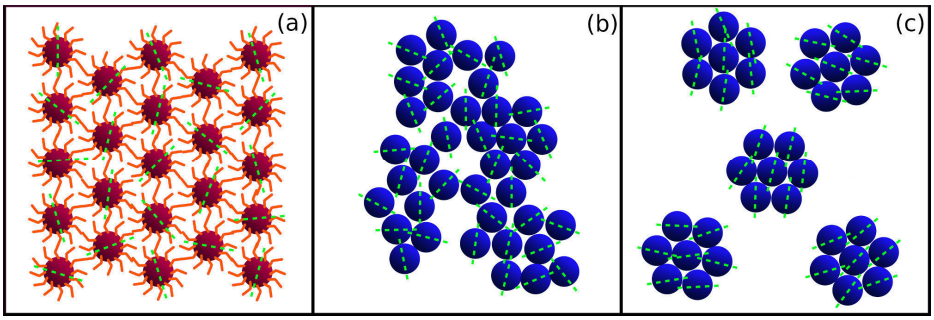


Figure 1: A schematic representation of the samples: (a) H-CoFeHTD, (b) I-CoFeDM and (c) S-CoFeDM.

[1] D. Peddis et al., Chem. Mater. 26 (2012) 1062-1071
[2] D. Peddis et al. Chem. Mater. 25 (2013) 2–10

# Structure and Magnetic Properties of Fe nanoparticles embedded in a Cr matrix

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The structure of ~2 nm diameter (~340 atoms) Fe nanoparticles (NPs) embedded in a Cr matrix was determined using X-ray Absorption Fine Structure (EXAFS) and the magnetic properties studied by Superconducting Quantum Interference Device (SQUID) magnetometry. The thin films were produced by the co-deposition of pre-formed gas-phase Fe clusters synthesised by a gas aggregation source with an atomic vapour of Cr produced by an MBE source. The behaviour was studied as a function of Fe NPs volume fraction in the range 5 – 20% and was compared to previous results on ferromagnetic NPs in antiferromagnetic matrices. EXAFS showed that the atomic structure in the Cr-embedded Fe NPs is the same as the bulk bcc structure. Whereas alloying between the NPs and matrix material has previously been shown to be very pronounced for Co NPs in antiferromagnetic Mn [1], in this case it was found that alloying between Fe NPs and Cr matrix material is limited. For dilute samples of Fe NPs in Cr the measured saturation magnetisation ($M_S$) was $1\mu_B$/Fe atom, which is significantly less than the bulk $M_S$ value of 2.22 $\mu_B$/Fe atom indicating that the surface of Fe NPs should be antiferromagnetic due to the interaction with Cr matrix [2]. An increase in the volume fraction produces an increase in the value of $M_S$ and at a volume fraction of 20%, $M_S$ exceeds the bulk value of Fe showing that some Cr spins provide a ferromagnetic contribution. After field cooling below 30K, all films show Exchange Bias (EB) and an increase of coercivity, which are both much larger for the most concentrated sample. The Cr spins at the surface of the Fe particles play a key role in determining the overall magnetic behaviour [3].

[1] C. Binns et al, . J. Phys. Condens. Matter 22 (2010) 436005
[2] C. Binns et al, Nanoletters 13 (2013) 3334
[3] M T Qureshi et al. J. Magn.Magn.Mater., in press

# Magnetic Properties of Small Magnetite Nanocrystals

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Among nanostructured magnetic materials, nanoparticles are unique complex physical objects. In fact, at the nanoscale magnetic single-domain particles are formed, leading to new supermagnetic behaviors, depending on nature and strength of interparticle interactions [1]. In addition, the physics of nanoparticles is influenced by the modification of the structural and electronic properties at the particle surface [2].

Nanoparticles of spinel ferrites are of great interest, not only for their technological applications but also from the point of view of fundamental science. In particular, magnetite ($Fe_3O_4$) has been one of the most widely studied and utilized magnetic materials in the life of humankind. It is characterized by high Curie temperature ($T_C$ = 850 K in bulk magnetite) and nearly full spin polarization at room temperature, which make it a potential material for spintronics. [3].

This paper focuses on the study of the magnetic properties of 9 nm magnetite nanocrystals. XRD and TEM measurements indicate the presence of crystalline particles, with a fraction of them only partially crystallized or highly defective. The analysis of the temperature dependence of the zero-field-cooled/field-cooled magnetization and of the thermoremanent magnetization provides evidence of the existence of three magnetic regimes [4]: 1) a high temperature superparamagnetic (SPM) regime (300−100 K), centered at a broad maximum due to the blocking process of particles moments; 2) an intermediate regime (100−30 K), centered at a maximum at the Verwey transition; 3) a low temperature regime (below 30 K) centered at a peak identifying a collective super-spin-glass type transition of particles moments.

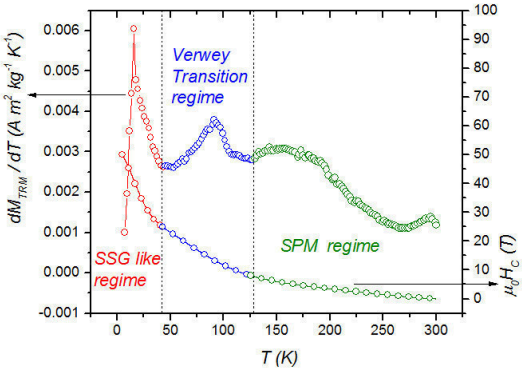


Figure 1: Three magnetic regimes evidenced in $Fe_3O_4$ nanoparticles by TRM curve derivative and coercive field temperature dependence

[1] S. Bedanta and W. Kleemann J. Phys. D: Appl. Phys. 42 (2009) 1–28

[2] *Surface Effects in Magnetic Nanoparticles*; Fiorani, D., Ed.; Wiley: New York, 2005

[3] Bohra et al. J. Magn. Magn. Mater. 321 (2009) 3738– 374

[4] G. Muscas et al. J. Phys. Chem. C 117 (2013) 23378–23384

# Magnetic properties in magnetite nano-crystals by ac magnetic measurements

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Two samples of iron oxides have been synthetized by high thermal decomposition process (HTD). TEM images show that both samples have similar particles size distribution, with an average grain size <D> ≅ 13.5 nm. XRD analysis shows the same spinel iron oxides structure for both samples, but with a different crystallization degree. The coherent crystalline domain is ≅ 13 nm and ≅ 9 nm for sample MAG4 and MAG5, respectively. By means of ac magnetic susceptibility, the magnetic properties of the two nanocrystalline samples have been investigated as a function of temperature at different frequencies: two magnetic regimes can be detected (Fig. 1) at high and low temperature in both samples.

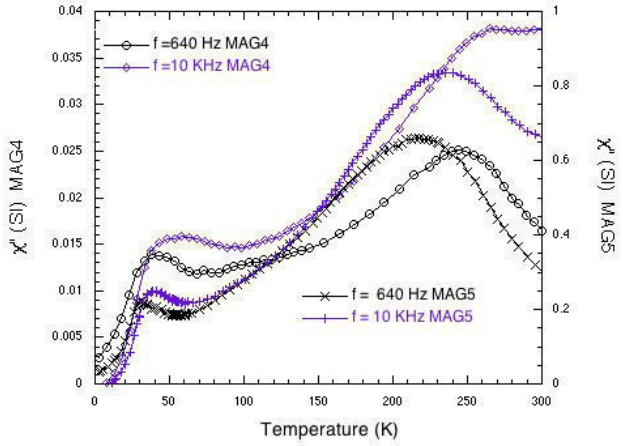


Figure 1: The imaginary (χ") part of the ac magnetic susceptibility for the samples MAG4 and MAG5. Selected frequencies are shown.

At high temperature, relaxation phenomena and a frequency dependent transition, associated to blocking process of particle moments, is detected for both samples, as clearly shown by the frequency sensitivity of the broad χ" maxima.

At low temperature a sharper χ" peak, at frequency dependent temperature, is observed in both samples. This magnetic behaviour reveals a spin-glass like random spin freezing at the particle surface, associated to the particle surface disorder.

# Analysis of perpendicular magnetic anisotropy in [Pt/Co] multilayers

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The realization of more efficient magnetic random access memories requires the development of MTJs with perpendicular magnetic anisotropy (PMA), since they show several advantages over in-plane MTJs [1,2], e.g. higher area density, low critical current density for current-induced magnetization switching and high post-annealing stability. [Pt/Co] multilayers with very thin platinum layers, ranging from 0.2 to 0.24 nm, have recently shown to possess maximized PMA when annealed at a temperature between 400 and 450 °C. This is connected to the minimization of the intermixing at the Co/Pt interface during sputtering [3]. A very thin Pt layer is also expected to allow for a low damping constant, which is a desirable feature for this kind of applications.
In this work, we measure, analyze and correlate the ferromagnetic resonance (FMR) and damping microwave properties to the static magnetic properties of several samples, consisting of $[Pt/Co]_6$ multilayers characterized by very thin platinum and cobalt layers (thicknesses ranging from 0.2 nm to 0.32 nm), according to the results obtained in [3]. A lower damping constant $\alpha$ means lower energy losses and higher quality, thus producing circuits based on such systems leads, in turn, to faster memories. Here a significant progress has been made in terms of reduction of $\alpha$ using a reduced Pt content, based on the understanding of the FMR behavior of multilayer stacks and of the various physical contributions on which $\alpha$ depends.
A vibrating sample magnetometer has been used to determine the samples hysteresis loops. Measurements have been performed with the external field H applied at several angles with respect to the film normal, in order to correctly identify the anisotropy easy axis and the anisotropy field $H_k$. The hysteresis loops in both in-plane (ip) and out-of-plane (oop) directions have been determined, the former being very linear and the latter showing a square shape with a remanence ratio of nearly 100% indicating a very well-developed PMA.
FMR experiments, conducted in the field-sweep mode, produce absorption peaks from which the FMR frequency and the full width at half maximum $\Delta H$, which determines $\alpha$, are obtained.
The agreement between the anisotropy field obtained from Kittel fitting results and the experimental magnetization data is very good in those samples where the Pt spacer is thinner than the Co layer, and the anisotropy field obtained are rather high with respect to other works [4].
The damping parameter $\alpha$ is also obtained from the absorption peak widths $\Delta H$, by means of the linear fit [5] $\Delta H(f) = \Delta H(0) + 1.16\,(2\pi f/\gamma)\,\alpha$. Here $\alpha$ ranges from 0.14 to 0.05 for Co and Pt layers from 0.2 nm to 0.32 nm respectively, which is in agreement with available literature [6] where similar values were found for Pt/Co multilayer structures with layers thicknesses of several nanometers. Therefore, we obtain similar $\alpha$ values, but with a noticeable reduction of expensive sputtering materials [7].

[1] S. Ikeda, et al.,IEEE Trans. Electron Devices 54, 991 (2007).
[2] S. Mangin, et al., Nature Mater. 5, 210 (2006).
[3] Tae Young Lee et al., J. Appl. Phys. 113, 216102 (2013).
[4] P. J. Metaxas et al., Phys. Rev. Lett. 99, 217208 (2007).
[5] B. K. Kuanr et al., J. Magn. Magn. Mat. 286, 276-281 (2005).
[6] S. Mizukami, et al, Appl. Phys. Lett. 96, 152502 (2010).
[7] A. Caprile, et al, Mag. Lett. 5, 3000304 (2014).

# The First SPIN and ANGLE-resolved Photoemission Setup at Elettra at APE Low Energy End-station within NFFA Demonstrator

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APE is a facility for spectroscopic investigation of solid surfaces and nanostructured matter for which the sample preparation and survey represent crucial and integral part of the experiment [1]. The APE concept is based on a state-of-the-art surface science laboratory as a support facility for advanced spectroscopies at two distinct beamlines using polarized synchrotron radiation in the ultraviolet and soft X-ray range from the Elettra storage ring (http://www.elettra.trieste.it/elettra-beamlines/ape.html). From 2013 APE became an integral part of the NFFA project demonstrator (www.nffa.eu) that allowed for an important upgrade of the ARPES end-station: new photoelectron analyzer (VG-Scienta DA30) with high angular acceptance of 30° has recently replaced the SES2002 (angular acceptance <14°) that was operational at APE since 1999. In addition, the new analyzer has two channels at the detector plane where photoelectrons are extracted and transported to two VLEED (very low energy electron diffraction) detectors for three-dimensional spin analysis that are currently under construction at APE. The whole system will further be fitted in a new mu-metal sample chamber, where improved magnetic shielding will allow measurements at low photon energies, thus providing more bulk-sensitive information with respect to standard ARPES at energies >15 eV. With this upgrade the users will gain access to a state of the art Spin-Resolved ARPES spectrometer with variable polarization quasi-periodic undulator radiation, connected directly with the NFFA-Demonstrator suite of in situ growth and characterization facilities including PLD and MBE growth of metal oxides, as well as to the APE-High Energy spectrometer for XAS/XMCD/XMLD/XPS. The new analyzer is available for users from November 2014. The full Spin Polarization option is scheduled to be on-line within March 2015.

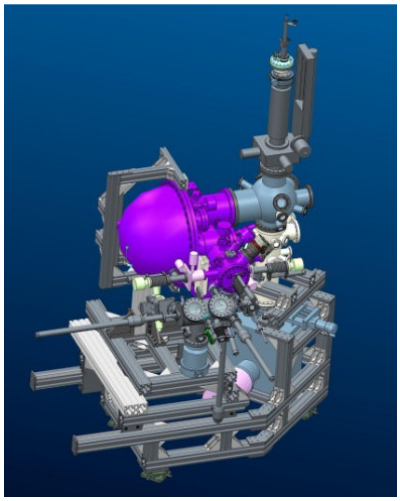

Figure 1: The scheme of the new experimental setup for SPIN and ANGLE-resolved photoemission at APE.

[1] G. Panaccione et al., Rev. Sci. Instrum. 80, 043105 (2009)

# XAS/XMCD investigation of the Au/LSMO interface

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The hole-doped perovskite $La_{0.7}Sr_{0.3}MnO_3$ (LSMO), which exhibits ferromagnetism up to room temperature and a large spin polarization at the Fermi level, is one of the most relevant materials in the context of organic spintronics [1,2]. To correctly design devices employing mixed-valence manganites, it is fundamental also to know how they react to perturbations arising from the formation of electrical contacts. The interface with gold is very interesting for both technological and fundamental reasons. Being Au a noble metal, it is expected to provide a limited chemical perturbation at the boundary with LSMO, however it has been demonstrated that the formation of Au particles on the LSMO surface causes a sizeable reduction in the Mn oxidation state. Conversely, a negligible chemical interaction with gold was obtained in calculations for a 2D ideal interface [3,4]. Here we present an experimental study performed for Au thin films deposited in-situ on a thick LSMO ferromagnetic layer, through resonant soft x-ray X-ray Absorption and Magnetic Circular Dichroism Spectroscopy (XAS/XMCD) at the Mn $L_{2,3}$ absorption thresholds. The early stages of the gold film deposition were characterized also by soft x-ray Photoemission Spectroscopy. The progressive increment of the Au thickness improves the sensitivity of the XMCD curves to the boundary region, showing that no strong reduction of the Mn atomic moments occurs, in agreement with the theoretical results.

[1] M. Prezioso, A. Riminucci, P. Graziosi, I. Bergenti, R. Rakshit, R. Cecchini, A. Vianelli, F. Borgatti, N. Haag, M. Willis, A.J. Drew, W.P. Gillin, and V.A. Dediu, Adv. Mater. **25**, 534 (2013).
[2] V. Dediu, L.E. Hueso, I. Bergenti, A. Riminucci, F. Borgatti, P. Graziosi, C. Newby, F. Casoli, M.P. De Jong, C. Taliani, and Y. Zhan, Phys. Rev. B **78**, (2008).
[3] S. Brivio, C. Magen, a. a. Sidorenko, D. Petti, M. Cantoni, M. Finazzi, F. Ciccacci, R. De Renzi, M. Varela, S. Picozzi, and R. Bertacco, Phys. Rev. B **81**, 094410 (2010).
[4] D. Petti, a. Stroppa, S. Picozzi, S. Brivio, M. Cantoni, and R. Bertacco, J. Magn. Magn. Mater. **324**, 2659 (2012).

# Surface Nanostructures in Manganite Films studied by Scanning Tunneling Microscopy

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Complex magnetic oxides display intriguing bulk and surface properties that make these materials very promising candidates for spintronics and other magnetic applications[1]. However, controlling material stoichiometry and homogeneity is extremely difficult, especially at the nanoscale. Scanning tunneling microscopy and spectroscopy are powerful tools for characterising the nanoscale properties of surface electronic states, acquiring local information without significant lateral averaging; however, the information obtained to date is sparse and does not provide a general or quantitative understanding of manganite surface features. To try to overcome these deficits, we investigated ultrathin films of the prototypical manganite $La_{0.7}Sr_{0.3}MnO_3$ (LSMO)[2], unambiguously imaging the atomic structures. Our results provide new insights into the surface properties of manganites as well as suggesting a new mechanism for the film growth of such complex materials[3]. We detected a minority phase dispersed on a stoichiometric crystalline matrix; this phase consisted of small (less than tens of $nm^2$) non-stoichiometric islands that represent a kinetic intermediate of single-layer growth. We propose a phenomenological mechanism for the formation of such defects suggesting that they are characteristic features of all manganite films, although the detection of these defects is mainly obstructed at greater thicknesses.

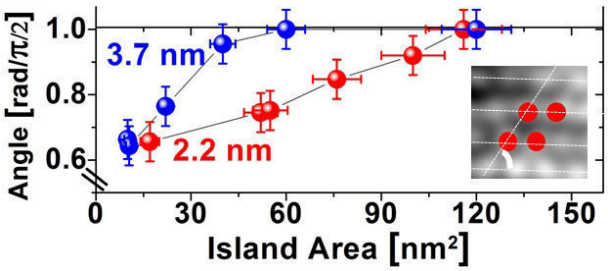


Figure 1: Evolution of the distortion angle vs island area as measured by STM (inset figure).

[1] M. Bibes and A. Barthélémy, Oxide spintronics. *IEEE T. Electron. Dev.* **54**, 1003-1023 (2007).
[2] P. Graziosi et al. *Thin Solid Films* **534**, 83-89 (2013).
[3] A. Gambardella et al *Scientific Reports* (Accepted 2014)

# Magnetic Bistability in a submonolayer of sublimated Fe4 Single-Molecule Magnets

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The possibility to bring, in the most conservative approach, Single Molecule Magnets (SMMs) on a surface represents the fundamental step to exploit their attractive quantum properties in nanodevices such as spin valve, data storing, etc.[1]. However, due to the intrinsic fragility of polynuclear clusters, the picking out of a good candidate for surface deposition has taken a long and troubled route[2]. In 2009, finally, our group found out that SMMs of the tetrairon(III) family, $Fe_4$, are able to preserve their magnetic memory effect when chemically grafted on a gold substrate[3]. Starting from these promising results, further synthetic efforts have been made to design $Fe_4$ clusters which can be sublimated in UHV conditions preserving unaltered their magnetic properties[4].

Taking advantage of the UHV processability of a specific $Fe_4$, the $Fe_4Ph$[4[a]], we demonstrate that a magnetic hysteresis comparable to that found in bulk samples is observed when a submonolayer film is thermally deposited on gold surfaces. Scanning tunneling microscopy (STM) evidences the coexistence of $Fe_4$ molecules assembled in a 2D lattice with short-range hexagonal order and traces of a smaller contaminant. The presence of intact $Fe_4$ molecules and the retention of their bistable magnetic behavior on the gold surface evidenced by our low temperature synchrotron characterization (XMCD) are supported by density functional theory calculations (DFT).

[1]L. Bogani, W. Wernsdorfer, Nat. Mater. 7 179 (2008)

[2]M. Mannini, P. Sainctavit, R. Sessoli, C. C. dit Moulin, F. Pineider, M.-A. Arrio, A. Cornia and D. Gatteschi, Chem. Eur. J. 14 (2008) 753;

[3]M. Mannini, F. Pineider, P. Sainctavit, C. Danieli, E. Otero, C. Sciancalepore, A. M. Talarico, M.-A. Arrio, A. Cornia, D. Gatteschi, and R. Sessoli, Nat. Mater. 8 (2009) 194

[4]a) L. Margheriti, M. Mannini, L. Sorace, L. Gorini, D. Gatteschi, A. Caneschi, D. Chiappe, R. Moroni, F. B. de Mongeot, A. Cornia, F. M. Piras, A. Magnani, and R. Sessoli, Small 5 (2009) 1460; b) L. Rigamonti, M. Piccioli, L. Malavolti, L. Poggini, M. Mannini, F. Totti, B. Cortigiani, A. Magnani, R. Sessoli and A. Cornia, Inor. Chem. 52 (2013) 5897

# Co/Pt multilayers for perpendicular exchange coupled dots: experimental characterization and *ab initio* calculations of magnetic anisotropy features

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Nowadays, the great development in spintronics offers opportunities for a new generation of devices based on the spin-dependent properties of the electrons [1]. In particular, perpendicular magnetic tunnel junctions (p-MTJ) are receiving a great interest in their application in magnetic random access memories (MRAMs) due to a number of advantages with respect to the in-plane junctions, making the p-MTJ systems the best candidate for achieving high-density storage [2]. Indeed, the high perpendicular anisotropy of the magnetic electrodes ensure a better thermal stability, which is strongly required when MTJs are reduced to sub-micrometer scale.
In this framework, our study is aimed at the production of arrays of exchange coupled soft-FM/hard-FM sub-50 nm dots, to be employed as electrodes in spin-valves of MRAM architecture. In particular, both reference and free layer are made of CoFe/$[Co_n/Pt_m]_x$ dots, in which the magnetic behaviour is ruled by interface exchange coupling. The use of $[Co_n/Pt_m]_x$ multilayers (ML) as hard magnetic layers whose perpendicular anisotropy can be varied by relative compositions (n, m) and repetition number (x), is aimed at suitably tuning the coercivity of the two electrodes. To this pourpose, *ab initio* electronic structure investigations have been performed, directed at providing guidelines for the ML design: magnetic anisotropy energy (MAE) of $[Co_n/Pt_m]_x$ ML are obtained from non-collinear spin-polarized total energy calculations within Density Functional Theory. Calculations are based on plane-wave and projector augmented-wave methods, as implemented in the VASP code [3], and using PBE generalized gradient approximation [4]. We have investigated different ML compositions, varying Co and Pt thickness as well as number of repetition, and considering two possible orientations of the ML z-axis, namely, the (100) and (111) out-of-plane geometry. The presence of a Pt substrate for the ML growth is explicitly included in the calculations. Except for the substrate atoms, kept fixed at their bulk interlayer distances, structural relaxations have been taken into account for all simulated ML compositions. Calculated MAE values suggest that the stability of out-of-plane magnetization is critically dependent on the number of Co layers and on ML orientation: a larger Co thickness threshold (nth≈ 6 nm) is in fact found for the (111) orientation with respect to the (100)-oriented ML (nth≈ 3 nm). Pt induced spin-polarization is found to be basically confined in the interface layer, decaying at the Pt surface.
Theoretical results are compared to experimental characterization of $[Co_n/Pt_m]_x$ ML grown by magnetron sputtering: structural order and growth orientations are investigated by XRD and TEM, while the magnetic response is obtained by VSM measurement. Experimental behaviour of the magnetic anisotropy features are interpreted through *ab initio* results, in terms of a possible decomposition of the total magnetic anisotropy into bulk-like and surface/interface contributions. The competition between the anisotropy of internal Co layers (favoring ML crystalline directions resembling the hcp-(0001) easy axis) and in-plane interface anisotropy, confined to few atomic layers, determines the overall magnetic anisotropy. The results allow us to set-up a predictive model to optimize the $[Co_n/Pt_m]_x$ compositions that stabilize the out-of-plane magnetization of the multilayers.

This work is supported by MIUR under project FIRB2010-NANOREST.

[1] S. A. Wolf et al. Science 294 (2001) 1488
[2] H. X. Wei et al. Appl. Phys. Lett. 94 (2009) 172902
[3] G. Kresse and J. Hafner, Phys. Rev. B 47 (1993) 558; G. Kresse and J. Furthmuller, Comput. Mater. Sci. 6 (1996) 15; *ibid.*, Phys. Rev. B 54 (1996) 11169; P. E. Blochl, Phys. Rev. B 50 (1994) 17953
[4] J. P. Perdew et al. Phys. Rev. Lett. 77 (1996) 3865

# Magnetothermal behavior of the antiferromagnet in exchange-coupled NiFe/IrMn bilayers

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The magnetothermal behavior of antiferromagnetic IrMn layers of different thickness ($t_{AFM}$ = 3, 6, 10 nm) has been studied exploiting the exchange coupling with a ferromagnetic 5nm-thick NiFe layer [1].
The NiFe/IrMn samples have been grown by DC magnetron sputtering at room temperature in a magnetic field of 400 Oe. A specific procedure has been devised for the measurement of the magnetization of the NiFe/IrMn bilayers as a function of temperature (5-400 K range) and time at different values of an external magnetic field $H_{inv}$, applied antiparallel with respect to the unidirectional exchange anisotropy. This analysis allows one to probe the effective distribution of anisotropy energy barriers of the antiferromagnetic phase, as it is sensed by the coupled ferromagnetic layer.
At temperature T < 100 K, a very weak magnetic relaxation is experienced and the barrier distribution features a peak, centered at T ~ 20 K, which does not depend significantly on $t_{AFM}$ and on $H_{inv}$; for T > 100 K, a large peak is visible in the barrier distribution, whose position depends on $t_{AFM}$ (it is centered at T ~ 230 K and at T ~ 400 K for $t_{AFM}$ = 3 nm and 10 nm, respectively) and shifts to lower temperature with increasing $H_{inv.}$ These results are consistent with the existence of a low-temperature magnetic regime (T < 100 K) in which the interfacial IrMn spins are frozen in a disordered glassy state and are collectively involved in the exchange coupling mechanism with the NiFe spins. At T ~ 100 K, the collective state breaks up and only the interfacial IrMn spins which are tightly polarized by the IrMn nanograins, forming the bulk of the layer, are effectively involved in the exchange coupling. Therefore, for T > 100 K, the coupling mechanism is ruled by the bulk IrMn nanograins, whose anisotropy energy barriers mainly give rise to the large peak in the distribution.
The thermal evolution of the exchange field and of the coercivity in the three samples is discussed and coherently explained in the framework of this description of the dynamic magnetic behavior of the IrMn phase.

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[1] F. Spizzo et al., J. Phys.: Condens. Matter 25 (2013) 386001

# Sheding light on Gr-intercalation processes in hybrid magnetic systems

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Part of the current research to optimize memory devices, is focused on ultra-high density media. These are based on the size of magnetic domains which is an intrinsic property of the materials they are made of. When trying to reduce domain size, one has to face the drawback of losing part of the intensity of the magnetization. To improve the storage amount without compromises, one can make use of hybrid systems. They are obtained through depositing a thin ferromagnetic film onto a non-magnetic substrate and have been proved to yield both an intense magnetization and small magnetic domains.

In particular, Co thin films on Ir(111) show a perpendicular magnetic anisotropy (PMA) which guarantees a very high intensity of magnetization[1]. Moreover, a graphene layer which covers the film, leads to enhanced magnetization while preventing the surface from oxidation. The capping process is relatively straightforward but the high temperatures required (500K) during Co intercalation may affect the Co/substrate interface and modify the system properties[1,2]. Detailed characterization of structure and morphology is then mandatory to reliably understand its magnetic response.

In this work, state of the art synchrotron radiation probes (surface x-ray diffraction: SXRD) and complementary laboratory techniques, were combined in order to characterize the structural modifications induced by the intercalation process and its influence on overall magnetism of the films (thickness from 1 to 2.6 nm). Complementary probes were applied to characterize the magnetic response (MOKE), depth resolved composition (XPS), crystallographic structure (LEED, XRD) and morphology (STM).

Co/Ir intermixing was observed for temperatures well below the ones used for the intercalation procedure: then the role of the Co-Ir alloy has to be taken into account. Furthermore the alloy formation is found to occur faster for thinner films. Magnetic hysteresis, on the other hand, present modifications only when the quantity of Co involved in the diffusion is comparable to the film thickness. These results allowed us to reveal the close relationship between magnetic response and atomic scale modifications (both structural and chemical) induced by thermal treatments. These findings must be considered carefully in tailoring optimal systems for applicative purposes.

[1] N. Rougemaille et al., Apll.Phys.Lett. 101 (2012) 142403
[2] J. Couraux et al., J. Phys. Chem. Lett. 3 (2012) 2059

# Magnetic anisotropy of $La_{0.7}Sr_{0.3}MnO_3$ thin films.

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We report the *in-plane* magnetic anisotropy of $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) thin films measured by longitudinal MOKE. Such films are currently used as spin injecting layer in model spintronic devices where layer magnetic anisotropy influences the overall device functionality.
Epitaxial LSMO films 40nm and 22nm thick were grown on STO (100) by Channel Spark Ablation[1]. AFM measurements indicate a quite flat surface with RMS=2 nm for the 22 nm and RMS=4 nm for 40 nm thick films.
Hysteresis cycles have been collected at different temperature 100, 150, 200 , 250 and 296 K. Uniaxial anisotropy have been detected in the 22 nm thick sample , while a biaxial anisotropy has been found in the 40 nm thick film.
The angular dependence of both switching and coercive fields has been associated to the magnetic anisotropy related to magnetostrictive strain induced by the substrate.

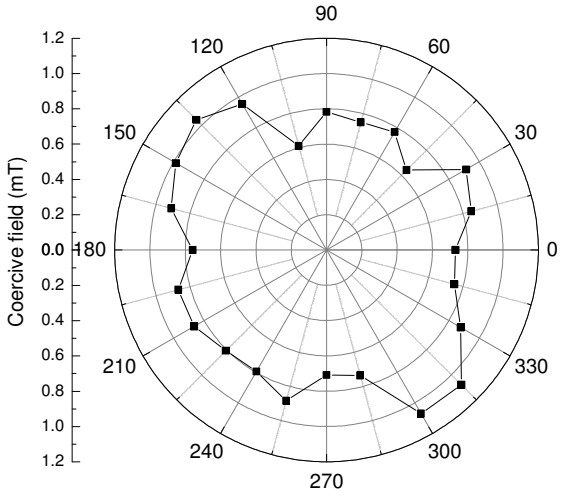


Figure 1: Azimuthal map of the coercive field for the 40nm sample at T= 296K.

[1] P Graziosi, et al. Thin Solid Films 534 (2013), 83

# Synthesis and characterization of PLD CoFe thin films as a function of composition and deposition conditions

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Nowadays, the emerging technologies based on spintronics devices, driven by the increasing demand for miniaturization, require a strict monitoring of the physical properties of the materials used in the spin-valve structures, which play a key role in the functioning of the GMR-TMR [1]. Among the magnetic materials used as electrodes in the spin-valve structures, the magnetically soft CoFe-based alloy, characterized by high saturation magnetization and high Curie temperature, showed the best magnetoresistive response in TMR systems with in-plane anisotropy [1]. However, the magnetic behaviour results to be strictly dependent on both composition and microstructural features of the alloy. In this work, we present a study of thin films of CoFe with 50:50 and 75:25 compositions deposited on MgO substrate by Pulsed Laser Deposition.
The effect of the deposition temperature on the crystallographic orientation is determined by means of XRD and HRTEM analysis and correlated with the anisotropic properties measured by angle dependent hysteresis loops. All the films showed a granular structure with a high degree of crystallographic order even at the lowest deposition temperature. The cubic symmetry is reflected in the angular dependence of remanent magnetization, showing a four-fold character, whose in-plane distribution is consistent with the different crystallographic orientation of the films.

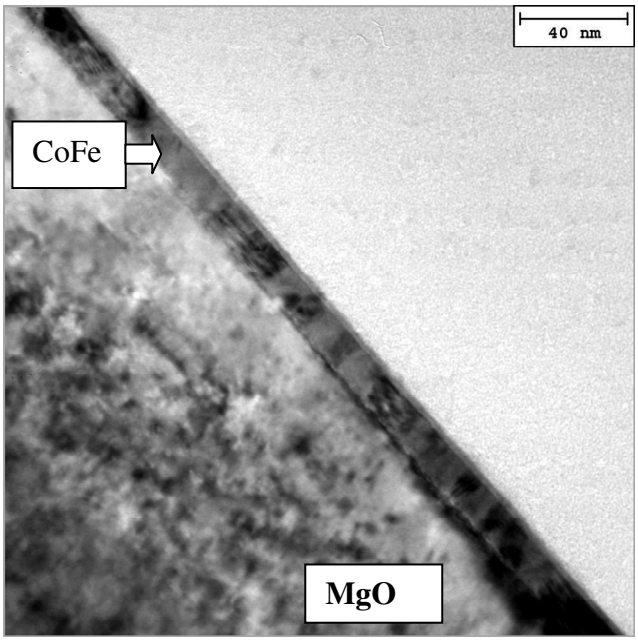


Figure 1: TEM image of the CoFe (50:50) sample deposited at room temperature. The columnar structure of the film is evident.

This work is supported by MIUR, under project FIRB2010 – NANOREST

[1] S.S.P. Parkin et al., Nature Mater. 3 (2004) 862

# Novel chiral metastable states in the discrete finite-size classical one-dimensional planar spin model with competing exchange interactions

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The classical one-dimensional planar spin model with competing nearest neighbor (nn) and next nearest neighbor (nnn) exchange interactions (Jnn>0 and Jnnn<0, respectively) was introduced decades ago [1] to account for the observation of a modulated phase (spiral or helix) in a class of magnetic crystals and alloys, including rare-earth elements and manganese compounds. In the thermodynamic limit, the helical ground state exists for $\gamma=Jnn/(4|Jnnn|)<1$ and the relative angle between neighboring spins is $\pm\arccos(\gamma)$; opposite signs correspond to helices with opposite chirality (i.e., clockwise/counterclockwise sense of rotation). In the present work, driven by the interest for artificially created nanoscale magnetic structures displaying a helical or spiral magnetic order (such as ultrathin films of rare-earth elements [2] or Fe chains deposited on the 5x1 reconstructed surface of Ir [3]), we investigate the effect of finite size and open boundary conditions on the equilibrium states of the above model. To calculate the non-collinear magnetization profile of a discrete, finite, open chain of N spins, we make use of a theoretical method recently developed [4]. The essence of the method is to reduce the difficult problem of finding minima of the thermodynamic potential in the (N−1)-dimensional space of the (N−1) relative orientation angles, to the much simpler problem of finding the (N−1) roots of a function in the one-dimensional space of the first relative orientation angle. Subsequently, the roots are analyzed in order to determine which of them correspond to stable, metastable or unstable states. In this way, we were able to determine, in a systematic and very accurate way, the equilibrium states of the model up to N=16. In addition to the ground state, which is symmetric with respect to the center of the chain, we found metastable states of two kinds: either antisymmetric or without a definite symmetry ("ugly" states). In the ground state, the modulated configuration is non uniform along the finite size of the chain, but the chirality of the helix does not change. In contrast, the metastable states are characterized either by a change of chirality in the middle of the chain (antisymmetric state) or a change of chirality located away from the middle of the chain ("ugly" state). The most interesting result, coming from our exact calculations [5], is that the antisymmetric states are metastable for even values of N and unstable for odd values of N, while the "ugly" states are always metastable. As N grows the difference between even-N and odd-N configurations is found to decrease, and for N tending to infinity it is expected to vanish.

[1] T. A. Kaplan, Phys. Rev. 116 (1959) 888; A. Yoshimori, J. Phys. Soc. Jpn. 14 (1959) 807; J. Villain, J. Phys. Chem. Solids 11 (1959) 303
[2] E. Weschke et al., Phys. Rev. Lett. 93 (2004) 157204
[3] M. Menzel et al., Phys. Rev. Lett. 108 (2012) 197204
[4] A. P. Popov, A. V. Anisimov, O Eriksson, and N. V. Skorodumova, Phys. Rev. B 81 (2010) 054440
[5] A. P. Popov, A. Rettori, and M. G. Pini, Phys. Rev. B 90 (2014) 134418

# Magnetic properties of (ultra)thin LaSrMnO films

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Doped manganite perovskite (ultra)thin films ($R_{1-x}A_xMnO_3$ - R = rare-earth, A = Ca, Sr, Ba and Pb) show a very rich phase diagram and are considered as model system in fundamental solid state physics [1]. Moreover ferromagnetic metallic manganites are employed as prototypical spin injectors in several systems in order to reveal insights in a variety of spin related effects [2]. The $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) compound has stimulated an intense study since, in bulk form, it has one of the highest ferromagnetic transition temperature $T_C$ ~ 370 K. Understanding and controlling the morpho-structural and magnetic properties of LSMO films as a function of thickness is crucial for realizing applications that commonly demand for ultrathin layers.

$La_{0.7}Sr_{0.3}MnO_3$ thin films, with thickness *t* in the 4 - 16 nm range, were deposited on (001) oriented $SrTiO_3$ substrates by means of channel spark ablation of a stoichiometric target in oxygen atmosphere [3]. The oxygen pressure in the chamber was $3.9 \cdot 10^{-2}$ mbar, the substrate temperature was around 890 °C and the deposition rate was between 0.10 and 0.15 Å per pulse for a repetition rate of 6 Hz. After the deposition the films were cooled in vacuum ($5.0 \cdot 10^{-4}$ mbar) down to about 400 °C, where they were in situ conditioned by an annealing before removing them from the vacuum. The film thickness was estimated by XRR measurements, which also provided information on roughness and density.

Both temperature (100 K ≤ T ≤ 300 K) and angular dependence of the magnetic properties were studied by a vector Vibrating Sample Magnetometer (vVSM). Ferromagnetism is observed down to 4nm ($T_C$ ~ 250 K), with $T_C$ increasing with the film thickness. For t = 16 nm, $T_C$ ~ 315 K and, at T = 100 K, the magnetization M ~ 490 emu/cm$^3$, not far from the saturation value of bulk LSMO (560 emu/cm$^3$). However, this gradual approach towards the ferromagnetic properties of bulk LSMO follows a non-monotonic trend. This suggests the existence of a strict correlation between the magnetic behaviour and the evolution of the microstructural and stoichiometric features during the growth process.

Moreover, with increasing T from 200 K up to 300 K, a change of the magnetic anisotropy from a biaxial to an uniaxial symmetry has been clearly observed in all the films. Such behavior – probably related to a crossover from a low-temperature regime, where crystalline anisotropy dominates, to a high-temperature one, governed by magnetoelastic anisotropy – occurs progressively, with a substantial isotropic behaviour actually existing in a narrow temperature range. Magnetotransport properties have been carried out in four probes geometry, with the magnetic field in the film plane in order to complement and support the vVSM characterization. Most features are confirmed while open issues are related to the observed coercive field .

[1] E. Dagotto, Science 309, 257 (2005)
[2] M. Bowen *et al.* J. Phys.: Condens. Matter 19, 315208 (2007); I. Bergenti *et al.* Philos. Trans. R. Soc. A 369, 3054 (2011)
[3] P. Graziosi *et al.* Thin Solid Films 534, 83 (2013)

# Synthesis by self-assembling of polystyrene nanospheres and static magnetic properties of Co dot arrays embedded in a $Ni_{80}Fe_{20}$ antidot matrix for magnonic applications

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Composite magnetic materials where magnetic phases presenting different coercivities are coupled by exchange interaction at the nanometer scale were introduced as a potential route to improve magnetic properties of multilayer systems for potential applications in different technological fields such as permanent magnets, information storage media and magnetic microactuators. In this context, antidot structures in which the holes are filled with another ferromagnetic material emerged of interest in magnonic applications for unique static and dynamic properties. By creating an array of Co dots dispersed in a $Ni_{80}Fe_{20}$ softer matrix, the effect of strong magnetic interactions among the two ferromagnetic materials leads to a modified magnetisation behaviour. Tu study such an effect, a continuous Co layer having thickness ranging in the interval 20-40 nm has been deposited by sputtering on a $Si/SiO_2$ substrate (oxide thickness 300 nm). The exploited patterning process is polystyrene nanosphere lithography by depositing a layer of 500 nm diameter nanospheres on the continuous magnetic film [1]. The sphere diameter is then reduced by plasma etching in Ar to reach dimension around 400 nm and sputter etching is performed to remove the residual magnetic film among the spheres. At this stage, by using the nanospheres as a mask, a $Ni_{80}Fe_{20}$ film having thickness around 30 nm, lower with respect to Co, is then deposited. The nnospheres are finally removed by sonication ending up with Co dots embedded in a $Ni_{80}Fe_{20}$ matrix (see Fig. 1a). Room temperature magnetic hysteresis loops have been measured by alternating gradient force magnetometry after each preparative step disentangling the contribution of each magnetic component and evaluating the exchange coupling effect in the final configuration (see Fig. 1b). Magnetisation reversal has been studied by magnetic force microscopy at magnetisation remanence ad as a function of magnetic field.

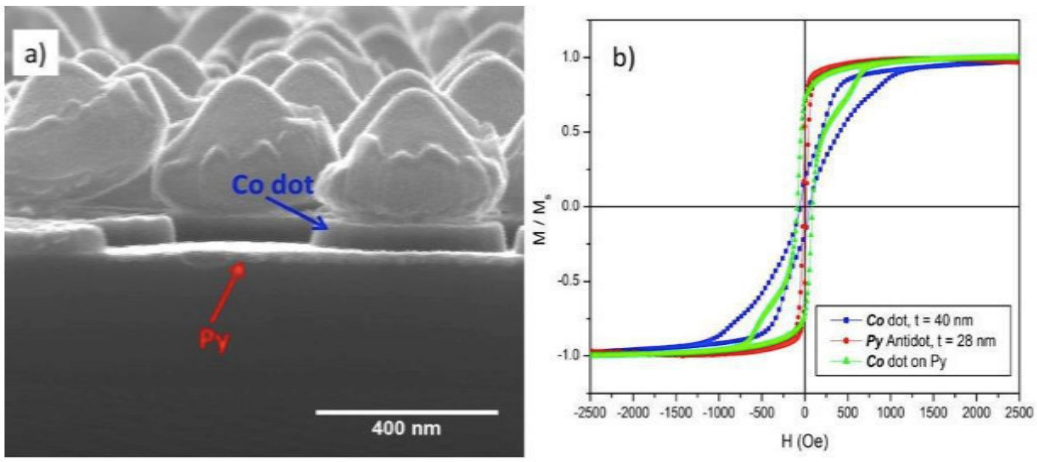


Figure 1: (a) SEM image of patterned bicomponent array of nanostructures. (b) Room temperature hysteresis loops of Co dot array (clue curve), $Ni_{80}Fe_{20}$ hole array (red curve) and combination of the two nanostructures (green curve).

[1] P. Tiberto, G. Barrera, F. Celegato, G. Barrera, N. De Leo, M. Coïsson, F. Albertini, F. Casoli, P. Ranzieri, J. Appl. Phys. 113 (2013) 17B516

# Selective electrochemical decomposition of outgrowths and nanopatterning in $La_{0.7}Sr_{0.3}MnO_3$ perovskite thin films

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The outgrowth formation in inorganic thin films is a dramatic problem that has limited the technological impact of many techniques and materials. Outgrowths are often themselves part of the films[1], but are detrimental for vertical junctions since they cause short-circuits or work as defects, compromising the reproducibility and in some cases the operation of the corresponding devices. The problem of outgrowth is particularly relevant in ablation-based methods and in some complex oxides, but is present in a large variety of systems and techniques. Here we propose an efficient local electrochemical method to selectively decompose the outgrowths of conductive oxide thin films by electrochemical decomposition, without altering the properties of the background film[1]. The process is carried out using the same set-up as for local oxidation nanolithography, except for the sign of the voltage bias and it works at the nanoscale both as serial method using a scanning probe and as parallel method using conductive stamps. We demonstrated our process using $La_{0.7}Sr_{0.3}MnO_3$ perovskite as a representative material but in principle it can be extended to many other conductive systems.

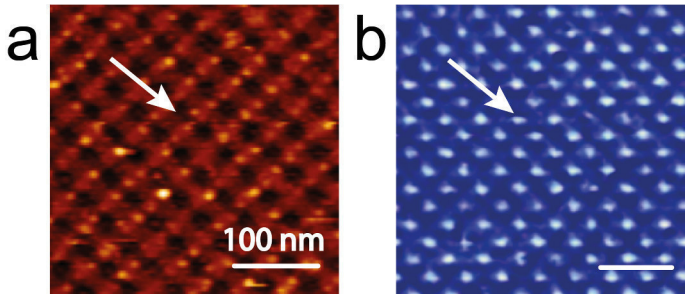


Figure 1: Pattern of LSMO anti-dots 20 nm diameter fabricated by local electrochemical decomposition. a) AFM Topography. The arrow indicates an anti-dot, Z scale 0-10 nm. b) Corresponding electrical

[1] F. Borgatti, I. Bergenti, F. Bona, V. Dediu, A. Fondacaro, S.Huotari, G. Monaco, D. A. MacLaren, J. N. Chapman, and G. Panaccione Source: Appl. Phys. Lett. 96 (2010) 043306

[2] M. Cavallini, P. Graziosi, M. Calbucci, D. Gentili, R. Cecchini, M. Barbalinardo, I. Bergenti, A. Riminucci & V. Dediu Sci. Rep. 4 (2014) 7397.

# Modeling experimental magnetization cycles of type II superconductors by finite element simulations

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Type II superconducting materials show magnetic irreversibility features which lead to low temperature dissipations. These hysteretic losses are crucial in the design of superconducting devices, like superconducting magnets for accelerators. In this context FEM analyses are a powerful tool to compute either field profiles and current distributions inside a superconductor, thus allowing to evaluate its hysteresis losses.
In this work we model the Bean critical state by using the *H*-formulation in the framework of Comsol™ Multiphysics FEM software. Solving the set of partial differential equations we computed the magnetic field and the current density $J_c$ penetration profile for different shapes, *i.e.* thin films, disks, and spheres, under a ramping perpendicular applied magnetic field. Either 2D or 3D models have been used. For each geometry we first checked the numerical simulations against the corresponding literature approximate analytical solutions, obtained with $J_c$ costant against field. The results of this computation gave us the magnetization moment $m$(B) value for a cycle, and consequently the energy dissipation $Q$ per cycle. In order to perform a comparison to experimental data, we also measured the magnetic moment under applied magnetic field of three superconducting samples having the same shapes used in the numerical models. To achieve this task we had to give as input in the model the experimental $J_c$(B) dependence of the superconductor, being the critical current density no longer constant in real sample. The computed magnetic moment loops well compare to the experimental ones, either in 2D and 3D models.

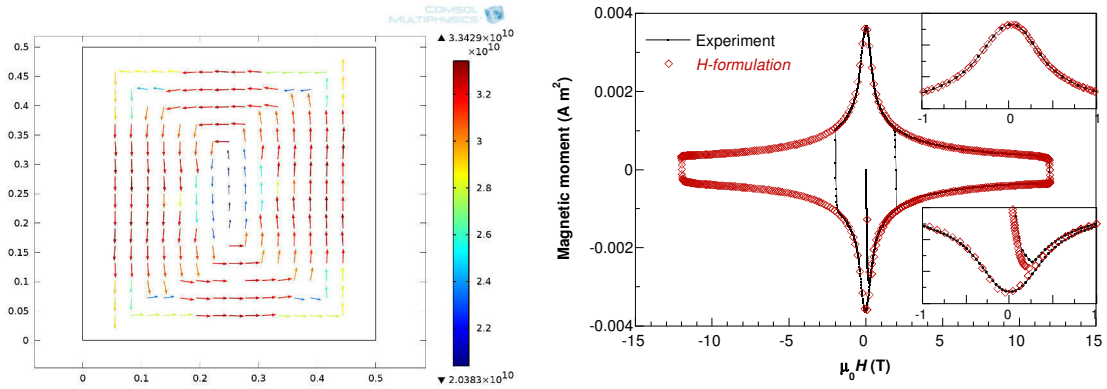


Figure 1: numerical results for a thin film in transverse magnetic field: a) current distribution; b) magnetic moment.

[1] S. Farinon, G. Iannone, P. Fabbricatore, U. Gambardella, "2D and 3D Numerical Modeling of Experimental Magnetization Cycles in Disks and Spheres", Superconductor Science and Technology, 27 (2014) 104005 DOI:10.1088/0953-2048/27/10/104005
[2] G. Iannone, S. Farinon, G. De Marzi, P. Fabbricatore, U. Gambardella, "Modeling Experimental Magnetization Cycles of Thin Superconducting Strips by Finite Element Simulations", IEEE Applied Superconductivity, (2014) to be published, DOI: 10.1109/TASC.2014.2345339

# Microwave determination of the superfluid density in S/F/S heterostructures: indications of a 0-π phase transition

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We have performed microwave measurements of the superfluid density in Superconductor/Ferromagnet/Superconductor (SFS) heterostructures, where the so-called 0-π transition may take place [1]. Trilayers with a weak $Pd_{0.84}Ni_{0.16}$ ferromagnetic layer of various thicknesses 1 nm < $d_F$< 9 nm, sandwiched between Nb layers of nominal thickness $d_S$=15 nm, were studied. A full structural characterization by means of TEM, EXAFS, and SIMS-TOF analyses has been performed, yielding their microscale disorder, local disorder and compositional profile properties, respectively.
We performed both wideband measurements in the 1-20 GHz (Corbino disk technique) and fixed frequency measurements at 8 GHz (dielectric resonator) with and without a d.c. magnetic field applied normally to the samples. The temperature dependence (3.3 K-$T_c$) of the London penetration depth was thus determined at zero and non-zero field, in the latter case inferring it from the condensation energy dependence of the fluxon pinning constant.
The temperature dependence of the superfluid density weakens, as well as the pinning strength, by increasing $d_F$. In addition, the sample with $d_F$ = 2 nm, having a nominal thickness close to the critical one needed for the appearance of the 0-π transition, shows a reentrant jump in the temperature dependence of the density of the superconducting condensate, exhibited both in the zero field and field-dependent measurements. This anomaly is explained in terms of the first observation of a temperature-induced 0-π thermodynamic transition [2], beyond the Josephson interference [1] or the zero-temperature superfluid density [3] results reported up to now.
Finally, ageing effects were subsequently studied, showing that the critical conditions for the transitions are quite delicate.

This work has been performed in collaboration with A. I. Buzdin, A. V. Samokhvalov, C. Attanasio, C. Cirillo, E. A. Ilyina, S. Sarti, L. Tortora and C. Meneghini.

[1] A. I. Buzdin, Rev. Mod. Phys. 77 (2005) 935
[2] N. Pompeo et al, Phys. Rev B. 90 (2014) 064510
[3] T. R. Lemberger et al., J. Appl. Phys. 103 (2008) 07C701

# Metal-to-superconductor transition, mesoscopic disorder and intrinsic charge instability in oxide heterostructures

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Keywords: oxide heterostructures, electronic phase separation, Rashba spin-orbit coupling, inhomogeneous superconductivity, quantum criticality

The observation of a two-dimensional (2D) metallic state at the interface of two insulating oxides have attracted much attention in the last decade. Among its many intriguing properties are a large Rashba spin-orbit coupling (RSOC) and a metal-to-superconductor transition, both tunable by an external gate voltage. Numerous experiments indicate that the 2D electron gas (EG) is inhomogeneous: transport measurements reveal a peculiar metal-to-superconductor (SC) transition suggestive of charge inhomogeneity at mesoscopic scale [1].

Motivated by the fact that these inhomogeneities persist in ever cleaner samples we propose they might result from an intrinsic electronic phase separation (EPS). We point out two generic mechanisms which can drive the interfacial EG towards such an EPS, based on (i) a density-dependent RSOC [2] and (ii) the electrostatic electron confinement at the interface [3].

Investigating how the two densities of the phase separated EG change upon varying the gate voltage we obtain the phase diagram at zero temperature. The resulting diagram has a dome-like shape and closes at negative gate voltage, signaling the existence of a quantum critical point (QCP). We argue that this QCP is related to the recently observed quantum critical behaviour of $LaTiO_3/SrTiO_3$ [4].

[1] S. Caprara, et al., Phys. Rev. B (Rapid Communications) 88, 020504(R); S. Caprara, D. Bucheli, N. Scopigno, N. Bergeal, J. Biscaras, S. Hurand, J. Lesueur, and M. Grilli, Supercond. Sci. Technol. 28 (2015) 014002.
[2] S. Caprara, F. Peronaci, and M. Grilli, Phys. Rev. Lett. 109, 196401 (2012); D. Bucheli, M. Grilli, F. Peronaci, G. Seibold, and S. Caprara,Phys. Rev. B 89, 195448 (2014).
[3] N. Scopigno, D. Bucheli, S. Caprara, J. Biscaras, N. Bergeal, J. Lesueur, and M. Grilli, in preparation.
[4] J. Biscaras, N. Bergeal, S. Hurand, C. Feuillet-Palma, A.Rastogi, R. C. Budhani, M. Grilli, S. Caprara, J. Lesueur, Nature Materials 12, 542 (2013).

# First principles analysis of magnetic and elastic properties of hexagonal perovskite-type $LaCrGe_3$

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The discovery of iron pnictides superconductors, which are characterized by reduced Fe moments and suppression of a magnetic ground state by doping or (chemical) pressure, renewed the interest for materials showing a borderline with a magnetically ordered state. Such a point of instability that is achieved by non-thermal tuning parameters between two stable phases of matter is called quantum phase transition and in the case of a continuous phase transition this point is called quantum critical point.
In this context, $LaCrGe_3$ has been recently reported to be an itinerant ferromagnet with a saturation magnetization of 1.4 $\mu_B$ per Cr atom and strong electronic dependence on chemical substitution and applied pressure [1-2].
In this work, the structural and magnetic properties of $LaCrGe_3$ under pressure are studied with the use of the *ab initio* pseudopotential density-functional method. Our calculations show that the ferromagnetic ground state is close to an antiferromagnetic ground state and that non-hydrostatic pressure can have a significant effect on the stability of the ferromagnetic state via modifications to the electronic dispersion.
From these results a phase diagram as a function of external pressure will be presented and compared with preliminary results from recent μSR experiments.

[1] X. Lin et al. Phys. Rev. B **88** 094405 (2013)
[2] Debarchan Das *et al, J. Phys.: Condens. Matter* **26** 106001 (2014)

# AC losses measurements of a trapezoidal shaped HTS coil with a capacity compensation technique

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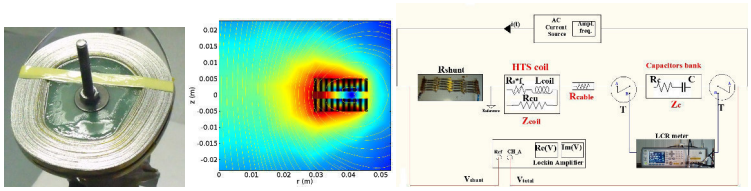
High Temperature Superconducting (HTS) coils of different shapes (typically circular or trapezoidal) wound on iron or ironless core, are fundamental components of many superconducting electrical power devices like SMES and various electrical machines. Power devices design reliability greatly benefits from a deep understanding of the electrical and magnetic properties of superconducting (*SC*) components. A trapezoidal coil in double pancake configuration (Fig. 1) could be a typical *SC* component to be found in many applications, so that we designed and realized a 150 turns (75 turns/pancake) specimen in our laboratory. Various epoxy resins and YBCO tapes have been tested in the temperature range room to liquid nitrogen, leading to the choice of AmSC (American Superconductor®) tape for the winding and araldite resin for the impregnation process. The *AC* transport current losses have been measured using a compensated electrical method, and expressed in term of a linearly frequency dependent resistance (Fig.1). The current-voltage curve has been measured in zero externally applied field condition, the results being in good agreement with a numerical simulations. The magnetic field distributions, at different air gaps from coil top and zero externally applied filed condition, have been simulated and reported as well.



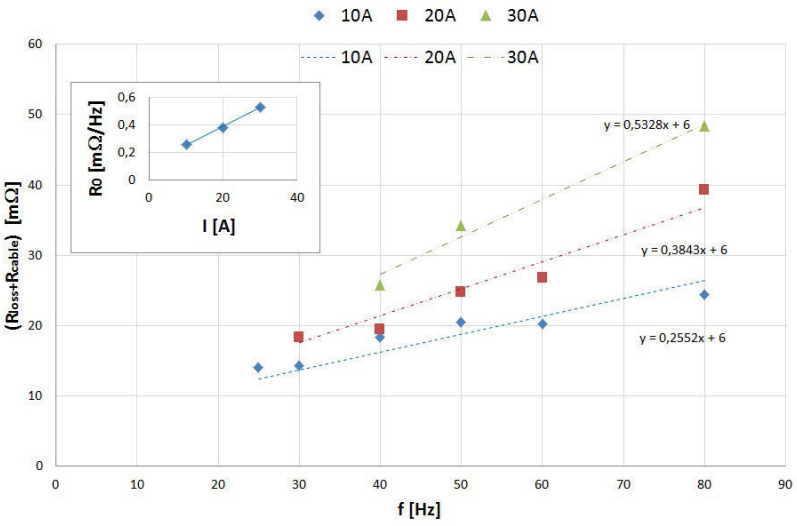




Figure 1: Top row: Left: Trapezoidal HTS coil; Centre: Snapshot of magnetic flux density B(T) at critical current $I_c$ = 59A; Right: AC loss electrical method configuration circuit

Figure 1: Bottom: $R_{loss}$ vs. f at various rms current values and line slope evolution with current inside insert.

# Enhancement of low-frequency magnetic fluctuations driven by Mn in $(La,Y)FeAsO_{0.89}F_{0.11}$ superconductors

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Defects and impurities often lead to marked effects on the critical temperature ($T_c$) and to significant changes in the phase diagram of the iron-based superconductors. Thus, understanding their influence on both the superconducting and normal state properties is very important in order to shed new light on the pairing mechanism in these materials. In this study we focused on the peculiar case of Mn impurities substitution on the Fe site in optimally doped $LaFeAsO_{0.89}F_{0.11}$ (La1111).

A very rapid drop of $T_c$ was observed by gradually increasing the Mn concentration, so that even a small amount of Mn, as low as $x$ = 0.2 %, is enough to completely suppress the superconductivity. Together with the lowering of $T_c$ the insurgence of a short range magnetic phase has been observed. The superconducting and the magnetic phases merge, coexisting at the nanoscopic level, at a quantum critical point (QCP) which is reached for $x$ around 0.2 %. Upon further increasing the Mn content magnetism develops through all the FeAs plane and superconductivity vanishes [1].

The phase diagram changes substantially when 20 % of $La^{3+}$ is substituted with $Y^{3+}$. The chemical pressure introduced by Yttrium stabilizes superconductivity so that the quantum critical point is attained at much higher Mn concentrations (~5%).

Nuclear Magnetic Resonance (NMR) spectroscopy, being sensitive both to the spin dynamics and to the local magnetic structure, is an ideal tool to study the effect of paramagnetic Mn impurities on the microscopic properties of (La,Y)1111 superconductors. Indeed the $^{19}F$ spin-lattice relaxation time ($1/T_1$) revealed the presence of slowing down of the spin fluctuations at low temperatures for all the concentrations of Mn both in the samples with and without Yttrium. Notably the low-frequency fluctuations get enhanced only when approaching to the QCP. This means that in the Yttrium-less sample strong low-frequency fluctuations were observed even for extremely low concentrations of Mn, around $x$ = 0.2 %. Conversely for the samples with 20% of Yttrium $1/T_1$ revealed reduced spin fluctuations at those low percentages of Mn, while enhanced fluctuations were detected for much higher Mn contents. The correlation times of the fluctuations were derived and discussed both in the framework of a nematic fluctuations scenario and in terms of spin-glass like fluctuations. Further information on the magnetic correlations can be derived from the study of $^{19}F$ NMR line width (FWHM) which allows to probe the local spin polarization around the Mn impurities.

[1] F. Hammerath et al. Phys. Rev. B 89 (2014) 134503

# Skin effect in magnetic steel sheets under rotating induction

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By means of a newly developed broadband measuring setup we have overcome the usual upper limit for the test frequency, around a few hundred Hz, which is encountered in the two-dimensional characterization of magnetic steel sheets at technical inductions and we have measured the rotational losses in low-carbon steels up to 1 kHz and peak induction 1.7 T. An important piece of information is thus retrieved upon a frequency range useful to predict the performance of high-speed electrical machines. We report here about measurements performed on thick (0.640 mm) laminations, which have brought to light the emergence of the skin effect under rotational fields. This is revealed by an abrupt deviation of the excess loss component, calculated under the conventional loss separation procedure, from its well-known linear dependence on the square root of the frequency. A simple magnetic constitutive law under rotating induction is proposed, where, exploiting the near isotropic properties of the material, vector magnetic induction and field are treated as complex quantities, related by a complex permeability. The so-found constitutive equation is introduced in the electromagnetic diffusion equation, which is solved by finite elements coupled to a non-linear algorithm. The classical rotational eddy current loss, largely prevalent with respect to the hysteresis and excess loss components on approaching the kHz frequencies in low-carbon steels, is then calculated in the presence of skin effect, permitting one to achieve full analysis of the rotational losses and good predicting capability upon a broad range of frequencies and peak inductions.

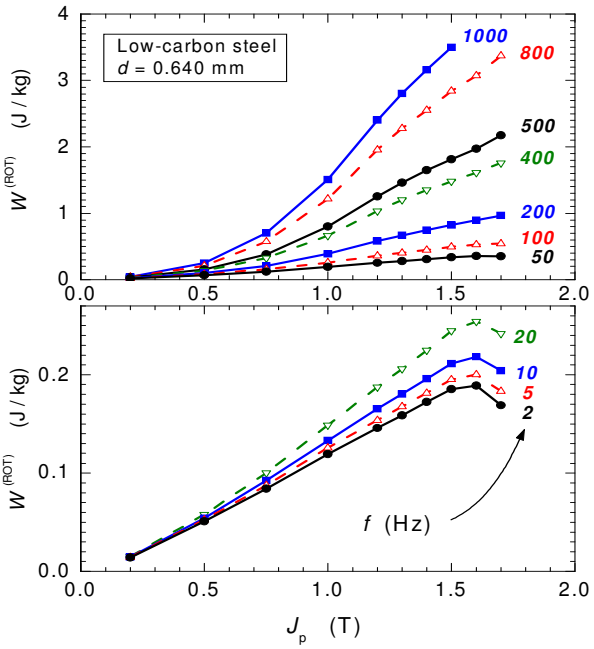


Figure 1: Rotational energy loss versus circular polarization $J_p$ measured in a 0.640 mm thick low-carbon steel sheet in the frequency range 2 Hz - 1 kHz.

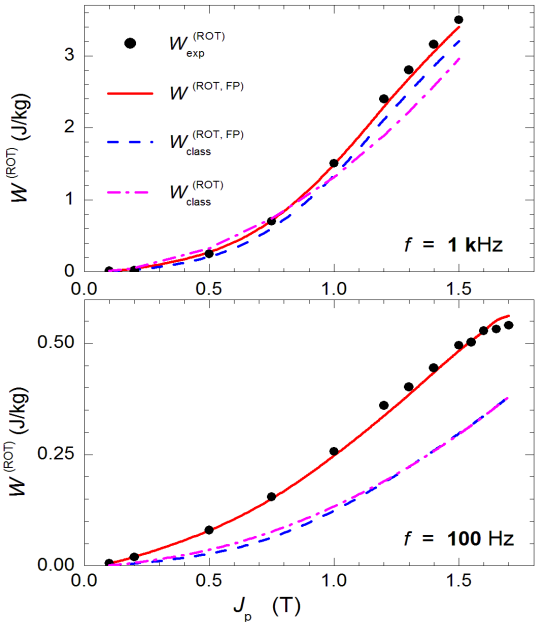


Figure 2: Measured rotational loss $W_{exp}^{(ROT)}$ versus polarization $J_p$ at 1 kHz and 100 Hz and theoretical prediction (solid line) calculated via the electromagnetic diffusion equation and its solution by the Fixed Point (FP) technique.

# Temperature dependence of coercivity in Ti substituted MnBi

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MnBi compound has a high uniaxial magnetocrystalline anisotropy which has the peculiar feature to increase with temperature up to 500 K where $K_u$ = 2.2 $10^6$ J/m$^3$ [1]. This makes the compound an interesting candidate as hard magnet because it is rare-earth-free and is suitable to operate at high temperatures. The difficulties in the preparation are related to the presence of a peritectic decomposition at 720 K and to the need to develop an appropriate microstructure. Several strategies were developed to refine the grain size without loosing phase fraction. Cryomilling and surfactant addition [2,3] have been shown to be effective, but the process becomes rather complex. Partial substitutions of Mn with other metals has been attempted. Pr is effective to increase coercivity but the saturation magnetization is drastically reduced [4].
Here we investigate the magnetic properties of $(Mn_{1-x}Ti_x)Bi$ polycrystalline alloys in which Mn is partially substituted by Ti. Ti is well suited to replace Mn because of similar electronegativity and ionic radius. The problems related to the peritectic decomposition can be safely avoided by exploiting the solid state reaction between Mn and Bi which starts already at temperatures as low as 520 K (Bi melts at 541 K). Samples were prepared by high-energy ball milling of Bi and Mn or $Mn_{1-x}Ti_x$ alloy in nitrogen atmosphere. The powders were then compacted in pellets and annealed in an applied magnetic field of 1 T in order to promote the growth of aligned MnBi grains. The phase fraction obtained is around 90 wt%. Figure 1(a) and 1(b) show the hysteresis loops of samples with x=0 and x=0.02: it can be seen that Ti is effective to increase the coercivity without losing significant magnetization, suggesting a role of Ti atoms in enhancing a fine microstructure. Fig. 1(c) shows the same properties after the sample has undergone once its first-order magnetostructural phase transition at 628 K, where cell parameters change and Mn atoms may diffuse into the interstices. In this case coercivity is almost completely suppressed. Since the grain size has not been optimized during preparation, we suspect the presence of a pinning-type mechanism for coercivity. The observed behaviour suggests that the transition is able to eliminate pinning sources.

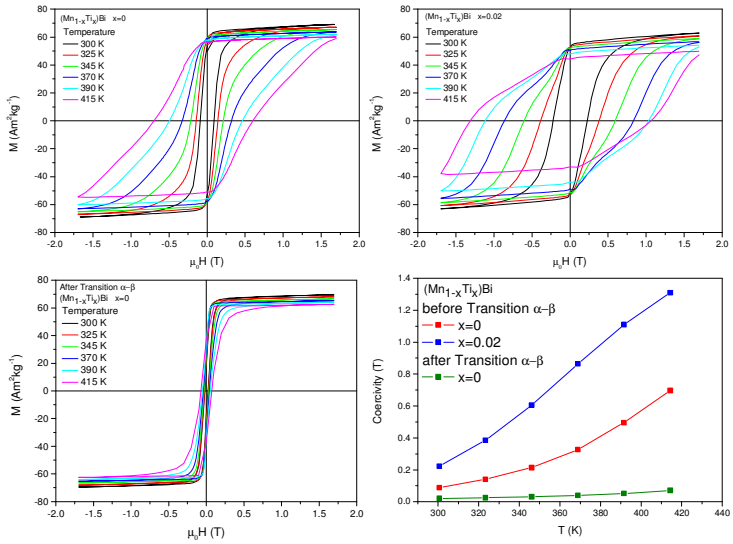


Figure 1: Hysteresis loops of $(Mn_{1-x}Ti_x)Bi$ in the temperature range 300-415 K with x=0 (a), x=0.02 (b) and x=0 after magnetostructural transition (c).
(d) Temperature dependence of coercivity of the studied samples.

[1] Chen, T., Stutius, E., IEEE Trans. Magn. 10, (1974) pp. 581-586
[2] N. V. Rama Rao et al. J. Phys D: Appl. Phys. 46 (2013) 265001
[3] Rongming Liu et al. J. Phys. D: Appl. Phys. 115 (2014) 17A742
[4] P. Kharel, et al. J. Phys. D: Appl. Phys. 46 (2013) 095003

# Rotatable magnetic anisotropy in anisotropy-graded FePt films induced by ion irradiation at low incidence angle

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Static magnetometry, Brillouin light scattering from thermally excited spin waves, and magnetic force microscopy have been used to investigate the static and dynamic magnetic properties of a 15-nm-thick FePt film after $Ar^+$ irradiation, performed at two different incidence angles, $85^o$ and $45^o$, with respect to the film normal. Ion irradiation induces atomic displacements and consequently modifies the chemical order of the material, turning the $L1_0$, chemically ordered, magnetically hard phase, into the A1, chemically disorderd, magnetically soft phase [1]. On decreasing the incidence angle of the ion beam, we obtained an anisotropy gradient along the film normal, characterized by a decreasing thickness of the hard phase and an increasing thickness of the soft phase. Moreover, in the sample irradiated at $45^o$, we found that the moderate perpendicular magnetic anisotropy and the negligible magneto-crystalline in-plane anisotropy induce a non-zero rotatable magnetic anisotropy [2]: namely, an anisotropy whose direction can only be rotated by a large saturating field [3]. The hypothesis was confirmed by magnetic force microscopy; a maze-like perpendicular domain pattern was observed at remanence irrespective of the sample being saturated, and subsequently demagnetized, along two mutually orthogonal in-plane crystallographic directions. The tunability of the zero-field frequency, obtained by $Ar^+$ irradiation varying the incidence angle of the ion beam, may have large applications for microwave magnetic devices.

[1] A. di Bona, et al., Acta Materialia 61 (2013) 4840
[2] L. M. Alvarez-Prado et al., Phys. Rev. B 56 (1997) 3306
[3] H. Fujiwara, Y. Sugita, and N. Saito, Appl. Phys. Lett. 4 (1964) 199

# POSTER SESSION II

## February 18th

# Iron oxide magnetic nanoparticles for magnetic fluid hyperthermia therapy: synthesis and characterization

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During recent years, an increased interest in magnetic nanoparticles (NPs) for their use in biomedical applications, in particular for hyperthermia therapy, has been observed [1]. This promoted the research on synthesis routes that allow better control in NPs shape and size, as the nanoparticles properties are strongly influenced by those parameters. In addition, due to the need of obtaining bio-compatible NPs, several strategies have been applied to stabilize them in aqueous media.

In this study, we synthesized iron oxide magnetic nanoparticles in presence of 2-pyrrolidone, as that acts both as surfactant and solvent [2] and permits to disperse the synthesized nanoparticles in water without any further functionalization. The magnetic NPs were synthesized by thermal decomposition of iron chloride (III) hexahydrate ($FeCl_3 \cdot 6H_2O$) in presence of 2-pyrrolidone; the reagents relative concentration was changed so to access the effect of that on the morphology and on the magnetic properties of the NPs. After the synthesis, the NPs were precipitated and dried, and then dispersed in deionized water with a 10 mg per 1 ml concentration. The magnetic properties of the NPs were investigated using a superconductive quantum interference device (SQUID) magnetometer and Mössbauer spectroscopy. Size and morphology of the particles were investigated with a transmission electron microscope (TEM), while the heating rate of the magnetic liquids was measured using an inductor suitably designed using numerical methods and optimization algorithms in order to maximize the magnetic field uniformity [3].

The sample with the smallest chloride concentration shows nanoparticles with a fine dispersion (NP size ~ 5 nm); an increase in chloride concentration produces flower-shaped NPs, as those presented in fig. 1, where fine nanoparticles are aggregated so to form "flowers" with an average size of 20 nm. A further increase in chloride concentration produces again a fine dispersion of magnetic NPs.

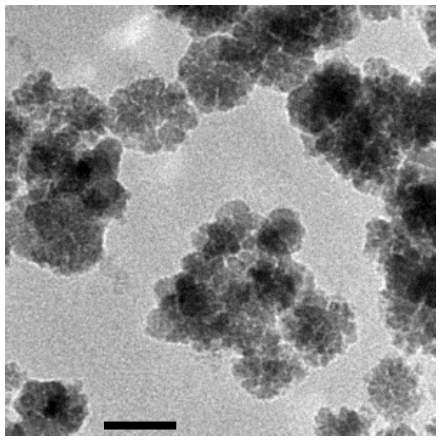

Figure 1: TEM picture representing flower-shaper nanoparticles. The black marker corresponds to 20 nm.

The magnetic fluid with flower-shaped NPs turns out to be the most interesting for hyperthermia, as it produces the highest heating rate; the combination of SQUID and Mössbauer characterization reveals the strong influence of magnetic dipolar interactions on sample magnetic behavior.

The results of the magnetic characterization of the different NPs will be presented and discussed, and also compared with the results obtained from heating rate measurements. Finally, cell culture experiments will be also presented, as NPs have been added to a cell culture in order to evaluate cellular uptake. In particular, TEM analyses revealed a time-dependent uptake of flower-shaped NPs by breast cancer cells.

[1] A. Akbarzadeh et al., Nanoscale Research Letters 7 (2012) 144.
[2] K. M. Krishnan, IEEE Trans. On Magnetics, 46 (2010) 2523.
[3] P. Di Barba et al., IEEE Trans. On Magnetics 46 (2010) 2931.

# Magnetite nanoparticles: hyperthermia and Lorentz microscopy

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In the last decade, many efforts have been devoted to the research of new nanostructured materials with functional properties that can be exploited in biomedical applications [1]. Magnetic nanoparticles (NPs) in the superparamagnetic state are suitable for both diagnostic and therapeutic approaches. In the field of diagnostics, they have been proposed as a contrast agent to enhance the magnetic resonance imaging (MRI) signal, while in the field of therapeutics they can be used as magnetic vectors in drug delivery and/or as heat mediators in hyperthermia treatment.
The magnetic hyperthermia can be effectively employed to locally induce cancer cell death. The ability of a material to be a good hyperthermic mediator is measured by the specific power absorption (SPA), that represents the thermic power developed by the magnetic NPs per unit mass under an applied external AC field. The dipolar interactions among particles strongly influence the heating power of the colloidal suspension, but their role is not completely understood.
In this work, magnetite nanoparticles with comparable size distributions and different aggregation states have been synthetized by two different chemical roots, co-precipitation and thermal decomposition. The samples can be considered as a model system to investigate the effects of magnetic dipolar interactions on the efficiency of the nanoparticles as hyperthermic mediator. In particular we exploit Lorentz microscopy, a very powerful tool which allows retrieving the phase of the electron wave function and reconstructing the in-plane magnetic induction among different magnetic NPs and clusters [2].
Combining microstructural, magnetic and Lorentz microscopy, it is possible to correlate the interaction degrees of magnetic nanoparticles to their magnetic behaviors, paving the way to the comprehension of the power losses mechanisms for nanoparticle aggregates with different dipolar interactions.

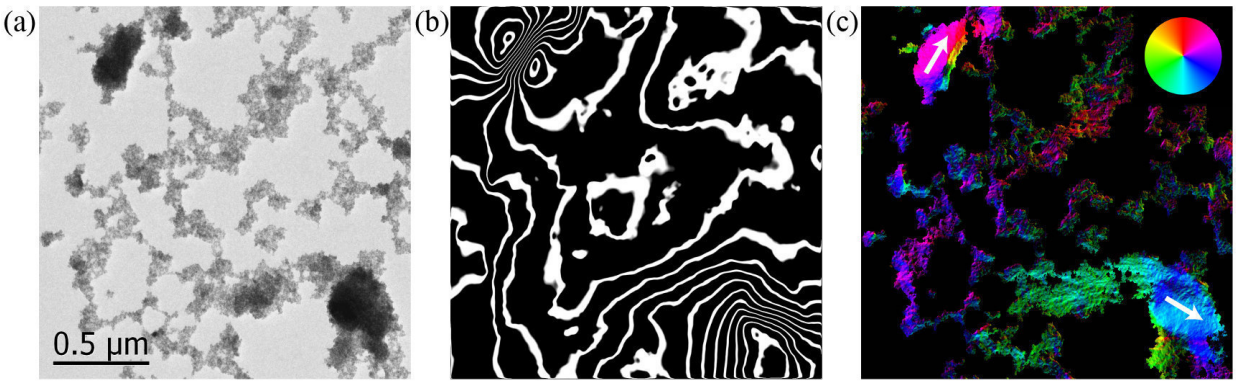


Figure 1: (a) Low magnification (6k) bright field image of co-precipitated NPs, showing the presence of clusters and irregular chains. (b) Cosine map of the phase (amplified 40 times) and (c) in-plane magnetic induction map, as obtained by Lorentz microscopy analysis.

[1] A. Hervault et al., Nanoscale, 6 (2014) 11553
[2] V. Grillo et al., Microscopy and Microanalysis, 20 (2014) 2134

# Development and utility of magnetic nanoparticles production by mammalian cells

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## Introduction

In recent years there has been an increasing interest in magnetosomes used as Superparamagnetic iron oxide nanoparticles (SPIONs) for magnetic hyperthermia cancer therapy [1], [2]. Magnetosomes are membrane bound magnetic organelles produced by Magnetotactic Bacteria (MTB), aquatic prokaryotes which can become aligned with the geomagnetic field. Although magnetosome chains have been seen to play a promising role in the elimination of solid tumour [3], the process of magnetosome formation still remains obscure. Studies of MTB genome show the importance of Mms6 and MmsF genes, encoding respectively Mms6 and MmsF proteins, in magnetosome formation. The aim of this work is to establish a standard procedure to create magnetosomes expressing mammalian cells, in order to create a new and non-invasive contrast agent that could be used for Magnetic Resonance Imaging (MRI) to precisely kill cancer cells by magnetic hyperthermia without any side effects for the neighbouring healthy cells.

## Experimental Method

Mesenchymal stem cells (MSC) and osteosarcoma cells (MG63) were transfected with Mms6 and MmsF genes, alone or in combination. Gene expression was assessed by RTPCR. Nanoparticle production was assessed by transmission electron microscopy (TEM). An alternating magnetic field was applied to pellets of fixed cells to investigate magnetic hyperthermia effects.

## Results and Discussion

Agarose gel electrophoresis following RTPCR on MG63 and MSC cells harvested 10 days after the transfection shows that both cells express the genes Mms6 and MmsF, alone or in combination. TEM analysis reveals the presence of electron dense nanoparticles similar to the magnetosomes structures. Application of an alternating magnetic field resulted in an increase of temperature in cells transfected with the genes in comparison with the control untransfected cells where no increase in temperature was seen.

## Conclusions

Experiments so far suggest that mammalian cells may be transfected with Mms6 and MmsF genes with production of nanoparticles similar to the ones observed in MTB. Next *in vitro* experiments will take in consideration the ability to effectively kill the tumour cells in a co-culture of tumour and transfected cells, under the action of an alternating magnetic field.

## References

[1] A.Arakaki et al. J R Soc Interface. 5 (2008) 977.
[2] F.M. Kievit et al. ACS Nano 6 (2012) 2591.
[3] E. Alphandery e al. Int J Pharm. 434 (2012) 444.

# ON-CHIP INVESTIGATION OF CELLULAR FUNCTIONS VIA MAGNETIC NANOPARTICLES: A NOVEL TOOL IN MECHANOBIOLOGY

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Single molecule imaging and handling are of relevance for in-vitro biological application, because they offer a clear and direct way to investigate functions and dynamics of single cells or biomolecules. Methods based on the remote manipulation of magnetic beads, via external magnetic fields, are receiving great attention because magnetic fields are not screened by biological or culture media. Moreover, magnetic nanoparticles manipulation does not involve relevant energy dissipation, which could eventually damage the cell structure.

In this work, we exploit magnetic Domain Wall Tweezers (DWTs) [1,2], based on the controlled nucleation and displacement of Domain Walls (DWs) in ferromagnetic conduits, for trapping and finely manipulating single superparamagnetic particle properly functionalized.

To this scope, nanometric $Ni_{80}Fe_{20}$ rings are patterned on a chip where cells are afterwards cultured and a pair of DWs, which attract and drag magnetic nanoparticles, are nucleated and displaced trough the application of a rotating in plane magnetic field of 300 Oe.

In this way, we demonstrate the possiblility to handle with high resolution (down to 100 nm) magnetic beads to a target cell in order to assess controlled forces in the range of pN-nN to mechanically and chemically activate relevant cellular pathways (e.g. genes activation) actually under investigation.
Furthermore, cellular response to localized stimuli is monitored in real time by means of optical methods like confocal microscopy.

*[1] M. Donolato et al., Adv. Mater. 2010, 22, 2706–2710*
*[2] M. Donolato et al Lab Chip, 2011, 11, 2976*

# MTJ-based platform for the detection of DNA pathogens in agrifood industries

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In the last years, magnetoresistive (MR) biosensor arrays in combination with magnetic markers have emerged as a new promising platform for biosensing. The most widely used scheme relies on the detection of molecular recognition events between the probe molecules, bound onto the sensor surface, and the magnetically labeled target molecules which bind specifically to the complementary probes [1]. The magnetic stray field of the superparamagnetic labels on the surface of the sensor causes a change in the electrical resistance of the sensor which is related to the concentration of the immobilized target molecules.

In this work, we demonstrate the detection of natural DNA from different classes of pathogens, precisely *Hepatitis E* virus (HEV) and *Pathogenic bacteria* (Salmonella, Listeria monocytogenes) using a highly sensitive biosensing platform based on magnetic tunneling junction (MTJ) [2,3]. The sensing array consists of 11 MTJ-based rectangular sensors with lateral dimensions 3 x 40 $\mu m^2$, a TMR value of 75% and a sensitivity S0 = 17 %/mT in the linear region.

The results show that the platform successfully meets the requirements for the detection of hybridized natural DNA. Moreover, this work represents a fundamental step towards the integration of MTJ-based biosensing platforms in compact Lab-on-a-chip devices for the straightforward detection of pathogens in the agrifood industry and for further medical applications.

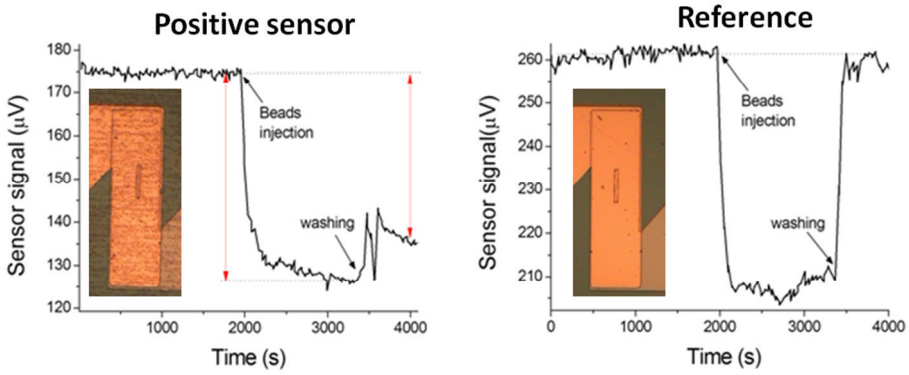


Figure 1: Signal from the positive (left) and reference (right) sensor during the hybridization of DNA from *Hepatitis E* virus (HEV) (probe DNA: 100 bp, 20µM, amplified target DNA: 9 ng/µL corresponding to 275 nM). In the reference sensor, the baseline is recovered after the washing steps, while in the positive one the binding signal is highlighted with a red arrow. In the inset, optical microscope images of the two sensors after the experiment.

[1] Albisetti, E., Petti, D. et al. Photolithographic bio-patterning of magnetic sensors for biomolecular recognition. Sensors and Actuators B 200 (2014) 39–46

[2] Albisetti, E., Petti, D. et al. Optimization of the bio-functionalized area of magnetic biosensors. Eur. Phys. J. B 86, 261 (2013).

[3] Albisetti, E., Petti, D. et al. Conditions for efficient on-chip magnetic bead detection via magnetoresistive sensors. Biosens. Bioelectron. 47, 213–7 (2013)

# Synthesis and characterization of magnetic nanogranular $Fe_3O_4$/biomimetic hydroxyapatite for potential applications in nanomedicine

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Nowadays, the potentiality of magnetic nanoparticles for a large range of biomedical applications is largely claimed and demonstrated, but their use is conditioned by the possibility to guarantee biocompatibility, actually. For this purpose, an investigated solution is coating them with a polymeric or inorganic shell, such as $SiO_2$ or Au. An alternative approach is exploiting a highly biocompatible material such as hydroxyapatite (HA) [$Ca_5(PO_4)_3OH$], which is the inorganic component of many biological hard tissues, i.e. bone and teeth. The synthesis of composite materials consisting of magnetic nanoparticles and HA is especially appealing for prospective uses in the field of bone tissue engineering, as the magnetic nanoparticles may act as drug carriers, favoring the tissue regeneration, and allow a controlled drug release under a magnetic or thermal stimulus, possibly exploiting their ability as hyperthermia agents.

In this context, we report about a two-step chemical synthesis process of a novel nanogranular system consisting of magnetite nanoparticles embedded in a matrix of biomimetic HA, hence with great potentiality as biocompatible magnetic material. In the first step, $Fe(SO_4)$, $Fe_2(SO_4)_3$ and a strong excess of Tetrabutilammonium hydroxide (TBAOH), acting as surfactant, are refluxed in aqueous solution. This leads to the formation of magnetite nanoparticles, which, in the second step, are coated with a $Ca(OH)_2$ layer to induce the growth of HA directly on their surface, by successive reaction of $Ca(OH)_2$ with $HPO_4^{2-}$.

Two nanogranular samples have been collected, differing for the magnetite content of ~ 0.8 wt % and 4 wt.%. The as-prepared magnetite nanoparticles and the composite material have been investigated by X-ray diffraction, Fourier transform infrared spectroscopy and transmission electron microscopy. This analyses have allowed us to estimate the mean size of the magnetite nanoparticles (~ 6 nm) and to reveal the presence of hydroxyl groups on their surface. The hydroxyl groups hinder the intimate contact among the nanoparticles and promote the subsequent growth of the carbonate HA phase, featuring a nanocrystalline lamellar structure (platelets dimensions range between 10 and 70 nm). We have measured, by SQUID magnetometer, hysteresis loops at different temperatures in the 5-300 K range, the thermal dependence of the magnetization at different values of the applied magnetic field and the field-dependent isothermal and demagnetized remanence.

At T=300 K, both the as-prepared and the HA-coated magnetite nanoparticles are superparamagnetic. However, the magnetization relaxation process is dominated by magnetic interparticle interactions of dipolar nature, which have comparable strength both in the sample of as-prepared magnetite and in the two composite samples, with different magnetite content. In all the three samples, a low-temperature collective frozen magnetic regime is established below T ~ 20 K. These results indicate that the magnetite nanoparticles tend to form agglomerates in the as-prepared state, which are not substantially altered by the subsequent HA growth, coherently with the creation of strong hydrogen bonds among the surface hydroxyl groups.

# A scanning probe investigation of hydroxyapatite thin films enriched with magnetic nanoparticles for bone tissue engineering

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Magnetic biomaterials are gaining more and more interest in tissue engineering thanks to the possibility to magnetically activate cell mechano-transduction pathways and conditioning cell fate [1] In this study, hydroxyapatite (HA) enriched with magnetic nanoparticles (MNPs) have been deposited by Pulsed Plasma Deposition (PPD) technique and investigated for the first time by Scanning Probe techniques. Scanning Tunneling Microscopy and Spectroscopy (STM-STS) have been used to gain novel informations on the electronic surface states of the films. The STM analysis revealed micrometer-sized regions where electron conduction occurred, enabling a sub-nanometric lateral resolution of the surface morphology . Moreover, tunnel spectra showed the convolution of a mixed metal /semi-metal phase, suggesting the presence of conductive MNPs embedded homogeneously into the insulating HA matrix. Magnetic Force Microscopy (MFM) measurements revealed the existence of a magnetic signal contrast at scales comparable with the MNPs dimensions. These domains were acquired in the Lift-Mode, thus they were not related to topography but to genuine magnetic surface features.

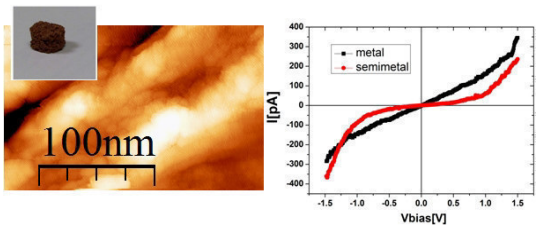


Figure 1: Left: STM topography of HA+MN sample (top inset image). Right: Tunnel Spectroscopy measurements showing mixed metallic + semimetallic contribution to tunnelling at room temperature.

[1] Russo, A. *et al. Eng Phys* **34**, 1287-1293 (2012)

# Direct measurement of the magnetocaloric effect in micrometric sheets

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The Magnetocaloric Effect is a promising way to develop more efficient and environmentally friendly energy conversion devices [1]. This effect is a temperature change in a magnetic material induced by an external magnetic field applied in adiabatic conditions.
In this work we present a new experimental setup, based on a non-contact temperature sensor, able to directly measure the magnetocaloric effect of thin samples (few micrometers). The direct measurement of the adiabatic temperature change of magnetocaloric foils and ribbons is fundamental to design innovative micro-solid state devices or for micro-structuring bulk samples. We show that this technique allows to reproduce good quasi-adiabatic conditions needed to pick up the absolute temperature variation in gadolinium sheet as thin as 27 µm. Heat transfer simulations of the measurement setup have been performed to confirm the experimental results and to predict the magnetic field pulse time-scale needed for reproducing good quasi-adiabatic conditions also in case of even thinner samples [2].
This technique may be a deft solution to measure directly other caloric effects (electrocaloric, barocaloric, elastocaloric): the absence of contact between sample and temperature sensor is a favourable condition in case of applications of high voltage or external pressure.

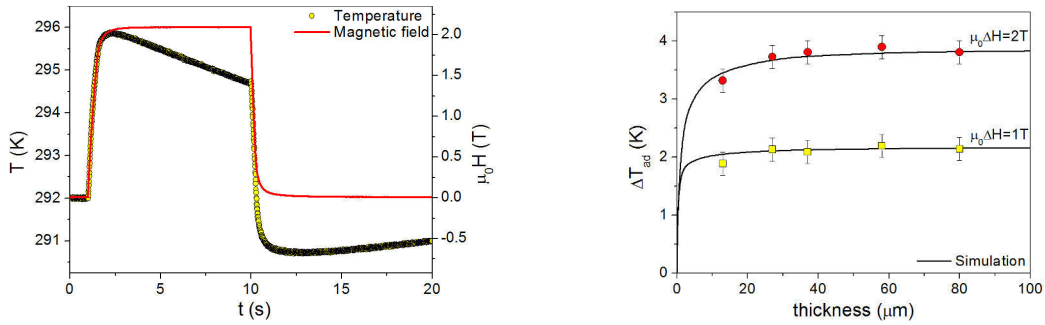


Figure 1: Left: Direct measurement of temperature variation of a gadolinium sheet (58 µm thick) both switching the magnetic field ($\mu_0$H=2T) on and off. Right: temperature variation of a gadolinium sheet as a function of its thickness ($\mu_0\Delta$H=1T and $\mu_0\Delta$H=2T).

[1] A. Smith et al. Adv. Energy Mater. 2 (2012) 1288
[2] F. Cugini et al. Rev. Sci. Instrum. 85 (2014) 074902

# Co and In doped $Ni_2MnGa$ multifunctional alloys for energy applications: a structural, magnetic and magnetocaloric study

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The vast family of Ni-Mn based Heusler alloys provides an extended playground of physical properties. The interplay between a reversible martensitic transformation (MT) and magnetically ordered states gives rise to a series of functional properties that can be exploited for developing innovative devices [1] which originate from the possibility to dramatically change the materials properties by an applied external stimulus, such as magnetic field, stress of pressure.
During the last decade, significant achievements have been obtained by introducing Co to the ternary Ni-Mn-Z compounds. Such quaternary full Heusler alloys show a metamagnetic martensitic transformation between a low moment martensite and a strongly ferromagnetic austenite: high values of giant magneto- and baro-caloric effects, giant magnetoresistance and magnetic superelasticity have been observed. For instance, giant magnetocaloric effect (MCE) with very high $\Delta T_{ad}$ values have been observed in several compositions of Ni-Co-Mn-In [2].
Furthermore, the remarkable values of magnetization discontinuity across the MT may be the key element for a new generation of energy-related devices, such as energy harvesters from dispersed heat sources [3] or from mechanical stresses[4].
Ga based quaternary Ni-Co-Mn-Ga Heuslers can be tuned to show both positive or negative magnetization change by proper compositional adjustments [5]. In a well defined compositional range they display a reverse metamagnetic transition which is associated to remarkable values of positive magnetic entropy change (inverse MCE), to high sensitivity of the MT to applied magnetic field and pressure (high values of $dT_C/dH$ and $dT_C/dp$) as well as high structural and magnetic discontinuities [6].
In this contribution we will review our findings on the role of In in the structural, magnetic and magnetocaloric properties of Ni-Co-Mn-Ga alloys: partial substitution of Ga with In allows to independently tune the magnetic and magnetostructural critical temperatures, emphasizing the figures of interest for applications and ultimately achieving promising values of adiabatic temperature change (up to 4 K in a 1.8T field span). We will show the MCE characterization both from direct and indirect methods, and we will discuss the non straightforward relation between the measured $\Delta S_{iso}$ and $\Delta T_{ad}$ values [7].
Starting from a thorough measurement analysis on an array of samples with different compositions, comprising magnetic, calorimetric, structural and under pressure measurements, we will discuss which properties are supposed to play a key role in the improvement of MCE.
Finally, we will highlight the possible correlations that exist between the magnetic and structural features of interest to the MCE with the hysteretic figures of the martensitic transition, a detrimental property which actually prevents the cyclic MCE operation in Heusler alloys.

[1] T. Graf, C. Felser, S. Parkin, Prog. Solid State Chem. 39, 1-50 (2011)
[2] J. Liu et al., Nature Mat. 11, 620 (2011)
[3] V. Srivastava et al., Adv. En. Mat. 1, 97-104 (2011)
[4] M. Kohl et al., Mat. Sci. Forum, 738-739, 411 (2013)
[5] S. Fabbrici et al., Acta Mater. 59, 412 (2011)
[6] F. Albertini et al., Mat. Sci. Forum 684,151 (2011)
[7] G. Porcari et al., Phys. Rev. B 85 024414 (2012)

# Magnetic and dielectric properties of cobalt ferrite/titania composites

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In order to develop materials with both magnetic and dielectric properties, recently a lot of researchers concentrate their work to process and study composite ceramics with both magnetic and dielectric phases. Cobalt ferrite Co $Fe_2O_4$ and $TiO_2$ are good candidates for this type of composites as they have good magnetic and dielectric properties respectively.

New cobalt ferrite/titania (CFO/TO) ceramics composites were prepared by conventional solid state reaction with a CFO/TO ratio ranging from 2 to 8. Composition, crystalline structure and microstructure of the sintered ceramic composite bodies were investigated and the phases content volume percentage were determined. Dielectric permittivity ( real part of permittivity and dielectric losses) and magnetic permeability (real part of permeability and magnetic losses) were measured at room temperature in a range of frequency from 100 Mhz-1 GHz. Dielectric and magnetic properties were analyzed as function of the microscopic structure (SEM analysis) and phase compositions (XRD analysis). The formation of the ternary compound (FCTO) was found in composites with the TO/CFO bigger than 3.

# Energy dissipation during Landauer erasure in sub-micrometric permalloy switches: magneto-optical measurements vs micromagnetic simulations

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It is well known that bistable nanomagnetic switches can be used to store information, associating each logic state to a different equilibrium orientation of the magnetization.
Here we address the question of the minimum energy required to change the information content of nanomagnetic switches consisting of elongated dots of permalloy, a crucial topic to face fundamental challenges of current technology, such as power dissipation and limits of scaling. The energy dissipated during a "reset to 1" operation, also known as Landauer erasure, was accurately measured at room temperature by vectorial magneto-optical measurements in large arrays of 10 nm thick Permalloy dots prepared by e-beam lithoghraphy and lift-off. Four different samples were investigated, where the longer axis D of the elliptical dots scaled down from about 1000 to 100 nm.
The experimental results show that in the case of the larger dots the dissipated energy is well above the theoretical Landauer limit of $k_B T \cdot \ln(2)$, while a value consistent with the above limit is achieved for the smallest dots. These experimental findings are corroborated by micromagnetic simulations where the Landauer erasure is performed on a single dot and the calculated energy dissipation averaged over many cycles. The simulations confirm that when D exceeds about 200 nm one observes significant deviations from the ideal macrospin behavior, because of inhomogeneous magnetization distribution and edge effects. These phenomena lead to an average dissipated energy that is appreciably larger than the Landauer limit, in agreement with the experimental findings.
This work was supported by the European Community (FP7/2007-2013) under Grant No. 318287 "LANDAUER" and by the MIUR under PRIN Project No. 2010ECA8P3 "DyNanoMag".

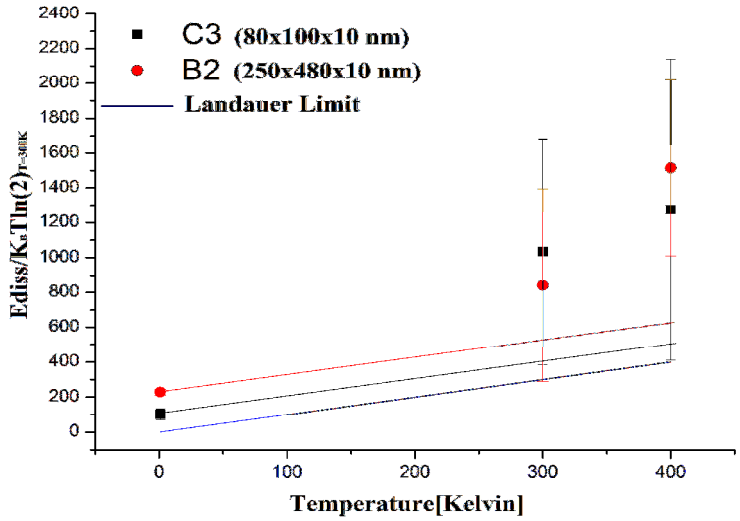


Fig. 1: Simulated values of the dissipated energy during a reset-to-one operation in Permalloy elliptical dots, as a function of the temperature for different dimension of the dots.

The zero temperature energy dissipation is due to finite time simulation.

# Magnetic properties of granular CoCrPt:$SiO_2$ thin films deposited on GaSb nanocones

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We report on the effect of microstructure on the magnetic properties of granular CoCrPt:$SiO_2$ films with weakly interacting magnetic grains deposited on pre-structured GaSb nanocones' templates fabricated by ion erosion technique. By tuning the irradiation conditions, nanocones' patterns of different cone size were prepared (from 28 to 120 nm in diameter and 32 to 330 nm high, respectively). The influence of the intergranular exchange coupling was also investigated by varying the $SiO_2$ content from 8 to 12 at. %. Deposition of CoCrPt:$SiO_2$ on samples with small nanocones leads to a close magnetic grain packing, which results in the formation of extended magnetic domains larger than the average distance between the GaSb cones. In contrast, on larger nanocones, the magnetic coating grows on the side-walls with large separation between neighbouring cones leading to magnetic single-domain regions, which are correlated to the underlying structure (Fig. 1). Magnetometry measurements indicate that both remanence and coercivity decrease with increasing cone size and/or $SiO_2$ content due to the combined effect of the angular distribution of the magnetic easy axis of the grains and the intergranular exchange coupling strength.

[1] D.K. Ball et al., Nanotechnology 25 (2014) 085703

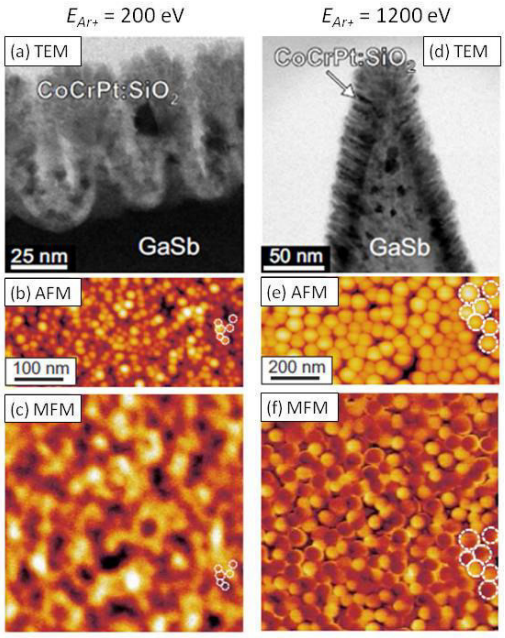


**Figure 1**. (a,d) Cross-sectional TEM, (b,e) AFM and (c-f) MFM images in the demagnetized state of the CoCrPt:$SiO_2$ coated nanocones prepared with ion energies of (a,b,c) 200 eV and (d,e,f) 1200 eV. The circles denote corresponding positions in the AFM and MFM images.

# The magnetic history of an assembly of Stoner-Wohlfarth particles

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We have developed a mathematical tool able to track irreversible processes in magnetic systems made up of an assembly of particles, each described by the Stoner-Wohlfarth model, and considering the role of local interaction fields $\boldsymbol{H}_i$. The response to alternating and rotating magnetizing fields has been investigated separately but, being possible to regard any applied field $\boldsymbol{H}_a$ vs. time history as a sequence of alternating and rotating episodes, one is able to track arbitrary field histories.

This vector problem is faced adopting the conventional "Slonczewski astroid": a tool permitting one to discuss the stability properties of the local magnetization $\boldsymbol{M}$, providing its two equilibrium angles $\vartheta\uparrow$ ("up") and $\vartheta\downarrow$ ("down"). On this background we have worked out a graphic representation of the system magnetic history (Fig. 1) that turns out to be an extension of the one developed for the Preisach model (PM), which is intrinsically scalar [1]. A "memory plane" with

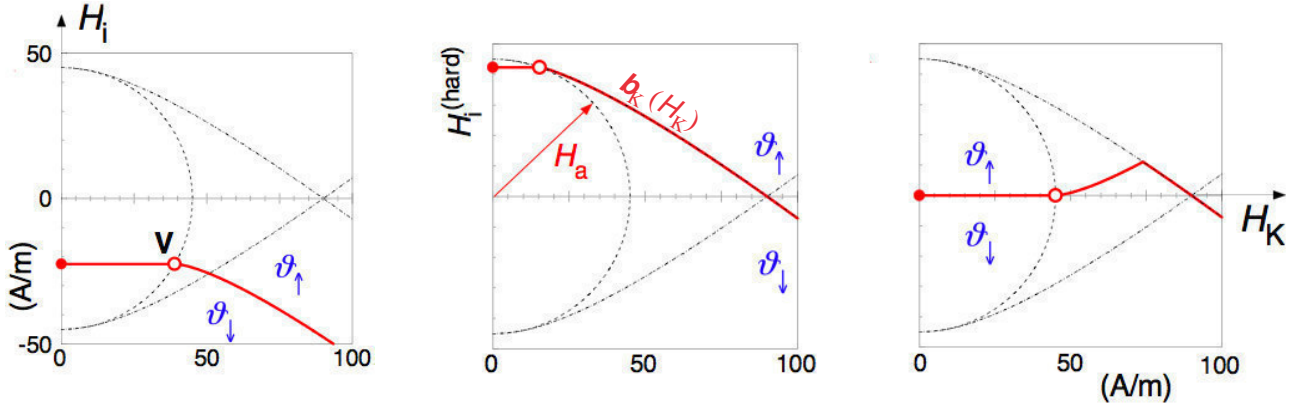


Fig. 1 Evolution, in the "memory plane", of the $\boldsymbol{b}_K(H_K)$ border line vs. the applied rotating field $H_a$. A sequence of three inversion angles for $\boldsymbol{H}_a$ gives rise to a partition of the $(H_K, H_i)$ plane in the two regions corresponding to the $\boldsymbol{M}$ equilibrium positions ($\vartheta\uparrow$ and $\vartheta\downarrow$).

coordinates $H_i$ and $H_K$ (the anisotropy field), and each $(H_K, H_i)$ point corresponding to a particle of the magnetic system, is introduced (Fig. 1). A strategy in dealing with hysteretic memory effects was envisaged working out an expression for a $\boldsymbol{b}_K(H_K)$ border (made up of a sequence of curved branches) that gives rise to a partition of the plane in two simply connected regions, corresponding to the two equilibrium positions ($\vartheta\uparrow$ and $\vartheta\downarrow$) for the local magnetization. Like to the PM, the evolution of the border with $\boldsymbol{H}_a(t)$ is able to track the system magnetic history. Contrary to PM, on the other hand, the knowledge of the border $\boldsymbol{b}_K(H_K)$ in the memory plane does not supply a complete description of the system magnetic configuration but only tells us, for all $(H_K, H_i)$ points of the plane, if $\boldsymbol{M}$ is aimed "up" ($\vartheta\uparrow$) or "down" ($\vartheta\downarrow$). Nevertheless, the non-local memory property of the system [2] is preserved, and one can neglect tracking the particles state one by one, so decreasing to a large extent the computational time.

Eventually, this approach can represent a suitable tool aimed at estimating the energy loss and entropy production in magnetic systems, and could help to envisage some kind of general mathematical strategy able to track the history of whatever magnetic system.

[1] I. Mayergoyz, *Mathematical Models of Hysteresis and Their Applications*. New York: Academic, 2003.
[2] G. Bertotti, *Hysteresis in Magnetism*, Academic Press (Elsevier), NewYork (USA), 1998.

# Spin-wave properties of IrMn/NiFe based spin-valves

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Brillouin light scattering (BLS) was exploited to study the effect of the exchange coupling (EC) at the interface between antiferromagnetic (AF) and ferromagnetic (FM) layers on spin-wave properties in spin-valves (SVs).

The stacking of the samples was Cu(5 nm)/IrMn($t_u$)/NiFe(5nm)/Cu(5nm)/NiFe(5nm)/IrMn($t_o$); $t_u$ and $t_o$ are the thicknesses of the AF IrMn ($Ir_{25}Mn_{75}$) underlayer and overlayer, respectively. Three different samples were studied: SVA, with $t_u$ = 10 nm, $t_o$ = 0 nm, SVB, with $t_u$ = 10 nm, $t_o$ = 6 nm, and a reference sample, SVR, with $t_u$ = $t_o$ = 0 nm, where just unpinned NiFe ($Ni_{80}Fe_{20}$) films are included. The samples were deposited by DC magnetron sputtering in a magnetic field of 400 Oe.

The EC strongly affects the SV magnetization process by inducing a bias field ($H_B$) on the pinned NiFe layer, that results in a shift of the NiFe loop along the measurement axis (fig. 1). BLS spectra were acquired by sweeping the applied field (H) over the upper branch of the hysteresis loop (from positive to negative saturation) and encompassing both the parallel (P) and antiparallel (AP) alignment of the NiFe layers.

In the saturated state, in SVA and SVB the frequencies of the two measured modes increase with respect to the ones in SVR, and their frequency difference depends on H orientation with respect to $H_B$ direction. At the transition from the P to the AP ground-state, the mode frequencies undergo an abrupt variation and the frequency modes dependence remarkably changes. The experimental frequencies are compared with those calculated by a theoretical model, based on the thin film formalism, that includes in a phenomenological way the effects of the EC at the IrMn/NiFe interface. For SVA, the accordance between experimental and theoretical frequencies is good in the P state, and larger differences are present in the AP state. In SVB, with two IrMn layers, larger discrepancies are found.

These results indicate that additional effects have to be included to describe the dynamic effects of the NiFe/IrMn coupling: different hypotheses will be presented and discussed.

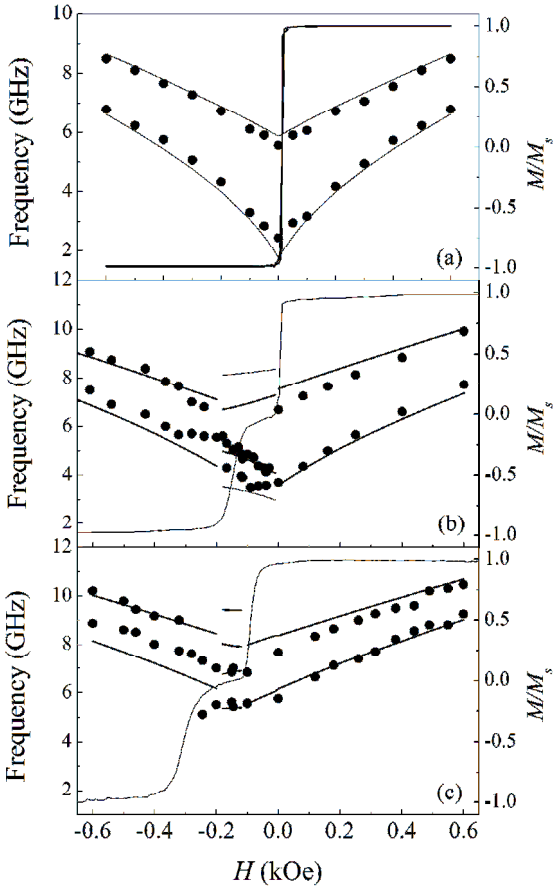


Figure 1: Spin-wave mode frequencies vs. H (full circles) and reduced magnetization loops (black line) for (a) SVR (b) SVA and (c) SVB samples. Black lines represent both the Stokes and anti-Stokes calculated frequencies.

# Two regimes of magnetization relaxation dynamics in $La_{0.66}Sr_{0.33}MnO_3$ films

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Hole-doped rare-earth manganites, like $La_{0.66}Sr_{0.33}MnO_3$ (LSMO), display exotic phenomena such as concurrent colossal magnetoresistance and half-metallicity which originate from the interplay of charge, spin, and orbital degrees of freedom [1]. The peculiar transport properties of LSMO thin films combined with the ferromagnetic order that persists up to about 350 K [2] render such system a most technologically attractive material for spin injection: the spin polarization at the Fermi level reaches about 100% for $T<T_{Curie}$.

The ultrafast manipulation of spin states in LSMO can be tested by state-of-the-art time-resolved pump-probe techniques. Previous studies by conventional pump-probe spectroscopy have given evidence of photoinduced effects in ferromagnetic manganites [3, 4].

The combination of static (time integrated) and dynamic (time resolved) spectroscopies may lead to the understanding of (i) the role of orbital and spin degree of freedom in metal-insulator transition, (ii) the relevant time-dependent non-equilibrium phenomena near the transition and (iii) the evolution from itinerant to localized behaviour when an external parameter (temperature, pressure, magnetic field) is varied.

We present time-resolved MOKE measurements from thin epitaxial films of $La_{0.66}Sr_{0.33}MnO_3$. We observe the dynamic magnetization response to femtosecond optical excitation as a function of different pump intensity and initial temperatures of the films. The samples were thoroughly characterized by advanced spectroscopy and magnetometry, including Synchrotron-radiation absorption spectroscopy (XAS), magnetic circular-dichroism (XMCD), core level photoemission (XPS), SQUID, MOKE and X-ray diffraction (XRD). The ensemble of data gave evidence of:

- Curie temperature of the epitaxial films well above room temperature ($T_c \sim 65°C$),
- good crystalline order of both the magnetic film and the substrate,
- surface cleanliness and preservation of the bulk stoichiometry.

The spin polarization of the surface layer was also measured by analysis of the ejected secondary electrons with a MOTT scattering electron-spin polarimeter.

The time-resolved MOKE measurements gave evidence of:

- A fast (few hundreds fs), though small (around 5%) electronic response. This feature was observed with high time-resolution, resolving its structure and pump intensity dependence.
- A strong decoupling between the electron-related magnetization dynamics and the effects due to magnetic and lattice excitations, with a partial recovery between the two regimes.
- A double exponential decay trend in the relaxation dynamics in the ps time-scale, that accelerates (shorter characteristic times) when approaching the FM-PM phase transition.

**References**

[1] Y. Tokura et al. J. Magn. & Magn. Mater. 200 1 (1999).
[2] K. Horiba et al. Phys. Rev. B 71, 155420 (2005).
[3] K. Matsuda et al. Phys. Rev. B 58, 4203 (1998).
[4] A.I. Lobad et al. Appl. Phys. Lett. 77, 4025 (2000).

# Heteroclinic tangle phenomena in nanomagnets subject to time-harmonic excitations

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One of basic operation on magnetic nanosystems used in magnetic and spintronics technologies is the application of external excitations, such as applied magnetic fields or injected currents, in order to move magnetization direction from one metastable state to another [1]. An important aspect of these processes is the nature and the time scale of the transient magnetization dynamics. In this work, we analyze transient evolutions of magnetization in nanomagnets subject to weak time-harmonic (AC) external fields or injected currents. More specifically, We analyze how the magnetization direction in a uniformly magnetized nanomagnet, initially tilted to an arbitrary direction, relaxes toward one of the coexisting AC-driven asymptotic regimes. It turns out that this transient dynamics has a chaotic character at moderately low power level. The chaotic and fractal nature of the transient AC is due to the phenomenon of heteroclinic entaglement which is produced by the combined effect of AC-excitations and saddle type dynamics [2]. The latter occurs at the top of potential barrier separating different metastable states. By using an analytical technique based on perturbation, and usually referred to as Melnikov function technique, we are able to derive analytical formulas which provide the values of critical applied fields and critical injected current necessary to create the heteroclinic entaglement. These critical values are expressed as function of frequency of excitation, of the direction and polarization of the applied fields, and of the direction of the spin-polarization. Then, by means of numerical simulations, we discuss how transient chaos is accompanied by the erosion of the safe basin around the stable regimes. This leads to a reduction of the stability range of the stable regimes with respect both deterministic as well as thermal perturbation [3]. Finally, implications of the this phenomenon on the microwave and thermal assisted switching are pointed out.

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[1] G.Bertotti, I. Mayergoyz, C. Serpico, Nonlinear Magnetization Dynamics in Nanomagnets, Elsevier 2009
[2] S. Wiggins, Introduction to Applied Nonlinear Dynamical Systems and Chaos, Springer 2003
[3] J.M.T. Thompson, Proc. R. Soc. Lond. A 421, 195 (1989)

# Static and Dynamic Properties of Magnetic Antivortices in Asteroid-Shaped Permalloy Nanomagnets

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Patterned nanomagnets display unconventional spin configurations like vortex, anti-vortex, bubble, which have unique static and dynamic properties. Such micro-magnetic structures are potentially applicable to ultrafast memory, rf oscillators and detectors [1]. Studies on magnetic thin films containing vortex structures exhibit interesting behavior under external field and/or current bias like polarity switching, core displacement and core gyration with high frequencies inside the nanomagnet. In this study, we report on our investigation of stable anti-vortex formation conditions and the subsequent magnetic field/dc current driven excitations in $2x2\mu m^2$ permalloy based asteroid geometry devices which exhibit an anti-vortex pair nucleation at the center [2]. Magnetic Force Microscopy analysis shows that the antivortex pair can be rotated around the center by an external magnetic field. We obtain a high frequency (GHz) signal measured via anisotropic magneto-resistance effect (AMR) under constant dc current-bias (see Fig 1, right panel) which triggers antivortex pair gyration around the center of the device through spin transfer torque. We study the dynamic response of the structure as a function of current and field to assess utilization of the device as a practical on-chip microwave oscillator.

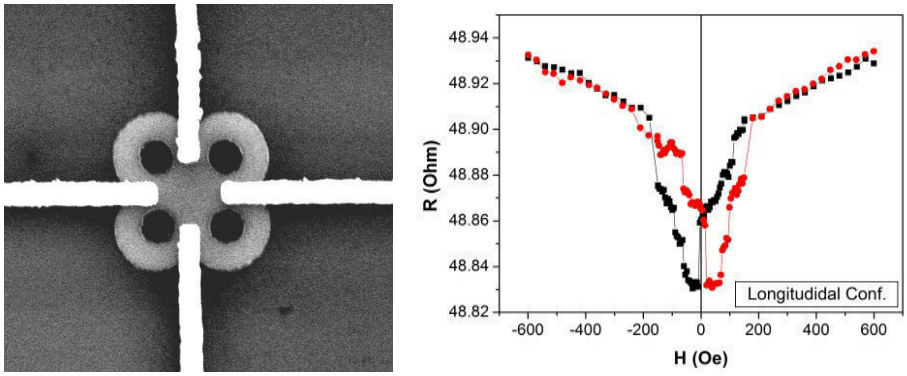


Figure 1: (left) SEM image of asteroid showing the four electrical contact; (right) Room-temperature electrical resistance behaviour of a single asteroid.

[1] Fert, A et al. Skyrmions on the track. *Nat Nano* **8,** 152–156 (2013). 2.V. S. Pribiag et al. Nature Phys. 3, 498-503 (2007)
[2] C. Ragusa et al. IEEE Trans. on Magn. 47 (2011) 2498

# Resonant spin-wave modes in trilayered magnetic nanowires studied in the parallel and antiparallel ground state

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Brillouin light scattering (BLS) has been exploited to study the field dependence resonant spin-wave modes in layered NiFe(30nm)/Cu(10nm)/NiFe(15nm)/Cu(10nm)/NiFe(30nm) nanowires (NWs) of rectangular cross-section, 150 nm wide and spaced laterally by 400 nm. The major and minor longitudinal hysteresis curves have been measure by magneto-optical Kerr-effect technique with the applied field parallel to the NWs length. The BLS spectra recorded by varying the magnetic field encompassing the parallel (ferromagnetic) and antiparallel (antiferromagnetic) alignment of the middle stripe magnetization with respect to those of the outermost ones. In the antiferromagnetic state the mode frequencies are different from those of the ferromagnetic one, and this is explained in terms of the different modes localization across the width and the layered structure. More specifically, at the ferromagnetic-to-antiferromagnetic state transition field and vice versa, the mode frequencies change abruptly. Moreover, those detected in the antiferromagnetic state have roughly constant values vs the intensity of the applied magnetic field either along the major and minor hysteresis curve, while in the ferromagnetic case they monotonically evolve as a function of the applied magnetic field. The BLS measurements along the minor M-H loop allow the study of resonant modes properties at remanence when the middle stripe magnetization is opposite to that of the outermost NWs. The experimental results (frequencies vs magnetic field strength) have been successfully interpreted in the whole range of magnetic field investigated by means of a microscopic (Hamiltonian-based) theory, which has been extended here to the case of non-parallel magnetic ground states.

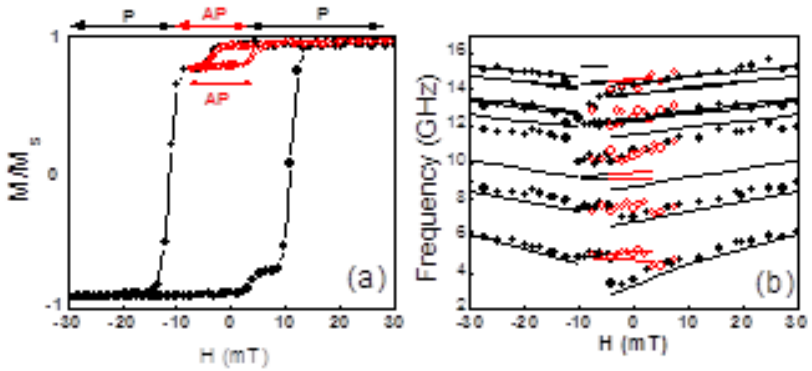


Figure 1: (a) Major (open points) and minor (full points) normalized MOKE hysteresis loop for the layered NWs array measured with the external field applied along the NW long axis. (b) Dependence of the magnetic eigeinmode wave frequency on the applied field strength on sweeping the applied magnetic field along the upper branch of the major (open point) and minor (full points) hysteresis loop.

# On the energy concentration factor in a binary magnonic crystal

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A quantitative estimation of the degree of localization of collective modes in binary magnonic crystals (BMCs) is given by recalling the definition of the energy concentration factor ($CF_{PHC}$) in a photonic crystal (PHC) expressed by the energy ratio [1]

$$CF_{PHC} = \frac{\int_{\varepsilon_H} \varepsilon(\mathbf{r})\left|\mathbf{E}(\mathbf{r})\right|^2 d\mathbf{r}}{\int_{V_{Cell}} \varepsilon(\mathbf{r})\left|\mathbf{E}(\mathbf{r})\right|^2 d\mathbf{r}} \tag{1}$$

where $\varepsilon(\mathbf{r}) = \varepsilon(\mathbf{r}+\mathbf{R})$ is the periodic non-uniform permittivity with $\mathbf{R}$ the translation vector, the subscript $\varepsilon_H$ denotes the highest permittivity region, $\mathbf{E}(\mathbf{r})$ is the spatially varying electric field associated to the electromagnetic mode fulfilling Bloch's theorem and $V_{cell}$ is the volume of the unit cell. The BMCs are composed by a periodic arrangement of cylindrical cobalt (Co) nanodots of 310 nm of diameter completely embedded into a permalloy (Py, $Ni_{80}Fe_{20}$) continuous magnetic film having thickness of 16 nm. The lattice constant of the two-dimensional BMC is 600 nm and the external magnetic field $\mathbf{H}$ is applied along the *y* direction in the plane of the system. In analogy with the definition given in Eq.(1) for a PHC, it is introduced the notion of the energy concentration factor $CF_{BMC}$ for periodic BMCs. In a general form, $CF_{BMC}$ can be written down as [2]

$$CF_{BMC} = \frac{\int_{H_{int}^H} U_{int}(\mathbf{r})\, d\mathbf{r}}{\int_{V_{Cell}} U_{int}(\mathbf{r})\, d\mathbf{r}}, \tag{2}$$

where $U_{int}(\mathbf{r})$ is the internal energy density of the collective mode proportional to the internal field and the region where the internal field is higher is denoted with $H_{int}^H$. The ratio in Eq.(2) measures the fraction of energy stored by the collective localized mode in the high-internal field region. The role of $\varepsilon(\mathbf{r})$ is replaced by the non-uniform internal field $H_{int}(\mathbf{r}) = H + H_{dem}(\mathbf{r})$, where $H_{dem}(\mathbf{r})$ is the demagnetizing field and $H_{int}(\mathbf{r}) = H_{int}(\mathbf{r}+\mathbf{R})$. The inhomogeneity of the internal field which influences the degree of mode localization can be set on equal footing with the non-uniform permittivity which gives a measure of how the electric field of the electromagnetic mode is affected by the dielectric medium. The collective mode in a 2D periodic BMC is characterized by an oscillating periodic dynamic magnetization $\delta\boldsymbol{m}(\mathbf{r})$ (in place of $\mathbf{E}(\mathbf{r})$) depending on the Bloch wave vector $\mathbf{K}$ (along the *x* direction). It can be shown that $CF_{BMC}$ strictly depends on the contrast between the saturation magnetizations of Co and Py. A numerical estimation at the center of the Brillouin zone at $H = 500$ Oe gives $CF_{BMC} = 9\%$, a low value due to the weak variation of $H_{int}(\mathbf{r})$.

This work was partially supported by MIUR-PRIN 2010-11 Project2010ECA8P3 "DyNanoMag".

[1] J.D. Joannopoulos, S.G. Johnson, J.N. Winn, R.D. Meade, Photonic Crystals: Molding the Flow of Light (Princeton University Press, Princeton, 2008)
[2] R. Zivieri et al. Photon. Nanostruct: Fundam. Appl. 12 (2014) 387

# Metamaterial description of perpendicularly magnetized 2D antidot lattices

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A metamaterial description of collective modes in 2D antidot lattice (ADLs) perpendicularly magnetized has been performed. ADLs are composed of circular nanoholes of diameter $d$ = 200 nm embedded into a CoFeB film having thickness of 41 nm. The analysis of collective modes has been carried out by means of a micromagnetic method, named Dynamical Matrix Method (DMM). The mode propagation is studied placing an external magnetic field **H** along the $z$-axis and the Bloch wave vector **K** is parallel to the $x$-axis. The aim of this study is to describe in terms of effective properties the spin dynamics in perpendicularly magnetized ADLs [1] by extending the simple rules on the effective wavelength and on the effective wave vector that were found for in-plane magnetized ADLs and their dependence on the corresponding Bloch quantities [2,3]. From the inspection of spatial profiles of collective modes it is possible to identify a characteristic wavelength which is commensurable with the periodicity $a$ of the system. In the 2D periodic magnetic system the collective excitations are supposed to fulfill the Bloch rule $\delta\boldsymbol{m}(\boldsymbol{r}+\boldsymbol{R}) = \delta\boldsymbol{m}(\boldsymbol{r})\, e^{i\boldsymbol{K}\boldsymbol{R}}$, where $\delta\boldsymbol{m}(\boldsymbol{r})$ is the dynamic magnetization and $\boldsymbol{R}$ is the in-plane lattice vector. As an example, we show in Fig.1 the spatial profiles of two modes at the border of the third Brillouin zone (3BZ) and of the fourth Brillouin zone (4BZ). In particular we show for the Damon-Esbach-like (DE) modes (the main propagating modes of the system) that the effective wavelength ($\lambda_{eff}$) is three times the Bloch wavelength ($\lambda_B$) at the border of the 3BZ and $\lambda_{eff}$ is two times $\lambda_B$ at the border of the 4BZ.

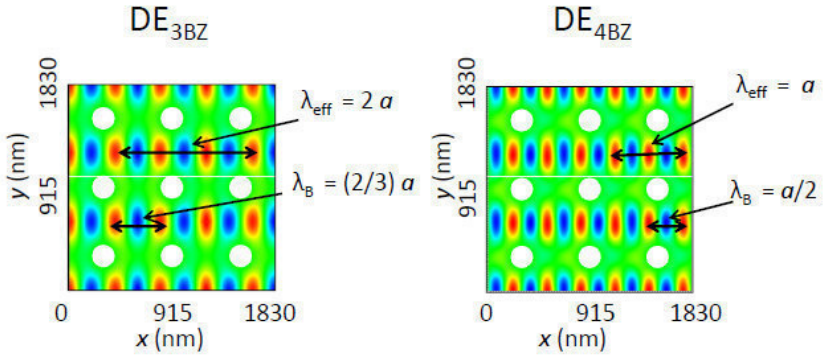


Figure 1: Calculated spatial profiles of $DE_{3BZ}$ and $DE_{4BZ}$ in 3×3 primitive cells, respectively according to DMM. The effective wavelength $\lambda_{eff}$ and the Bloch wavelength $\lambda_B$ are indicated.

Also for this kind of magnonic crystals, looking at the spatial profiles of magnonic modes depicted in Fig.1, it is possible to define an effective wavelength $\lambda_{eff}$ corresponding to the distance between two maxima (or two minima) of the collective mode profile and equal either to $2a$ or the $a$. The effective wavelength is directly related to the scattering of collective modes at the border of the holes.

This work was partially supported by MIUR-PRIN 2010-11 Project2010ECA8P3 "DyNanoMag".

[1] P. Malagò et al., "Effective properties of perpendicularly magnetized 2D antidot lattices" in preparation
[2] R. Zivieri and L. Giovannini Metamaterials 6 (2012) e126
[3] R. Zivieri and L. Giovannini Photon. Nanostruct: Fundam. Appl. 11 (2013) 191

# A micromagnetic study of spin wave eigenmodes excited by spin transfer torque in circular nanopillars: influence of Oersted field and lateral size

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It is well known that a spin-polarized current can excite persistent dynamics in nanopillars once it overcomes a critical threshold, thanks to the energy balance between the Spin Transfer Torque (STT) and intrinsic damping. Under the application of a sufficiently strong external field, the precession occurs around the local energy minimum defined by the magnetic field direction.

In this paper we present the results of a micromagnetic study of the low-amplitude, linear, eigenmodes excited by STT in circular Permalloy nanopillars, 5 nm thick, having a diameter of either 100 nm or 300 nm. Both in-plane and out-of-plane externally applied fields are considered, with emphasis given to the effect of the Oersted field (OeF) on the frequency and spatial symmetry of the excitations. In the case of an in-plane applied field, the main excited mode is localized at the dot edges, where it oscillates out-of-phase (in-phase) if the OeF is considered (neglected). The out-of-phase mode is at slightly larger frequency than the in-phase one, due to the exchange energy contribution. For the out-of-plane case, instead, the main mode excited taking into account the contribution of the OeF is an orthoradial mode with azimuthal number l=1 and zero amplitude in the center of the dot. This is completely different from the fundamental mode with maximum amplitude in the dot center that the current would excite, at an appreciably lower frequency, neglecting the presence of the OeF. Therefore, it turns out that inclusion of the OeF has a major impact on the output of simulations, because it modifies the symmetry of the excitation and the specific subset of eigenmodes activated by the injected current. This findings make it clear that simplistic models where the OeF contribution is ignored are not suitable to reproduce neither the frequency nor the spatial symmetry of the low-amplitude eigenmodes and this is relevant in view of a detailed understanding of experiments.

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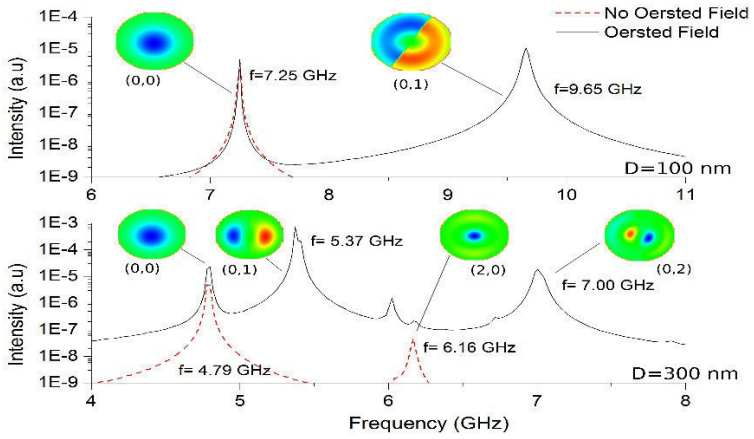


Fig. 1 Simulated eigenmodes spectra excited by STT in a Py pillar under the application of a perpendicular field. Solid (dashed) line spectra refer to the case where the OeF is considered (neglected) in the simulations. The spatial profiles of the main eigenmodes are shown in the insets.

# Chemical Physical and Magnetic Characterization of iron-rich fired clays

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Many studies of ancient pottery concern composition, firing, manufacturing methods and technological variability. Information on these issues helps explaining the nature of the raw materials used in the manufacture, the possible origin, and the production technology. The firing process involves the breakdown of some phases and the formation of new ones. The growth of new phases is related to the temperature of the firing and the composition of microsites where the phases started to grow. In this framework in a previous work[1] chemical physical (TEM, SEM, XRD, EPR, NMR) study of the modification induced by firing on an illite-rich clay from Deruta was carried out. In particular clays were fired in an oxidizing atmosphere at different temperatures, namely, 600, 700, 800, 900, 1000, and 1100 °C, in a kiln of a ceramist's workshop. This investigation evidenced that dehydroxylation occurs between 600 and 700 °C, whereas between 800 and 900 °C, the aluminum in octahedral sites disappears, due to the breakdown of the illite structure, and all iron was oxidized to $Fe^{3+}$. In samples fired at 1000 and 1100 °C iron clustering was observed as well as large single crystals of iron with the occurrence of ferro or ferrimagnetic effects. In this work, we present the result of a magnetic investigation performed by means of a SQUID magnetometer, to study the field and temperature dependence of magnetization. The M *vs* H curves recorded at 5 K and 300 K clearly showed that up to 600 °C the magnetic behavior of the clays is dominated by the antiferromagnetic properties of oxo-hydroxides. Increasing the temperature above 1000 °C, the formation of ferro(ferri)magnetic phases (i.e magnetite or maghemite) was observed. At 900 °C the ZFC-FC curves evidenced a blocking process typical of an assembly of very weakly interacting single-domain magnetic particles with a distribution of blocking temperatures, probably related to a distribution of size[2]. ZFC-FC measurements indicated that the increase of annealing temperature (i.e. 1000, 1100 °C) induces an increase of particle size and particle size distribution, in agreement with the previous chemical physics characterization. The results were used to determine by comparison the firing temperature of an ancient pottery founded in Deruta. In fact, the disappearance of the signal of aluminum in an octahedral environment suggested that the firing temperature of the pottery was higher than 900 °C. On its turn, the magnetic investigation, clearly highlighted the presence of ferromagnetic phases compatible with a clay annealed at temperature not higher than 1000 °C. This combined NMR/magnetic approach allowed us to estimate the firing temperature of the sample in the range 900- 1000°C.

1. F. Presciutti, D. Capitani, A. Sgamellotti, B.G. Brunetti, F. Costantino, S. Viel, and A. Segre. *Electron Paramagnetic Resonance, Scanning Electron Microscopy with Energy Dispersion X-Ray Spectrometry, X-Ray Powder Diffraction, and NMR Characterization of Iron-Rich Fired Clays*. *J. Phys. Chem. B* **109,** 22147–22158 (2005).

2. D. Peddis, C. Cannas, G. Piccaluga, E. Agostinelli, and D. Fiorani. *Spin-Glass-like Freezing and Enhanced Magnetization in Ultra-Small CoFe2O4 Nanoparticles*. *Nanotechnology* **21,** 125705 (2010).

# Teaching Nanomagnetism: Peer Education By E- learning Platform

G. Righini[1], V. Abiuso[2], S. Laureti[1], G. Varvaro[1], E. Agostinelli[1], S. Rossignoli[2], L. Saccoccio[2], A. Tiscioni[2], B. Tonetto[2], R. Moncado[2] and D. Peddis[1]

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If magnetism is one of the most difficult subject in science, according to Encyclopedia Britannica, nanomagnetism is even a more complex one. In fact, on entering the nanometer-scale regime the magnetic properties of condensed matter show substantial differences with respect to the bulk state, leading to new physical properties. Among nanostructured magnetic materials, nanoparticles (NPs) are unique complex physical objects. Magnetic NPs are important in ferrofluid technology, catalysts, color imaging, and biomedicine (magnetically guided drug delivery and hyperthermic treatments). Furthermore, iron oxide nanoparticles (e.g. $Fe_3O_4$, $\gamma$-$Fe_2O_3$) play an important role in nature, being commonly found in soils and rocks; they are also important in several ways for the functioning of living organisms[1]. Despite their extraordinary range of applications, the fascinating physical chemistry of magnetic nanoparticles is totally absent in the teaching programs of physics and chemistry in secondary schools. In this framework, a collaboration between scientists working at ISM - CNR and teachers working at Liceo Scientifico G Peano (Monterotondo, RM), generated an experimental teaching project devoted to set up an interdisciplinary didactic route to teach chemical physics of nanostructured magnetic materials in the fourth and fifth year of the secondary school. As didactic methodology a blended learning approach will be used: regular lessons and experimental activities will be supported by an e-learning platform based on Moodle (Moe), allowing a strong interaction among teachers, students and scientists. The Moe platform delivers a powerful set of learner - centric tools and collaborative learning environments, allowing to set up a peer education program. The recruited students will by trained in chemical physics properties of magnetic NPs as well as in communication skills. In particular, lectures on supermagnetism[2] , chemical synthesis of nanoparticles and main features of moodle e-lerning platform will be given. Then, two experimental activities focused on chemical synthesis of NPs will be proposed: ferromagnetic and antiferromagnetic particles will be prepared by self combustion[3] and co-precipitation process (i.e ferrofluids), highlighting for each experiment the most important physical and chemical issues. In order to reinforce the interdisciplinary nature of the project, some philosophical issues related to the physical chemistry of nanostructures will be given, too. As an example, the philosophical evolution of the concept of surface will be discussed, aimed at highlighting the key role of the surface in nanostructured materials and nanoparticles[4,5]. Armed with these skills, each student will become peer educator and then engages their peers in conversations about the issue of concern, seeking to improve the experiments. The intent is that the student community will learn and teach at the same time the physical chemistry of magnetic nanoparticles. In this framework 20-30% of the students (group A) will be encouraged to deepen some experimental or theoretical issues and for these students a stage at the ISM-CNR is planned Mimicking the peer review process driving the scientific production in experimental science, the remaining 60% of the students (group B), will peer review the work of the A group, to improve the scientific quality of their work.

1. D. Peddis. in *Magn. Nanoparticle Assem.* (Trohidou, K. N.) **7,** 978–981 (Pan Stanford Publishing, 2014).
2. S. Bedanta, and W. Kleemann.. *J. Phys. D. Appl. Phys.* **42,** 013001 (2009).
3. C. Cannas, D. Peddis et al *J. Nanoparticle Res.* **8,** 255–267 (2006).
4. E. Paparazzo, *Surf. Interface Anal.* **38,** 357–363 (2006).
5. E. Paparazzo.*Nat. Mater.* **2,** 351–353 (2003).

# Finite element simulation to investigate the effects of the ferromagnetic materials characteristics in linear magnetic actuator

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**Abstract:** In this paper we investigate the influence of the material characteristics on the electromagnetic behaviors in a linear actuators. In particular, using specific customized tools , we analyze several soft ferromagnetic materials with different heat treatments, considering also the eddy currents phenomena and the effect of the hysteresis loop. The goal is to adapt the material magnetic proprieties in each electromagnetic device, using advanced FEM software considering the complete electromechanical behavior and energy consumption.

**Key words:** electromagnetic actuators, FEM simulation, heat treatment, eddy currents, hysteresis loop, energy consumption.

# Quantum effects and spin dynamics in open antiferromagnetic rings: A $^1$H NMR study of Cr8Zn

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The problem of the spin dynamics evolution at the level crossing in molecular clusters, is of fundamental interest. Since Nuclear Magnetic Resonance (NMR) has been proved to be a very useful technique to study the hyperfine interactions and spin dynamics, we performed $^1$H NMR measurements on the antiferromagnetic molecular ring $Cr_8Zn$ as a function of the external magnetic field (1<H<8T) at low temperature (T=1.7K). Theoretical calculations allow to calculate the energy levels and to estimate the crossing magnetic fields corresponding to the first and second ground state level crossings, that resulted (for H parallel to a axis of the crystal) $H_{c1}$=2.2 and $H_{c2}$=6.9T, respectively, and to the first excited states crossing, $H_{ces}$=4.4T[1].

The NMR spin-lattice relaxation rate, $1/T_1$, as a function of the external magnetic field displays a dramatic enhancement when the magnetic field reaches $H_{c1}$=2.2T ($S_T$=0 → $S_T$=1), and also a reduced (in height) maximum around the second crossing field $H_{c2}$=6.9T ($S_T$=1 → $S_T$=2), due to the inelastic term which reflects a direct energy exchange among nuclei and electrons. Far from level crossing conditions, the nuclear relaxation rate appears to be dominated by the quasi-elastic component of the spin-lattice relaxation rate, in good agreement with theory [2,3]. From the analysis of the transverse nuclear magnetization relaxation curve we observed for the first time a field-dependent wipe-out effect, by plotting $M_{xy}(0)/H$ as a function of the external magnetic field, with the same model used for temperature dependent wipeout [4]. According to our analysis the origin of the wipe-out effect is in the enhancement of the relaxation rates, $1/T_1$ and $1/T_2$. Finally, the low temperature $^1$H NMR spectra display an increase of the line width by increasing the field (until 8 Tesla) at constant T=1.7K, because of the increase of the average electronic magnetization value.

[1] A. Bianchi et al. Phys. Rev. B 79 (2009) 144422
[2] E. Micotti et al. Phys. Rev. B 72 (2005) 020405(R)
[3] A. Cornia et al. Europhys. Lett 50 (2000) 88
[4] M. Belesi et al. Phys. Rev. B 72 (2005) 014440

# Spin dynamics in highly processable Lanthanide Single-Molecule Magnets with tetraazaporphyrin ligands

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In the last decades Single Molecule Magnets (SMM) have been envisaged as the future functional units of quantum computing and molecular spintronics devices [1] and of high density magnetic memories [2]. The most promising candidates for these applications are Lanthanide-based double deckers (DD), characterized by very high zero field splittings of the J ground state manifold arising from the high magnetic anisotropy [3]. This assures a low blocking temperature of the molecular magnetization along the anisotropy axis and long magnetization relaxation times, following a typical activated behaviour on increasing temperature (T). Few years ago the record barrier of 800-900 K, between the ground ($J_z$=+/-6) and the first excited ($J_z$=+/-5) states were detected in Terbium Phthalocyanine ($TbPc_2$) by means of Nuclear Magnetic Resonance (NMR) [4], and a correlation time of the electronic spin fluctuations $\tau_c$ above 1 μs at liquid nitrogen T was derived, evidencing that these SMM are appealing as spintronics logic units. However the poor solubility and stability in the gas and liquid phase of these molecules hinders their organization in arrays suitable for the development of future devices.

Very recently other DD have been developed at the aim of improving anchoring on substrates, stability, processability and solubility with respect to $TbPc_2$. Hereafter we present in particular spin dynamics studies of novel DD Terbium complexes with octaethyltetraazaporphyrin (OETAP) ligands, which are more easily processable for future spintronics applications since they are highly soluble in organic solvents and can even be sublimed by using relatively mild conditions. NMR spin dynamics studies in these materials show that, similarly to $TbPc_2$, $\tau_c$(T) is characterized by a high T activated trend and by a low T tunneling regime involving fluctuations within the double degenerate ground-state. In particular, in $Tb(OETAP)_2$ a high barrier of the order of 480 K is found proving that these SMM are promising candidates for future applications in devices [5]. The study of the dynamics by means of $^1$H NMR is hindered over a few tens of Kelvin degrees around 50 K, where the relaxation is too fast. In order to overcome this problem and to complement the information on spin dynamics obtained by means of NMR, μSR (muon spin relaxation) measurements in longitudinal field have been recently performed and will be presented and discussed.

[1] L. Bogani and W. Wernsdorfer, Nat. Mater., (2008) 7, 179.
[2] D. Gatteschi and R. Sessoli, Angew. Chem., Int. Ed., (2003) 42, 268.
[3] N. Ishikawa, M. Sugita, T. Ishikawa, S. Koshihara, Y. Kaizu, J. Am. Chem. Soc. (2003) 125, 8694.
[4] F. Branzoli, P. Carretta, M. Filibian, G. Zoppellaro, M.J. Graf, J. R. Galan-Mascaros, O. Fuhr, S. Brink, and M. Ruben, J. Am. Chem. Soc. (2009) 131, 4387.
[5] N. Giménez-Agulló, C. Sáenz de Pipaón, L. Adriaenssens, M. Filibian, M. Martínez-Belmonte, E. C. Escudero-Adán, P. Carretta, P.Ballester and J. R. Galán-Mascarós, Chem. Eur. J. (2014) 20, 12817.

# NMR investigation of Er(III)-polyoxometalate single molecule magnet

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In the last fifteen years single molecule magnets (SMMs) have been extensively studied for their fascinating low-temperature quantum properties such as quantum tunneling of the magnetization [1], decoherence [2] or quantum entanglement between distinct cores [3] and also for their possible groundbreaking technological applications, for instance quantum information processing [4]. In this framework, many systems of this kind, consisting in polynuclear homo- or hetero-complexes formed by magnetic ring and clusters of metal ions coupled by exchange interactions, with high-spin ground states, have been synthesized. In recent years a new class of compounds have attracted interest, since the SMMs properties have been found also in "double-decker" structures containing only one lanthanide (Ln) trivalent ion (such as phthalocyaninatolanthanide complexes [5] and $Na_9[Ln(W_5O_{18})_2]\cdot xH_2O$) [6]. Here we investigated the magnetic properties and the spin dynamics of the derivative containing Er(III) ion (referred as $ErW_{10}$) [6] which is characterized by a strong uniaxial magnetic anisotropy as displayed by previous measurements of susceptibility with magnetic field applied parallel and perpendicular to the axis of the system [7]. In particular we studied $ErW_{10}$ through $^1H$ Nuclear Magnetic Resonance (NMR) and Muon Spin Relaxation (MUSR) techniques at different magnetic field applied as a function of temperature in the range $0.02K<T<290K$, and as a function of the external longitudinal magnetic field at constant $T=0.05K$. The main features highlighted by NMR investigation are: (i) an extreme slowing down of the magnetization signaled by the progressive increment of the nuclear spin-lattice relaxation rate (NSLR, $T_1^{-1}(T)$) on decreasing the temperature with a possible peak around 25÷40K and the line–broadening observed in the $^1H$ absorption spectra; (ii) a very strong wipe-out effect [8], caused by the shortening of the relaxation times, below 80K, which prevents the detection of the signal given by the fast-relaxing nuclear spins around the temperature of the peak. The difficulty to single out the exact location of the peak at different applied fields, has been overwhelmed by complementary MUSR measurements which can detect also very fast relaxation, allowing us to have a thorough picture of the system spin dynamics at low temperature.

[1] J. R. Friedman et al. Phys. Rev. Lett. 76 (1996) 3830
[2] S. Carretta et al. Phys. Rev. Lett. 98 (2007) 167401
[3] W. Wernsdorfer et al. Nature (London) **416**, (2002) 406
[4] F. Troiani et al. Phys. Rev. Lett. 94, (2005) 207208
[5] F. Branzoli et al. J. Am. Chem. Soc. (2009) 131, 4387
[6] M. A. AlDamen et al. Inorg. Chem. 48 (2009) 3467
[7] F. Luis et al. Phys. Rev. B 82 (2010) 060403R
[8] M. Belesi et al. Phys. Rev. B 72 (2005) 014440

# Effective magnetic moment in cyclodextrin-polynytroxides

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Among persistent nitroxyl radicals (nitroxides), those having cyclic structure like 2,2,6,6.tetramethylpiperidine-1-oxyl (TEMPO), have found particularly appealing for advanced diagnostic techniques like Electron Spin Resonance (ESR) and by Magnetic Resonance Imaging (MRI) techniques [1,2]. Thanks to their low toxicity nitroxides can be used as MRI-contrast-agent in higher concentration as respect to the usually-adopted gadolinium and dysprosium complexes which, unfortunately, are more effective due to their higher magnetic moment. Therefore, in order to be competitive, nitroxides must be combined in poly-radical structures to increase the total magnetic moment carried per molecule. In this scenario an interesting complex can be obtained by functionalizing cyclodextrin (CD) molecules with TEMPO radicals (s=1/2) [3]. CDs are macrocyclic oligosaccharides which find many applications (i.e. as drug delivery) due to their natural predisposition to form host-guest complexes with other molecules and their very low toxicity. In view of possible applications of such materials as MR or ESR imaging sensor, the knowledge of the magnetic moment carried per formula unit is fundamental.

In this work we present the magnetic properties of mono- and hepta-TEMPO functionalized β-CD by DC-SQUID magnetometry. We found that the low temperature magnetization of the mono-TEMPO CDs is well reproduced by an independent spin-1/2 model (see Figure 1). Instead, in the case of hepta-TEMPO CDs the low temperature magnetization is well below the values expected for independent s=7/2 spins. Relevant intra-molecular first and second neighbours spin–interactions were taken into account in a Heisenberg Hamiltonian [4] by considering three different possible configurations of the seven interacting radicals [5]. As main result we found that the regular heptagonal symmetry suggested by the β-CDs shape must be somehow distorted in order to reproduce the experimental magnetization and justify an effective magnetic moment of about 4.2 μB/f.u. instead of the expected value of 7.9 μB/f.u.

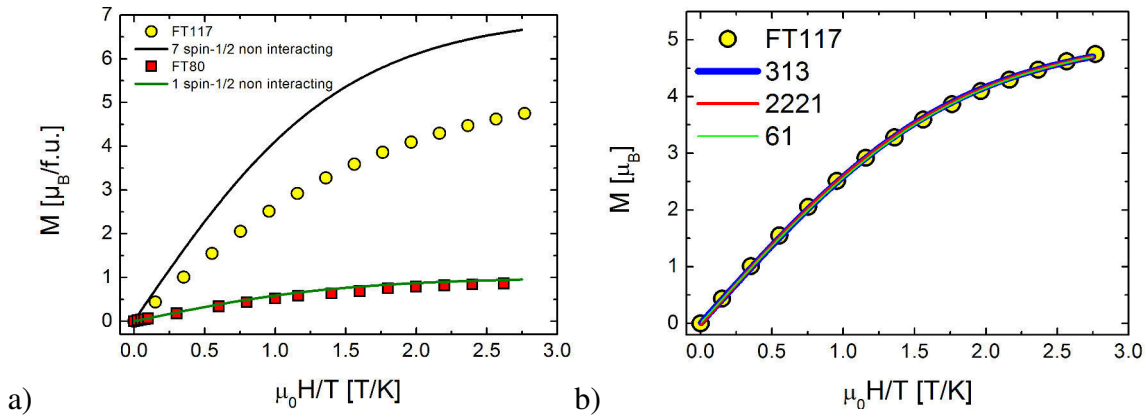


**Figure 1**: (a) mono-TEMPO CDs (FT80) and hepta-TEMPO CDs (FT117) magnetization data at T=2K compared with non-interacting spin models. (b) hepta-TEMPO CDs (FT117) magnetization data fitted by spin interacting model set up for three different radical configurations (313, 2221, 61).

[1]F. H. et al., J. Magnetic Resonance 197 (2009).
[2] Z. Z. et al., Chem. Commun. Commun 53-55 (2009).
[3]G. I. et al., Soft Matter 10 (2014).
[4] A. Rajca, Chem. Rev. 94, 871 (1994).
[5] E. Belorizky and P. H. Fries, J Chim Phys , 1077 (1993).

# Dipolar ordering in a molecular nanomagnet detected using muon spin relaxation

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Implanted muons have been used as a local probe to detect the magnetic ordering in the molecular magnetic nanodisk system Fe19 [1]. Two distinct groups of muon sites are identified from the relaxation data, reflecting sites near the magnetic core and sites distributed over the rest of the molecule. Dipole field calculations and Monte Carlo simulations confirm that the observed transition in Fe19 is consistent with magnetic ordering driven by interactions between molecules that are predominantly dipolar in nature. The triclinic crystal structure of this system gives the dipolar field a significant component transverse to the easy spin axis and the parallel component provides a dipolar bias closely tuned to the first level crossing of the system. These factors enhance the quantum tunneling between levels, thus enabling the system to avoid spin freezing at low temperatures and efficiently reach the dipolar ordered state.

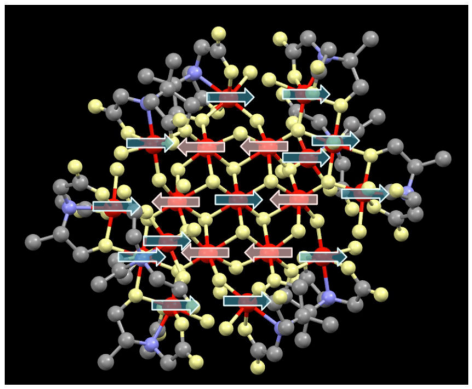

Figure 1: The ferrimagnetic spin arrangement of S = 5/2 Fe atoms within the Fe19 molecule leading to the S = 35/2 ground state (the easy axis is within the plane of the disk pointing in the direction shown by the central spin [2]).

[1] F. L. Pratt et al, Phys. Rev. B 89 (2014) 144420.
[2] L. Castelli et al, Dalton Trans. 40 (2011) 8145.

# Local spin dynamics at low temperature in the slowly relaxing molecular chain [Dy(hfac)3{NIT(C6H4OPh)}]: a $\mu^+$SR study

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A $\mu^+$SR investigation of the spin dynamics for the molecular chain [Dy(hfac)3{NIT(C6H4OPh)}] (in short DyPhOPh) is presented. This system consists of a magnetic lattice of alternating Dy(III) ions and radical spins and exhibits single-chain-magnet behavior [1]. The requirements necessary to observe Glauber dynamics [2] are fulfilled: (i) a strong Ising-like anisotropy and (ii) a very low ratio of interchain/intrachain magnetic exchange interaction.

We studied powders of DyPhOPh, measuring its magnetization [1, 3] at different applied magnetic fields (H= 5, 3500 and 16500 Oe), thus deducing the temperature dependence of the effective magnetic moment ($\propto\chi T$). The effective magnetic moment shows a strong magnetic field dependence as witnessed by the disappearance of the low temperature rounded peak, typical of 1D behavior, when the field is increased above 3500 Oe.

To investigate the local spin dynamics, we performed $\mu^+$SR experiments in longitudinal applied magnetic fields H=0 and 3500 Oe. The muon asymmetry P(t) was fitted by the sum of three components, two stretched-exponential decays with fast and intermediate relaxation times, and a third slow exponential decay. The muon longitudinal relaxation rate $\lambda_{interm}$ of the second component displayed a rapid increase when temperature is decreased, for both H=0 and H=3500 Oe, and a peak at T ~ 12K for H=3500 Oe. The experimental $\lambda_{interm}(T)$ data were fitted with a corrected phenomenological Bloembergen-Purcell-Pound law by using a distribution of thermally activated correlation times, which average to $\tau = \tau_0 \exp(\Delta/k_BT)$, corresponding to a distribution of energy barriers $\Delta$. From the analysis of the magnetization and $\mu^+$SR data, we suggest new insights on the correlation times dominating the local spin dynamics at temperatures below 40K.

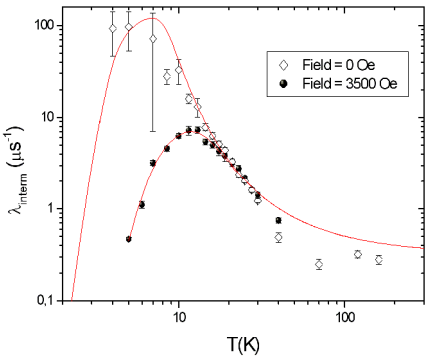


Figure 1: Temperature dependence of the intermediate muon longitudinal relaxation rate $\lambda_{interm}$ of DyPhOPh powders in LF=0 and 3500 Oe. The solid lines represent the fits of the muon longitudinal relaxation rates

[1] L. Bogani, C. Sangregorio, R. Sessoli and D. Gatteschi, Angew. Chem., Int. Ed., 2005, 44, 5817.
[2] R. J. Glauber, J. Math. Phys., 1963, **4**, 294.
[3] K. Bernot, J. Luzon, A. Caneschi, R. Sessoli, L. Bogani, A. Vindigni, A. Rettori and M.G. Pini, Phys. Rev.B, 2009, 79, 134419.

# Study of Quantum Decoherence and Relaxation of $Cr_8Zn$ Molecular Rings by means of High Field/High Frequency Pulsed EPR Spectroscopy

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Low-dimensionality molecular spin clusters exhibit discrete spectrum of excitations and genuine quantum phenomena, such as mixing of states with different total spin [1]. Molecular systems have been proposed for quantum information processing applications because the can provide scalable qubits, suitable logical states and wide range of tunability of the magnetic interactions. Decoherence remains a critical aspect that needs to be properly understood and controlled [2].
Here we report studies on single-crystals of $Cr_8Zn$ molecular magnets that are characterized by an open chain of eight $s(Cr^{3+})=3/2$ spins interrupted by the presence of the non-magnetic $Zn^{2+}$ site [3]. Thermodynamic measurements (up to 26 T) and high frequency (241 GHz) EPR spectra are used to determine the parameters of the spin Hamiltonian. The energy diagram, calculated for magnetic fields up to 12 T, allows labelling the transitions between the lowest lying states. In particular, in addition to the "allowed" $\Delta M=\pm 1$ EPR transition between the states |2,-2> and |2,-1> at 9.1 T (labelled "D" in fig. 1), a formally "forbidden" transition is observed at about 8.6 T and attributed to an anticrossing between the states |2,-1> and |0,0> ("B").
Spin echo experiments were performed in the range 1.5 – 2.2 K to evaluate the spin-spin

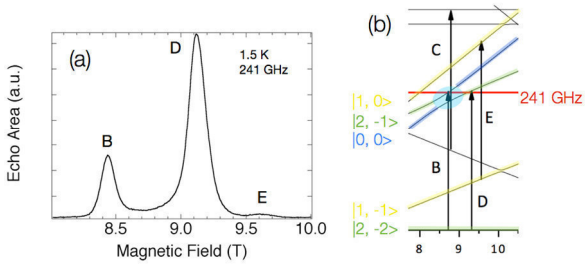


Figure 1: (a) Echo-detected EPR spectrum measured at 1.5 K on a single crystal of $Cr_8Zn$. (b) Energy diagram derived from the spin Hamiltonian model.

decoherence for the different transitions. At 1.5 K we observed a decay rate sizably slower for the transition "B" [$T_2$ (B)=658 ns] respect to "D" [$T_2$ (D)=471 ns]. This behaviour persists also for higher temperature. The spin-phonon relaxation, which is measured with the saturation recovery technique, conversely show $T_1$ (B)=6.41 μs and $T_1$ (D)=12.74 μs at 1.5 K. These results show that EPR transitions belonging to the same cluster can behave differently respect to the spin-spin dephasing and to the spin-phonon relaxation.

[1] S. Carretta et al., Phys. Rev. B 72 (2005) 060403(R).
[2] A. Ghirri et al., Molecular Nanomagnets and Related Phenomena - Structure and Bonding Ed. Song Gao Springer (2014). DOI: 10.1007/430_2014_145.
[3] A. Ghirri et al., Phys. Rev. B 76 (2007) 214405.

# Towards room temperature antiferromagnetic memories: investigation of the MgO influence on the IrMn properties in IrMn/MgO-based devices without ferromagnetic elements

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Memory elements entirely based on antiferromagnets (AF), without ferromagnetic components, deserve large interest because of their high packaging density and robustness versus external perturbations. Recently, it has been demonstrated by some of the authors that in IrMn(2.5 nm)/MgO/Ta tunnelling junctions distinct metastable resistance states can be set by field cooling the heterostructures from above the Néel temperature (~173 K), with the external magnetic field applied along different orientations. Tunneling Anisotropic Magnetoresistance (TAMR) [2] up to 10% at 120 K, upon field cooling along the in-plane or out-of-plane direction, provided the first demonstration of an electrically readable magnetic memory device, in which the information is stored within the AF active layer without the need of any ferromagnetic counterpart.
As a first step, in order to extend the operation of the device to room temperature, we studied the temperature dependence of the exchange bias versus the IrMn thickness in $Si/SiO_2$//CoFeB/IrMn($t$)/MgO/Ru structures. In Fig. 1 is reported the blocking temperature of IrMn as a function of its thickness, for both the cases of Ru capping and MgO capping. For $t$<6 nm, the presence of MgO suppresses the exchange bias (present if the MgO layer is removed), whereas $t$= 6 nm guarantees operating temperature above 180 °C.

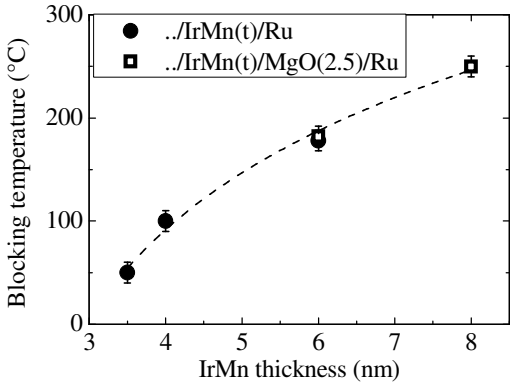


Figure 1. Blocking temperature as a function of thickness of IrMn, for both the cases of Ru capping and MgO capping.

Being AF/MgO an essential building block of AF spintronics, we investigated by photoemission spectroscopy the influence of MgO on IrMn (oxidation, stoichiometry, etc.), in order to shed a light on the mechanisms leading to the disappearance of exchange bias at low IrMn thickness,
Finally, we end up with the realization of IrMn/MgO/Ru tunnel junctions to understand the feasibility of TAMR at room temperature. Preliminary results on $Si/SiO_2$//CoFeB/IrMn/MgO/Ru devices operating above room temperature will be reported.

[1] D. Petti et al., Appl. Phys. Lett. 102 (2013) 192404.
[2] A. B. Shick, Phys. Rev. B 81 (2010) 212409.

# *Synchronization of spin-Hall nano oscillators*

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In this work, we demonstrate that propagating spin-waves are excited in spin-Hall nano-oscillators. The system is composed by a heavy metal (Ta) coupled with a thin out-of-plane ferromagnet (CoFeB). The scenario is similar to the one studied in [1] for in-plane fields. Differently from what observed in spin-torque nanocontact oscillators [2], we achieved an asymmetric propagation patterns for the spin-waves [3]. We have also proposed a device design where it is possible to study the synchronization between two spin-Hall oscillators (Fig. 1). The current is injected (along the *x*-direction) via the two Gold contacts deposited over the ferromagnet, SHO-1 and SHO-2 indicate the two spin-Hall oscillators. We have performed a systematic study based on micromagnetic simulations to understand the origin of the exited modes and the dynamical behavior as a function of field and current [4]. Fig. 2a summarizes the oscillation frequency of the excited mode as a function of the current, for different external fields (H=200, 400, 600, and 800 mT) applied at 15 degrees with respect to the out-of-plane direction. Those results are referred to the current region where the two oscillators are synchronized. Fig. 2b shows the snapshots of the magnetization for the points A, B, C and D as displayed in Fig. 2a. As the field is reduced, the wavelength of the excited spin-waves increases. In fact, while for H=800 mT a clear identification of the two sources of spin-waves can be observed, at 200mT the wavelength of the propagating modes become comparable with the distance between the two oscillators giving rise to an excitation pattern where the two contacts cannot be identified anymore. Further, by setting the distance between the two contacts and applying in-plane magnetic field, it is possible to observe the synchronization of localized bullet modes. Our results show how spin-Hall nano-oscillators can find application as high tunable spin-wave emitters for magnonic applications, where spin waves are used for transmission and processing information on nanoscale.

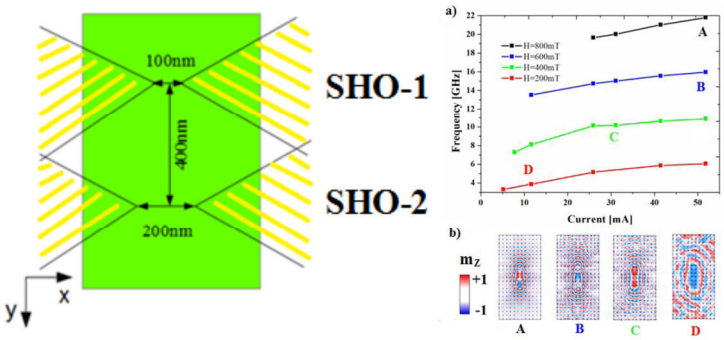


Figure 1. Device structure indicating the spacing between the two contacts and the two spin-Hall oscillators (SHO).
Figure 2. a) Oscillation frequency vs current at different fields. b) Examples of propagation pattern of spin-waves related to the points A, B, C and D as displayed in Fig. 1a (the color is related to the out-of-plane component of the magnetization).

[1] V. E. Demidov, S. Urazhdin, H. Ulrichs, et al., Nat. Mater. 11, (2012) 1028.
[2] S. Kaka, M. R Pufall, W. H Rippard, et al., Nature, 437, (2005) 389.
[3] A. Giordano, M. Carpentieri, A. Laudani, et al, App. Phys. Lett. 105, (2014) 042412.
[4] L Lopez-Diaz, D Aurelio, L Torres, E Martinez, et al., J. Phys. D: Appl. Phys. 45, (2012) 323001.

# Power Behaviour of Vortex Oscillations in Co-Fe-B Magnetic Tunnel Junctions in Presence of Defects

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The characterization of defects in ferromagnetic nanostructures is of special importance for magnetic data storage based on vortices or domain walls moving through nano-devices, since their presence may modify critically the vortex or domain wall dynamics [1,2]. The magnetic vortex configuration in magnetic tunnel junctions (MTJs) is a unique possibility to probe single defects. Due to the strong tunnel magneto-resistance effect it is possible to observe small power oscillations caused by thermal fluctuations, which are especially sensitive to defects [3,4]. In this paper we study frequency, line-width and in particular power of the vortex oscillations in $Co_{40}Fe_{40}B_{20}$(3nm)/MgO(1.1nm)/$Co_{40}Fe_{40}B_{20}$(2nm)/$Ni_{81}Fe_{19}$(30nm) MTJ pillars in presence of defects. The multilayer stack was prepared by sputter deposition and patterned into pillars with circular cross section (d=460nm,590nm,780nm). Thermally induced vortex oscillations were measured using a spectrum analyzer. When applying an in-plane magnetic field the oscillation frequency shows a characteristic behaviour: the frequency oscillates from a maximum at certain field values to a steep minimum which tends towards zero frequency. In this frequency minima the power of the measured signal increases strongly (see figure 1). This behaviour is well reproduced in micromagnetic simulations of the vortex oscillations in the Py disk in presence of a distribution of pinning centers (taken into account as material grains with reduced exchange coupling at the boundaries [5]). By applying an analytical model based on the Thiele equation and taking into account a single Gaussian pinning potential we show that the power increase corresponds to the depinning of the vortex by the applied field. At the depinning field the energy landscape becomes flat so that large amplitude and high power oscillations occur.

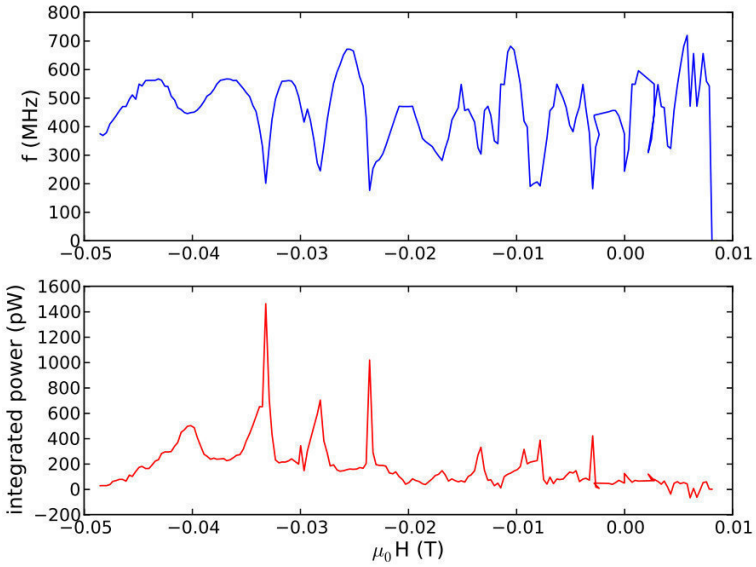


Figure 1: integrated power and frequency of vortex oscillations ($I_{DC}$ =3mA, diameter of device: 590nm)

[1] Min, H., et al., Phys Rev Lett 104, 217201 (2010)
[2] Zaspel, C.E., et al., Phys Rev B 87, 134425 (2013)
[3] Min, H., et al., Phys Rev B 83, 06441 (2011)
[4] Dussaux, et al., Nat Comms 1, 8 (2010)
[5] J. Leliaert, et al., J App Phys 115, 233903 (2014)

# Analysis of reliable ultra-fast spin-torque switching under transverse bias magnetic fields

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The high-speed and energy-efficient switching of magnetic nano-elements is a fundamental issue in magnetization dynamics for its application to magnetic storage nano-devices[1]. In the last decade, considerable research has been devoted to study magnetization switching in spintronic devices acting as potential MRAM cells[2]. For such devices, high speed (sub-nanosecond) switching is possible under spin-polarized electric current pulses. However, ultra-fast spin-torque magnetization switching under pulsed injected current suffers from the very similar issue as precessional switching by transverse external magnetic fields[3]. In fact, for both approaches, in order to achieve successful switching, a very precise timing of the excitation pulse is needed in order to switch it off at the right moment. Then, the equilibrium magnetization is reached after a relaxation from high to low energy state[4]. This relaxation mechanism is probabilistic in nature even when thermal fluctuations are neglected. The reason is the presence of multiple stable states combined with extreme sensitivity to initial conditions. Recently, it has been theoretically demonstrated that, for small magnetic particles, the probability of magnetization relaxing from high energies to one of the stable magnetization orientations can be tuned to whatever desired value between 0 and 1 by applying a small transverse magnetic field of appropriate amplitude[5]. These analytical predictions have been derived under the assumption of uniformly magnetized particles and negligible thermal fluctuations. In this work, we show that reliable and ultra-fast spin-torque switching under current pulses can be realized in the presence of an appropriate bias transverse magnetic field. We perform a combined analytical and micromagnetic study of spin-torque switching processes for realistic magnetic nanodots in order to check the applicability and robustness of the theoretical predictions. The influence of thermal fluctuations is also investigated. It is expected that this study will be instrumental to devise novel ultra-fast magnetization switching strategies for spin-torque MRAMs.

This work is partially supported by MIUR-PRIN 2010-11 Project2010ECA8P3 "DyNanoMag"

[1] J-P. Wang, Nature Materials 4, 191 - 192 (2005).
[2] N. Locatelli, V. Cros and J. Grollier, Nature Materials 13, 11 (2014).
[3] S. Kaka, S.E. Russek, Appl. Phys. Lett. 80 (2002) 2958.
[4] G. Bertotti, I. D. Mayergoyz, C. Serpico, and M. d'Aquino, IEEE Trans. Magn. 39, 2501 (2003).
[5] G. Bertotti, C. Serpico, I.D.Mayergoyz, Phys. Rev. Lett. 110, 147205 (2013).

# Topological modes driven by spin-transfer torque

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It is shown that in a spin-valve consisting of Pt(5 nm)/Co(0.6 nm)/Cu (4 nm)/CoPt(4 nm) a perpendicular spin current, in the presence of the Dzyaloshinskii–Moriya interaction [1,2] and strong perpendicular anisotropy, induces the rotation of the spins from the hedgehog-like to the vortex-like texture in the topological droplet state and excites low-frequency topological modes. The negative current ($J < 0$) flows from the free layer (Co) to the fixed (nanocontact, CoPt) layer. The topological character of these spin-wave excitations results from the synchronized dynamics between the $360^o$ rotation of the spin of the outer droplet domain and the expansion/shrinking of the droplet core. A quantitative description of topological droplet modes is given according to an analytical model based on the linearization of the equations of motion including intrinsic positive Gilbert damping and negative damping related to the spin-transfer torque [3]. The analytical frequency of the topological droplet mode is expressed as the solution of a second-order algebraic equation written in terms of the magnetic parameters including the intrinsic and extrinsic damping. As shown in Fig.1, it is found a red-shift behaviour of the topological mode frequencies as a function of the current density above its threshold value.

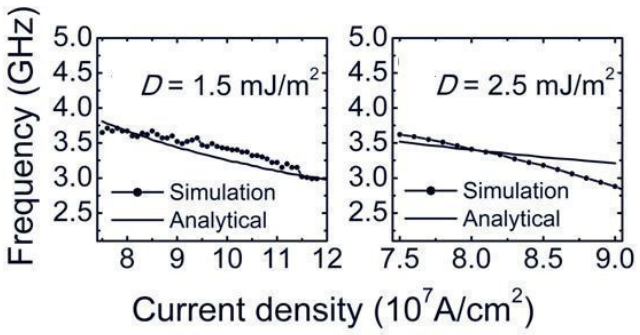


Figure 1: Topological mode frequency as a function of the current density for $D = 1.5$ mJ/m$^2$ and $D = 2.5$ mJ/m$^2$, respectively.

The analytical calculations are in very good accordance with micromagnetic simulations. The analysis of the symmetry properties of the linearized equations of motion demonstrates the non-reciprocal role of the spin polarized current on the topological mode dynamics.

[1] T. Moriya Phys. Rev. Lett. 4 (1960) 228

[2] I. Dzyaloshinskii J. Phys. Chem. Solids 4 (1958) 241

[3] R. Zivieri et al. "Topological skyrmion dynamics driven by spin-transfer torque" submitted

# Integrating magnetic molecules in spin valves

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The development of molecular devices based on magnetic molecules is one of the most active fields of research joining together chemistry, physics and material science. Going beyond the groundbreaking tests of single molecule – based devices [1–3] there is an intense activity focused on the realization of novel hybrid molecular-inorganic "macroscopic" devices where a magnetic molecular layer may play a crucial role in the spin and electronic transport [4–7] expanding the capabilities of the molecular spintronics. In this context the use in molecular spintronics of Single Molecule Magnets (SMM), the magnetic molecule by definition, discloses new exciting possibilities linked to the richness the magnetic properties of SMMs.[8] In these molecular systems classical properties, like the magnetic hysteresis, coexist with quantum features such as the resonant quantum tunneling of the magnetization[9] or topological effects due to interference of the tunneling pathways.[10] However the coupling of these complex molecules with the spin transport phenomena is not trivial and it requires taking into account several aspects ranging from the stability of the molecules in the designed devices [11,12] as well as the interactions between the inorganic substrates and molecular layers. The realization of a hybrid device including simpler magnetic molecules like organic radicals constitutes a key phase towards the optimization of the hybrid interface between the inorganic and organic layers in this novel type of spin valve.

Here we will present our recent efforts in inserting magnetic molecules, including organic radicals and SMMs, in new hybrid spin valve devices exploiting wet chemistry and UHV-compatible strategies to modify the interface between the standard spin injecting electrode (i.e. the $La_{0.7}Sr_{0.3}MnO_3$, LSMO) and an organic semiconductor (OSC) in order to introduce a molecular paramagnetic layer in the standard OSC-based spin-valve device.[13,14] Using a multi-technique characterization approach, we verified the integrity of the molecules, the occurrence of specific interactions between the molecules and the magnetic substrate and finally we tested the performances of the hybrid spin valves.

[1] Urdampilleta, M. et al., *Nat. Mater.*, **10**, 502 (2011).
[2] Burzurí, E. et al., *Phys. Rev. Lett.*, **109**, 147203 (2012).
[3] Atodiresei, N. et al., *Phys. Rev. Lett.*, **105** (2010).
[4] Camarero, J. et al., *J. Mater. Chem.*, **19**, 1678 (2009).
[5] Carlegrim, E. et al., *Org. Electron.*, **11**, 1020 (2010).
[6] Raman, K. V et al., *Nature*, **493**, 509 (2013).
[7] Sun, D. et al., *Chem. Commun.*, **50**, 1781 (2014).
[8] Gatteschi, D. et al., *Molecular nanomagnets*, Oxford University Press, UK, (2006).
[9] Thomas, L. et al., *Nature*, **383**, 145 (1996).
[10] Wernsdorfer, W. et al., *Science*, **284**, 133 (1999).
[11] Malavolti, L. et al., *Chem. Commun.*, **49**, 11506 (2013).
[12] Mannini, M. et al., *Nat. Commun.*, **5**, 4582 (2014).
[13] Hueso, L. E. et al., *Adv. Mater.*, **19**, 2639 (2007).
[14] Dediu, V. A. et al., *Nat. Mater.*, **8**, 707 (2009).

# A joint research project on molecular nanomagnets on metallic and magnetic surfaces for applications in molecular spintronics

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We briefly describe the research activity within a national FIRB project that addresses, from both experimental and theoretical sides, radically new nanostructured materials for spintronics based on hybrid organic-inorganic architectures and containing magnetic molecules as active components.
The project encompasses four activities, each dealing with an important aspect of the research:
*i*) Chemical design and synthesis of new magnetic molecules suitable to be evaporated or chemically grafted on surfaces, showing also enhanced blocking temperature, enhanced conductivity or additional properties like chirality.
*ii*) Optimization of the deposition procedures through a detailed characterization of the hybrid surfaces by scanning probe techniques, photo-electron spectroscopy and ion scattering techniques.
*iii*) *Ab initio* modellization of the adsorption process, of transport properties, of substrate-induced effects on magnetic properties, and of a possible control of magnetic properties through external stimuli.
*iv*) Realization and characterization of spin-valve hetero-structures based on well-known organic semiconductors featuring an additional molecular magnetic layer, or solely on magnetic molecules arranged in either vertical or planar architectures, such as interdigitated contacts or nanojunctions.

Some of the first achievements of the project involve the increased evaporability of fluorinated $Fe_4$ SMMs[1] and the detailed characterization of the topmost layers of a manganite (LSMO) substrate[2] used as magnetic electrode for the realization of spin valves, on which Single Molecule Magnets (SMMs)[3] and organic radicals have been deposited. The retention of SMM behaviour in a sub-monolayer of $Fe_4$ SMMs deposited on gold,[4] or in $TbPc_2$ molecules grafted to silicon[5] suggests that magnetic bistability of SMMs should be observed also in the magneto-resistance. Preliminary results show that the spins of the magnetic molecules are not detrimental to spin-valve behaviour. The possibility to use an electric field to control the dynamics of the magnetization, through a predicted novel magneto-electric effect, is currently under investigation in magnetic molecular helices.[6,7]

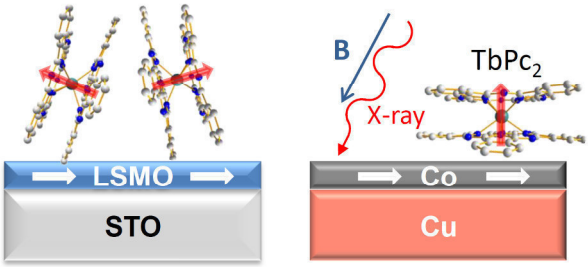


Figure 1. Co and LSMO substrates, the most commonly employed electrodes in organic spintronics, have been selected for the investigation of sub-monolayers of $TbPc_2$ Single molecule Magnets.

[1] L. Rigamonti et al. Inorg. Chem. 52 (2013) 5897.
[2] L. Poggini et al. J. Phys. Chem. C 13631 (2014) 118.
[3] L. Malavolti et al. Chem. Commun. 49(2013) 11506.
[4] L. Malavolti et al. Nano Letters, in press.
[5] M. Mannini et al. Nat. Commun. 5 (2014) 4582.
[6] R. Sessoli et al. Nat. Phys., in press. DOI: 10.1038/NPHYS3152.
[7] M. Scarrozza et al. Phys. Rev. B, submitted.

# Multifunctional organic spintronic device acting as a magnetically enhanced memristor

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Information and communication technology (ICT) is calling for solutions enabling lower power consumption, further miniaturization and multifunctionality requiring the development of new device concepts and new materials. A fertile approach to meet such demands is the introduction of the spin degree of freedom into electronics devices, an approach commonly known as spintronics. This already lead to a revolution in the information storage (GMR readheads) in the last decades. Nowadays, the challenge is to bring spintronics also into devices dedicated to logics, communications and storage within the same material technology [1].
In this context the electric control of the magnetoresistance represents one of the most promising issues enabling both further miniaturization and multifunctional operation of spintronic devices. Likewise, also the electronics community is committed to follow the Moore's law, and one of the promising approaches is the use of arrays of crossbar memristors capable of information processing and storing ('stateful' logic) [2].
We show that an electrically controlled magnetoresistance can be achieved in organic devices [3] combining magnetic bistability (spin-valve) and resistance switching effects. In such devices the GMR effect can be turned ON and OFF by a programming bias that sets the device in low or high resistance state respectively. The magnitude of the GMR depends on the bias history and can be recovered up to the pristine value [4].
We show [4] that such devices operate like Magnetically Enhanced Memristors (MEM). MEMs can be operated in both memory and logic gate applications merging together spintronic and electronic approaches towards new future device concepts [5].

[1] Awschalom, D. D. & Flatte, M. E. "Challenges for semiconductor spintronics", Nat. Phys. 3, 153 (2007)
[2] Borghetti, J. et al. "Memristive' switches", Nature 464, 873 (2010)
[3] Dediu, V. A. et al. "Spin routes in organic semiconductors", Nat. Mater. 8, 707 (2009)
[4] Prezioso, M. et al. "A Single-Device Universal Logic Gate Based on a Magnetically Enhanced Memristor", Adv. Mater. 2012, DOI: 10.1002/adma.201202031
[5] Sanvito S. & Dediu V. A. "News from the Organic Arena", Nature Nanotechnology 7, 696 (2012)

# Efficient scheme for *ab initio* muon site assignment based on the double adiabatic approximation

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We present an efficient method for identifying interstitial muon sites in matter with Density Functional Theory (DFT) simulations.
The proposed approach extends the results already obtained in this context [1-3] and is designed to assist muon spin rotation (μSR) data analysis by allowing a first principles determination of the muon stopping site(s) and the evaluation of the local perturbation produced by the muon implantation. Indeed these information are usually unknown to the experimenter in standard μSR experiments and in most cases it is not possible to characterize muon sites and muon perturbation from experimental knowledge. However an accurate determination of muon sites can significantly improve the capabilities of this experimental technique.

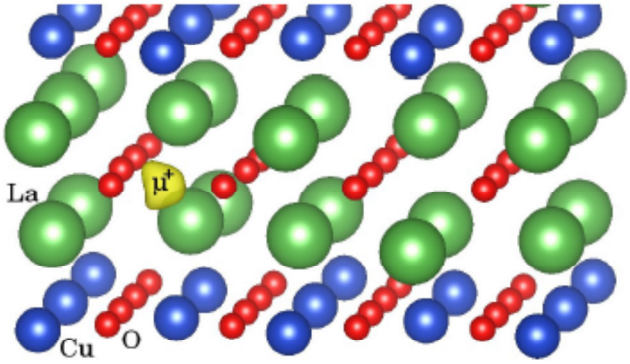


Figure 1. The muon stopping site in T'-$La_2CuO_4$ is depicted with an isosurface of its probability density.

In this contribution we shall review the successful results obtained so far. These include the study of F-μ-F centers in fluorides, muon diffusion in FCC Copper and the recent identification of muon sites in MnSi and $La_2CuO_4$ [4-5]. All these results confirm the validity of the DFT approach and highlight the importance of accurate muon site predictions.

[1] F. Bernardini et al., Phys. Rev. B **87**, 115148(2013)
[2] J. S. Moller et al., Phys. Scripta, **88**, 068510 (2013)
[3] S. J. Blundell et al., Phys. Rev. B 88, 064423 (2013)
[4] R. Hord et al., Phys. Rev. B 82, 180508(2010)
[5] A. Amato et al., Phys. Rev. B 89, 184425 (2014)

# Effects of strain and size reduction on structural and magnetic properties of NiMnGa 2D and 1D systems

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Magnetic shape memory alloys, like NiMnGa, are very promising multi-functional materials exhibiting a coupling between magnetic and structural order in the martensitic phase. The martensitic phase transition gives rise to a complex hierarchical structure, which extends down to the nanoscale; in particular, the presence of different kinds of twin variants is of fundamental importance for the shape memory effect [1]. The possibility to obtain thin films with a martensitic microstructure has recently attracted a growing interest for the promising applications, like microactuators, valves, solid-state microrefrigerators [2]. Recently, it has been demonstrated that changing the substrate and the film thickness could strongly affect the martensitic microstructure and, consequently, the film properties. [3] Moreover, the exploitation of suitable under-layers is commonly reported in literature [4] but their effect on the martensitic microstructure is still not investigated.

The aim of this contribution is to analyse and discuss the effect of a Cr under-layer on the martensitic microstructure of NiMnGa thin films with thicknesses up to 200 nm. Furthermore, the effects induced by the reduction of the dimensionality from 2D to 1D will be discussed describing a novel system consisting in sub-micrometric disks obtained by patterning the thin film.

A multiscale structural and magnetic characterization was performed on thin films and disks mainly exploiting transmission electron microscopy (HREM/STEM, SAED, Lorentz microscopy, Holography). The achieved results are compared with complementary information obtained by means of X-ray diffraction, atomic/magnetic force microscopy, AGFM and SQUID magnetometry and susceptometry.

Making a comparison to the model system of NiMnGa directly grown on MgO we have found that a Cr under-layer strongly affects the martensitic microstructure of epitaxial thin films thanks to the induced strain, As for 1D systems, we have demonstrated the survival of the martensitic transformation and of the magnetic properties even in free-standing disks..

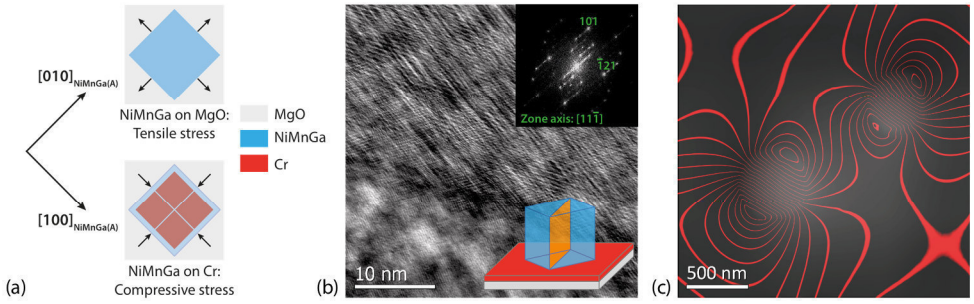


Figure 1: (a) Scheme of the under-layer strain effect, (b) strain-induced selective twin variant formation in NiMnGa(75nm)/Cr(50nm) film, (c) Lorentz microscopy investigation on NiMnGa disks.

[1] S. Kaufmann et al., New Journal of Physics 13 (2011) 053029
[2] A. Backen et al., *Adv. Eng. Mat.* **14**, 696 (2012).
[3] P. Ranzieri et al., *Acta Mater.* **61**, 263 (2013).
[4] A. Backen, et al., *Acta Mat.*, **58**(9), (2010), 3415.

# Magnetic characterisation and phase diagram of join CaCo-$CoCoSi_2O_6$ pyroxenes

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Pyroxenes are chain silicate minerals, widespread constituents of the Earth crust and of the upper mantle, as well as of rocky planets and meteorites. Synthetic pyroxenes are used for glass ceramics, and recently Co-based pyroxenes are investigated as ceramic pigments [1]; in addition they are acquiring a lot of interest in solid state physics for their magnetic and multiferroic properties [2].
The general formula of pyroxenes is $M2M1T_2O_6$, where M2 are the cations ($Mg^{2+}$, $Fe^{2+}$, $Ca^{2+}$, …), in the distorted polyhedron M2, with coordination from 6 to 8, M1 are cations ($Co^{2+}$, $Mg^{2+}$, $Al^{3+}$, $Fe^{3+}$, …) in the regular M1 octahedron, i.e. in a six-fold coordination and T refers to the cations ($Si^{4+}$, $Ge^{4+}$) present into the tetrahedral forming the pyroxene chains [3]. Wide chemical substitutions may occur within each site. The pyroxenes are composed by three kinds of infinite chains running parallel to the *c*-axis: $\mathbf{M1O_6}$ octahedral chains, edge-sharing $\mathbf{M2O_{8\text{-}6}}$ polyhedral chains and corner-sharing $\mathbf{TO_4}$ tetrahedral chains. A peculiar aspect of these systems is the fact that the net magnetic properties are the sum of the competition of the inter- and intra-chain coupling of spins inside the quasi 1D infinite chains of transition metal in octahedral sites in the (100) plane.
Of particular interest is the structure with a ferromagnetic (FM) coupling of spins within the M1 chains and an antiferromagnetic (AFM) one between the chains. It has to be noted that the interaction between the two structural sites is crucial in determining the alteration from AFM and FM coupling.
For the present work, synthetic pyroxenes with composition $Ca_{1-x}Co_{1+x}Si_2O_6$, ($0 \leq x \leq 1$, step 0.1) were synthesized at P = 3 GPa and in a T range from 1200 to 1350 °C with a ½ inch piston cylinder apparatus and a pyrex–talc assembly containing an internal graphite furnace. For the Ca-free end member ($Co_2Si_2O_6$) the synthesis was made with a multi-anvil apparatus, at the P = 7 GPa and T = 900 °C. The single-phase nature of the samples was checked by powder X-ray diffraction.
A thorough magnetic characterisation was performed on the whole sample series, in terms of Zero Field Cooling (ZFC) and Field Cooling (FC) curves, measured at H=10 Oe and H=5 kOe in the temperature range 5-300 K. Low and room temperature hysteresis loops were also measured.
While the magnetic characterisation of the two end members $CaCoSi_2O_6$ and $Co_2Si_2O_6$ confirmed the expected literature data [4], that is an overall AFM behaviour and a FM one respectively, solid solutions ones allowed to build for the first time a complete magnetic phase diagram that correlates M2 site occupancy, crystallographic structure and magnetic behaviour in terms of the competitive inter- and intra- chain interactions.

[1] F. J. Torres and J. Alarcón J. Eur. Ceram. Soc., 25(4), (2005) 349.
[2] S. Jodlauk S. et al. Phys. Condens. Matter, 19, (2007) 432201.
[3] A. Putnis Cambridge University Press (1992).
[4] G. Durand et al. J. Sol. State Chem. 124 (1996) 374; A. Sawaoka et al., J. Phys. Soc. Jap. 25 (1968) 1253.

# Magnetocaloric effect at the exchange-inversion in antiferromagnetic systems with magnetoelastic coupling

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Magneto-volume coupling is of primary importance in explaining the thermodynamics of the phase transition in magnetocaloric systems. The complexity of the phenomenon may be greatly reduced by assuming a dependence of the exchange coupling constant $W$ on the lattice volume change $\Omega = (v\text{-}v_0)/v_0$, i.e. $W = W_0(\delta + \beta\Omega)$ with $\delta = 0, \pm 1$ [1-3]. The case $\delta = 1$ describes systems showing a para- (PM) to ferromagnetic (FM) transition and the nature of the phase transition depends upon the value of two parameters $\zeta$ and $\eta$, directly related to the system compressibility, thermal expansion coefficient and steepness $\beta$ [3]. The case corresponding to an antiferromagnetic (AFM) ground state ($\delta = 0, -1$) is investigated in this work. By using the Néel mean field theory with two equivalent sublattices A and B, we derive the free energy, the magnetization and the entropy. From the phase diagram we find that for $-1 < \zeta < 1$ the system undergoes an AFM-PM transition, while for $\zeta > 1$ an high temperature FM phase is stabilized by the lattice entropy. The exchange-inversion is obtained if $\eta > \eta_c$ (the latter being a critical value depending on $J$). The entropy change $\Delta s = \Delta s_M + \Delta s_W = s(h,t) - s(h{=}0,t)$, the sum of magnetic ($s_M$) and structural ($s_W$) contributions, is enhanced for $0 < \zeta < 1$, where both $\Delta s_M > 0$ and $\Delta s_W > 0$, giving a giant magnetocaloric effect. In this paper we numerically evaluate, in the case $J = 1/2$, the relevant magnetic and thermodynamic quantities (see Figs. 1 and 2) as a function of the temperature $t$ and of the field $h$ for different values of $\zeta$, $\eta$.

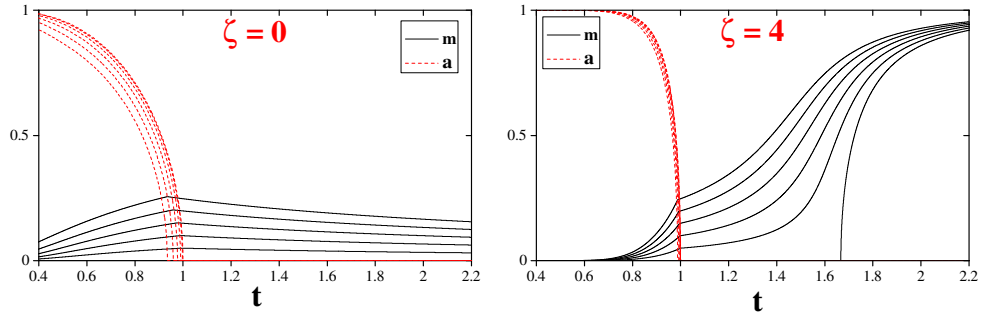


Figure 1: Magnetization $m = (m_A+m_B)/2$ (solid black lines) and antimagnetization $a = (m_A-m_B)/2$ (red dash lines) curves, at $\eta = 0$ (second order transition) and $J = 1/2$, for different fields $h$ from 0 to 0.5 in steps of 0.1: (*left*) $\zeta = 0$, AFM-PM; (*right*) $\zeta = 4$, AFM-PM-FM.

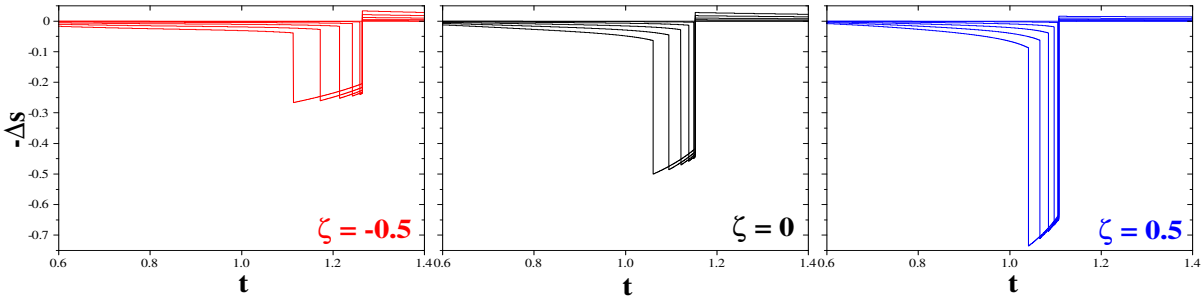


Figure 2: Entropy change $-\Delta s(t)$, evaluated at $\eta = 3$ (first order transition), $J = 1/2$ and same $h$ of Fig. 1, at $\zeta$: -0.5 (*left*), 0 (*centre*) and 0.5 (*right*).

[1] C. P. Bean et al. Phys. Rev. 126 (1962) 104
[2] P. J. von Ranke et al. J. Phys.: Condens. Matter 21 (2009) 056004
[3] V. Basso J. Phys.: Condens. Matter 23 (2011) 226004

# Influence of thermal conductivity on the Dynamic Response of MCE materials

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Magnetocaloric materials push forward the development of a new generation of more efficient and environmentally friendly refrigerators. The success of this new technology is tightly bound with the ability to produce materials presenting high reversible magnetocaloric effect (MCE), good mechanical stability and adjustable thermal conductivity. [1,2]

Here we study the Magnetocaloric Effect (MCE) of materials prepared with different thermal conductivity to understand whether the development of composite MCE systems may be a promising route to improve the efficiency of future devices. We compare a parent $La_{0.67}Ca_{0.33}MnO$ (LCMO), an Ag-filled LCMO, a parent $Mn_{1.27}Fe_{0.68}P_{0.48}Si_{0.52}$ and an epoxy filled $Mn_{1.27}Fe_{0.68}P_{0.48}Si_{0.52}$. The materials magnetocaloric response to an external field applied in operating conditions of real devices is compared with the outcomes of heat transfer simulations.
As a result of this study, we report the addition of silver substantially increases the frequency of LCMO's magnetocaloric cycles (see Figure 1). We identify the system's response time $\tau$ as a new parameter that ultimately limits the maximum frequency of an efficient refrigerant cycle and may offer fundamental information about evolution of the microstructure when the material is stressed under service conditions of future devices.

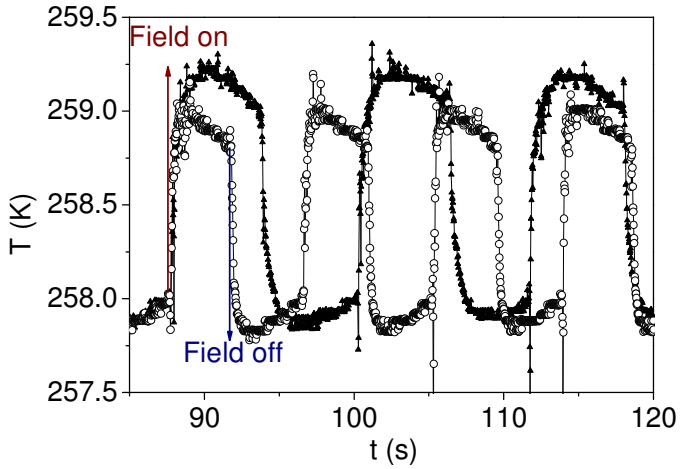


Figure 1: Experimental thermomagnetic cycles performed across $T_C$ of parent LCMO (black) and Ag-filled LCMO (grey). Magnetic field change 1 T.

[1] J. Lyubina et al. J. Appl. Phys. 109 (2011) 07A902.
[2] K. G. Sandeman, Scr. Mater. 67, 566 (2012).

# Electrical and calorimetric properties at the transition of the magneto-caloric compound $LaFe_{11.41}Mn_{0.3}Si_{0.29}$-$H_{1.65}$

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$La(Fe_xSi_{1-x})_{13}$–based alloys are promising candidates for magnetic cooling due to their large entropy change and low thermal hysteresis. Mn substitution has been shown to decrease the Curie temperature of these compounds while interstitial H can increase it. The full hydrogenation of the matrix helps the stability over the time of these compounds [1], thus improves the interest toward applications. Here we present a calorimetric and electrical study on small masses of the magneto-caloric compound $LaFe_xMn_ySi_z$-$H_{1.65}$ with x = 11.41, y = 0.30 and z = 0.29 with Curie temperatures, $T_c$ , near ambient temperature. By differential scanning calorimetry (DSC) we studied the sample transition from a high temperature paramagnetic phase (PM) to a low temperature ferromagnetic phase (FM).

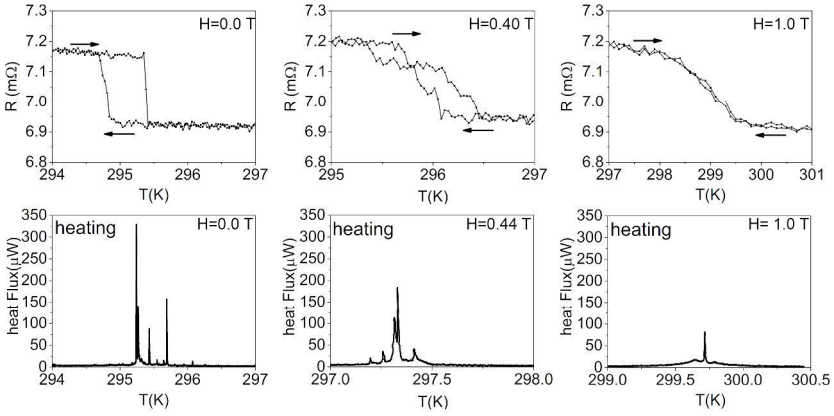


Figure1: *R*vs*T* for different external magnetic fields of a $LaFe_{11.41}Mn_{0.3}Si_{0.29}$-$H_{1.65}$ sample of mass 5.26 mg and corresponding low rate DSC data on heating of a sample of mass 4.32 mg (bottom row).

Slowing down the temperature rate, it is possible to measure the growth rate of the new phase in the form of numbers and entity of separated heat flux avalanches whose spatial phase propagation was visualized with a magneto-optical imaging technique [2]. As the magnetic field is increased, $T_c$ rises and the transition transforms from first order, rich of avalanche events, to second order, smoother and single peaked [3]. By a standard four point probes technique, we analyzed the dependence of the electrical resistance, *R*, and of the magneto-resistance on temperature. Collected data show jumps and thermal hysteresis near $T_c$. By increasing the external magnetic field, jumps become smoother confirming the crossover between a first to a second order transition. In the PM phase, and far from the transition, the current path does not change over many cycles even with applied fields up to 3 T, but in the transition region, the scattering mechanisms of conduction electrons change since a higher value of resistance at the FM phase is reached. The decrease in conductivity and the positive magneto-resistance at the transition have been interpreted in the similar compound $LaFe_{11.2}Co_{0.7}Si_{1.1}$ as consequences of the lattice expansion at the magneto-structural transition [4], but a better understanding on the competition between spin disorder suppression, lattice expansion and spin splitting of the energy bands near the Fermi level [5] at the FM phase is needed.

[1] A. Barcza et al. IEEE Transactions on Magnetics 47**,** 3391–3394 (2011).
[2] M. Kuepferling et al. J. Appl, Phys., 115, 17A925 (2014).
[3] V. Basso et al. Proceeding of the 6th IIF-IIR International Conference on Magnetic Refrigeration Victoria,BC(2014).
[4] F.X. Hu et al. IEEE Trans. Magn. IEEE Transactions on Magnetics 40, 2754–2756 (2004).
[5] Z. Gercsi et al. http://arxiv.org/abs/1407.7975 (2014).

# Magnetocaloric effect at single molecule level: a spectroscopic investigation on Fe14 and Gd4M8 on surfaces

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Magnetic cooling relies on large entropy variation of magnetic systems under the application of an external magnetic field. While giant magnetocaloric effect (MCE) in intermetallic compounds is related to the interplay between long range magnetic and lattice order, molecular nanomagnets have recently shown superior cooling performances at cryogenic temperatures. The molecular cage $Fe_{14}(bta)_6$ was one of the first examples on which enhanced MCE was experimentally observed in bulk samples [1]. Analysis of the low temperature thermodynamic properties of these molecular compounds shows that a large part of the entropy variation is due to the magnetic degeneracy of the ground molecular state and therefore high cooling power is expected at single molecule level, an interesting feature that can be exploited for applications down to the nanoscale. Yet, the deposition of large molecular cages on surfaces might be a non-innocent process since the interaction with the surface may provoke some drastic chemical changes or structural distortions that may alter the magnetic features and therefore the functionalities of the molecule.

Here we report an investigation on two molecular nanomagnets to demonstrate that large MCE is a property held at single molecule level. We have investigated two families of molecules $Fe_{14}(bta)_6$ and $Gd_4M_8$ (where M=Zn, Ni, Cu) deposited on a gold and HOPG surfaces by liquid phase by a combined analysis carried out by STM, XPS, XAS and XMCD to independently check the chemical, electronic and magnetic features of the isolated molecules. While chemical features are essentially preserved, we found that the ground magnetic state of $Fe_{14}(bta)_6$ is decreased when molecules are deposited on both Au and HOPG, probably as a results of slight distortion of this molecular cage [2]. Conversely $Gd_4Ni_8$ shows that structural and magnetic features are preserved when molecules are dispersed on surfaces [3]. This demonstrates, for the first time, that large contribution to magnetic refrigeration come from intrinsic molecular properties and it opens the way of scaling cooling devices down to molecular level with no need of a cooperative behaviour.

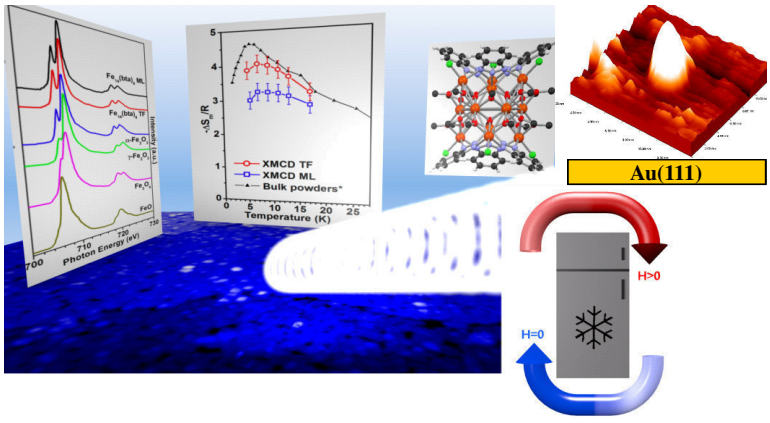


Fig. 1: A sub-ML distributions of isolated molecular $Fe_{14}(bta)_6$ nanomagnets is deposited intact on the Au(111) surface and investigated by XMCD spectroscopy. The entropy variation respect to the applied magnetic field, extracted from the magnetization curves, shows the preservation of the MCE at single-molecule level.

[1] M. Evangelisti, A. Candini, A. Ghirri, M. Affronte, E.K. Brechin, E.J. McInnes, Appl. Phys. Lett. 2005, 87, 072504.
[2] V. Corradini, A. Ghirri, A. Candini, R. Biagi, U. del Pennino, G. Dotti, E. Otero, F. Choueikani, R. J. Blagg, E. J.L. McInnes, M. Affronte, Adv. Mater. 2013, 25, 2816.
[3] V. Corradini, A. Ghirri, A. Candini, R. Biagi, U. del Pennino, V. De Renzi, G. Dotti, E. Otero, T. N. Hooper, R. Inglis, E. K. Brechin and M. Affronte, Adv. Funct. Mater. 24, 4782 (2014).

# The polaronic framework fully accounts for transport properties in metallic ferromagnetic manganites

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We propose a model for the consistent interpretation of the transport behaviour of manganese perovskites in both the metallic and insulating regimes [1]. The concept of polarons as charge carriers in the metallic ferromagnetic phase of manganites also solves the conflict between transport models, which usually neglects polaronic effects in the metallic phase, and, at the other hand, optical conductivity, angle resolved spectroscopy and neutron scattering measurements which identified polarons in the metallic phase of manganites down to 6 K. Transport characterizations of epitaxial $La_{0.7}Sr_{0.3}MnO_3$ thin films in the thickness range 5 – 40 nm and 25 – 410 K temperature interval have been accurately collected. We show that taking into account polaronic effects allows to achieve the best ever fitting of the transport curves in the whole temperature range. The Current Carriers Density Collapse picture accurately accounts for the properties variation across the metal-insulator transitions. The electron-phonon coupling parameter $\gamma$ estimations are in a good agreement with theoretical predictions. The results promote a clear and straightforward quantitative description of the manganite films involved in charge transport device applications and promises to describe other oxide systems involving a metal-insulator transition. The model is successfully applied also to manganite single crystals of other compositions taking data from literature [2].

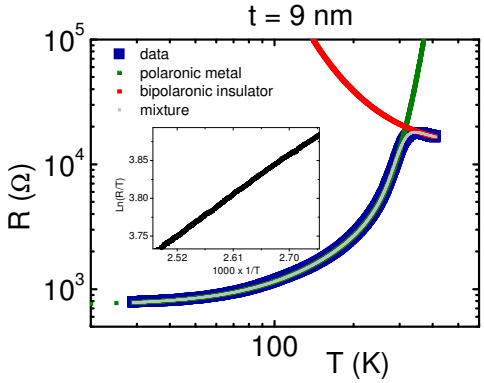


Figure 1: transport data and fits for a 9 nm LSMO/STO thin film; the metallic side is fitted with the proposed model while the insulating branch is described by thermal activated adiabatic hopping, which linearizes the data above the MIT (inset). The whole R(T) is fitted by a combination of the twos following the CCDC model.

[1] P. Graziosi *et al.* Physical Review B 89 (2014) 214411

[2] Y. Lyanda-Geller *et al.* Physical Review B 63 (2001) 184426

# Amorphous ferromagnetism and re-entrant magnetic glassiness in single-crystalline $Sm_2Mo_2O_7$

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We report on the investigation of a high-quality single crystal of $Sm_2Mo_2O_7$ by means of dc magnetometry, muon spin spectroscopy ($\mu^+$SR) and high-harmonics ac susceptibility [1]. The magnetic phase of the $Mo^{4+}$ sublattice develops below $T_C$ = 78 K, in agreement with several previous reports in the literature. The $T_C$ value would be significantly reduced by a substantial amount of $O^{2-}$ vacancies, showing that this critical issue can be safely neglected for the currently investigated sample. Such magnetic phase for $Mo^{4+}$ is typically discussed in the literature as a conventional itinerant ferromagnetic state. However, our results clearly detect a complicated superposition of conventional and highly disordered magnetic behaviors below 78 K sharing several common features with amorphous ferromagnetic alloys (AmFA) and with other insulating spin-glass (SGI) pyrochlore molybdates. This scenario for $Sm_2Mo_2O_7$ is supported by the anomalously high values deduced for the critical exponents of the magnetic transition, approaching values typically reported for AmFA. These were calculated by a scaling analysis of the dc magnetization data and confirmed by $\mu^+$SR and first-harmonic ac susceptibility. At the same time, $\mu^+$SR detects a sizable static magnetic disorder at the microscopic scale resulting in strongly damped coherent oscillations in the time depolarization of the $\mu^+$ spin. Moreover, the critical divergence of the third-harmonic component of the magnetic ac susceptibility around 80 K leads to additional evidence towards the disordered nature of this magnetic phase. Some degree of magnetic glassiness has been reported in the literature also in the metallic ferromagnetic (FMM) phase near to the metal-to-insulator boundary. However, $Sm_2Mo_2O_7$ is located far enough from such boundary and glassy features are typically neglected in this case. Finally, as typical for several amorphous ferromagnets, a re-entrant spin-glass (RSG) phase is evidenced at low temperatures by means of both the longitudinal magnetic relaxation of $\mu^+$ and by magnetic ac susceptibility.

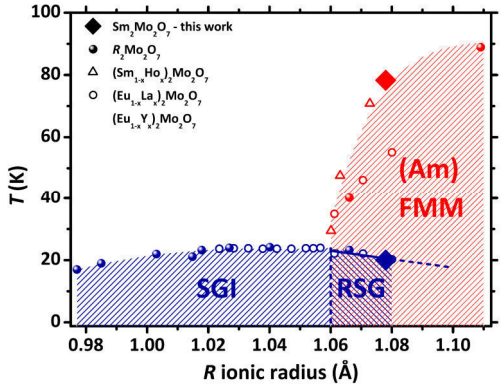


Figure 1: Proposed electronic phase diagram of pyrochlore molybdates (Am stands for "amorphous").

Accordingly, our results shed new light on the magnetic properties of $Sm_2Mo_2O_7$ and on the overall electronic phase diagram commonly accepted for pyrochlore molybdates, which is hereby proposed in a new version (see figure 1).

[1] G. Prando et al., Phys. Rev. B 90 (2014) 085111

# Magnetoelectric composite bilayer film by electrophoretic deposition

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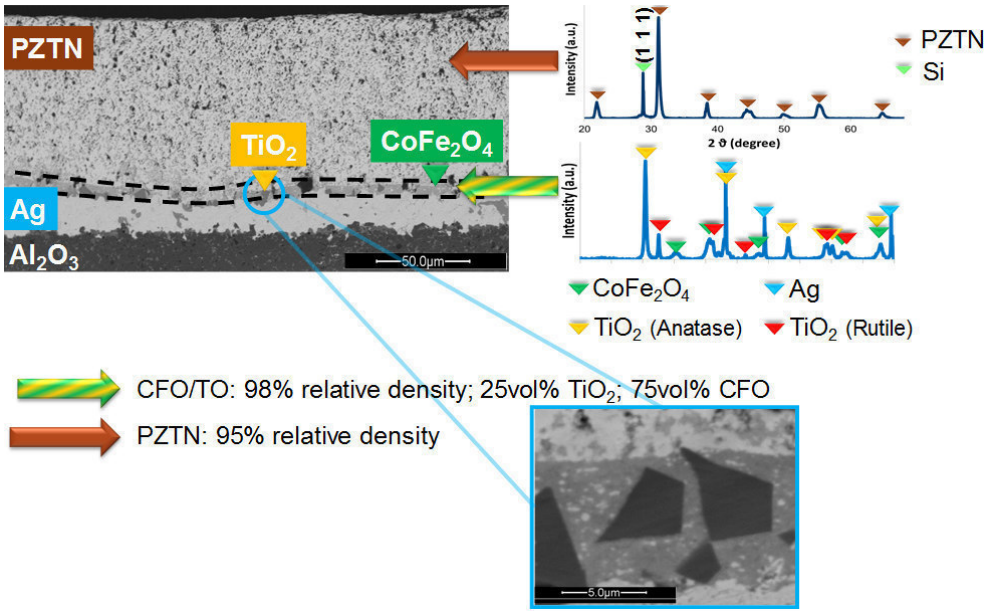
In the recent years the interest of the research community towards multiferroic composite materials was growing fast [1,2]. A number of papers relates to bulk materials while less attention is focused on films.
Electrophoretic deposition (EPD) was applied to prepare magnetoelectric (ME) composite bilayer thick films based on perovskite phase and spinel cobalt ferrite as some of the best piezoelectric and magnetostrictive oxides belong these crystal groups. The co-deposition of titanium oxide (TO) and cobalt ferrite (CFO) nanoparticles and the deposition of niobium-doped lead titanate zirconate (PZTN) were made from colloidal suspensions in ethanol keeping constant voltage and recording the current. Good adhesion and compaction of the green film were achieved by optimization of deposition voltage and time while high density of the film and minimized interphase reactions occurred after sintering. The deposited volume, the mixing of dielectric and magnetic phases and the density and ordering of the films have been verified by electron scanning microscopy after heat treatment. No reactions between the different phases was found. The piezoelectric properties were measured on the sintered films.




[1] N.A. Spaldin, M. Fiebig, Science 309 (2005) 391.
[2] R. Ramesh, N.A. Spaldin, Nat. Mater. 6 (2007) 21.

# Recent advances in X-Ray Magnetic Circular Dichroism experiments at the BACH beamline

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Some recent scientific results on magnetic systems will be presented in order to highlight the novel possibilities offered to the user community by the beamline BACH at Elettra synchrotron light source.

BACH offers a unique multi-spectroscopy technique approach for the investigation of the magnetic, electronic, chemical, structural and dynamical properties of solid surfaces, interfaces, thin films and solid samples in the UV-soft x-ray photon energy range with selectable light polarization, very high resolving power, high magnetic fields and also time resolution.

Recently the spectroscopy possibilities have undergone a significant advance.
In particular we have developed a new UHV ±6 Tesla 1.8 K cryomagnet endstation for x-ray magnetic circular/linear dichroism (XMCD/XMLD) with a surface-preparation/sample-growth chamber, a special sample holder to study samples in liquid environment and a setup for time resolved pump-probe x-ray absorption spectroscopy realized with a table top laser pump combined to synchrotron x-ray absorption (XAS) probe for the study of dynamical processes with time resolution down to 70 ps.
We have furthermore implemented the possibility to acquire -in the same endstation and in a wide photon range from 40 eV to 1600 eV -: XMCD/XMLD (in remanence or low field) and pump-probe XAS in combination with fast high-resolution photoemission (UPS/XPS), x-ray emission (XES), fully-automatized resonant photoemission (RESPES), photolelectron diffraction (PhD) and angle-resolved photoemission (ARPES).

# Detection of vortex chirality via local hysteresis loops measured by Magnetic Force Microscopy

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Magnetic Force Microscopy (MFM) has been recently exploited to measure local hysteresis loops on sub-micrometric magnetic structures. The technique consists in repeatedly scanning the same profile of the sample by disabling the slow scan axis while synchronously changing the magnetic field. A suitable analysis of the phase channel in pass 2 provides a means of measuring local hysteresis loops and investigating the magnetisation reversal processes [1].
In the present work this technique is exploited to investigate the effect of vortex chirality on the shape of the local hysteresis loops of square dots of $Ni_{80}Fe_{20}$ (lateral size 800 nm, thickness 30 nm) prepared by EBL. MFM has been performed with Co-Cr coated tips at a lift scan height of 50 nm under static magnetic fields up to 800 Oe applied in-plane and parallel to dot edges. Out of the several investigated dots, two have been chosen because they reliably either revert or preserve the vortex chirality when brought first to positive and then to negative magnetic remanence (see insets in figure). MFM local hysteresis loops are significantly affected by vortex chirality. In particular, when the chirality is inverted between the first and the second loop branch, symmetric hysteresis loops are observed (left panels of the figure). Conversely, when the chirality is preserved between the two loop branches, the local hysteresis loops turt out to be asymmetric (right panels of the figure). Micromagnetic simulations have been performed on dots having the same shape, size and composition to calculate their domain configuration as a function of the applied field and the corresponding MFM images and local hystersis loops as if they were measured by the exploited MFM-derived technique. The loops shape and their different symmetries have been accurately reproduced and discussed.

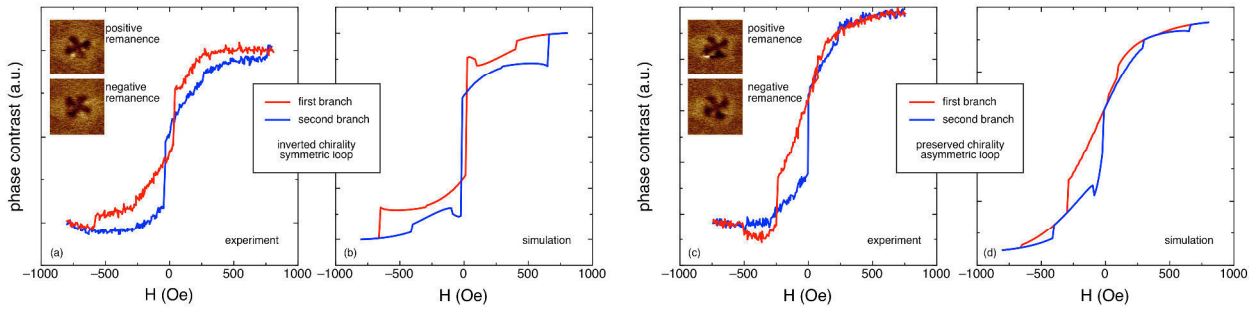


Figure 1: (Left) Experimental and simulated local hysteresis loops by MFM on a $Ni_{80}Fe_{20}$ dot whose chirality reverses from the first to the second loop branch (in the inset: MFM images taken at positive and negative remanence). The loops are symmetric. (Right) The same on a dot whose chirality is preserved from the first to the second loop branch. The loops are asymmetric.

[1] M. Coïsson, G: Barrera, F. Celegato, E. Enrico, A. Manzin, E.S. Olivetti, P. Tiberto, F. Vinai, J. Phys. D: Appl. Phys. 47 (2014) 325003

# Detecting magnetic anisotropy by using torque magnetometry: from single crystals to thin films

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Cantilever magnetometry has to be considered a very sensitive technique to detect magnetic anisotropy of molecular magnets. We present here a study that intended to fully exploit the extreme sensitivity of this technique, using two examples that enlighten several advantages that this kind of investigation can bring.

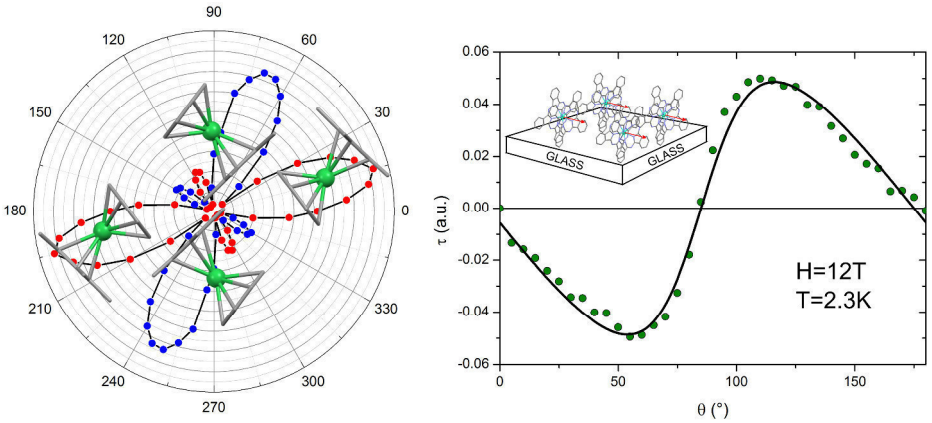


Figure 1: Angular dependence of the magnetic torque for a single crystal of Cp*ErCOT (polar plot, left) and for a 5nm thick layer of $TbPc_2$ of different thickness (right).

1) Cp*ErCOT [1]

Cp*ErCOT is an organic molecule that crystallizes in the orthorhombic space group, with two families of molecules almost orthogonal in the unit cell. While standard single crystal magnetometry can hardly provide information about this system [2], torque magnetometry is able to precisely determine the easy axis of the Er(III) ions, furthermore a study in temperature (2-250K) and as a function of the sweep rate of the applied field, gave access to the Crystal Field parameters (and thus to the energy level splitting of the ground *J* multiplet) and allowed detecting hysteresis loops, respectively.

2) $TbPc_2$ layers

$TbPc_2$ is a well-known Single Molecule Magnet with a huge energy barrier for the reversal of the magnetization and a strong Ising anisotropy. The molecular structure of this compound makes it ideal for the deposition in several substrates like gold and glass. When deposited on surface this robust molecule retain its magnetic properties [3], however up to now only synchrotron techniques are able to extract information about the magnetism of few layers of molecules. By using cantilever magnetometry we were able to detect and rationalize the magnetic torque of layers of different thickness (1μm- 5nm) thus proving the extreme sensitivity of this technique.

[1] M. Perfetti et al. Chem. Eur. J. 20 (2014) 14051
[2] M.E. Boulon et al. Chem. Eur. J. 19 (2013) 13726
[3] L. Margheriti et al. Adv. Mater. 22 (2010) 5488

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