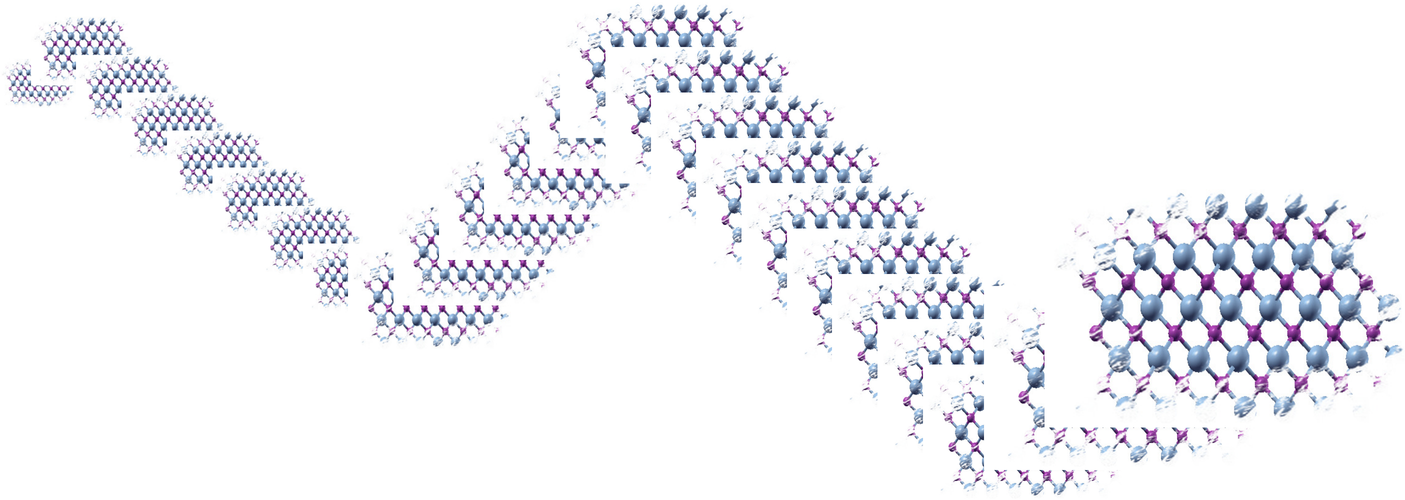
Scientific Report 2010 - 2011



Consiglio
Nazionale
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Table of contents

Foreword

On February 1st, 2010, the Italian CNR Institute INFM (Istituto Nazionale per la Fisica della Materia) was formally closed. On the same day, three new Institutes were created inside CNR (National Research Council). One of these is "SPIN", an evocative name as well as an acronym for "SuPerconductors, oxides and other INnovative materials and devices".

SPIN has included four previous INFM structures: Coherentia (Naples), LAMIA (Genova), SUPERMAT (Salerno) and CASTI (l'Aquila). Accordingly, SPIN has now four "Operative Units" (UOS), one in each of these cities. A fifth SPIN location is in Rome.

The Institute headquarters are in Genova, in a CNR building (Villa Balbi-Brignole), the other UOS are hosted inside University locations.

SPIN brings together most of the Italian research groups active in superconductivity, novel oxide and hybrid and nanostructured materials. The Institute derives its strength from the internationally recognized activities in thin film deposition and device realization historically present in the area of Napoli and Salerno due to the pioneering work on the Josephson effect by Prof. Antonio Barone, recently depassed*, as well as the tradition in materials synthesis and in large-scale applications of superconductivity present in the Genova area, originally strongly encouraged by Prof. Carlo Rizzuto.

This Report presents the CNR-SPIN structure, research focus and experimental facilities, as well as the scientific achievements of the first two years of activity.

We are confident that the high level of our researchers, the high qualification of the management structure and the rich set of advanced scientific instrumentation as well as the advice of our International Advisory Board, will make in the next few years CNR-SPIN a relevant European institution in the area of superconductors, oxides and innovative materials, fully open to collaboration with all groups active at international level in these fields.

Ruggero Vaglio

Director, CNR-SPIN

* See "In memory of Antonio Barone" - pag. 113

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Locations

SPIN belongs to the **CNR Material and Devices Department**, directed by Prof. Massimo Inguscio, and includes the following Operative Units:

Genova - *main focus: superconductivity, innovative materials*

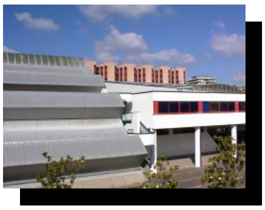
Corso F.M. Perrone, 24
16152 Genova, Italy

www.spin.cnr.it

University of Genova
Physics Department

Deputy Director: Carlo Ferdeghini

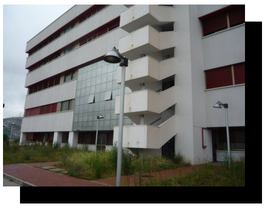
Napoli - *main focus: superconducting devices/oxide and organic electronics*



University of Napoli Federico II
Physical Science Department

Deputy Director: Giovanni Piero Pepe

Salerno - *main focus: superconductivity and magnetic hybrids*



University of Salerno
Physics Department

Deputy Director: Sergio Pagano

L'Aquila - *main focus: ferroics and multiferroics*

University of L'Aquila
Physics Department

Deputy Director: Silvia Picozzi

Roma - *main focus: oxide thin films/optical properties*

University of "Tor Vergata"
University of "La Sapienza"

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Research Lines

SPIN mission is the study of superconductors and other innovative materials for electronic devices and for energetics. The research activities span over :

Basic experimental and theoretical studies on superconducting and magnetic materials, strongly correlate oxides and other innovative materials

Material preparation (bulk, single crystals, thin films, multilayers, epitaxial superlattice)

Advanced material characterization based on radiation-matter interactions (also at Syncrotron Radiation Facilities), transport and electronic properties measurements also in presence of high external fields.

Micro/nano superconducting electronic devices (for quantum computation and other applications), electronic devices based on oxides (“*oxide electronics*”) and other innovative materials.

Realization of superconducting cables and tapes for power applications in the fields of biomedicine and high energy physics

The activities are formally organized into five “Activities”:

Materials and mechanisms of superconductivity and its power applications

(Activity leader: Marina Putti)

Superconductive and hybrid quantum nanostructures and devices

(Activity leader: Francesco Tafuri)

Cooperative phenomena in advanced materials with magnetic and/or dipolar electric ordering

(Activity leader: Antonio Vecchione)

Functional materials and novel devices for electronics and energy applications

(Activity leader: Daniele Marre’)

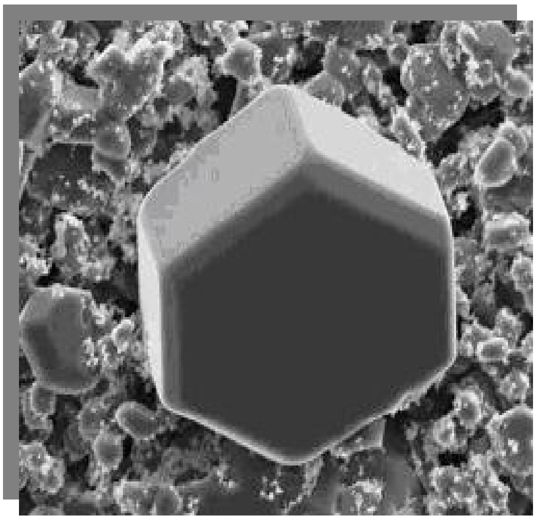
Dynamical, electronic and transport properties of complex systems and functional materials

(Activity leader: Vittorio Cataudella)

Research Lines

Materials and mechanism of superconductivity and its power application

Activity leader: Marnia Putti



The recent discovery of novel superconducting materials is going to offer new challenges in the understanding of the mechanisms, the development of new preparation techniques and the exploring of potential in view of applications. The activities of this commessa cover all these aspects. The synthesis of superconducting materials in form of bulks, single crystals, thin films and multilayers. The theoretical and experimental investigation of superconducting and normal state properties. The development and test of wires and cables for power applications.

General description

The discovery of superconductivity in cuprates, borocarbides, diborides and pnictides has brought the attention on the importance of non conventional pairing mechanisms, multiband effects and the coexistence of superconductivity and antiferromagnetic ordering. These features offer new opportunities for understanding of high-temperature superconductivity, and also limitations and advantages of non conventional superconductors. Thanks to the skills developed in sample synthesis, as well as in theoretical and experimental investigations the SPIN researchers established a fruitful network of national and international research collaborations: all started with the cuprates, later with MgB2 and finally with the newly discovered Fe-based superconductors (FeSC).

The commessa activities range over the preparation of materials in the form of bulk, thin films and tapes, wide-range investigation of the properties, development and test of cables for power applications.

All these activities will be carried on in two research units in strong connection each others, being aware that only a full control of the preparation techniques, a in-depth knowledge of material properties will allow significant step improvements for future application.

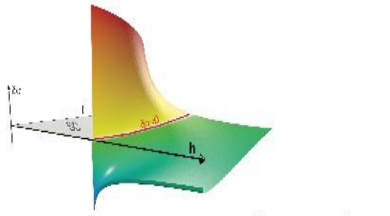
Research Lines

Materials and mechanism of superconductivity and its power application

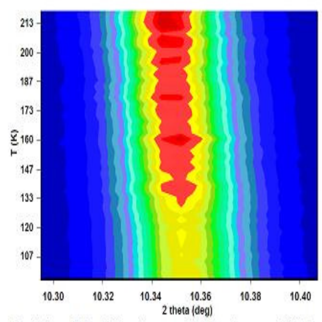
Activity leader: Marina Putti

1.1 Superconductivity: materials, mechanisms e technological transfer (Genoa)

Researchers of the Genoa unit belong both to the physics and chemistry fields and have long tradition and competence in material science.



Fluctuation conductivity



Evolution of the 110 peak on cooling for the sample $SmFeAs(O_{0.80}F_{0.20})$

The activities range over: material preparation: bulks and single crystals synthesis, thin film deposition, superconducting tape and wire manufacturing; structural and chemical characterization by XRD, neutron diffraction and synchrotron radiation experimental investigations by thermal, transport, magnetic, optical properties measurements and muon spin spectroscopy; theoretical modelling: ab-initio calculations, phenomenological models and fluctuoscopy of superconductors.

At present the research is focused on MgB2 and FeSC. FeSC are investigated with the twofold aim of understanding the coupling mechanisms and exploring their potential for application. Research on MgB2 is devoted to the improvements of cable performances for application like MRI systems and fault current limiters.

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Research Lines

Materials and mechanism of superconductivity and its power application

Activity leader: Marina Putti

References:

Giant Nernst effect due to fluctuagting Cooper pairs in superconductors, M.N.Serbin, M.A.Skvortsov, A.A.Varlamov, Viktor Galitski, PHYSICAL REVIEW LETTERS, 102, 067001, (2009)

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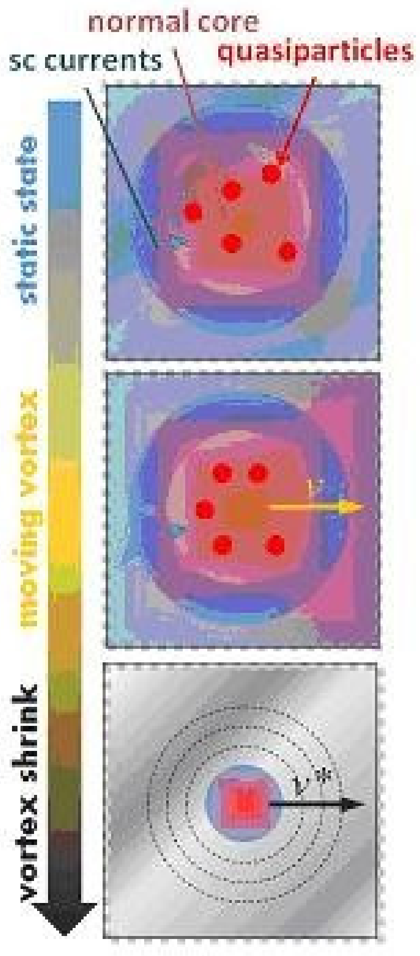
Materials and mechanism of superconductivity and its power application

Activity leader: Marina Putti

1.2 Static and dynamic properties of type-II superconductors, and their functional use for energy applications (Salerno)



Superconducting materials offer a huge potential applicability due to the high current carrying capability in high magnetic fields. Electric and magnetic properties in type-II superconductors play a crucial role in determining energy losses and critical currents and fields available for applications. Dissipations occur whenever vortices move through the pinning potential due to material defects, so to preserve lossless superconducting state the dynamic interaction between vortices and defects should be investigated. On the other hand, the stability of the superconducting state has to be pursued in most superconducting devices for energy: MRI, SMES, FCL, magnetic levitation, electric motors. Quenching, flux jumping and vortex instability due to electronic and/or thermomagnetic instability afflict all high field superconductors. Research activities in Salerno focus on bulk fabrication andcharacterization of innovative materials: transport, magnetic, thermal and electric noise measurements..

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Research Lines

Materials and mechanism of superconductivity and its power application

Activity leader: Marina Putti

References:

Granularity and vortex dynamics in $LaFeAsO_{0.92}F_{0.08}$ probed by harmonics of the ac magnetic susceptibility, M. Polichetti, M.G. Adesso, D. Zola, J. Luo, G.F. Chen, Z. Li, N.L Wang, C. Noce, S. Pace, PHYSICAL REVIEW B 78, 224523 (2008)

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Weak localization and 1/f noise in NdCeCuO thin films, C. Barone, A. Guarino, A. Nigro, A. Romano, and S. Pagano, PHYSICAL REVIEW B 80, 224405 (2009)

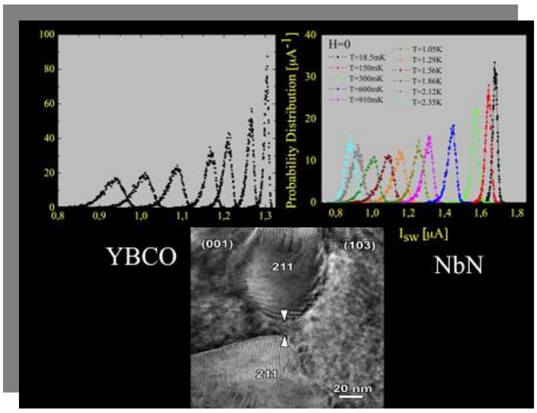
Evidence for low-field crossover in the vortex critical velocity of type-II superconducting thin films, G. Grimaldi, A. Leo, D. Zola, A. Nigro, S. Pace, F. Laviano, E. Mezzetti, PHYSICAL REVIEW B 82, 024512 (2010)

Research Lines

Superconductive and hybrid quantum nanostructures and devices

Activity leader: Francesco Tafuri

The research activity is focussed on fundamental aspects of superconductivity and possible applications. Junctions, hybrid nanostructures and nanowires of both traditional and unconventional superconductors (including high-Tc cuprates) are investigated. Mesoscopic hybrid structures and nanowires are engineered as particle and radiation sensors. Quantum coherence is the target of experimental activities on macroscopic quantum phenomena in Josephson junctions and on optical systems.



General Description

The physics of superconductivity in structures with reduced dimensions, macroscopic quantum phenomena in superconducting junctions, the possibility to develop a nano-hybrid platform incorporating superconductors are examples of intriguing and still unsettled topics of condensed matter physics with relevant implications for advanced high-tech applications. These represent the main targets of the research activity.

Quantum suppression of superconductivity in nanowires, the phase diagram of the superconductor-insulator transition, the dissipative dynamics induced by phase slips mechanism, for instance, are not only the bridge to novel physics, but also the key for a new generation of particle and radiation sensors. In addition transport studies of nanoscale devices can be instrumental in discerning the nature of the ground state of unconventional materials, and especially of strongly correlated systems.

Studies on quantum properties of Josephson junctions respond to the wide-spread need of expanding quantum technologies and in particular of developing quantum computation. In solid state qubit architectures, superconducting junctions can be considered as “atoms with wires”, which display energy-level quantization and strongly interact with electromagnetic environment.

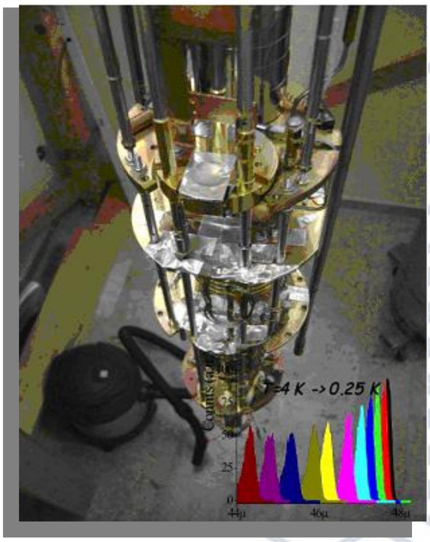
Research Lines

Superconductive and hybrid quantum nanostructures and devices

Activity leader: Francesco Tafuri

2.1 Quantum and non-equlibrium effects in junctions and hybrid nanostructures (Naples)

Within the general lines outlined abova, the activity of the Naples node is more specifically directed:



- to realize and measure the properties
  - of superconducting hybrid devices, to study transport mechanisms in Josephson junctions and to evaluate applicative impact;
  - of mesoscopic devices and nanostructures;
  - of superconducting and optical devices for quantum computation, to study macroscopic quantum effects in Josephson junctions, coherence and dissipation issues;
- to study non equilibrium superconductivity, radiation and particle sensors;
- to the physics of high critical temperature superconductivity through nano scale experiments
- to experiments aimed to optical entanglement and to realize hybrid superconducting/optical systems
- to perform non destructive evaluation tests on nanostructured materials.

Part of these activities are carried out in collaboration with prestigious National (NEST SNS) and International Institutions (IBM, Chalmers, Columbia,…).

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Research Lines

Superconductive and hybrid quantum nanostructures and devices

Activity leader: Francesco Tafuri

References:

Quantum dynamics of a d-wave Josephson junction, Thilo Bauch, Tobias Lindström, Francesco Tafuri, Giacomo Rotoli, Per Delsing, Tord Claeson, Floriana Lombardi, Science 311, 57 (2006)

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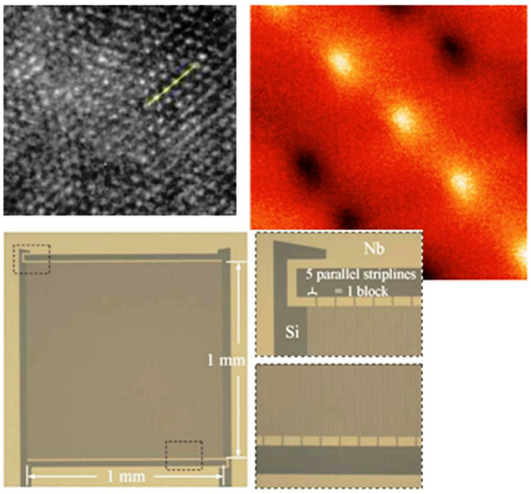
Superconductive and hybrid quantum nanostructures and devices

Activity leader: Francesco Tafuri

2.2 Superconducting and hybrid materials devices (Salerno)



The research activity focuses on both superconducting and innovative materials, with the twofold goal of deepening the knowledge of fundamental physics and of designing new devices. The study is performed on thin films and nanostructures based on traditional but also non-conventional superconductors. In this respect great effort has been devoted to the investigation of hybrid structures consisting of superconductors and ferromagnets. The research also covers the field of innovative materials, such as carbon nanotubes and graphene.

The unit has a well known experience in the fabrication and in the characterization of these materials, whose application of the analysed materials covers the field of superconducting and organic electronics, spintronics and radiation detectors.
More specifically some of the main activities are:

- electrical transport measurements on thin superconducting films and hybrid nanostructures
- design of nanostructured superconducting devices (valves, diodes, radiation and macromolecules detectors)
- low frequency voltage-noise-spectral density analysis on innovative materials, such as Fe based superconductors
- low temperature and high field local scale scanning probe microscopy (AFM, STM, MFM) on both unconventional superconductors and heterostructures
- field emission from carbon nanotubes and graphene flakes

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Research Lines

Superconductive and hybrid quantum nanostructures and devices

Activity leader: Francesco Tafuri

References:

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Asymmetry, bistability, and vortex dynamics in a finite-geometry ferromagnet-superconductor bilayer structure, G. Carapella, P. Sabatino, and G. Costabile, Phys. Rev. B 81, 054503 (2010)

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Thermal and voltage activated excess 1/f noise in FeTe0.5Se0.5 epitaxial thin films
C. Barone, S. Pagano, I. Pallecchi, E. Bellingeri, M. Putti, and C. Ferdeghini
Physical Review B 83, 134523 (2011)

Research Lines

Cooperative phenomena in advanced materials with magnetic and/or dipolar electric ordering

Activity leader: Antonio Vecchione

The activity is focused on materials where the coupling of spin, charge, and orbital degrees of freedom emerging from the electron-electron and electron-lattice interaction leads to electrical and magnetic unconventional properties strongly depending on cooperative phenomena of coexistence and / or competition of different types of long-range orderings. The research associated with these topics is carried out through the synthesis, analysis and modeling of advanced materials based on these phenomena. Systems of interest are the manganites, ferroics (including oxides, fluorides, sulphides), multiferroics and magnetoelectrics materials, oxides of copper, titanium, manganese, ruthenium and their associated features (high-temperature and triplet superconductivity, dielectric / ferroelectricity and magnetic orderings).

General Description

Advanced materials with magnetic and/or dipolar electric ordering (eventually based on transition metal oxides) have been attracting an ever-increasing interest, due to the wide variety of physical properties that they exhibit, including unconventional superconductivity, piezo- and ferro-electricity, colossal magnetoresistance, multiferroicity and a number of exotic magnetic, charge and orbital orderings. Furthermore, interface made of those materials can show properties at the nanometer scale that are qualitatively different from their single building blocks, allowing to engineer novel functionalities by resorting to the controlled growth of epitaxial heterostructures.

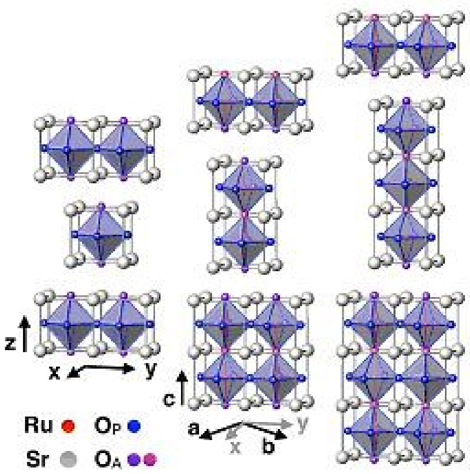
Within these activities the aim is to face the scientific challenge behind the complexity of these kind of advanced materials. Then, by exploiting the available expertise of the groups belonging to the present Commessa, we realize high quality samples in the different shapes of epitaxial thin films and single crystals also integrated together in complex heterostructures. Advanced material characterizations based on matter-light interaction, on scanning probe techniques and on magneto-electric transport measurements joined to theoretical modelling and advanced multi-scale computation are employed to analyze and get insight into different physical properties of materials with magnetic and/or dipolar electric ordering.

Research Lines

Cooperative phenomena in advanced materials with magnetic and/or dipolar electric ordering

Activity leader: Antonio Vecchione

3.1 Realization and study of materials with strong spin, charge and orbital correlations (Salerno)



The present activity points to the synthesis of material systems, within different methods of growth, such as thin films, single crystals and oriented samples in massive shape, that present strong correlations of spin, charge and orbital degrees of freedom and to their study by using ab-initio techniques, many-body approaches and numerical simulation techniques for the determination of the structural, magnetic, electronic and ferroelectric properties. Systems that will be the focus of the research activities include oxides based on transition metals, multiferroic perovskites and hybrid combination of them.

For the latter, ferromagnet hybrid structures (or normal metal) interfaced with a variety of systems that show the coexistence of magnetic and other type of orderings will be at the centre of investigation too.

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Research Lines

Cooperative phenomena in advanced materials with magnetic and/or dipolar electric ordering

Activity leader: Antonio Vecchione

References:

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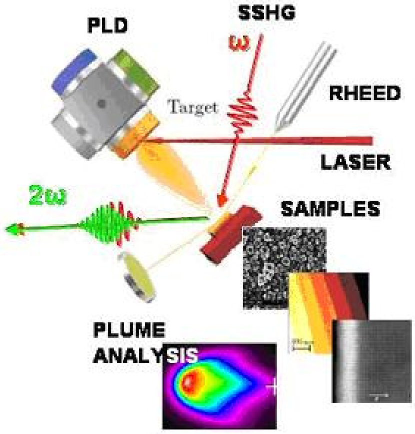
Research Lines

Cooperative phenomena in advanced materials with magnetic and/or dipolar electric ordering

Activity leader: Antonio Vecchione

3.2 Growth and characterization of epitaxial and nanostructured films, and interfaces: pulsed laser deposition, in-situ analysis, optical, magnetic and transport properties (Naples)



The study of physical properties and technological applications of innovative materials, like thin films of 'half metal' oxides or magnetic nanoparticles, high electronic mobility interfaces between insulating oxides and heterostructures with different functionalities (dielectric, ferroelectric, superconductive), require a fine control of the fabrication process as well as the use of advanced characterization techniques.

The samples will be grown by means of pulsed laser ablation, in the ns as well as fs time regime. The growth will be monitored in real time through different complementary techniques, capable of probing both the generated plasma and the surface. The 'in situ' characterization of the samples will be performed by means of photoemission spectroscopy, electronic diffraction and surface second harmonic generation (SSHG). The study of the electronic, magnetic, optical and structural properties of the fabricated samples will exploit several advanced characterization techniques: SSHG, transport measurements in external fields, magnetization measurements, THz spectroscopy, and advanced spectroscopies at large scale facilities.

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Research Lines

Cooperative phenomena in advanced materials with magnetic and/or dipolar electric ordering

Activity leader: Antonio Vecchione

References:

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Spectral and spatial distribution of polarization at the $LaAlO_3/SrTiO_3$ interface, A. Rubano, M. Fiebig, D. Paparo, A. Marino, D. Maccariello, U. Scotti di Uccio, F. Miletto Granozio, L. Marrucci, C. Richter, S. Paetel, and J. Mannhart, Physical Review B 83, 155405 (2011)

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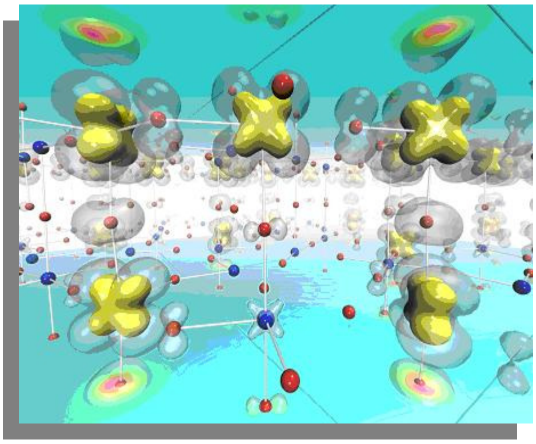
Research Lines

Cooperative phenomena in advanced materials with magnetic and/or dipolar electric ordering

Activity leader: Antonio Vecchione

3.3 Structural, electronic and vibrational properties of strongly-correlated systems (L'Aquila -Rome)



The activity deals with the study of materials in which there are strong electronic correlations and/or electron-phonon interactions (eg manganites, superconductors in the normal state) both by means of modeling of the properties of interest and through sub-THz, infrared and optical spectroscopy. The systems of interests are mainly multiferroics (materials showing at the same time ferroelectricity and magnetism) and charge-ordered compounds (hole-doped manganites, iron oxides etc).

Understanding the microscopic mechanisms underlying the observed phenomena and the quantitative estimate of the properties of interest, are the main objectives of our activity, available through an accurate comparison between theoretical predictions and experimental results. In particular, the research is focused on the interplay between structural and electronic (charge, spin or orbital) degrees of freedom and the consequences that these interactions have on the relevant properties (ferroelectricity, spin configuration, metal-insulator transitions, etc.).

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Research Lines

Cooperative phenomena in advanced materials with magnetic and/or dipolar electric ordering

Activity leader: Antonio Vecchione

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Research Lines

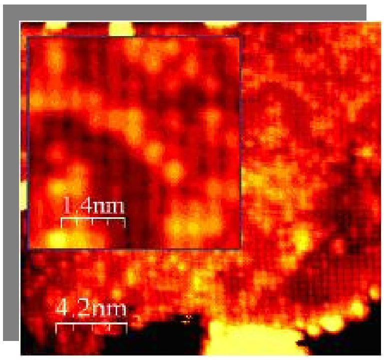
Functional materials and novel devices for electronics and energy applications

Activity leader: Daniele Marrè

The integration of innovative functional materials, such as transition metal or organic compounds, in the existing technologies is expected to be at the basis of future advances in crucial fields of electronics and energy. In order to prepare the ground for applications, fundamental properties of such innovative functional materials must be:
- studied and understood
- tailored to a specific application.

Together with the development of new technologies for devices realization and new approaches to electronics based on spin or lattice excitations, these are the main tasks of the "commessa".

General Description



Transition metal compounds (oxides, calcogenides,..), organic and hybrid (Org./Inorg). materials offer a rich spectrum of physical properties which encompasses ferromagnetism, ferroelectricity, superconductivity, very high-k dielectric, semiconducting and metallic behaviour. These properties turn out to be very sensitive to external parameters such as electric and magnetic fields, pressure, doping, etc. opening the possibility of creating new classes of sensors or devices adding new functionalities to existing technologies.

The research within the commessa aims to investigate innovative materials, achieve the control at atomic scale of their physical properties and tailor them to selected applications in the fields of (opto)electronics, sensors, spintronics, photonics and energy.

To this goal, we synthesize materials in form of bulk, nanoparticles and thin films, study their physical, morphological and structural properties and realize heterostructures and prototypes of novel (nano)devices.

The activity involves 33 researchers among chemists, physicists and material scientists plus several post docs and PhD students.

Research Lines

Functional materials and novel devices for electronics and energy applications

Activity leader: Daniele Marrè

4.1 Functional materials and novel devices for electronics and energy (Genoa)

The research carried out in Genoa is markedly committed to the realization of prototypical innovative devices based on transition metal compounds and to the development of new techniques to realize and characterize them. Nonetheless, fundamental studies on such materials are also performed.

More specifically some of the main investigated topics are:

- Interface phenomena in complex oxides heterostructures: 2DEG at oxide interfaces
- Optical and magnetic properties of transition metal nanoparticles and ultra-thin films
- Influence of strain, doping and external fields on transition metal compound films
- Fabrication and characterization of All-Oxides micro and nanodevices such as:
  - MEMS
  - Spin valve and spin torque devices
  - FET and MOSFET
  - μ-Fuel Cells
- Synthesis of oxide nanoparticles by in-liquid PLD
- Epitaxial Thin film and heterostructures growth by PLD
- Ink-jet deposition of chalcogenides for photovoltaic applications
- AFM nanopatterning of complex oxides
- Low temperature STM/STS

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Research Lines

Functional materials and novel devices for electronics and energy applications

Activity leader: Daniele Marrè

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Functional materials and novel devices for electronics and energy applications

Activity leader: Daniele Marrè

4.2 Fundamental properties of functional materials suitable for application in energetics (Rome and Salerno)

The growing demand for miniaturized systems for energy conversion and storage has required extensive research aimed at manufacturing of new solid-state devices in the form of thin films. In this respect, the recent developments of the thin film deposition techniques, such as molecular beam epitaxy (MBE) and pulsed laser deposition (PLD), have allowed the manipulation of these materials at the atomic level, opening the possibility of investigating and using their physical properties for the different engineering applications.

The activity of this "modulo" focuses on the study of physical properties of thin films of various materials for different fields of application (spintronics, optoelectronics, electronic) and with particular attention to the possible repercussions in energetics, exploiting the ability to control various extrinsic parameters (such as stoichiometry of heavy ions, the oxygen content of multiple materials, heterostructures strain induced by substrate, and others).

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Research Lines

Functional materials and novel devices for electronics and energy applications

Activity leader: Daniele Marrè

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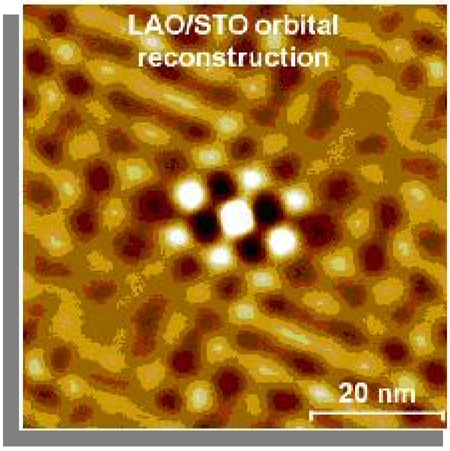
Research Lines

Functional materials and novel devices for electronics and energy applications

Activity leader: Daniele Marrè

4.3 Emerging routes for the control of the (opto)electronic properties of multifunctional materials and devices (Naples)

The activities are focused on the emerging routes for control and analysis of electronic properties of innovative materials, systems and devices going beyond the conventional chemical and physical techniques.



They concern materials presenting sensitivity to the strain, light, electric or magnetic field, chemical and electrical doping or present charge transfer or phase transition:

a) Organic: p- or n-type oligomer (6T, Pentacene, perilene) and polymers (Azo-benzene, polythiophene)

b) Oxides: conductive and semiconductive conventional oxides (ITO; ZnO, TiO2), strongly correlated oxides like manganites (LSMO), cuprates (NBCO), multiferroics

These studies include the realization of organic and oxide heterostructures such as T6/perilene or LAO/STO heterostructures. The techniques used are also based on advanced spectroscopies: RIXS and XAS by synchrotron radiation, impedance spectroscopy, SPM, SHG, SNOM, and use different deposition techniques such as evaporation, sputtering, PLD and MAPLE.

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Research Lines

Functional materials and novel devices for electronics and energy applications

Activity leader: Daniele Marrè

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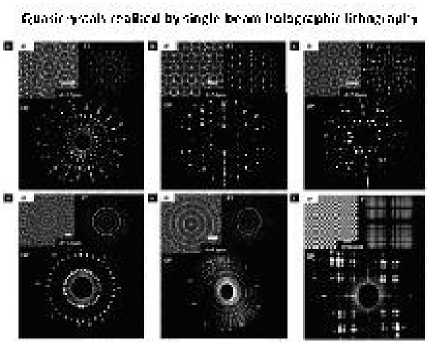
4.4 Novel materials and devices for electronics, plasmonics and photonics (Naples and L'Aquila)



The activity aims at theoretically and experimentally investigating the unconventional electromagnetic properties of artificial materials comprising metal, dielectric and metallo-dielectric micro and nano-structures. Examples of such artificial materials are metamaterials, photonic band gap materials, hybrid materials, etc.

The main target of the activity research is to exploit the novel electromagnetic features of these artificial materials to designing suitable devices for manipulating electromagnetic radiation from THz to visible frequencies. We focus our attention on optical devices characterized by micrometric and nanometric size.

Main research themes are:
1) Metamaterials with negative (e,m);
2) Highly nonlinear media with very small e;
3) Design and manufacturing of hybrid metamaterials with active components;
4) Metallic periodic nanostructures;
5) Photonics crystals and quasi-crystals;
6) Mechanisms of liquid crystals self-organization and reorientation in complex geometries.

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Research Lines

Functional materials and novel devices for electronics and energy applications

Activity leader: Daniele Marrè

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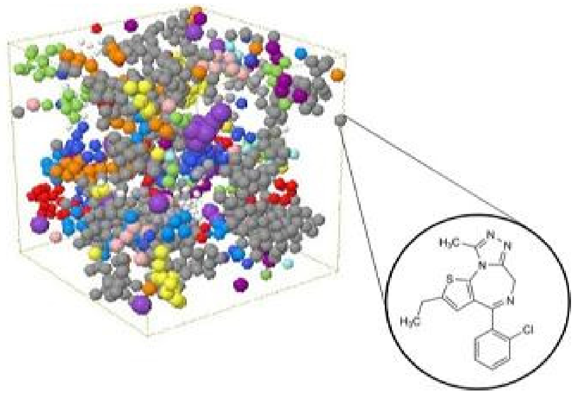
Research Lines

Dynamical, electronic and transport properties of complex systems and functional materials

Activity leader: Vittorio Cautadella

The integration of innovative functional materials, such as transition metal or organic compounds, in the existing technologies is expected to be at the basis of future advances in crucial fields of electronics and energy.



Complex dynamics of silica gel

In order to prepare the ground for applications, fundamental properties of such innovative functional materials must be:

- studied and understood
- tailored to a specific application.

Together with the development of new technologies for devices realization and new approaches to electronics based on spin or lattice excitations, these are the main tasks of the “commessa”.

General Description

The recent advances of materials and devices fabrication have allowed to address unprecedented properties and phenomena facing the demand for materials with new functionalities and the need for molecular-scale electronic devices. Insights in such complex systems can be obtained exploiting the synergy among different approaches able to describe material properties at different length scales (multi-scale approach), ranging from the microscopic (first-principles electronic structure calculations) to the mesoscopic (analytic methods of quantum field theory) to the macroscopic (Monte Carlo and molecular dynamics approaches, numerical methods for the analysis and image reconstruction) level.

The final goal is the understanding/prediction of the magnetic, optical, transport, and thermal properties of systems as correlated oxides, graphene and carbon nanotubes, hybrid surfaces and interfaces, nano-mechanical devices with emphasis on the control of quantum state (information). Our focus will also be on the complex behavior of “classical” systems such as granular media, colloids and polymers with the ambition to propose new functionalities and to model processes of interest for the science of life borrowing methods of statistical mechanics.

Research Lines

Dynamical, electronic and transport properties of complex systems and functional materials

Activity leader: Vittorio Cautadella

5.1 Models and first-principles approaches for functional materials and complex systems (Naples)

This sub-activity will mainly focus on the following themes:

study of disordered soft materials, based on mesoscopic elementary components, exhibiting unconventional thermodynamic, mechanical and rheological properties (polymers, colloids and granular particles)

first-principles studies of multifunctional materials for electronics and optics (graphene, carbon-based nanostructures, nanostructured oxides in presence of organic adsorbates for photovoltaic cells, complex surfaces and interfaces)

model studies of underdoped cuprates: phonon and electron spectral functions, optical conductivity

(spin) transport properties in interacting nanostructures (quantum dots, OFET, hetero-structures F/S, molecular electronic devices)

statistical mechanics models for systems of biological interest: X chromosome inactivation; chromosome 3D organization

multi-scale approach to molecular transport including the coupling with the lattice degrees of freedom

development of new theoretical tools (computer software and models).

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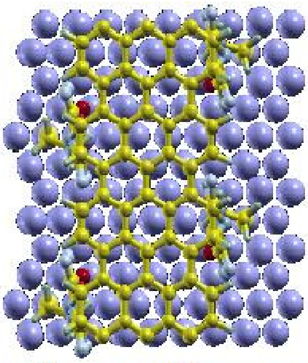

graphene nanoribbon on a metallic surface

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A. Coniglio, G. Iadonisi, V. Cataudella, L. De Arcangelis, D. Ninno, R. Citro, A. De Candia, G. De Filippis, M. Nicodemi, C. A. Perroni, T. Abete, I. Borriello, N. R. D' Amico, A. Iacomino, A. Iorio, F. Romeo

Research Lines

Dynamical, electronic and transport properties of complex systems and functional materials

Activity leader: Vittorio Cautadella

References:

Sharp Transition for Single Polarons in the One-Dimensional Su-Schrieffer-Heeger Mode, D. J. J. Marchand, G. De Filippis, V. Cataudella, M. Berciu, N. Nagaosa, N. V. Prokof’ev, A. S. Mishchenko, and P. C. E. Stamp, Phys. Rev. Lett. 105, 266605 (2010)

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Spin Channels in Functionalized Graphene Nanoribbons G. Cantele, Y.S. Lee, D. Ninno, N. Marzari, Nano Letters 9, 3425 (2009)

Charge dynamics of doped holes in high Tc cuprates - A clue from optical conductivity A. S. Mishchenko, N. Nagaosa, Z.-X. Shen, G. De Fillipis, V. Cataudella, T. P. Devereaux, C., Bernhard, K. W. Kim, and J. Zaanen, Phys. Rev. Lett. 100, 166401:1-4 (2008)

Static and dynamic heterogeneities in a model for irreversible gelation T. Abete, A. de Candia, E. Del Gado, A. Fierro, and A. Coniglio, Phys. Rev. Lett. 98, 88301 (2007)

Dynamical, electronic and transport properties of complex systems and functional materials

Activity leader: Vittorio Cautadella

5.2 Quantum nano devices and complex systems (Genoa)

This sub-activity will focus mainly on the following themes:

nano-devices based on Hall effect: calculations based on models of current, noise and study of interference effects

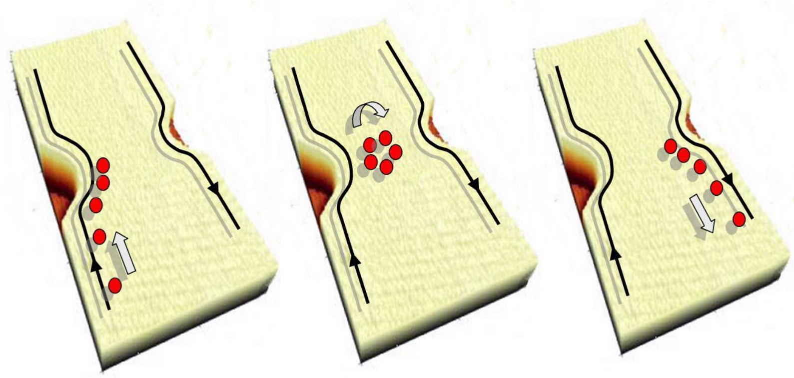
modelling of dynamical effects on quantum nano-electromechanical devices (NEMS) out of equilibrium

transport properties in suspended carbon nanotubes

development of 'image enhancement' techniques for magnetic resonance data in order to improve the signal-noise ratio

development of methods of source modeling applied to Electro-encephalography (EEG) and magneto-encephalography (MEG) data

applications of pattern recognization methods to the analysis of RHEED images obtained during the film growth.



Contact person: Maura Sassetti (sassetti@fisica.unige.it)

Researchers:
A. Braggio, A. M. Massone

Associate researchers:
A. Verri, M. Sassetti, M. Piana, F. Napoli, R. Raimondi, F. Cavaliere, D. Ferraro, G. Piovano, G. Giorni, S. Allavena

Research Lines

Dynamical, electronic and transport properties of complex systems and functional materials

Activity leader: Vittorio Cautadella

References:

Charge tunneling in fractional edge channels D. Ferraro, A. Braggio, N. Magnoli and M. Sassetti, Phys. Rev. B 82, 085323 (2010)

Asymmetric Frank-Condon factors in suspended carbon nano tube quantum dots F. Cavaliere, E. Mariani, R. Leturcq, C. Stampfer, and M. Sassetti, Phys. Rev. B 201303(R) (2010)

Dynamical MEG source modelling with multi-target Bayesian filtering A. Sorrentino, L, Parkkonen, A. Pascarella, C. Campi and M. Piana, Human Brain Mapping, Vol. 30 pp. 1911 (2009)

Counting Statistics of non-markovian quantum stochastic processes C. Flindt, T. Novotny, A. Braggio, M. Sassetti and A.-P. Jauho, Phys. Rev. Lett. 100, 150601 (2008)

Relevance of Multiple Quasiparticle Tunneling between Edge States at ν=p/(2np+1) D. Ferraro, A. Braggio, M. Merlo, N. Magnoli, and M. Sassetti, Phys. Rev. Lett. 101, 166805 (2008)

Selected experimental facilities

SPIN is endowed with a large set of advanced scientific equipments, including nearly 20 thin film deposition systems, 3 clean rooms, 3 low temperature - high field STM systems, numerous laser sources emitting form IR to UV and ranging form CW mode to femtosecond pulses.

SPIN equipments can be grouped into the following homogeneous AREAS :

Thin film Deposition (Resp. Giuseppe Balestrino)

Lithography (Resp. Nadia Martucciello)

Bulk material preparation (Resp. Alberto Martinelli)

Structural, morphological and chemical properties (Resp. Umberto Scotti di Uccio)

Optical properties and characterization (Resp. Domenico Paparo)

Electronic and transport properties (Resp. Luigi Maritato)

Computation (Resp. Mario Cuoco)

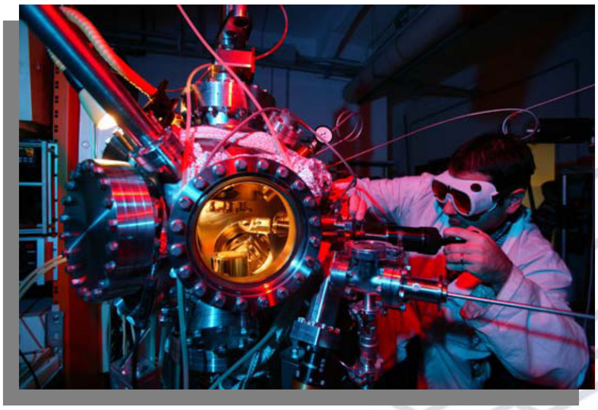
The role of the AERA Responsible is to guarantee the optimal use of the Institute equipments and to promote new acquisitions to improve the Institute potentialities in the specific area.

Selected experimental facilities

Thin Film Deposition

Deposition system PLD 700 mJ "oxides"

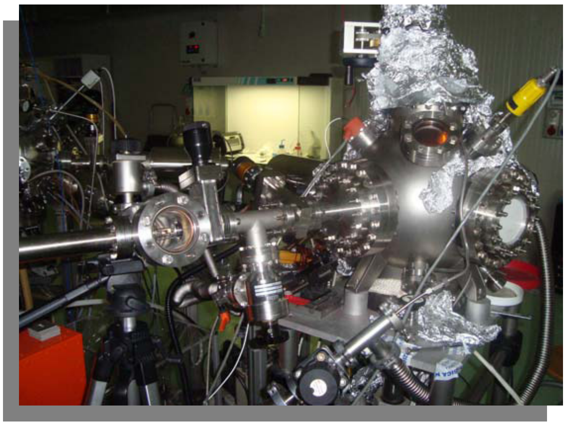
Contact: Emilio Bellingeri (GE)



Pulsed laser deposition system Pressure down to 10-9 mBar and substrate temperature up to 900°C also in O2 atmosphere. Fast entry system for sample loading, differentially pumped RHEED working up to 10-2Mbar O2; Pulsed gas inlet synchronized with laser pulses; 6 targets; HV sample manipulation by wooblestick. The system is specifically designed for oxide thin films deposition and is interfaced with a cryogenic STM by a HV transfer chamber.

Deposition system PLD 700 mJ "metals"

Contact: Emilio Bellingeri (GE)



Pulsed laser deposition system Pressure down to 10-11 mBar and up to 10-5 mBar O2; substrate temperature up to 1200°C. Fast entry system for sample loading, RHEED; 4 targets; UHV sample manipulation by wooblestick. The system is specifically designed for intermetallic thin films deposition and is interfaced with a cryogenic STM by a UHV transfer chamber.

Experimental set-up for the deposition of ultrathin metallic films by MBE

Contact: Riccardo Moroni (GE)

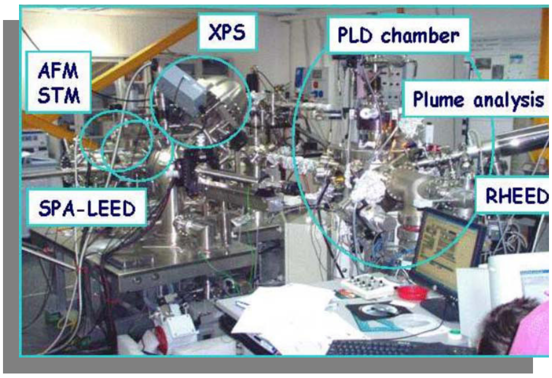
UHV chamber equipped with: electron-beam deposition sources for the growth of ultrathin metallic films; ion gun for sputter cleaning; UHVcompatible 5 degree-of-freedom sample manipulator; variable temperature sample holder (130–800 K). The UHV chamber also features an Auger electron spectrometer (AES) and a low-energy electron diffraction (LEED) set-up.

Selected experimental facilities

Thin Film Deposition

MODA: Modular facility for Oxide Deposition and Analysis system

Contacts: Fabio Miletto / Marco Salluzzo (NA)



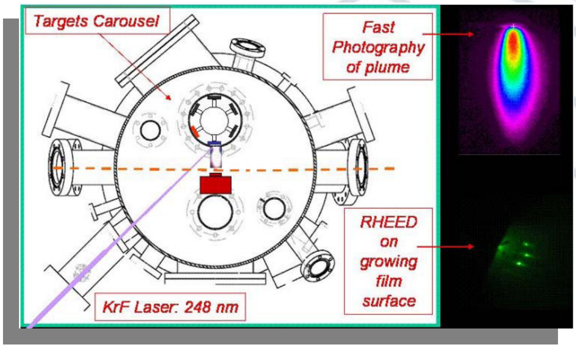
Surface Analysis Chamber

The MODA surface Analysis chamber is equipped with several experimental techniques aimed to the study of the chemical, structural and electronic properties of thin films and single crystals.
A manipulator with independent 5 degrees of freedom allows XPS, UPS analysis of the samples in a temperature range from 300K to 1200K (upgradable 20K-1200K).

The MODA surface Analysis chamber is equipped with several experimental techniques aimed to the study of the chemical, structural and electronic properties of thin films and single crystals.
A manipulator with independent 5 degrees of freedom allows XPS, UPS analysis of the samples in a temperature range from 300K to 1200K (upgradable 20K-1200K). The chamber has been designed to be further implemented with other surface preparation and characterization techniques, like ion sputtering and photoelectron diffraction. the Analysis chamber is also equipped with a SPM microscope and an SPA-LEED instruments as described below:

Pulsed Laser Deposition chamber

UHV chamber for Pulsed Laser Deposition with in-situ control of the growth process by high pressure Reflection High Energy Electron Diffraction (RHEED). Heterostructures and superlattices can be grown thanks to a multi target carrousel where up to six different targets can be mounted. The deposition is performed with an KrF excimer laser (Compex Pro 205) at 248 nm wavelength, delivering laser pulses of 25 ns duration, maximum energy 800mJ.



Top view of the deposition chamber and of the two diagnostic tools used for monitoring the plume expansion (ICCD camera) and the film growth (RHEED)

The substrate is placed on a heater which can heat up to 850°C, also in Oxygen atmosphere. The final vacuum of about 10-9 mbar is obtained by a turbopump. The system is also equipped with two load-lock chambers to transfer the substrates and the targets without breaking the vacuum conditions. The samples can be in-situ transferred in UHV conditions to the analysis chamber for the surface characterizations by XPS, UPS, SPA-LEED, STM, AFM. The ICCD camera can be also installed to study the plume expansion dynamics.

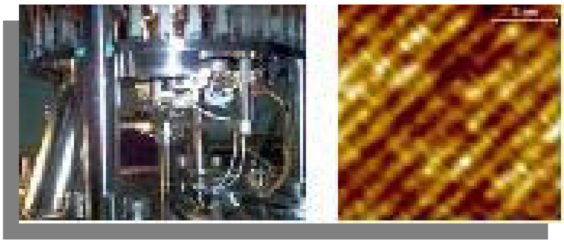
Selected experimental facilities

Thin Film Deposition

UHV XPS/UPS

The substrate is placed on a heater which can heat up to 850°C, also in Oxygen atmosphere. The final vacuum of about 10-9 mbar is obtained by a turbopump. The system is also equipped with two load-lock chambers to transfer the substrates and the targets without breaking the vacuum conditions. The samples can be in-situ transferred in UHV conditions to the analysis chamber for the surface characterizations by XPS, UPS, SPA-LEED, STM, AFM. The ICCD camera can be also installed to study the plume expansion dynamics.

UHV STM/AFM plus Surface Analysis Chamber



A close view of the VT-AFM instrument and 4x1reconstruction of a TiO2 anatase atomic row of a thin film deposited in situ by PLD. (M. Radovic et al. unpublished.)

The UHV Omicron VT-AFM system is designed to operate as scanning tunneling microscope, atomic force microscope, and hybrid scanning probe microscopes, in a temperature range between 300K-1000K (20K-1000K upgradable). This instrument is especially intended to the characterization of clean crystalline surfaces, in particular thin films prepared in-situ either by PLD or other deposition techniques, or single crystals (cleaved or annealed).

The max scan area is 8x8 µm2 with a spatial resolution below 0.1 nm. The vertical resolution is 0.01nm. The VT-AFM is capable to operate in a variety of spectroscopic modes: I-V and G(V) (conductance) spectroscopy in STM and contact AFM modes Electrostatic force microscopy Magnetic force microscopy Kelvin probe microscopy Piezoforce microscopy
The UHV (P<10-11mbar) surface anaysis chamber is equipped a manipulator having 5 degrees of freedom, heatable up to 1000°C.

UHV SPA-LEED

4x1reconstruction of a TiO2 anatase atomic row of a thin film deposited in situ by PLD. (M. Radovic et al. unpublished.)

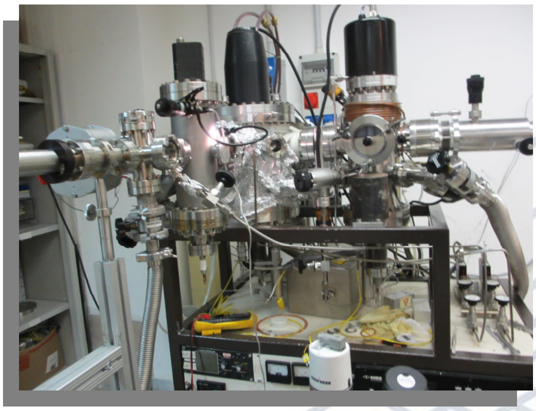
The Spot Profile Analysis Low Energy Electron Diffraction instrument (SPA-LEED) is a special LEED designed to allow high resolution reciprocal space mapping of ordered surfaces.
This LEED is used for the thorough analysis of defect structures on single crystal surfaces. The technique enables precise quantitative analysis of lateral and vertical lattice constants, terrace/islands size and height distribution, ordering parameters in phase transitions etc. The main part of the SPA LEED is an octopole which enables the scanning of the diffracted beam over a detection assembly, thus improving the signal to noise ratio and resolution compared to conventional, screen and camera based systems.

Thin Film Deposition

Multi Chamber sputtering deposition system

Contact: Marco Salluzzo (NA)

The Multi-chamber UHV sputtering system is designed for the growth of very thin oxide thin films on area up to 2 inches. It is equipped by a chamber dedicated to the growth of HTS cuprate superconductors (NdBCO, YBCO, LSCO), a chamber dedicated to the deposition of ferroectric and multiferroic thin films (BiMnO3, SrMnO3) and by a chamber for the in-situ growth of metal contacts (joule evaporator and sputtering) with suitable geometry by shadow mask.
All-in-situ field effect prototipes and stacked HTS / dielectric / metal structure can be realized in this system.



Sputtering system for materials and junctions

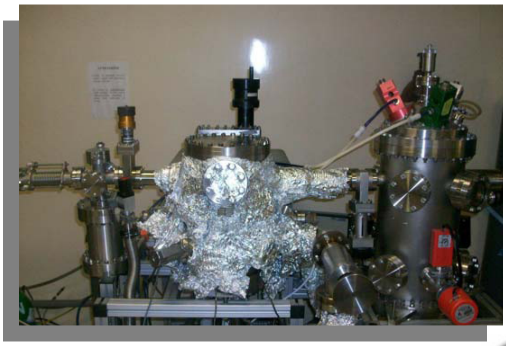
Contact: Loredana Parlato (NA)

Three chambers ultra-high vacuum system: one of these, equipped with three DC and RF 2.0” sputtering magnetrons, is connected to the other two, both with independent access. The second chamber is equipped with an etching ion gun and a self-made substrate cooling system based on N2 gas flow, while the third one has a 2” DC and RF sputtering magnetron and a substrate holder with a distance that can be changed without breaking vacuum.

Deposition system for hybrid (organic/inorga nic) materialsand devices

Contact: Antonio Cassinese (NA)

Thin-film deposition system consisting of two deposition chambers connected by a load lock and equipped with a flash evaporation system and 2 knudsen cells allowing deposition of organic material and metals.



Selected experimental facilities

Thin Film Deposition

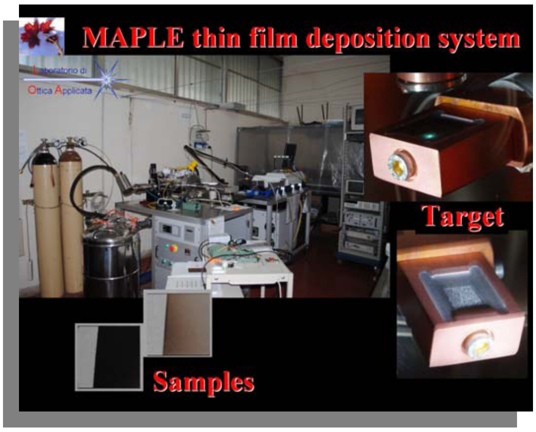
PLD system for nanoparticles an thin films deposition (Fs-PLD)

Contact: Xuan Wang (NA)

PLD system for ultrafast laser ablation, nanoparticle generation and nanoparticle assembled film deposition. The laser spourse is a Light Conversion Nd:glass Twinkle (3mJ/1054 nm/850 fs; 1 mJ/527 nm/300 fs; 0.25mJ/266nm/300 fs). The PLD system is equipped with a vacuum chamber with accessories and feedthroughs.

MAPLE thin film deposition system

Contact: Francesco Bloisi (NA)



MAPLE (Matrix Assisted Pulsed Laser Evaporation) system for biomaterials and polymeric thin film deposition composed by a vacuum chamber (pressure down to 10-7 mbar) and a Qswitched Nd:YAG pulsed (7ns, 0.5-10Hz) laser operating in IR (1064nm, 1.17eV, 500mJ/pulse) VIS (532nm, 2.33eV, 100mJ/pulse) or UV (355nm, 3.49eV, 90mJ/pulse) with in place target refrigeration (liquid nitrogen, 77K) and substrate heating (up to ~470K

PLD thin films deposition system with insitu RHEED diagnostics

Contact: Antonello Tebano (RM)

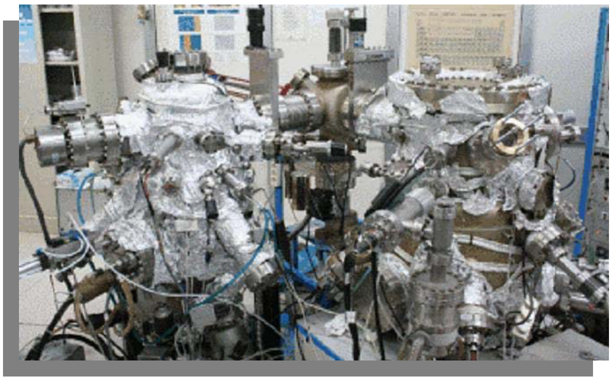
It is a system equipped with an excimer laser. The apparatus has a multitarget system for oxide heterostructures and superlattices deposition. A Reflection High Energy Electron Diffraction (RHEED) system allows the in-situ growth diagnostics. It is also possible to use an oxygen deposition atmosphere enriched with 12% of ozone.

Selected experimental facilities

Thin Film Deposition

Molecular Beam Epitaxy deposition system

Contact: Pasquale Orgiani (SA)



The system consists of a UHV Chamber equipped with different effusive cells inferred (by DCA) to the evaporation of individual materials. The system is equipped with e-gun STAIB for the analysis of in-situ growth (RHEED). It is also equipped with a pre-Chamber for loading the samples without breaking the vacuum conditions in the main Chamber. This last room is also equipped with an indipendent pumping system.

RF Sputtering

Contact: Giovanni Carapella (SA)

Magnetron Rf sputtering (13 MHz, 1.5 KW) with three 6 inch deposition sources and one sputter etch cathode. Cryopumped deposition chamber and turbo-pumped load lock. Used for deposition of superconducting (Nb, Al), insulators (SiO2), normal (Cu, Mg), and magnetic (Co, Cr, NiFe, CoFe, FeMn) thin films. The load lock is also used for growth of very thin films of Al2O3 by thermal oxidation of Al. Used for Ferromagnet-Superconductor devices or nanoscale superconducting devices.

Three sources UHV sputtering

Contact: Carla Cirillo (SA)

UHV dc magnetron sputtering equipped with a load-lock chamber. The systems has 3 sources, one especially designed for the fabrication of ferromagnetic materials. The deposition chamber is equipped with a movable protecting shutter driven by a pc controlled step motor, in order to fabricate up to 8 samples in the same deposition run. This solution allows the realization of different layered hybrid structures under identical deposition conditions.

Lithography

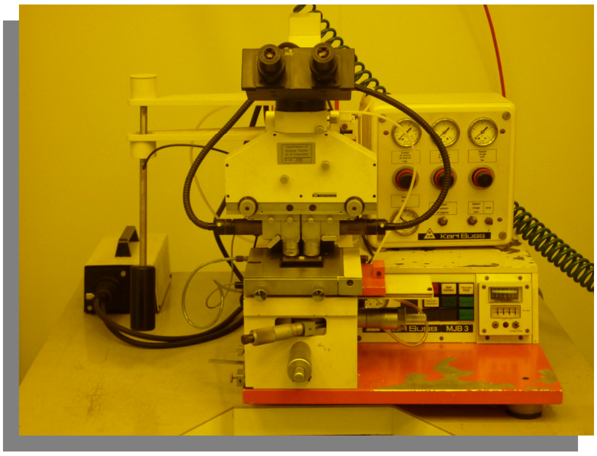
Photolitographic Laboratory

Contact: Antonio Cassinese (NA)

Photolitographic room and substrate treatment room allowing processes with a resolution of 1µm. The room is dedicated to activities concerning oxide materials of interest for electronics and soft – lithography technique for the realization of PDMS microchannel.

Photolithography laboratory

Contact: Nadia Martucciello (SA)



Laboratory dedicated to optic lithography in class 1000 Clean Room, with Mask Aligner Karl Suss with UV lamp, spinner Cammax and spinner Laurell, drying oven, chemical bench, optical transmission and reflection microscope.

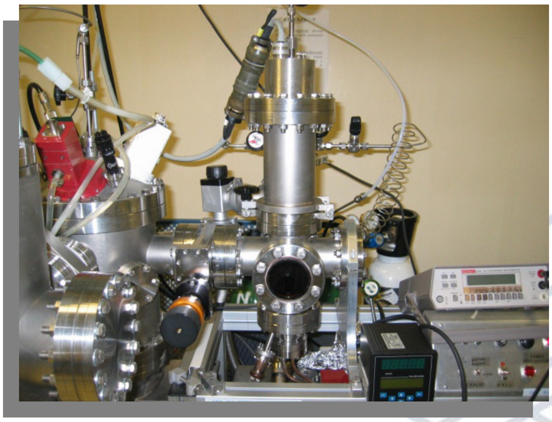
Selected experimental facilities

Lithography

Ion milling system

Contact: Loredana Parlato (NA)

High vacuum chamber equipped with ion gun for etching process and a self-made substrate cooling system based on N2 gas flow. The substrate's temperature can be monitored during the process.



Electron Beam Lithography

Contact: Giovanni Carapella (SA)

Electron Beam Lithography with beam control system and Raith software for writing. Resolution 100 nm.
The system is installed in class 10000 Clean Room.

SIMC-SA (Station for Ion-Milling and Contact deposition)

Contact: Pasquale Orgiani (SA)

UHV Riber system allows milling of thin films using argon ions with energies of 300eV-500eV and current density near 1mA/cm2. The sample is kept fixed, also inclined with respect to the ionic beam. In addition, the system is equipped with an 3-crucibles e-beam RIBER for in-situ deposition of metal contacts in the form of pure materials and/or alloys..

Bulk material preparation

Isostatic Press

Contact: Alberto Martinelli (GE)

Isostatic Press for the preparation of powder greens with different morphologies. Maximum pressure: 1000 bar; chamber diameter 10 cm. The powders to be sintered are put inside a rubber mould, that is inserted within the oil contained in the chamber. By applying a pressure in the chamber it is possible to obtain powder compacts (green) with minimum porosity.

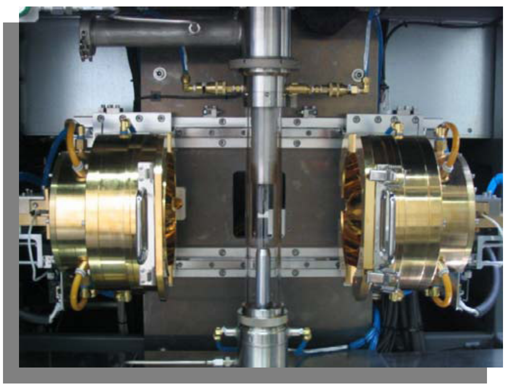
Glove Box

Contact: Alberto Martinelli (GE)

Glove-box working under a controlled atmosphere with H_2O and O_2< 1ppm.

Infrared image furnace

Contact: Antonio Vecchione (SA)



The main equipment related to the single crystal growth activity is the infrared image furnace installed in 2005. This was the first time an instrument of this kind was used in Italy. It is a two mirror system, where the light from the two halogen bulbs is focused by the semi-ellipsoidal mirrors onto a central zone. The efforts of the SPIN researchers involved in the field of single crystal growth are focused on the growth of large superconducting and magnetic oxides. Single crystals of high Tc superconducting oxides, pure and eutectic strontium ruthenates and multiferroics are regularly produced and made available to collaborators within the Italy and abroad.

Structural, morphological and chemical properties

Theta-2theta diffractometer for thin films and powders

Contact: Emilio Bellingeri (GE)

Bragg Brentano diffractometer for powders and thin films. The theta angle movement is independent from 2theta. The setup allows low angle measurements so that it can be used for thin films thickness measurements (range 10-100nm). It mounts 1°,1/2°, 1/4°,1/30° slits on the incident beam. 1°,1/2°, 1/4° slits, Ni filter and graphite monochromator are on the diffracted beam side.

4-circles diffractometer

Contact: Emilio Bellingeri (GE)

4-circle (theta, omega, phi and chi) automatic diffractometer equipped with quartz monochromator on the diffracted beam (presently to be substituted by a Ni/C parabolic monochromator on the incident beam). The setup allows phase analysis (theta-2theta) and preferential orientation (rocking curve, phi scan, polar maps reciprocal lattice maps) measurements. Equipped with steady or oscillating bulk-sample holder and goniometric head for thin films and single crystals, with telescopic laser alignment.

AFM

Contact: Renato Buzio (GE)

AFM with 50um x 50um or 5um x 5um maximum scanningsample capabilities. It is equipped with an optical microscope with lateral resolution of 5um. It operates under ambient conditions or within a liquid cell - with temperatures up to 150°C - in standard contact mode and dynamic modes. Control unit allows to acquire 2 simultaneous maps. STM, Kelvin, conductive, capacitive and force-volume modes are readily available. AFM can also be used for constant-current electrochemical nanolithography.

Structural, morphological and chemical properties

SEM

Contact: Antonio Vecchione (SA)

The electron microscopy facility is constituted by a tungsten/LaB6 scanning electron microscope (SEM) (LEO EVO 50) with a secondary electron detector for surface imaging and a 4-quadrant back-scatter electron detector for density imaging detector. The analytical instrumentation is comprised of an Oxford Instruments INCA ENERGY (EDX) xray analysis system, INCA WAVE (WDX) wavelength dispersive x-ray spectrometer and INCA CRYSTAL (EBSD) electron back-scatter diffraction.

High Resolution X-ray Diffraction

Contact: Antonio Vecchione (SA)

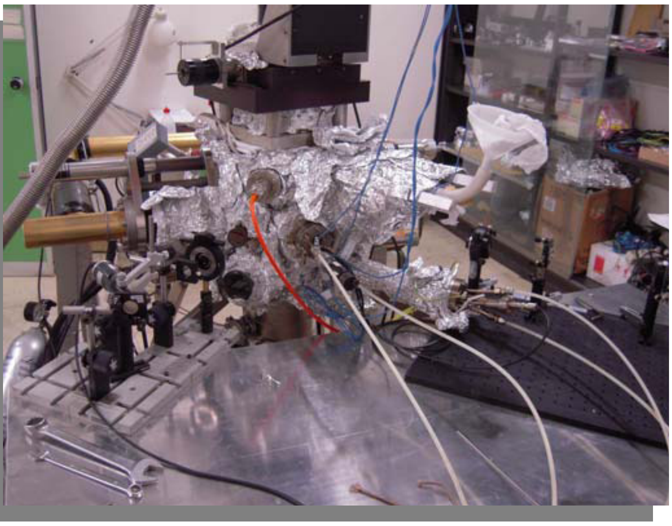
The high resolution x-ray diffractometer (Pananalytic X'Pert MRD PRO) is a highly advanced, versatile materials characterization system. Interchangeable PreFIX incident and diffracted beam optics can be configured for optimal measurement of high resolution scans and reflectivity experiments. By combining incident (with graded parabolic x-ray mirror and four-bounce Ge(220) monochromator) and diffracted (with triple axis setup using a three bounce (022) channel cut Ge crystal) beam optics, high resolution configuration can be applied to highly ordered crystals and epitaxial thin films.

Selected experimental facilities

Optical properties and characterization

Variable temperature UHV MOKE magnetometer

Contact: Riccardo Moroni (GE)



In-situ UHV magneto-optical Kerr effect (MOKE) magnetometer working with laser diodes at 670 and 532 nm. Lock-in detection of the Kerr signal to achieve extreme sensitivity. Longitudinal and polar MOKE configurations can be implemented for the measurement of the in-plane and out-ofplane components of the magnetization. Sample temperature from 130 to 800 K. Maximum magnetic field 1000 Oe.

Interferometer for infrared spectroscopy

Contact: Paolo Calvani (RM)

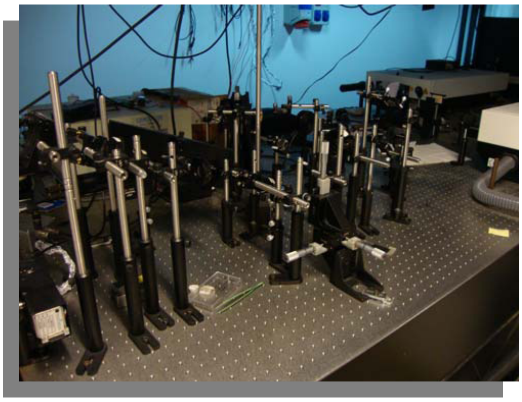
BRUKER 66V model, equipped for measurements under vacuum of reflectivity, diffuse reflectivity, and transmittance, from 30 to about 20000 cm-1, with spectral resolution up to 0.2 cm-1. It is also equipped with a cryostat working between 8 and 300 K, and an infrared microscope BRUKER IRscope I with lateral resolution 10 microns.

Selected experimental facilities

Optical properties and characterization

Surface Second Harmonic Generation Apparatus

Contact: Domenico Paparo (NA)



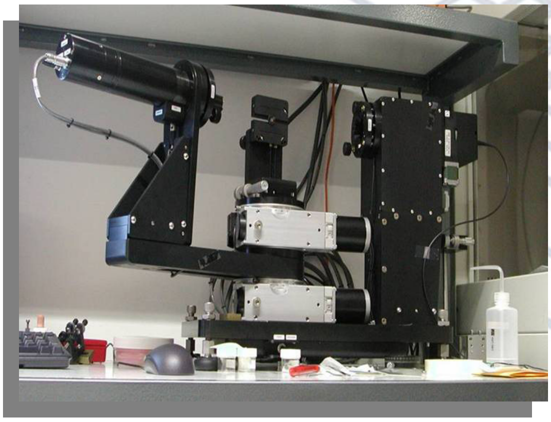
Experimental apparatus for phase-resolved second harmonic generation from surfaces for characterization of surfaces and buried interfaces. The set-up is based on a Nd:YAG laser system delivering pulses of 30 ps of duration at a repetition rate of 10 Hz and energy per pulse up to 60 mJ. The laser is provided with crystals for frequency duplication and triplication.

The apparatus is completed with acquisition electronics based on a Gated Integrator for increasing the signal-to-noise ratio and permitting, hence, operation in the photon-counting regime.

Spectroscopic ellipsometer

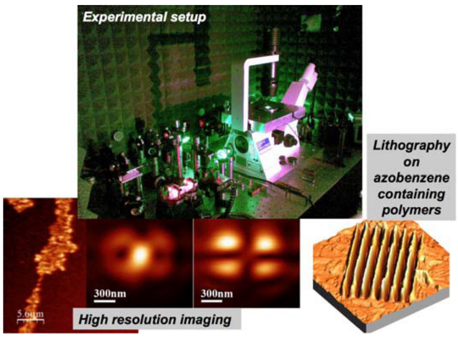
Contacts: Voloadymir Tkanchenko (NA)

Spectroscopic ellipsometer for linear optical characterization of thin films and multi-layers (spectral range 270-1700nm)



Surface Second Harmonic Generation Apparatus

Contact: Antonio Ambrosio (NA)



Home-made Confocal Microscope equipped with a highresolution 3D piezo-scanner and a spectrograph. Two light sources are included, an Ar+ laser (514 and 488nm wavelengths) and a Helium-Neon laser (632.8nm). So far, the system has been used for high-resolution spectral imaging of different samples; lithography on azobenzene-containing polymers; high-resolution imaging, by means of gold nanoparticles, of the field distribution in the focal plane of high numerical aperture aplanatic lenses.

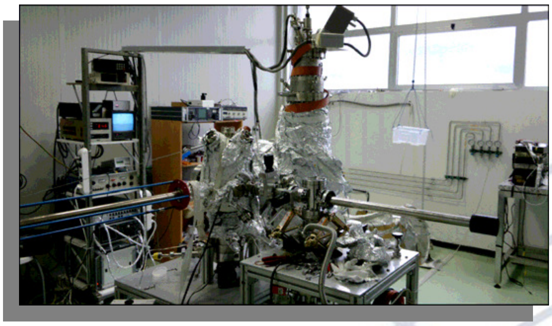
Selected experimental facilities

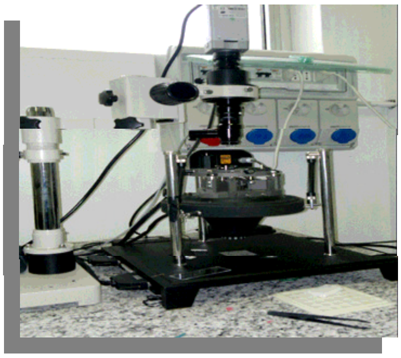
Electronic and transport properties

Cryogenic STM

Contact: Renato Buzio (GE)

STM for the morphological and spectroscopic characterization of conductive samples under UHV at ambient temperature and cryogenic temperatures (80K – 140K and 5K-65K). Tunnelling current varies in the range 5pA -300nA. Scanning area is 10 um x 10um x 1um at room temperature and 1.8um x 1.8um x 0.2um at 5K.



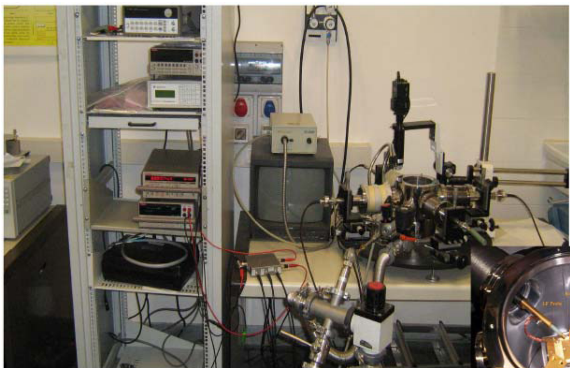


A tailored samples holder allows to perform in situ 4-wires transport measurements on the studied specimens. AFM with 50um x 50um or 5um x 5um maximum scanning sample capabilities. It is equipped with an optical microscope with lateral resolution of 5um. It operates under ambient conditions or within a liquid cell - with temperatures up to 150°C - in standard contact mode and dynamic modes. Control unit allows to acquire 2 simultaneous maps. STM, Kelvin, conductive, capacitive and force-volume modes are readily available. AFM can also be used for constant-current electrochemical nanolithography

Cryo-Probe

Contact: Mario Barra (NA)

The Probe station system is suited for electrical measurements both in DC and AC regimes (up to 1 MHz). Electrical contacts are realized by three metallic tips mounted on micrometric slides. Probe station is equipped with a vacuum chamber to perform measurements in controlled atmosphere. It is possible to carry our variable temperature measurements in the range between 5K and room temperature by using cryogenic liquids. The temperature of the samples is monitored by two thermometers.



Electronic and transport properties

PPMS – Physical Properties Measurement System

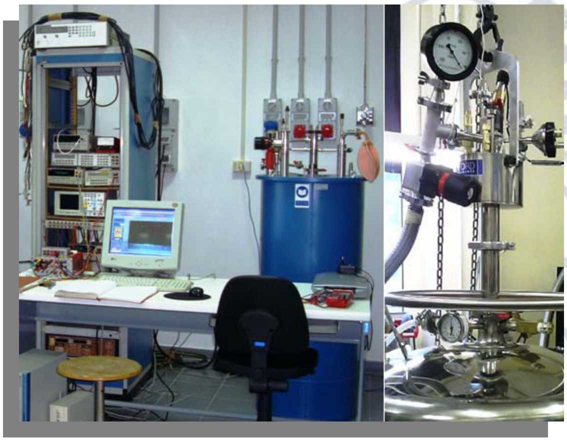
Contact: Massimiliano Polichetti (SA)

PPMS is a system for modular measurements, that schematically is constituted by a 9 Tesla superconducting magnet, a cryostate for the sample temperature control, electronics needed to manage through PC all present sensors and devices, and a series of interchangeable inserts appropriately designed to measure different physical quantities.

Cryomagnet + 300 mK insert
High magnetic field 3He-4He cryostat

Contact: Carla Cirillo (SA)

The cryostat consists in a nitrogen shielded 4He low loss dewar, equipped with a superconducting magnet up to 11 Tesla. The system operates in the temperature range 1.8 - 300 K. A HelioxVL vacuum loaded 3He insert enables temperatures down to 300mK to be achieved.



High field low temperature STM-AFM

Contact: Fabrizio Bobba (SA)

UHV low temperature (5K - 300K), high field (7 Tesla), STM-AFM . The system can operate in STM microscopy and spectroscopy modes, contact and tapping microscopy modes AFM , magnetic force microscopy (MFM) and electrostatic force microscopy (EFM)

Selected experimental facilities

Computation

NANOMAT

Contact: Annalisa Fierro (NA)

Cluster multiprocessors for advanced computation and high performance made of 38 nodes biprocessors (Intel Xeon with multicore technology, clock from 2.8 to 3.2 GHz), with 8 to 48 GB RAM per node.
The overall number of cores and RAM is 200, 624 GB. The nodes are connected with Infiniband to have high speed data transfer.

CLUES

Contact: Giovanni Cantele (NA)

99 biprocessors Athlon 2800+ with Gigabit ethernet, NAS (network attached storage) by 1 Terabyte in RAID5.

Projects

SPIN Active Projects

Type of Project	Coordinator	Title	SPIN Leader	UOS	Grant (€)
EU FP7	SPIN Genova	Exploring the potential of Iron-based Superconductors	Marina Putti	GE	500.877,00
EU FP7 - ERC	SPIN Aquila	Breaking Inversion Symmetry in Magnets: Understand via Theory	Silvia Picozzi	AQ	684.000,00
EU FP7	SPIN Salerno	Unlocking research potential for multifunctional advanced materials and nanoscale phenomena	Mario Cuoco	SA	2.400.00,00
EU FP7	Weizman Inst.	Macroscopic interference devices for atomic and solid-state systems: quantum control of supercurrents	Antonio Barone	NA	217.865,00
EU FP7	Univ. de Liege	Engineering Exotic Phenomena at Oxide Interfaces	Daniele Marrè	GE	354.797,00
EU FP7	Lancaster Univ.	Nanoelectronics : concepts, theory and modelling	Maura Sassetti	GE	266.838,90
EU FP7	Univ. Carlo III de Madrid	Magnetic-Superconductor Cryogenic Non-contact Harmonic Drive	Carlo Ferdeghini	GE	255.258,00
EU FP7	Leibniz Institute	Establishing the basic science and technology for Iron-based superconducting electronics applications	Sergio Pagano	SA	288.136,20
FIRB - FUTURO IN RICERCA	SPIN Napoli	Transizione di unjamming nei materiali granulari e precursori sismici: teoria, esperimenti e simulazioni	Massimo Pica Ciamarra	NA	209.990,00
PRIN 2008	Univ. Napoli	Establishing the basic science and technology for Iron-based superconducting electronics applications	Domenico Paparo	NA	48.498,00
PRIN 2008	Univ. Bologna	Studio, definizione e sviluppo di un cavo in MgB2 con proprietà elettriche e termiche adatte al suo utilizzo in un limitatore di corrente	Carlo Ferdeghini	GE	21.683,90
PRIN 2008	Univ. Genova	Studio teorico e con tecniche spettroscopiche degli effetti del disordine e della presenza di piu' bande nei pnictidi supercondutori Fe-As	Andrei Varlamov	RM	26.200,30
N. 5 REGIONAL projects - (LEX 5)	SPIN Napoli Salerno	Argomenti vari: Superconduttori, Ossidi, Organici	Orgiani, Gombos, Salluzzo, Perroni, Aruta	NA SA	52.000,00
REGIONAL project (CAMPANIA)	ORION	Sistemi innovativi Integrati di Analisi di gas prodotti da scarichi industriali	Pasqualino Maddalena	NA	67,200,00
FONDAZIONE CARIPLO	Politecnico Milano	Electronic Control of Magnetization in Spintronic Devices	Silvia Picozzi	AQ	50.000,00
FONDAZIONE CARIGE	SPIN Genova	Potenziamento della strumentazione per le ricerche nel settore dei nuovi materiali superconduttori	Carlo Ferdeghini	GE	55,000,00
FONDAZIONE CARIGE	SPIN Genova	Materiali e tecnologie per celle fotovoltaiche a basso costo	Daniele Marrè	GE	40.000,00

Projects

Main industrial partners

ASG Spa

CSM Spa

Columbus Superconductors Spa

Thin Film Equipment Srl

KME Italy Spa

Piaggio AeroIndustries Spa

Cooper Standard Automotive Italy Spa

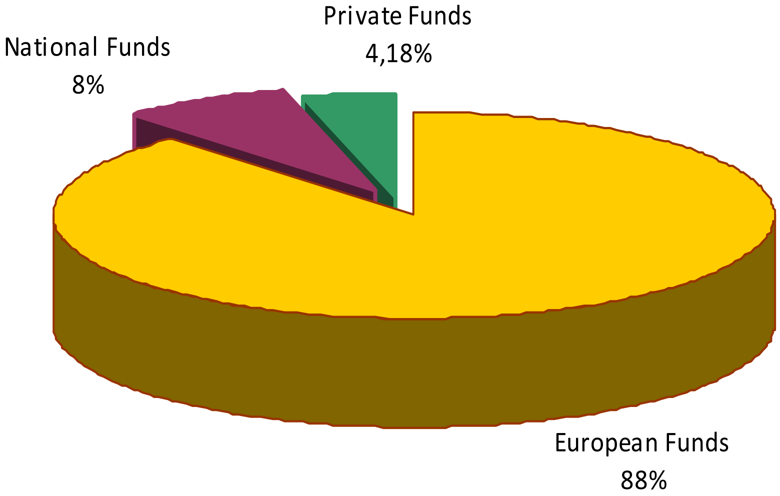
Fibre Ottiche Sud Spa

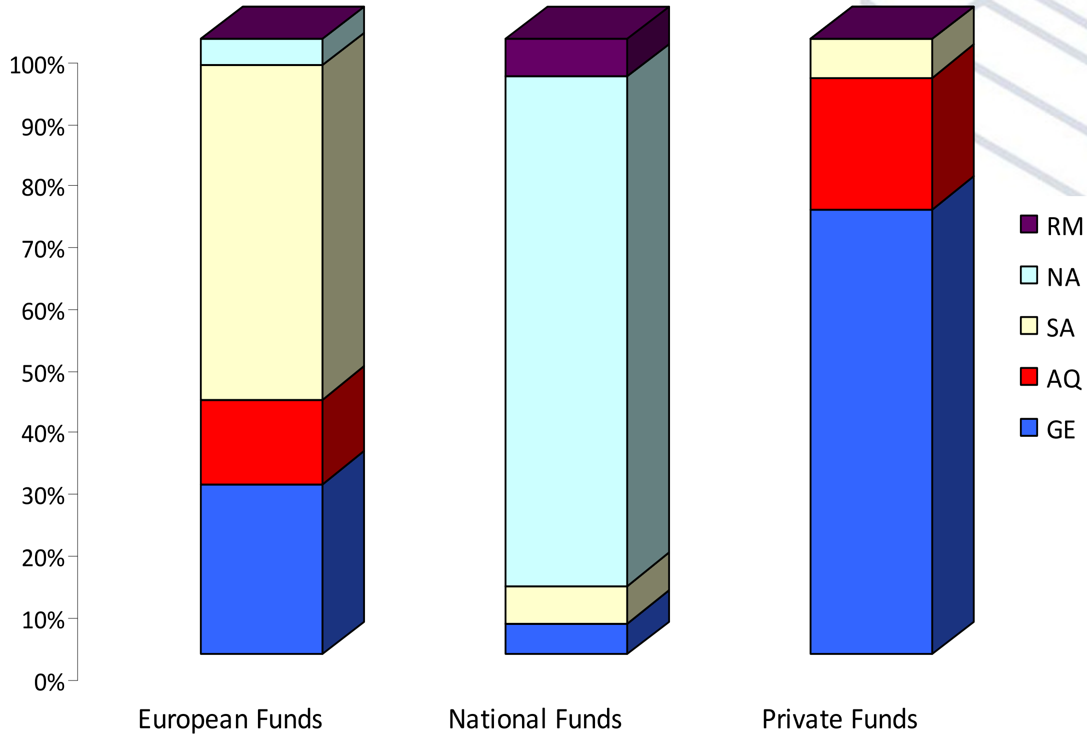
Magaldi Techno Sas

Criotec Impianti Srl

Projects

Distribution of the origin of income



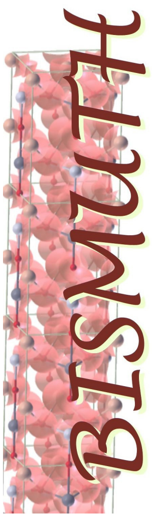


Projects

Main Projects

Title	Breaking Inversion Symmetry in Magnets: Understand via THeory
Acronym	**BISMUTH**
Source of funding	EC FP7 through European Research Council
Specific funding program	2007 ERC Starting Grant within the call "IDEAS"
Coordinator	Silvia Picozzi, SPIN AQ
Other partners	//

Project objetives

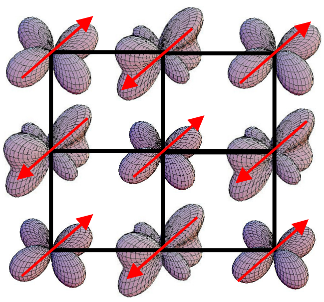


Multiferroics (i.e. materials where ferroelectricity and magnetism coexist) are presently drawing enormous interests, due to their technologically-relevant multifunctional character and to the astoundingly rich playground for fundamental condensed-matter physics they constitute.
BISMUTH puts forward several concepts on how to break inversion symmetry and achieve sizable ferroelectricity in magnets; our approach is corroborated via first-principles calculations as tools to quantitatively estimate relevant ferroelectric and magnetic properties as well as to reveal ab-initio the main mechanisms behind the dipolar and magnetic orders.
In closer detail, we focus on the interplay between ferroelectricity and electronic degrees of freedom in magnets, i.e. on those cases where spin- or orbital- or charge-ordering can be the driving force for a spontaneous polarization to develop. Antiferromagnetism is considered as a primary mechanism for lifting inversion symmetry; however, the effects of charge disproportionation and orbital ordering are also studied by examining a wide class of materials, ranging from transition metal oxides to organic-inorganic hybrids.

Projects

Main Projects

Title	Unlocking research potential for multifunctional advanced materials and nanoscale phenomena
Acronym	**MAMA**
Source of funding	EC
Specific funding program	FP7-REGPOT-2010-1
Coordinator	Mario Cuoco, SPIN SA
Other partners	Kamerlingh Onnes Laboratory, Leiden School of Physics & Astronomy, St. Andrews IFW, Institute for Theoretical Solid State Physics, Dresden Institut für Festkörperforschung and Institute for Advanced Simulation, Jülich University of Twente, Twente University of Geneve, DPMC, Geneve Risø National Laboratory, Roskilde Bonn University, Bonn IMDEA, Madrid Chalmers University of Technology, Chalmers
Project objetives	The project aims to unlock the research potential on the growth, the characterization and the theoretical modelling of multifunctional advanced materials and to improve the coordination of research activities in the area of complex multifunctional materials. In particular the project will focus on the acquisition of new enabling technologies and expertise for the study and for the application of the unconventional properties of transition metal oxides (TMO's), allowing the team of MAMA researchers to acquire a leading position in the growth, the characterization and the theoretical modelling of single crystals, epitaxial thin films, complex all oxide heterostructures and hybrid organic-inorganic structures based for example on TMO's and organic functional materials. This objective will be achieved by: - the improvement of know-how and human resource potential via recruitment, exchange. - the reinforcement of the visibility of the research capacity. - the involvement of 10 prestigious groups with a high reputation in the appropriate fields. - the reinforcement of research potential by recruiting new researchers, by the acquisition of tools for fabricating and characterizing the materials and computation of multifunctional advanced materials.

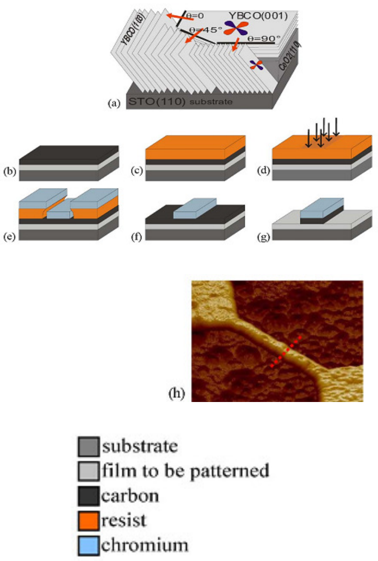


Projects

Main Projects

Title	Macroscopic Interference Devices for Atomic and Solid-State Systems
Acronym	**MIDAS**
Source of funding	EC
Specific funding program	STREP
Project Coordinator	Prof. Gershon Kurizki, Weizmann Institute, IL
SPIN Coordinator	Prof. Antonio Barone. SPIN NA
Other partners	TU Vienna (TUW) Austria - Heidelberg University (UHEI) Germany CEA Saclay (CEA) France - Erlangen University (FAU) Germany SPIN CNR Naples Italy - Chalmers University (Chalmers) Sweden CNRS (Grenoble+Paris) (CNRS) France - TU Delft (TUD) The Netherlands

Project objetives



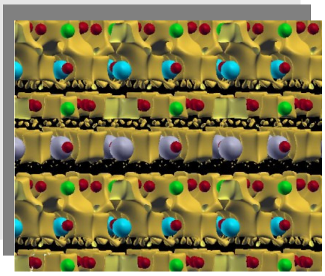
Quantum physics has been fundamental to our understanding of nature and consequently central to physical research for the past 80 years. Yet, only in recent years have we begun to grasp its tremendous potential for technological applications. Our reponse to the formidable challenge of expanding the range of quantum-technologies is to capitalize on the remarkable analogies that have recently emerged between two previously unrelated classes of quantum systems with potentially fascinating applications: ultracold-atom (UCA) degenerate gases and solid-state superconductors (SC). These analogies stem from the notion of macroscopic quantum-coherent transport known as Josephson supercurrent, common to both fields. This project will create a unified base for genuinely quantum regimes of operation in both fields. This unified base will serve a twofold purpose: (a) It will allow substantial improvement in the state of-the-art of both fields: our ability to exploit the properties of macroscopic quantum coherence/ supercurrents in novel UCA- and SC-based devices will greatly benefit from active cooperation between leading teams in the two fields. (b) It will be used to explore the feasibility of integrating the two types of devices. Significant progress towards this ambitious goal will create a principally new quantum technology suitable for various applications. The project will draw upon several landmarks achieved thus far in the realm of Josephson junctions (JJs), the basic schemes of supercurrent flow: a) The striking demonstrations of supercurrent effects and JJ physics for atomic Bose-Einstein condensates (BECs) in double-well and periodic potentials, pioneered by our Heidelberg and Vienna partners, have opened a new vista onto SC-UCA supercurrent analogies1. Other such analogies have been revealed by experiments on 2d supercurrent vorticity in BEC, by our CNRS Paris partners and others. b) Macroscopic quantum dynamics and coherence in SC-based JJs has been demonstrated. Our Saclay and CNRS-Grenoble, as well as Naples-Chalmers partners have been among the leaders of this research, using low-TC (LTS) and high-TC (HTS) SC materials, respectively. c) Two-state artificial-atom SC circuits, “qubits”, and their pairwise entanglement allowing quantumgate operations have been developed. Our Saclay partner has been at the forefront of this research. d) Observations of quantum-nonlinear (soliton) properties in long SC JJs have been pioneered by our Erlangen partner. e) A crucial step towards hybridization of SC and UCA (BEC) elements has been pioneered by our Vienna partner, through the development of the solid-state Atom Chip, which allows coherent micro-manipulations of UCA gases. Current work in the US and Japan has diversified the methods of BEC trapping and interference near low-temperature and superconducting chips.

Projects

Main Projects

Title	Engineering Exotic Phenomena at Oxide Interfaces
Acronym	**OXIDES**
Source of funding	EC
Specific funding program	FP7
Project Coordinator	Philippe Ghosez (Université de Liège)
SPIN Coordinator	Daniele Marrè, SPIN GE
Other partners	Consejo Superior de Investigaciones Científicas Barcelona, Universidad de Cantabria, Universität Ausburg, Université de Genève, PHASIS (SME)

Project objetives



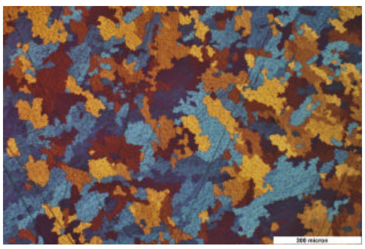
The field of oxide interfaces is still at an incipient stage and evolving from recent fundamental discoveries to applications and designing optimized structures based on these concepts is still a major challenge requiring combined theoretical and experimental progress. We need a deep understanding of the microscopic phenomena at oxide interfaces, the design and realization of optimized heterostructures exhibiting such effects, and the demonstration that useful devices based on such materials can be produced. All these issues are at the heart of OxIDes – Oxide Interface Design –, a project aiming at engineering exotic phenomena at oxide interfaces and at exploring their potentialities to yield new applications and devices. The scientific and technological objectives of OxIDes are: • the development of a set of multi-scale theoretical tools going beyond present capabilities and appropriate for the predictive modelling of properties of complex and realistic oxide interfaces; • the application of such techniques, in collaboration with experimentalists, to design a new generation of artificially layered oxides with unique and experimentally-confirmed properties; • the evaluation of the possible integration of such new materials into devices, including application-oriented characterisation of specific interfaces and of a microbalance prototype.
OxIDes will generate new fundamental knowledge concerning: • theory level: the first-principles description of correlated electron systems and the applicability and predictive power of different models (H eff , BBT, BDR) in complex oxides; • materials level: the microscopic origin of interfacial phenomena in oxide heterostructures and how to take advantage of them to obtain new properties; • application level: the potential inclusion of advanced oxide materials into devices.
OxIDes will investigate the possibility of engineering new properties at three types of oxide interfaces, each of them motivated by a simple fundamental physical concept, targeting a specific technological application and requiring specific theoretical developments: • insulating interfaces between insulating oxides, where novel couplings between structural instabilities can lead to unusual phenomena such as improper ferroelectricity; • conducting interfaces between insulating oxides, where an interfacial 2-dimensional electron gas can be induced that might, for example, exhibit large thermoelectric power; • interfaces between metallic and insulating oxides, where interfacial screening and depolarizing fields are key issues for ferroelectric capacitor and ferroelectric tunnel junction memory devices.

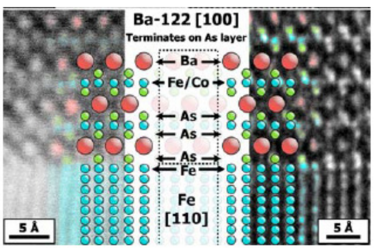
Projects

Main Projects

Title	Exploring the potential of Iron-based Superconductors
Acronym	**SUPER-IRON**
Source of funding	EC
Specific funding program	FP7-NMP-2011-Eu-Japan
Coordinator	Marina Putti, SPIN GE
Other partners	J Karpiski (Institute of Condensed Matter Physics) B. Holtzapfel (Institute for Solid State and Materials Research-IFW) D. Johrendt (Ludwig-Maximilians-Universität München) M. Eisterer (Vienna University of Technology) J.-I. Shimoyama (University of Tokyo) T. Kiss (Kyushu University) Y.Takano (NIMS) H.Eisaki (National Institute for Materials Science)

Project objetives





In 2008 the group of Prof. Hosono discovered the superconductivity in a new compound containing FeAs planes, thus opening the age of Fe-based superconductors (FeSC). Several different phases were rapidly discovered and today the FeSCs show the second high Tc behind the high-Tc superconductors and very high critical fields. These characteristics suggested that FeSCs can be candidates for power application. Within SUPER-IRON we depict the roadmap for exploring and exploiting the potentialities of these materials: 1) understanding the fundamental mechanisms of superconductivity and their implication, 2) control material quality, 3) manipulate superconducting properties, 4) assess the potential of FeSCs with respect to other superconductors, 5) identify application fields, where FeSCs lead to a step-like change with respect to the current state of the art.

To cover this road SUPER-IRON has joined the efforts of the leader groups involved in the investigation of FeSCs throughout EU and Japan. Different phases of FeSCs and also the new pnictide oxides SC, in form of single crystals, polycrystals, thin films, tapes and wires will be realized by using different synthesis methods. Superconducting properties will be investigated also under high magnetic field and/or pressure and visualization of local electric field and current will be carried out with sophisticated techniques. This wide variety of experimental activities will be supported by an intense theoretical work including ab-initio calculations and theoretical modelling. The achievement of the planned objectives through synergic and coordinated activities will set the basis for future collaborations between Japan and EU.

Projects

Main Projects

Title Magnetic-Superconductor Cryogenic Non-contact Harmonic Drive

Acronym MAGDRIVE

Source of funding EC

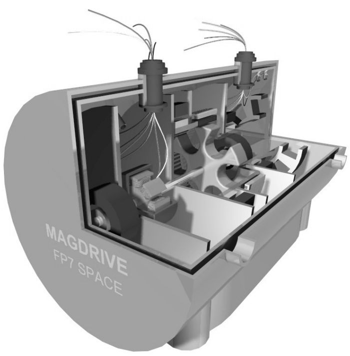
Specific funding program FP7 Collaborative Project. Small or medium-scale focused research project

Project Coordinator Prof. José Luis Pérez Diaz, Universidad Carlos III de Madrid, Spain

SPIN Coordinator Carlo Ferdeghini, SPIN GE

Other partners Universitá degli Studi di Cassino, Italy, CNR-SPIN, Italy, CAN Superconductor, Czech Republic, BPE Germany, LIDAX, Spain, Fundacao da Faculdade de Ciencias da Universidade de Lisboa, Portugal

Project objetives



The objective of this project is to design, build and test a harmonic drive able to work at low temperatures for space application.
The Harmonic Drive (HD) mechanism is a power transmission capable of developing high ratios, providing a high positional precision to the assembly, with relatively low weight/volume ratio, high torque capability and near zero backlash. It was invented by Musser (1955) for aerospace applications, but it is widely used now in robotics, medical equipment, printing presses, vehicles or military industry. The application of HD mechanisms at low temperature (T<100 K) is limited by lubrication. Any kind of oil or grease freezes at cryogenic conditions, losing all the lubricant properties. Other dry lubricants present also problems like grating, clutching, rapid wear out, instability of friction coefficient, formation of cold weld centres and losses or decomposition of the lubricant at cryogenic conditions. In addition, fatigue due to the intrinsic flexural functioning of the HD also limits its effective work life.
The objective of this project is to design, build and test a magnetic-superconductor cryogenic non contact harmonic drive. This harmonic drive will be a mechanism provided with an input axle and an output hub with a great reduction ratio and it will be able to function at cryogenic temperatures. It will be based on a non-contact interaction between magnets, soft magnetic materials and superconductors. Therefore the drive has not any wearing neither fatigue and it will not need any lubrication. It will greatly increase the life time of the drives. As drives are profusely used in many different fields the result of this project is a qualitative jump that will open many opportunities.
This harmonic drive will be based on "non-contact magnetic teeth" instead of fitting teeth on a flexural wave as conventional harmonic drives are based on. Non-contact magnetic teeth may be activated by a magnetic wave (similar to an electrical engine) and stabilized by the use of superconductor materials. This would solve the problems of contact wearing and mechanical fatigue.
Superconductors will be also used for non-contact bearings and for shielding the magnetic fields to avoid electromagnetic interferences or emission.

Projects

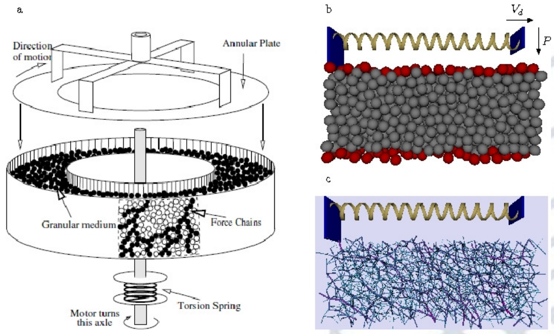
Main Projects

Title	Nanoelectronics: Concepts, Theory and Modelling
Acronym	**NanoCTM**
Source of funding	EC
Specific funding program	Initial Trainign Network, FP7, Marie Curie Action
Project Coordinator	Prof. Colin Lambert, Lancaster University UK
SPIN Coordinator	Maura Sassetti, SPIN GE
Other partners	Universiteit Leiden NL Universitaet Karlsruhe DE Universite de Geneva CH Universidad Complutense de Madrid ES Commissariat Energie Atomique CEA FR Eotvos Lorand Tudomanyegyetum HU I. Fizyki Molekularnej Polskiej Akademii Nauk PL Consiglio Nazionale Delle Ricerche-SPIN IT Jacobs Uni. Bremen DE Uni. De Oviedo ES Inst. Jozef Stephan SL
Project objetives	The NanoCTM network will tackle major challenges in the theory of nanoelectronics. Internationally-leading European theory-of-condensed-matter groups have joined forces, combining theoretical expertise in nanowires, quantum dots, carbon-based electronics, and spintronics, along with interaction and proximity effects in small dimensions. Our highly-integrated approach to nanoscale transport will represent a major step towards the realisation of future scalable nanotechnologies and processes. In the longer term, the insights gained will contribute to the fabrication of novel functional nanoscale architectures and their integration into a higher hierarchical level. The training dimension of the NanoCTM network is reflected in a series of high-priority actions specifically aimed at early stage researchers (ESRs). These include: education and knowledge dissemination through the organisation of Thematic Workshops, Tutorial Courses, Annual Network Meetings, Summer Schools and Mobility Programmes. The network has a strong focus on interdisciplinary training, builds on several fruitful collaborations between the partners and seeks to close an existing educational gap in the European Research Arena.

Projects

Main Projects

Title	Unjamming transition in granular systems and earthquake precursors: theory, experiments and simulations
Acronym	**UTGM**
Source of funding	MIUR
Specific funding program	FIRB 2008
Coordinator	Massimo Pica Ciamarra, SPIN NA
Other partners	CNR-ISC (Dr. Fergal O'Daltuin) Sec. University of Naples (Dr. Eugenio Lippiello)
Project objetives	



When the applied shear stress overcomes a threshold, the yield stress, a material start flowing. While it is known that in crystals this occurs because of the presence of dislocations, which are the 'weak points', much less is known regarding how disordered solids loses their mechanical strength, and whereas it is possible to understand how close a system is to its failure point. These questions are relevant to a number of different fields, ranging from soft matter science where it is important to control the viscosity and the moduli of complex liquids, to geophysical phenomena such as earthquakes and avalanches. The objective of this project is to understand how a disordered solids looses its mechanical rigidity, and whereas it is possible to identify precursors. The project aims to achieve these goals via a combined theoretical, numerical and experimental study of different models. It will also experimentally and numerically investigate a model system of a fault, illustrated in the figure, where granular particles, representing the fault gouge, are enclosed between two shearing plates.
The projects exploits recent theoretical tools and methods developed in the study of the slow dynamics of viscous liquids.

Projects

Main Projects

Title	Establishing the basic science and technology for Iron-based superconducting electronics applications
Acronym	**IRONSEA**
Source of funding	EC
Specific funding program	NMP.2011.2.2-6 Fundamental properties of novel superconducting materials (coordinated call with Japan)
Project Coordinator	Leibniz-Institut Fuer Festkoerper- Und Werkstoffforschung Dresden E.V. IFW Dresden Germany
SPIN Coordinator	Domenico Paparo, SPIN NA
Other partners	Friedrich-Schiller-Universitaet Jena FSU Jena Germany Univerzita Komenskeho V Bratislave Bratislava Slovakia Politecnico di Torino Italy Consiglio Nazionale Delle Ricerche - Istituto SPIN Italy Universiteit Twente Netherlands

Project objetives

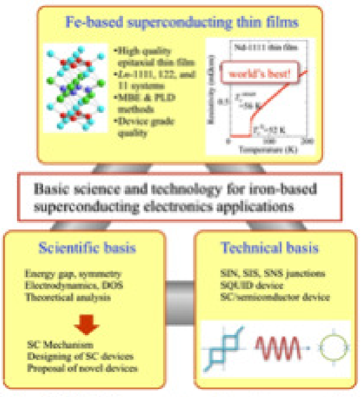


Figure 1: Graphical presentation of the project concept and objectives

Recent investigations on iron-based superconductors have revealed a lot of similarities to MgB2 and the cuprates, for instance, a multiband nature, high upper critical fields and a short coherence length. Now immediate interest of a new class of materials would be exploring potential electronics applications such as Josephson devices and SQUIDs. In this project, we will address the feasibility of electronics applications by establishing the fundamentals of the iron-based superconductors. Examining the Josephson effect and SQUIDs, the so-called phase-sensitive experiment, also paves the way to understanding fundamental properties such as order parameters symmetry and energy gap, which is one of the main objective in this project. Investigations by point contact spectroscopy, infrared spectroscopy and transport properties are also conducted within the same frame of this work. Such fundamental studies may find unique physical properties, which lead to exploring new kinds of devices and applications. Since the iron-based superconductors are multi-band natures, comparative studies to MgB2 are also carried out.

CNR will contribute to several activities using expertise and facilities available in various locations. The Genoa SPIN section will be mainly involved in preparation of Fe-based (11) thin films on ordinary and bicrystal substrates and their morphologic and transport characterization. The Salerno SPIN section will fabricate high quality MgB2 thin films, will perform noise spectroscopy and fast photo-response measurement, and will design and characterise innovative nanowire devices. The Naples SPIN section will deposit trilayers for hybrid (S-N and S-S') junctions and perform pump probe measurements for characterisation of non-equilibrium processes in the materials and devices developed, and will fabricate and characterize bilayer devices with SC/M and SC/N. The researchers at ICIB will pattern hybrid junctions, fabricate bicrystal grain boundary junctions and characterize both hybrid and bicrystal grain boundary junctions and innovative devices, and develop theoretical modeling of Josephson processes.

2010

Optical Properties of $(SrMnO_3)_n/(LaMnO_3)_{2n}$ Superlattices: An Insulator-to-Metal Transition Observed in the Absence of Disorder

Perucchi A. [1], Baldassarre L.[1], Nucara A[2], Calvani P.[2], Adamo C.[3], Schlom D.G.[3], Orgiani P.[4], Maritato L.[4], Lupi S.[5]

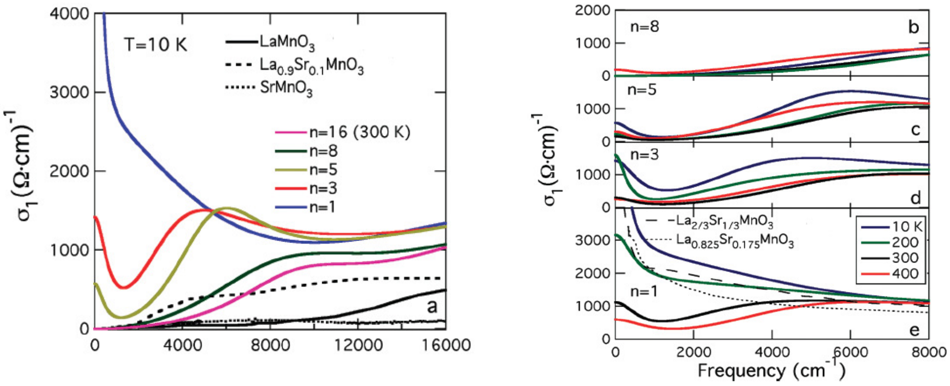
[1]Sincrotrone Trieste, Area Science Park, Trieste, Italy
[2]CNR-SPIN and Dip.to di Fisica, Università di Roma La Sapienza, Piazzale Aldo Moro 2, Rome, Italy
[3]Department of Materials Science and Engineering, Cornell University, Ithaca, New York, USA
[4]CNR-SPIN and Dip.to di Matematica ed Informatica, Università di Salerno, Baronissi, Salerno, Italy
[5]CNR-IOM and Dip.to di Fisica, Università di Roma La Sapienza, Piazzale Aldo Moro 2, Rome, Italy

Nano Lett., 10 (12), pp 4819–4823 (2010)

The insulator-to-metal transition (IMT) coupled to ferromagnetic ordering in hole-doping compuonds is understood through the double-exchange mechanism, once the localization tendency due to polaron formation has been taken into account. However, quenched disorder weakens long-range order and causes ferromagnetism to break up into clusters, an essential ingredient of the observed Colossal Magneto-Resistance effect. We measure the optical conductivity, $\sigma_1(\omega)$, of $(SrMnO_3)_n/(LaMnO_3)_{2n}$ superlattices (SL) for n= 1, 3, 5, and 8 and 10 <T < 400 K: these heterostructures offer the opportunity to observe the IMT in the absence of the disorder due to chemical doping.

Our data show a T-dependent insulator to metal transition for n < 3, where eventually the charge reaches a uniform distribution throughout the film; the transition is driven by the softening of a polaronic mid-infrared band, more evident in the n= 1 sample. At n = 5 the softening of the polaronic band is incomplete, while at the largest-period n = 8 compound the mid-infrared band is independent of T and the SL remains insulating, thus suggesting a strong localization of the charges at the interfaces. Unsuccessful reconstruction of the SL optical properties from those of the original bulk materials suggests that $(SrMnO_3)_n/(LaMnO_3)_{2n}$ heterostructures give rise to a novel electronic state.

In the present collaboration, the SPIN groups have provided and partly characterized the samples, and have participated both to the infrared data collection, and to the delicate phase of data analysis.



Panel (a): $\sigma_1(\omega)$ at T = 10 K for the n = 1, 3, 5, 8 compounds, showing the Mott transition induced by the proximity between the layers. $\sigma_1(\omega)$ at T = 300 K , for n = 16 is reported as well. Data on single crystals of $LaMnO_3$ and $La_{0.9}Sr_{0.1}MnO_3$ and on $SrMnO_3$ at 10 K are also shown for comparison. Panels (b-e): $\sigma_1(\omega)$ at different T for n = 8, 5, 3, and 1, respectively. Low-T conductivity of cleaved $La_{0.825}Sr_{0.175}MnO_3$ single crystals and $La_{2/3}Sr_{1/3}MnO_3$ films is also reported for comparison in panel e.

Highlights

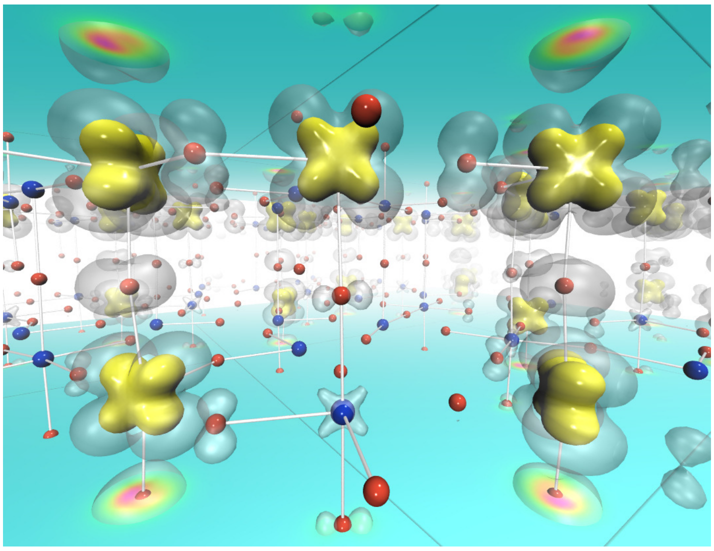
2010

Interplay between Charge Order, Ferroelectricity, and Ferroelasticity: Tungsten Bronze Structures as a Playground for Multiferroicity

Kunihiko Yamauchi and Silvia Picozzi
CNR-SPIN L'Aquila, Italy

Appeared in Phys. Rev. Lett. 105, 107202 (2010)

Charge order is proposed as a driving force behind ferroelectricity in iron fluoride $K_{0.6}Fe_{0.6}^{II}Fe_{0.4}^{III}F_3$. By means of density functional theory, we propose several noncentrosymmetric d5/d6 charge-ordering patterns, each giving rise to polarization with different direction and magnitude. Accordingly, we introduce the concept of "ferroelectric anisotropy" (peculiar to improper ferroelectrics with polarization induced by electronic degrees of freedom), denoting the small energy difference between competing charge-ordered states.



Moreover, we suggest a novel type of charge-order-induced ferroelasticity: a monoclinic distortion is induced by a specific charge-ordering pattern, which, in turn, determines the direction of polarization. $K_{0.6}Fe_{0.6}^{II}Fe_{0.4}^{III}F_3$ therefore emerges as a prototypical compound, in which the intimately coupled electronic and structural degrees of freedom result in a peculiar multiferroicity.

Fig. Perspective view of charge-orbital order of t2g minority-spin states in iron-fluoride K0.6FeF3

Highlights

2010

Sharp Transition for Single Polarons in the One-Dimensional Su-Schrieffer-Heeger Model

D. J. J. Marchand[1], G. De Filippis[2], V. Cataudella[2], M. Berciu[1], N. Nagaosa[3,5], N. V. Prokof'ev[4,6], A. S. Mishchenko[5,6], and P. C. E. Stamp[1]

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[4]Dept of Physics, University of Massachusetts, Amherst, Massachusetts 01003, USA
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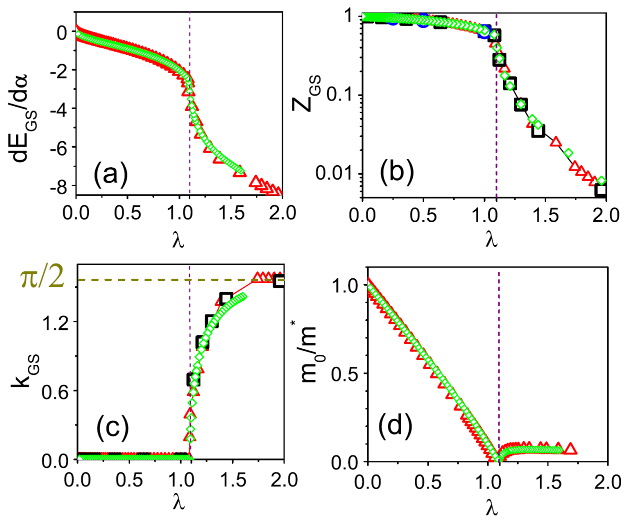
Phys. Rev. Lett. 105, 266605 (2010)

Polarons have been of broad interest in physics ever since they were introduced in 1933 and, apart the their central role in solid state physics, they exemplify in quantum field theory the passage from weak to strong coupling in a non trivial model of a single particle coupled to a bosonic field. In the paper we have studied a single polaron in the Su-Schrieffer-Heeger (SSH) model by using four different techniques (three numerical and one analytical). We show that the model exhibits sharp transition, at a critical coupling strength λc, between states with zero and nonzero momentum of the ground state. This results is unexpected since polarons show a smooth crossover from weak to strong coupling, as a function of the electron-phonon coupling strength λ, in all models where this coupling depends only on phonon momentum q.

Our result prove that in models where the coupling depends also on the electron momentum k, as in the SSH model, the physics of the intermediate regime is very different. This result is representative of all polarons with coupling depending on k and q, and can have important experimental consequences (e.g., in angle-resolved photoemission spectroscopy and conductivity experiments). Within this collaboration, in particular CNR-SPIN research unit developed the Limited Phonon Basis Exact Diagonalization that has been successfully applied also to other models in different contexts.



Derivative of the GS energy with respect to α, (b) Z factor of the GS, (c) wave vector of the GS, and (d) the ratio m_0/m^* of the bare and effective polaronic masses at K_{GS} for ω_{ph}=0.5. Red triangles, green rhombi, black squares, and blue circles correspond to LPBED, MA, DMC, and BDMC methods, respectively. The vertical dashed line indicates the critical coupling λ_c.

Highlights

2010

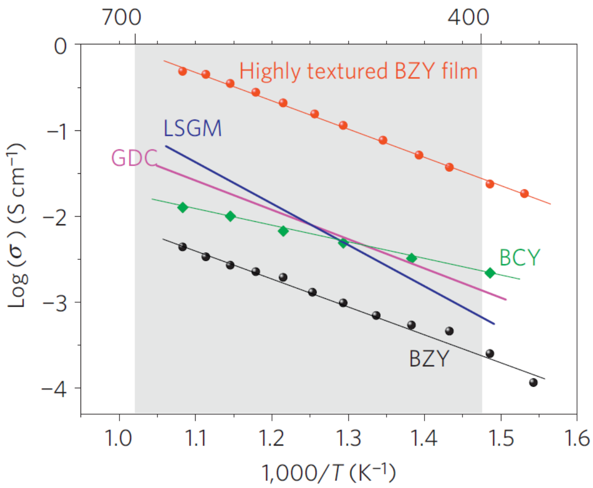
High proton conduction in grain-boundary-free yttrium-doped barium zirconate films grown by pulsed laser deposition

Daniele Pergolesi[1,2], Emiliana Fabbri[1,2], Alessandra D'Epifanio[2], Elisabetta Di Bartolomeo[2], Antonello Tebano[3], Simone Sanna[1], Silvia Licoccia[2], Giuseppe Balestrino[3], Enrico Traversa[1,2]

[1]NAST Center & Dip.to di Scienze e Tecnologie Chimiche, University of Roma 'Tor Vergata', Rome, Italy
[2]International Research Center for Materials Nanoarchitectonics (MANA), National Institute for Materials Science (NIMS), Tsukuba, Ibaraki, Japan
[3]CNR-SPIN and Dipartimento di Ingegneria Meccanica, University of Roma 'Tor Vergata', Rome, Italy

Nature Materials 9, 846–852 (2010)

High quality, grain-boundary free, thin films of yttrium-doped barium zirconate ($BaZr_{0.8}Y_{0.2}O_{3-\delta}$, BZY) were produced using the pulsed laser deposition apparatus available at the CNR-SPIN "Tor Vergata" laboratories. These films exhibited the largest proton conductivity values ever reported for BZY samples, namely 0.11 S/cm at 500°C and 0.01 S/cm temperatures as low as 350°C.



Electrical conductivity comparisons. (a) Comparison between the electrical conductivity and activation energy values of the BZY films grown on MgO and sapphire, and of BZY sintered pellets, measured in the intermediate temperature range, with the bulk conductivity values of BZY pellets measured at low temperature. The differences in the measured activation energy values with the literature data indicate some structural and/or chemical differences between the bulk of the samples prepared using PLD and ceramic processing. (b) Comparison between the electrical conductivity values of the BZY film grown on MgO, and of BZY and BCY sintered pellets, measured in the intermediate temperature range. Conductivity values of the most performing oxygen ion conducting materials, $La_{0.8}Sr_{0.2}Ga_{0.8}Mg_{0.2}O_3$ (LSGM) and $Ce_{0.8}Gd_{0.2}O_{1.9-\delta}$ (GDC), are also reported.

These conductivity values are substantially larger than those attained by the $La_{0.8}Sr0.2Ga_{0.2}O_3$ (LSGM) and $Ce_{0.8}Gd^{0.2}O_{1.9-\delta}$ (GDC) that were presently considered to be the oxygen ion conductors with the highest conductivity in the same temperature range. The high conductivity values of the BZY films, in the intermediate temperature range, mean that the this proton conductor maybe thought of as a possible substitute for the oxygen-ion conductor electrolytes conventionally used in solid oxide fuel cells (SOFCs).

Common to other proton conductors the BZY also offers the important advantage that the water exhaust is produced at the cathode side, avoiding fuel dilution with water and improving efficiency. In order to be used in a wide range of applications it is mandatory for the SOFCs to exhibit a decrease in operating temperature to below 700°C and more specifically to below 450°C for their use in portable electronic devices (laptop, mobile phone, etc.) to substitute Li-ions batteries. The absence of charge-discharge cycles and a larger energy density are the main benefits offered by the SOFCs with respect to Li-ions batteries. Our results demonstrated that the highly ordered BZY films without grain boundaries, obtained by pulsed laser deposition, are one of the most performing electrolytes ever developed for SOFC use and open new perspectives in the development of miniaturized SOFCs for a wide range of electronic device applications

Highlights

2010

High-Temperature Optical Spectral Weight and Fermi-liquid Renormalization in Bi-Based Cuprate Superconductors

D. Nicoletti[1], O. Limaj[,2], P. Calvani[1], G.Rohringer[3], A. Toschi[3], G. Sangiovanni[3], M. Capone[4], K. Held[3], S. Ono[5] , Yoichi Ando[6] and S. Lupi[2]

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Physical Review Letters PRL 105, 077002 (2010)

Since their discovery in 1986, the research on superconducting cuprates has been focused on their ”low-temperature” properties, like the superconductivity and the so-called pseudogap, while the high-T properties of the cuprates have been scarcely investigated up to now. The present work is, to our knowledge, the first optical study of two Bi-based cuprates at optimum doping, from their critical temperature Tc to 500 K. We have measured their optical conductivity σ(ω) and their spectral weight W (Ω,T) up to a cut-off frequency Ω. The T-dependence of the carrier kinetic energy (which is proportional to W (T)) is described in terms of the Sommerfeld expansion, which is usually limited to the first term in T^2. We have found that, above 300 K, W (T) deviates from the T^2 behavior in both compounds, even though the extrapolation to a dc conductivity σ(ω → 0) remains well far from the Ioffe-Regel limit. As shown in the Figure, the deviation is well described by the second term of the Sommerfeld expansion, namely that in T^4. This shows that, despite all the anomalies encountered in the behavior of high-Tc superconductors, a Fermi-liquid picture works well up to such a high T. However, the coefficients of both the T^2 and the T^4 term are much enhanced by strong correlations, as shown by our dynamical mean field theory (DMFT) calculations. All measurements have been done by CNR-SPIN and CNR-IOM personnel, using the apparata of the CNR-SPIN laboratory at University La Sapienza.

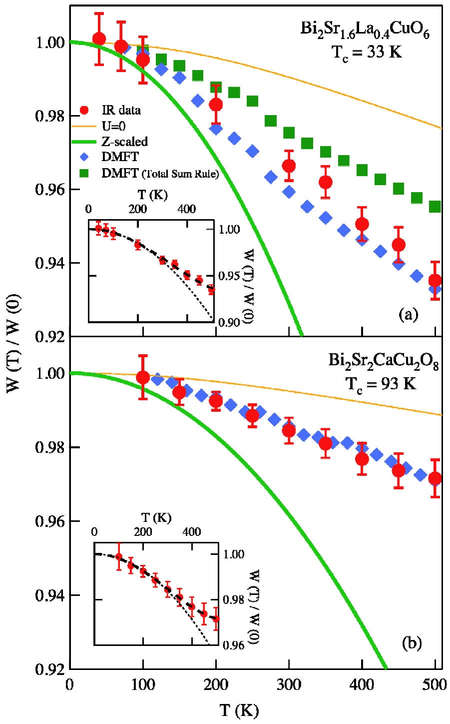

Figure caption. Temperature-dependent optical spectral weight W(T) of optimally doped (a) Bi2Sr1.6La0.4CuO6 and (b) Bi2Sr2CaCu2O8, normalized to the (extrapolated) value at T = 0. The IR data (red dots) are compared with DMFT calculations for the restricted sum rule (blue diamonds) of the single-band Hubbard model. Also shown are theoretical calculations for the non-interacting system (U = 0) and the lowest-order Sommerfeld expansion, where the coefficient B is simply rescaled by the DMFT quasi-particle weight (Z-scaled). In panel (a) DMFT calculations for the total sum rule are displayed for comparison (green squares). In the inset the dotted (dashed) line indicates the fit performed on W(T) data using the Sommerfeld expansion up to the second (fourth) order.

Highlights

2010

Magnetism in C- or N-doped MgO and ZnO:
A Density Functional Study of Impurity Pairs

Hua Wu[1,2], Alessandro Stroppa[3], Sung Sakong[4], Silvia Picozzi[3],
Matthias Scheffler[5], and Peter Kratzer[4]

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[2]*Department of Physics, Fudan University, Shanghai, China*
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[4]*Fakultät für Physik and Center for Nanointegration (CeNIDE), Universität DuisburgEssen, Duisburg, Germany*
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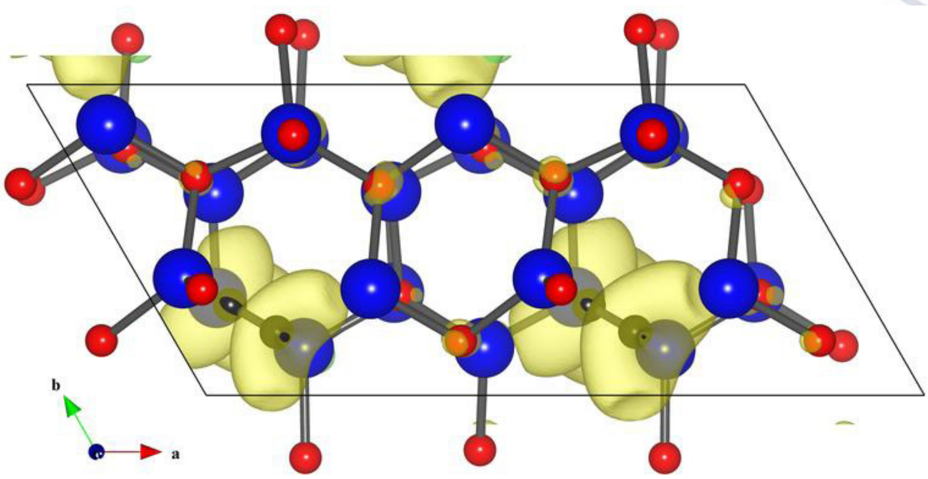
Physical Review Letters 105.267203 (2010)

It is shown that substitution of C or N for O recently proposed as a way to create ferromagnetism in otherwise nonmagnetic oxide insulators is curtailed by formation of impurity pairs, and the resultant C2 spin =1 dimers as well as the isoelectronic $N2^{2}+$ interact antiferromagnetically in ptype MgO. For Cdoped ZnO, however, we demonstrate using the Heyd-Scuseria-Ernzerhof hybrid functional that a resonance of the spinpolarized C2 ppπ * states with the host conduction band results in a longrange ferromagnetic interaction. Magnetism of openshell impurity molecules is proposed as a possible route to d^0-ferromagnetism in oxide spintronic materials.



Spin density at C_2 dimers in ZnO.

Highlights

2010

Suppression of the critical temperature in NdFeAs(OF) single crystal by Kondo-like scattering induced by irradiation

C. Tarantini[1], M. Putti[3], A. Gurevich[1], Y. Shen[2], R.K. Singh[2], J.M. Rowell[2], N. Newman[2], D.C. Larbalestier[1], Peng Cheng[4], Ying Jia[4], Hai-Hu Wen[4]

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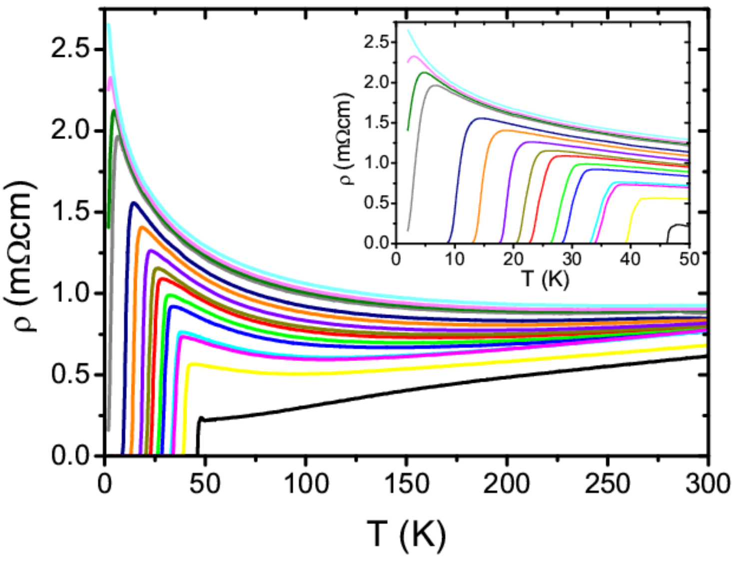
Physical Review Letters 104.087002 (2010)

The paper report the first comprehensive investigation of the suppression of the critical temperature Tc of NdFeAs(OF) single crystal by disorder induced by α-particle irradiation. Our data indicate that irradiation defects produce both nonmagnetic and magnetic scattering, resulting in the Kondo-like excess resistance $\Delta\rho(T)\propto \ln T$ over 2 decades in temperatures above Tc.



Despite high densities of irradiation defects, the dose at which Tc is suppressed to zero is comparable to that for MgB2 but is well above the corresponding values for cuprates. Such remarkably weak Tc suppression by strong magnetic and nonmagnetic disorder may reveal novel features of superconductivity and magnetism in pnictides.

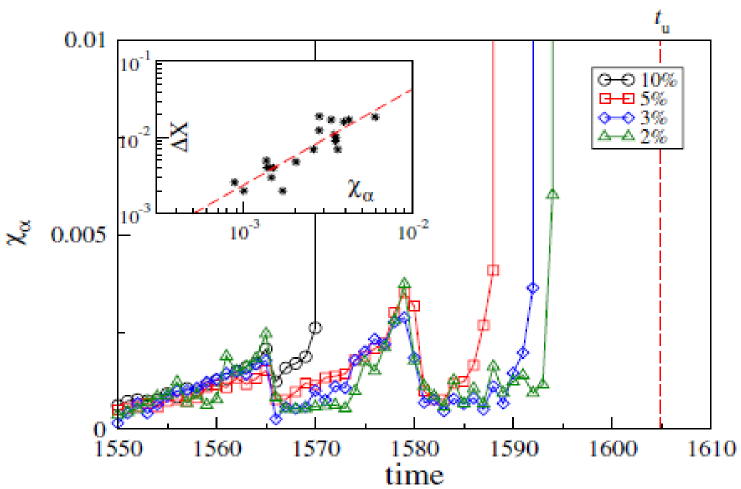
2010

Unjamming Dynamics: The Micromechanics of a Seismic Fault Model

M. Pica Ciamarra, CNR-SPIN, U.O.S. Napoli
E. Lippiello, Sec. University of Naples, Dep. of Environmental Sicences
C. Godano, Sec. University of Naples, Dep. of Environmental Sicences
L. de Arcangelis, Sec. University of Naples, Dep. of Information Engineering

Physical Review Letters 104.238001 (2010)

The unjamming transition of granular systems is investigated in a seismic fault model via three dimensional molecular dynamics simulations. A two-time force-force correlation function, and a susceptibility related to the system response to pressure changes, allow us to characterize the stick-slip dynamics, consisting in large slips and microslips leading to creep motion. The correlation function unveils the micromechanical changes occurring both during microslips and slips. The susceptibility encodes the magnitude of the incoming microslip.



The figure shows the response of the system to perturbations of different intensities, as a function of time, across small and large slips. Before a slip of size ΔX, the susceptibility reaches a maximum χ_α. The inset illustrates that these two quantities are correlated. This implies that by measuring the system's response to external perturbations it is possible to infer the size of the next slip, i.e. the amount of energy the system will release.

Highlights

2010

Evidence for a minigap in YBCO grain boundary Josephson Junctions

P. Lucignano[1,2], D. Stornaiuolo[1], F. Tafuri[3,1], B. L. Altshuler[4] and A. Tagliacozzo[1,5]

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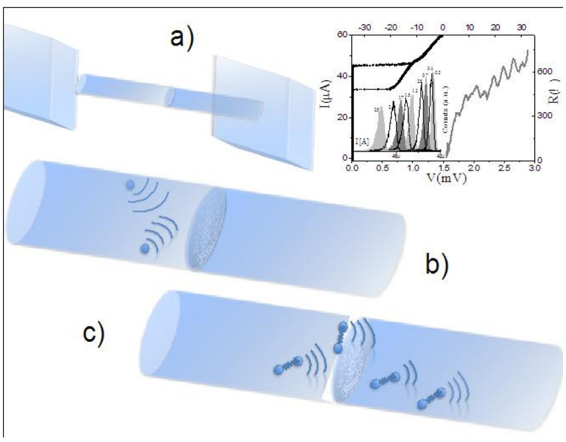
Physical Review Letters 105, 147001 (2010)

Future information technology and new generation of fast computing rely on tailoring and designing of quantum devices. Nanolitography provides scale reduction of devices at an unprecedented pace, but it will soon come to its physical limit. Superconductivity of dissipationless electron pairs realizes macroscopic quantum states (MQS). Josephson junctions represent a unique system to measure and manipolate MQS. High Tc cuprates are recent materials with novel properties common to strongly correlated systems, waiting to be exploited. In the last years hybrid systems are being syntetized at an intermediate, mesoscopic scale, in which sample dependent quantum behavior at low temperatures turns into robust emerging universal responses (independent of the disorder) under electronic control which allows for applications in metrology and quantum computing. One of the goals of our CNR-SPIN group is to investigate the interplay between superconducting coherence and mesoscopic disorder. The nature of HTS promotes an intriguing length scale hierarchy where the mesoscopic normal state coherence prevails over the superconducting order induced in the barrier of grain boundary nanocontacts. It is found that conduction channels are secured, in which high energy anti-nodal quasi-particles coherently interfere with surprisingly long decay times. This provides further understanding for the appearance of Macroscopic Quantum Tunnelingin YBCO Josephson Junctions, as measured in our devices at low temperatures. In our paper, the experimental observation of another mesoscopic property is reported, i.e. a minigap in the excitation spectrum of a Grain Boundary HTS Josephson Junction, which has been quite elusive to observation in transport measurements, up to now. More is to expect from the confluence of HTS and nanophysics



Top right inset: Current-Voltage characteristics. Switching current probability distributions versus bias current for different temperatures down to 300 mK. Resistance versus voltage (voltage scale at the top).
a) Scheme of the YBaCuO nano-channel; b) and c) enlargement of grain boundary (GB) region belonging to the naochannel. Interfering quasiparticles and Cooper pairs transport processes across the GB are sketched in b) and c) respectively.

2010

Persistent currents and quantized vortices in a polariton superfluid

D. Sanvitto[1], F. M. Marchetti[2], M. H. Szymańska[3,4], G. Tosi[1], M. Baudisch[1], F. P. Laussy[5], D. N. Krizhanovskii[6], M. S. Skolnick[6], L. Marrucci[7], A. Lemaître[8], J. Bloch[8], C. Tejedor[2] and L. Viña[1]

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[2]Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, Spain
[3]Department of Physics, University of Warwick, UK
[4]London Centre for Nanotechnology, London, UK
[5]School of Physics and Astronomy, University of Southampton, UK
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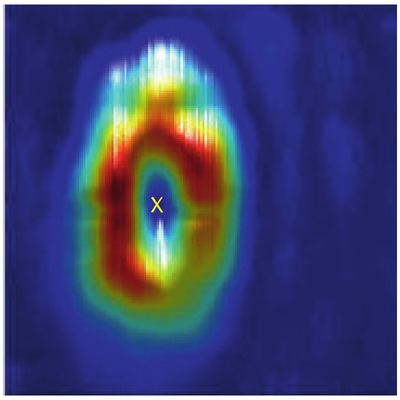
[8]LPN/CNRS, Route de Nozay, Marcoussis, France

Nature Physics 6, 527-533 (2010)

After the discovery of zero viscosity in liquid helium, other fundamental properties of the superfluidity phenomenon have been revealed. One of them, irrotational flow, gives rise to quantized vortices and persistent currents. Those are the landmarks of superfluidity in its modern understanding. Recently, a new variety of dissipationless fluid behavior has been found in microcavities under the optical parametric regime. In this paper, the authors report the observation of metastable persistent polariton superflows sustaining a quantized angular momentum, $m\hbar$, after applying a 2-ps laser pulse carrying a vortex state. The latter was prepared by diffraction of an input Gaussian beam on suitable holograms specifically developed in CNR-SPIN. Different holograms were used for injecting different values of angular momentum m, or to obtain more complex superposition states. In all cases, the authors observe a transfer of angular momentum to the steady-state condensate, which then sustains vorticity for as long as it can be tracked.



False-colors image of a metastable polariton superfluid vortex. The “x” labels the vortex core.

The stability of quantized vortices with m = 2 was also investigated. The appearance of secondary vortices of various signs around the injected vortex was finally observed and explained (in follow-up studies) thanks also to theoretical insights from researchers of CNR-SPIN. All experiments were analyzed using a generalized two-component Gross–Pitaevskii equation. These results demonstrate the control of metastable persistent currents and show the peculiar superfluid character of non-equilibrium polariton condensates.

2011

Intense paramagnon excitations in a large family of high-temperature superconductors

M. Le Tacon[1], G. Ghiringhelli[2], J. Chaloupka1, M. Moretti Sala[2], V. Hinkov[1,3], M.W. Haverkort[1], M. Minola[2], M. Bakr[1], K. J. Zhou[4], S. Blanco-Canosa[1], C. Monney[4], Y. T. Song[1], G. L. Sun[1], C. T. Lin[1], G. M. De Luca[5], M. Salluzzo[5], G. Khaliullin[1], T. Schmitt[4], L. Braicovich[2] and B. Keimer[1]

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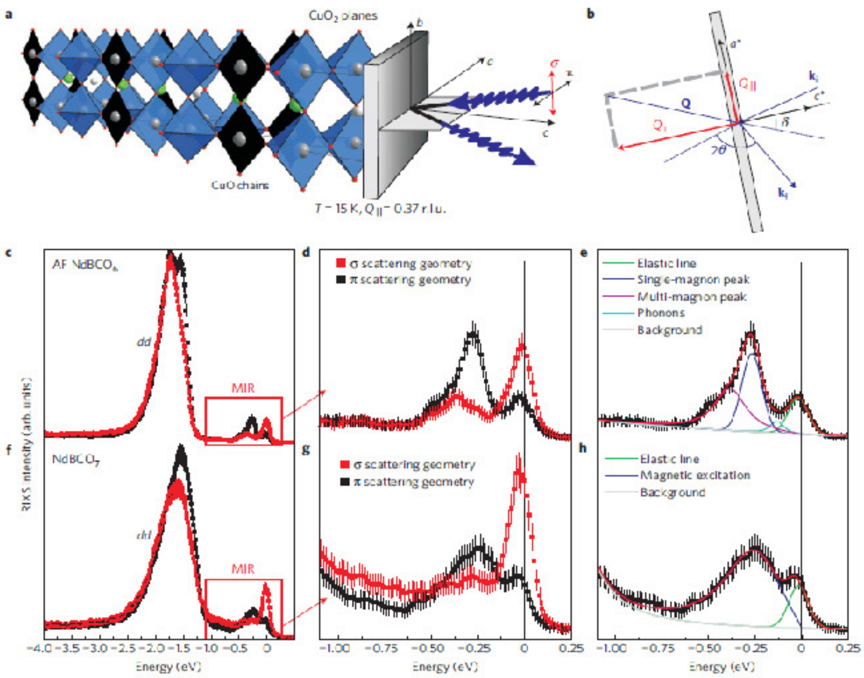
[3]Quantum Matter Institute, University of British Columbia, Vancouver, Canada,
[4]Swiss Light Source, Paul Scherrer Institut, Villigen PSI, Switzerland,
[5]CNR-SPIN, Napoli, Italy

Nature Physics 2041 (2011)

In the search for the mechanism of high-temperature superconductivity, intense research has been focused on the evolution of the spin excitation spectrum on doping from the antiferromagnetic insulating to the superconducting state of the cuprates. Because of technical limitations, the experimental investigation of doped cuprates has been largely focused on low-energy excitations in a small range of momentum space. Here we use resonant inelastic X-ray scattering to show thata large family of superconductors, encompassing underdoped $YBa_2Cu_4O_8$ and overdoped $YBa_2Cu_3O_7$, exhibits damped spin excitations (paramagnons) with dispersions and spectral weights closely similar to those of magnons in undoped cuprates. The comprehensive experimental description of this surprisingly simple spectrum enables quantitative tests of magnetic Cooper pairing models. A numerical solution of the Eliashberg equations for the magnetic spectrum of $YBa_2Cu_3O_7$ reproduces its superconducting transition temperature within a factor of two, a level of agreement comparable to that of Eliashberg theories of conventional superconductors.



Scattering geometry and typical Cu L_3-edge RIXS response of cuprates.
a,b, Schematic representations of the scattering geometry.
c-h, Typical RIXS spectra of undoped antiferromagnetic (AF) $Nd_{1.2}Ba_{1.8}Cu_3O_0$ (**c-e**) and superconducting underdoped $Nd_{1.2}Ba_{1.8}Cu_3O_7$ (**f-h**), obtained at T=15K for $Q_{||}$=0.37 r.l.u., in both π (black squares) and σ (red squares) scattering geometries. The error bars indicate the statistical error (s.d. to the number of deteted photons).

Highlights

2011

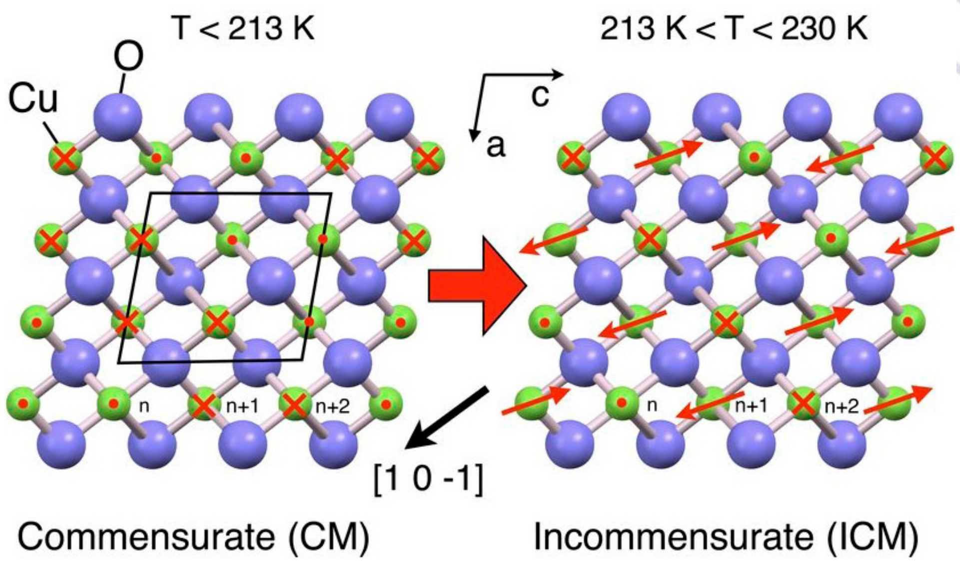
High-T(c) Ferroelectricity Emerging from Magnetic Degeneracy in Cupric Oxide

Giovannetti G[1,2], Kumar S[3,4], Stroppa A[5], van den Brink J[3], Picozzi S[1], Lorenzana J[2]

[1]CNR-SPIN L'Aquila;
[2]ISC-CNR, Dip. Fisica, Università "La Sapienza", Roma
[3]Institute for Theoretical Solid State Physics, Dresden
[4]Indian Institute of Science Education and Research Mohali, Chandigarh
[5]CNISM-Dip. Fisica, University of L'Aquila

Physical Review Letters 106, 026401 (2011)

Cupric oxide is multiferroic at unusually high temperatures. The CNR-SPIN group of L'Aquila, by performing high accurate density functional calculations have confirmed for the first time, that the low-T magnetic phase is paraelectric, and the higher-T one is ferroelectric with a size and direction of polarization in good agreement with experiments. By mapping the ab initio results on to an effective spin model, we show that the system has a manifold of almost degenerate ground states. In the high-T magnetic state noncollinearity and inversion symmetry breaking stabilize each other via the Dzyaloshinskii-Moriya interaction. This leads to an unconventional mechanism for multiferroicity, with the particular property that non-magnetic impurities enhance the effect.



In the ICM phase, the CuO becomes multiferroic, with a finite and switchable Pb along the b axis (Fig. adapted from http://www.zeitnews.org/)

2011

Electric Control of Magnetization and Interplay between Orbital Ordering and Ferroelectricity in a Multiferroic Metal–Organic Framework

A. Stroppa[1], P. Jain[2], P. Barone[1], M. Marsman[3], J.M PerezMato[4],
A. K. Cheetham[5], H. W. Kroto[2], S. Picozzi[1]

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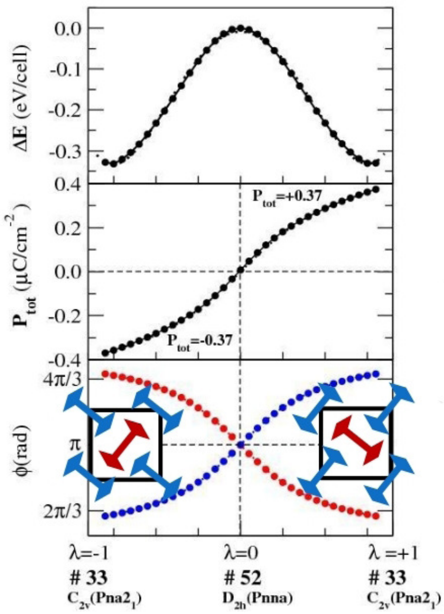
[2]Dept of Chemistry and Biochemistry, Florida State University, Tallahassee, FL 32306 (USA)
[3]Univ. of Vienna, Faculty of Physics and Center for Computational Materials Science (Austria)
[4]Dept de Fisica de la Materia Condensada, Facultad de Ciencia y Tecnologia, UPV/EHU, Bilbao (Spain)
[5]Department of Materials Science and Metallurgy, University of Cambridge (UK)

Angewandte Chemie International Edition, 50 (26), 58475850 (2011)



Path connecting the the virtual nonpolar and the two polar phases with opposite polarizations. a) Total energy difference with respect to the paraelectric phase; b) The polarization Ptot a a function of λ; c) Evolution of the Jahn-Teller phases as a function of λ. Blue and red color refer to the two Cu sublattices with different direction of the elongation axis in the ab plane.

Metal Organic Frameworks (MOFs) are hybrid crystalline materials made up of both inorganic and organic structural elements. They are driving enormous interest not only for many interesting properties, but also owing to the large variety of structural topologies, modifications of the organic units, useful for functionalizing specific materials properties. A class of dense MOFs having a ABX3 topology where A is an organic linker, B is a metal atom, and X is a carboxylic acid. is particularly appealing since shows eye-catching properties in areas that have traditionally been dominated by inorganic materials, like magnetism and ferroelectricity. The coexistence of magnetic and ferroelectric order in the same material, i.e. multiferroicity (MF), is of great technological and fundamental importance, in particular when both orders are coupled, i.e. magneto-electric coupling. Despite the large activity devoted to multiferroics, most of the past and current studies have focussed on inorganic compounds, mainly in the family of perovskite like oxides. On the other hand, there is a growing expectation that MF in MOFs should show unprecedented properties, not fully realized in standard inorganic compounds, opening a curnucopia of new horizons. A few experimental studies on multiferroic MOFs started to emerge, but theoretical simulations are an almost totally unexplored field. The CNR-SPIN group in l'Aquila performed a pioneering study based on ab-initio calculations of a Cu based MOF compound showing that i) It should be a multiferroic, i.e. it is both a ferroelectric and a weak-ferromagnet. ii) It should also be magnetoelectric, i.e. the weak-ferromagnetism is coupled to the ferroelectric polarization, therefore allowing the electrical control of magnetic properties. iii) The above ferroelectric polarization emerges from a subtle interplay between Jahn Teller distortions (which are nonpolar in common inorganic perovskite compounds) and organic A-groups through hydrogen bonding. This is a unique mechanism and demonstrates the rich field for the development of new physics in this class of materials, which have not yet been characterized theoretically.

Anomalous Charge Tunneling in Fractional Quantum Hall Edge States at a Filling Factor nu =5/2

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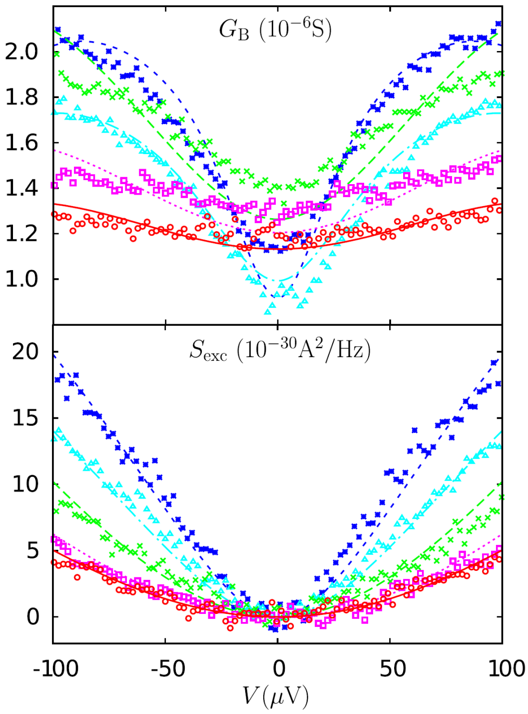
Physical Review Letters 107 (1) 46404 (2011)

The theoretical unit in Genoa leaded by Prof. Maura Sassetti has a long experience in the study of strongly correlated systems and their applications in nanodevices. One of the ultimate challenges in nanotechnology is the fabrication of a "quantum computer". Between the different proposals one of the most promising system seems represented by electrons living on a plane and exposed to a strong magnetic field at very low temperatures. Under these conditions one has the fractional quantum Hall effect, where the intimate quantum nature of matter emerges dramatically leading to intriguing properties such as the fractionalization of the charge and non-Abelian statistics.



Fit of the experimental data for the conductance (top panel) and noise (bottom panel) taken at Weizmann Institute of Science using our theory"

Recent experiments carried out at the Weizmann Institute of Science have shown that the fractionalization of tunneling charges unexpectedly occurs in a variety of forms. In particular noise measurements suggest an increasing of the carrier charge in tunneling of a quantum point contact at the lowest temperatures. In our paper we fit very convincingly two independent experimental quantities such as the current and the excess noise in the quantum point contact (see the figure) for filling factor 5/2. The most accredited low-energy effective field theory for the edges states was used. In particular we found that two are the main excitations: the "single-quasiparticle", charge e/4 and non-Abelian statistics, and the "2-agglomerate", charge e/2 and Abelian statistics, with e the electron charge. A crucial ingredient, to explain the experiment, was the inclusion of renormalization effects determined by the coupling of the edge states with external degrees of freedoms (such as unavoidable 1/f noise and dissipative baths). At low enough temperature, the 2-agglomerates becomes the protagonist, with a charge twice that of the fundamental quasiparticle.
This result could have deep consequences because only non-Abelian excitations, such as the single-quasiparticles, could be used to encode the topological quantum computation

Highlights

2011

Giant Nernst-Ettingshausen Oscillations in Semiclassically Strong Magnetic Fields

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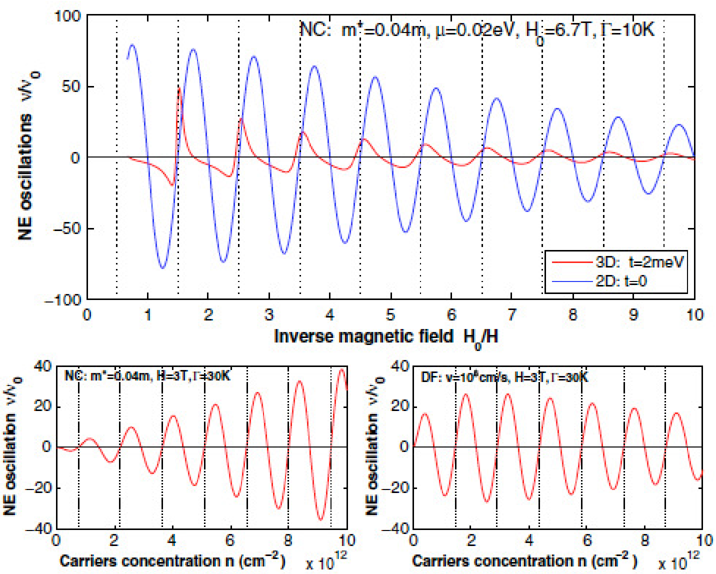
Physical Review Letter 107 Issue: 1 Article Number: 016601 (2011)

The Nernst-Ettingshausen (NE) effect is a thermoelectric counterpart of the Hall effect. It consists in induction of an electric field E_y normal to the mutually perpendicular magnetic field H_z and temperature gradient ∇T. Quantitatively, the effect is characterized by the NE coefficient $\nu = \frac{E_y}{(-\nabla T)H_z}$ which varies by several orders of magnitude in different materials ranging from about 7 mV/ (KT) in bismuth up to 10-5mV/(KT) in some metals. NE effect was discovered in 1886 and remained poorly understood until 1948 when Sondheimer in the framework of the transport equation calculated for a degenerated electron system. Its study became a powerful tool in investigation of the character of scattering mechanisms in semiconductors, but did not find its special role in metals. At the beginning of 2000 Ong discovered the giant growth of NE signal approaching T_c in pseudogap phase of HTC materials, later the colossal growth of the NE coefficient was detected by Behnia in $Nb_{0.15}Si_{0.85}$ above T_c , the experiments on graphene demonstrated the giant oscillations of the NE signal with growth of magnetic field. In order to explain the physical essence of all these anomalies and to learn how to extract from them the useful information in SPIN was developed the new general approach to the description of the NE effect, where is expressed in terms of the temperature derivatives of the chemical potential and magnetization of the charge carriers system. In the previous publications [1,2] this method was successfully probed on explanation of the NE anomalies in conventional and HTC superconductors, being used side by side with the rigorous calculus of the NE coefficient in the framework of the diagrammatic Matsubara technique.



Normalized Nernst-Ettingshausen oscillations in 2D and 3D as a function of the inverse magnetic field and carriers concentration for normal carriers (NC) and Dirac fermions (DF).

In the present work we consider the NE effect in the presence of semi-classically strong magnetic fields for a quasi-two dimensional system with a parabolic or linear dispersion of carriers. We show that the occurring giant oscillations of the NE coefficient are coherent with the recent experimental observation in graphene, graphite and bismuth. In the 2D case we find the exact shape of these oscillations and show that their magnitude decreases/increases with enhancement of the Fermi energy for Dirac fermions/normal carriers. With a crossover to 3D spectrum the phase of oscillations shifts, their amplitude decreases and the peaks become asymmetric.

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Highlights

2011

Retention of the tetragonal to orthorhombic structural transition in F-substituted SmFeAsO: a new phase diagram for $SmFeAs(O_{1-x}F_x)$

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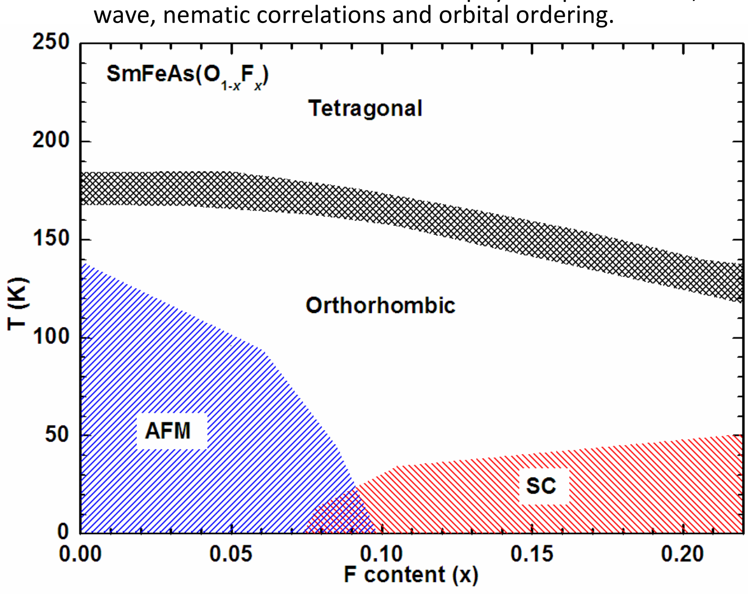
Physical Review Letters 106 227001 (2011)

Fe-based superconductors were intensively studied during the very last years. Whatever their composition, they are structurally based on planar layers of edge-sharing tetrahedra, centred by Fe, and stacked along the c-axis. Compounds characterized by a LnFeAsO chemical formula (Ln: lanthanide) belong to the so-called 1111-type family where superconductivity can be induced both by hole or electron doping. Around ~150 K undoped and faintly doped compounds undergo a tetragonal to orthorhombic structural transition that is followed by an antiferromagnetic ordering of Fe spins at a slight lower temperature. Many investigations report that both structural and magnetic transitions are suppressed above a critical value of electron doping induced by F substitution; in addition the natures of the structural transition and magnetic ordering are still debated and related to different physical phenomena, such as magnetic frustration, spin density wave, nematic correlations and orbital ordering.



We used synchrotron powder diffraction analysis (BM1B beamline at ESRF) to investigate the origin of symmetry breaking in a series of samples belonging to the $SmFeAs(O_{1-x}F_x)$ system prepared at SPIN laboratories in Genoa, where they were also characterized by resistivity measurements. By a careful analysis of the high resolution – high intensity synchrotron diffraction data collected as a function of temperature we found that the tetragonal to orthorhombic transition is retained for the superconducting samples, even at optimal doping. In particular the transition temperature is slightly affected by F content, whereas the orthorhombic distortion progressively decreases with the increase of electron doping.

Integrating these results with those obtained by muon spin rotation on the same samples we drew a new phase diagram for the system $SmFeAs(O_{1-x}F_x)$.
These findings relate the AFM transition on a different ground with respect to the structural one and suggests that orbital ordering could be the driving force for symmetry breaking.

Highlights

2011

Microfluidics analysis of red blood cell membrane viscoelasticity

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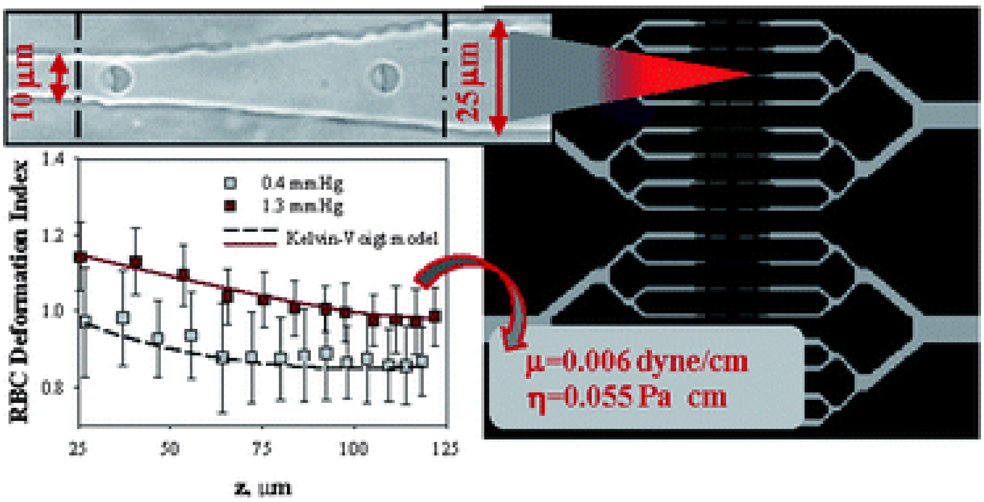
Lab on Chip 11, 449-454 (2011)

A microfluidic system to investigate the flow behavior of red blood cells in a microcirculation-mimicking network of PDMS microchannels with thickness comparable to cell size is presented. In collaboration with the group of S. Guido of the University of Naple, we provide the first quantitative description of cell velocity and shape as a function of the applied pressure drop in such devices. Based on these results, a novel methodology to measure cell membrane viscoelastic properties in converging/diverging flow is developed. In particular, in the diverging channel the effect of RBC surface viscosity is dominant with respect to shear elasticity.
The role of the researcher of CNR-SPIN and of the Physics Departments of Naples University was mainly devoted, by using soft lithography techniques to the realization of the devices that perfectly mimics a network of human blood vessels.



Highlights

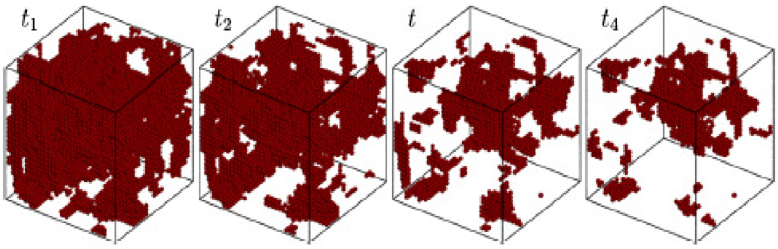
2011

Dynamical Correlation Length and Relaxation Processes in a Glass Former

R. Pastore, CNR-SPIN
M. Pica Ciamarra, CNR-SPIN
A. de Candia, Univ. di Napoli Federico II, Dep. of Physics, and CNR-SPIN
A. Coniglio, Univ. di Napoli Federico II, Dep. of Physics, and CNR-SPIN

Physical Review Letters 107.065703 (2011)

We investigate the relaxation process and the dynamical heterogeneities of the kinetically constrained Kob-Andersen lattice glass model and show that these are characterized by different time scales. The dynamics is well described within the diffusing defect paradigm, which suggests that we relate the relaxation process to a reverse-percolation transition. This allows for a geometrical interpretation of the relaxation process and of the different time scales.



The figure shows the particles of the investigated model system which have not moved in the time interval 0-t. These particles are correlated space over a distance known as the dynamical correlation length. Different theories predict this length to be the one governing the slow dynamics of the system. Our work proved that in this model system this is not the case, and therefore challenges existing theories of the structural glass transition.

Highlights

2011

Correlated trends of coexisting magnetism and superconductivity in optimally electron-doped oxy-pnictides

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G. Lamura[6], A. Martinelli[7] and M. Putti[6]

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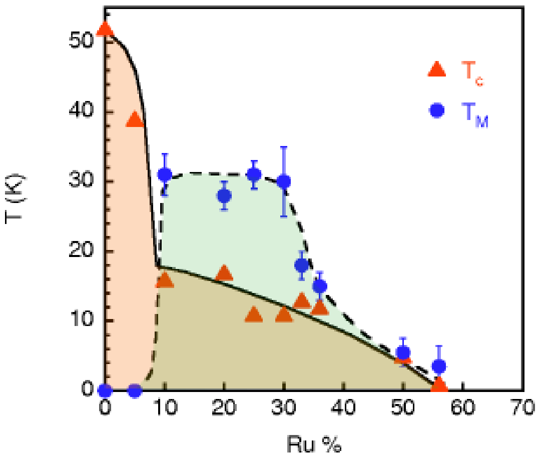
[5]Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland
[6]CNR-SPIN and Universita di Genova, via Dodecaneso 33, I-16146 Genova, Italy
[7]CNR-SPIN Corso Perrone 24, I-16146 Genova, Italy

Physical Review Letters 107.227003 (2011)



The paper reports on the recovery of short range static magnetic order and on the concomitant degradation of the superconducting state in optimally F-doped $SmFe_{1-x}Ru_xAsO_{0:85}F_{0:15}$ for 0:1 ≤ x ≤0.5 synthesized at CNR-SPIN. The two reduced order parameters coexist within nanometer-size domains in the FeAs layers and finally disappear around a common critical threshold xc ~ 0:6.

Superconductivity and magnetism are shown to be tightly related to two distinct well defined local electronic environments of the FeAs layers. The two transition temperatures, Tc and TM, controlled by the isoelectronic and diamagnetic Ru substitution, scale with the volume fraction of the corresponding environments.
This is evidence that superconductivity is assisted by magnetic fluctuations, which are frozen where short range static order appears, and totally disappear above the magnetic dilution threshold xc.

Highlights

2011

Ferroelectricity due to orbital ordering in E-type undoped rare-earth manganites

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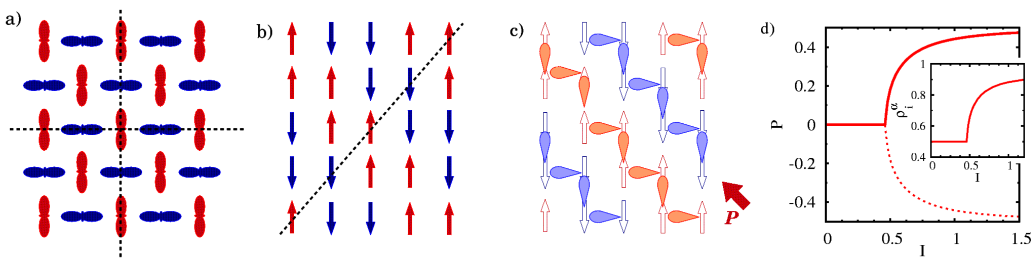
CNR-SPIN L'Aquila, Italy

Physical Review Letters 106, 077201 (2011)

Among other multiferroic materials, orthorhombic rare-earth manganites RMnO3 (R belonging to lanthanum series) represent an important class of "improper multiferroics", where the ferroelectricity is not only coexisting with, but also intrinsically related to some kind of magnetic order. For small rare-earth cations, such as Ho or Tm, the ground state displays an E-type antiferromagnetism characterized by zigzag ferromagnetic chains antiferromagnetically coupled. This collinear magnetic ordering has been predicted to induce a ferroelectric polarization via an exchange-striction mechanism, where the double-exchange interaction between Mn e1g electrons in the symmetry-broken ↑↑↓↓ spin configuration is responsible for polar atomic displacements of oxygens bridging Mn ions. Ab-initio calculation partially confirmed this picture, but also pointed out a comparable contribution to polarization having a purely quantum mechanical origin, possibly related to the AFM-E-induced asymmetric electron hopping of orbitally polarized e1g states. Aim of this Letter is to set a clear correspondence between the electronic polarization and the onset of orbital ordering on the background of the magnetic AFM-E configuration. In the framework of the degenerate double-exchange model relevant for manganites, we evaluated the Berry phase of the orbitally polarizable Bloch electrons, which allows to directly measure the electronic contribution to polarization, as the orbital ordering is tuned either by Jahn-Teller electron-lattice coupling or by electron-electron interaction. In the orbital-ordered state, Bloch electrons acquire a phase depending on the clockwise or counterclockwise motion around each site. Similarly, a phase change in electronic wavefunctions arises along each chain from the direction dependence of hopping amplitudes. The interplay of these two phases, realized only in the presence of both the E-type magnetic order and of the orbital ordering is responsible for the appearence of a purely electronic polarization.



a) Schematic picture of orbital-ordering pattern in RMnO3, with alternating d3x^2-r^2, d3y^2-r^2 orbitals. b) Schematic picture of E-type antiferromagnetic configuration, with zigzag ferromagnetic chains antiferromagnetically coupled. Dashed lines in a) and b) are mirror planes underlying the different symmetries of the two ordered states. c) Combination of E-type and orbital-ordered state; the asymmetric hopping at each Mn site is pictorially shown, the red arrow indicating the resulting Berry-phase polarization. d) Evolution of the polarization in the degenerate double-exchange model as a function of the interaction tuning the orbital-ordered state. Dashed line is the switched polarization obtained by rotating all occupied orbitals by 90o; the inset shows the average occupancy of d3x^2-r^2,(d3y^2-r^2) orbital states on even (odd) sites along a single chain as a function of interaction, underlying the relationship between P and orbital ordering.

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Events

- ✓ SPIN Kick-off meeting, Genova 10-11 June 2010

  http://www.spin.cnr.it/index.php/kickoff

- ✓ SM-2010: Superconductivity and Magnetism, Paestum 5-11 Sept. 2010

  http://sm2010.sa.infn.it/

- ✓ ESMF 2010: European School on Multiferroics, L'Aquila 26 Sept. - 1 Oct. 2010

  http://www.casti.aquila.infn.it/homepages/bismuth/ESMF2010/index.html

- ✓ AQUIFER: AQUila Initiative on FERroics, L'Aquila 19 Sept. - 23 Oct. 2010

  http://www.icmr.ucsb.edu/programs/aquifier.html

- ✓ Materiali innovativi e stati della materia: come e perché utilizzarli, Napoli 14 March 2011 and Salerno 23 March 2011

  http://mama.spin.cnr.it/index.php/eventsl/74-meeting-na
  http://mama.spin.cnr.it/index.php/eventsl/76-meeting-sa

- ✓ 1st Advisory Board Meeting, Genova 23-24 May 2011

  http://www.spin.cnr.it/index.php/1stadvisoryboard

In memory of Antonio Barone

Antonio Barone (AB) prematurely passed away on Dec 4th 2011 at the age of 72, after a one-year battle with cancer.

He left behind his wife Sveva and his two sons, Alberto and Livio. Antonio was currently Professor Emeritus at the University of Napoli Federico II, where he had been teaching for about 40 years. The initial research activity of AB was in the field of nuclear physics. In this context, almost 45 years ago, the Ge “Lithium drift” semiconductor detectors represented a novelty, due to the high energy resolution allowed by those devices.

Superconductors stimulated new approaches to radiation detection and this motivated Antonio’s interests toward the superconductivity.

In the 1967 the birth of the Laboratorio di Cibernetica of the CNR offered him the possibility to work in a joint project USA-Italy (University of Wisconsin, Madison - CNR Naples) in the field of superconductivity on the peculiar subject of the superconductive “Neuristors”. His research activity on Josephson junctions opened a wide variety of very stimulating subjects in which AB was deeply involved, ranging from the soliton propagation in “long” Josephson structures to fluctuations phenomena, from light-sensitive junctions and proximity effect to the development of innovative superconducting devices.

The strong interaction of AB with the Landau Institute for Theoretical Physics of the Academy of Sciences, in Moscow, characterizes a long period of his research activity with a precious merging of theoretical and experimental aspects. All this body of work converged into the famous monograph on the “Physics and Applications of the Josephson Effect”, written in collaboration with Gianfranco Paternò in 1982. This became rapidly the reference text for the Josephson effect, as documented by thousands of citations and the fact it was translated into Russian, Japanese and Chinese. In 1983, AB was awarded by the Academy of Sciences in Moscow the highest academic title of “Doctor of the Physical-Mathematical Sciences”, and later the coveted Kapitza Prize.

In memory of Antonio Barone

The discovery of high-Tc superconductors (HTS) opened new problems and perspectives. In this context, AB and his group, significantly contributed by reporting original results on the "archetype" high-Tc Josephson junctions. Of great impact were the studies on unconventional superconductivity, first developed for "p-wave" superconductors, but definitely very inspiring for the d-wave experiments on HTS compounds, and later on the physics of HTS Josephson junctions.

Macroscopic quantum phenomena and "particle detectors" are the keywords and the logical paths where to bring back several relevant contributions of Antonio scattered in more than 40 years of activity. Topics of his interest ranged from the fundamentals of macroscopic quantum tunnelling to barrier penetration in nonstationary fields, to finally a project into a wider vision of macroscopic quantum phenomena in unconventional systems.

Antonio is universally considered not only the founder of the Superconductivity School in the Napoli area, but also as the "grande maestro" and one of the most representative physicists in Italy. He has filled very relevant positions of scientific management in Italy and participated in many international committees. He has significantly contributed to the popularization of superconductivity as a divulgator, as a professor, as a researcher and as a manager.

An intense wave of sympathy and friendships has arrived from all over the world testifying how his gentleness, his sense of science and his smile were a solid bridge of friendship and respect with colleagues, students and people of everyday life. This premature departure cannot be dissociated from so many years spent working together. This moment cannot be dissociated from the awareness of having had the privilege to deal with a real gentleman of science and life, a man of vision and perspective.

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