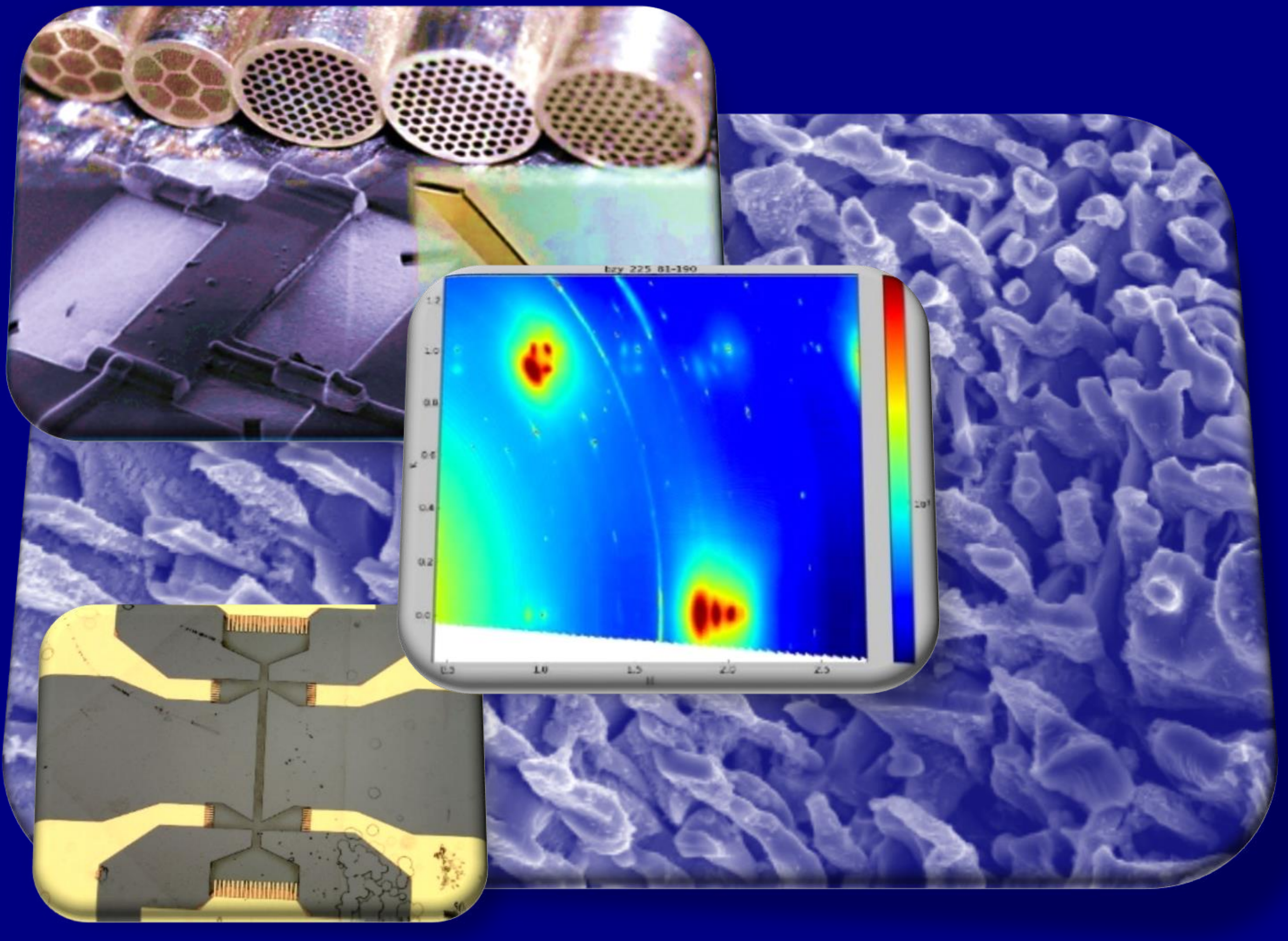
SPIN

Scientific Report 2014 - 2015

Consiglio Nazionale delle Ricerche



Front cover images:

- *Superconductivity: from basic properties of a single crystal to long wires for power applications, by* ***Andrea Malagoli***
- *Reciprocal space mapping of the dislocation network existing at the interface between a proton conducting $BaZr_{0.8}Y_{0.2}O_3$ film and a $NdGaO_3$ substrate, by* ***Roberto Felici***
- *Hall bar for quantum measurement in ZnO/(Zn,Mg)O two-dimensional electron gas, by* ***Alessandro Leveratto***
- *Scanning electron microscopy image of fast solidified non-centrosymmetric $Ba_2CuGe_2O_7$ crystals in a matrix of Cu_2O and $BaGeO_3$ grown by floating zone technique, by* ***Antonio Vecchione***

Back cover images:

- *Scanning electron microscopy image of the four micro-tips used to acquire room temperature I-V characteristic of a single Ru plate embedded in a Ca_2RuO_4 crystal, by* ***Antonio Vecchione***
- *High resolution transmission electron image of crystalline boron; a schematic view of boron structure is sketched for comparison, by* ***Alberto Martinelli***
- *A different coloring of the front image by* ***Roberto Felici***

SPIN

Scientific Report 2014 - 2015

Contributions from all SPIN Researchers

Edited by
Roberta De Donatis

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Foreword

Welcome to the third SPIN biennial report!

Six years of life: Spin (SuPerconducting and other INnovative Materials and devices) was born in 2010, assembling in a single Institute of the National Research Council (CNR) research groups working on materials science in Genoa, Naples, Salerno, L'Aquila, and Rome, previously operating within INFM.

SPIN is now an important and recognizable scientific institution, with headquarters in Genoa and branch offices in the aforementioned cities: SPIN brings together more than 200 people, including staff researchers, associate researchers, and technical and administrative support staff and trainees; SPIN is therefore a CNR Institute with appreciable critical mass. The Institute is affiliated to the Department of Physical Science and Technologies of the Matter (DSFTM), a CNR Department with a high degree of internationalization.

The scientific work done at SPIN is characterized by a multidisciplinary approach that devotes much care and attention to the relationship between basic research and the application potential; many of the scientific activities are concentrated on key enabling technologies (Kets). Spin has its scientific mission focused on innovative materials, superconductors, oxides, and hybrid nanostructured materials.

The activities range from basic experimental and theoretical studies on magnetic and superconducting materials, strongly correlated oxides, and other innovative materials. Relevant issues are material preparation (bulk, single crystals, thin films, multilayers, and epitaxial superlattice), material characterization based on the radiation-matter interactions and electronic transport properties measurements in the presence of high external fields. Moreover, SPIN researchers deal with sensors, micro/nano superconducting electronic devices (for quantum computation and other applications), electronic devices based on oxides ("oxide electronics") and organics ("organic electronics"). They also fabricate superconducting cables and tapes for power applications in the fields of biomedicine, energy, and high energy physics.

The scientific community of SPIN is heavily involved in the promotion, education and communication in the field of innovative materials.

SPIN draws most of its research budget from projects related to national and international calls, and this is why an important section of the report is dedicated to the description of major projects.

I think these pages may offer an overview of the research activities, planning, equipment, and main achievements of the past two years.

To show the variety of achievements, in this edition of the scientific report it was decided to give more space to the highlights, considered to be a more effective way to describe the Institute. They are divided in four sections: Superconductivity, Oxides, Other Materials and Fundamental properties.

For the preparation of this report thanks are due to the editor, Roberta De Donatis, to all the activity leaders and deputy directors of the various units, and to Elisabetta Narducci, Sabrina Poggi and Ruggero Vaglio for the final revision.

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Director, CNR-SPIN

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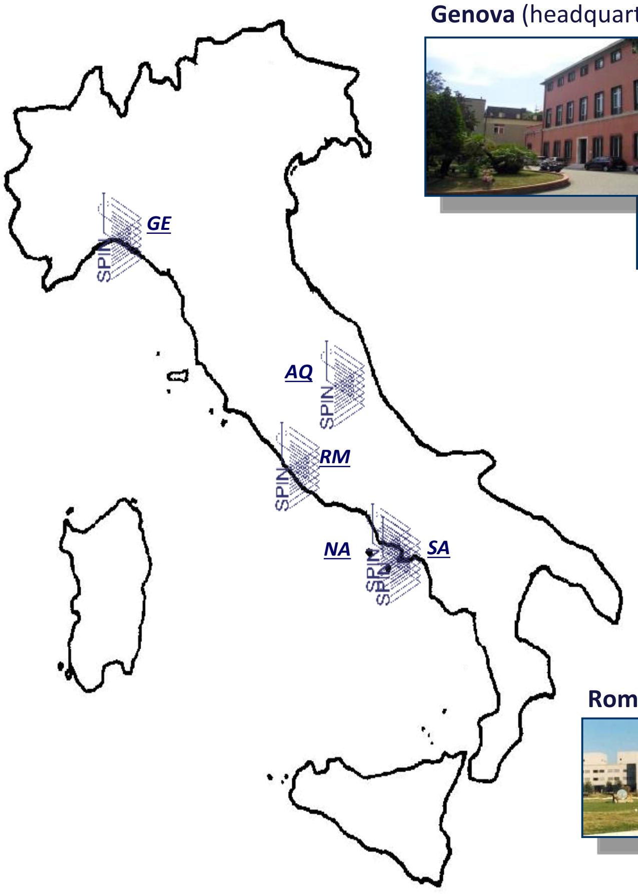
Locations

SPIN belongs to the **CNR Physical Sciences and Technologies of the Matter Department** (www.dsftm.cnr.it) directed by Dr Corrado Spinella, and includes the following locations:



Genova (headquarter) **-** *main focus: superconductivity, innovative materials*

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16152 Genova, Italy

University of Genova

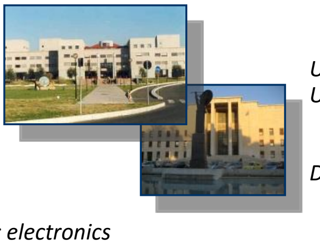
Deputy Director: Daniele Marrè

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

University of L'Aquila
Physics Department

Deputy Director: Gianni Profeta

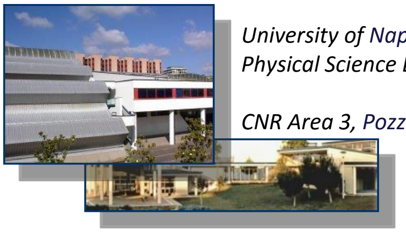
Roma - *main focus: oxide thin films/optical properties*



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

Deputy Director: Carmela Aruta

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



University of Napoli Federico II
Physical Science Department

CNR Area 3, Pozzuoli

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Salerno - *main focus: superconductivity and magnetic hybrids*

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Research Lines

Research Lines

The Research Lines are organized into five “Activities” :

1. Materials and mechanisms of superconductivity and its power applications
(Activity leader: Andrea Malagoli)

2. Superconductive and hybrid quantum nanostructures and devices
(Activity leader: Procolo Lucignano)

3. Cooperative phenomena in advanced materials with magnetic and/or dipolar electric ordering
(Activity leader: Mario Cuoco)

4. Functional materials and novel devices for electronics and energy applications
(Activity leader: Emilio Bellingeri)

5. Dynamical, electronic and transport properties of complex systems and functional materials
(Activity leader: Giovanni Cantele)

Research Lines

1. Materials and mechanism of superconductivity and its power application

Activity leader	**Andrea Malagoli** (andrea.malagoli@spin.cnr.it)
Researchers	C. Bernini, V. Braccini, C. Ferdeghini, A. Gerbi, G. Grimaldi, G. Lamura, A. Martinelli, A.M. Massone, I. Pallecchi, A. Varlamov, M. Vignolo.
Associate Researchers	F. Canepa, M.R. Cimberle, P. Dore, U. Gambardella, P. Manfrinetti, A. Nigro, S. Pace, M. Pani, M. Piana, M. Polichetti, M. Putti, A. Siri, P. Romano.

The activity mission is focused on the study of superconductivity and its power applications. The research is carried out by Genova and Salerno units, which share several skills and expertise. The Genova unit is mainly active on the preparation of superconducting materials in form of bulks, films and wires and their characterization. The Salerno unit is mainly devoted to the investigation of pinning mechanisms, which may be of significant interest for technological application.

During this last period, in Genova, several research activities related to Fe-based superconductors involved our scientific community. The study of the basic properties of such new superconductors led to remarkable results, among them: a) the identification of a strong magnon drag effect, which is a direct evidence of the charge carriers-spin waves coupling in unconventional superconductors in the parent compounds of the 1111 phase; b) new insights about the interplay among the lattice, spin and orbital degrees of freedom in $La(Fe_{1-x}Ru_x)AsO$ and $La(Fe_{1-x}Mn_x)AsO$ phases. The Image and Data Analysis Group developed computational techniques based on inverse problems, pattern recognition and image processing theory for automatic processing STM images of $FeSe_xTe_{1-x}$ thin films. Remarkable results came also from the applicative side of our research. For the first time in Europe, a superconducting Fe-based tape (Ba-122) was realized and the crucial points of the possible scaling up of the process were analyzed. A new scalable process for the realization of high-performance Bi-2212 wires was developed, which should boost their application in high field magnets. A pilot system for the fabrication on larger scale of nano-sized MgB_2 precursors was developed as well.

Superconductivity at SPIN: from single crystal to multifilamentary wires for applications. On the right the new cryogenic system at SPIN-GE for high critical current measurements in variable magnetic field and temperature.

The research in Salerno focused in particular on the study of the current stability and the phase diagram of mesoscopic superconductors: it was proved that confined vortex dynamic results in a limiting maximum velocity for the Abrikosov lattice. Pinning properties of the optimal doped compound were investigated in NCCO thin film: the analysis suggests the presence of two possible kinds of pinning centers in such compound within a weak collective pinning landscape. Finally, Salerno unit successfully closed the PON Project NAFASSY NAtional FAcility for Superconducting Systems, and a new laboratory Material Science and TEchnology Research Lab (MASTER) was set to measure advanced materials and devices in extremely high magnetic fields and very low temperatures.

2. Superconductive and hybrid quantum nanostructures and devices

Activity leader	**Procolo Lucignano** (procolo.lucignano@spin.cnr.it)
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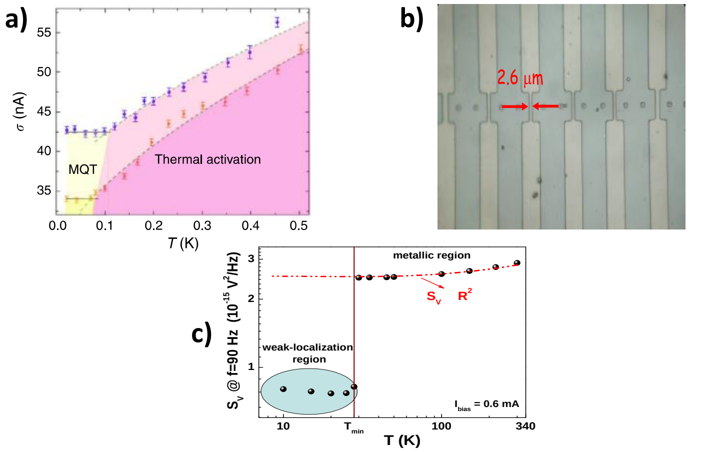
Associate Researchers	A. Andreone, C. Attanasio, F. Bobba, G. Carapella, A. Cucolo, C. De Lisio, S. Pagano, L. Parlato, G.P. Pepe, F. Tafuri, A. Tagliacozzo.

The activity focuses on fundamental and applied topics in superconducting electronics.
Superconducting devices are adopted as a fertile playground to attack fundamental issues in physics, such as macroscopic quantum tunneling or topological phases of matter. The same devices, are studied as building blocks for future quantum electronic devices and/or for novel sensors.
The superconducting materials can either be conventional s-wave BCS or unconventional superconductors, e.g. cuprate high critical temperature or iron based superconductors.
We study a wide number of devices including conventional Josephson junctions, hybrid structures involving unconventional materials acting as “normal” barrier or nanowire shaped superconductors (mostly studied for single photon detectors).
Barrier materials can be conventional metal-oxides, semiconductors, topological insulators, ferromagnets and other innovative materials, as graphene or nanowires with spin orbit interaction.
Most of the people are involved in experimental researches, mainly carrying transport measurements at low temperatures (ranging from few tens of mK to some K’s). Such measurements can also be done in the presence of electromagnetic radiation, ranging from visible to microwave wavelengths.
Local microscopy and noise measurements are also performed, as well as magneto-optical characterizations and optical pump and probe spectroscopies.



a) Widths of Switching current distributions in SFS junctions, showing MQT, Nat.Comm. 6, 7376 (2015); b) High-angle Fe(Se,Te) bicrystal grain boundary junctions, APL 104, 162601 (2014); c) Power spectral density of 1/f noise in ultrathin Cu samples showing the crossover to the weak localization, Scientific Reports 5, 10705 (2015)

There are also two research lines closer to optics, one on entanglement and quantum properties of optical systems, and one on photonic metamaterials both sharing the common root of “quantum coherence” with the bulk of the project.
Theoretical modeling aims at understanding our experimental findings, and designing/engineering novel experimental proposals. It is mostly based on analytical and numerical description of super-conducting hybrid systems in low dimensions and, in general, applies the techniques of mesoscopic quantum electron trasnport to the systems under investigation.

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

Activity leader **Mario Cuoco** (mario.cuoco@spin.cnr.it)

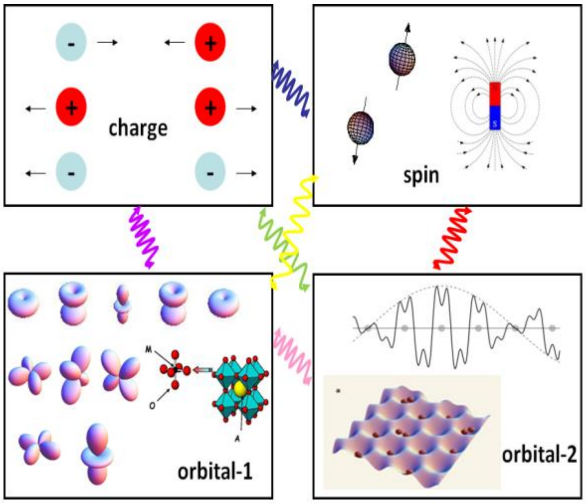
Researchers A.Ciattoni, R.Fittipaldi, P.Gentile, A.Marino, F.Miletto, D.Paparo, S.Picozzi, A.Stroppa, V. Tkachenko, A.Vecchione, X. Wang

Associate Researchers G.Abbate, S.Amoruso, G.Ausanio, R.Bruzzese, P. Calvani, V.Iannotti, L.Lanotte, L.Marrucci, P.Maselli, C. Noce, A. Nucara, L.Ottaviano, G.Profeta, A. Romano, U.Scotti di Uccio

The present research deals with the synthesis, the analysis and the modelling-computation of materials where the coupling of spin, charge, and orbital degrees of freedom, as due to the electron-electron and electron-lattice interaction, leads to electrical and magnetic unconventional properties. The research has been focused on systems where the properties depend on cooperative phenomena of coexistence and/or competition of different types of orderings.

Systems of interests are grown as thin films and single crystals. The key aims in the synthesis are to achieve controlled interfaces in epitaxial heterostructures, nano-particles by means of laser ablation with ultra short pulses and high quality single crystals. The effort devoted in the realization of materials with a high degree of orientation and purity were crucial to gain a better control of the fundamental interactions that determine the occurrence of different quantum correlated phases.

The properties of the investigated systems are typically carried out by advanced techniques based on the interaction of radiation with matter, such as linear and non-linear optical spectroscopy, tunnel and atomic force microscopy, electron diffraction and photoemission. Concerning the thin films and multilayers artificial systems, real-time diagnostic based on optical techniques are performed to get an atomic level control of the deposition process. This investigation is complemented by experiments based on high and low temperature and applied magnetic field of magnetization, ac susceptibility and dc magnetoresistance, current-voltage characteristic, etc.



Schematic representation of the coupling between spin, charge and orbital degrees of freedom.

Theoretical modeling based on ab-initio and many-body methodologies with analytical and numerical techniques are employed to face the quantum complexity of systems with strong electron correlation. The main effort is devoted to the determination of the structural, magnetic, electronic and magneto-electric properties. The synergy between the computational and experimental research activities is much relevant as it allows to get an accurate description of the properties in bulk materials as well as in thin films, surfaces and interfaces of oxides based on transition metals, this allows a deep insight into the mechanisms that mark the behavior of multifunctional materials, such as multiferroics, correlated spin-orbital-lattice systems at large, etc.

Research Lines

4. Functional materials and novel devices for electronics and energy applications

Activity leader	**Emilio Bellingeri** (Emilio.Bellingeri@spin.cnr.it)
Researchers	A. Ambrosio, C. Aruta, M. Barra, F. Bisio, R. Buzio, V. Foglietti A.Gerbi (50%), A. Kavokine, R. Moroni, P. Orgiani, I. Pallecchi, L. Pellegrino, S. Lettieri, M. Salluzzo.
Associate Researchers	G. Ambrosone, G. Balestrino, F. Bloisi, L. Braicovich, R. di Capua, A. Cassinese, D. Di Castro, G. Ghiringhelli ,G. Costa, M. Ferretti, P. Maddalena, L. Maritato, D. Marré, S. Siri, A. Tebano, R. Vaglio, L. Vicari.

The research on transition metal compounds and organic materials whose properties are appealing for applications in electronics and energy are the main objectives of this research line. The activity can be resumed in four main tasks:

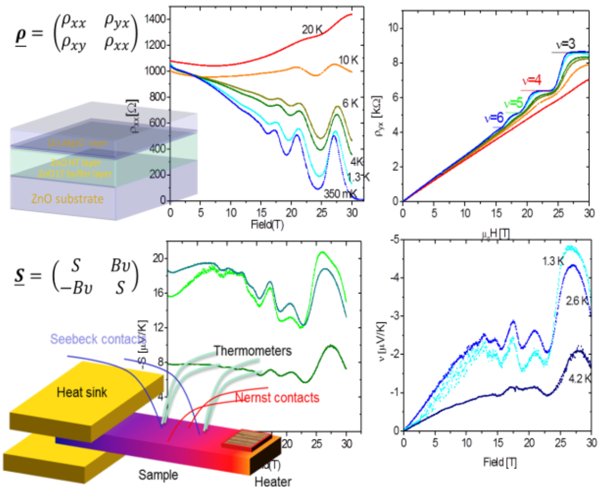
1) Preparation and studies of thin film of transition metals compounds (oxides , chalcogenides , ..) and of organic or hybrid compounds for applications in the fields of electronics , spintronics and energetics.

2) Study of interface phenomena in heterostructures of functional materials .

3) Innovative devices for applications in electronics, optoelectronics, spintronics, sensors and energy

4) Realization and study of nanostructured materials with properties artificially controllable by optimizing the morphology at the nanoscale.

In particular, a large effort is devoted to the investigation of: interfacial properties both in transition metal oxide heterostructures ($SrTiO_3$-based and ZnO-based heterostructures) and in organic multilayers; investigation of ferromagnetic and ferroelectric properties of multiferroic films; study of electronic and magneto-electronic properties of manganite and cuprate thin films and heterostructures. Charge transport and trapping phenomena in organic semiconductors and interfacial electronic phenomena in organic-organic and organic-inorganic heterostructures are studied in the framework of organic electronics.



First observation of quantum oscillation in the thermoelectric properties of 2DEG in ZnO/(Zn,Mg)O high mobility heterostructure

Studies on materials at the nanoscale are also addressed to the development and characterization of magnetic nanoparticles and realization and Investigation of mechanical and electrical memory effects on oxide-based MEMS.

About energy related materials, engineering of materials and or heterostructures with high proton/ion conductivity for application in micro-Solid Oxide Fuel Cells are studied, as well as plasmonic resonances of transition metal nanoparticles for photovoltaic cells absorption enhancement. For termopower application the role of quantum confinement in enhancing thermoelectric properties in oxides materials is studied.

Research Lines

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

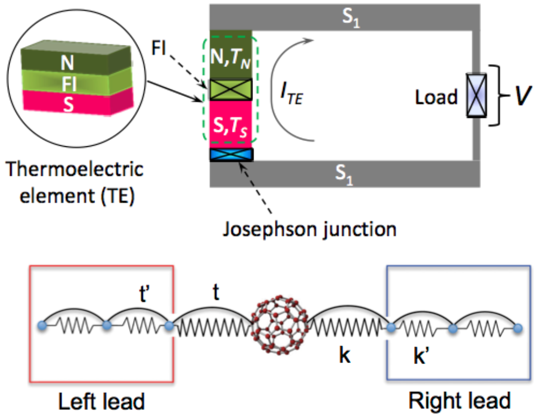
Activity leader	**Giovanni Cantele** (giovanni.cantele@spin.cnr.it)
Researchers	A. Braggio, A. Fierro, P. Solinas.
Associate Researchers	V. Cataudella, R. Citro, A. Coniglio, A. De Candia, G. De Filippis, M. Nicodemi, D. Ninno, C.A. Perroni, M. Sassetti.

This research line has been focused on advanced properties of complex materials and devices with new functionalities, highlighting possible applications, such as (nano)electronics, thermoelectricity and energy conversion, (nano)electromechanics. The theoretical methods encompass first-principles calculations, effective model Hamiltonians for the study of electron-phonon effects and quantum transport in innovative devices, statistical mechanics.

-Ultrafast optical response in highly correlated materials. Models based on the Hubbard-Holstein Hamiltonian show that the cooperative photoexcitation of the electronic and other (bosonic) degrees of freedom in a charge-transfer insulator such as $La_2CuO_{4+\delta}$, drives the formation of itinerant quasi particles, that in turn lead to an effective renormalization of the charge-transfer gap. The predictions match experimental outcomes on this class of materials.

Electron-vibration effects on the thermoelectric efficiency of molecular junctions. The search of new efficient materials for energy conversion has encompassed the possibility of controlling material properties by reducing their dimensions, eventually reaching the molecular limit. Appropriate models have been able to point out that the junction thermoelectric efficiency is substantially reduced by the electron-vibration coupling.

-Thermal and transport effects in low-dimensional materials and topological insulators. Several theoretical approaches have been employed to explain the electron transport in hybrid nanosystems and junctions, as well as in topological materials under external voltage and time-dependent potentials. Accurate analyses have shown the possibility of heat transport, storage and manipulation in quantum systems.



Schematic view of thermoelectric devices based on (top panel) a normal metal-ferromagnetic insulator-superconductor junction and (bottom panel) a molecular junction.

-Electronic properties of complex interfaces. Using first principles approaches the microscopic properties of complex semiconductor-semiconductor and metal-semiconductor interfaces have been unravelled. In particular, the role of stoichiometry, as a new degree of freedom for tuning interface barriers, has been highlighted.

-Statistical mechanics of complex systems. Molecular dynamics simulations have revealed the mechanisms of sol-gel transitions in polymeric suspensions as well as is systems of interest for biomedical applications.

Equipment

Main experimental facilities

Genova

The Research Unit of Genova has a large amount of scientific equipment allowing preparation of different materials in bulk, wire, tape and thin film form, as well as morphological, structural magnetic and transport properties characterization. The UOS own also a Helium liquefier allowing L-HE production of about 15 liters per hour and a setup for He gas recovery and storage.
Main equipments in SPIN-Genova Laboratories are:

Bulk and (nano) powders preparation

Different chemical laboratories equipped for synthesis of different materials by solid state reactions and chemical characterization.

Superconducting Wires and tapes

Rollling and Drawing machines allowing the realization of tapes and wires on kilometer length scale using the powder in tube technique. Various furnaces in different controlled atmosphere

Thin Film Deposition

Two excimer lasers and one Nd:YAG laser, two PLD systems with multitarget carousel and RHEED tools for in situ monitoring of the growth. One mixed MBE/PLD system, several effusive cells for transition metal deposition. The lab own also an ink-jet printer for low cost material deposition

Device fabrication

Clean room equipped with optical lithography facilities, DC sputtering system, AFM nanolithography system, supercritical drier system.

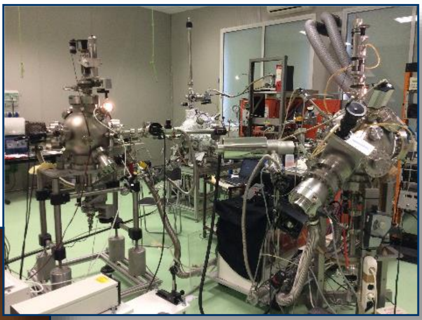
Scanning Probe Microscopy

Atomic Force Microscope and Low Temperature Scanning Tunnel Microscope allowing investigation of morphological and functional properties of thin films and devices.

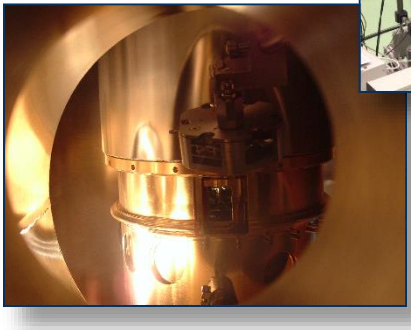
Optical Spectroscopy and transport and magnetic properties measurements

Variable temperature MOKE system, Spectroscopic ellipsometry, 2 Squid systems for magnetic characterization and a Physical Properties Measurement System by Quantum Design, several cryostats for electrical, thermoelectrical and thermal transport properties measurements.

Thin film deposition laboratory



Deformation Laboratory



Low Temperature Scanning Tunnel Microscope

Main experimental facilities

Napoli

The UOS-Napoli has a considerable set of scientific equipment covering the following areas: advanced thin films deposition, micro- and nano-patterning, structural/morphological and electronic transport characterization down to ultra-low temperatures in the presence of high magnetic fields or external radiation, advanced optical characterization and spectroscopy in the wavelength range 200 - 1500 nm also time resolved, low noise electronic characterization of devices, sensors and detectors, high/performance calculus. Part of the equipment is located in the C.N.R. in Pozzuoli CNR Area 3, while some equipment is part of a larger pool belonging to the Department of Physics of the University *Federico II* and is located in shared laboratories. Recently advanced cryogenic equipments have been set up in collaboration with the Seconda Università di Napoli (SUN), and located in the laboratories of CNR SPIN Napoli.

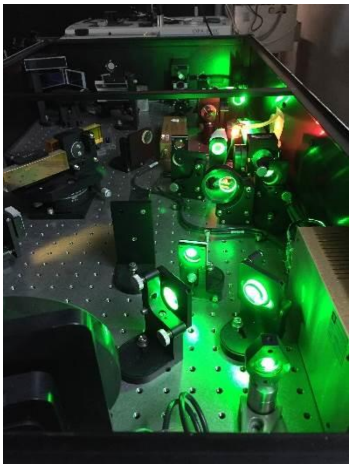
Some relevant equipments are:

MODA system: Modular facility for oxide deposition and in-situ analysis of epitaxial thin films;

Configurable dilution refrigerator TRITON 400 operating at temperatures below 10 mK combined with low noise signal lines and a rapid sample exchange mechanism;

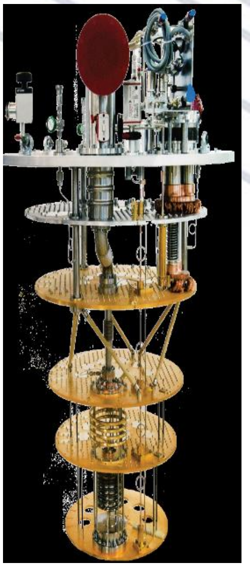
Quanta-600 FEI Scanning Electron Microscopy (SEM) with field emission (FEG) combined with a Raith Electron Beam nano-Litography (EBL) system;

Ultrafast optical pump-probe system based on a Ti:Sapphire laser amplifier delivering sub-100-fs laser pulses at a repetition rate of 1 kHz and with a working spectral bandwidth ranging between 500 and 1500 nm.



Ultrafast Pump-Probe <100fs spectroscopy

SEM-EBL nanolitography



<10mK cryogen free cryostat for quantum measurements

M.O.D.A.

Main experimental facilities

Salerno

The UOS Salerno has a large amount of scientific equipment covering the following areas: advanced material fabrication in bulk and thin film form, structural and transport characterization, micro and nano patterning, advanced calculus. Some equipment is part of a larger pool belonging to the University host Departments (Physics and Engineering) and is located in shared laboratories.

Some relevant equipments are:

Electron microscopy facility: one tungsten/LaB6 SEM (LEO EVO 50) with a secondary electron and 4-quadrant back-scatter electron detectors, EDX, WDX and EBSD analysis; one FESEM (Σigma by ZEISS) with InLens, SE2 and BSE detectors, and nano-manipulators.

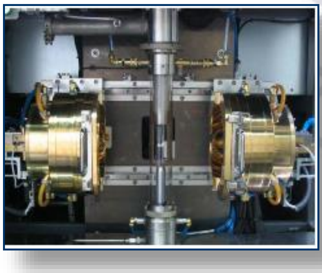
Bulk: Infrared image furnace for floating zone crystal growth.

Thin Films: molecular beam epitaxy system equipped with different effusive cells and e-gun for RHEED analysis , PLD system (shared with CNR-IOM Institute at ELETTRA-Trieste), different sputtering systems.

Transport:

Cryomagnet systems for thermoeletric effects as well as magnetic and transport properties in magnetic field up to 16 T and down to the lowest temperature of 50 mK.

FESEM (Sigma by ZEISS)



Infrared image furnace

Molecular beam epitaxy deposition system

Cryogen Free Magnet Variable Temperature Insert

Main experimental facilities

L'Aquila

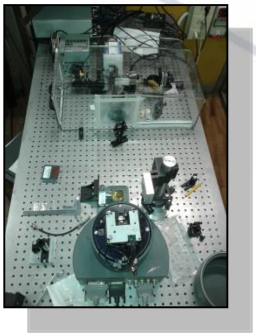
The research Unit in L'Aquila is mostly composed by theorists. The computational resources used by the SPIN-Aq researchers are predominantly located at Supercomputing centers all around Europe (Cineca, Barcelona Supercomputing Centers, etc). Therefore, no specific equipment is located in L'Aquila.

Roma

At University of Tor Vergata, SPIN laboratory is hosted in the Engineering Department. The relevant equipments are devoted to the thin films growth (mainly heterostructures and superlattices based on oxide perovskite systems) by pulsed laser deposition (PLD) and their characterization by structural and transport measurements. Relevant equipments are:
three PLD chambers, a 3 circle diffractometer allowing reciprocal space mapping and two cryocoolers able to go down to 15 K are available, one of the two cryocoolers also equipped with an electromagnet able to produce a magnetic field up to 1 T along an arbitrary crystallographic direction. A recent upgrade of an electrical measurements workstation allows four point transport and I-V measurements up to 800°C in oven with quartz tube with controlled gas environment.

Pulsed laser Deposition system with in-situ RHEED Diagnostics equipped with a multitarget system for oxygen deposition atmosphere enriched with 12% of ozone.

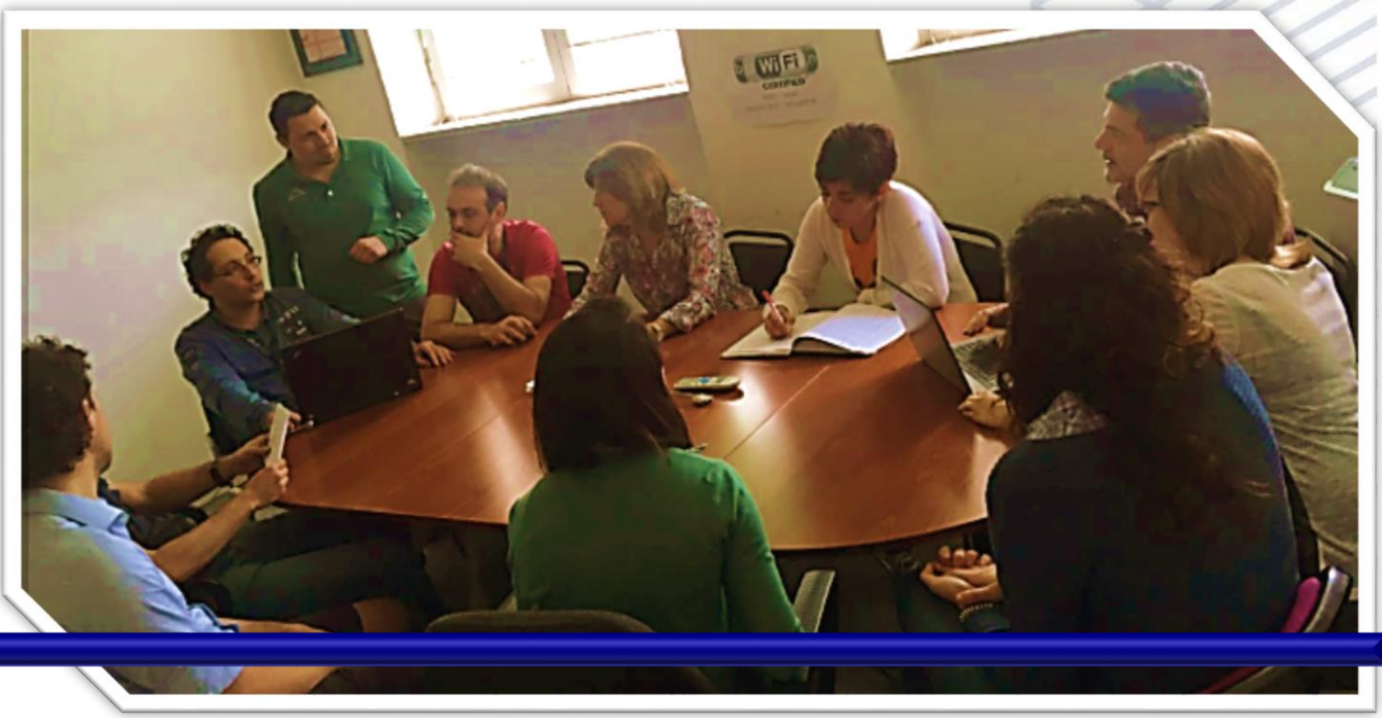
At University of La Sapienza, SPIN is hosted in the Physics Department. The scientific equipments are covering the investigation of solid-state materials, nanostructures and biological systems by optical spectroscopy from the very far-infrared range through the mid-infrared up to the ultraviolet. Relevant equipments are: broadband Fourier-transform spectroscopy is the main experimental tool, but grating spectrometers, infrared microscopes, quantum cascade lasers and terahertz amplifier-multiplier chains are also available.



AFM coupled to a Quantum Cascade Laser for infrared microscopy below the diffraction limit.

Interferometer BRUKER 66V equipped with a cryogenic apparatus for transmittance and reflectivity measurements down to 5 K and with an infrared microscope Hyperion-II

Projects and Grants



Projects & Grants

SPIN Active Projects – European and International funds

Source of funding	Title of the project	Coordinator of the project	SPIN leader	SPIN UOS involved	Grant (€)
EU H2020	UFOX - Unveiling in functional hybrides oxides	SPIN Salerno	Mario Cuoco	Salerno	180.277
EU H2020	FLARECAST - Flare likelihood and Region eruption forecasting	Academy of Athens	Anna Maria Massone	Genova	135.500
EU H2020	To BE - Towards an Oxide-Based Electronics	SPIN Napoli	Fabio Miletto	Napoli	330.000
EU fp7	SUPER-IRON - Exploring the potential of Iron-based Superconductors	SPIN Genova	Marina Putti	Genova	493.912
EU fp7	IRON-SEA - Establishing the basic science and technology for Iron-based superconducting electronics applications	IFW Dresden	Sergio Pagano	Salerno	287.110
EU fp7	CNTQC - Curved nanomembranes for topological quantum computation	IFW Dresden	Paola Gentile	Salerno	308.220
EU fp7	COHEAT - Coherent heat and energy transport in quantum system -	SPIN Genova	Alessandro Braggio Paolo Solinas	Genova	100.000
CNR Bilateral Projetc	Scientific cooperation CNR - BAS (Bulgaria)	-	Salvatore Amoruso	Napoli	12.000
CNR Bilateral Project	Scientific cooperation CNR - RA (Romania)	-	Alessandro Stroppa	L'Aquila	11.400
CNR Bilateral Project	Scientific cooperation CNR - CNRS (Francia)	-	Procolo Lucignano	Napoli	15.000
CNR Bilateral Project	Scientific cooperation CNR - BAS (Bulgaria)	-	Massimiliano Polichetti	Salerno	12.000
MAE Italy/Israel	IMESS - Improved MgB2 wires for energy storage in liquid hydrogen cooled superconducting coils	SPIN Genova	Maurizio Vignolo	Genova	66.000
MAE Italy/Japan	Joint research projects within the executive programme of cooperation in the field of science and technology	-	Luca Pellegrino	Genova	-
Other	Joint Laboratory CNR - NTU Singapore on Amorphous materials for energy harvesting applications	CNR – NTU	Annalisa Fierro	Napoli	50.000

Projects & Grants

SPIN Active Projects – National funds

Source of funding	Title of the project	Coordinator of the project	SPIN leader	SPIN UOS involved	Grant (€)
MUR PRIN	Oxides interfaces: new emergent properties, multifunctionality and devices for electronics and energy	Università di Napoli	Silvia Picozzi	L'Aquila Salerno Napoli	197.277
MIUR FIRB Accordi di progr.	Nanostructured oxides: multifunctionality and application	Università Milano Bicocca	Ruggero Vaglio Daniele Marrè	Genova Napoli Salerno	220.360
MIUR FIRB Accordi di progr.	Molecular nanomagnets on metal and magnetic surfaces for applications in molecular spintronics	Università di Firenze	Silvia Picozzi	L'Aquila	242.611
MIUR FIRB Futuro in Ricerca	Unjamming transition in granular and seismic precursor materials: theory, experiments and simulations	SPIN Napoli	Massimo Pica Ciamarra	Napoli	209.990
MIUR FIRB Futuro in Ricerca	Hybrid superconductor-semiconductor nanostructures: nanoelectric applications, topological properties, correlation and disorder	Università di Napoli	Alessandro Braggio Procolo Lucignano	Genova Napoli	414.623
MIUR FIRB Futuro in Ricerca	COCA - Coherent caloritronics in mesoscopic superconducting circuits	CNR - NANO	Paolo Solinas	Genova	251.292
MIUR Premiali Grant	Integrated and eco-sustainable technologies for production, storage and use of energy	CNR	Valeria Braccini Gaia Grimaldi	Genova Salerno	188.833
MIUR Premiali Grant	Magnetic and superconducting materials and devices for sensing and ICT	CNR	Giampiero Pepe	Napoli	47.000
MIUR Premiali Grant	Beyond the classic limits of measurement	INRIM	Giampiero Pepe	Napoli	25.000
MIUR Premiali Grant	EOS - Organic electronics for research innovative instrumentation	INFN	Antonio Cassinese Renato Buzio Andrea Gerbi	Napoli Genova	225.000
PON	New nanotechnological strategies for the development of drugs and diagnostic tools directed towards surrounding cancer cells	Biogem Scarl	Giampiero Pepe	Napoli	102.000

Projects & Grants

SPIN Active Projects – Regional and local funds

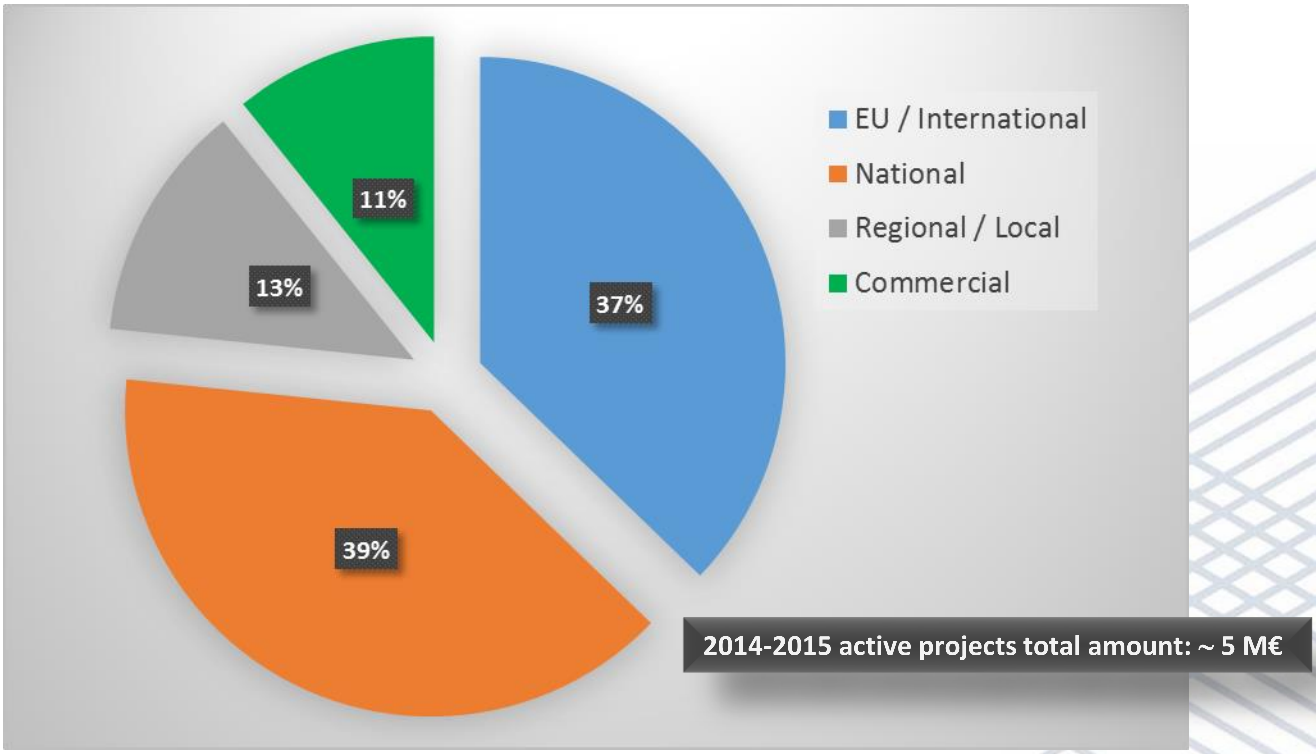
Source of funding	Title of the project	Coordinator of the project	SPIN leader	SPIN UOS involved	Grant (€)
Fond. CARIPLO	MAGISTER - Magnetic information storage in antiferromagnet spintornic devices	Politecnico di Milano	Alessandro Stroppa	L'Aquila	77.000
Regione Campania L.5	Electronic reconstruction at STO / LAO interface of interest for microelectronics	SPIN Napoli	Marco Salluzzo	Napoli	14.000
Regione Campania L.5	The role of interfaces in magnetic oxides with strong electron correlation: manganite heterostructures	SPIN Napoli	Antonio Carmine Perroni	Napoli	14.000
Regione Campania L.5	Superconductivity in Nano-systems: macroscopic quantum effects in nanostructured superconducting devices	SPIN Salerno	Pasquale Orgiani	Salerno	8.000
Regione Campania L.5	Deposition and characterization of n-type organic films for electronic applications	SPIN Roma	Carmela Aruta	Roma	8.000
Regione Campania L.5	Optical second harmonic generation for the study of conductive interfaces between insulating oxides	SPIN Napoli	Lorenzo Marrucci	Napoli	15.000
Regione Campania L.5	Interface states and competition between ordered phases in eutectic oxides with perovskite structure	SPIN Salerno	Sandro Pace	Salerno	15.000
Regione Campania PO FESR	SIMAC - Innovative system for continuous environmental monitoring	Filippetti Spa	Xuan Wang	Napoli	60.000
Regione Campania PO FESR	Production of laser systems in the violet and the near-IR spectral region for the printing industry using soliton waveguides in photonic crystals	Metoda Spa	Alberto Porzio	Napoli	27.840
Regione Campania	New/upgraded equipment and infrastructures		Giampiero Pepe Antonio Vecchione	Napoli Salerno	273.000
Internal Funds	EUCAS - Strengthening of applied superconductivity activities	SPIN Genova	Maurizio Vignolo	Genova	168.616

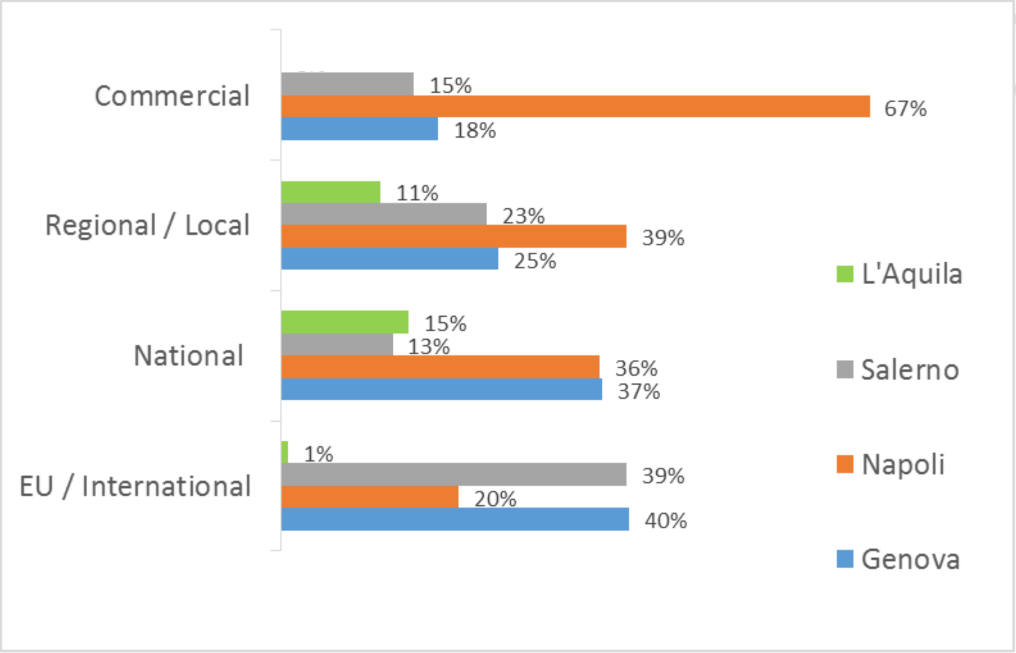
Projects & Grants

SPIN Active Projects – Commercial funds

Typology of Activity	SPIN leader	SPIN UOS involved	Grant (€)
Congress Sponsorships	Filippo Giubileo	Salerno	22.500
Testing and laboratory measurements	Rosalba Fittipaldi Cristina Bernini, Andrea Malagoli	Salerno Genova	94.000
Research Contract with CNISM	Xuan Wang	Napoli	140.000
Research Contract with ENEA - SMARTAGS	Ruggero Vaglio	Napoli	248.050
Research Contract with ENEA	Umberto Gambardella	Salerno	10.550
Research Contract with CIEMAT	Umberto Gambardella	Salerno	10.000
Research Contract with ALA Srl	Anna Maria Massone	Genova	40.000
Research Contract with IMC Srl	Sergio Pagano	Salerno	14.640

Projects & Grants



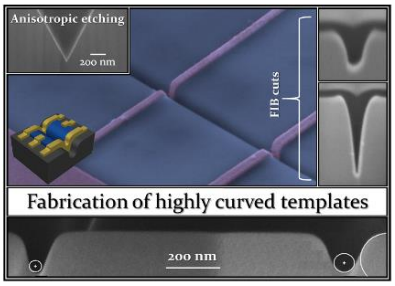


Projects

Main Projects

Title	Curved nanomebranes for topological Quantum Computation
Acronym	**CNTQC**
Source of funding	EC funds
Specific funding program	FP7 - ICT-2013 - C
Project Coordinator	Leibniz Institute for Solid State and Materials Research Dresden
SPIN Coordinator	Paola Gentile, SPIN SA
Other partners	University of Groningen

Project objectives



SEM images of a 3D groove-like architecture with large curvature (from the project website http://www.nano2qc.eu)

Majorana fermions - particles that are their own antiparticles - are at the heart of topological quantum computation.
Although the solid-state-devices so far proposed to detect such states consist of rather "conventional" building blocks, the actual experimental observation of Majorana modes is still the biggest challenge in the field. The experimental difficulty stems from a delicate fine-tuning of intrinsic materials properties and external quantities.
The aim of the CNTQC project is to overcome these hurdles by designing novel three-dimensional nanoarchitectures in which the curved geometry can act as an effective quantum tuning knob to regulate on demand the required physical ingredients for the generation of bound Majorana fermions. The feasibility of this concept is rooted in the theoretical observation that by inducing curvature in a nanomembrane, a tunable spin-orbit coupling for the electrons is generated.
The main objectives of the project are:

• To fabricate curved nanomembranes of conventional semiconductors, metallic and superconducting materials with curvature radii down to tens of nanometers.

• To establish the fundamental effect of a curved space on spin-orbit and electron-phonon interactions in different geometries both in conventional semiconductors and superconducting materials.

• To measure the influence of curvature on the spin-orbit interaction with smoking-gun spin transport experiments, in order to design novel curved three-dimensional spintronic nanodevices.

• To investigate the effective “topological” superconducting regime in strongly curved s-wave superconductive nanomembranes and to detect experimentally the curvature-induced generation of Majorana bound states.

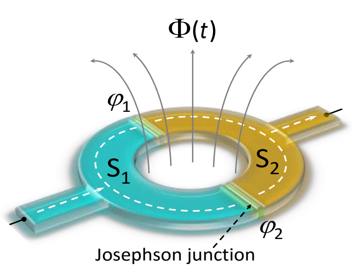
Projects

Main Projects

Title	Coherent caloritronics in mesoscopic superconducting circuits
Acronym	**CoCa**
Source of funding	MIUR National funds
Specific funding program	FIRB Futuro in Ricerca 2013
Project Coordinator	CNR-NANO
SPIN Coordinator	Paolo Solinas, SPIN GE
Other partners	CNR-NANO, Pisa

Project objectives

The project aims at strengthening our understanding of phase-coherent heat transport in mesoscopic superconducting circuits and at developing new strategies for exploiting it in new coherent caloritronic devices. In analogy to electronics, caloritronics encompasses the techniques for controlling, measuring, distributing, storing and converting heat ("calor" in Latin). Caloritronic devices allow to manipulate the heat transport by controlling the superconducting phase though the external magnetic flux.
The project has a twofold approach. The CNR-SPIN unit will develop the theoretical framework necessary to the design of innovative and more efficient caloritronic devices. These devices will then be implemented and experimentally tested in the facilities of the CNR-NANO unit. Since the CoCa project started, the collaboration between CNR-SPIN and CNR-NANO has constantly being strengthened.
On the theoretical side, the most interesting results achieved so far have been the proposal for a Josephson Radiation Comb, a Microwave Josephson Refrigerator and thermal transistor and memory. The first allows us to to generate sharp and accurate voltage pulses with metrological applications. The second one with time dependent magnetic flux allows us to actively transport heat between two superconductors and cool one of them. The high cooling performances, the scalability and simplicity in the control of the device open the way to its use for many cooling applications.
The thermal transistor would allow us to store and manipulate information in terms of bits of heat.
The main experimental achievements have been the implementation of a double-loop SQUID heat interferometer and the realization of a thermal diode able to rectify the heat transport between superconductors.



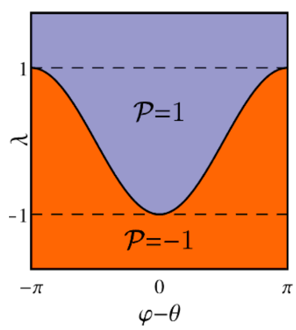
A Superconducting Quantum Interference Device (SQUID) pierced by a time-dependent magnetic flux. The device can be used a refrigerator to cool one of the superconducting electrode.

Projects

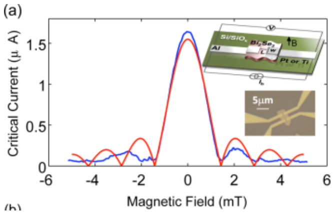
Main Projects

Title	Hybrid superconductor-semiconductor nanostructures: nanoelectronic applications, topological properties, correlation and disorder
Acronym	**HybridNanoDev**
Source of funding	MIUR National funds
Specific funding program	FIRB Futuro in Ricerca 2012
Project Coordinator	University of Naples
SPIN Coordinator	Alessandro Braggio SPIN GE- Procolo Lucignano, SPIN NA
Other partners	- -

Project objectives



Topological phase diagram of hybrid nanoSQUID.



Magnetic pattern of a Superconductor-Topological Insulator-Superconductor junction

The goal of this project is to design and study device prototypes based on a nano-hybrid quantum architecture encompassing superconductors and semiconductors. Nanotechnologies provide a unique way to link the superconducting and semiconducting materials, combining the complementary properties and realizing new functionalities. The study of hybrid nano devices has a strong impact both on fundamental and on applied physics, responding to one of the most recent issues in condensed matter physics: the ability to measure and manipulate complex particles/electronic excitations.
Superconductor-semiconductor nanostructures are the key ingredient towards the superconducting transistor and they are very promising for a variety of applications ranging from low-power spintronics to ultra-sensitive detectors in the THz regime and quantum information. The project aims at 1) understanding how superconducting coherence propagates in one-dimensional barriers and across 'smart' interfaces composed by unconventional superconductors and nanostructures; 2) defining theoretically and experimentally signatures of Majorana fermions and of topological protected states, both substantially driven by correlations, out-of-equilibrium conditions and disorder.

In these years, we have studied transport of charge, spin and energy in structures based on conventional and unconventional superconductors, with barriers composed of semiconducting nanowires (InAs, InSb, InP), ferromagnetic insulators, normal metals as well as flakes of graphene or topological insulators ($Bi2Te_3$ and Sb_2Te_3). Also, the coupling with the two-dimensional electron gas at the $LaAlO_3/SrTiO_3$ interface has been approached and characterized.

Projects

Main Projects

Title	Flare likelihood and Region eruption forecasting
Acronym	**FLARECAST**
Source of funding	EC funds
Specific funding program	HORIZON 2020
Project Coordinator	Academy of Athens
SPIN Coordinator	Anna Maria Massone, SPIN GE
Other partners	Academy of Athens, Trinity College Dublin, Università degli Studi di Genova, Centre National de la Recherche Scientifique, Université Paris-Sud, Fachhochschule Nordwestschweiz, MET Office

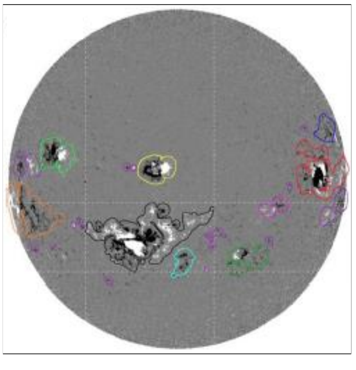
Project objectives

Space weather can have detrimental, and in some cases catastrophic, effects upon a multitude of technologies on which we depend as part of our daily lives. Adverse space weather is now known to result from solar eruption released from the turbulent and highly complex magnetic fields of active regions. Understanding how active region magnetic fields evolve and produce these events is therefore of fundamental importance to develop accurate and reliable space-weather monitoring and forecasting capabilities.

This project proposes to develop an advanced flare prediction system (FLARECAST) that is based on automatically extracted physical properties of active regions coupled with state-of-the-art flare prediction methods.

Active region properties, such as area, magnetic flux, shear, magnetic complexity, helicity and proxies for magnetic energy, will be extracted from solar magnetogram and white-light images in near-realtime using advanced image-processing techniques. Once active region properties have been extracted, they will be correlated with solar activity and used to optimize prediction algorithms based on statistical, unsupervised clustering and supervised learning methods. At the end of the project, this will enable the consortium to launch a near-realtime flare forecasting service, the first of its kind in the world.

In this framework, the CNR partner is leading Work Package 3 (“Prediction Algorithms”) and is addressing the computational task of this project by realizing a transfer-of-knowledge process of numerical algorithms formulated in the framework of machine-learning disciplines to the problem of flare prediction. Among them particular focus is given to unsupervised clustering techniques recently used for the automatic recognition and classification of Fe, Se, Te atomic species in high resolution Scanning Tunnelling Microscopy images of crystal lattice surfaces.



Active region detections. Each separately coloured contour has more than 25 magnetic properties calculated from an input pair of line-of-sight magnetograms recorded by the NASA SDO/HMI satellite. FLARECAST is using these active region properties to give accurate, up-to-date flare forecasts.

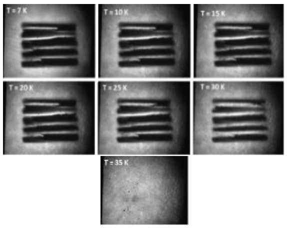
Projects

Main Projects

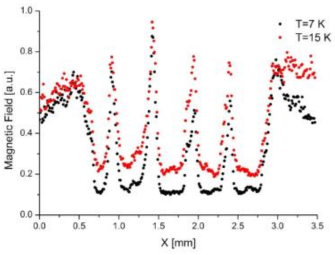
Title	Improved MgB_2 wires for energy storage in liquid hydrogen cooled superconducting coils
Acronym	**IMESS**
Source of funding	MAECI National funds
Specific funding program	Italian-Israel joint research projects
Project Coordinator	SPIN GE
SPIN Coordinator	Maurizio Vignolo, SPIN GE
Other partners	Institute of Superconductivity, Laboratory for Magnetic Measurements, Department of Physics, Bar-Ilan University; Rafael Advanced Defense Systems Ltd; Columbus Superconductors s.p.a.

Project objectives

The project is expected to lay down the foundations for the development of LH2 cooled SMES. Such SMES is expected to operate as a double-function energy storage solution for allowing renewable energy generation sources to connect to existing grids. The SMES serves for levelling the power added to the grid by absorbing and storing excess energy in an MgB_2 superconducting coil and by providing the stored energy to the grid when required. This levelling operation of the SMES is designed for a short time periods of seconds, time necessary to start and initiate the conversion of LH2 combustible into electric energy for maintaining normal, sustainable and reliable grid operation. This conversion process will be applied thanks to hydrogen fuel-cell or directly from LH_2 combustion. Our intent is not to evaluate the best conversion process but to improve the MgB_2 coil useful for future application. It must be pointed out that the energy density of hydrogen is really high but long times are necessary for the system to reach the maximum efficiency (energy release). Then, during this time the SMES is the best solution to release the required energy in few seconds. This project will provide the specifications of MgB_2 wires required for SMES coils winding. New precursors, wire types, short samples and demonstration coils will be made and will be fully characterized for SMES operation mode. The success of this project will pave the way for large hydrogen cooled SMES projects in Europe and worldwide. Short samples of MgB_2-Ti have been prepared and characterized, in particular a study of wires using DC magnetization loops, static and ultra fast dynamic magneto-optic imaging and preliminary AC losses measurements have been performed.



Magneto-optic images of MgB_2-Ti wire at various T.



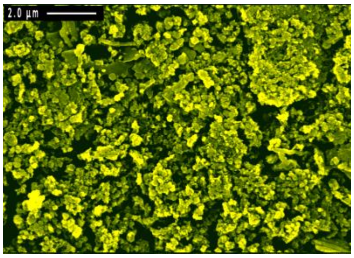
Induction intensity (a.u.) along the white line into the inset.

Projects

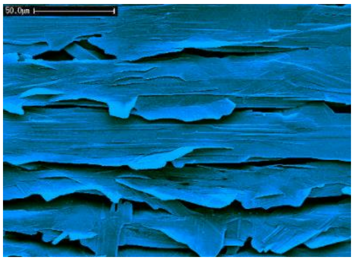
Main Projects

Title	Integrated and eco-sustainable technologies for production, storage and use of energy
Acronym	--
Source of funding	MIUR National funds
Specific funding program	CNR "Premiali" projects
Project Coordinator	CNR
SPIN Coordinator	Valeria Braccini, SPIN GE
Other partners	CNR- DIITET, DSFTM, DSCTM

Project objectives



B nano-sized powders for the fabrication of MgB_2 wires



Dense Bi-2212 filaments within a multifilamentary wire

.

In order for the renewable energy industry to take full advantage of the earth's resources, it is essential that superconductivity solutions such as wind turbine generators, SMES, current limiters and long distance transmission lines be fully developed, demonstrated and deployed into the grid. This requires further development of HTS / MgB_2 wire capabilities. Within this project we work at the development and improvement of the performances of superconducting wires based on MgB_2, Bi-2212 and Fe(Se,Te), and on the improvement of their properties in magnetic field and low temperatures.

Concerning MgB_2, the focus is on the fabrication of boron nano-powders useful for nanosized MgB_2 synthesis and on the progress towards the large scale production. A pilot scale system for nebulization of precursors has been assembled, as well as a reaction chamber for the reaction of > 20 kg of reagents and a purification system for large amounts of product. The preliminary results show that we can reach the production of about 1 kg of boron.

We developed an innovative technique for the fabrication of Bi-2212 multifilamentary round wires which is consisting of a proper alternation of drawing and groove-rolling steps, with the aim of obtaining denser conductors with high current densities homogeneous over long lengths.

Given the very promising results in terms of Jc obtained on the deposition of Fe-based thin films on technical substrates such as IBAD or RABiTS, and based on the fact that at the relatively low processing temperatures a very limited oxidation of the metal templates is foreseen, we are developing metallic substrates much simpler than those used for the Coated Conductors. Cold deformation procedures suitably alternated with high temperature heat treatments are under study to obtain oriented Fe/Ni alloys for the deposition of Fe-based thin films.

Projects

Main Projects

Title	OXide Interfaces: emerging new properties, multifunctionality, and DEvices for electronics and energy
Acronym	**OXIDE**
Source of funding	MIUR National funds
Specific funding program	PRIN
Project Coordinator	University of Naples
SPIN Coordinator	Silvia Picozzi, SPIN AQ
Other partners	Consiglio Nazionale delle Ricerche, Univ. Napoli, Univ. Cagliari, Univ. Roma “La Sapienza”, Univ. Roma “Tor Vergata”, Univ. Genova, Univ. Salerno

Project objectives

The OXIDE project aimed at tackling different aspects of the physics at oxide-based interfaces, with objectives ranging from clarifying open fundamental issues to exploring some of the more promising features in view of technological applications. In particular, the project addressed three main interface phenomena: i) 2D electronic gases, with respect to formation mechanisms, electrical transport properties, applications for electronics and for thermoelectrics; ii) interface magnetic properties and spin-transport, with respect to fundamental mechanisms and applications within spintronics and low-power electronics; iii) interface ionic conduction, with respect to mechanisms and properties, of possible interest for fuel cells. A lot of attention was devoted to $LaAlO_3/SrTiO_3$ (LAO/STO) heterostructures; by means of transport measurements and of techniques based on syncrotron radiation (such as X-ray Absorption Spectroscopy (XAS), Angle Resolved Photoemission Spectroscopy, etc), it was shown that it is possible to create a 2D electron gas – spinpolarized and superconducting – whose properties can be modulated via an electric field. This was made possible thanks to the introduction of few layers of $EuTiO_3$ at the LAO/STO interface and to the related exchange interaction between Eu 4f and Ti 3d electrons. Moreover, the interface between prototypical ferromagnets and ferroelectrics, such as $Fe/BaTiO_3$, was studied via X-ray magnetic circular dichroism and first-principles calculations, highlighting a new interface magnetoelectric coupling based on the presence of an oxidized iron layer whose magnetization can be controlled by the $BaTiO_3$ polarization. Electrical, thermal and thermoelectric transport properties were investigated in LAO/STO as a function of temperature and upon field-effect, showing, for the first time, the existence of in-gap trap states.

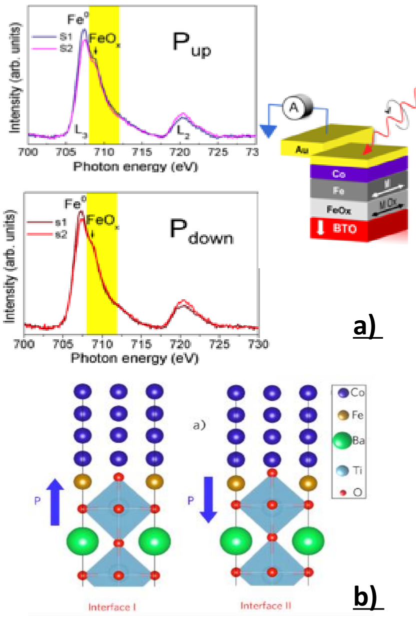


Figure: a) XAS Fe–L2,3 spectra on Au/Co/Fe/BaTiO capacitors;
b) $Fe/BaTiO_3$ unit cells with different polarization direction.

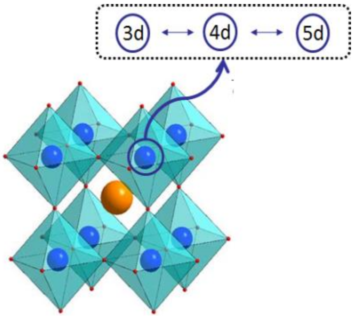
Projects

Main Projects

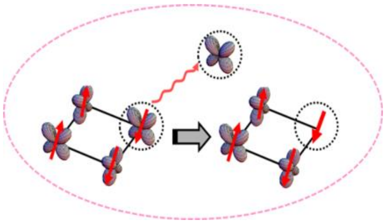
Title	Unveiling complexity in functional hybrides oxides
Acronym	**UFOX**
Source of funding	EC funds
Specific funding program	HORIZON 2020, Marie Curie EF
Project Coordinator	SPIN SA
SPIN Coordinator	Mario Cuoco, SPIN SA

Project objectives

The purpose of this research project is to get a deeper understanding of the mechanisms and the fundamental interactions that control the formation of electronic ordered phases and the competition between different phenomena in 4d and 3d-4d hybrid transition metal oxides (TMO). Investigation of 4d materials, proposed here, provides new challenges and opportunities – they share some common features with 3d systems which stem from electron correlations, but have in addition subtle sensitivity of the electronic states to the lattice structure, effective dimensionality and, most importantly, to relativistic effects due to stronger spin-orbit coupling. The aim of the project is to exploit the class of 4d perovskite ruthenium oxides together with different 4d-3d families of doped materials as a platform for exploring in a controlled way the interplay between correlations, dimensionality and spin-orbit effects when moving from 4d to 3d oxides. Doping a 4d host with 3d impurities might be extremely effective in tuning valence, spin and orbital characteristics and, in turn, the macroscopic physical properties of bulk and layered systems.
An ultimate goal is to exploit the variety of physical phenomena inherited in these classes of materials to design interfaces and heterostructures which can show properties at the nanometer scale that are qualitatively different from their single building blocks, thus allowing to engineer novel functionalities. Such a rich scenario can open the route to the fabrication and design of systems where novel and multiple functionalities are coherently nano-integrated.



Perovskyte structure and schematic of the transition metal substitution

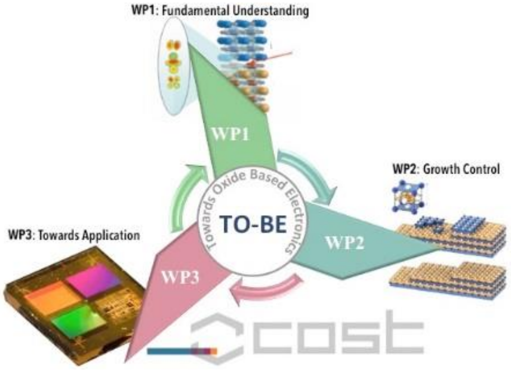

Sketch of the orbital doping process

Projects

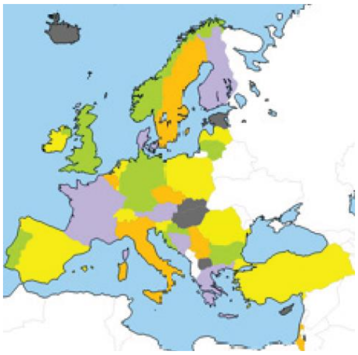
Main Projects

Title	Towards Oxide-Based Electronics
Acronym	**TO-BE**
Source of funding	EC funds
Specific funding program	Horizon 2020 – Cost Action
Project Coordinator	SPIN NA
SPIN Coordinator	Fabio Miletto Granozio, SPIN NA
Other partners	TO-BE participants are about 300 from 29 different EU countries and over 50 different institutions

Project objectives



Representation of the three Work Groups of the TO-BE COST Action



Countries participating to the TO-BE COST Action

The TO-BE Action aims to network nationally and EU funded researches active on synthesis, analysis, modelling and applications of transition metal oxides within the European Research Area (ERA), allowing to: define targets, strategies and methods; reduce fragmentation; aggregate communities with complementary know-how; attract and train a new generation of researchers; establish a regular know-how transfer with private corporations and other stakeholders; built the future oxide electronics community by fostering the participation of early stage researchers and tackling gender unbalance. The Action aims to strengthen the innovative capacity of EU industry by making qualitatively new enabling technologies accessible for commercial exploitation.
The TO-BE community is today established as the reference EU community for fundamental studies and for epitaxial-thin-film-based applications of transition-metal oxides. Many of the major EU scientists in the field have joined the Action, either directly of through their group members. Some of them are actively involved in the Action management.
29 COST countries, also including Slovakia that is actually on the way to complete the process, have signed so far the memorandum of understanding. Applicants willing to participate to the Action fill a registration form. The great majority of applications are accepted. Registered participants to date are about 300. This number gets updated day by day. Registered participants get included in the mailing list where our events are advertised.

Projects

Main Projects

Title	Organic electronics for research innovative instrumentation
Acronym	**EOS**
Source of funding	MIUR funds
Specific funding program	CNR Premiali Projects
Project Coordinator	INFN
SPIN Coordinator	Antonio Cassinese, SPIN NA
Other partners	CNR- ISM, NANO, IOM, IMEM, ISMN, IMCB/IRC

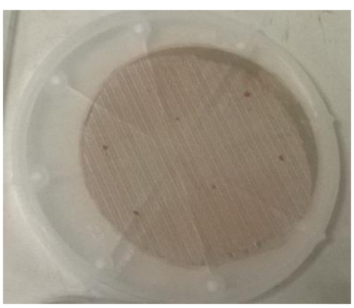
Project objectives

Through the use of conjugated polymers and small molecules, in form of crystals and nanostructured films, organic electronics allows designing sensors and transistors with highly innovative features and remarkable technological interest. Organic devices, indeed, can be fabricated by exploiting cost-effective techniques, involving low-temperature processes and being compatible with non conventional substrates (e.g. plastics, paper, fabric, biocompatible surfaces, etc.). These characteristics make organic conjugated materials particularly appealing for a wide number of companies dealing with the fabrication of low-cost electronic systems, featuring negligible mass and power consumptions and being theoretically capable to provide “smart functionalities” to generic and traditionally-considered passive products (i.e. clothes, packaging, envelopes, furniture, general consumer goods).

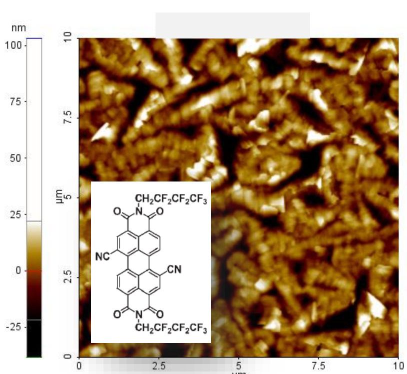
In this framework and relying on strong skill synergies between CNR and INFN (National Institute for Nuclear Physics) researchers, the EOS project is aimed at developing complex organic electronic circuits to equip innovative instrumentation for research in fundamental and applied physics. To this aim, the project is basically focused on the search of new materials and on the optimization of processes for the fabrication of high-performance organic field-effect transistors and related analog and digital integrated circuits. More in detail, specific objectives of the project are:

Fabrication of p and n-type organic filed-effect transistors exhibiting mobility values exceeding 0.5 and 0.1 cm2/V on rigid and flexible substrates, respectively;

Design and testing of organic analog (currents mirrors, cascode amplifiers) and digital circuit blocks (inverters, Nand gates, flip-flop).



Organic field-effect transistors fabricated on a flexible substrate



Morphology of a perylene-diimide film deposited on plastic substrates

The SPIN / NTU Singapore Joint Laboratory: “**Amorphous materials for energy harvesting applications**”

The CNR is promoting Joint Laboratory initiative to foster the scientific interaction with renowned international research institutions.

The first call for joint laboratories, that as was held in 2014, aimed at supporting a research of great relevance for the SPIN Institute, that of energy. The Nanyang Technological University, in Singapore, appeared as an ideal partner in this strategic initiative, due to its strong research record in the field of renewable energy. CNR researcher Dr. Annalisa Fierro therefore decided to propose a joint laboratory focused on the investigation of “New materials for energy harvesting applications”, in conjunction with NTU Prof. Massimo Pica Ciamarra, a former NTU researcher. The Italian National Agency for New Technologies, Energy and Sustainable Development appeared as a strategic partner and was also involved. Both CNR and NTU decided to support the proposed laboratory, and signed a Memorandum Of Understanding to formalize their mutual research interests. The joint laboratory is active since January 2015.


Massimo Pica Ciamarra


Annalisa Fierro

The joint laboratory fosters the interaction between the National Research Council, the Nanyang Technological University, and the Italian National Agency for New Technologies, Energy and Sustainable Development, in the fundamental and applied investigation of new materials for environmental friendly energy harvesting devices, by bringing together researchers with theoretical, experimental and numerical expertise in this field. The focus is on the investigation of new materials for thermoelectricity and photovoltaics. The partners cooperate through mutual visits, and through the support of research fellows investigating topics of common interest, carrying out study of (i) the thermal conductivity of amorphous materials, (ii) the charge transport processes in bulk heterojunctions, (iii) hybrid perovskite materials, (iv) optimization of thin film deposition processes for electronic organic applications.

Mutual visits: there have been mutual visits between CNR and NTU, including those by M. Pica Ciamarra, R. Pastore, F. Chiarella, A. Coniglio, A. Bruno.

Participants: CNR: A. Fierro, C. Aruta, M. Barra, G. Cantele. G. Carotenuto, A. Cassinese, V. Cataudella, A. Coniglio, A. de Candia, F. Miletto, D. Ninno, G. Pepe, C.A. Perroni, M. Salluzzo, F. Chiarella, G. De Luca, A. Sambri, G. De Filippis,
ENEA: E. Terzini, C. Minarini, A. Bruno, P. Delli Veneri.
NTU: M. Pica Ciamarra, C. Soci, R. Singh, A. Cakir, R. Arevalo, E. Png, A. Piscitelli, C. Panagopulos

Participants: Co-authoring in more of 10 publications

Projects

Seed Projects

CNR-SPIN launched a call for “Seed Project” proposals, with the aim of supporting original frontier research projects by young researchers to be carried out within SPIN. The Projects are related to the SPIN activities and mission. The overall available budget was low (of the order of 40 K€) and three projects were supported in the third call here described. The Principal Investigators are young SPIN researchers or University associated researchers with a temporary position.
The review process was carried out by external referees with specific expertise in the topic of each proposal and three projects were selected among 17 proposals. The selection was based solely on the scientific quality of the project, its impact on networking and training and the potential of the PI and research team to make it successful.
The call for seed projects resulted an important tool for the growth of young people and for the recognition of the most promising activities centered on the institute's mission.

Title: Synthesis, experimental and theoretical investigation of Ca-112 a new family of iron based superconductors

Seed Project Coordinator: Federico Caglieris, Genova

Project objectives and results:

The aim of this project was the investigation of the newly discovered 112 family of Iron Based Superconductors (IBS) through transport properties. Resistivity (ρ), magnetoresistivity (MR), Hall effect (R_H), upper critical field (H_{c2}), critical current density (J_C) measurements were performed at the CNR-SPIN Institute of Genova on a micrometric-size sample of $Ca_{0.80}La_{0.20}FeAs_2$, patterned using Focus Ion Beam (FIB) techniques (Inset Fig. 1 (a)).

Moreover we succeed in measuring for the first time the transport J_c in this family reaching the value of 10^5 A/cm^2 at 3-5 K in self field (Fig. 1 (b)).

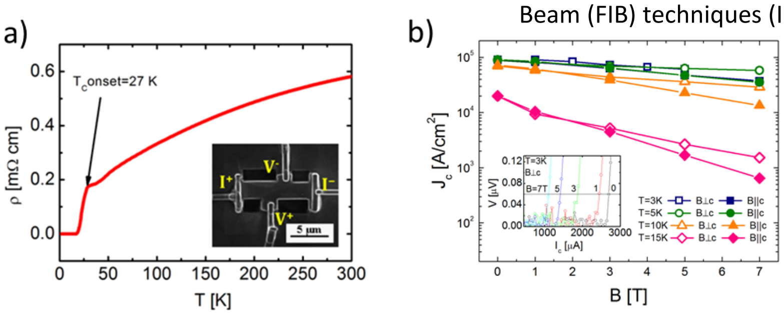


Fig. 1 a) Resistivity vs *T* of a $Ca_{0.8}La_{0.2}FeAs_2$ single crystal. Inset: FIB image b) Transport critical current densities J_c

Projects

Seed Projects 2014-2015

Title: Heat Transport in Topological Devices

Seed Project Coordinator: Giacomo Dolcetto, Genova

Project objectives and results:

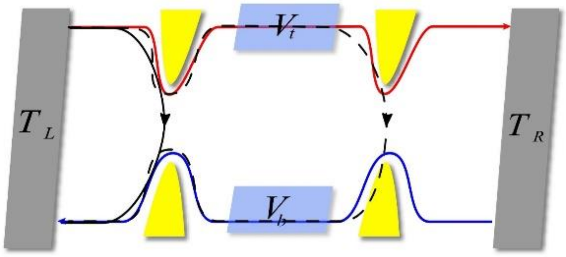


Fig.: Edge states allow to create and control interference patterns which give rise to peculiar thermoelectric properties.

This project has been focused on the study of the thermal and thermoelectric properties of topological devices, in particular quantum Hall systems and topological insulators.
It has been shown that the chirality of the protected edge states allows phase-coherent manipulation of heat currents and heat rectification. Spin caloritronics has also been investigated in topological insulators, where pure spin currents are generated by thermal gradients.
The role of electron interactions leading to fractionalization and spin-charge separation has been studied.

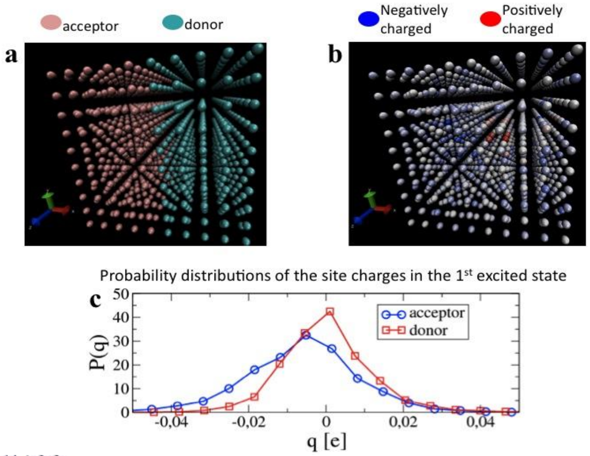
The results have been published in 5 international journals and presented in conferences and workshops.

Title: Charge separation and charge transport in hybrid solar cells

Seed Project Coordinator: Raffaele Pastore, Napoli

Project objectives and results:

We are investigating electronic properties of organic/hybrid hetero-junctions for photovoltaic applications. In collaboration with the Raos group (Politecnico di Milano), who introduced a novel quantum chemical model (JCTC 2013), we show that this method is able to simulate much larger systems than allowed by any other quantum chemical approach (see Fig.). This leads to investigate the charge delocalization and the exciton separation over the full length-scale relevant to these processes. In addition, we are performing Monte Carlo and Molecular Dynamics simulations to investigate how the morphological and dynamical properties of the active layer affect the macroscopic charge transport.



a) One realization of the system. b) Site colours depend on its charge in the 1st excited state. c) P(q) over 100 realizations.

Technology transfer activities

SPIN is traditionally involved in industrial networks and close collaborations between research and industry.

The Spin-Off company Columbus Superconductor is a successful example coming from the research collaboration with ASG Superconductors SPA for the production and the commercialization of innovative MgB_2 superconducting wires, based on a SPIN international patent.

SPIN was also involved in the realization of an interventional tomograph that is currently placed on the market by Paramed SRL. This R&D activity was funded by the Italian Ministry of Research.

SPIN owns a well-selected number of patents appealing to Industry in the fields of Biomedicine and Applied Superconductivity.

Some examples:

SPIN is also member of:

- 2 R&D Ligurian Clusters: “Tecnobionet”, operating in the field of biotechnology; “Sustainable Energy” operating in the field of energy;

and, in Campania:

- CRdC Tecnologie operating in the fields of electronics, energy, innovative materials;
- District for Polymeric and Composite Materials Engineering, operating in the fields of aeronautical/aerospace, automotive, bio-medical, polymer electronics;
- District for Aerospace Technology, for developing advanced characterization of composite structures for both transport regional aircraft and general aviation airframe structure.

Some initiatives:

MASTER LAB — MAterials Science and TEchnology Research Laboratories

CRdC Tecnologie Scarl

DAC Distretto Aerospaziale della Campania

IMAST S.C.A.R.L. District for Polymeric and Composite Materials Engineering

energia sostenibile POLO DI RICERCA E INNOVAZIONE

PROGETTO NAFASSY "NAtional FAcility for Superconducting Systems"

tecnobionet

Technology transfer activities

Main industrial partners

MIMITALIA STAMPAGGIO AD INIEZIONE DI POLVERI METALLICHE

CSA COOPER STANDARD™ AUTOMOTIVE

PIAGGIO AERO

SOL SOLGROUP

PARAmed MEDICAL SYSTEMS

ALA

IMC cavi cables

La.Sp.ed. tirreno s r l

Columbus Superconductors GRUPPO MALACALZA

fos Fibre Ottiche Sud s.p.a.

RIVOIRA

SHI Cryogenics Group

METZELER Automotive Profile Systems

CRYOGENIC CRYOGENIC LIMITED

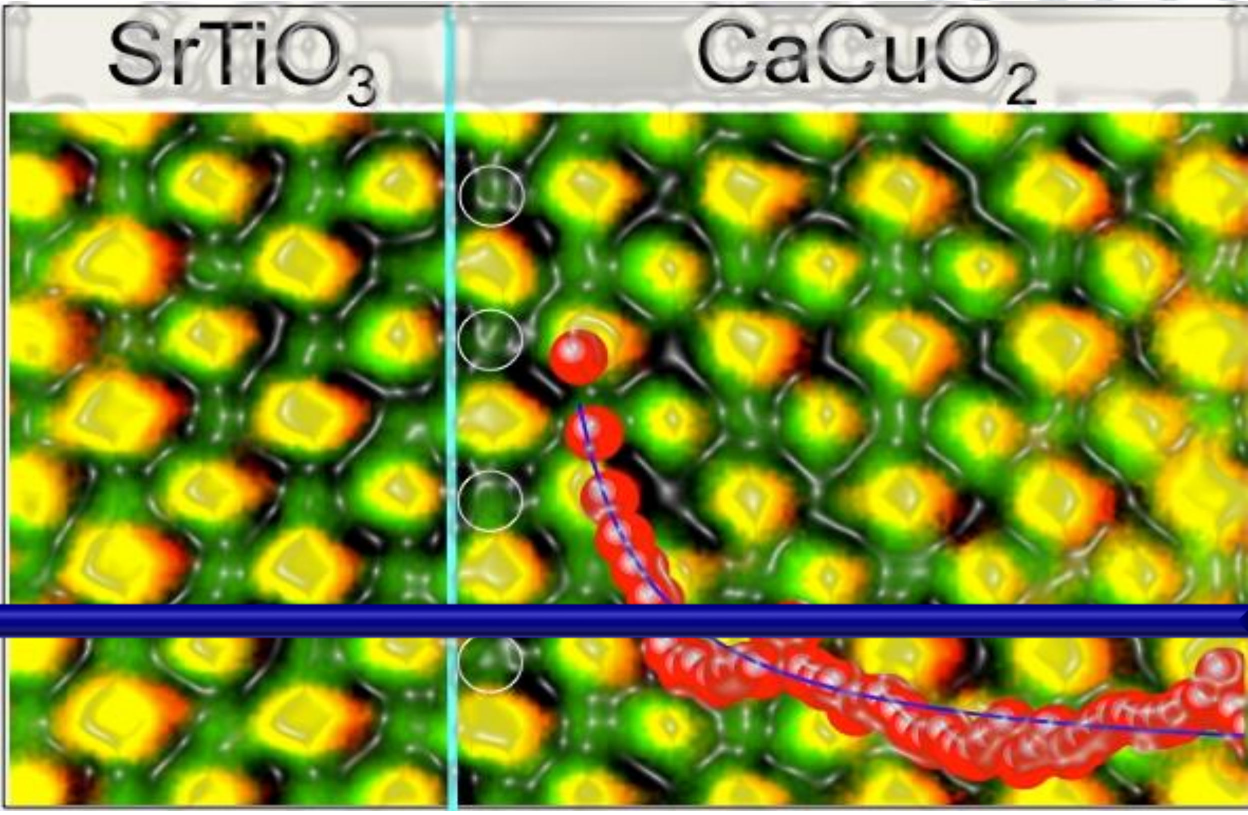
Termotech Eco

PRYSMIAN CABLES & SYSTEMS

ASG Superconductors

Highlights

- Superconductivity
- Oxides
- Other Materials
- Fundamental Properties



Highlights

Superconductivity - 2014

Synthesis and physical properties of $Ca_{1-x}RE_xFeAs_2$ with RE = La – Gd

Alberto Sala[1,2], Hiroyuki Yakita[1], Hiraku Ogino[1], Tomoyuki Okada1, Akiyasu Yamamoto[1], Kohji Kishio[1], Shigeyuki Ishida[3], Akira Iyo[3], Hiroshi Eisaki3, Masaya Fujioka[4], Yoshihiko Takano[4], Marina Putti[2] and Jun-ichi Shimoyama[1]

[1]*Department of Applied Chemistry, The University of Tokyo, Bunkyo, Tokyo 113 8656, Japan*
[2]*University of Genova and CNR-SPIN, Via Dodecaneso 33, 16146, Genova, Italy*
[3]*National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki 305-8565, Japan*
[4]*National Institute for Materials Science* (NIMS)*, Tsukuba, Ibaraki 305-0047, Japan*

APPLIED PHYSICS EXPRESS 7, 073102 (2014)

In this study we report the synthesis and characterization of five new related to the Ca1-*xREx*FeAs2 112 iron-based superconductors with *RE* = Ce, Pr, Nd, Sm, Eu and Gd. Samples were prepared using the high pressure synthesis technique, cubic-anvil type cell, applying 2 GPa and 1000° C.
From XRD analysis the 112 phase was successfully observed in all samples, with some impurities of FeAs and FeAs2. From magnetic susceptibility measurements the Nd, Sm, Eu and Gd doped samples exhibited diamagnetism suggesting superconductivity, while the Ce doped sample showed a paramagnetic like behaviour without any traces of superconductive transition down to 2 K. The critical temperatures evaluated form the magnetic susceptibility (Tc-mag) for the La-, Pr-, Nd-, Sm-, Eu-, and Gd-doped samples are 24.5, 13.2, 11.9, 11.6, 9.3, and 12.6K, respectively. Tc-mag progressively decreases with decreasing the ionic radii of the substituted RE (Figure); Those results are in agreement with the resistivity measurements too; suggesting a general decreasing of Tc with smaller RE substituted atoms. Distance between Fe planes, $d_{Fe–Fe}$, evaluated from the XRD patterns of single crystals decreases in agreement with the ionic radii of the substituted RE, only the Eu doped sample show an unexpected value, suggesting the presence of the Eu^{2+} ions.

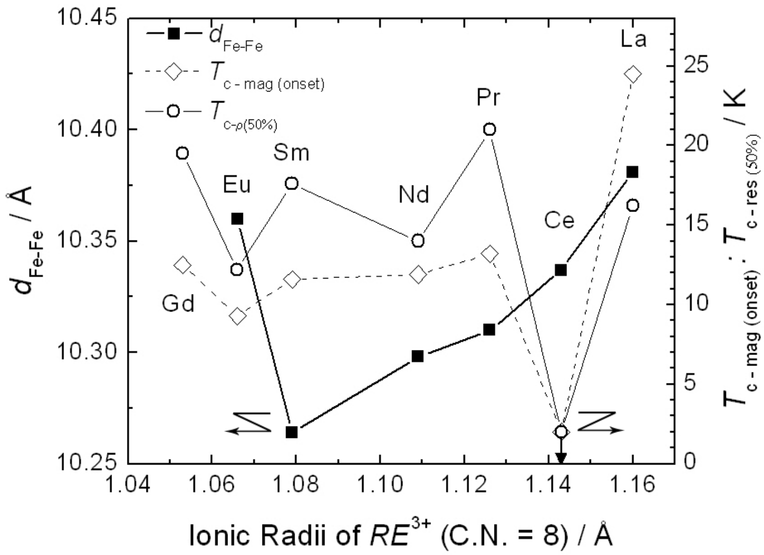


Figure: $d_{\text{Fe-Fe}}$, T_c - mag, and T_c – res(50%) as functions of ionic radi of the *RE* $^{3+}$ ions in a coordination number (C.N.) of 8, for the (Ca,*RE*)$FeAs_2$ samples. Straight and dashed lines are only guides for the eyes.

Highlights

Superconductivity - 2014

Properties of high-angle Fe(Se,Te) bicrystal grain boundary junctions

E. Sarnelli,[1] M. Adamo,[2] C. Nappi,[1] V. Braccini,[3] S. Kawale,[3] E. Bellingeri,[3] and C. Ferdeghini[3]

[1]CNR SPIN Napoli, Via Campi Flegrei 34, I-80078 Pozzuoli, Napoli, Italy
[2]CNR SPIN Salerno, Università di Salerno, I-84084 Fisciano, Salerno, Italy
[3]CNR SPIN Genova, Corso Perrone 24, I-16152 Genova, Italy

APPLIED PHYSICS LETTERS 104, 162601 (2014)

The pairing symmetry in the new iron-based superconductors is still matter of debate, particularly because of the possibility of the existence of a reversing sign s^{+-} of the order parameter. In this work, we report on the characterization of Fe(Se,Te) grain boundary Josephson junctions fabricated on a 45° [001] tilt symmetric (22.5°, 22.5°) $SrTiO_3$ bicrystal substrate. We find that the IV characteristics of these weak links may be described by the resistively shunted junction model, with an excess current Iexc increasing with the junction dimensions (see Figure). The presence of an excess current and the very low normal-state resistance values are typical of superconductor-normal metal-superconductor Josephson junctions, characterized by high-transparency barriers. We observe that the I_cR_n products of the smallest junctions are of the order of 30 μV, suitable for the fabrication of dc-SQUIDs. Moreover, all the junctions on the same substrate are characterized by the same critical current densities Jc, of the order of 104 A/cm², independently of the junction width. We have developed a model describing the critical current distribution in coplanar geometries, as is the case of bicrystal junctions. As a result, J_c = const is in agreement with our model and demonstrates the good quality of the junctions. Moreover, uniform critical current densities is what is expected in the case of s-wave symmetry of the order parameter (s^{++} or s^{+-} indifferently). In fact, for different order parameter symmetries than s-wave, the high angle of the substrate and the presence of faceting along the bicrystal

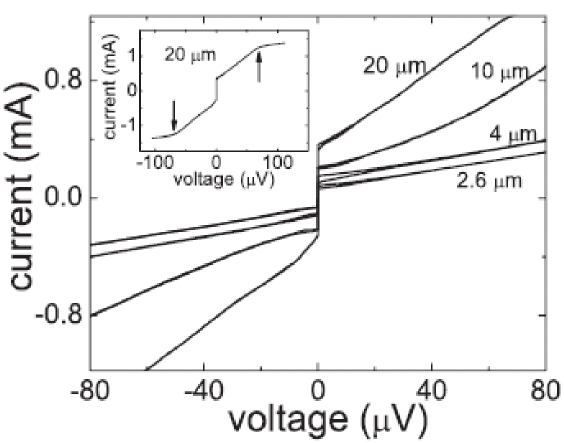


Figure: Current-voltage characteristic of 45° [001] tilt bicrystal GBJs with different sizes measured at T = 4.2 K. In the inset, the IV characteristic of a junction 20 μm wide shows peaks due to flux motion.

Superconductivity - 2014

Superconducting nanowire quantum interference device based on Nb ultrathin films deposited on self-assembled porous Si templates

C. Cirillo[1], S. L. Prischepa[2], M. Trezza[1], V. P. Bondarenko[2], and C. Attanasio[1]

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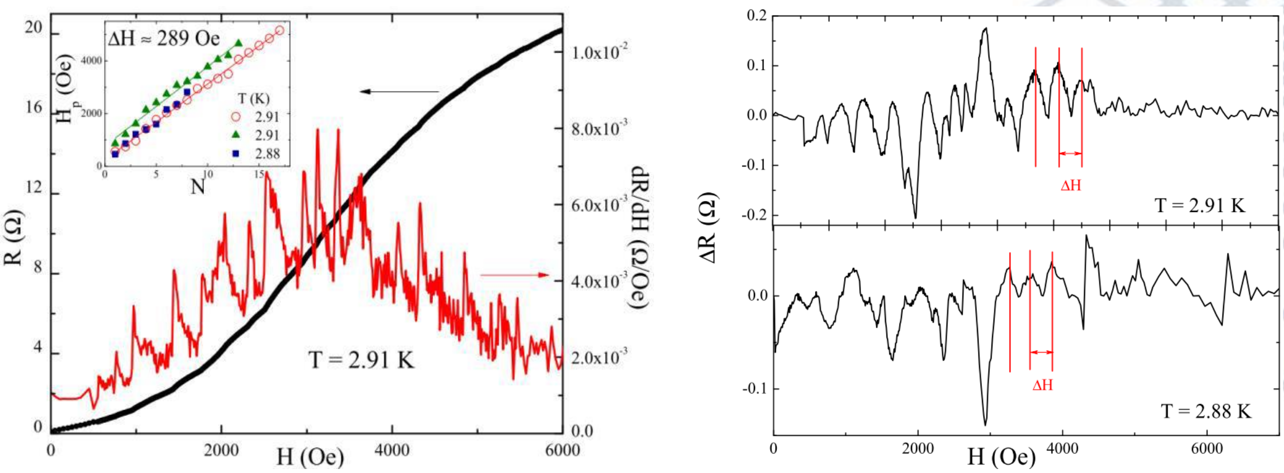
NANOTECHNOLOGY 25, 425205 (2014)

Magnetoresistance oscillations were observed on networks of superconducting ultrathin Nb nanowires presenting evidence of either thermal or quantum activated phase slips. The magnetic transport data, discussed in the framework of different scenarios, reveal that the system behaves coherently in the temperature range where the contribution of fluctuations is important.



Left: Magnetoresistance transitions, R(H), (left axis) and first R(H) derivative, dR/dH(H), (right axis) for the sample 9 nm thick grown on a porous substrate with pore diameter (interpore distance) 10 nm (40 nm). Inset: peaks positions Hp, vs index number, N, extracted from the dR/dH curve and ΔR curves on the right. ΔH is the slope of the best fit lines. Right: after the subtraction of a smooth background the R(H) curves for the same sample reveal the presence of periodic peaks of period ΔH, as highlighted by the red lines.

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Highlights

Superconductivity - 2014

Ubiquitous long-range antiferromagnetic coupling across the interface between superconducting and ferromagnetic oxides

G.M. De Luca[1], G. Ghiringhelli[2], C.A. Perroni[1], V. Cataudella[1], F. Chiarella[1], C. Cantoni[3], AR Lupini[3], N.B. Brookes[4], M. Huijben[5], G. Koster[5], G. Rijnders[5] and M. Salluzzo[1]

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NATURE COMMUNICATION 5, 5626 (2014)

The latest advancements in the atomic control of oxide heterostructures represents a unique opportunity for the uncovering of unsolved topics in condensed matter physics. Using a combination of polarization dependent x-ray absorption spectroscopy and atomically resolved electron spectro-microscopy, we investigated the interplay between superconductivity and magnetism in manganite/cuprate superconductor $La_{0.66}Sr_{0.33}MnO_3$/ $La_{1.85}Sr_{0.15}CuO_4$ superlattices. We found that the charge transfer of spin-polarized electrons from the $La_{0.66}Sr_{0.33}MnO_3$ ferromagnet to the CuO_2 layers of $La_{1.85}Sr_{0.15}CuO_4$ induces an unusual weak ferromagnetic order in the superconductor. This unusual magnetic order is associated to the canting of the Cu^{2+} magnetic moments and propagates inside the superconductor via the Dzyaloshinskii-Moriya interaction over distances from the interface much larger than the superconducting coherence length. This effect modifies substantially the magnetic correlations within and among the CuO_2 planes, ultimately reducing the superconducting critical temperature *o*f the cuprate layer in the superlattice.

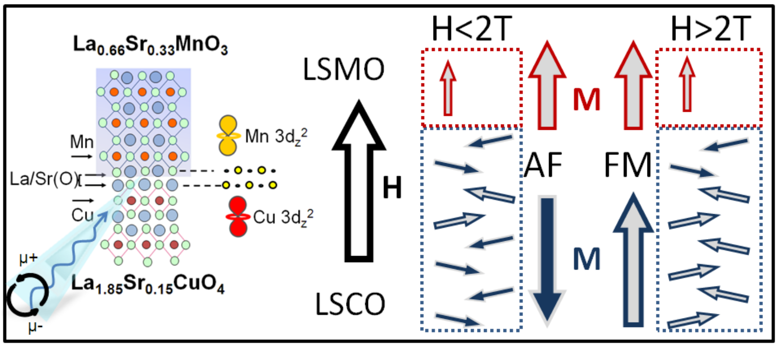

Figure:
On the left of the panel circular x-ray beam in the two directions from synchrotron source is absorbed or diffracted from the interfacial atoms belonging to ferromagnetic $La_{0.66}Sr_{0.33}MnO_3$ (LSMO) and superconductor $La_{1.85}Sr_{0.15}CuO_4$ (LSCO) crystals. On the right of the panel, we show at the LSCO/LSMO interface a strong AF coupling between Mn (red/grey) and Cu (blue/grey) moments is established.
The Dzyaloshinskii-Moriya interaction for H<2T propagates the antiparallel orientation of Cu with respect to Mn far from the interface, whereas for H>2 T the external field establishes a parallel direction as in bulk LSCO.

Highlights

Superconductivity - 2014

Probing transport mechanisms of $BaFe_2As_2$ superconducting films and grain boundary junctions by noise spectroscopy

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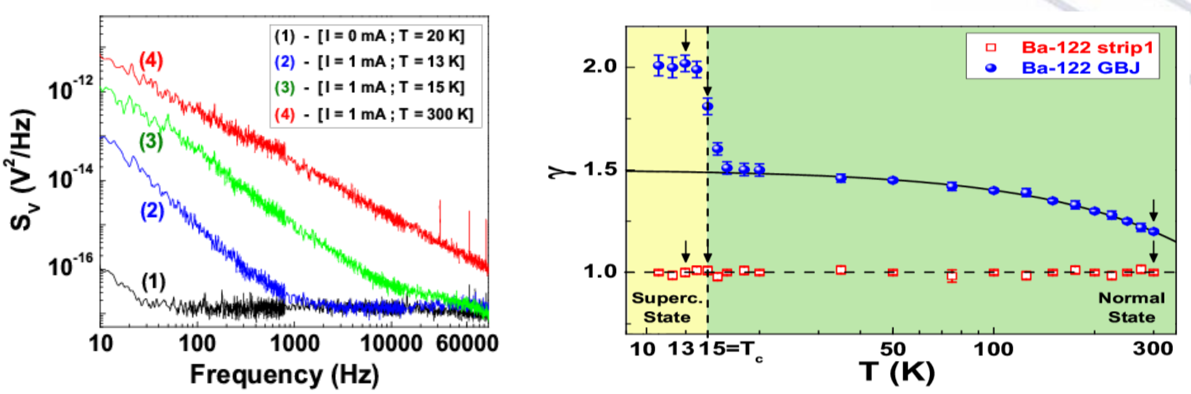
SCIENTIFIC REPORTS 4, 6163 (2014)

The discovery of iron-based superconductors has been an important step forward for the understanding of high-temperature superconductivity. In addition, iron pnictides could be used for high-field magnet applications, resulting more advantageous over conventional superconductors, due to a high upper critical field as well as its low anisotropy at low temperatures. Grain boundaries are, however, the principal obstacle in fabricating high quality superconducting wires and tapes. To investigate these effects, the dc transport and voltage-noise properties of Co-doped $BaFe_2As_2$ superconducting films with artificial grain boundary junctions (GBJs) have been measured. Using a specific procedure, the film noise can be separated from that of the grain boundary junctions. While the former shows a standard 1/f behaviour, the latter is characterized by an unconventional temperature-dependent multi-Lorentzian voltage-spectral density. Moreover, below the film superconducting critical temperature, a peculiar noise spectrum is found for the GBJ. The presence of a small number of fluctuating Josephson weak-links seems to be a crucial ingredient to explain the noise of the GBJ in the superconducting state.



(Left) Frequency dependence of the voltage-spectral density, at three reference temperatures and at a fixed bias current, for the strip containing a grain boundary junction. (Right) Temperature dependence of the noise frequency exponent γ. Red open squares refer to the strip without the grain boundary junction; blue full circles refer to the intrinsic grain boundary junction.

Highlights

Superconductivity - 2014

Magneto-Seebeck effect in RFeAsO (R = rare earth) compounds: Probing the magnon drag scenario

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PHIYSICAL REVIEW B 90, 134421 (2014)

In this work, we carried out a careful analysis of the Seebeck effect (S) in the 1111 (RFeAsO, with R=rare earth) parent compounds with different R and different degrees of disorder. We explored the dependences on temperature, observing a puzzled and articulated phenomenology (Figure a)). The multiband character of these compounds seems to be insufficient to explain the behavior of the thermopower. In particular we elaborated a simplified model for the multiband diffusive contribution based on Mott-formula, verifying that it doesn't account for the local minimum around 50 K. To study this feature we performed some measurements of Seebeck effect as a function of magnetic field up to 30 T (Figure b)) at the HFML laboratories of Nijmegen. The Seebeck values increase in magnitude with rising the field with a tendency to saturation observed at low temperature. For this scenario we propose an interpretation based on magnon-drag by antiferromagnetic spin waves. To support our thesis we have developed a theoretical model for AFM-magnon drag contribution, identifying a scaling behavior as a function of the ratio B/T, well obeyed by experimental data (Figure c)). The existence of a dominating magnon-drag contribution in the 1111-parent compounds is an important evidence of the strong interaction between charge carriers and spin waves. Within this picture the Seebeck effect comes out to be a privileged property which effectively probes the coupling mechanisms supposed to induce unconventional superconductivity.

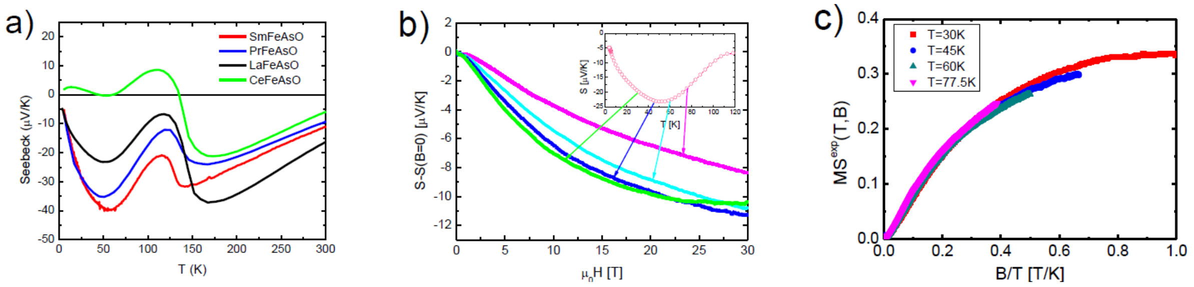

Figure: a) Seebeck coefficient curves of RFeAsO (R = Sm, Pr, La, Ce) polycrystals, b) S curves versus the magnetic field of theLaFeAsO sample performed at T = 30, 45, 60, and 77 K c) AFM magnon drag contribution to the Seebeck effect MSexp(T,B)=[S(T,B)−S(T,0)]/SDRAG(T) extracted from the experimental S curves of Fig. 1 b) and plotted as a function of B/T.

Superconductivity - 2014

Influence of topological edge states on the properties of $Al/Bi_2Se_3/Al$ hybrid Josephson devices

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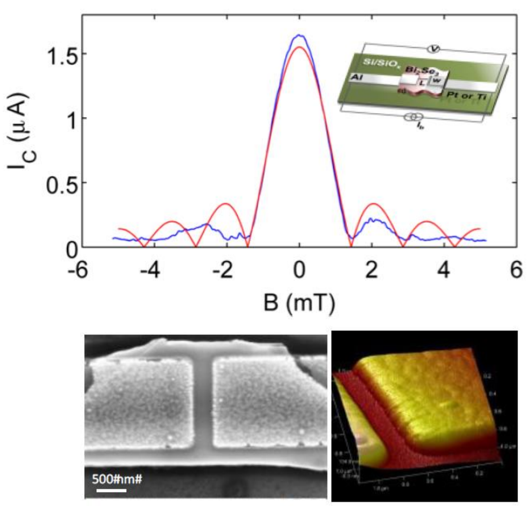
PHYSICAL REVIEW B, 89, 134512 (2014)

The understanding of how superconductivity propagates in unconventional barriers has progressively become more and more comprehensive, taking advantage of the possibility of manufacturing a larger variety of interfaces and materials. The recent introduction of topological insulators represents a milestone for this study. The standards of proximity effect in these types of structures have to be settled for a neat identification of possible new entities.

In this work we present a systematic study of transport properties of superconductor-topological insulator-superconductor coplanar Josephson junctions. These devices are characterized by a ballistic coherent transport through the topological edge states of the barrier, which is expected to generate unconventional proximity effects and, possibly, to signal the presence of Majorana bound states. A comparative study of Shubnikov–de Haas oscillations and scanning tunneling spectroscopy gave an experimental signature compatible with a two-dimensional electron transport channel with a Dirac dispersion relation.

A reduction of the size of the Bi_2Se_3 flakes to the nanoscale is an unavoidable step to drive Josephson junctions in the proper regime to detect possible distinctive features of Majorana fermions.



(Top) Critical current as a function of the external magnetic field in a $Al/Bi_2Se_3/Al$ Josephson junction at 300 mK. The red line is the reference curve appropriate for a small junction with uniform critical current density. The inset shows a sketch of the device. (Bottom left) scanning electron microscopy image of the device, and (Bottom right) atomic force microscopy of the same device. The morphology of the Bi2Se3 barrier is clearly visible, showing an atomically flat surface.

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Superconductivity - 2015

High-T_c Superconductivity at the Interface between the $CaCuO_2$ and $SrTiO_3$ Insulating Oxides

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PHYSICAL REVIEW LETTERS, 115 (2015)

At interfaces between complex oxides it is possible to generate electronic systems with unusual electronic properties, which are not present in the isolated oxides. One important example is the appearance of superconductivity at the interface between insulating oxides, although, until now, with very low T_c. We report the occurrence of high T_c superconductivity in the bilayer $CaCuO_2/SrTiO_3$, where both the constituent oxides are insulating. In order to obtain a superconducting state, the $CaCuO_2/SrTiO_3$ interface must be realized between the Ca plane of $CaCuO_2$ and the TiO_2 plane of $SrTiO_3$. Only in this case can oxygen ions be incorporated in the interface Ca plane, acting as apical oxygen for Cu and providing holes to the CuO_2 planes. A detailed hole doping spatial profile can be obtained by scanning transmission electron microscopy and electron-energy-loss spectroscopy at the O *K* edge, clearly showing that the (super)conductivity is confined to about 1–2 $CaCuO_2$ unit cells close to the interface with $SrTiO_3$. The results obtained for the $CaCuO_2/SrTiO_3$ interface can be extended to multilayered high T_c cuprates, contributing to explaining the dependence of T_c on the number of CuO_2 planes in these systems.

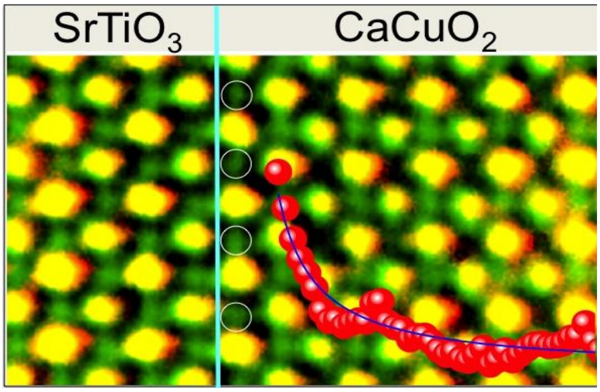

Figure: STEM image of the $CaCuO_2/SrTiO_3$ interface. The white circles indicate the excess oxygen ions at the interface Ca plane. The red bullets indicate the holes concentration decay on going far from the interface with $SrTiO_3$.

Macroscopic quantum tunnelling in spin filter ferromagnetic Josephson junctions

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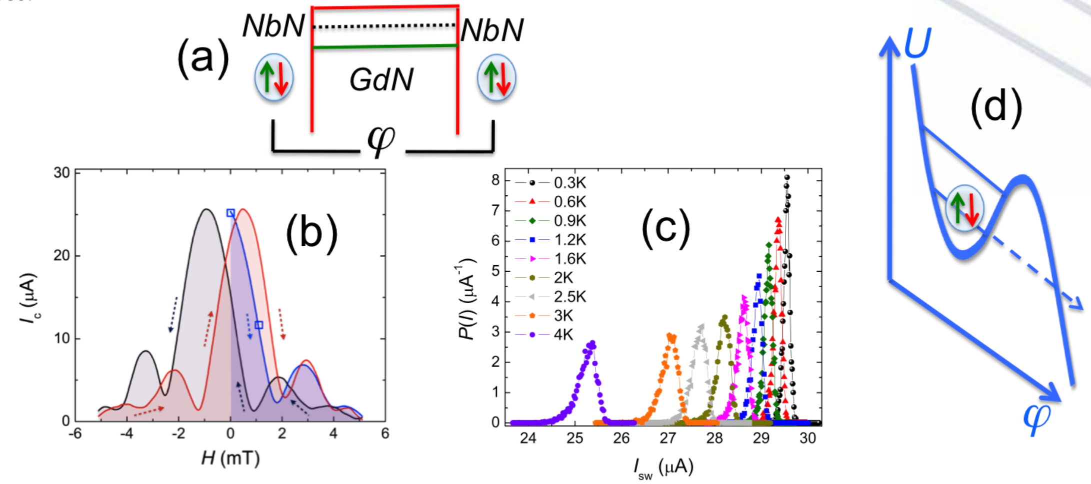
NATURE COMMUNICATIONS 6, 7376 (2015)

Macroscopic quantum tunneling (MQT) is a pre-requisite for the possible use of a junction in quantum circuits and qubits. This experiment is the first observation of MQT in superconductor (S) - ferromagnet (F) - S Josephson junctions (JJs). The coexistence of these two (S and F) ordered phases combined to other unconventional unique features as spin filter properties and triplet superconductivity, is extremely inspiring for new quantum functionalities and for innovative applications. The use of Gadolinium Nitride (GdN) ferromagnetic insulator (FI) as a barrier is the key of the Cambridge S-F-S JJs to obtain an effective tunnel barrier able to activate spin-filtering and a series of magnetic behaviors. Through measurements of switching current distributions and the expertise of the Napoli team on the quantum physics of superconducting junctions, we show a clear transition from thermal to quantum regime at a crossover temperature of about 100 mK. Our result paves the way to the active use of spin filter JJs in quantum technologies and hybrid devices.



(a) Schematic illustration of the spin-splitting of tunnelling barrier height in the GdN layer below the Curie temperature. (b) Magnetic field pattern of a spin filter JJ. The black and red curves show a distinctive shift of the absolute maximum of the critical current, arising from the hysteretic reversal of the FI barrier. (c) Measurements of switching current distributions as a function of temperature. Below 100 mK, the switching distributions saturate indicating the transition to the macroscopic quantum tunneling regime, qualitatively sketched in panel (d).

Highlights

Superconductivity - 2015

An automatic method for atom identification in scanning tunnelling microscopy images of Fe-chalcogenide superconductors

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JOURNAL OF MICROSCOPY, 260 (2015)

We describe a computational approach for the automatic recognition and classification of atomic species in scanning tunnelling microscopy images. The approach is based on a pipeline of image processing methods in which the classification step is performed by means of a Fuzzy Clustering algorithm. As a representative example, we use the computational tool to characterize the nanoscale phase separation in thin films of the Fe-chalcogenide superconductor $FeSe_xTe_{1-x}$, starting from synthetic data sets and experimental topographies. We quantify the stoichiometry fluctuations on length scales from tens to a few nanometres.

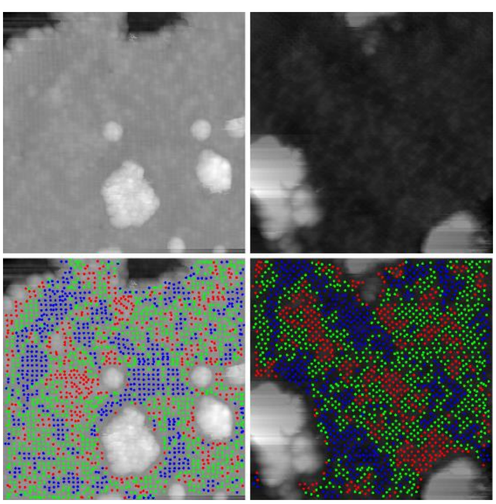

Figure 1. Original images (top line) and the corresponding atomic classifications (bottom line). In the images showing the classification results, red dots represent Fe, green dots represent Te and blue dots represent Se.

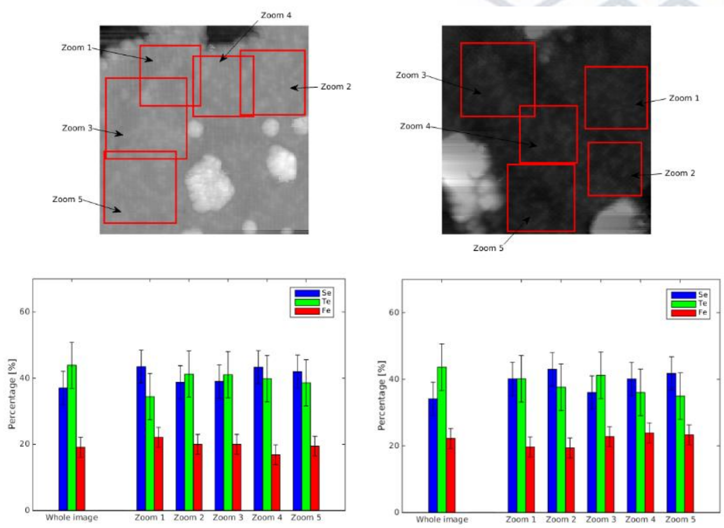

Figure 2. Zoomed regions of the original images (top line) and the corresponding population ratios (bottom line).

Superconductivity - 2015

Resonant Andreev Spectroscopy in normal-Metal/thin-Ferromagnet/Superconductor Device: Theory and Application

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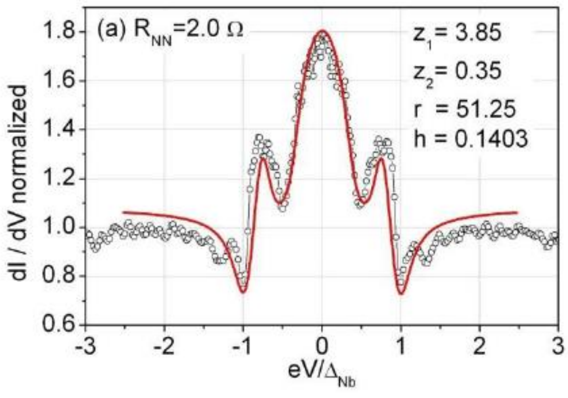
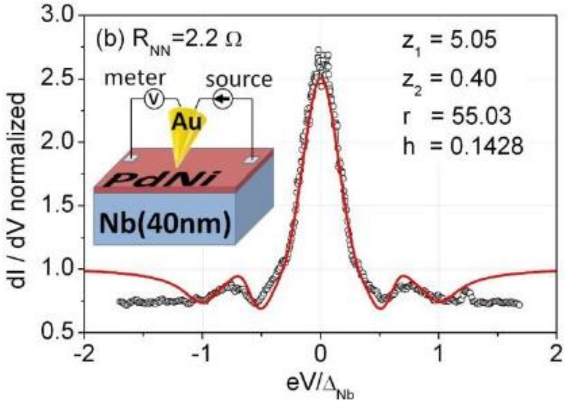
SCIENTIC REPORTS 5, 17544 (2015)

Using the Bogoliubov-de Gennes formalism, we studied the transport properties of normal-metal/ferromagnet/superconductor device (Figure) in which a thin ferromagnetic layer (of the order of ξ_F) is deposited on a superconducting electrode, realizing a double-barrier structure. The spectroscopic features (i.e. differential conductance spectra) calculated within the theoretical model show a sensitive dependence on the thickness and polarization of the ferromagnet. This peculiar behaviour, originated by the resonant proximity effect, suggests the possibility to use Resonant Andreev Spectroscopy on ferromagnet/superconductor bilayer as a powerful characterization method to precisely probe local ferromagnetic properties. As a preliminary test of the theoretical expectations, we realized point contact Andreev reflection spectroscopy experiment by pushing a metallic tip on PdNi/Nb bilayer. Differential conductance spectra for several contacts have been measured at low temperature, showing a variety of features (e.g. ZBCP, conductance dips at the gap edge, and subgap structures) not expected in single-barrier PCAR theories. Theoretical fittings allowed to consistently explain all measurements. The ferromagnet thickness and the polarization have been estimated.



Differential conductance curve (empty dots) and the theoretical fit (full red line). A ferromagnet polarization h of 14.03 % is deduced from the data.



Differential conductance measured in a different sample position; (inset) artist view of the experimental measuring setup.

Highlights

Oxides - 2014

Effect of Doping on Surface Reactivity and Conduction Mechanism in Samarium-Doped Ceria Thin Films

Nan Yang[1], Alex Belianinov[2], Evgheni Strelcov[2], Antonello Tebano[1], Vittorio Foglietti[1], Daniele Di Castro[1], Christoph Schlueter[3], Tien-Lin Lee[3], Arthur P. Baddorf[2], Nina Balke[2], Stephen Jesse[2], Sergei V. Kalinin[2], Giuseppe Balestrino[1], and Carmela Aruta[1]

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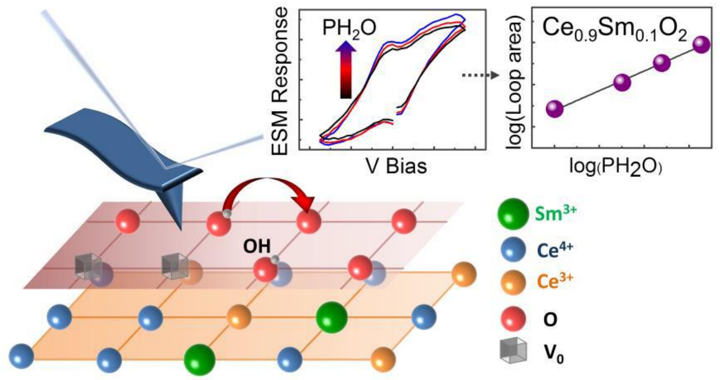
ACS NANO 8, 12494–12501 (2014)

Pure and doped Ceria based materials attracted great attention in last two decades due to their wide range of applications, e.g. catalysts, gas sensors, memristors and micro solid oxide fuel cells. It is well known that doping and granularity influence the type of conduction, if electronic, protonic or oxygen ionic. With a systematic study on epitaxial thin films by electrochemical strain microscopy and hard x-ray photoemission, we answer to the open question on how doping affects the conduction mechanism and the related surface activity, such as water adsorption and dissociation with subsequent proton transport in the lattice. We find that at lower Sm concentration, thanks to presence of Ce^{3+}, the proton conduction is prevalent, featured by lower activation energy and higher conductivity, which is interpreted in terms of different energy landscapes involving hydroxyl group and oxygen ions in the crystal lattice. Our work demonstrates that trivalent doping element concentration must be considered as an important factor for the design of ceria-based systems, helping in improving the performance of energy storage devices.



Hysteresis loop behavior(top-left) and area (top-right) of the electrochemical strain microscopy measurements at different relative humidity, showing the effect of proton conduction in $Ce_{0.9}Sm_{0.1}O_2$ thin films, together with the schematic representation of the proton conduction mechanism (bottom).

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Oxides - 2014

Ballistic Transport at the Nanometric Inhomogeneities in Au/Nb:$SrTiO_3$ Resistive Switches

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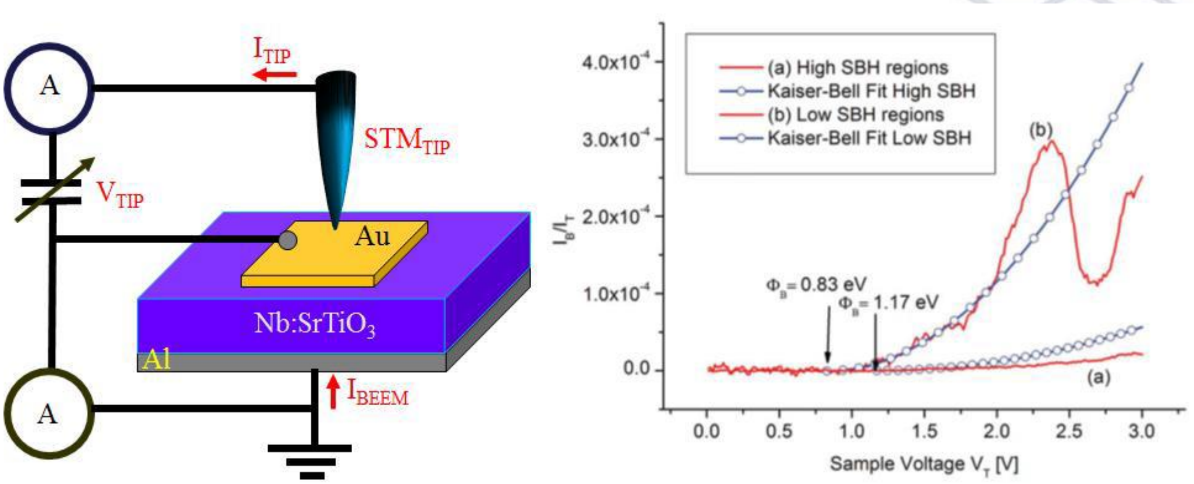
ADVANCED MATERIALS INTERFACES, 1300057 (2014)

Nanometer-scale alterations of the Schottky barrier represent one of the microscopic mechanisms proposed to explain the resistance switching in transition-metal oxide cells. We report on novel Ballistic Electron Emission Microscopy (BEEM) experiments aimed to directly visualize and quantify the local inhomogeneities of the effective Schottky barrier height on Au/Nb:$SrTiO_3$ Schottky junctions dominated by interfacial resistance switching effects. The voltage-dependent variation of the local barrier height of the nanometric patches could explain the non-ideal behaviour of the resistance switching effects.



(Left) Schematic diagram of BEEM: The hot electrons are injected from the Scanning Tunneling Microscopy (STM) tip into a thin Au film (metal base) grown on Nb:$SrTiO_3$ substrate. The electrons with an energy higher than the local Schottky barrier high (SBH) travel through the Au/ Nb:$SrTiO_3$ interface and are collected at an Ohmic contact at the backside of Nb:SrTiO3. The energy, location and flux of the hot electrons can be controlled by varying the tip voltage, position and tunnelling current respectively. (Right) BEEM spectra (ballistic current normalized to the tunnelling current vs tip voltage) were acquired over different locations showing (a) regions with low transmittance and high SBH and (b) high transmittance with lower SBH (solid lines). The solid line-open circles curves are fits with the Kaiser-Bell model.

Metal – insulator transition in free-standing VO_2/TiO_2 microstructures through low-power Joule heating

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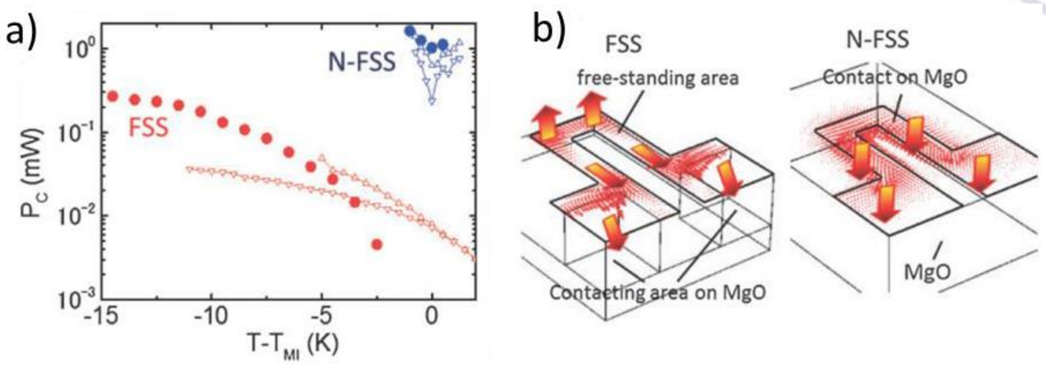
APPLIED PHYSICS EXPRESS 7, 023201 (2014)

Vanadium Dioxide (VO2) shows a large decrease of electrical resistance of several orders of magnitude at around 340 K with the formation of a mixed phase containing insulating and metallic domains that can be controlled by external *stimuli* such as electrical biases or temperature. We reported multi-resistive VO2-based microdevices by fabricating free-standing (FSS) VO_2/TiO_2 microstructures that can be easily heated by Joule effect. In this work, we investigate the thermal behavior of FSS and non-freestanding (N-FSS) VO_2-based structures. The electrical resistance of the devices shows an abrupt jump with increasing the voltage bias across their two input terminals. We analyze and compare the electrical power needed to drive the devices from the (low temperature) insulating to the (high temperature) metallic state. Our results indicate how the power needed to drive the FSS is two orders of magnitude lower that that required for the N-FSS and how thermal flow design of the microstructures is a critical issue for developing optimized switching and memristive devices.



a) Dependence of the electrical power Pc at the insulator to metal transition driven by the voltage bias at different temperatures T (TMI is the metal insulator transition temperature). Solid symbols are experimental data, while open ones show calculated data by Finite Element Analysis. b) Thermal flow of FSS and N-FSS structures calculated by Finite Element Analysis showing how in the FSS heat flows mainly along the structures toward the contacts to the substrate (MgO).

Highlights

Oxides - 2014

Potential-well depth at amorphous-$LaAlO_3$/crystalline-$SrTiO_3$ interfaces measured by optical second harmonic generation

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APPLIED PHYSICS LETTERS 104, 261603 (2014)

The discovery[1] of a two-dimensional electron gas (2DEG) formed at the interface between the two band insulators $LaAlO_3$ (LAO) and $SrTiO_3$ (STO) has driven a lot of attention to this material system. In particular, the origin of the charge carriers immediately emerged as a highly debated question, since different doping mechanisms can be at play in this oxide heterostructure. By using second harmonic generation (SHG) we have investigated various aspects of the physics of LAO/STO interfaces.[2] Here, by combining SHG and transport measurements, we have studied interfaces formed by either crystalline (c-) or amorphous (a-) thin films of LAO grown on TiO_2-terminated STO(001) substrates. The comparison between these two interfaces allows disentangling the relative role of intrinsic and extrinsic doping mechanisms in the formation of the 2DEG, with the latter being dominant in the case of amorphous LAO over layer. For the first time, we have measured the depth of the quantum well formed at the interface of both systems, finding that the value of this depth is almost constant above the threshold for the onset of conduction found in c-LAO/STO samples (4 crystalline unit cells). These findings point to the existence of a universal depth of the interfacial potential well, despite the fundamentally different doping mechanism acting in these two material systems. This result was highly unexpected**.**

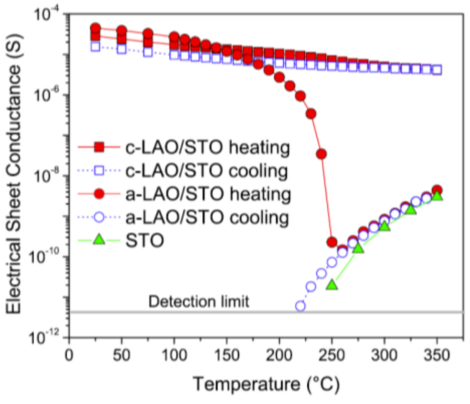

Fig. 1: Sheet conductance measured in air for the two a- and c-LAO/STO samples as a function of temperature during a heating-cooling cycle. Note the irreversible change occurring in a-LAO/STO upon heating because of the oxygen vacancies refilling in air.

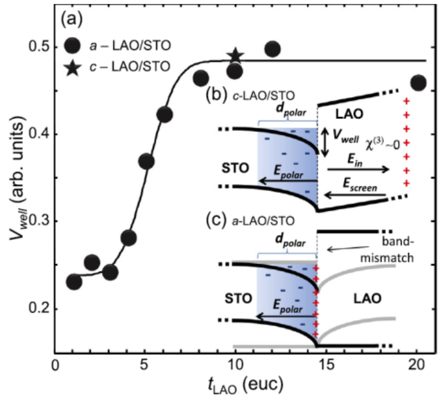

Fig. 2: The potential-well depth for a-LAO/STO and c-LAO/STO determined from SHG as a function of LAO thickness. Note the almost equal values of Vwell for the c-LAO/STO and a-LAO/STO samples above 7 euc. In

[1]A. Ohtomo and H. Hwang, Nature 427, 423 (2004).
[2]A. Rubano, C. Aruta, U. S. di Uccio, F. M. Granozio, L. Marrucci, T. Günter, T. Fink, M. Fiebig, and D. Paparo, Phys. Rev. B 88, 245434 (2013).

Highlights

Oxides - 2014

Witnessing the formation and relaxation of dressed quasi-particles in a strongly correlated electron system

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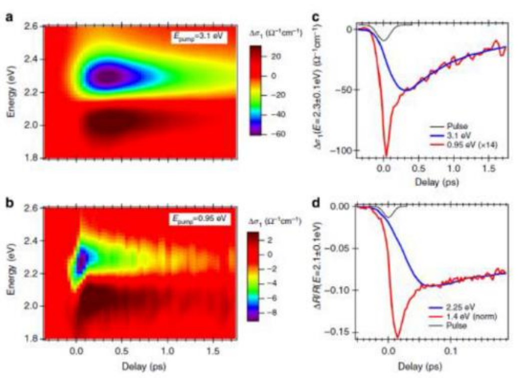
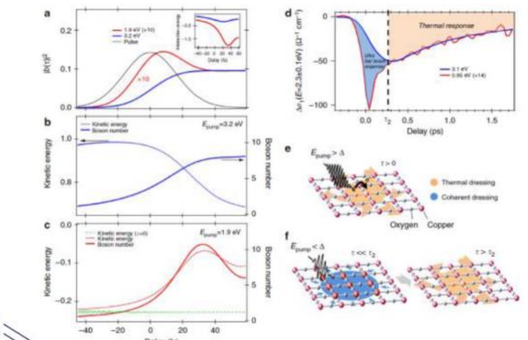
NATURE COMMUNICATIONS, 5:5112, (2014)

The non-equilibrium approach to correlated electron systems is often based on the paradigm that different degrees of freedom interact on different timescales. Photo-excitation is treated as an impulsive injection of electronic energy that is transferred to other degrees of freedom only at later times. By studying the ultrafast dynamics of quasi-particles in a strongly correlated charge-transfer insulator ($La_2CuO_{4+\delta}$), we show that the interaction between electrons and bosons manifests itself directly in the photo-excitation processes of a correlated material. We reveal that sub-gap excitation pilots the formation of itinerant quasi-particles, dressed by an ultrafast reaction of the bosonic field. The exact diagonalization of the Hubbard–Holstein model explains the different response measured for above-gap and sub-gap excitations (Figures). In particular, a perturbation with sub-gap photon energy drives a non-thermal tendency to create strongly dressed quasi-particles. This discloses several possible scenarios where coherent electromagnetic fields can be used to manipulate quantum coherent phases of matter.



Time-domain evolution of optical conductivity. The measurements performed at 130 K are reported as a function of probe energy for pump energy (a) larger (3.1 eV with 0.04 eV bandwidth) and (b) smaller (0.95 eV with 0.04 eV bandwidth) than Δ. (c) The transient optical conductivity at Eprobe at 2.3 eV for both pump energies is shown (3.1 eV in blue, 0.95 eV in red). The response for sub-gap excitation is multiplied by the ratio of the absorbed energy densities. The black curve depicts the 3.1 eV pump autocorrelation. (d) Normalized pump–probe reflectivity measurements performed at room temperature with 10 fs pulses (in black the pulse duration).



Hubbard–Holstein calculations. (a) The weight, $|b(t)|^2$ of the photo-excited component of the wave function as a function of pump–probe delay for excitations below (red) and above (blue) Δ. In the inset of a, the interaction energy in eV is shown. The average number of bosons (thick line) and the electron kinetic energy in eV (thin line) for the two excitation wavelengths are reported in b and c. In a, b and c, the differences between the pump-perturbed quantities and the ground state ones are shown. In e and f, cartoons of the physical mechanism are sketched. $E_{pump}>\Delta$ (e): thermal dressing scenario; $E_{pump}<\Delta$ (f), a 'coherent dressing' mechanism is in action at very short time delays.

Highlights

Oxides - 2014

Optical Response of Sr_2RuO_4 Reveals Universal Fermi-Liquid Scaling and Quasiparticles Beyond Landau Theory

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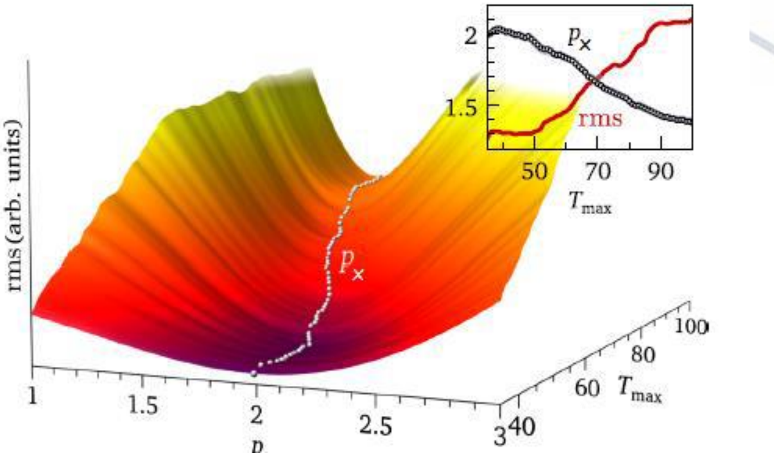
PHYSICAL REVIEW LETTERS, 113, 087404 (2014)

The relevance of Fermi Liquid (FL) theory in solids is supported by a number of materials. Among transition-metal oxides, Sr_2RuO_4 represents a remarkable example. Indeed, transport properties display low-temperature FL characteristics [1] and there is evidence for p-wave symmetry of its superconducting phase [2] as in superfluid 3He. FL theory predicts for the inelastic optical relaxation rate to vanish according to the scaling law $1/\tau \propto (\hbar\omega)^2+(p\pi k_B T)^2$, with p=2 [3,4]. Here, we report optical measurements of Sr_2RuO_4 demonstrating that the low-energy relaxation rate (1/τ) of the conduction electrons in this system obeys scaling relations for its frequency (ω) and temperature (T) dependence in accordance with FL theory. We established experimentally for Sr_2RuO_4 the universal value p = 2 and demonstrated remarkable agreement between the experimental data and the theoretically derived scaling functions in the FL regime. We also performed DMFT calculations which yield excellent agreement with the measured optical spectra.

Figure: Root-mean square deviation of the relaxation rate $M_2(\omega,T)$ from a linear dependence in $\xi^2 p$, for $\hbar\omega \leq 36$ meV and $T \leq T_{max}$, as a function of p and T_{max}. The inset shows the value px and the rms at the minimum versus T_{max}. A value px = 2 is found below T_{max} ~ 40 K.



[1] N. E. Hussey et al., Phys. Rev. B 57, 5505 (1998).
[2] C. Kallin, Rep. Prog. Phys. 75, 042501 (2012).
[3] R. N. Gurzhi, Sov. Phys. JETP 35, 673 (1959).
[4] C. Berthod et al., Phys. Rev. B 87, 115109 (2013).

Defective Interfaces in Yttrium-Doped Barium Zirconate Films and Consequences on Proton Conduction

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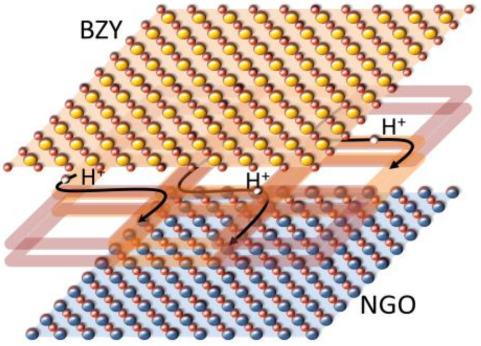
[2]Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, United States
[3]NAST Center and Department of Chemical Sciences and Technologies, University of Rome“Tor Vergata”, Rome I-00133, Italy

NANO LETTERS 15, 2343−2349 (2015)

Yttrium-doped barium zirconate (BZY) is one of the most promising electrolyte materials for protonic solid oxide micro fuel cells based on thin films. In this field, it was largely reported, both theoretically and experimentally, that disorder and reduced dimensionality offer new routes to enable high performance electrochemical energy conversion devices. Therefore, a direct characterization of interfaces between the electrolyte film and the substrate is important, but also a very challenging task.
In this framework, here we use state-of-art electrochemical strain microscopy in a novel cross-sectional measuring setup to directly visualize the interface reactivity of BZY films with nanoscale resolution. The local electrochemical investigation is compared with the structural information obtained by state of art scanning transmission electron microscopy, the unique technique able to give information on the local distortions at the interface between film and substrate.
The results of this study show a clear correlation between the conductivity of BZY films and the misfit dislocation network, which introduces a novel 2D transport phenomenon at the interface. The relevance of these results consists in opening a new avenue to understand low-dimensional properties at the nanoscale which are critical for several current and future technologies, especially in the field of energy storage and production. This work, in perspective, will shine a light in exploitation of the extraordinary properties of these strongly defective interfaces.



Schematic drawing of the interface between BZY film and NGO substrate with the dislocation network as fast pathway for proton conduction.

V. Foglietti et al. Appl. Phys. Lett. 2014, 104, 081612.

Oxides - 2015

Spin-Orbital Order Modified by Orbital Dilution in Transition-Metal Oxides: From Spin Defects to Frustrated Spins Polarizing Host Orbitals

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PHYSICAL REVIEW X 5, 011037 (2015)

Understanding the origin of the complex behavior of transition-metal oxides with orbital degrees of freedom is a central problem in strongly correlated electrons and quantum magnetism. Applying magnetic impurities to systems with spin-orbital order is particularly challenging and is still unexplored. Immobile defects with no orbital degree of freedom in spin-orbital-ordered Mott insulators may disturb both magnetic and orbital order; such "substitutional doping" can generate novel types of order at high doping concentrations. We study local changes in spin-orbital order in an insulating 4d transition-metal oxide when 3d impurities (Mn^{4+} and Cr^{3+} ions) with no orbital degrees of freedom are added, leading to orbital dilution. We employ a microscopic model whose physical properties are controlled by a few parameters. Our analysis demonstrates that the 3d impurities can behave either as spin defects surrounded by inactive orbitals or polarized orbitals around them that change spin interactions to ferromagnetic (Figure).

We investigate a few representative doping concentrations and show that certain unexpected changes in global spin-orbital order are triggered by finite doping and that frustration of impurity spins, which emerges classically at the crossover between different types of magnetic order, is removed by quantum effects. We predict local and global changes of spin-orbital order induced by such impurities, and we suggest how the final spin-orbital order could be detected experimentally. Our results are generic and pave the way toward a better understanding of heavy (4d and 5d) transition-metal oxides with immobile magnetic ions. Our theory provides the framework to investigate the consequences of quantum fluctuations and of spin-orbit coupling in Mott insulators, which will likely lead to novel quantum behaviour in spin-orbital systems.

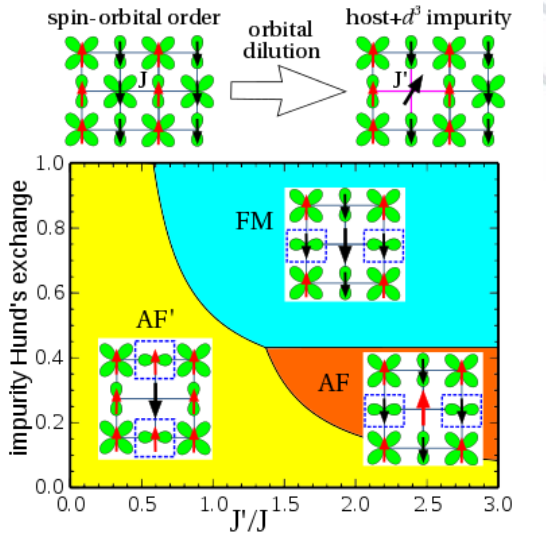

Figure: Phase diagram of a single 3d impurity in a 4d host in terms of the local Hund coupling and the impurity-host spin-orbital exchange.

Highlights

Oxides - 2015

Photoresponse dynamics in amorphous-$LaAlO_3/SrTiO_3$ interfaces

Emiliano Di Gennaro[1], Ubaldo Coscia[2], Giuseppina Ambrosone[1], Amit Khare[1], Fabio Miletto Granozio[1] & Umberto Scotti di Uccio[1]

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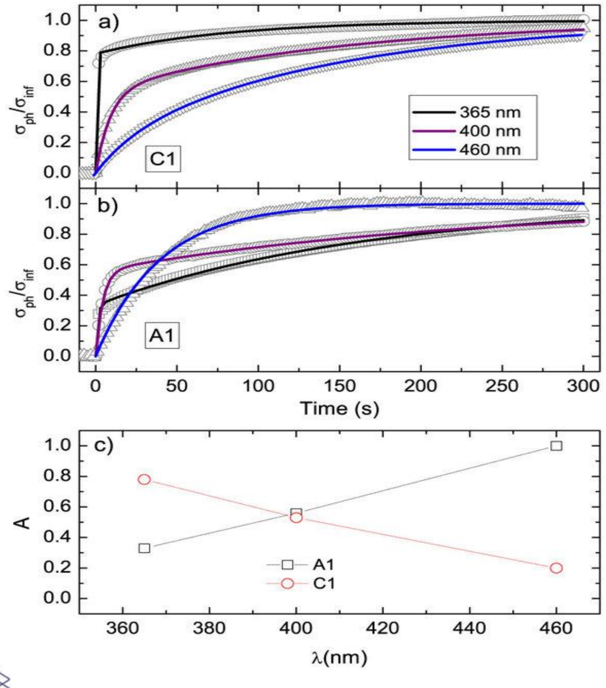
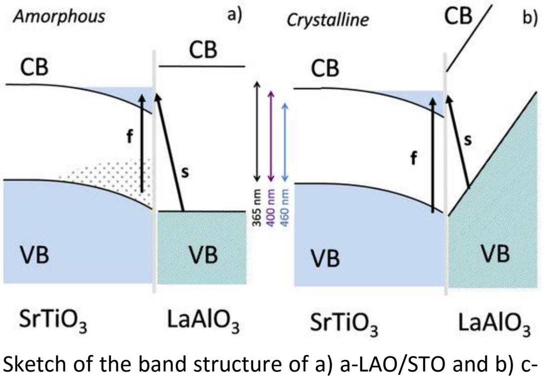
[2]Dipartimento di Fisica,Univ. di Napoli Federico II and CNISM Unita´ di Napoli, Compl.Univ. di Monte S. Angelo, ViaCinthia I-80126 Napoli (Italy)

SCIENTIFIC REPORTS, 8393 (2015)

The time-resolved photoconductance of amorphous and crystalline $LaAlO_3/SrTiO_3$ interfaces, both hosting an interfacial 2-dimensional electron gas, is investigated under irradiation by variable-wavelengths, visible or ultraviolet photons. Unlike bare $SrTiO_3$ single crystals, showing relatively small photoconductance effects, both kinds of interfaces exhibit an intense and highly persistent photoconductance with extraordinarily long characteristic times. The temporal behaviour of the extra photoinduced conductance persisting after light irradiation shows a complex dependence on interface type (whether amorphous or crystalline), sample history and irradiation wavelength. The experimental results indicate that different mechanisms of photoexcitation are responsible for the photoconductance of crystalline and amorphous $LaAlO_3/SrTiO_3$ interfaces under visible light. We propose that the response of crystalline samples is mainly due to the promotion of electrons from the valence bands of both $SrTiO_3$ and $LaAlO_3$. This second channel is less relevant in amorphous $LaAlO_3/SrTiO_3$, where the higher density of point defects plays instead a major role.



(a) Photoresponse of C1 and (b) photoresponse of A1 at 365 nm (black), 400 nm (red), and 460 nm (green). The data are normalized to the asymptotic value σ_{inf}; solid lines are fit curves. (c) Dependence of A vs. radiation wavelength λ for both samples.



Sketch of the band structure of a) a-LAO/STO and b) c-LAO/STO.

Highlights

Oxides - 2015

Noncontact Atomic Force Microscope Dissipation Reveals a Central Peak of $SrTiO_3$ Structural Phase Transition

M. Kisiel,[1] F. Pellegrini,[2,3] G. E. Santoro,[2,3,4] M. Samadashvili,[1] R. Pawlak,[1] A. Benassi,[5,6] U. Gysin,[1] R. Buzio,[7] A. Gerbi,[7] E. Meyer,[1] and E. Tosatti[2,3,4]

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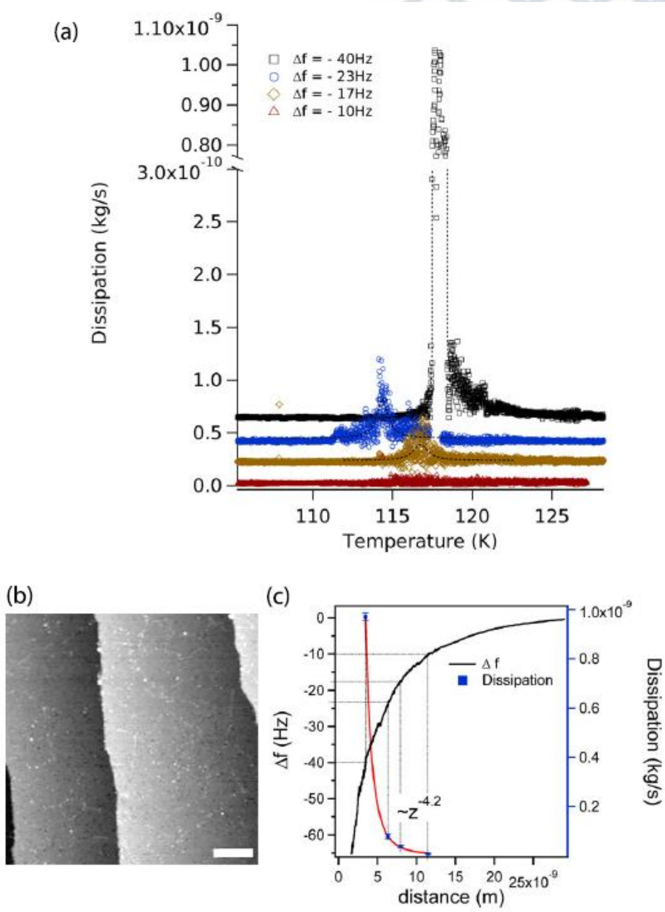
PHYSICAL REVIEW LETTERS 115, 046101 (2015)

The critical fluctuations at second order structural transitions in a bulk crystal may affect the dissipation of mechanical probes even if completely external to the crystal surface. Here, we show that noncontact force microscope dissipation bears clear evidence of the antiferrodistortive phase transition of $SrTiO_3$, known for a long time to exhibit a unique, extremely narrow neutron scattering "central peak." The noncontact geometry suggests a central peak linear response coupling connected with strain. The detailed temperature dependence reveals for the first time the intrinsic central peak width of order 80 kHz, 2 orders of magnitude below the established neutron upper bound.



(a) Experimental AFM dissipation W as a function of temperature. Raw data, taken at different surface spots and different tip sample distances z. The sharp peak corresponds to the critical temperature of $SrTiO_3$ in the bulk region under the tip. (b) Low temperature (T = 5 K) STM image of $SrTiO_3$ (100) surface. The image is obtained at constant current I = 10 pA and bias voltage U = 1 V. The length of the scale bar is equal to 20 nm. (c) The distance dependence of the dissipation W, taken as the maximum of the peak shown in (a), at four different spots on the sample. A fit to the experimental data, $W \propto z^{-p}$, is shown in red, with $p \sim 4.2$. This exponent is close to the value p = 4 expected for phononic dissipation, as appropriate for coupling to acoustical surface fluctuations of an insulating bulk material.

Oxides - 2015

Giant Oscillating Thermopower at Oxide Interfaces

I. Pallecchi [1], F. Telesio [1], D. Li [2], A. Fête [2], S. Gariglio [2], J.M. Triscone [2], A. Filippetti [3], P. Delugas [4], V. Fiorentini [3], D. Marré [1]

[1] CNR-SPIN and Genova University, via Dodecaneso 33, 16146-Genova, Italy
[2] Departement of Quantum Matter Physics, University of Geneva, 24 Quai E.-Ansermet, 1211 Geneva 4, Switzerland
[3] CNR-IOM and Università di Cagliari, S.P. Monserrato-Sestu Km.0,700, Monserrato (Ca), 09042, Italy
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NATURE COMMUNICATIONS, 6:6678 (2015)

Thermoelectric spectroscopy, is a formidable tool to investigate the electronic structure of the $LaAlO_3/SrTiO_3$ interface [1] and achieve full comprehension of charge confinement in oxide heterostructures. In this work, we explore thermopower in $LaAlO_3/SrTiO_3$ at low temperature as a function of gate field, in order to monitor the electronic properties at varying doping concentration (see experimental configuration in Figure a). Under large negative gate voltage, corresponding to the strongly charge depleted regime, thermopower displays record-high negative values of the order of 10^4-10^5 μV/K, oscillating at regular intervals as a function of the gate voltage (see figure b). The huge thermopower magnitude can be attributed to the phonon-drag contribution, which is boosted by 2D electron confinement. Indeed, in the low temperature limit, the coupling of acoustic phonons with 2D confined electrons is enhanced by the loss of crystal momentum conservation in the interface-orthogonal direction, enabling the interaction of the electron gas with many more phonon frequencies. On the other hand, the thermopower oscillations map the Fermi level descent across a dense array of localized states lying at the bottom of the Ti 3d conduction band (see in Figure c and d the model electronic band structure of the two-dimensional electron gas (2DEG) which allows to reproduce the experimental results, as shown in Figure e). This study is the first direct evidence of a localized Anderson tail in the $LaAlO_3/SrTiO_3$ two-dimensional electron liquid.

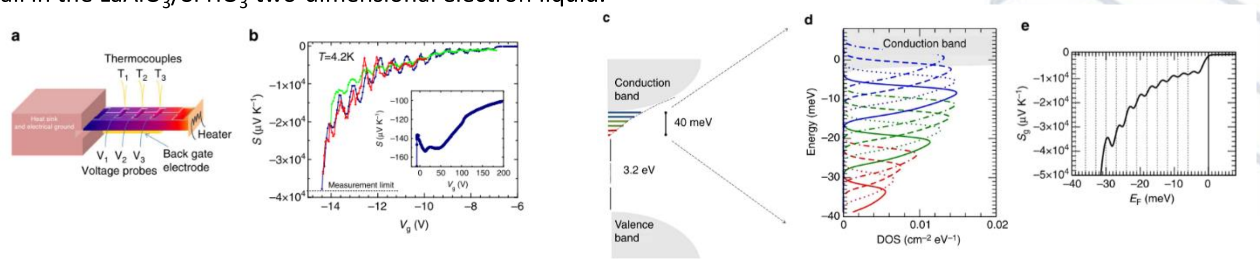

Figure : Seebeck measurement configuration and behavior under gate field of a $LaAlO_3/SrTiO_3$ interface. a) Sketch of the sample and experimental configuration for the Seebeck measurements. b) Seebeck coefficient versus gate voltage measured in a $LaAlO_3/SrTiO_3$ interface at 4.2 K. In the main panel, the different traces correspond to different thermal and Vg cycles. In the inset, a blow-up of the accumulation regime (Vg>0) is shown. c) Sketch of the model band structure purposely built to reproduce the experimental results. Gray areas indicate valence and conduction states; the colored lines below the conduction states represent a tail of localized states. d) Actual Density of States (DOS) of the model band structure considered for the calculations. The shaded gray area is the DOS relative to the conduction band bottom (CBB) of t_{2g} d_{xy} orbital character. Below the CBB lies a tail of 12 localized states, placed at regular intervals of 3 meV from each other, indicated by different colors and type of lines. From the bottom: red solid, dotted, dashed, dot-dashed, and then the same sequence repeated in green and blue. Zero energy is fixed at the CBB. e) Phonon-drag calculated for the model DOS. The dotted vertical lines indicate the bottom energy of each localized state, the solid line is the CBB. S_g oscillates at each intersection of E_F with the bottom energies.

[1] Ohtomo, A. and Hwang, H. Y., *"A high-mobility electron gas at the $LaAlO_3/SrTiO_3$ heterointerface"*, Nature 427, 423–426 (2004)

Highlights

Oxides - 2015

Coupling Ferroelectricity with Spin-Valley Physics in Oxide-Based Heterostructures

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PHYSICAL REVIEW LETTERS 115, 037602 (2015)

The coupling of spin and valley physics is nowadays regarded as a promising route toward next-generation spintronic and valleytronic devices. Valley-contrasting physical quantities may emerge whenever inversion symmetry is broken; when realized in ferroelectrics, the valley phenomenology could be controlled by acting on the ferroelectric polarization. We focus on the quest for ferroelectric spin-valley physics in the perovskite oxide heterostructure shown in Fig a), where a (111) bilayer of $BiIrO_3$ is embedded in the robust ferroelectric $BiAlO_3$. The interplay of spin-orbit coupling and trigonal crystal-field effect in the (111) oxide bilayer leads to graphene-like low-energy electronic properties, hence to the appearance of coupled spin-valley physics. Specifically, a large valley spin polarization is induced and modulated by the ferroelectric polarization, as shown in Figs. b) and c). Our theoretical analysis suggests that the realization of spin-valley physics in oxide heterostructures is possible, allowing, in principle, for larger effects (due to the large spin-orbit coupling of *4d* or *5d* transition-metal ions), increased tunability (brought in by oxygens, both determining the trigonal crystal-field splittings and mediating the hopping interactions), and the integration of additional functionalities, such as ferroelectricity, which could be exploited in advanced next-generation electronic devices aiming at a full-electric control of spin polarization.

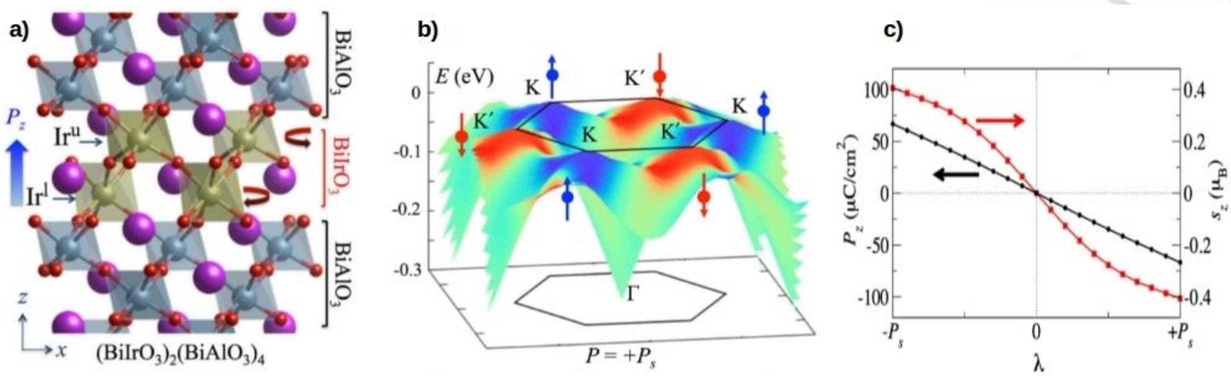

Figure: a) Multilayer structure of $(BiIrO_3)_2(BiAlO_3)_4$ heterostructure; the direction of the ferroelectric polarization is shown by the blue arrow. b) Energy dispersion of the top valence band, with projected valley-dependent spin polarization s_z, showing opposite directions at different valleys. c) Ferroelectric polarization P_z and spin polarization s_z of the top valence band at the valley K as a function of the polar structural distortion parametrized by λ.

Electric-Field Control of the Orbital Occupancy and Magnetic Moment of a Transition-Metal Oxide

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[2]Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom
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PHYSICAL REVIEW LETTERS 115, 157401 (2015)

By using soft-x-ray linear and magnetic dichroism on $La_{0.825}Sr_{0.175}MnO_3/PbZr_{0.2}Ti_{0.8}O_3$ ferromagnetic-ferroelectric heterostructures we demonstrate a non-volatile modulation of the Mn 3d orbital anisotropy and magnetic moment. X-ray absorption spectroscopy at the Mn $L_{2,3}$ edges shows that the ferroelectric polarization direction modifies the carrier density, the spin moment, and the orbital splitting of t2g and eg Mn 3d states. These results are consistent with polar distortions of the oxygen octahedra surrounding the Mn ions induced by the switching of the ferroelectric polarization.

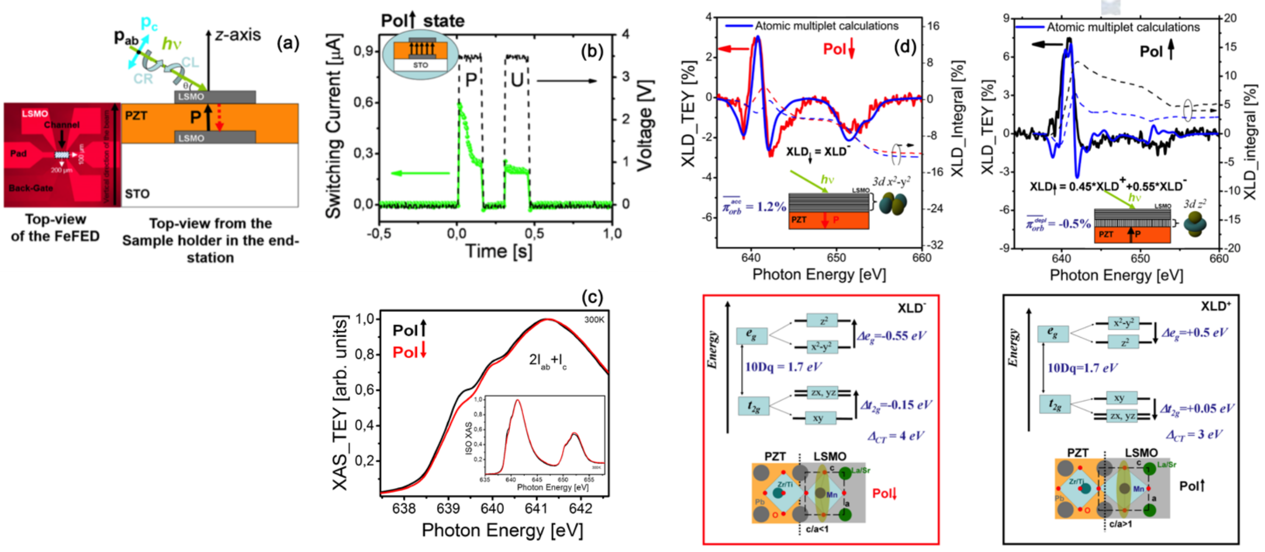

Figure: (a) Top view of the Ferroelectric Field Effect (FEFED) devices and schematic view of the XAS experiment on the LSMO/PZT/LSMO FEFED. (b) Ferroelectric switching of the PZT layer with positive voltage pulses P and U, corresponding to the Pol↑ state (P pointing toward the top LSMO layer, see inset). (c) TEY-XAS spectra of the FEFED the Polarization in two possible states. (d) XLD spectra with Pol down and (e) XLD spectra with Pol up and corresponding orbital interfacial configuration deduced from the fitting of the data using atom multiplet codes.

Universal electronic structure of polar oxide hetero-interfaces

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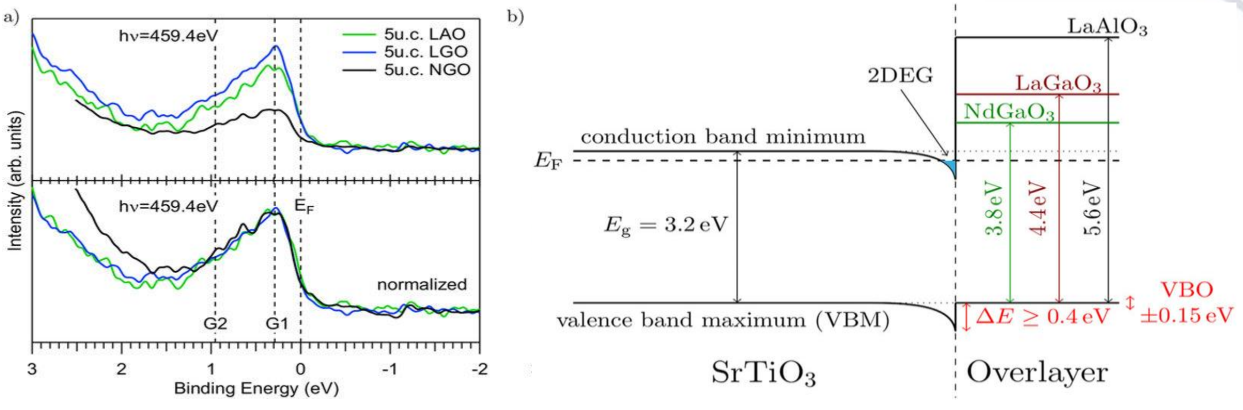
SCIENTIC REPORTS, (2015)

The electronic properties of $NdGaO_3/SrTiO_3$, $LaGaO_3/SrTiO_3$, and $LaAlO_3/SrTiO_3$ interfaces, all showing an insulator-to-metal transition as a function of the overlayer-thickness, are addressed in a comparative study based on x-ray absorption, x-ray photoemission and resonant photoemission spectroscopy. The nature of the charge carriers, their concentration and spatial distribution as well as the interface band alignments and the overall interface band diagrams are studied and quantitatively evaluated. The behavior of the three analyzed heterostructures is found to be remarkably similar. The valence band edge of all the three overlayers aligns to that of bulk $SrTiO_3$. The near-interface $SrTiO_3$ layer is affected, at increasing overlayer thickness, by the building-up of a confining potential. This potential bends both the valence and the conduction band downwards. The latter one crossing the Fermi energy in the proximity of the interface and determines the formation of an interfacial band offset growing as a function of thickness. Quite remarkably, but in agreement with previous reports for $LaAlO_3/SrTiO_3$, no electric field is detected inside any of the polar overlayers. The essential phenomenology emerging from our findings is discussed on the base of different alternative scenarios regarding the origin of interface carriers and their interaction with an intense photon beam.



Left image: Resonant photoemission on the Ti 3+ states of the Ti L-edge. The presence of states at the Fermi level, with similar spectral shape, is seen for all samples. Right image: band diagrams are derived from our data.

Highlights

Other Materials - 2014

Pushing the high-energy limit of plasmonics

Francesco Bisio,[1] Remo Proietti Zaccaria,[2] Riccardo Moroni,[1] Giulia Maidecchi,[3] Alessandro Alabastri,[2] Grazia Gonella,[4] Angelo Giglia,[5] Laura Andolfi,[5] Stefano Nannarone,[5] Lorenzo Mattera,[3] and Maurizio Canepa[3]

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ACS NANO 8, 9239-9247 (2014)

The localized surface plasmon resonance (LSPR) is a resonant oscillation of the free-electron gas within a metallic nanoparticle (NP), induced by an external electromagnetic (EM) field. The LSPR of metal nanoparticles allows confining the electromagnetic field in nanosized volumes, creating high- field "hot spots", most useful for enhanced nonlinear optical spectroscopies. However, Au and Ag, the materials that conjugate high-quality LSPR with low reactivity, cannot exhibit plasmon resonances at photon energies above the visible-light regime. Stretching upward, this energy limit becomes however possible with one of the cheapest and most abundant materials available: aluminium. Al exhibits indeed a LSPR theoretically extending up to the deep-ultraviolet. However, complex nanofabrication issues and the unavoidable Al oxidation have so far prevented the achievement of this ultimate high-energy response. We overcame these hurdles by means of a bottom-up nanofabrication technique based on template-driven metal deposition, producing ultrafine and purely metallic Al nanoparticles. Under these conditions, we successfully pushed the plasmon resonance to a record value of 6.8 eV photon energy (λ≈ 180 nm), observing an experimental LSPR energy matching theoretical predictions and broadening the spectral range of plasmonics' numerous applications.

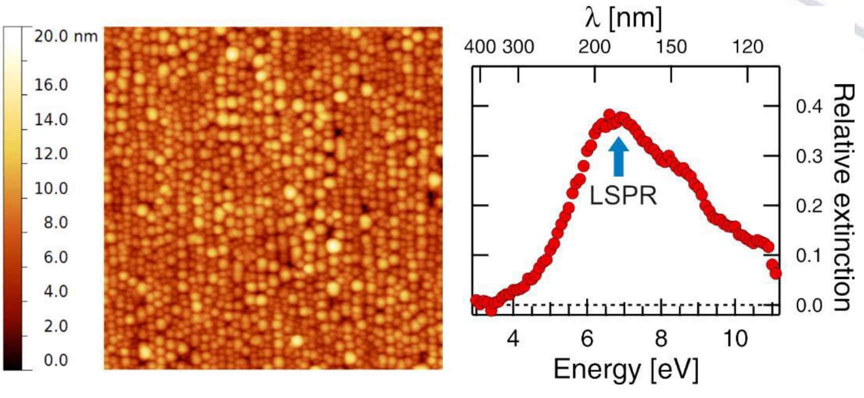

Figure: left: Al-particles nanoarray (image size 1×1μm2); right: extinction spectrum of Al nanoparticles. The prominent peak is the fingerprint of the LSPR.

Femtosecond laser surface structuring of silicon using optical vortex beams generated by a q-plate

K. K. Anoop,[1,2] A. Rubano,[1,2] R. Fittipaldi,[3] X. Wang,[2] D. Paparo,[2] A. Vecchione,[3]
L. Marrucci,[1,2] R. Bruzzese,[1,2] and S. Amoruso[1,2]

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[2]CNR-SPIN, UOS Napoli, Complesso Universitario di Monte S. Angelo, Via Cintia, I-80126 Napoli, Italy
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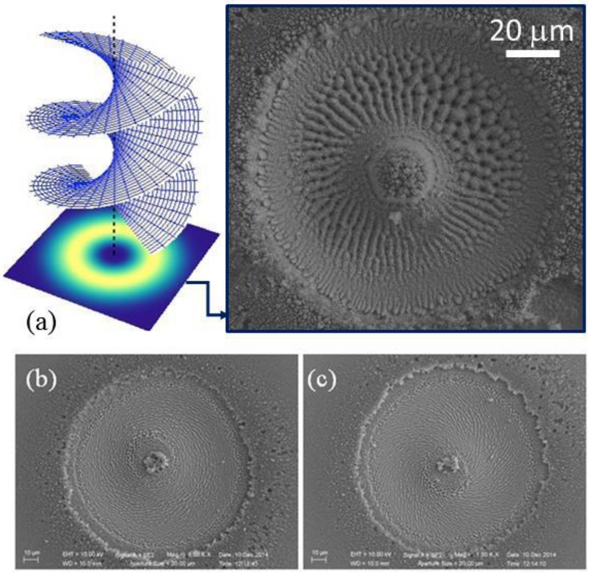
APPLIED PHYSICS LETTERS 104, 241604 (2014)

Creation of patterns/structures on a surface at the micro- and nano-scale has many potential applications (e.g. in material processing, tailoring of optical properties, THz optics, etc.). Many patterns can be obtained by direct laser structuring through femtosecond (fs) laser ablation, with Gaussian-like beam spatial intensity profile. Recently, non-Gaussian laser beams are emerging as interesting candidates for strategic tailoring in material processing. We demonstrated fs laser structuring using optical vortex (OV) annular beams created with a liquid crystal q-plate [1]. Our findings show emergence of diverse (radial, azimuthal, spiral, etc.) surface micro-structures, highlighting the multi-pulse feedback mechanism responsible for the surface structuring process. Moreover, the central zero intensity singularity of the OV ring intensity profile also leads to a central micro-needle decorated with nanoparticles. Direct laser structuring with fs pulses is very promising to create complex surface microstructures [2], also providing a powerful method to evaluate focal intensity and polarization distribution of complex, unconventional ultrashort laser beams.

[1] L. Marrucci, C. Manzo, and D. Paparo, Phys. Rev. Lett. 96, 163905 (2006).
[2] K. K. Anoop, R. Fittipaldi, A. Rubano, X. Wang, D. Paparo, A. Vecchione, L. Marrucci, R. Bruzzese, and S. Amoruso, J. Appl. Phys. 116, 113102 (2014).



(a) Schematic representation of an OV beam and annular spot on a Si (100) target surface showing the developed radial microstructure. Panels (b) and (c) show examples of circular and spiral microstructures, respectively. Interestingly, the microstructure formed in the annular beam region is sensitive to the local laser polarization. A micro-needle is present at the laser spot center, corresponding to the nearly zero intensity central singular region of the OV beam, with a nanoparticles-assembled structure on the top.

Highlights

Other Materials - 2014

High mobility *n*-type organic thin-film transistors deposited at room temperature by supersonic molecular beam deposition

F. Chiarella[1], T. Toccoli[2], M. Barra[1], L. Aversa[2], F. Ciccullo[1], R. Tatti[2], R. Verucchi[2], S. Iannotta[3], and A. Cassinese[1]

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APPLIED PHYSICS LETTERS 104, 143302 (2014)

In this paper, we report on the fabrication of N,N0-1H,1H-perfluorobutil dicyanoperylenediimide (PDIF-CN2) organic thin-film transistors by Supersonic Molecular Beam Deposition (SuMBD). The devices exhibit mobility up to 0.2 cm^2/V s even if the substrate is kept at room temperature during the organic film growth, exceeding by three orders of magnitude the electrical performance of those grown at the same temperature by conventional Organic Molecular Beam Deposition (OMBD)(see Figure). The possibility to get high-mobility n-type transistors avoiding thermal treatments during or after the deposition could significantly extend the number of substrates suitable to the fabrication of flexible high-performance complementary circuits by using this compound.

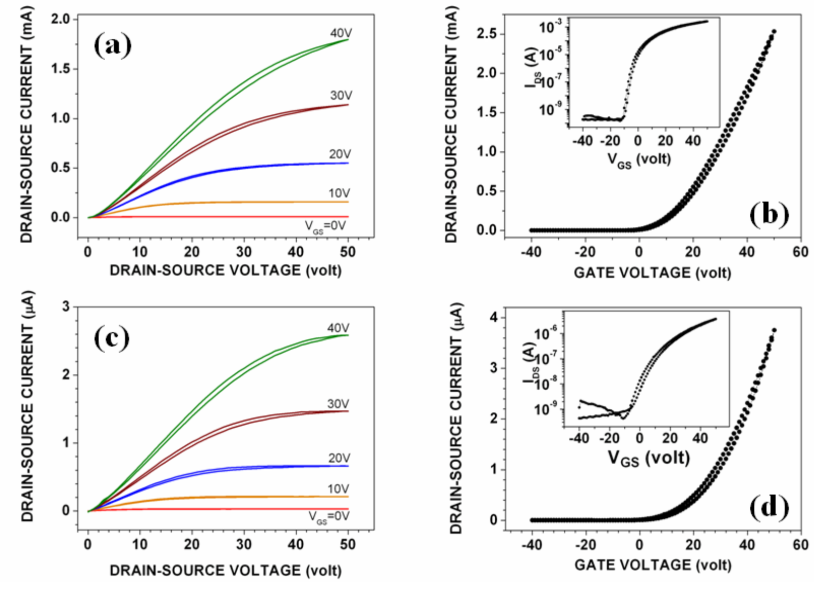

Figure: Output and transfer-curves in the saturation regime measured in vacuum for PDIF-CN2 transistors fabricated by (a), (b) SuMBD and (c), (d) OMBD techniques on HMDS-treated Si++/SiO2 substrates. In the inset of (b) and (d), semi-log plots of the transfer-curves are shown.

Applying the SuMBD technique to the PDIF-CN2 compound, we demonstrated that the kinetic energy (Ek) enhancement of the depositing molecules is an effective route to get n-type layers with good structural and electrical properties, even when the substrate is kept at room temperature during the deposition. Beyond the appealing applicative interest of this result, the possibility to combine Ek and Tsub should open the possibility to more accurately control the growth mode of PDIF-CN2 films, commonly exhibiting structure polymorphs when deposited by OMBD at high T_{sub} (140 °C).

Highlights

Other Materials - 2014

Tunable ferroelectric polarization and its interplay with spin–orbit coupling in tin iodide perovskites

Alessandro Stroppa[1], Domenico Di Sante[1,2], Paolo Barone[1], Menno Bokdam[3], Georg Kresse[3], Cesare Franchini[3], Myung-Hwan Whanbgo[4], Silvia Picozzi[1]

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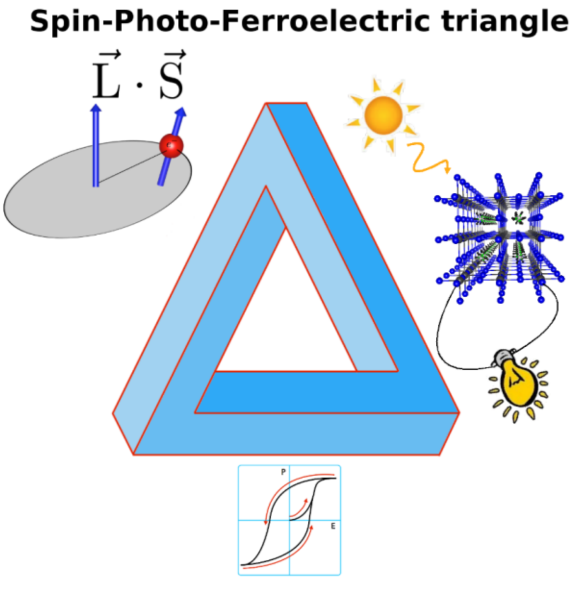
NATURE COMMUNICATIONS, 5, 5900 (2014)

Halide perovskites represent an emerging photovoltaic technology. Using density functional theory simulations and symmetry analysis, we discuss the properties in lead-free perovskite iodide (FA)SnI_3, containing the polar formamidinium cation FA, $(NH_2CHNH_2)^+$. We have shown that the perpendicular arrangement of FA molecules , leading to a 'weak' ferroelectric polarization, is energetically more stable than parallel arrangements of FA planes, being either antiferroelectric or 'strong' ferroelectric. Moreover, we show that the 'weak' and 'strong' ferroelectric states with the polar axis along different crystallographic directions are competing in energy, thus suggesting that, at least at low temperatures, an electric field could stabilize different states with the polarization rotated by 45°, resulting in a highly tunable ferroelectricity appealing for multistate logic. Intriguingly, the relatively strong spin–orbt coupling in noncentrosymmetric (FA)SnI_3 gives rise to a co-existence of Rashba and Dresselhaus effects and to a spin texture that can be induced, tuned and switched by an electric field controlling the ferroelectric state.



A pictorial triangle representing the interplay of dipolar ordering, photovoltaic properties and spin-orbit related phenomena in lead-free solid-state organic-inorganic halide perovskite solar cells.

Highlights

Other Materials - 2014

Giant frictional dissipation peaks and charge-density-wave slips at the $NbSe_2$ surface

Markus Langer[1], Marcin Kisiel[1] , Rémy Pawlak[1], Franco Pellegrini [2,3], Giuseppe E. Santoro[2,3,4], Renato Buzio[5], Andrea Gerbi[5], Geetha Balakrishnan[6], Alexis Baratoff[1], Erio Tosatti[2,3,4] and Ernst Meyer[1]

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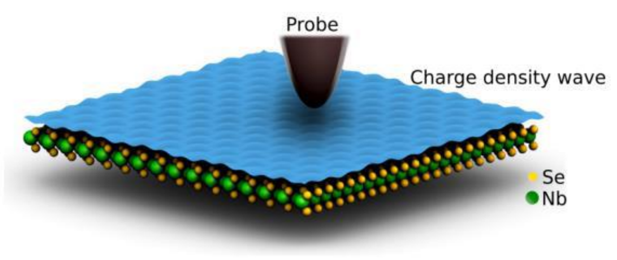
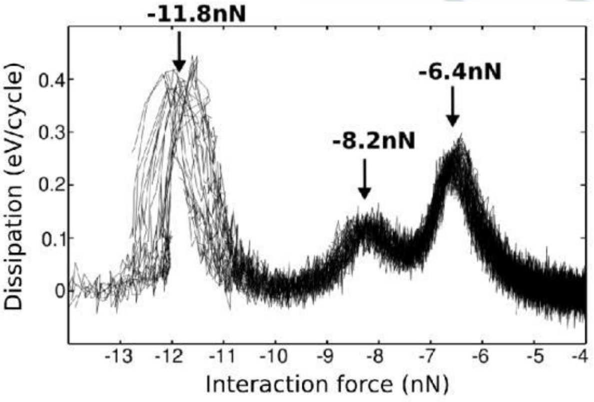
NATURE MATERIALS, 13, 173 - 177 (2014)

Understanding nanoscale friction and dissipation is central to nanotechnology. The recent detection of the electronic friction drop caused by the onset of superconductivity in Nb by means of an ultrasensitive non-contact pendulum atomic force microscope (AFM) raised hopes that a wider variety of mechanical-dissipation mechanisms become accessible. Here, we report a multiplet of AFM dissipation peaks arising a few nanometres above the surface of $NbSe_2$ — a layered compound exhibiting an incommensurate charge-density wave (CDW). Each peak appears at a well-defined tip–surface interaction force of the order of a nanonewton, and persists up to 70 K, where the short-range order of CDWs is known to disappear. Comparison of the measurements with a theoretical model suggests that the peaks are associated with local, tip-induced 2π phase slips of the CDW, and that dissipation maxima arise from hysteretic behaviour of the CDW phase as the tip oscillates at specific distances where sharp local slips occur.





(Left) An oscillating AFM tip in proximity to the charge-density wave on the $NbSe_2$ surface. (Right) Energy dissipation versus tip–sample interaction force. Three dissipation maxima appear, indicating tip-induced CDW phase slips.

Other Materials - 2014

Reentrant Surface Anisotropy in the Antiferromagnetic/Ferromagnetic Bilayer Mn/Co/Cu(001)

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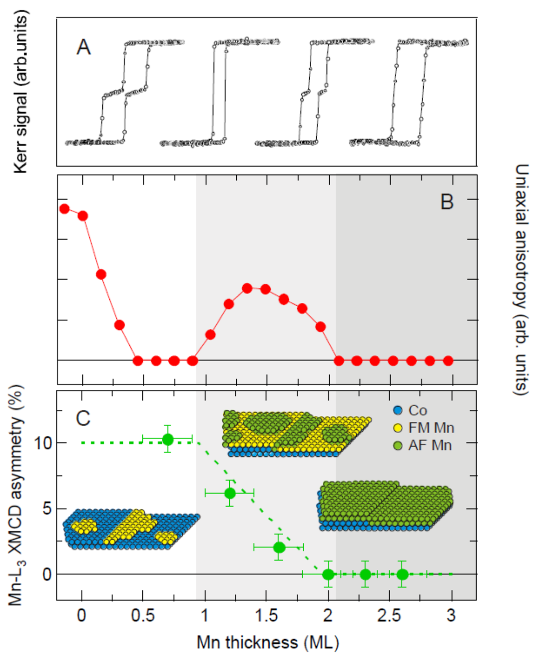
PHYSICAL REVIEW LETTERS 112, 037201 (2014)

The magnetic anisotropy of ferromagnetic (FM) nanostructures is strongly influenced by the presence of symmetry-breaking elements. This is for instance the case of low-coordinated sites at the surface of ultrathin magnetic films, whose contribution to the magnetic anisotropy may overwhelm that of the constituent material in the bulk form [1-3]. In antiferromagnetic (AF) nanostructures, the difficulty in assessing the magnetic anisotropy has hampered the identification of the role played by the same symmetry-breaking elements. In this respect, we have investigated the magnetic anisotropy energy of monatomic surface-step atoms in AF/FM epitaxial Mn/Co bilayers grown on stepped Cu(001) surfaces. As shown in Fig. B, a reentrant uniaxial surface anisotropy was observed for Mn thickness (tMn) between 1 and 2 monolayers (ML). X-ray magnetic circular dichroism (XMCD) experiments (Fig. C) show that the Mn films undergo a tMn-dependent transition from FM to AF in the 1–2 ML range, which entails the coexistence of FM and AF Mn phases in the film.



The observation of a sizeable uniaxial anisotropy exclusively in the Mn-thickness range of coexistence of the FM and AF phases points out the crucial role of the boundaries between FM and AF regions, thus showing that the magnetic anisotropy of low-coordinated atoms may not be the sole consequence of a geometric symmetry breaking, but rather arise at the boundary between two different magnetic phases.

Figure: (A) Hysteresis loops measured with external magnetic field perpendicular to the steps of Co/Cu(001) for increasing Mn coverage: 0, 0.7, 1.6, and 2 ML (from left to right); (B) Uniaxial anisotropy as a function of tMn in Mn/Co/Cu(001); (C) XMCD asymmetry at the Mn−L3 edge as a function of tMn. The insets schematically show the growth model.

[1] R. Moroni *et al.*, Phys. Rev. Lett. 91, 167207 (2003)
[2] F. Bisio *et al.*, Phys. Rev. Lett. 96, 057204 (2006)
[3] R. Moroni *et al.*, Phys. Rev. B 76, 214423 (2007)

Other Materials - 2014

Pattern formation of photoactivated functional polymers

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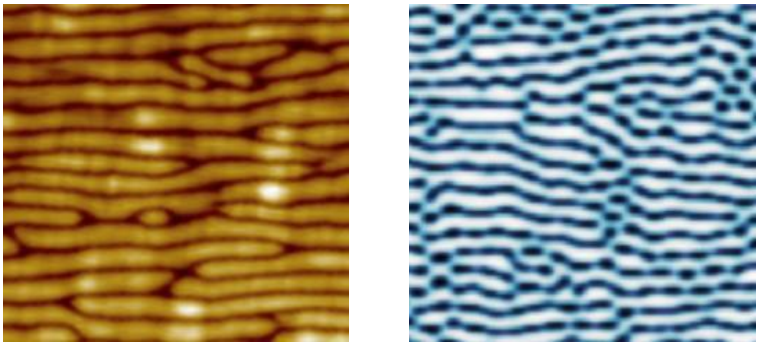
CNR-SPIN and Dipartimento di Fisica Università di Napoli Federico II

PROCEEDINGS OF THE NATONAL ACADEMY OF SCIENCE (PNAS), 111 (2014)

In 1952 the famous mathematician and computer science pioneer Alan Turing published his visionary work *The Chemical Basis of Morphogenesis*. In his work Turing developed an intuitive model explaining the formation of complex patterns found in nature, as for example the striped coat of a tiger.

Recently we showed that the complex patterns formed on the surface of azobenzene-containing polymers films can be understood in the spirit of Turing's work.

Azobenzene-containing polymers are special. They are *smart* polymers that alter their shape and properties when illuminated by light of suitable wavelengths. Under illumination, the polymer surface spontaneously reorganizes its morphology according to the light intensity and polarization state. The peculiar azopolymer sensitivity to illuminating light may have important application prospects in the area of optical nanolithography where photoresists are used in the fabrication process.



Atomic Force microscopy image of the reorganized polymer morphology (left) and simulation (right) after exposure to light

According to our new work [1], the role of light in photo-patterning of azo-polymers is of triggering the instability by creating two phases in the polymer, called *cis*- form and *trans*-form. Although these two forms are two configurations of the same molecule, they are quite different in terms of their chemical/physical properties. So, similarly to oil in water, these two phases do not mix and try to separate. This simple picture accounts for all the patterning found so far and actually adds new comprehension of the response of this important class of polymers to external light stimuli.

[1] H. Galinski, A. Ambrosio, P. Maddalena, I. Schenker, R. Spolenak, and F. Capasso, Instability-induced pattern formation of photoactivated functional polymers**,** *PNAS* vol. 111, p. 17017 (2014)

Highlights

Other Materials - 2015

Controlled steering of Cherenkov surface plasmon wakes with a one-dimensional metamaterial

Patrice Genevet[1], Daniel Wintz[1], Antonio Ambrosio[1,2], Alan She[1], Romain Blanchard[1], and Federico Capasso[1]

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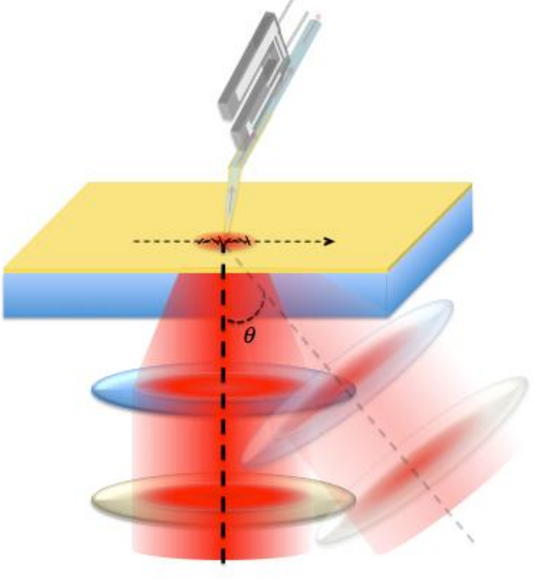
NATURE NANOTECHNOLOGY, 10 (2015)

In the Cherenkov effect a charged particle moving with a velocity faster than the phase velocity of light in the medium radiates light that forms a cone with a half angle determined by the ratio of the two speeds. Here, we show that by creating a running wave of polarization along a onedimensional metallic nanostructure consisting of subwavelength- spaced rotated apertures that propagates faster than the surface plasmon polariton phase velocity, we can generate surface plasmon wakes, a two-dimensional analogue of Cherenkov radiation. The running wave of polarization travels with a speed determined by the angle of incidence and the photon spin angular momentum of the incident radiation. By changing either one of these properties we demonstrate controlled steering of the Cherenkov surface plasmon wakes.



Scanning Near-Field Optical microscope operating in collection mode.

Nonequilibrium fluctuations as a distinctive feature of weak localization

C. Barone [1,2], F. Romeo [1,2], S. Pagano [1,2], C. Attanasio [1,2], G. Carapella [1,2], C. Cirillo [1,2], A. Galdi [2,3], G. Grimaldi [2], A. Guarino [1,2], A. Leo [1,2], A. Nigro [1,2] and P. Sabatino [1,2]

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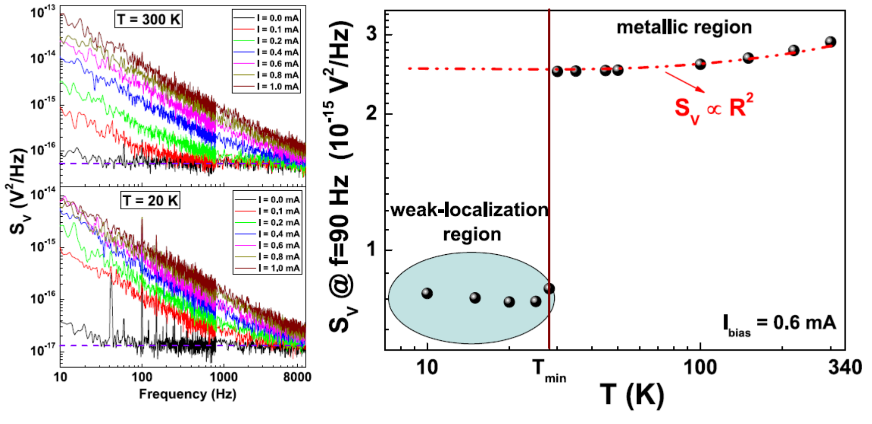
SCIENTIFIC REPORTS 5, 10705 (2015)

In two-dimensional materials, such as graphene, topological insulators, and two-dimensional electron gases, quantum interference effects, and in particular weak localization (WL), are likely to occur. These coherence effects are usually characterized by well-defined features in dc electrical transport, such as a resistivity increase and negative magnetoresistance below a crossover temperature. Recently, it has been shown that in magnetic and superconducting compounds, undergoing a WL transition, a specific low-frequency 1/f noise appears (see left panels in the figure below). An interpretation in terms of nonequilibrium universal conductance fluctuations (UCFs) has been given [1]. The universality of this unusual electric noise mechanism has been here verified by detailed voltage-spectral density investigations on ultrathin copper films. Also in the case of a simple metallic thin film, it has been observed that the amplitude of the noise is different when the crossover between WL and metallic region occurs (see right panel in the figure below). In particular, the voltage-noise is characterized by an anomalous linear dependence versus *I*, which is due to the dephasing effect on the local conductance fluctuations of the current bias exploring the percolative network of the sample. This anomalous fluctuation behaviour, detected in the WL regime, is a material-independent feature only associated with partial restoration of the sample coherence.



(Left) The spectral traces in the metallic (300 K) and WL (20 K) regions are shown for a 12 nm ultrathin copper film. (Right) Its noise amplitude, at 90 Hz and at a fixed bias current of 0.6 mA, is reported as a function of temperature.

[1] Barone, C. et al., Phys. Rev. B 87, 245113 (2013).

Highlights

Other Materials - 2015

Electron injection barrier and energy-level alignment at the Au/PDI8-CN_2 interface via current–voltage measurements and ballistic emission microscopy

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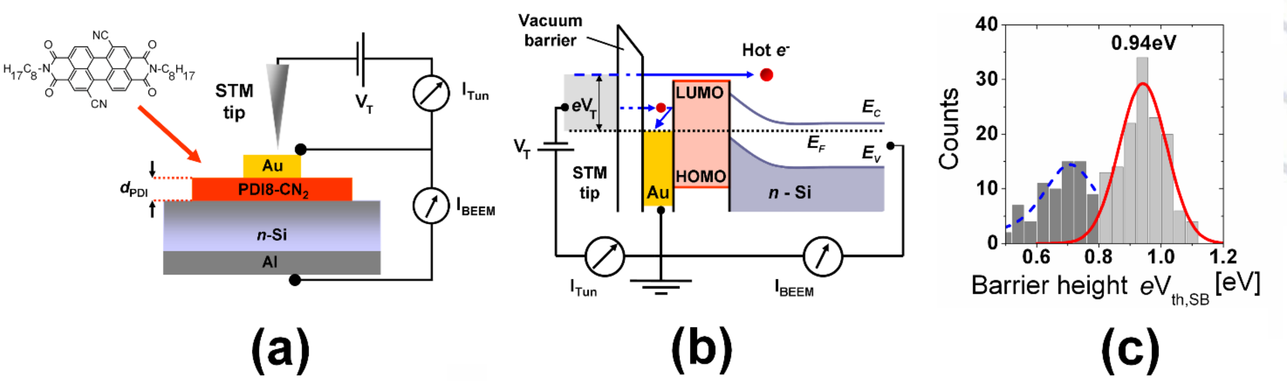
ORGANIC ELECTRONICS, 18 44 (2015)

We probe electron transport across the Au/organic interface based on oriented thin films of the high-performance n-type perylene diimide semiconductor PDI8-CN_2. Temperature-dependent current–voltage characteristics and complementary ballistic electron emission microscopy studies reveal that rectification at the Au/PDI8-CN_2 interface is controlled by a spatially inhomogeneous injection barrier, that varies on a length scale of tens of nanometers according to a Gaussian distribution with mean value ~0.94 eV and standard deviation ~100 meV. The former gradually shifts to ~1.04 eV on increasing PDI8-CN_2 thickness from 5 nm to 50 nm. Experimental evidences and general arguments further allow to establish the energetics at the Au/PDI8-CN_2 interface. Our work indicates injection-limited current flow in PDI8-CN_2-based devices with evaporated Au electrodes.



(a) Schematic diagram of the Au/PDI8-CN_2/n-Si contact barrier diode and (b) the set-up for ballistic electron emission microscopy BEEM measurements. (c) Histogram of the local barrier heights extracted from individual BEEM spectra.

M. Barra, F.V. Di Girolamo, F. Chiarella, M. Salluzzo, Z. Chen, et al., J. Phys. Chem. C 114, 20387 (2010)
A. Gerbi, R. Buzio, A. Gadaleta, A. Anghinolfi, et al., Adv. Mater. Interfaces 1, 1300057 (2014)

One-Dimensional Chirality: Strong Optical Activity in Epsilon-Near-Zero Metamaterials

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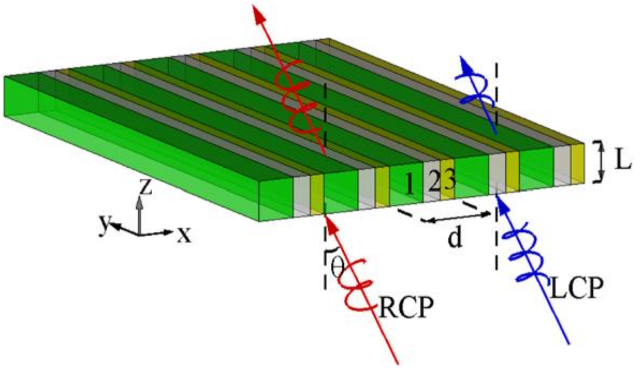
[4]Charles M. Bowden Research Center RDMR-WDS-WO, RDECOM, Redstone Arsenal, Alabama 35898-5000, USA

PHYSICAL REVIEW LETTERS 115, 057401 (2015)

We suggest that electromagnetic chirality, generally displayed by 3D or 2D complex chiral structures, can occur in 1D patterned composites whose components are achiral. This feature is highly unexpected in a 1D system which is geometrically achiral since its mirror image can always be superposed onto it by a 180 deg rotation. We analytically evaluate from first principles the bianisotropic response of multilayered metamaterials and we show that the chiral tensor is not vanishing if the system is geometrically one-dimensional chiral; i.e., its mirror image cannot be superposed onto it by using translations without resorting to rotations. As a signature of 1D chirality, we show that 1D chiral metamaterials support optical activity and we prove that this phenomenon undergoes a dramatic nonresonant enhancement in the epsilon-near-zero regime where the magnetoelectric coupling can become dominant in the constitutive relations.



Sketch of metamaterial slab (with N = 3 layers) and waves scattering geometry. The transmission amplitudes of the right-handed (RCP;+) and left-handed (LCP;−) circular polarized plane waves are not equal for $\theta \neq 0$ as manifestation of 1D chirality.

Zigzag and Checkerboard Magnetic Patterns in Orbitally Directional Double-Exchange Systems

Wojciech Brzezicki[1,2], C. Noce[1], A. Romano[1], and Mario Cuoco[1]

[1]CNR-SPIN, IT-84084 Fisciano (SA), Italy, and Dipartimento di Fisica "E. R. Caianiello," Universitá di Salerno, IT-84084 Fisciano (SA), Italy

[2]Marian Smoluchowski Institute of Physics, Jagiellonian University, prof. S. Łojasiewicza 11, PL-30348 Kraków, Poland

PHYSICAL REVIEW LETTERS 114, 247002 (2015)

The formation of spin-charge density modulations is strongly related to the orbital character of the electronic system as demonstrated by the dominant role of lattice distortions in itinerant e_g systems compared with the spin-orbital exchanges in models of insulating t_{2g} electrons. More unexplored is the case of partially localized t_{2g} electrons in systems with low dimensionality and competing magnetic correlations. In this context, new phenomena have recently been observed and investigated in hybrid oxides with partial substitution of inequivalent transition metal ions.

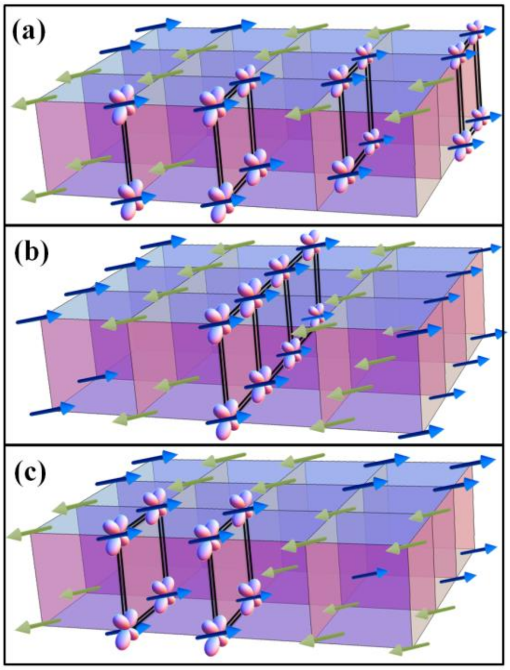


Figure: Schematic view of layered t_{2g} systems with d_{xz-yz} itinerant degrees of freedom and different antiferromagnetic and orbital patterns: (a) two-site segment zigzag (E phase), (b) straight stripes, and (c) 2 × 2- cell checkerboard.

We analyze a t_{2g} double-exchange (DE) system where the orbital directionality of the itinerant degrees of freedom is a key dynamical feature that self-adjusts in response to doping and leads to a phase diagram dominated by two classes of ground states with zigzag and checkerboard patterns.

The DE mechanism is known to be at the origin of itinerant ferromagnetism in e_g systems and to yield exotic magnetic structures and quantum states based on electronic self-organization. In the orbitally directional DE system, we show that the prevalence of distinct quantum orderings (Figure) is tied to the formation of orbital molecules that in one-dimensional paths make insulating zigzag states kinetically more favorable than metallic stripes, thus allowing for a novel doping-induced metal-to-insulator transition. We demonstrate how the breaking of the orbital directionality as well as the inclusion of the Coulomb interaction can significantly affect the zigzag-checkerboard competition and lead to orbital or charge ordering in the ground state.

Highlights

Other Materials - 2015

Crossover from Super- to Subdiffusive Motion and Memory Effects in Crystalline Organic Semiconductors

Giulio De Filippis[1], Vittorio Cataudella[1], A.S. Mishchenko[2], N. Nagaosa[2,3] et al.

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[2] RIKEN Center for Emergent Matter Science (CEMS), Wako, Saitama 351-0198, Japan.
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PHYSICAL REVIEW LETTERS, 114, (2015)

The transport properties at finite temperature of crystalline organic semiconductors are investigated, within the Su-Schrieffer-Heeger model, by combining an exact diagonalization technique, Monte Carlo approaches, and a maximum entropy method. The temperature-dependent mobility data measured in single crystals of rubrene are successfully reproduced: a crossover from super- to subdiffusive motion occurs in the range $150 \leq T \leq 200$ K, where the mean free path becomes of the order of the lattice parameter and strong memory effects start to appear. We provide an effective model, which can successfully explain features of the absorption spectra at low frequencies. The observed response to slowly varying electric field is interpreted by means of a simple model where the interaction between the charge carrier and lattice polarization modes is simulated by a harmonic interaction between a fictitious particle and an electron embedded in a viscous fluid.

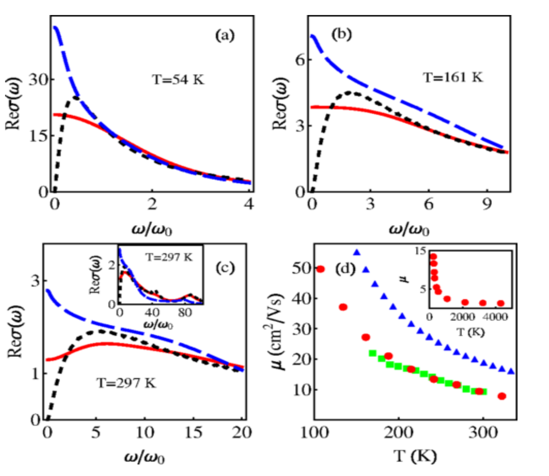

Figure 1 [(a)–(c)] OC, in units of $a^2\ e^2/\hbar$, in different approximations: exact results (solid red line), Boltzmann (long-dashed blue line), and adiabatic (short-dashed black line) approaches. (d) Temperature dependence of the mobility in rubrene [1] (green squares) compared with exact results (red circles) and Boltzmann approach (blue triangles). In the inset is mobility (exact results in units cm^2/Vs) in a wider range of temperatures.

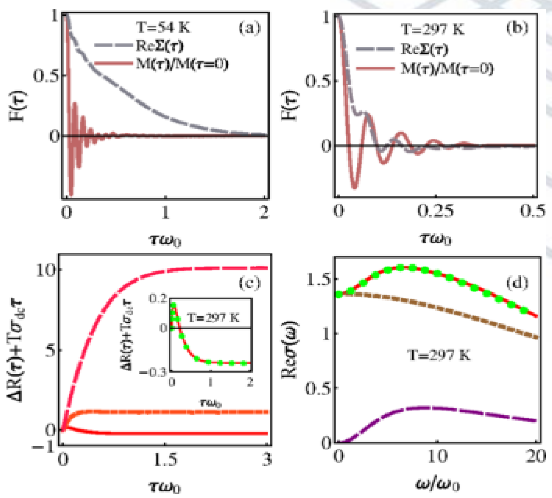

Figure 2 [(a) and (b)] Comparison between current operator relaxation function and memory function at two temperatures; $F(\tau)$ stands for the dimensionless quantities $\mathrm{Re}\Sigma(\tau)$ and $M(\tau)/M(\tau=0)$. (c) Relaxation function of the polarization at different temperatures; in the inset is a comparison with the model (green circles). (d) $\mathrm{Re}\sigma(\omega)$: exact results (red solid line); Drude-Lorentz contribution (DLC) (long-dashed purple line), and note that the mobility of DLC is zero; Drude contribution (DC) (short-dashed brown line); DCL+DC (green circles).

[1] V. Podzorov, E. Menard, J. A. Rogers, and M. E. Gershenson, Phys. Rev. Lett. 95, 226601 (2005).

Highlights

Other Materials - 2015

Ferroelectric Polarization of $CH_3NH_3PbI_3$: A detailed Study Based on Density Functional Theory and Symmetry Analysis

Alessandro Stroppa*, Claudio Quarti#, Filippo De Angelis#, and Silvia Picozzi*

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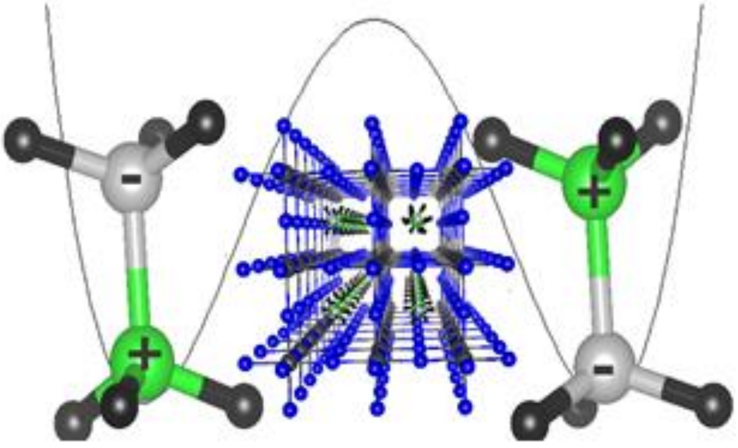
#Computational Laboratory for Hybrid/Organic Photovoltaics (CLHYO), CNR-ISTM, 06123, Perugia, Italy

THE JOURNAL OF PHYSICAL CHEMISTRY LETTERS 6 (12), P.2223-2231 (2015)

Ferroelectricity in halide perovskites currently represents a crucial issue, as it may have an important role for the enhancement of solar cells efficiency. Simulations of ferroelectric properties based on density functional theory are conceptually more demanding compared with “conventional” inorganic ferroelectrics due to the presence of both organic and inorganic components in the same compound. Here we present a detailed study focused on the prototypical $CH_3NH_3PbI_3$ perovskite. By using density functional theory combined with symmetry mode analysis, we disentangle the contributions of the methylammonium cations and the role of the inorganic framework, therefore suggesting possible routes to enhance the polarization in this compound. Our estimate of the polarization for the tetragonal phase at low temperature is ~4.42 μC/cm^2, which is substantially lower than that of traditional perovskite oxides.



Possible dipole ordering at low temperature in perovskite halides.

Highlights

Fundamental Properties - 2014

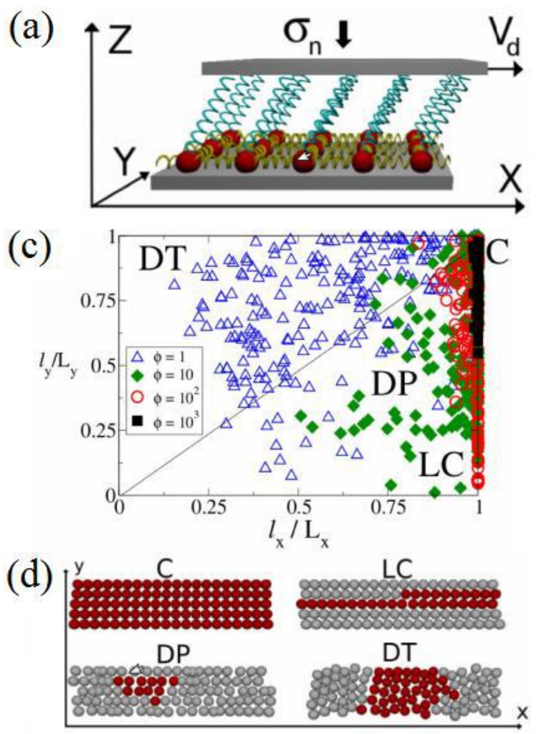
Non-monotonic dependence of the friction coefficient on heterogeneous stiffness

F. Giacco[1,2], L. Saggese[3], L. de Arcangelis[3], M. Pica Ciamarra[1,4], E. Lippiello[2]

[1]CNR-SPIN, Dep. of Physics, University of Naples ``Federico II'', Naples, Italy
[2]Dep. of Mathematics and Physics, Second University of Naples and CNISM, Caserta, Italy
[3]Dep. of Industrial and Information Eng., Second University of Naples and CNISM, Aversa, Italy
[4]Division of Physics and Applied Physics, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore

NATURE SCIENTIFIC REPORT 4, 6772 (2014)

The complexity of the frictional dynamics at the microscopic scale makes difficult to identify all of its controlling parameters. Indeed, experiments on sheared elastic bodies have shown that the static friction coefficient depends on loading conditions, the real area of contact along the interfaces and the confining pressure. We have shown, by means of numerical simulations of a two dimensional spring-block model with a simple local friction law, that the macroscopic friction coefficient depends non-monotonically on the elastic properties of the system. This occurs because elasticity controls the geometrical features of the rupture fronts during the stick-slip dynamics.



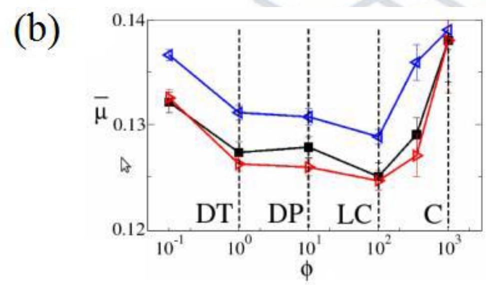


Figure: (a) Schematic representation of the 2D Burridge-Knopoff spring-block model. (b) The macroscopic friction coefficient μ depends non-monotonically on the degree of elastic heterogeneity ⍰. The dashed vertical lines indicate four regimes: crystalline C, laminar crystalline LC, disorder-parallel DP and disorder-transverse DT. (c) Scatter plot of the dimensions of the clusters of moving particles, along the directions parallel and transverse to the shear. By reducing the stiffness of the system, ⍰, we observe regions with different cluster morphology. (d) Sketch of the cluster geometries corresponding to the regions indicated in (c).

Highlights

Fundamental Properties - 2014

Heat-exchange statistics in driven open quantum systems

S. Gasparinetti[1], P. Solinas[2] , A. Braggio[2] and M. Sassetti[2,3]

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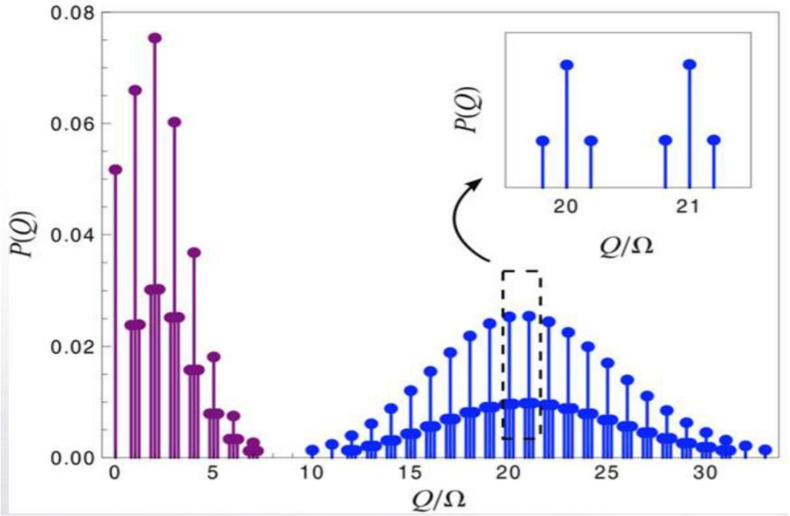
NEW JOURNAL OF PHYSICS, 16, 115001 (2014)

As the dimensions of physical systems approach the nanoscale, the laws of thermodynamics must be reconsidered due to the increased importance of fluctuations and quantum effects. While the statistical mechanics of small classical systems is relatively well understood, the quantum case still poses challenges. Here, we set up a formalism that allows us to calculate the full probability distribution of energy exchanges between a periodically driven quantum system and a thermalized heat reservoir. The formalism combines Floquet theory with a generalized master equation approach. For a driven two- level system and in the long-time limit, we obtain a universal expression for the distribution, providing clear physical insight into the exchanged energy quanta. We illustrate our approach in two analytically solvable cases and discuss the differences in the corresponding distributions. Our predictions could be directly tested in a variety of systems, including optical cavities and solid-state devices. Particularly promising in this direction are the fast thermometry techniques recently developed in the group of Prof. J. Pekola [1].



Probability distribution of the dissipated energy for a driven two level system interacting with the environment. The purple and the blue distribution are for short and long time distribution, respectively. The energy is dissipated in triplet quanta corresponding to the multiple of the drive frequency and the energy gap of the system.

[1] S Gasparinetti *et al* , Physical Review Applied 3 (1), 014007 (2015).

Highlights

Fundamental Properties - 2014

Correlation dynamics during a slow interaction quench in a one dimensional Bose gas

Roberta Citro,[1] Jean-Sébastien Bernier,[2] Corinna Kollath,[3] and Edmond Orignac[4]

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PHYSICAL REVIEW LETTERS 112, 065301-065305 (2014)

We investigate the response of a one-dimensional Bose gas to a slow increase of its interaction strength. We focus on the dynamics of equal-time single-particle correlations treating the Lieb-Liniger model within a bosonization approach and the Bose-Hubbard model using the time-dependent density-matrix renormalization group method (t-DMRG). For short distances, correlations follow a power law with distance with an exponent given by the adiabatic approximation. In contrast, for long distances, correlations decay algebraically with an exponent understood within the sudden quench approximation. This long distance regime is separated from an intermediate distance one by a generalized Lieb-Robinson criterion. In this intermediate regime, bosonization predicts that single-particle correlations decay following a stretched exponential, an unconventional behavior. We develop here an intuitive understanding for the propagation of correlations, in terms of a generalized light cone, applicable to a large variety of systems and quench forms.

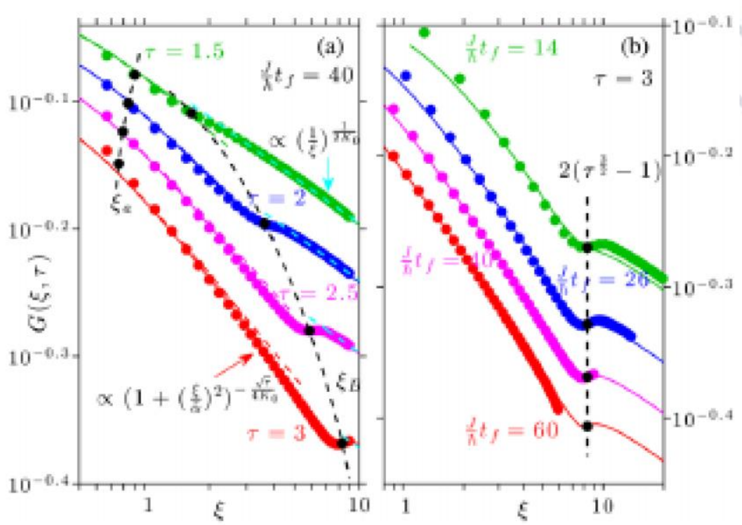

Figure: Decay of single-particle correlations with increasing distance for different τ (inverse velocity of the ramp). Comparison between results obtained using bosonization and t-DMRG for the Bose-Hubbard model (circles) for a quench from on-site interaction equal to hopping amplitude J (lattice length: L =100, filling n=1). (a) The two dashed lines define the generalized Lieb-Robinson bound. (b) Comparison between different ramp times tf for a fixed value of τ=3. The position of the bound does not depend on the velocity of the ramp.

Fundamental Properties - 2014

Scale Invariance and Universality in a Cold Gas of Indirect Excitons

S. V. Andreev,[1] A. A. Varlamov,[2] and A. V. Kavokin[3]

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[2]CNR-SPIN, Tor Vergata, Viale del Politecnico 1, I-00133 Rome, Italy
[3]Physics and Astronomy School, University of Southampton, Highfield, Southampton SO171BJ, United Kingdom

PHYSICAL REVIEW LETTERS, 112, 036401 (2014)

We address, theoretically, the puzzling similarity observed in the thermodynamic behavior of independent clouds of cold dipolar excitons in coupled semiconductor quantum wells. We argue that the condensation of self-trapped exciton gas starts at the same critical temperature in all traps due to the specific scaling rule. As a consequence of the reduced dimensionality of the system, the scaling parameters appear to be insensitive to disorder.

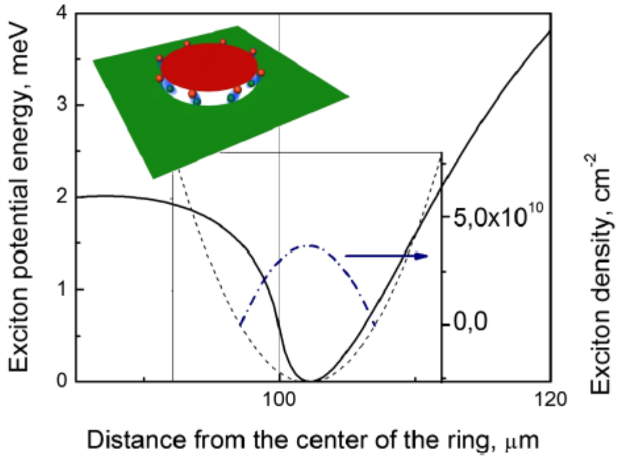

Fig. 1 Calculated potential profile for the radial motion of an indirect exciton in the vicinity of the ring (solid line) and the model harmonic trap (dashed line). The localization is due to the macroscopic charge separation (color inset on the left) which induces an in-plane electric field. The field tilts the exciton dipoles and thus reduces their potential energy. At low temperatures, excitons condense at the potential minimum located near the charge boundary. As a consequence of strong repulsive interactions, the density profile of the exciton condensate is very smooth and merely reproduces the shape of the trap (dotted-dashed line).

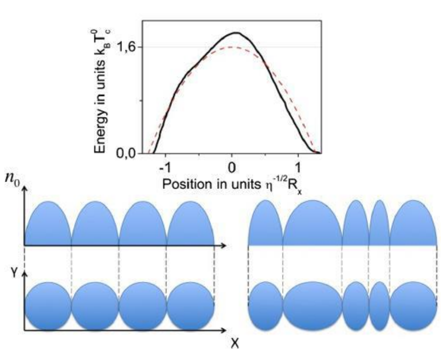

Fig. 2. The T=0 Thomas-Fermi result for the variation of exciton energy along the ring. The exciton resonance position measured in [1] from PL spectra is shown by the solid line. The Thomas-Fermi radius of the bead is measured to be Rx=20 μm.
(Bottom) The topological transformation of the condensate density conserving the total number of particles.

[1] S. Yang, A.V. Mintsev, A.T. Hammack, L.V. Butov, and A.C. Gossard, Phys. Rev. B 75, 033311 (2007).

Highlights

Fundamental Properties - 2015

Mobility of Holstein Polaron at Finite Temperature: An Unbiased Approach

A.S. Mishchenko[1], N. Nagaosa[1,2], G. De Filippis[3], A. de Candia[3] and V. Cataudella[3]

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[2] Department of Applied Physics, The University of Tokyo, Tokyo 113-8656, Japan
[3] SPIN-CNR and Dipartimento di Fisica, Università di Napoli Federico II, I-80126 Napoli, Italy

PHYSICAL REVIEW LETTERS, 114, (2015)

We present the first unbiased results for the mobility μ of a one-dimensional Holstein polaron obtained by numerical analytic continuation combined with diagrammatic and worldline Monte Carlo methods in the thermodynamic limit. We have identified for the first time several distinct regimes in the $\lambda-T$ plane including a band conduction region, incoherent metallic region, an activated hopping region, and a high-temperature saturation region. We observe that although mobilities and mean free paths at different values of λ differ by many orders of magnitude at small temperatures, their values at T larger than the bandwidth become very close to each other.

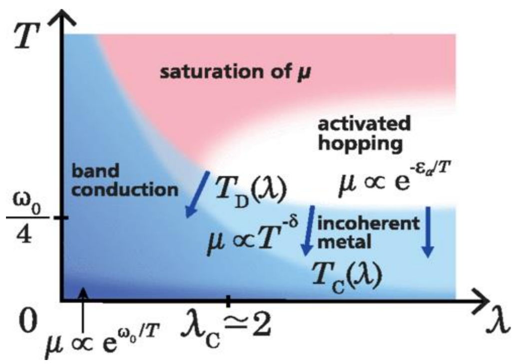

Figure 1 Transport regimes of polaron. Schematic phase diagram showing the four different regimes of polaron mobility μ in the plane of $\lambda-T$ (λ: EPC strength, T: temperature). Here, the unit of energy is t=1, and ω_0 is the phonon frequency. Arrows show the direction of shift of the borderlines between different regimes when the phonon frequency decreases.

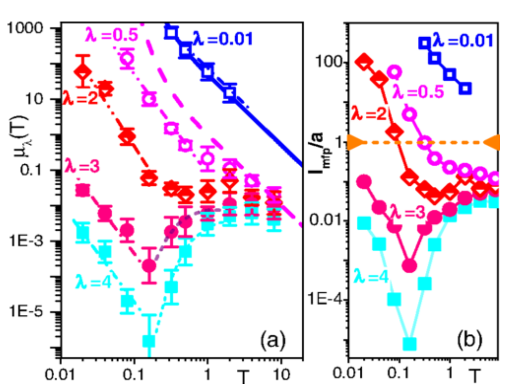

Figure 2 Temperature dependence of mobility and MFP at ω_0 =t. (a) dc mobility μ_λ (T) (in units of $ea^2/\hbar$). Unbiased numeric values at λ=0.01 (open squares), λ=0.5 (open circles), λ=2 (semifilled diamonds), λ=3 (filled circles), and λ=4 (filled squares). Solid bold (λ=0.01) and dashed bold (λ=0.5) lines in the top part of the figure show the results obtained by the Boltzmann approach [1]. Fit of the mobility by the activation law is shown for T>0.2 at λ=3 (short-dash line) and λ=4 (dotted line). Linear dash-dot-dot lines are fits of the low-temperature contribution of mobility, for all the values of λ, by a power law $\mu\sim T^{-\delta}$. (b) MFP, in units of the lattice parameter a, vs temperature.

[1] G. De Filippis, V. Cataudella, A. de Candia, A. S. Mishchenko, and N. Nagaosa, Phys. Rev. B 90, 014310 (2014).

Fundamental Properties - 2015

Edge States and Topological Insulating Phases Generated by Curving a Nanowire with Rashba Spin-Orbit Coupling

Paola Gentile[1], Mario Cuoco[1], and Carmine Ortix[2,3]

[1]CNR-SPIN and Dipartimento di Fisica "E. R. Caianiello", Università di Salerno, I-84084 Fisciano (Salerno), Italy
[2]Institute for Theoretical Solid State Physics, IFW-Dresden, Helmholtzstraße 20, D-01069 Dresden, Germany
[3]Institute for Theoretical Physics, Center for Extreme Matter and Emergent Phenomena, Utrecht University, Leuvenlaan 4, 3584 CE Utrecht, Netherlands

PHYSICAL REVIEW LETTERS 115, 256801 (2015)

Spin-orbit coupling (SOC) is considered a key ingredient to generate topological phases. Although this requirement largely restricts the number of potential candidate materials, an appealing perspective comes from recent predictions [1] about the possibility to induce via geometric curvature a sizeable Rashba spin-orbit interaction in materials that intrinsically do not possess an appreciable SOC. Within this context, by considering the paradigmatic example of quantum wires with Rashba SOC, periodically corrugated at the nanometre scale, we prove that curvature effects in low-dimensional nanomaterials can promote the generation of topological states of matter. The effect of the periodic curvature generally results in the appearance of insulating phases with a corresponding novel butterfly spectrum characterized by the formation of finite measure complex regions of forbidden energies (Fig. 1).

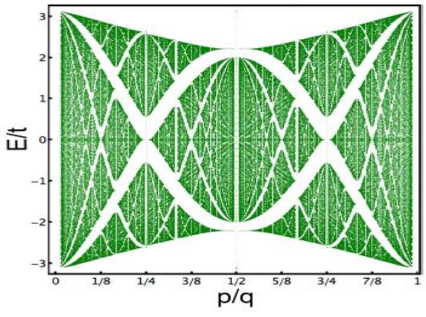

Fig. 1) Butterfly spectrum for the peridically corrugated nanowire as a function of the period p/q.

When the Fermi energy lies in the gaps, the system displays localized end states protected by topology (Fig.2a). We show that for certain superstructure periods the system possesses topologically non-trivial insulating phases at half-filling (Fig.2b).

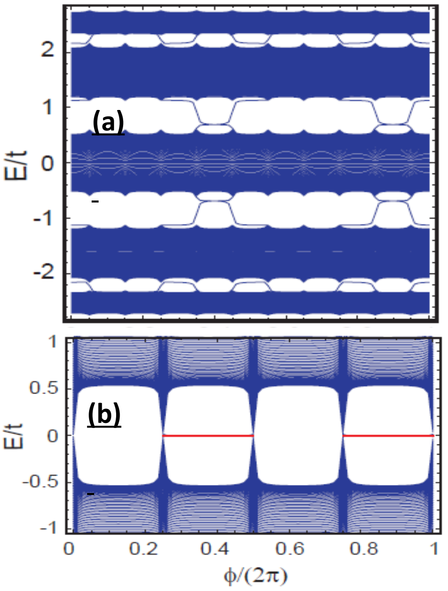

Fig. 2) Energy spectrum of the peridically corrugated nanowire for p/q=1/5 (a) and p/q= 1/4 (b).

[1] P. Gentile, M. Cuoco, C. Ortix, SPIN, Vol. 3, No. 2, 1340002 (2013).

Highlights

Fundamental Properties - 2015

Quantum transport in Rashba spin–orbit materials: a review

Dario Bercioux[1,2,3] and Procolo Lucignano[4,5]

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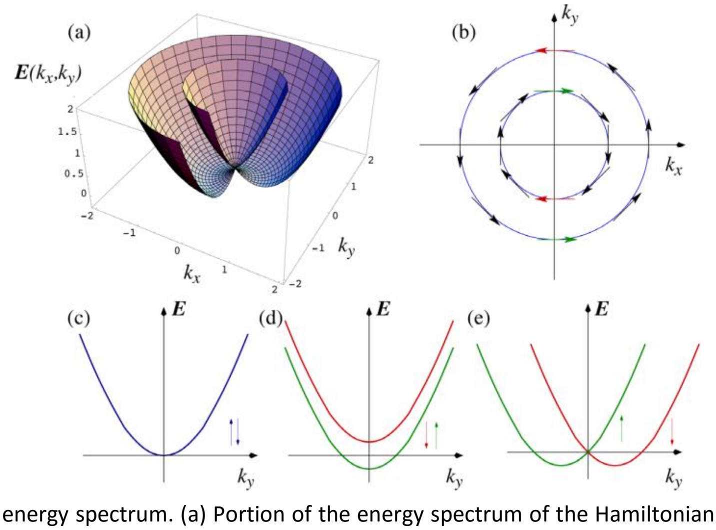
[2]IKERBASQUE, Basque Foundation of Science, 48011 Bilbao, Basque Country, Spain
[3]Dahlem Center for Complex Quantum Systems and Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, D-14195 Berlin, Germany
[4]CNR-SPIN Napoli, Monte Sant'Angelo: via Cinthia, I-80126 Napoli, Italy
[5]Dipartimento di Fisica, Università di Napoli 'Federico II', Monte Sant'Angelo, I-80126 Napoli, Italy

REPORTS ON PROGRESS IN PHYSICS 78, 106001 (2015)

In this review article we have described spin-dependent transport in materials with spin–orbit interaction of Rashba type. We mainly focused our attention on semiconductor heterostructures, however we have considered topological insulators, graphene and hybrid structures involving superconductors as well. Starting from the Rashba Hamiltonian in a two dimensional electron gas we have then described transport properties of two- and quasi-one-dimensional systems. The problem of spin current generation and interference effects in mesoscopic devices is described in detail. We have addressed also the role of Rashba interaction on localisation effects in lattices with nontrivial topology, as well as on the Ahronov–Casher effect in ring structures. In the end, we have included a brief section describing also some related topics including the spin-Hall effect, the transition from weak localisation to weak anti localisation and the physics of Majorana fermions in hybrid heterostructures involving Rashba materials in the presence of superconductivity.



Properties of the Rashba energy spectrum. (a) Portion of the energy spectrum of the Hamiltonian. (b) The Fermi contours relative to the Hamiltonian, the spin states are shown as well. (c) section of the energy spectrum for a free electron. (d) section of the energy spectrum for an electron in presence of a magnetic field, e.g. Zeeman splitting. (e) section of the energy spectrum for an electron in presence of RSOI.

Highlights

Fundamental Properties - 2015

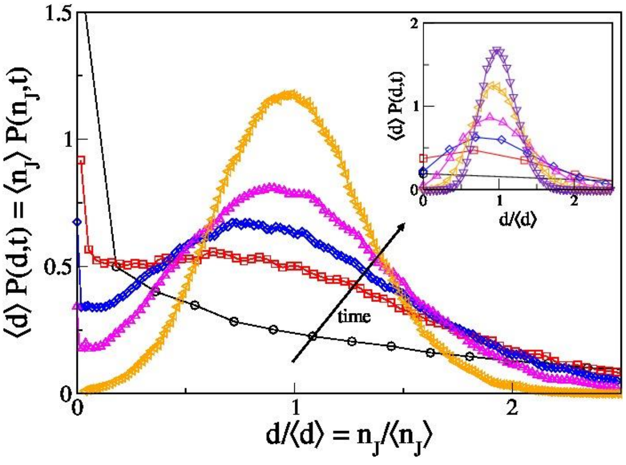
Dynamic phase coexistence in glass forming liquids

Raffaele Pastore[1,2], Antonio Coniglio[1] and Massimo Pica Ciamarra[1,3]

[1]CNR-SPIN, Napoli, Italy
[2]University of Cincinnati and Procter and Gamble Co., Cincinnati, Ohio, USA
[3]Nanyang Technological University, Singapore

NATURE SCIENTIFIC REPORTS 5, 1170 (2015)

In liquids approaching the glass transition, the structure remains almost unchanged but the dynamics becomes dramatically sluggish and heterogeneous. A fascinating hypothesis for explaining this dynamics postulates the temporary coexistence of two phases of fast and slow particles [1]. However, this speculative scenario is poorly supported by quantitative results, as a dynamical order parameter that acquires a transient bimodal shape has never been found, and the two phases are commonly identified empirically [2]. Here we provide the first direct observation of the dynamical coexistence of two phases with different diffusivities, by showing that in the deeply supercooled regime the distribution of the single-particle diffusivities acquires a transient bimodal shape. Our work offers a basis for rationalizing the dynamics of supercooled liquids and for highlighting the elusive correlations between structure and dynamics [3].



Diffusivity distribution in a glass-former model. Probability distribution of the single particle diffusion coefficient at different time, rescaled by the average diffusivity, for a moderately (inset) and a deeply supercooled liquid (main panel), respectively. At deep supercooling and intermediate time, the distribution acquires a temporary bimodal shape with the maxima at d/<d>=0 and d/<d>=1 corresponding to the slow and to the fast particles, respectively.

[1] E.R. Weeks et al., Science 287, 627 (2000).
[2] L.O. Hedges et al. Science 323, 1309 (2009).
[3] R. Pastore et al., arXiv 1604.03043 (2016), accepted in JSTAT.

Life & events

Main events

2014

Apr

L.G. Aslamazov, A.A. Varlamov, "The Wonders of Physics" Chinese translation, *China Science Publishing & Media Ltd. (Science Press)*, Beijing ISBN 978-7-03-039444-6, (2014) .

May

5 - 6

"From Condensed to Dark Matter"

http://webdip.fisica.unina.it/firb/hnd/majoranaws/majoranaws.html
Frascati (RM)

The aim of this workshop was to collect prominent scientists who are actively working on Majorana fermions in several fields, ranging from Condensed Matter to High Energy Physics.
The workshop has been held at INFN Laboratories in Frascati and is supported by INFN (Nuclear physics Institute Italy), CMTP (Center for Mathematics and theoretical Physics, Rome), CNR-ISC (Rome) and by CNR-SPIN and the Department of Physics of the University of Naples "Federico II" through the FIRB-HybridNanodev project.

15 - 19

"Superconductivity for Energy"

The Conference pointed at joining together researchers with high expertise and international recognition in the field of large scale applications of superconducting materials.
Topics: High Power Applications of Superconductors: materials, cables and magnets; Frontiers in High Field Magnet technology; Superconductors for Energy; Power Devices (Motors, SMES, FCL); High Current superconductivity; Superconducting properties and functionalities for new applications

http://s4e.fisica.unisa.it
Paestum (SA)

June

25 - 27

Surfaces, Interfaces and Functionalization Processes in Organic Compounds and Applications

SINFO II - Workshop
http://organics2014.spin.cnr.it
Trieste

The workshop aims at providing scientists from the CNR and associated Institutions with a forum to share the latest information and ideas on the fundamental properties of organic semiconductor and small molecule overlayers as well as their future applications and implementation into working devices. It is expected to identify emerging routes for the control and analysis of the electronic, magnetic, and optical properties of organic compounds, hybrid systems and bio-functionalized surfaces.

30

July

1

SPIN Scientific Annual Conference
http://www.spin.cnr.it/images/events/congressospin2014.pdf
Genova

The conference saw the participation of many researchers from different SPIN sections and aimed to verify the SPIN scientific activities by critically examining the scientific structure and organization of the institute itself. The most significant highlights and the results of the call for SEED projects for young researchers were presented. Here it was discussed and gained a new organization by identifying six research lines that will characterize the institution.

Main events

2014

Aug. 31 – Sept. 4

"Physics and Applications of Superconducting Hybrid Nano-Engineered Devices"
Nanoscale Superconductivity (NanoSC) COST Action

http://www.leibniz-ipht.de/en/snc2014/info.html
Santa Maria di Castellabate (SA)

The conference organized in in collaboration with Seconda Università di Napoli, Università di Napoli Federico II, CNR-SPIN, covered the following topics: superconducting hybrid and/or nano junctions: physics and applications; phase dynamics of Josephson junctions; vortex physics; nanoscale imaging; high frequency and optical detection by Josephson junctions and superconducting nanowires; novel superconducting materials and unconventional superconductivity; superconductiivity at the nanoscale; superconducting nanostructures for plasmonics; superconducting nanostructures for plasmonic

7

Superconducting Nanocircuits
International workshop

http://www.leibniz-ipht.de/en/snc2014/info.html
Acquafredda di Maratea (PZ)

The Workshop is intended to bring together leading scientists actively working in different sub-fields of mesoscopic superconductivity in order to overview the present status of the field and most recent advances, to visualize further research prospects and to promote new collaborations. The Workshop program will include talks of the leading experts, both theorists and experimentalists, in a number of most exciting topics in the field.

22 - 23

TO-BE
fallmeeting2014

http://to-be.spin.cnr.it/events/fall-meeting-2014
Roma

The first scientific meeting of the TO BE COST Action entitled "Towards Oxide-Based Electronics: science, sample growth and applications of transition metal oxides" has been held in University La Sapienza. The meeting program covered the topics ones of the Memorandum of Undestanding of the TO-BE COST Action: Fundamental understanding of transition metal oxides and heterostructures: theory and experiment; Large area growth of transition metal oxides film; Epitaxial Growth of oxides on Si and other electronic substrates; Real-time monitoring of oxide thin films; Transition metal oxides for nanoelectronics; Transition metal oxides for microactuation and microsensing; Transition metal oxides for energy conversion applications.

24 - 26

Conference on Superconductivity and Functional Oxides
http://www.phys.uniroma1.it/fisica/archivionotizie/superfox-2014
Rome

SuperFOx 2014

The SuperFox workshop has interdisciplinary character and addresses a wide variety of topics: Superconductive materials and applications; Films, interfaces, Graphene; Topological Insulators and other low-dimensional systems; Strongly correlated systems; Nanostructured materials and devices; Magnetic oxides; Dielectrics, ferroelectrics and multiferroics. This conference is the merger of SATT (Conferenza Nazionale di Superconduttività) and FOxE (Congresso Nazionale sugli Ossidi Funzionali per l'Elettronica). SuperFOx will provide a common forum for scientists from the fields of superconductivity, functional oxides and low-dimensional systems, with prime focus on new ideas, concepts and applications.

Main events

2015

Mar. 30 – Apr. 2

The meeting aims at sharing information on emerging global trends in the field of Transition Metal Oxides: novel methods for growth and nanofabrication, new device concepts, and future funding opportunities.

As part of the TO-BE (TOWARDS OXIDE BASED ELECTRONICS) COST action, that aims at creating a network of scientists working on complementary aspects of transition metal oxide-based science and technology, the Spring Meeting is especially thought to promote mutual collaboration and define common strategies among the TO-BE COST partners, as well as to attract more scientists and companies to join the Action.
http://tobe2015.web.ua.pt/

May 13

In the presence of the Rector of the University of Naples (Prof. G.Manfredi) and directors of DSFTM and DSCTM (C. Spinella and L. Ambrosio), the CNR President, Prof. L .Nicolais met the SPIN scientific community at the Physics Departement of the Naples University Federico II. The conference was divided into the following sessions: Novel scenarios for superconductivity, Innovative materials with entangled spin, orbital and charge degrees of freedom, Advanced Spectroscopies & Ultrafas Condensed Matter, New nanostructured and functional materials for green energy, environment and sensors, Tecnology tranfer. At the conference contributed prestigious international SPIN friends: Y. Maeno, A.A. Golubov, A.Kimal, O. Mukhanov, G.Grasso.

14 - 15

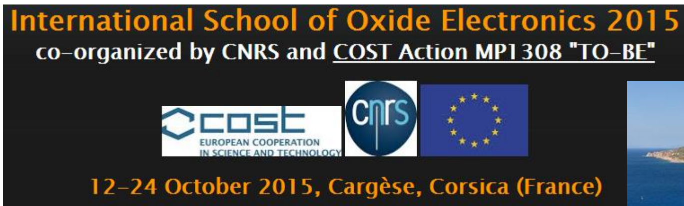
The TOP-SPIN Workshop is organized in the framework of the FP7 European FET-OPEN Project "CNTQC - Curved Nanomembranes for Topological Quantum Computation".

The aim of the TOP-SPIN Workshop is to join together leading scientists involved in the study of topological and spin phenomena in advanced nanostructures and materials. The topics will cover both theoretical and experimental aspects, with a special focus on topological superconductivity and spin-orbit coupled systems.
http://top.spin.cnr.it/

Sep. 15-18

A "COST" Symposium (Symposium "L") has been organised at the Fall EMRS meeting in Warsaw .
Transition metal oxides are ideal candidates as functional materials for next generation of electronic and energy devices. This symposium, organized by the MP1308 TO-BE COST Action "Towards Oxide-Based Electronics", is open to all scientists of the field. It warmly welcomes all contributors and participants, whether they are or are not members of the TO-BE Action. It will focus on the latest progresses in thin films epitaxial growth, on emergent functionalities at oxide interfaces, and on applications of oxides in the fields on nanoelectronics, energy, sensing and actuation.

Oct. 14-24



After ISOE2011 and ISOE2013, the 3rd Edition of the International School of Oxide Electronics aims at gathering PhD students, post-docs, young scientists and senior researchers working in Oxide Electronics for almost two weeks in the peaceful and scenic Cargèse Scientific Institute, to build up the future Oxide Electronics scientific community.
Basic notions of solid-state physics (superconductivity, ferroelectricity, magnetism, optics, correlations, etc) will be recalled, but the school will also give an extended overview of the field, covering topics such as multiferroics, oxide interfaces, domain walls or topogically insulating oxides. Oxide-based devices for electronics, spintronics, optics and other fields will also be presented in detail, as well as key advanced characterization and computational techniques.

24

[*] Festival della Scienza

"Hype Curves" : a tool to predict success !

To predict the success of a new technology product to market is critical. For this reason, many high-tech business analyzers rely on "Hype cuves" (or popularity curves), graphical representations with characteristic ups and downs, that help to predict the evolution and use of a specific echnology as a function of time, from the initial 'peak of interest' up to reach equilibrium. However, at the moment, there are no theoretical or empirical models that justify their validity.
In his Conference Ruggero Vaglio presents a simple mathematical model for the Hype cuves and experimental verification of the model in specific cases. He will also discuss their possible use in fields far from the original one, such as the evolution of scientific research , or even the psychology of interpersonal relationships.

27

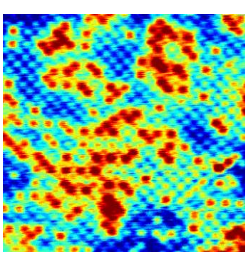
[*] Festival della Scienza

Liquid light

Photonics: from the study of crystals to technological applications.

Alexey Kavokin discusses recent experiments that revealed the unusual properties of light in liquid crystals and that have repercussions in the construction of new lasers, in communications and in the computer and device production.

Nov.



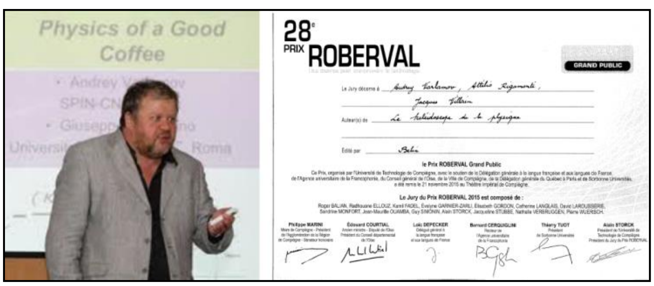
Automatic atom identification in STM images

The "Automatic atom identification in STM images" is a software for the automatic localization and recognition of atoms in high-resolution STM images of crystal lattice surfaces, showing the coexistence of different atomic layers and species. It utilizes image processing for artifact removal and the identification of the basic crystal structure and applied machine learning for the classification of the different atomic species.
Reference:
Perasso A, Toraci C, Massone A M, Piana M, Gerbi A, Buzio R, Kawale S, Bellingeri E and Ferdeghini C
An automatic method for atom identification in Scanning Tunneling Microscopy images of Fe-chalcogenide superconductors
Journal of Microscopy , Vol. 260, Issue 3, pp. 302–311, 2015.

13

The day November 13th was held at CERN, Geneva, a meeting between CERN researchers and a delegation of SPIN on the possibilities offered by not traditional superconducting materials for their possible use for Future Circular Collider. The extremely severe conditions of use in FCC suggest the study and development of such materials.
The SPIN delegation included Emilio Bellingeri, Maurizio Vignolo, Marina Putti, Andrea Malagoli, Ruggero Vaglio, Sergio Antonio Siri and Carlo Ferdeghini; for the CERN were present, among others, Lucio Rossi, Sergio Calatroni, Amalia Ballarino and Michael Benedikt.
During the day, a Memorandum of Understanding for Future Circular Collider (FCC) was signed by Michael Benedikt, FCC Study Leader (CERN) and Carlo Ferdeghini, director of SPIN and scientific issues of common interest have been identified.

21



Roberval Jury composed of academics, industrialists and actors of scientific dissemination awards the ROBERVAL Price. After receiving 107 candidates for 28th edition of ROBERVAL Price, Four Committees assessed each work according to evaluation criteria established by the Jury Prize ROBERVAL. Based on this work, Saturday, November 21, 2015, at the Imperial Theatre of Compiègne, the Jury proclaimed the book “Le Kaleidoscope de la Physique”, written by Attilio Rigamonti, Andrey Varlamov and Jacques Villain, published by BELIN (Paris) in 2014, as the winner of GRAN PRIX PUBLIC”.

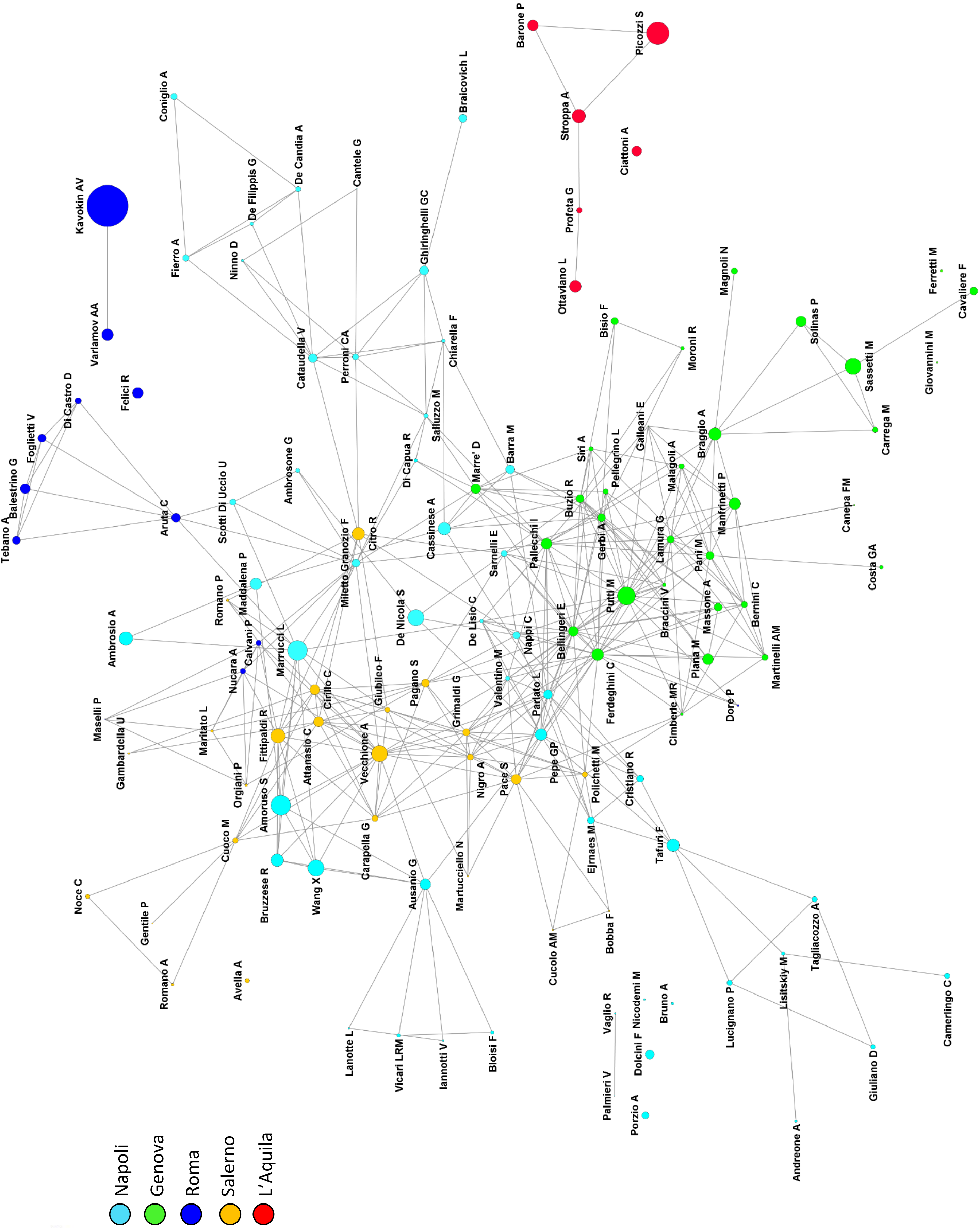
On November 21st 2015, the first USER project within the NFFA-Trieste demonstrator has been successfully completed.

Carmela Aruta (CNR-SPIN) and Nan Yang (UniCusano) did propose a multi-facility experiment on rare-earth ions doped CeO_2 catalytic active thin films. The project has involved the growth of thin films by Pulsed Laser Deposition, their structural/chemical characterization by X-ray diffraction and Scanning Electron Microscope/Energy Dispersive Spectroscopy and a detailed electronic characterization by X-ray Photo-emission Spectroscopy, Resonant Photo-emission Spectroscopy and X-ray Absorption Spectroscopy. Dr. Aruta and Dr. Yang have successfully performed XPS and XAS experiments at APE High-Energy end station on both in-situ transferred Ceria samples (grown by the PLD station UHV-connected to APE beamline) as well as on ex-situ as-grown and treated samples.
http://www.trieste.nffa.eu/news/2015/12/the-first-user/

Co-authoring Analysis

Co-authoring Analysis

The graph in the next page shows synergies among SPIN researchers operating in different locations.
Different colors concern different sites:
Green for Genoa, Light Blue for Naples, Blue for Rome, Yellow for Salerno and Red for L'Aquila.
Each point is a researcher and the spot size is proportional to the number of publications in the biennium.
The lines connecting the various points (authors) represent the existence of at least one joint publication between the two authors in 2014-2015 biennium.
The Institute, although fractionated in various venues, shows a good scientific compactness.


Kavokin AV
Varlamov AA
Felici R
Di Castro D
Foglietti V
Balestrino G
Tebano A
Aruta C
Coniglio A
Fierro A
De Filippis G
De Candia A
Ninno D
Cantele G
Cataudella V
Perroni CA
Ghiringhelli GC
Braicovich L
Chiarella F
Salluzzo M
Di Capua R
Ambrosone G
Scotti Di Uccio U
Miletto Granozio F
Citro R
Cassinese A
Marre' D
Barra M
Sarnelli E
Maddalena P
Romano P
Ambrosio A
Calvani P
Nucara A
Marrucci L
De Nicola S
De Lisio C
Nappi C
Cirillo C
Giubileo F
Pagano S
Grimaldi G
Valentino M
Parlato L
Maselli P
Gambardella U
Maritato L
Orgiani P
Fittipaldi R
Attanasio C
Vecchione A
Amoruso S
Carapella G
Nigro A
Pace S
Pepe GP
Polichetti M
Cristiano R
Ejrnaes M
Tafuri F
Cuoco M
Noce C
Gentile P
Romano A
Avella A
Bruzzese R
Wang X
Ausanio G
Martucciello N
Cucolo AM
Bobba F
Lanotte L
Vicari LRM
Iannotti V
Bloisi F
Barone P
Picozzi S
Stroppa A
Ciattoni A
Profeta G
Ottaviano L
Bisio F
Moroni R
Siri A
Pellegrino L
Galleani E
Buzio R
Gerbi A
Pallecchi I
Malagoli A
Lamura G
Braggio A
Manfrinetti P
Putti M
Bellingeri E
Ferdeghini C
Braccini V
Pani M
Massone A
Piana M
Cimberle MR
Dore P
Bernini C
Martinelli AM
Magnoli N
Solinas P
Sassetti M
Carrega M
Ferretti M
Cavaliere F
Giovannini M
Canepa FM
Costa GA
Vaglio R
Nicodemi M
Bruno A
Palmieri V
Dolcini F
Porzio A
Lucignano P
Lisitskiy M
Tagliacozzo A
Camerlingo C
Giuliano D
Andreone A
Napoli
Genova
Roma
Salerno
L'Aquila

Pubblications

Publications

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3. Mazzani, M.; Bonfà, P.; Allodi, G.; Sanna, S.; Martinelli, A.; Palenzona, A.; Manfrinetti, P.; Putti, M.; De Renzi, R. **75As NQR signature of the isoelectronic nature of ruthenium for iron substitution in LaFe1-xRuxAsO** Physica Status Solidi (B) Basic Research *Volume:* 251 *Issue:* 5 *DOI:* 10.1002/pssb.201350237

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