Scientific Report 2016 - 2017

Consiglio Nazionale delle Ricerche

Front cover image:

- *A detail of the "Elettronica di Plastica" exhibition, by Francesca Messina, CNR Direzione Generale, Ufficio Comunicazione, Informazione e URP.*

Back cover images:

- *Vortex configurations at the peaks of the simulated magnetoresistance curve, from Scientific Reports 6, 38677 (2016).*
- *STM topography of a FeTe thin film, from Journal of Physics: Condensed Matter, 29, 48 (2017).*
- *SPIN logo in 1x2 mm PMMA made on an aluminum film. The thin lines are about 30 nm wide.*
- *Optical images of a hybrid meta-device after liquid crystals infiltration, from Scientific Reports 6, 34536 (2016).*

Scientific Report 2016 - 2017

Edited by
Roberta De Donatis

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Foreword

This is the fourth biennial report on the scientific activities of the SPIN (SuPerconducting and other INnovative Materials and Devices) Institute of the National Research Council (CNR). The Institute belongs to the Department of Physical Sciences and Technologies of 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 attention to the relationship between basic research and the application potential; many of the scientific activities are concentrated on key enabling technologies. A signature of the Institute is the experimental and theoretical study of a wide class of materials, in particular superconducting and magnetic materials, highly correlated oxides, materials with strong entanglement of spin-orbital-charge-lattice degrees of freedom, organic materials.

Just in 2016 the scientific organization of SPIN was reviewed and reconsidered and six research activities were identified. They are: A) Novel superconducting and functional materials for energy and environment, B) Superconducting and correlated low dimensional materials and devices for quantum electronics and spintronics, C) Innovative materials with strong interplay of spin, orbital, charge and topological degrees of freedom, D) Light-matter interaction and non-equilibrium dynamics in advanced materials and devices, E) Advanced materials and techniques for organic electronics, biomedical and sensing applications, F) Electronic and thermal transport from the nanoscale to the macroscale.

In the framework of this reorganization SPIN researchers were able, in the following two years, to get a large number of new projects approved, both in national and international highly competitive calls. Among them, it appears significant to mention the numerous projects on superconductivity, in particular two with CERN (FCC study), one with EUROFUSION and the national ones Q-SecGroundSpace – ("premiale") and DRYSMSE4GRID (MISE). Of great relevance are also the projects coordinated by SPIN researchers, just selected within the QuantERA and FLAG-ERA initiatives. It will be discussed in detail in the next report.

The scientific community of SPIN is deeply involved in the promotion, education and communication in the field of innovative materials, particularly through the organization of schools and conferences on this topic.

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

To show the variety of achievements, the present edition of the scientific report gives more space to the highlights, considered as the most effective way to describe the Institute. They are arranged into four sections: Superconductivity, Oxides, Other Materials and Physics of Materials.

For the preparation of this document, I have to thank the whole SPIN community for contributions, Roberta De Donatis for editing the report and Sabrina Poggi for coordinating the collection of the whole material. Special thanks for the support and for the final review also to Renato Buzio and Ruggero Vaglio.

Carlo Ferdeghini
CNR-SPIN Director

Management

The Director and the Executive Board are the management bodies of the Institute.

Carlo Ferdeghini

The Director leads and coordinates the activities of the Institute, and is responsible for the overall working and the results of such activities.

The Executive Board represents the SPIN scientific community and consists of the Director, who presides over it, and an elected representation of SPIN researchers and technicians.
The Executive Board carries out the following tasks:

- expresses opinions on the development of the competences, on the progress of the activities and on the mission of the institute;
- makes proposals for the improvement of the research quality and of the skills development;
- assists the director in the drawing up of the management plan and the annual report.

Valeria Braccini

Renato Buzio

Giuseppe Balestrino

Vittorio Cataudella

Roberto Cristiano

Mario Cuoco

Roberto Felici

Fabio Miletto Granozio

Sergio Pagano

Marina Putti

Salvatore Abate

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Community

Community

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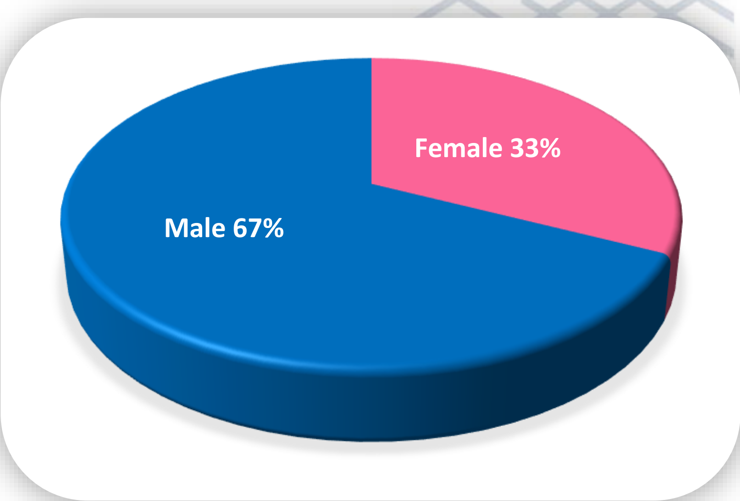
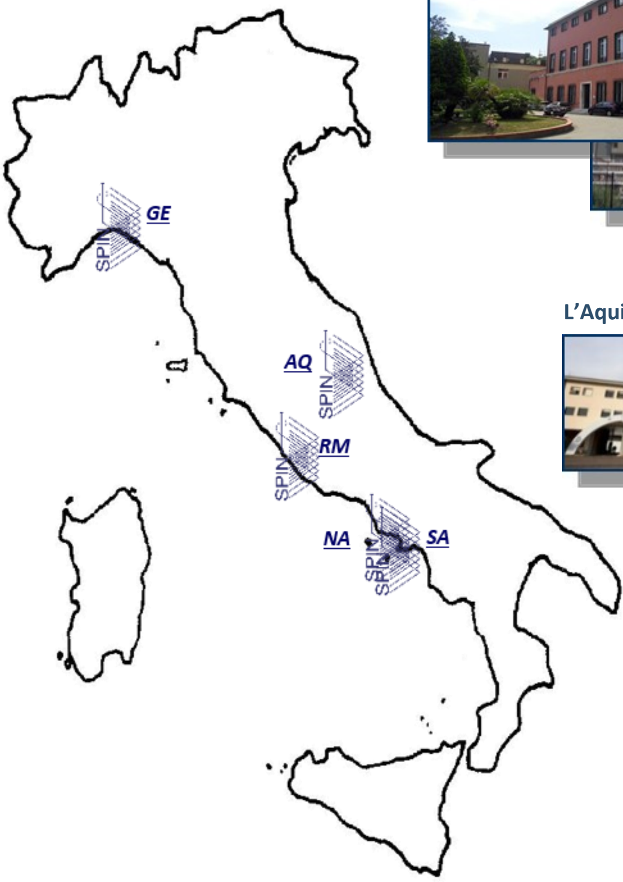
SPIN Community Gender distribution



Locations

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



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

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

University of Genova

Physics Department, Chemistry and Industrial Chemistry Department, Mathematics Department

Deputy Director: Daniele Marrè
marre@fisica.unige.it

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

University of L'Aquila, Physics Department

University of Chieti,
Neuroscience and Imaging Department

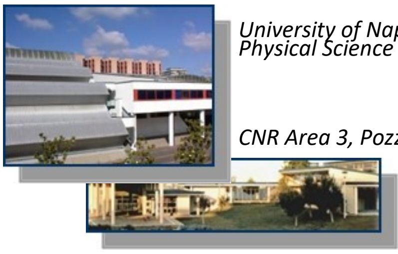
Deputy Director: Gianni Profeta
giovanni.profeta@spin.cnr.it

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

University of Roma Tor Vergata
University of Roma La Sapienza

Deputy Director: Carmela Aruta
carmela.aruta@spin.cnr.it

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



University of Napoli Federico II
Physical Science Department

CNR Area 3, Pozzuoli

Deputy Director:
Giampiero Pepe
g.pepe@na.infn.it

Salerno - *main focus: superconductivity and magnetic hybrids*

University of Salerno,
Physics Department

Deputy Director: Antonio Vecchione
antonio.vecchione@spin.cnr.it

… more info at www.spin.cnr.it

Research activities

Research activities

The research lines are organized into six “Activities”:

Activity A — Novel superconducting and functional materials for energy and environment
Superconductors and functional materials for the transition to a sustainable energy system. Synthesis, development and optimization of materials and their deep characterization, with the goal to understand basic properties, establish full potential and shorten distance to applications. Realization of prototypal devices.
Leader: **Andrea Malagoli**

Activity B — Superconducting and correlated low dimensional materials and devices for quantum electronics and spintronics
Physics of low dimensional materials and of superconducting devices in quantum technologies, with attention to quantum electronics and spintronics. Fabrication of materials and devices and their characterization by low-temperature magneto-transport measurements and advanced spectroscopies. Theory on novel phenomena and experimental measurements.
Leader: **Procolo Lucignano**

Activity C— Innovative materials with strong interplay of spin-orbital-charge and topological degrees of freedom
Fundamental mechanisms and emergent phenomena in materials with strong entanglement of spin-orbital-charge-lattice degrees of freedom, mainly driven by electron-electron correlations, spin-orbit interaction and their combination with quantum topology. Material platforms involve transition metal oxides and other transition-metal-based systems. A long-term perspective is to find the best candidates for new paradigms in emergent technologies, e.g. orbitronics, magnonics, topotronics.
Leader: **Mario Cuoco**

Activity D — Light-matter interaction and non-equilibrium dynamics in advanced materials and devices
Phenomena and effects arising when light meets superconductors, oxides, non-linear optical materials etc.. Understanding and control of light-matter interaction points to new functionalities and technologies, based on quantum components and light-driven micro/nano-structuring and fabrication, having impact in the fields of quantum technologies, metamaterials and advanced sensing.
Leader: **Roberto Cristiano**

Activity E — Advanced materials and techniques for organic electronics, biomedical and sensing applications
Fundamental properties of functional organic and inorganic materials with specific responsiveness to physical and chemical external stimuli. Realization of innovative sensing and electronic devices for biomedicine and smart systems. Development of computational techniques for processing of data produced by such devices.
Leader: **Annamaria Massone**

Activity F — Electronic and thermal transport from the nanoscale to the macroscale
Fundamental processes involved in the motion of carriers, lattice vibrations and other excitations in a large variety of materials and devices (e.g. new generation solar cells, thermoelectrics, nanoelectromechanic devices) of interest for energy transport and conversion. Theoretical efforts tightly match experimental results, e.g. from angle-resolved photoemission, optical spectroscopy and nano-spectroscopies.
Leader: **Giovanni Cantele**

Equipment

Main experimental facilities

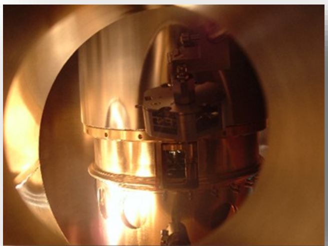
Genova

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 characterization of morphological, structural, magnetic and transport properties. The unit owns 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 are:

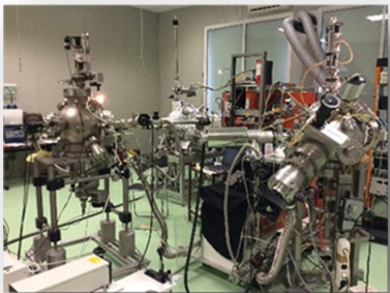
- Bulk and (nano) powders preparation: different chemical laboratories equipped for synthesis of different materials by solid state reactions and chemical characterization.
- Superconducting wires and tapes: rolling and drawing machines for the realization of tapes and wires on kilometers length scale 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 in-situ monitoring of the growth by RHEED. One mixed MBE/PLD system, several effusive cells. The lab owns also an ink-jet printer for low-cost materials deposition.

Deformation Laboratory

- Hazardous materials lab: the lab is equipped for safe working of toxic materials in form of powder or liquid. A forced aeration system is installed in order to have an adequate air change. The lab is equipped with a sink and a classical chemical hood for usual product manipulation.
- 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 the study of morphological and functional properties of thin films and devices.
- Optical spectroscopy and transport and magnetic properties measurements: variable temperature MOKE system, spectroscopic ellipsometry, two SQUID systems and a Physical Properties Measurement System by Quantum Design, several cryostats for magnetic, electrical, thermoelectrical and thermal transport properties measurements.



Low Temperature Scanning Tunnel Microscope



Thin film deposition laboratory

Hazardous material laboratory

Main experimental facilities

Napoli

The research unit of Naples 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 Pozzuoli CNR Area 3, while some equipment is part of a larger pool belonging to the Department of Physics of the University of Naples “Federico II” and is located in shared laboratories. Recently, advanced cryogenic equipments have been set up in collaboration with the Second University of Naples (SUN), and located in the laboratories of CNR-SPIN Naples.

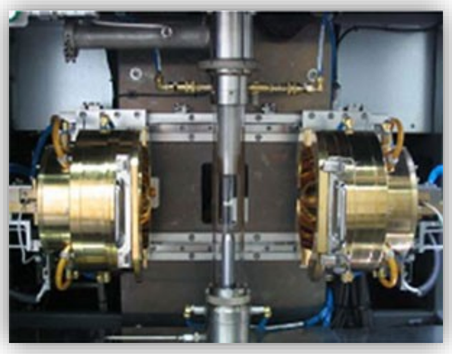
Some relevant equipments are:

- 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.

SEM-EBL nanolitography

Main experimental facilities

Salerno



The research unit of 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.

Cryogen Free
Magnet Variable Temperature Insert

Main experimental facilities

L'Aquila

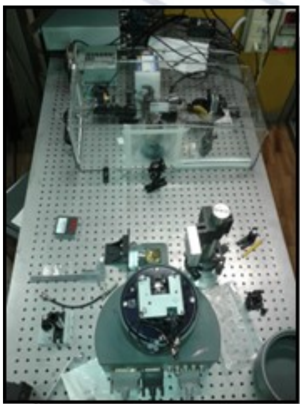
The research unit of L'Aquila is mostly composed by theorists. The computational resources used by researchers are predominantly located at supercomputing centers all around Europe (Cineca, Barcelona Supercomputing Centers, etc).

Roma

At the University of Roma Tor Vergata, SPIN laboratory is hosted in the Engineering Department. The relevant equipment 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 equipment are three PLD chambers, a 3 circle diffractometer allowing reciprocal space mapping and two cryocoolers able to go down to 15 K, 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 and 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 the University of Roma 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. Broadband Fourier-transform spectroscopy is the main experimental tool, with three fast-scanning interferometers, additionally 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 & Grants

Projects & Grants

2016-2017 running Projects—European and International funds

Source of funding	Title	Coordinator	SPIN Leader	SPIN Unit involved	Duration
EU FP7	CNTQC - Curved nanomembranes for topological Quantum Computation	IFW	Paola Gentile	Salerno	Jun-2014 May-2017
EU FP7	COHEAT - Coherent heat and energy transport in quantum system	SPIN	Alessandro Braggio Paolo Solinas	Genova	Feb-2014 Feb-2018
EU H2020	UFOX - Unveiling in functional hybrides oxides	SPIN	Mario Cuoco	Salerno	May-2015 May-2017
EU H2020	FLARECAST - Flare likelihood and Region eruption forecasting	Academy of Athens	Anna Maria Massone	Genova	Jan-2015 Dec-2017
EU H2020	TO BE - Towards Oxide-Based Electronics	SPIN	Fabio Miletto	Napoli	Apr-2014 Apr-2018
UE/ EURATOM H2020	EUROFUSION Enabling Research projects proposals - Alternative HTS wires	University of Vienna	Andrea Malagoli	Genova	Jan-2017 Dec-2018
EU H2020	MAGENTA - Magnetic nanoparticle based liquid Energy materials for Thermoelectric device Applica-tions	CEA	Andrey Varlamov	Roma	Jan-2017 Dec-2019
EU H2020	European Advanced Superconductivity Innovation and Training	CERN	Emilio Bellingeri Marina Putti	Genova	Oct-2017 Oct-2021
CNR Bilateral Project	Scientific Collaboration CNR – BAS (Bulgary)	-	Salvatore Amoruso	Napoli	Jan-2016 Dec-2018
CNR Bilateral Project	Scientific Collaboration CNR – RA (Romania)	-	Alessandro Stroppa	L'Aquila	Jan-2014 Dec-2016
CNR Bilateral Project	Scientific Collaboration CNR – CNRS (France)	-	Procolo Lucignano	Napoli	Jan-2014 Dec-2016
CNR Bilateral Project	Scientific Collaboration CNR – PAN (Poland)	-	Carlo Ferdeghini	Genova	Jan-2017 Dec-2019
MAECI Italy/ Israel	IMESS - Improved MgB2 wires for energy storage in liquid hydrogen cooled superconducting coils	SPIN	Maurizio Vignolo	Genova	Dec-2014 Nov-2016
MAECI Italy/ Japan	Solid State Actuators for Micro Nanorobotics	SPIN	Luca Pellegrino	Genova	Jan-2017 Dec-2017
CNR—NTU	Joint Laboratory CNR - NTU Singapore on Amor-phous materials for energy harvesting applications	SPIN	Annalisa Fierro	L'Aquila	Jan-2014 Dec-2017

Projects & Grants

Source of funding	Title	Coordinator	SPIN Leader	SPIN Unit involved	Duration
US ARMY	Slightly high index inclusion metamaterials: a novel physical and feasible route to enhance and harness spatial dispersion	SPIN	Alessandro Ciattoni	L'Aquila	Sep-2017 Sep-2018
CERN/CNR	Collaboration Agreement on Future Circular Collider (FCC) Study: Beam screen	CERN	Emilio Bellingeri	Genova	Mar-2016 Feb-2019
CERN/CNR	Collaboration Agreement on Future Circular Collider (FCC) Study: Superconductivity for high field	CERN	Marina Putti, Valeria Braccini, Andrea Malagoli, Maurizio Vignolo	Genova	Jan-2017 Oct-2019
ESRF	Collaboration Agreement on Study of engineered oxide heterostructures with peculiar electronic properties or of possible application in heterogeneous catalysis	SPIN	Roberto Felici	Roma	Jul-2016 Mar-2017

2016-2017 running Projects—National funds

Source of funding	Title	Coordinator	SPIN Leader	SPIN Unit involved	Duration
MIUR PRIN	NEWLI: NEW LIght on transient states in condensed matter by advanced photon - electron spectroscopies	CNR ISM	Francesco Bisio	Genova	Feb-2017 Feb-2020
MIUR FIRB Futuro e Ricerca	Superconducting-semiconductor hybrid nanostructures: nanoelectric applications, topological properties, correlation and disorder	University of Naples	Alessandro Braggio Procolo Lucignano	Genova Napoli	Mar-2013 Nov-2016
MIUR FIRB Futuro e Ricerca	CoCa—Coherent caloritronics in mesoscopic superconducting circuits	CNR NANO	Paolo Solinas	Genova	Mar-2014 Mar-2017
MIUR Premiali Grant	Integrated and eco-sustainable technologies for energy storage and delivery	CNR	Valeria Braccini Gaia Grimaldi	Genova Salerno	Jul-2014 Jul-2017
MIUR Premiali Grant	Magnetic and superconducting materials and devices for sensors and ICT	CNR	Giampiero Pepe	Napoli	Jul-2014 Jul-2017
MIUR Premiali Grant	Beyond the classical limits of measurement	INRIM	Giampiero Pepe	Napoli	Apr-2014 Apr-2016

Projects & Grants

Source of funding	Title	Coordinator	SPIN Leader	SPIN Unit involved	Duration
MIUR Premiali Grant	Organic electronics for innovative research instrumentation	INFN	Antonio Cassinese Renato Buzio Andrea Gerbi	Napoli Genova	Jan-2015 Jan-2017
MIUR Premiali Grant	Q-SecGroundSpace - "Intermodal Secure Quantum Communication on Ground and Space	INRIM	Giampiero Pepe	Napoli	Jan-2017 Dec-2017
PON	DATABENC Social Network of the historical centers entities - SNECS	INNOVA	Giampiero Pepe	Napoli Salerno	May-2016 Apr-2017
MISE POA	DRYSMES4GRID—Superconducting Energy Storage for Smart Electrical Grid	Columbus Superconductors	Maurizio Vignolo	Genova	Jun-2017 Jun-2020

2016-2017 running Projects—Regional and Local funds

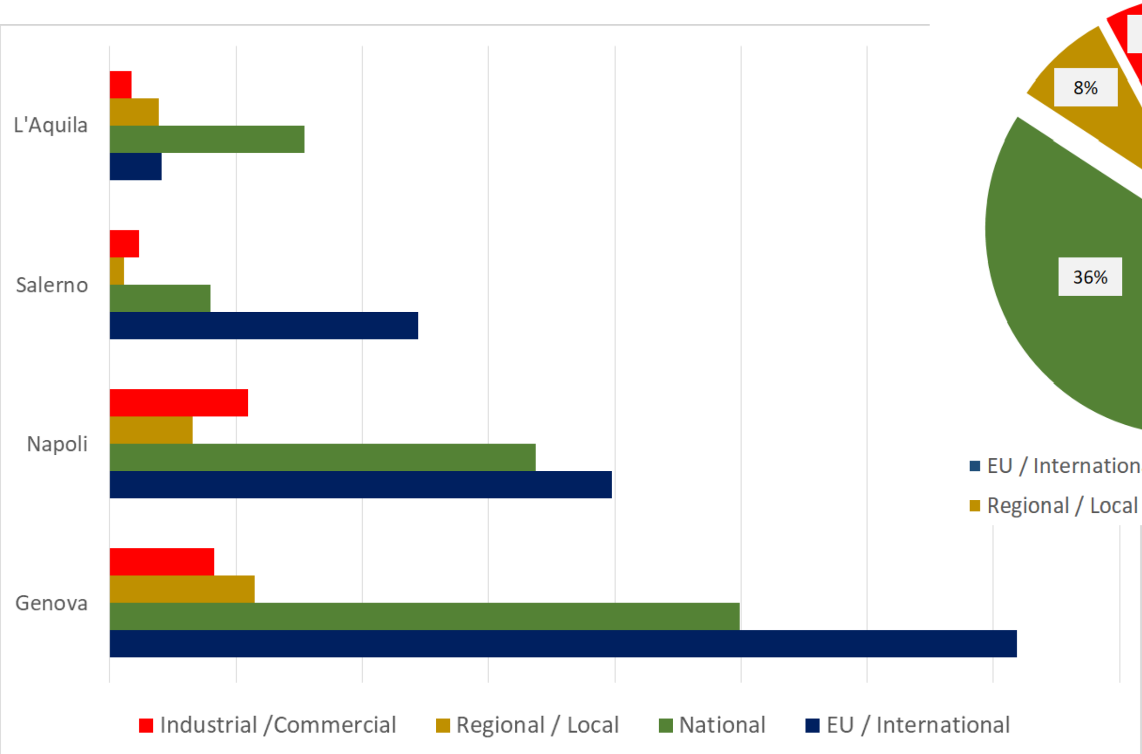
Source of funding	Title	Coordinator	SPIN Leader	SPIN Unit involved	Duration
Regione Campania L.5	Electronic reconstruction at STO / LAO interface of interest for microelectronics	SPIN	Marco Salluzzo	Napoli	Jul-2015 Mar-2017
Regione Campania L.5	The role of the interfaces in magnetic oxides with strong electron correlation: manganite heterostructures	SPIN	Antonio Carmine Perroni	Napoli	Jan-2016 Mar-2017
Regione Campania L.5	Interface states and competition between ordered phases in eutectic oxides with perovskite structure	SPIN	Sandro Pace	Salerno	May-2016 Mar-2017
R. Campania PO FESR	SIMAC—Innovative system for continuous environmental monitoring	Filippetti Spa	Xuan Wang	Napoli	Jan-2015 Apr-2016
R. Campania PO FESR	Production of laser system in the violet and the near-IR spectral region for the printing industry using soliton waveguides in photonic crystals	Metoda Spa	Alberto Porzio	Napoli	Jan-2015 Apr-2016
CARIPLO Foundation	MAGISTER—Magnetic information storage in antiferromagnet spintronic devices	Polytechnic of Milan	Alessandro Stroppa	L'Aquila	May-2014 Oct-2017
ARISLA Foundation	SCM-ALS Spinal Cord Metabolism in Amyotrophical Lateral Sclerosis	University of Genoa	Anna Maria Massone	Genova	Jun-2016 Jan-2019
Compagnia di San Paolo Foundation	Pan-lab: plasmonic biosensoristics for early diagnostics	SPIN	Francesco Bisio	Genova	Apr-2016 Apr-2018

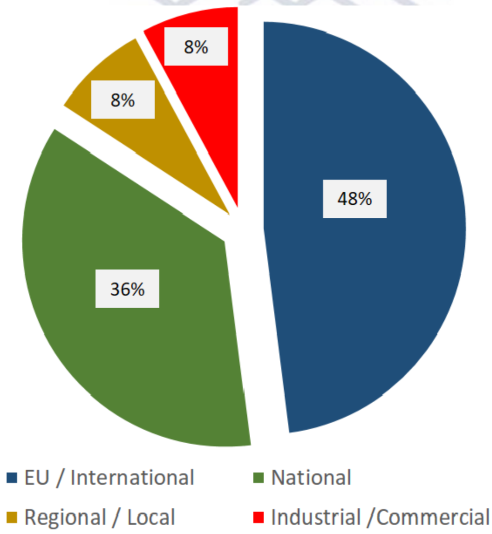
Projects & Grants

2016-2017 running Projects—Industrial and Commercial funds

Tipology of activity	SPIN Leader	SPIN Unit involved	Duration
Research contract with ALA System Srl	Anna Maria Massone	Genova	Nov-2015 Jul-2017
Research contract with IMC Srl	Sergio Pagano	Salerno	Sep-2015 Jun-2016
Research contract with Columbus Superconductors Srl	Maurizio Vignolo	Genova	Nov-2017 Jun-2017
Research contract with CNISM	Xuan Wang	Napoli	Jun-2014 Apr-2018
Testing and laboratory measurements	Andrea Malagoli Cristina Bernini Rosalba Fittipaldi Umberto Gambardella	Genova Salerno	Jan-2016 Jan-2018

2016-2017 running projects total amount: ~ 6 M€





Projects & Grants

Main Projects

Title	Tl based superconducting coating for FCC beam screen at CERN
Source of funding	CERN/CNR
Scientific funding program	FCC Study
Project coordinator	CERN
SPIN coordinator	Emilio Bellingeri, SPIN Genova
Other partners	Technical University Wien, CERN

Project objectives

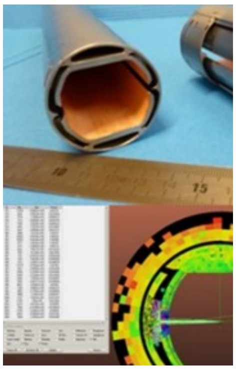
CERN has recently started a design study for a possible next-generation high-energy hadron–hadron collider (Future Circular Collider—FCC-hh). The FCC-hh study calls for an unprecedented center-of-mass collision energy of 100 TeV, achievable by colliding counter-rotating proton beams with an energy of 50 TeV steered in a 100 km circumference tunnel by superconducting magnets which produce a dipole field of 16 T. The beams emit synchrotron radiation at high power levels, which, to optimize cryogenic efficiency, is absorbed by a beam-facing screen, coated with copper, and held at 50 K in the current design. The surface impedance of this screen has a strong impact on beam stability, and copper at 50 K allows for a limited beam stability margin only. This motivates the exploration of whether high-temperature superconductors (HTS), the only known materials possibly having a surface impedance lower than copper under the required operating conditions, would represent a viable alternative.

Among the high-temperature superconductors Tl-cuprates stand out due to their very high critical temperatures and upper critical fields. In particular $TlSr_2Ca_2Cu_3O_x$ with a T_c of about 120 K, very high H_{c2} and H_{irr}, and moderate anisotropy is a promising material for the realization of a low surface resistance coating for the FCC beam screen. This superconducting material can be grown textured on pure silver by simple and cheap techniques, and has the additional advantage of a potentially lower surface resistance.

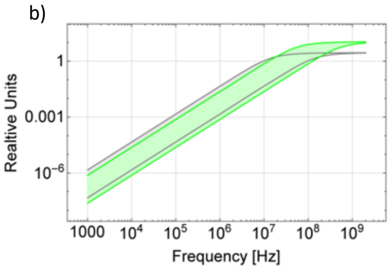
The main objectives of the project are:

- the preparation of a suitable coating by electrochemical deposition of a metallic precursor followed by a high temperature phase formation reaction in oxidizing atmosphere;
- the study of behaviour of high temperature superconductor under these extreme conditions of temperature, magnetic field, frequencies and radiation.

a)



b)



a) FCC beam screen design.

b) Ratio of expected surface resistances of Tl-1223 and Cu at 1 T (gray band, injection energy), and at 16 T (green band, operating energy).

Projects & Grants

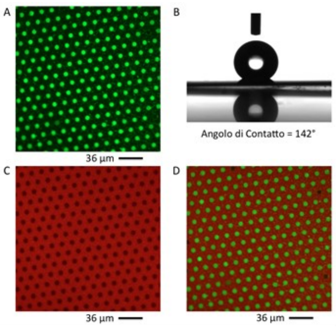
Main Projects

Title	Pan-lab: plasmonic biosensoristics for early diagnostics
Acronym	**Pan-Lab**
Source of funding	Compagnia di San Paolo Foundation
Scientific funding program	Call for research projects from scientific entities located in Genoa city
Project coordinator	SPIN, Genova
SPIN coordinator	Francesco Bisio, SPIN Genova
Other partners	IIT, University of Genoa (Deartment of Physics)

Project objectives

The development of sensors for detection and identification of molecular species at ultralow concentration within biologic samples is a research field with huge fallouts in biomedics, allowing the early diagnosis of pathological states via detection of specific markers. The ability to detect the presence of very few molecules in a bio sample, either because rare or because at ultralow concentrations, is nowadays one of the main targets of biomedics.

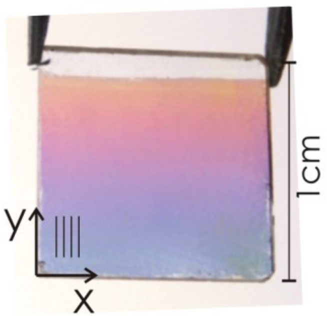
The project targets the development of innovative ultrasensitive bio-detectors based upon the combination of superhydrophobic (SHF) concentrators for delivering molecular species within pre-determined nanovolumes, and ultradense lattices of plasmonic nanoparticles for molecular-specific detection by surface plasmon-enhanced Raman spectroscopy (SERS), located within the "target" nanovolumes.



Representative images of the SHF platform. The test fluorescent molecule (green) is selectively delivered to specific areas.

Within the PanLab project, SHF systems have been successfully realized, capable of selectively delivering a given molecule to pre-determined micro-wells endowed with sensitive structures (see top Figure). It can be observed that the green fluorescence signal of the target-molecule only originates from selected areas, corresponding to the concentration volumes.

In parallel with the development of SHF systems, micro-chips with spatially-graded plasmonic resonances for plasmon enhanced SERS have been developed and validated against specific test molecules, reaching a potential sensitivity to 1nM concentration. The next objective will be represented by the integration of the two types of structure to yield an empowered sensor, and the test of the hybrid plasmonic/SHF system with molecules of biological interest.

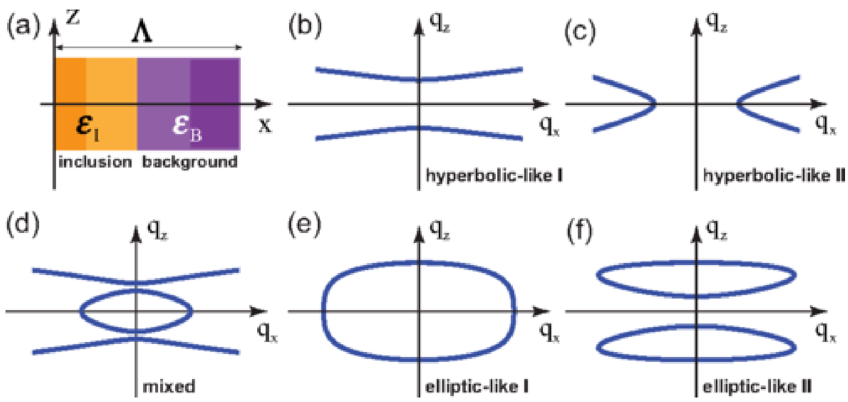


Plasmon-graded sensor.

Projects & Grants

Main Projects

Title	Large artificial optical nonlocality in Kaptiza-like metamaterials
Source of funding	US Army Research Laboratory Nds
Scientific funding program	W911NF-12-R-0012
Project coordinator	SPIN, L'Aquila
SPIN coordinator	Alessandro Clattoni, SPIN L'Aquila
Project objectives	We revisit the effective medium theory in Kapitza metamaterials which are a novel class of stratified media characterized by a rapidly modulated dielectric permittivity with a large modulation depth. Our latest findings show that Kapitza media support a novel and robust regime of diffractionless electromagnetic propagation which is not fundamentally affected by medium losses. The diffraction suppression is achieved by the vanishing of the longitudinal field component (along the stacking direction) produced by the large depth of the dielectric modulation. In this project we aim at considering Kapitza-like metamaterials whose unit cell, in addition to the large permittivity layers, comprises layers with much smaller permittivity. The presence of the additional low permittivity layers is such that the average longitudinal field component does not vanish so that its very large fluctuations (in turn produced by the overall large dielectric modulation) are incompatible with the standard effective medium description. Since additional nonlocal contributions to the effective medium response generally appear when the stratified medium cannot be fully homogenized, we expect our Kapitza-like metamaterial to host a novel photonic regime dominated by a giant optical nonlocality. These kind of nonlocal metamaterials could suggest novel strategies for realizing efficient photonic devices based on different physical ingredients such as chirality and additional waves.



Different dispersion regimes hosted by Kapitza metamaterials

(in C. Rizza et al., Physical Review B 96, 081113(R) (2017)

Projects & Grants

Main Projects

Title	Alternative HTS Wires
Source of funding	EUROfusion Consortium
Scientific funding program	WPENR—Enabling Research
Project coordinator	Technical University Wien
SPIN coordinator	Andrea Malagoli, SPIN Genova
Other Partner	ENEA

Project objectives

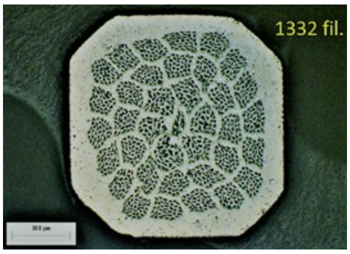
Since the magnet system is one of the most expensive parts of a fusion device, a cost reduction is mandatory for making fusion power plants competitive with established energy sources. The largest share of the magnet cost is the conductor itself. A cheap conductor can thus obviously contribute to a significant cost reduction, but HTS offer more perspectives in this respect. They can be operated at higher temperatures and fields, which could enable a more compact design of the tokamak and hence strongly reduce the necessary investment.

The aim of the proposed project is to break the ground for the development of a round, multifilamentary, and inexpensive high-performance HTS wire, which can replace Nb_3Sn strands, while enabling an increase in operation temperature and/or field. We split this general aim into two main objectives:

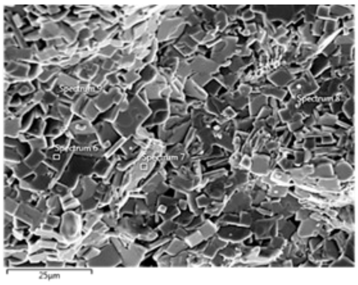
1) Optimization of the thermo-mechanical pre-treatment of the Bi-2212 wires to obtain the performance required for fusion magnets (J_e > 500 A/mm^2 at high fields) without the need of a high-pressure treatment during the formation of the superconducting phase. The wire is aimed to be an alternative to existing HTS and LTS wires for fusion magnets.

2) Development of suitable precursors for the Tl-1223 wire production. Nano-crystalline or amorphous powders which result in textured-growth without the need of heating above the melting temperature are in the focus. Demonstration of textured-growth at interfaces is planned.

These objectives are challenging and guarantee on one side a significant forward step in the performances of the existing Bi-2212 wires and on the other side the opening of a new route for the development of Tl-1223 wires.



Cross section of a Bi-2212/Ag miltifilamentary superconducting wire with 1332 filaments realized within “Alternative HTS wires” project



SEM image of a Tl-1223 pellet: plate-like grains are visible. Realized within "Alternative HTS wires” project

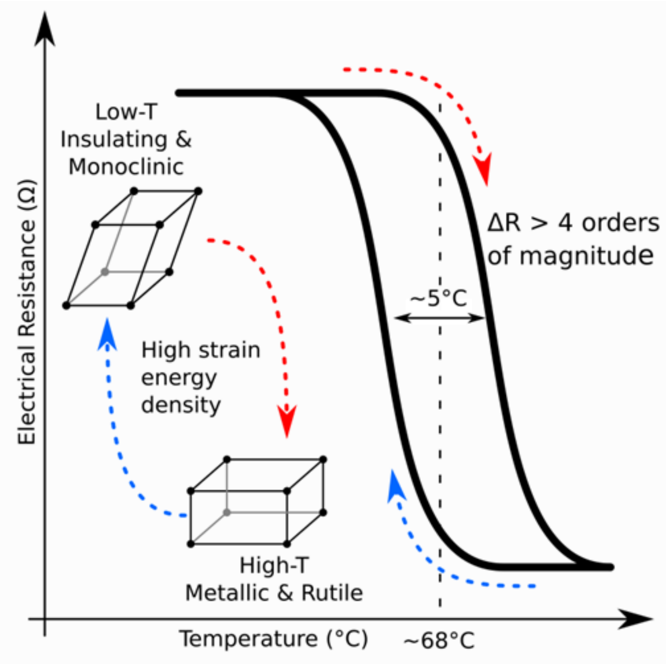
Projects & Grants

Main Projects

Title	Solid state actuators for micro/nanorobotics
Acronym	**ACROBOT**
Source of funding	Ministry of Foreign Affairs (MAECI) - Italy / Japan
Scientific funding program	Executive Programme of Science and Technology cooperation between Italy and Japan
Project coordinator	SPIN and Institute of Scientific and Industrial Research, Osaka University (Prof. Teruo Kanki)
SPIN coordinator	Luca Pellegrino, SPIN Genova
Other Partner	University of Genova, ISIR-Osaka University
Project objectives	

Micromechanical actuators have enormous applicative potential in numerous technologies such as microfluidics, drug delivery, artificial muscles, opto/micromechanical switches. Actuation at microscopic scale is mainly performed electrically through capacitive couplings and piezoelectrics or thermally (electrothermally or light irradiation), exploiting the change of shape of specific materials (i.e. Shape Memory Alloys, SMA) or thermal expansion (bimorphs).

Schematic drawing of the phase transition occurring in VO_2 involving both resistivity and lattice parameters values. (see also http://www.vo2actuators.spin.cnr.it/)



Best performances are characterized by high relative elongation, large force output and high actuation speed. Vanadium dioxide (VO_2) has been recently considered as an optimum active material in micro/nanoactuators, due to its fast (ps) and sharp solid state phase transition (SSPT) nearby 68°C from monoclinic (M1-M2) phases to the rutile type tetragonal (R) phase that in single crystal can produce strain up to 1% and large applied forces [K. Liu et al. Adv. Mater. 2014, 26, 1764]. This SSPT is accompanied by a Metal-Insulator Transition with a large change (up to 4 orders of magnitude) of electrical resistivity. In this project, we setup strategies for the development of thin film actuators and resonant devices based on the SSPT of VO_2. We plan to establish the scalability limits and the advantages of this technology with respect to the existing state-of-the-art. We aim at realizing micro and nanomechanical devices exploiting the change of lattice parameters of VO_2 thin film nanostructures upon heating. Although energy efficiency of thermal-based actuation schemes is generally low, thermal actuation at nanoscale can be particularly interesting due to the easiness of fabrication associated with large applied forces.

Projects & Grants

Main Projects

Title	Magnetic information storage in antiferromagnet spintronic devices
Acronym	**MAGISTER**
Source of funding	CARIPLO Foundation
Project coordinator	Polytechnic of Milan, Dept. Phys. (Matteo Cantoni)
SPIN coordinator	Alessandro Stroppa, SPIN L'Aquila

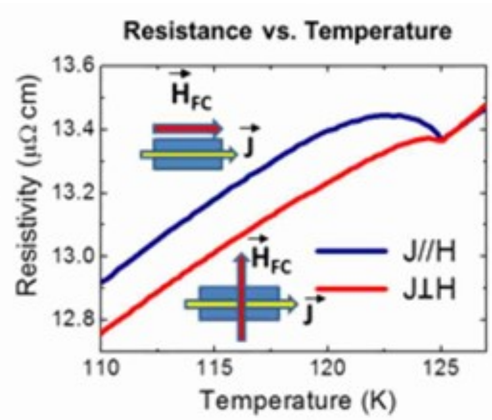
Project objectives

Spintronics explores phenomena that interlink the charge and spin degrees of freedom, aiming to develop novel devices where the spin, in addition or in substitution of the charge, is employed in order to store and manipulate information. For a long time spintronics was essentially focused on devices made by *two* ferromagnetic (FM) layers whose relative magnetization directions (parallel/antiparallel) lead to different resistance states (low/high). However, very recently, antiferromagnet spintronics started to emergence as a new paradigm. In fact, antiferromagnets (AFMs) have some appealing features, such as the absence of stray fields and the higher robustness versus external perturbations, with respect to their FM counterparts, that allow for larger packaging density and higher reliability and durability, two key requisites for new generation memories.

Chromium has recently emerged as a promising candidate because of its Néel temperature above room temperature and the possibility of growing fully epitaxial heterostructures, but the AFM functionality at the thin films level of both metal and oxides has not been demonstrated up to now.

The project aims to explore AFM devices based on the Anisotropic Magneto Resistance (AMR) of the AFM film and Anomalous Hall Effect (AHE) induced in non magnetic metals in contact with the AFM. In particular the goals of the project are:

- to fabricate Cr-based antiferromagnetic memory cells, being able to permanently store a bit of information, with electrical reading and magnetically- or electrically-assisted writing procedures.
- to grow ultrathin Cr and Cr_2O_3 films (about 2 nm thick) on a $BaTiO_3$/Nb $SrTiO_3$ (001) template to tune the AFM magnetic properties by an electric field, thus envisaging the electrical control of the spin configuration.



Resistivity as a function of temperature in a Cr-based planar device fabricated with optical lithography.

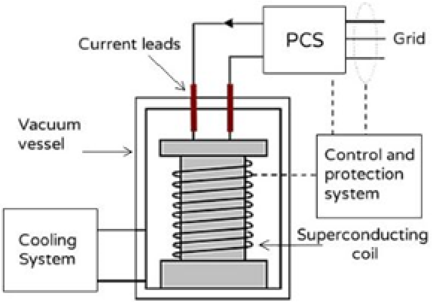
Projects & Grants

Main Projects

Title	Cryogen free superconducting energy storage for smart grid
Acronym	**DRYSMES4GRD**
Source of funding	Ministry of Economic Development (MISE) of Italy
Specific funding program	POA 2013 National Projects
Project coordinator	Columbus Superconductors Srl
SPIN coordinator	Maurizio Vignolo, SPIN Genova
Other partners	RSE spa, ICAS Italian Consortium for Applied Superconductivity, University of Bologna
Project objectives	Energy storage is a key technology for modern electric power systems, especially in the perspective of smart grids and distributed renewable energy production. Its introduction in the grid contributes to cope with the inherent imbalance between load and generation, which is becoming very acute due to increasing penetration of green distributed generation in the energy mix. Furthermore, application of energy storage at the customer site can provide immunity with respect to voltage disturbance, uninterruptible power supply (UPS) service and power modulation.

Superconducting magnetic energy storage (SMES) offers complementary characteristics with respect to other storage methods: high charge/discharge power, fast response, extremely high number of cycles, high round trip efficiency. However, significant improvements on SMES technology, able to increase both the technical and economical attractiveness, can still be obtained by means of new HTS (YBCO, MgB_2) compatible with cryogen free cooling.

The project goal is to demonstrate the feasibility of cost-competitive SMES based on MgB_2 with a cryogen free cooling system. All engineering aspects, needed to the development of the SMES technology, will be dealt within of the project. i.e.: MgB_2 cable manufacturing and winding, stability and loss of the winding during the fast discharge, electrical insulation of the dry coil, temperature uniformity, minimization of cooling losses and converter losses. Furthermore, all aspects related to the development of power and control electronics needed for the appropriate operation of the SMES in the power network will also be dealt with.



Schematic of the MgB2 SMES prototype (from the website http://www.drysmes4grid.spin.cnr.it).

Projects & Grants

Main Projects

Title	Exploring high performing superconducting materials for FCC
Acronym	**HTS Advancement**
Source of funding	CERN/CNR
Specific funding program	Future Circular Collider Study (FCC)
Project coordinator	CERN
SPIN coordinator	Marina Putti, SPIN Genova
Other partners	University of Genova

Project objectives

Metallic flexible substrate (INVAR) for the deposition of innovative IBS coated conductors.

The scope of this collaboration is to advance the performance of three superconducting materials (Bi-2212, MgB_2, IBS), using industrially scalable productive methods, to make them suitable for high-field magnet applications.

Bi-2212 wires realized by the powder-in-tube method (PIT) have shown good performance at high fields. However, these results have been obtained with heat treatment under pressure that is incompatible with the production of large coils for magnets. MgB_2 wires can be realized by PIT and have the advantages of lower cost and operation temperatures up to 15 K. However, Hc_2 and pinning in these conductors is still not optimized and they presently cannot be used at high magnetic fields. Recently discovered iron-based superconductors (IBS), which exhibit high T_c and huge Hc_2, have great potential for high field applications. PIT tapes and wires have been successfully realized, but scalable techniques for the production of long conductors remain to be developed. Considering the different performance and levels of technological advancement of each of the materials, the following detailed objectives are set:

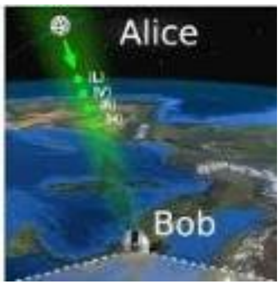
- **MgB_2**: increase the operating field by adopting an original doping method (Maurizio Vignolo);
- **Bi-2212**: reproduce the performance today obtained by high pressure heat treatment with a mechanical deformation process (Andrea Malagoli);
- **IBS**: develop prototype IBS conductors that meet the critical current density (J_c) requirements through reliable, simpler and scalable techniques that would permit industrialization (Valeria Braccini).

CERN contributes its expertise in cable development and characterisation. CNR-SPIN specialises in the investigation of superconducting materials for power applications and PIT manufacturing. It will take the leading role in the production of powders, substrates and short samples of superconducting wires and tapes, and contribute to characterisation and low-field Ic measurements. This work is also supported by the University of Genova, with its expertise in superconducting material synthesis.

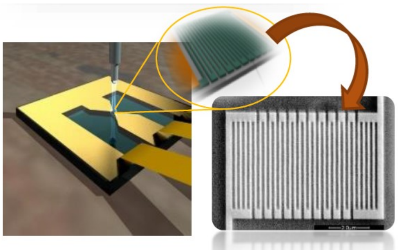
Projects & Grants

Main Projects

Title	Intermodal Secure Quantum Communication on Ground and Space
Acronym	**Q-SecGroundSpace**
Source of funding	Ministry of Education, University and Research (MIUR) of Italy
Specific funding program	“Premiali” Grant
Project coordinator	Istituto Nazionale di Ricerca Metrologica -INRIM - Torino
SPIN coordinator	Giampiero Pepe, SPIN Napoli
Other partners	University of Padova, ASI, CNR-INO, CNR-IMM, CNR-IFN
Project objectives	SecGroundSpace aims establishing the experimental feasibility of technologies for the realization of a “free-space” ground-space QKD-link. SecGroundSpace also aims developing the metrological infrastructure for the characterization of single-photon devices on satellite for transmission and detection.



Space -Gound QKD transmission



Schematic of a SNSPD. On the left the SNSPD chip with the gold electrodes. The inset explodes the SNSPD detail.
On the right a NbN-SNSPD nanowire meander realized at SPIN. The linewidth and thickness are 100 nm and 10 nm respectively. The device area is 5×5 square microns

Quantum Key Distribution QKD is the most secure form of communication yet devised. QKD based on optical fiber networks have been tested in the metropolitan areas of all the five continents. Nevertheless, at the global scale it is not realistic that QKD optical fiber networks can be the viable solution. To cover continental distances, the scenario is a QK distribution in “free space” via satellite.

The main objective of the project is the realization of a prototype QKD transmitter for space, with sources, detectors and systems operating at the single-photon level, which will be characterized by an ad-hoc realized metrological infrastructure. The satellite QKD transmitter and receiver will be realized with the integration of commercially available components (e.g. a pulsed laser attenuated at the single-photon level as source of pseudo-single-photons and single-photon detectors based on Si-SPAD).

During the project, the Consortium will also develop and characterize (metrologically) new types of optical components. In addition to the extensive use and development of semiconductor detectors, the project will explore the use of superconducting nanowire single photon detectors (SNSPDs). These devices are completely based on the technology of superconductors and promise to overcome the semiconductor companions in terms of dark counts, efficiency and timing precision.

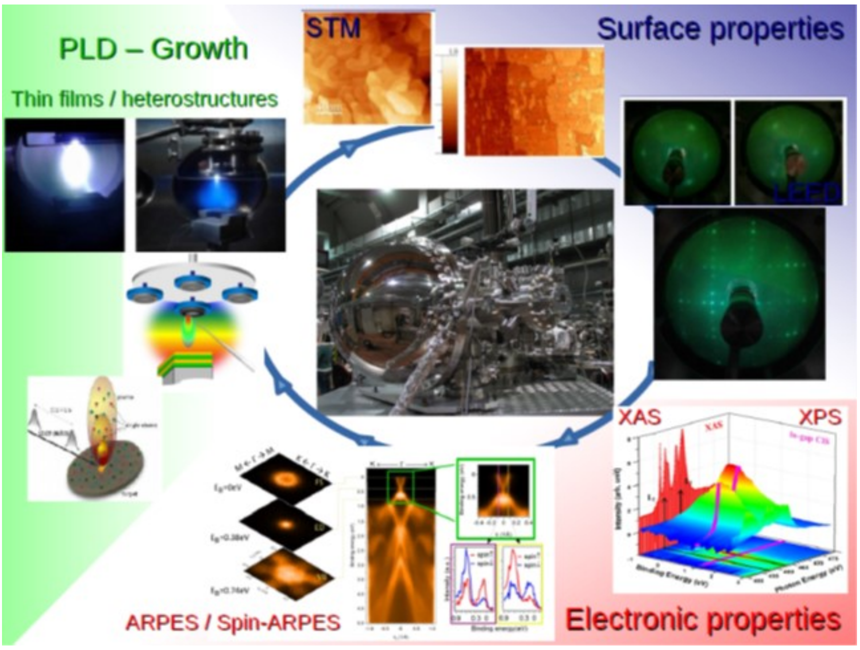
The role of SPIN in the project is the development and characterization of the SNSPD technology.

Projects

Focus on APE NFFA @ELETTRA

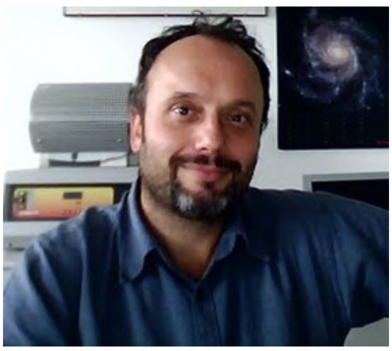
On 2015, in collaboration with the University of Salerno and the CNR-IOM, CNR-SPIN has designed a multi-purpose Pulsed Laser Deposition (PLD) system that was developed and implanted on the operational infrastructure of the APE-NFFA laboratory at Elettra synchrotron radiation facility. The PLD chamber is directly connected to the all-UHV APE-beamline distribution center chamber, which allows the transferring of the as-grown samples to all surface characterization stations. This infrastructure provides, in a suite of interconnected UHV chambers, all the surface science environment and methods needed for the manipulation and characterization of the as-grown PLD samples. In particular, structural properties at the surface of as-grown films and hetero-structures can be probed by room-temperature STM while possible surface reconstruction can be revealed by LEED investigation.

At the APE-IOM beamline at Elettra facility, soft X-ray and ultraviolet synchrotron radiation spectroscopies (XPS, resonant photoemission spectroscopy, XAS, and ARPES) can be also carried out without breaking the vacuum condition. Moreover, very recently, the beamline has been upgraded with a wide angle ARPES analyzer equipped with a vectorial very low energy electron diffraction (VLEED) analyzer for spin-resolved ARPES experiments.



Besides the in-house research activity, since 2017, the PLD facility is among the available techniques for users through the NFFA project. The scope of the NFFA (Nano-Foundry and Fine Analysis) facility in Trieste (c/o IOM-CNR and Elettra-Sincrotrone Trieste; http://trieste.nffa.eu/) and of the NFFA-Europe international collaboration (http://nffa.eu/) is to provide free open access, regulated accordingly to the European Charter of Access to Research Infrastructures as well as to carry on own research projects.

NFFA-Users from CNR-SPIN: C.Aruta, A.Galdi, F.Miletto Granozio



Pasquale Orgiani, SPIN Salerno, is the Principal Investigator of this joint activity.

Projects

Seed Projects

In the last years CNR-SPIN launched four calls 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 calls for seed projects resulted to be an important tool for the growth of young people and for the recognition of the most promising activities centered on the institute's mission.

Five projects were supported in the fourth call here described:

Electron quantum optics with quantized energy packets

The on-demand generation of single-electron states in mesoscopic systems has opened the way to the fascinating field of electron quantum optics. Inspired by the achievements in this field, the project examines the energy dynamics in one-dimensional conductors at the single-particle level, studying the partition of energy for single-electron excitations in optical-like setups.

PI: Luca VANNUCCI, GENOVA

Nuclear magnetic resonance based metamaterials

This project investigates cutting-edge artificial structured materials, whose electromagnetic radio-frequency response is strongly driven by a nuclear magnetic resonance: nuclear magnetic resonance based metamaterials. This approach could radically advance MRI performance in material science and clinical applications.

PI: Carlo RIZZA, L'AQUILA

CMOS Compatible Graphene-Semiconductor Hybrid Schottky Junctions AIRDEG

AIRDEG aims at exploring a novel class of radiation detectors based on graphene-semiconductor hybrid Schottky junction for accurate and precise detection of all kinds of ionizing radiations. The final goal is the fabrication and demonstration of a general-purpose detector with high sensitivity and excellent energy resolution for real-time or integral radiation detection.

PI: Giuseppe LUONGO, SALERNO

Complex magnetism At transition MEtal Oxide interface CAMEO

CAMEO studies the interplay between electronic correlations, structural distortions and spin orbit coupling in order to understand the mechanisms for the formation of new complex ordered phases at the $SrRuO_3/SrIrO_3$ interface, having high technological potential for the achievement of novel spintronics and spinorbitronics devices.

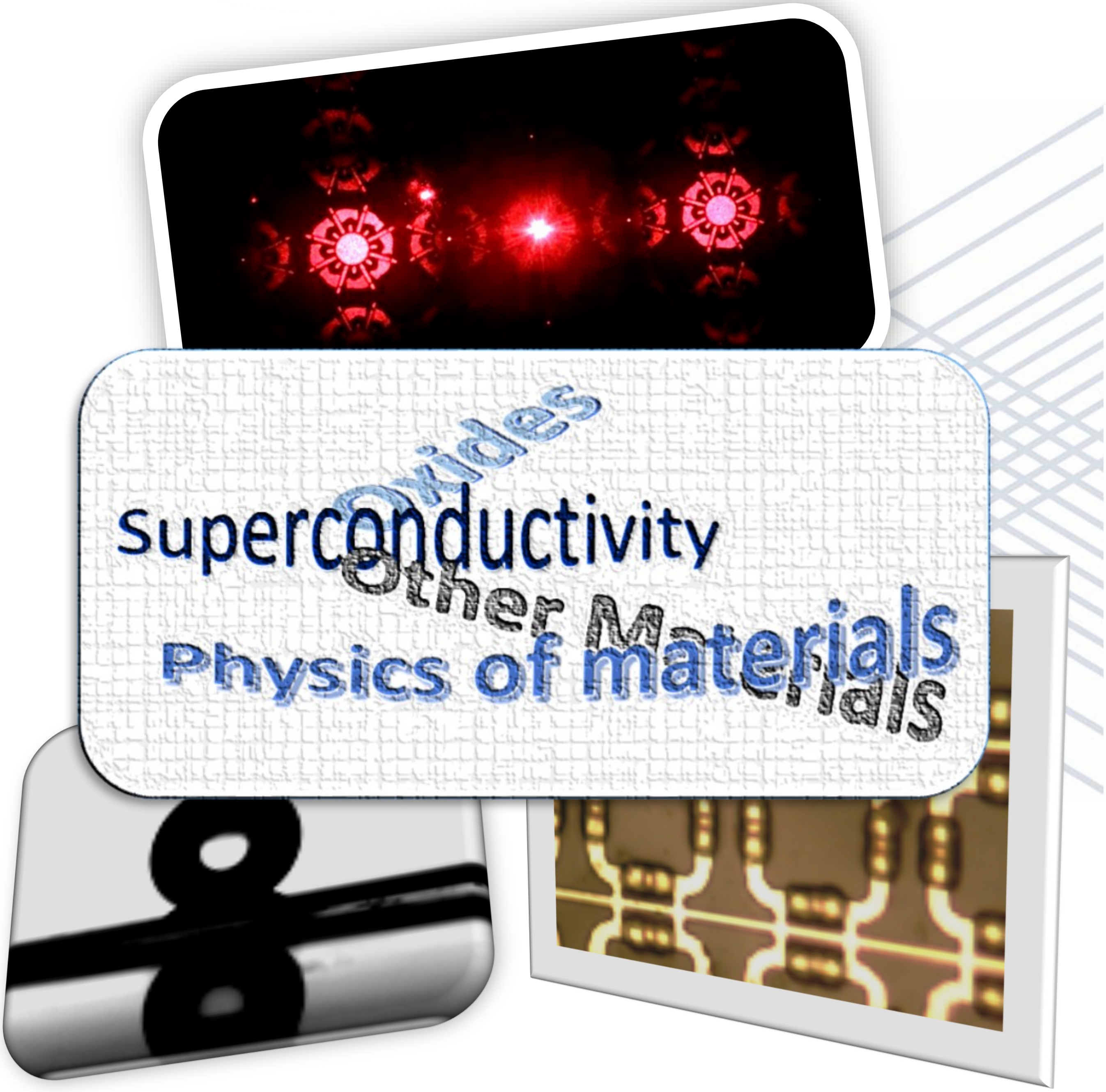
PI: Carmine AUTIERI, L'AQUILA/SALERNO

Hybrid Superconductor/Ferromagnet Josephson junctions for memory applications

The project pursues detailed experiments and modelling of magnetic Josephson junctions MJJs, aiming to demonstrate improved energy efficiency in memory applications. Moreover, a specifically designed MJJ is prepared for single flux quantum control.

PI: Roberta CARUSO, NAPOLI

Highlights


Oxides
Superconductivity
Other Materials
Physics of materials

Signatures of topological phase transitions in Josephson current-phase discontinuities

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Physical Review B 93, 220507(R) (2016)

Topological superconductors differ from topologically trivial ones due to the presence of topologically protected zero-energy modes. To date, experimental evidence of topological superconductivity in nanostructures has been mainly obtained by measuring the zero-bias conductance peak via tunneling spectroscopy. Here, we propose an alternative and complementary experimental recipe to detect topological phase transitions in these systems. We show in fact that, for a finite-sized system with broken time-reversal symmetry, discontinuities in the Josephson current-phase relation correspond to the presence of zero-energy modes and to a change in the fermion parity of the ground state. Such discontinuities can be experimentally revealed by a characteristic temperature dependence of the current, and can be related to a finite anomalous current at zero phase in systems with broken phase-inversion symmetry.

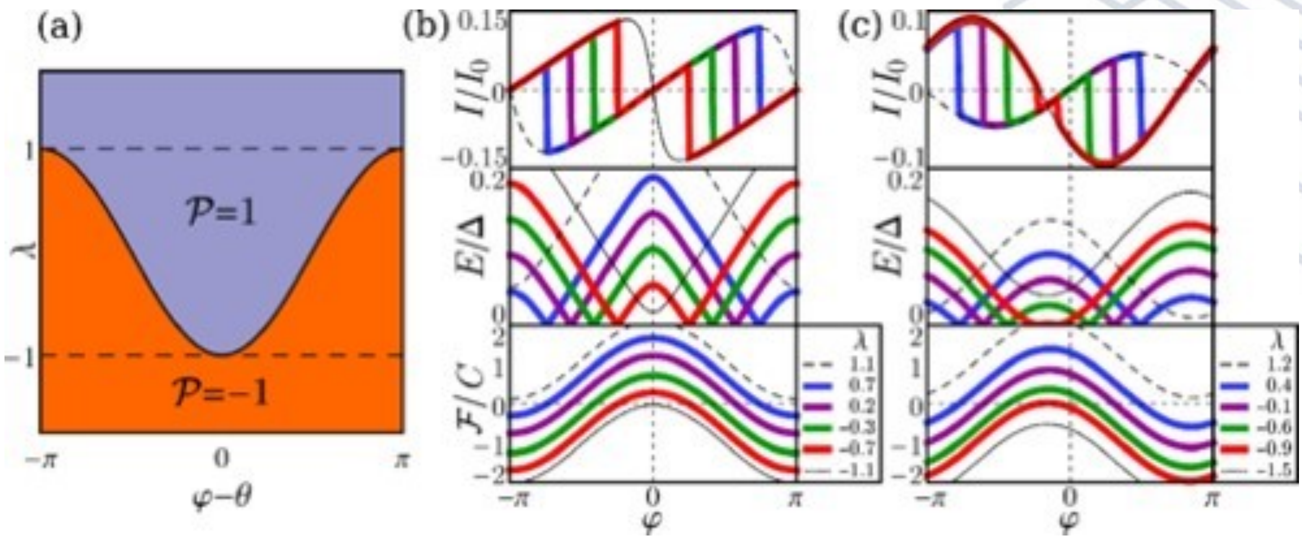

Figure: Topological phase space (a) of a finite-sized topological superconductor. Topological transitions between states with different fermion parities occur as a function of the phase difference between the edges of the system. Current phase relation, lowest-energy Andreev level, and Pfaffian for a quantum wire (b) and a planar well (c). Current discontinuities correspond to zero-energy modes and to variations of the fermion parity between the trivial and nontrivial branch (dashed and dotted lines respectively).

Highlights

Superconductivity—2016

Transport properties in aggregates of Nb nanowires templated by carbon nanotube films

M. Salvato[1,2], C. Cirillo[2,3], R. Fittipaldi[2,3], S.L. Prischepa[4], A. Vecchione[2,3],
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Carbon 105, 163 (2016)

Films of multiwall carbon nanotubes (CNTs), arranged on Si/SiO_2 substrates, are used as templates for Nb films with thickness in the range 3-50 nm deposited by sputtering. The resulting aggregates show normal state and superconducting properties similar to those observed in networks of superconducting nanowires (SNW) obtained by other methods. Decreasing the Nb thickness a superconductor-insulator transition is observed. Moreover, thermally activated phase slips in thicker samples, evolving in quantum phase slips in thinner nanowires, are observed in the superconducting state. The experimental results indicate that the template method based on CNTs is a promising alternative to the nanolithography techniques for obtaining SNWs.

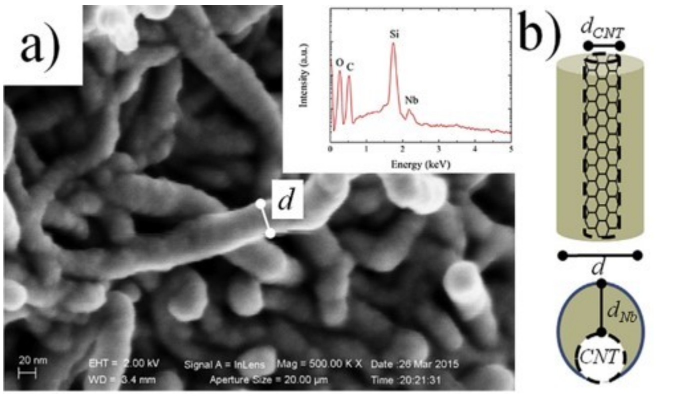

Figure 1. a) SEM image of the sample CNTNb30. The dot-ended line white line indicates the average diameter of a SNW. Inset: Energy Dispersive Spectrum of the same sample. b) Schematic of a SNW built using a CNT as a template (upper panel) and its cross section (lower panel); d_{Nb}, d_{CNT} and d represent the Nb thickness, the CNT diameter and the diameter of the whole structure, respectively.

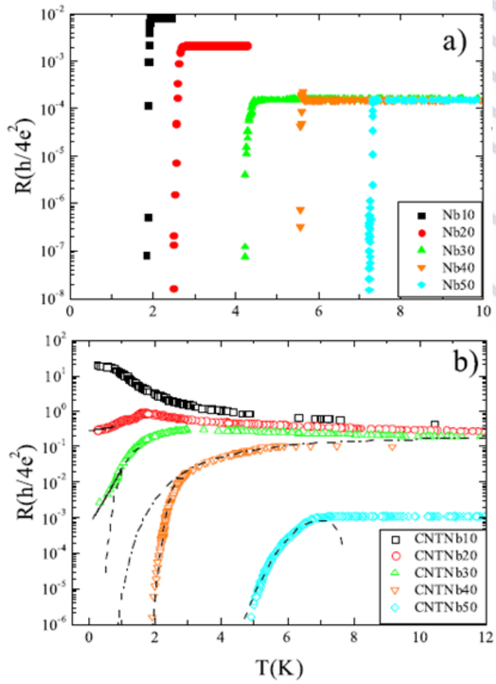

Figure 2. Resistance in units of quantum resistance for (a) the Nb reference samples and (b) the SNW aggregates. The lines in the right panel are fits to the data using the TAPS model (dashed lines), QPS model (solid lines) and Ambegaokar-Halperin (AH) model (dot-dashed line for CNTNb40).

Highlights

Superconductivity—2016

Competition between intrinsic and extrinsic effects in the quenching of the superconducting state in Fe(Se,Te) thin films

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Physical Review B 93, 054503 (2016)

We report the first experimental observation of the quenching of the superconducting state in current-voltage characteristics of an iron-based superconductor, namely, in Fe(Se,Te) thin films. Based on available theoretical models, our analysis suggests the presence of an intrinsic flux-flow electronic instability (FFI) along with non-negligible extrinsic thermal effects. The coexistence and competition of these two mechanisms classify the observed instability as halfway between those of low-temperature and of high-temperature superconductors, where thermal effects are, respectively, largely negligible or predominant.

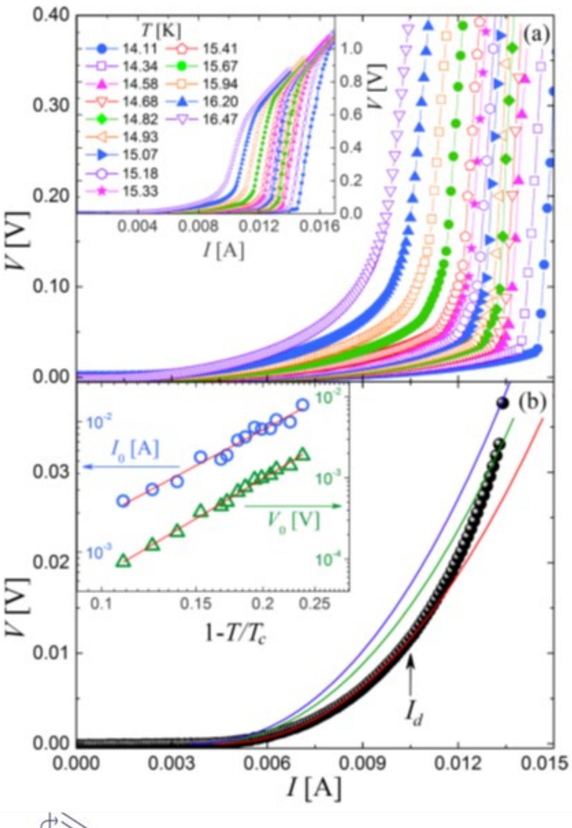

Figure 1. (a) I-V characteristics of Fe(Se,Te) microbridge at different temperatures in a magnetic field $B = 5$ T. Inset: I-V's in the full voltage range. Solid lines are guides for the eye. (b) Experimental I-V characteristic at 14.58 K. Here, solid lines are isothermal curves from model equation $V(I,T)=V_0(T)[I/I_c(T) - 1]^n$, with $T =$ 14.58 K, 14.82 K, and 14.93 K. Inset: Temperature dependence of the critical current I_c (left scale) and of the fitting parameter V_0 (right scale) as a function of $1 - T/T_c$. Solid lines are best fits of Eq. (2).

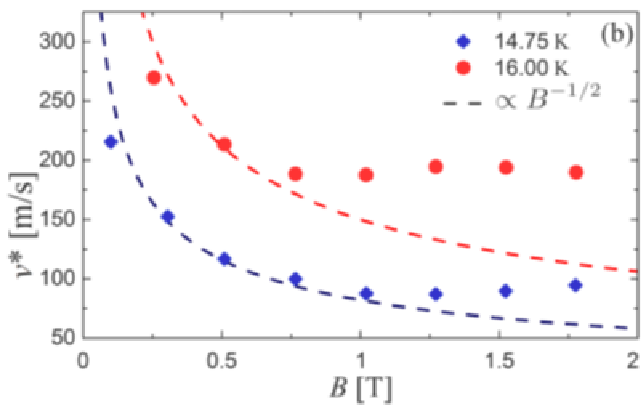

Figure 2. Critical vortex velocity v^* as a function of applied magnetic field B for both temperatures. Dashed lines are best fits of the expected behaviour $v^* \propto B^{-1/2}$ for FFI.

Highlights

Superconductivity—2016

Current driven transition from Abrikosov-Josephson to Josephson-like vortex in mesoscopic lateral S/S'/S superconducting weak links

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Scientific Reports 6, 35694 (2016)

Vortices are topological defects accounting for many important effects in superconductivity, superfluidity, and magnetism. Here we address the stability of a small number of such excitations driven by strong external forces. We focus on Abrikosov-Josephson vortex that appears in lateral superconducting S/S'/S weak links with suppressed superconductivity in S'. In such a system the vortex is nucleated and confined in the narrow S' region by means of a small magnetic field and moves under the effect of a force proportional to an applied electrical current with a velocity proportional to the measured voltage. Our numerical simulations show that when a slow moving Abrikosov-Josephson vortex is driven by a strong constant current it becomes unstable with respect to a faster moving excitation: the Josephson-like vortex. Such a current-driven transition explains the structured dissipative branches that we observe in the voltage-current curve of the weak link. When vortex matter is strongly confined phenomena such as magnetoresistance oscillations and reentrance of superconductivity can possibly occur. We experimentally observe these phenomena in our weak links.

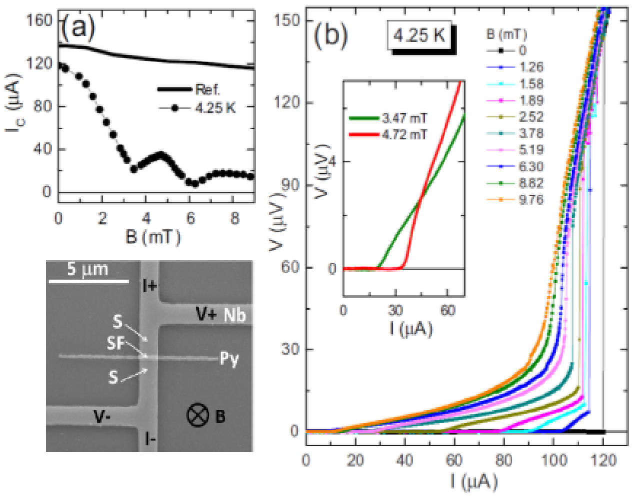

Figure 1. Evidence for critical current oscillations (a) and Abrikosov-Josephson to Josephson-like vortex transition (b). The micrograph of the addressed weak link is also shown in the left bottom image.

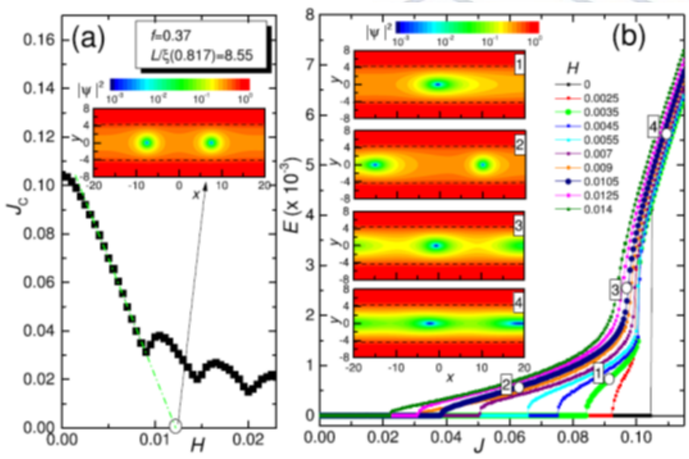

Figure 2. (a) Calculated critical current of the weak link as a function of magnetic field H. The inset is a snapshot of the squared order parameter $|\Psi|^2$ at the marked points of the E(J) curves, showing transition from Abrikosov-Josephson vortex flow (1,2) to Josephson-like vortex flow (3,4)

Highlights

Superconductivity—2016

Thermoelectric properties of iron-based superconductors and parent compounds

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Topical Review in Superconductor Science and Technology 29, 073002 (2016)

We review experimental data of thermoelectric transport properties of iron-based superconductors and parent compounds. We discuss possible Seebeck effect mechanisms into play, from whence one can extract information about Fermi surface reconstruction and Lifshitz transitions, multiband character, coupling of charge carriers with spin excitations, nematicity, quantum critical fluctuations close to the optimal doping for superconductivity, correlation. Additional information is obtained from the Nernst effect, whose enhancement in parent compounds must be related partially to multiband transport and low Fermi level, but mainly to the presence of Dirac cone bands at the Fermi level. In the superconducting compounds, large Nernst effect in the normal state is explained in terms of fluctuating precursors of the spin density wave state, while in the superconducting state it mirrors the usual vortex liquid dissipative regime. A comparison between the phenomenology of thermoelectric behavior of different families of iron-based superconductors and parent compounds allows to evidence the key differences and analogies.

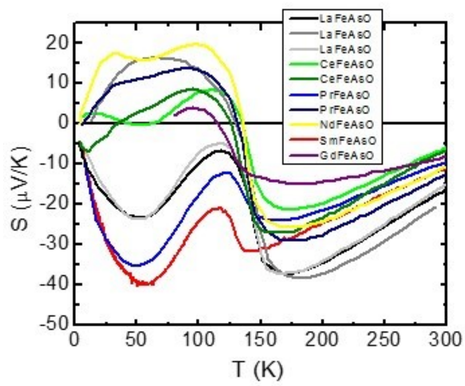

Figure 1. Seebeck coefficient curves of REFeAsO (RE=La, Ce, Pr, Nd, Sm, Gd) polycrystals taken from literature, exhibiting diffusive and phonon drag regimes.

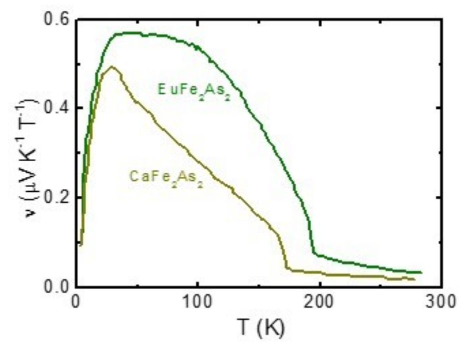

Figure 2. Nernst effect curves measured in 122 parent compounds $EuFe_2As$ and $CaFe_2As_2$ single crystals, exhibiting anomalous enhancement attributed to the formation of Dirac cones in the electronic structure.

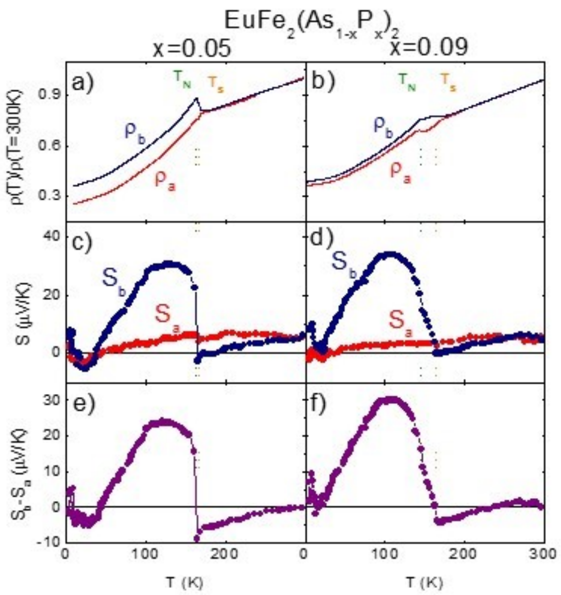

Figure 3. Nematicity in of $EuFe_2(As_{0.95}P_{0.05})_2$ and $EuFe_2(As_{0.91}P_{0.09})_2$ single crystals: electrical resistivity (a,b) and Seebeck coefficient (c,d) along the orthorhombic a and b axes, and temperature dependences of the Seebeck coefficient anisotropy (S_b-S_a) (e,f).

Highlights

Superconductivity—2016

First-principles and angle-resolved photoemission study of lithium doped metallic black phosphorous

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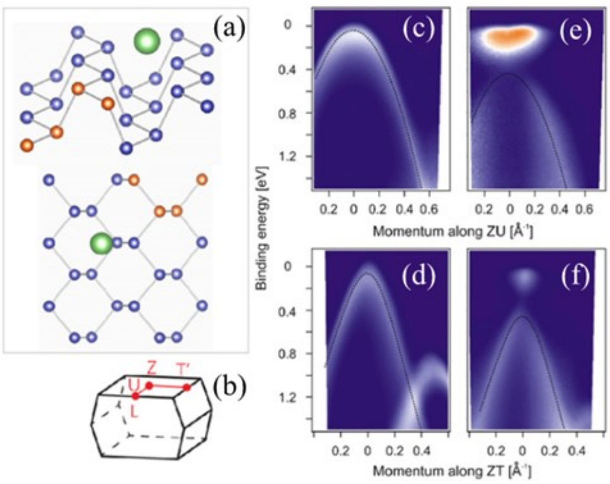
2D Materials 3, 025031 (2016)

First principles calculations demonstrate the metallization of phosphorene by means of Li doping filling the unoccupied antibonding *p z* states. The electron-phonon coupling in the metallic phase is strong enough to eventually lead to a superconducting phase at T_c = 17 K for LiP_8 stoichiometry. Using angle-resolved photoemission spectroscopy we confirm that the surface of black phosphorus can be chemically functionalized using Li atoms which donate their 2s electron to the conduction band. The combined theoretical and experimental study demonstrates the semiconductor-metal transition indicating a feasible way to induce a superconducting phase in phosphorene and few-layer black phosphorus.

The theoretical predictions of sizable electron-phonon coupling and superconducting phase at 17 K in lithium doped black phosphorus's surface or phosphorene, and its demonstrated experimental feasibility deserves further dedicated studies, already performed on other 2D systems, like four-point probe electrical transport measurements to confirm the existence of a superconducting phase in phosphorene.



Highlights

Superconductivity—2016

Superconductivity in metastable phases of phosphorus-hybride compounds under high pressure

J. A. Flores-Livas[1], M. Amsler[2], C. Heil[3], A. Sanna[4], L. Boeri[3], G. Profeta[5], C. Wolverton[2], S. Goedecker[1], and E. K. U. Gross[4]

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Physical Review B 93, 020508 (2016)

Reports on sulfur hydride attaining metallicity under pressure and exhibiting superconductivity at temperatures as high as 200 K have spurred an intense search for another room-temperature superconductor among hydrogen-rich compounds. Recently, compressed phosphorus hydride (phosphine) was reported to metallize at pressures above 45 GPa, reaching a superconducting transition temperature (T_c) of 100 K at 200 GPa.
However, neither the exact composition nor the crystal structure of the superconducting phase have been conclusively determined. This work reports an extensive study of the phase diagram of PHn (n=1-6) by means of *ab initio* crystal structure predictions using the minima hopping method (Fig. 1).
The results do not support the existence of thermodynamically stable PHn compounds, which exhibit a tendency for element decomposition at high pressure even when vibrational contributions to the free energies are taken into account.
Although the lowest energy phases of PH1,2,3 display Tc's comparable to experiments (Fig. 2), it remains uncertain if the measured values of Tc can be fully attributed to a phase-pure compound of PHn.

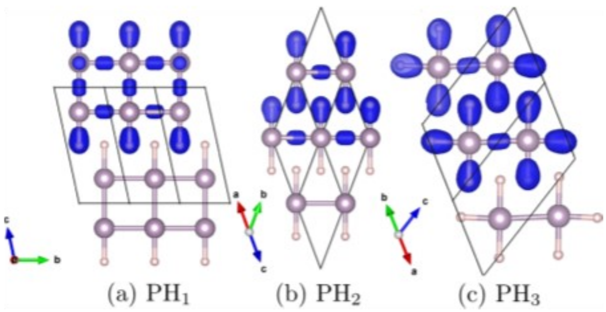

Fig. 1. Low-lying enthalpy structures found for different compositions under pressure 120 GPa. The large and small spheres denote the P and H atoms, respectively.
The Electron Localization Function ad a fixed value of 0.8 is shown in the upper part of the figure.

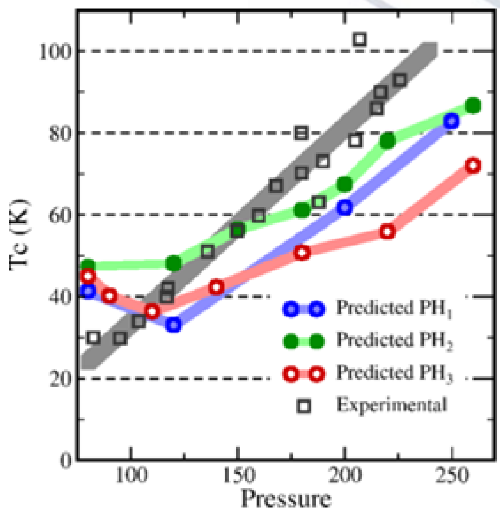

Fig. 2. Predicted superconducting critical temperature for PH1, PH2 and PH3 as function of the pressure compared with experimental results.

Highlights

Superconductivity—2016

Research Update: Structural and transport properties of (Ca,La)$FeAs_2$ single crystal

F. Caglieris[1], A. Sala[1,2,3], M. Fujioka[4,5], F. Hummel[6], I. Pallecchi[1], G. Lamura[1], D. Johrendt[6], Y. Takano[4], S. Ishida[3], A. Iyo[3], H. Eisaki[3] H. Ogino[2], H. Yakita[2], J. Shimoyama[2,7] and M. Putti[1]

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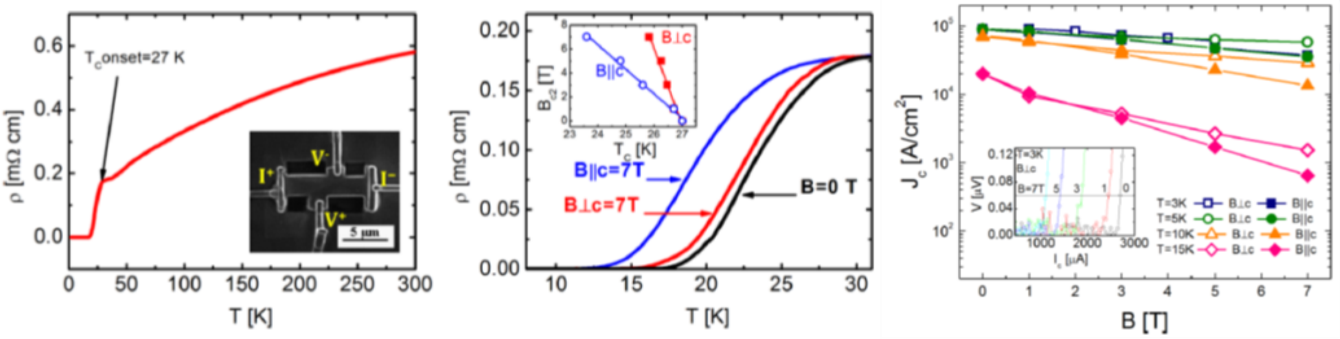
APL Materials 4, 020702 (2016)

Structural and transport properties in the normal and superconducting state are investigated in a $Ca_{0.8}La_{0.2}FeAs_2$ single crystal with T_c=27 K, belonging to the newly discovered 112 family of iron based superconductors. The transport critical current density J_c for both field directions measured in a focused ion beam patterned microbridge reveals a weakly field dependent and low anisotropic behaviour with a low temperature value as high as $J_c(B=0)=10^5$ A/cm^2. This demonstrates not only bulk superconductivity but also the potential of 112 superconductors towards applications. Interestingly this superconducting compound undergoes a structural transition below 100 K which is evidenced by temperature-dependent X-ray diffraction measurements. Data analysis of Hall resistance and magnetoresitivity indicate that magnetotransport properties are largely dominated by an electron band, with a change of regime observed in correspondence of the onset of a structural transition. In the low temperature regime, the contribution of a hole band to transport is suggested, possibly playing a role in determining the superconducting state.



Left: Resistivity vs *T* measurement of a $Ca_{0.8}La_{0.2}FeAs_2$ single crystal. Inset: IB image of the FIB patterned crystal. Center: Resistivity transition for magnetic fields B=0 and B=7T, applied both parallel (B∥c) and perpendicular (B ⊥ c) to the *c*-axis. Inset: B_{c2} vs T_c up to B_{c2}=7T for B∥c and B ⊥ c. *Right:* Transport J_c measurements at fixed temperatures as a function of B∥c and B ⊥ c. Inset: V-I curves measured at T=3K at different perpendicular fields.

Highlights

Superconductivity—2016

Geometrical vortex lattice pinning and melting in YBaCuO submicron bridges

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[3]Northern Illinois University, Department of Physics, USA; [4]NEST and Scuola Normale Superiore, Pisa, Italy; [5]CNR-SPIN UOS Napoli, Italy;
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* These authors contributed equally to this work.

Scientific Reports 6, 38677 (2016)

We report on the geometrical melting of the vortex lattice in a wide YBCO submicron bridge preceded by magnetoresistance (MR) oscillations fingerprinting the underlying regular vortex structure. Combined MR measurements and numerical simulations unambiguously relate the resistance oscillations to the penetration of vortex rows with intermediate geometrical pinning and uncover the details of geometrical melting.
Our findings offer a reliable and reproducible pathway for controlling vortices in geometrically restricted nanodevices and introduce a novel technique of geometrical spectroscopy, inferring detailed information of the structure of the vortex system through a combined use of MR curves and large-scale simulations.

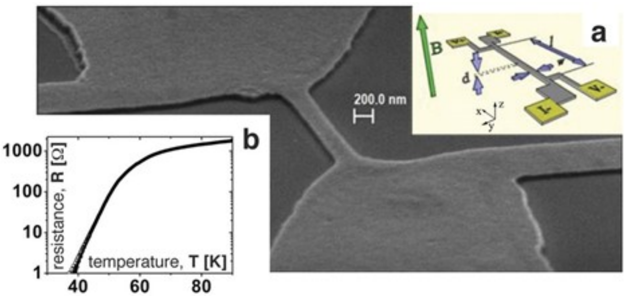

Figure 1. SEM image of a 230 nm wide YBCO bridge. Inset a) shows the scheme of the magnetoresistance setup, inset (b) shows the log-linear plot of the bridge resistance in the temperature range 30–90 K.

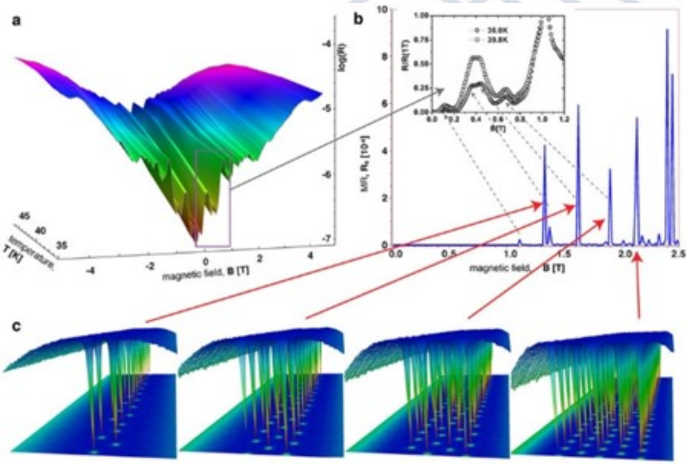

Figure 2. Magnetoresistance and vortex configurations. (a) Experimental MR of the 230 nm wide sample as a function of T. Important to note is that the position of the peaks does not change much with temperature. (b) Simulated MR of a 2D system with dimensions similar to those of the experimental system. The periodicity and the relative peak heights are reproduced correctly. The inset shows comparable experimental curves at 36 K and 39.8 K at low fields. (c) Vortex configurations at the peaks of the simulated MR curve.

Highlights

Oxides—2016

Role of Associated Defects in Oxygen Ion Conduction and Surface Exchange Reaction for Epitaxial Samaria-Doped Ceria Thin Films as Catalytic Coatings

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ACS Applied Materials & Interfaces 8, 14613 (2016)

Samaria-doped ceria (SDC) thin films are particularly important for a wide range of applications, such as catalysts, gas sensors, memristors, solar-to-fuel convertors, oxygen storage devices, and microsolid oxide fuel cells. In this paper, we report a comparative study investigating ionic conductivity and surface reactions for well-grown epitaxial SDC films varying the samaria doping concentration. With increasing doping an enhancement in the defect association is observed by Raman spectroscopy. By using complementary techniques, such as electrochemical impedance spectroscopy and electrochemical strain microscopy (ESM), we show for the heavily doped films the detrimental effects of associated defects on the "bulk" ion conduction properties and the beneficial effects on the "surface" oxygen exchange activity. In a model experiment, through a solid solution series of samaria doped ceria epitaxial films, we reveal that the occurrence of associated defects in the bulk affects the surface charging state of the SDC films to increase the exchange rates. The implication of these findings is the design of coatings with tuned oxygen surface exchange by controlling the bulk associated clusters for future electrocatalytic applications

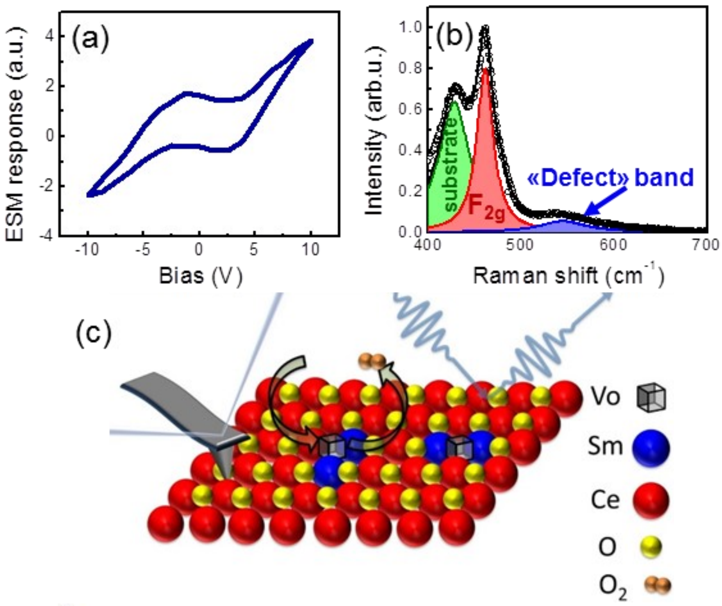

Figure 1. (a) ESM hysteresis loop related to the needed finite voltages to activate the forward and reversed redox-processes in the SDC films. (b) Raman spectra normalized to the maximum peak intensity showing the peak corresponding to the $NdGaO_3$ substrate, while the F_{2g} and "Defect" (D) band are ascribed to the film: F_{2g} is the oxygen anionic–cationic stretching Raman band of the ceria cubic fluorite structure and D is the second order phonon scattering on oxygen vacancies. (c) Schematics of the ESM tip scan and Raman laser radiation interaction on the SDC surface during the oxygen exchange reaction

A-Site Cation Substitutions in Strained Y-Doped $BaZrO_3$ Multilayer Films Leading to Fast Proton Transport Pathways

C. Aruta[1],C. Han[2], S. Zhou[3], C. Cantoni[4], N. Yang[1], A. Tebano[1] , T.L. Lee[5], C. Schlueter[5] and A. Bongiorno[6]

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The Journal of Physical Chemistry C 120, 8387 (2016)

Proton-conducting perovskite oxides form a class of solid electrolytes for novel electrochemical devices operating at moderate temperatures. Our nanometer-thick epitaxial $BaZr_{0.8}Y_{0.2}O_3$ (BZY) films on $NdGaO_3$(110) substrates have been shown to possess high values of the proton conductivity at temperatures of 550−600 °C. Here we elucidate the atomistic origin of the fast proton transport properties of strained ultrathin BZY films by hard X-ray photoelectron spectroscopy (HAXPES), scanning transmission electron microscopy (STEM) and density functional theory (DFT) calculations. HAXPES measurements demonstrate that our BZY films incorporate a significant amount of Y dopants substituting for Ba^{2+} and STEM shows that these substitutional defects agglomerate forming columnar regions crossing vertically from the surface to the interface the entire film. DFT calculations also show that, in regions rich in Y substitutions for both Zr and Ba, the proton transfer process involves nearly zero-energy barriers, indicating that A-site cation substitutions by Y lead to fast transport pathways and hence are responsible for the previously observed enhanced values of the proton conductivity of these perovskite oxide films.

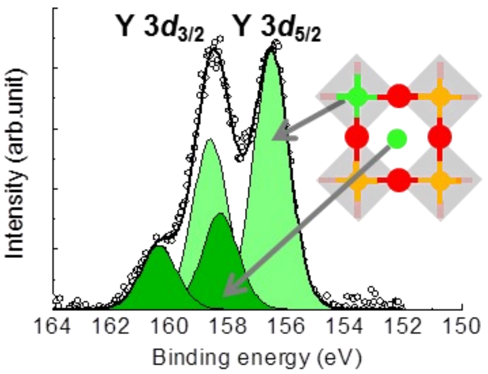

Figure 1. Y 3d HAXPES peaks together with the result of the fitting. The inset shows a ball and stick illustration of the chemical species in the strained BZY film assigned to the peaks.

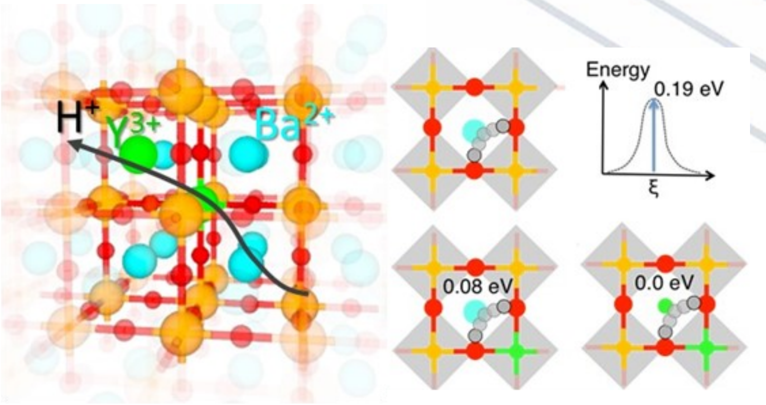

Figure 2. (Left) BZY lattice with the relaxed atomic positions as obtained from a DFT calculation. (Right) Proton transfer between two nearest neighbor O2− ions coordinated or in close proximity of substitutional Y dopants, together with a schematics of the energy profile visited during the proton transfer process. The energy barrier values calculated by DFT are also shown in each panel.

Highlights

Oxides—2016

Unravelling the low-temperature metastable state in perovskite solar cells by noise spectroscopy

C. Barone[1], F. Lang[2], C. Mauro[1], G. Landi[3], J. Rappich[2], N. H. Nickel[2], B. Rech[2], S. Pagano[1], H. C. Neitzert[3]

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Scientific Reports 6, 34675 (2016)

The hybrid perovskite methylammonium lead iodide $CH_3NH_3PbI_3$ recently revealed its potential for the manufacturing of low-cost and efficient photovoltaic cells. However, many questions remain unanswered regarding the physics of the charge carrier conduction. In this respect, it is known that two structural phase transitions, occurring at temperatures near 160 and 310 K, could profoundly change the electronic properties of the photovoltaic material, but, up to now, a clear experimental evidence has not been reported. In order to shed light on this topic, the low-temperature phase transition of perovskite solar cells has been thoroughly investigated by using electric noise spectroscopy. Here it is shown that the dynamics of fluctuations detect the existence of a metastable state in a crossover region between the room-temperature tetragonal and the low-temperature orthorhombic phases of the perovskite compound. Besides the presence of a noise peak at this transition, a saturation of the fluctuation amplitudes is observed induced by the external DC current or, equivalently, by light exposure. This noise saturation effect is independent on temperature, and may represent an important aspect to consider for a detailed explanation of the mechanisms of operation in perovskite solar cells.

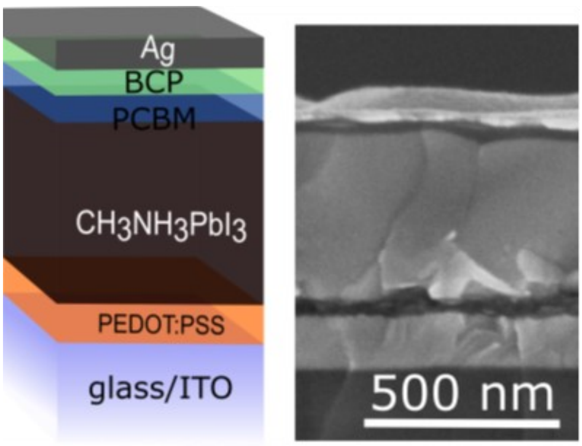

Figure 1. Sketch of the used inverted perovskite solar cell structure, consisting of the layer stack glass/ITO/PEDOT:PSS/$CH_3NH_3PbI_3$/$PC_{61}BM$/BCP/Ag. The cross sectional scanning electron micrograph is shown in the right image.

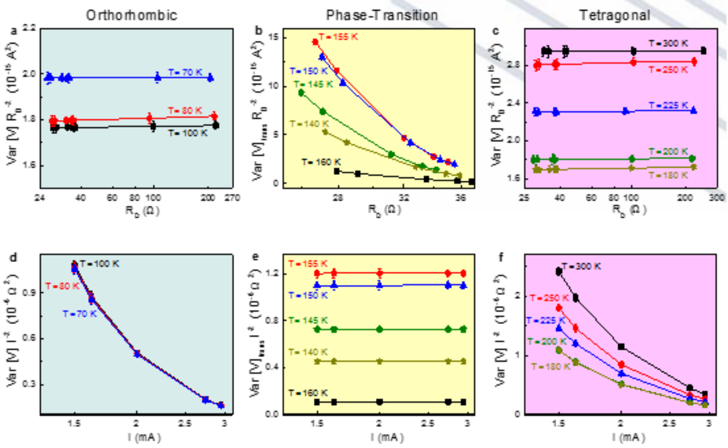

Figure 2. Behavior of the noise amplitude in different temperature regions. The normalized noise is shown as a function of the differential resistance R_D (upper panels) and of the bias current I (lower panels).

Highlights

Oxides—2016

Tunable spin polarization and superconductivity in engineered oxide interfaces

D. Stornaiuolo[1, 2*], C. Cantoni[3], G. M. De Luca[1, 2], R. Di Capua[1, 2], E. Di. Gennaro[1, 2], G. Ghiringhelli[4], B. Jouault[5], D. Marrè[6], D. Massarotti[1, 2], F. Miletto Granozio[2], I. Pallecchi[6], C. Piamonteze[7], S. Rusponi[8], F. Tafuri[2, 9] and M. Salluzzo[2]

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[5]Laboratoire Charles Coulomb, CNRS, Université Montpellier 2, France
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[7]Swiss Light Source, Paul Scherrer Institut, Villigen PSI, Switzerland
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Nature Materials 15, 278 (2016)

In the study published on Nature Materials the CNR-SPIN researchers realized a new kind of 2DEG that possesses, besides a superconducting ground state, a strong spin-polarization. The result was obtained by inserting two atomic layers of the antiferromagnetic and insulating compound $EuTiO_3$ between $LaAlO_3$ and $SrTiO_3$. The resulting heterostructures shows at the same time a robust ferromagnetic transition at a Curie temperature of 8 K and a superconducting transition below 150 mK. Using a prototype field effect device, the researchers showed that the degree of spin-polarization and the superconductive critical temperature can be both controlled by the electron carrier density of the 2DEG. As a consequence, the system is characterized by a complex phase diagram superconductivity emerges from a ferromagnetic normal state.
This result has important implication for the potentialities of these materials in the field of oxide electronics alternative, at least in some particular cases, to the traditional semiconducting silicon based technology and to the new emerging 2D-materials of interest in spintronics.

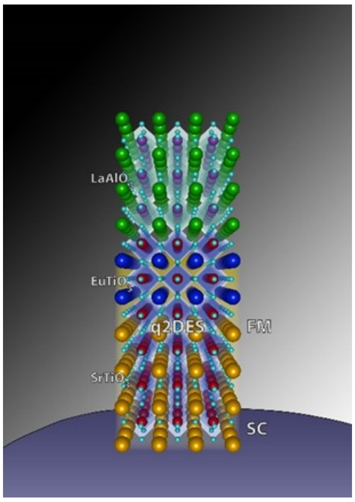

Figure 1. A sketch of the novel spin-polarized q2DEG obtained by embedding a FM $EuTiO_3$ between $LaAlO_3$ and $SrTiO_3$.

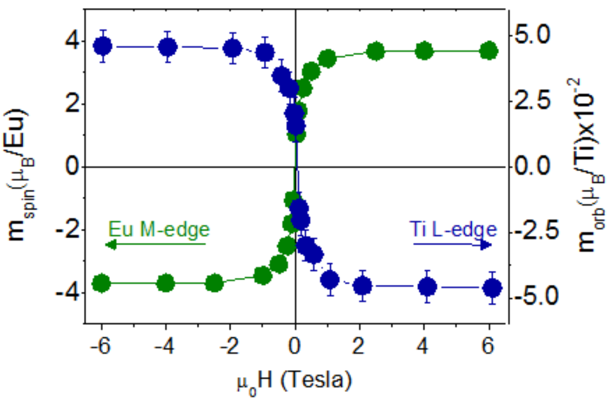

Figure 2. Eu spin moment and Ti orbital moment measured by XMCD at 2 K, showing a link between ETO magnetism and 2DEG spin-polarization.

Highlights

Other Materials—2016

Intertwined Rashba, Dirac, and Weyl Fermions in Hexagonal Hyperferroelectric

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Physical Review Letters 117, 076401 (2016)

By means of density functional theory based calculations, we study the role of spin-orbit coupling in the new family of ABC hexagonal hyperferroelectrics, which spontaneously polarize even in the presence of an unscreened depolarization field. We unveil an extremely rich physics strongly linked to ferroelectric properties, ranging from the electric control of bulk Rashba effect to the existence of a three-dimensional topological insulator phase, with concomitant topological surface states even in the ultrathin film limit. Dirac cones are found to be strongly modulated by the ferroelectric switching, opening interesting perspectives, e.g., for domain engineering and control of topological p-n junctions . Topological interface states and bulk bandgap can be tuned by interfacing few layers of a topological hyperferroelectric with a normal ferroelectric. Finally, a Weyl semimetal phase can be achieved by alloying the topological hyperferroelectric in a diluite solution with a normal ferroelectric.

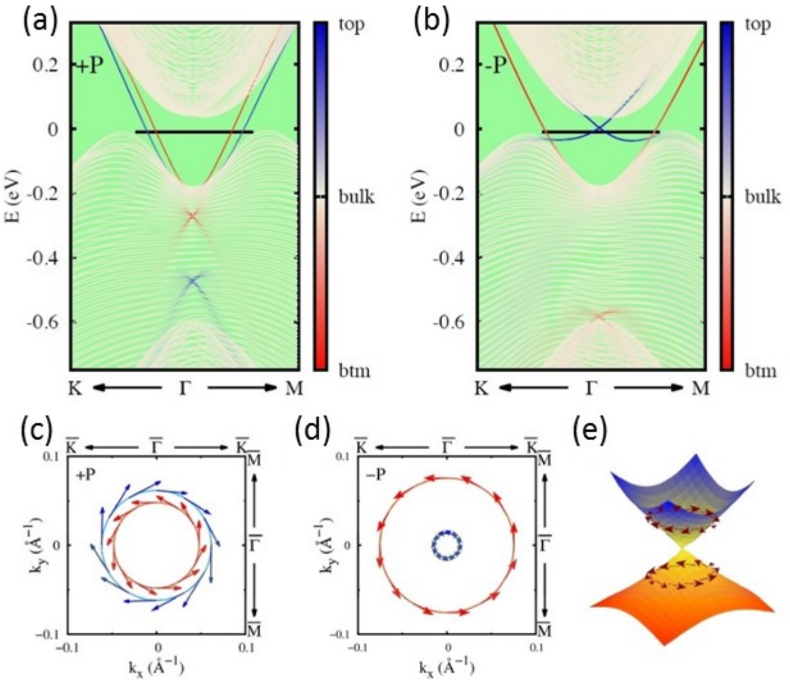

Figure 1. Surface states of KMgBi calculated in slab geometry for opposite direction of ferroelectric polarization, showing the strong tenability of Dirac cones arising from the interplay with ferroelectricity. Characters of top (MgBi-terminated) and bottom (K-terminated) surface states are highlighted by the color scale, revealing that the Dirac cones of K-terminated surfaces are always buried in the continuum of bulk states. (c), (d) display spin textures of the surface states at the energy cut shown in panels (a), (b), while (e) shows the reversal of spin-polarization chirality when crossing the Dirac cone.

Enhanced nonlinear effects in pulse propagation through epsilon-near-zero media

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Laser & Photonics Review 10, 517 (2016)

In recent years, unconventional metamaterial properties have triggered a revolution of electromagnetic research which has unveiled novel scenarios of wave-matter interaction. A very small dielectric permittivity is a leading example of such unusual features, since it produces an exotic static-like regime where the electromagnetic field is spatially slowly-varying over a physically large region. The so-called epsilon-near-zero (ENZ) metamaterials thus offer an ideal platform where to manipulate the inner details of the "stretched" field. Here we theoretically prove that a standard nonlinearity is able to operate such a manipulation to the point that even a thin slab produces a dramatic nonlinear pulse transformation, if the dielectric permittivity is very small within the field bandwidth. The predicted non-resonant releasing of full nonlinear coupling produced by the epsilon-near-zero condition does not resort to any field enhancement mechanism and opens novel routes to exploiting matter nonlinearity for steering the radiation by means of ultra-compact structures.

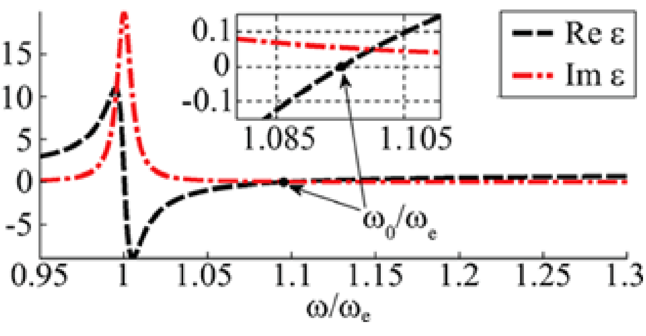

Figure 1. In the linear regime the slab has a dielectric permittivity $\varepsilon(\omega)$ with a standard Lorentz profile located at the resonant frequency ω_e and with a zero-crossing-point of its real part at ω_0. Dispersion parameters have been chosen in such a way that the imaginary part of the permittivity is low around zero-crossing-point so that $|\varepsilon(\omega)|$ is much smaller than one in a spectral bandwidth around ω_0 and the slab can support the ENZ regime.

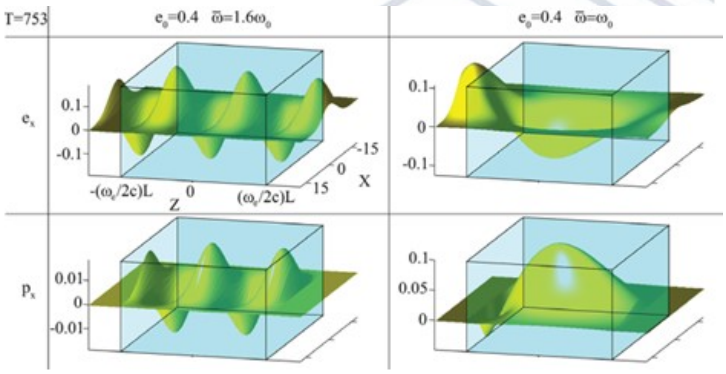

Figure 2. Mechanism supporting the full potential of the nonlinear wave-matter interaction in the ENZ regime. Spatial profiles of the dimensionless electric e_x and polarization p_x fields at the normalized time T = 753 of two pulses propagating within the slab of thickness L with normalized amplitude e_0 = 0.4 and central frequencies $1.6\omega_0$ (outside of the ENZ regime) ω_0 (in the ENZ regime). In the first case the electric field e_x is "large" only at the regions around the peaks of the wave and the time drift of such regions does not allow the polarization p_x to increase and to trigger the nonlinear wave-matter coupling. In the second case, in a physically large volume, the spatially slowly varying character of e_x yields the onset of the nonlinear regime.

A hybrid tunable THz metadevice using a high birefringence liquid crystal

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Scientific Reports 6, 34536 (2016)

We investigate a hybrid re-configurable three dimensional metamaterial based on liquid crystal (Lc) as tuning element in order to build novel devices operating in the terahertz range. The proposed metadevice is an array of meta-atoms consisting of split ring resonators having suspended conducting cantilevers in the gap region. Adding a "third dimension" to a standard planar device plays a dual role: (i) enhance the tunability of the overall structure, exploiting the birefringence of the liquid crystal at its best, and (ii) improve the field confinement and therefore the ability of the metadevice to efficiently steer the THz signal. We describe the design, electromagnetic simulation, fabrication and experimental characterization of this new class of tunable metamaterials under an externally applied small voltage. By infiltrating tiny quantities of a nematic liquid crystal in the structure, we induce a frequency shift in the resonant response of the order of 7–8% in terms of bandwidth and about two orders of magnitude change in the signal absorption. We discuss how such a hybrid structure can be exploited for the development of a THz spatial light modulator.

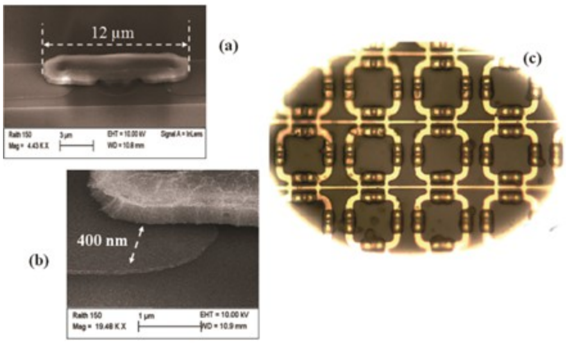

Figure 1. Details of the fabricated meta device. SEM magnification of (**a**) the mushroom-shaped structure formed by two adjacent cantilevers on each side of the gap and (**b**) a single cantilever. (**c**) Optical image (× 100) of the final hybrid meta-device after LC infiltration.

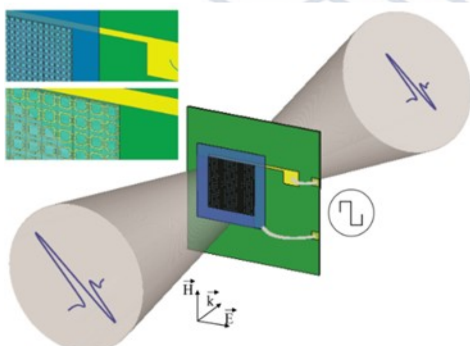

Figure 2. Sketch of the experimental set-up used to test the tunability of the metamaterial response.

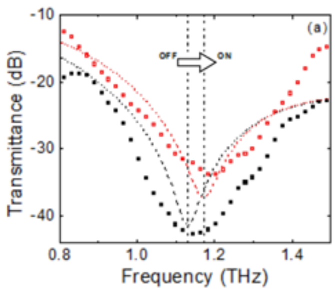

Figure 3. Transmission spectra of the hybrid metamaterial measured at zero bias (state OFF, full black square points) and at 10 V (state ON, open red square points). Dashed curves refer to the results of simulations (OFF, black line; ON, red line), assuming a LC not perfectly aligned with the THz field in the unpolarized state and with a complex anisotropic dielectric permittivity (see text for details). Dashed vertical lines highlight the frequency blue shift switching the metadevice from OFF to ON.

Highlights

Other Materials—2016

A noise model for the evaluation of defect states in solar cells

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Scientific Reports 6, 29685 (2016)

A theoretical model, combining trapping/detrapping and recombination mechanisms, is formulated to explain the origin of random current fluctuations in solar cells. The applicability of the proposed model has been verified on pristine and artificially degraded silicon-based devices. Distinct differences between dark and photo-induced noise have been found and interpreted in terms of a Shockley-Read-Hall theory. The reported results show that the formation of the defects, activated under illumination or charge carrier injection, is related to long-term degradation of the solar cells.
Noise analysis can also provide interesting information on radiation damage, and can be used for a detailed temperature-dependent electrical characterization of the charge carrier capture/emission and recombination kinetics. This aspect represents an advantage of the fluctuation spectroscopic technique, which gives the possibility to directly evaluate the cell health state.
Application of this noise model to other photovoltaic materials, such as organic and perovskite compounds, is currently in progress.

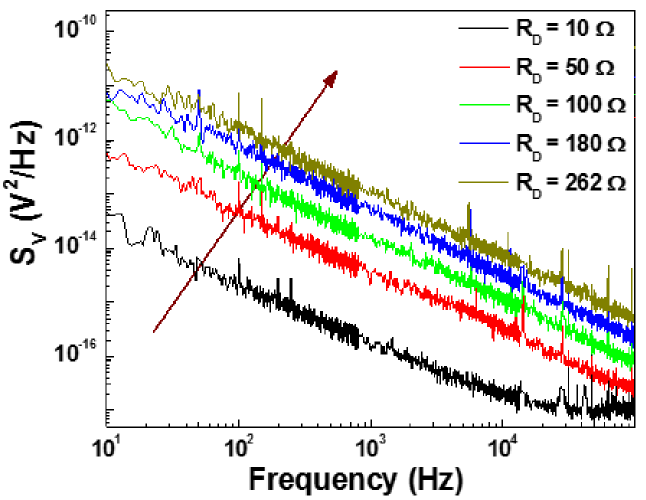

Figure 1. Frequency dependence of the voltage-spectral density S_V, at 300 K and for several differential resistance R_D values. A similar behavior is observed for pristine and proton irradiated silicon solar cells.

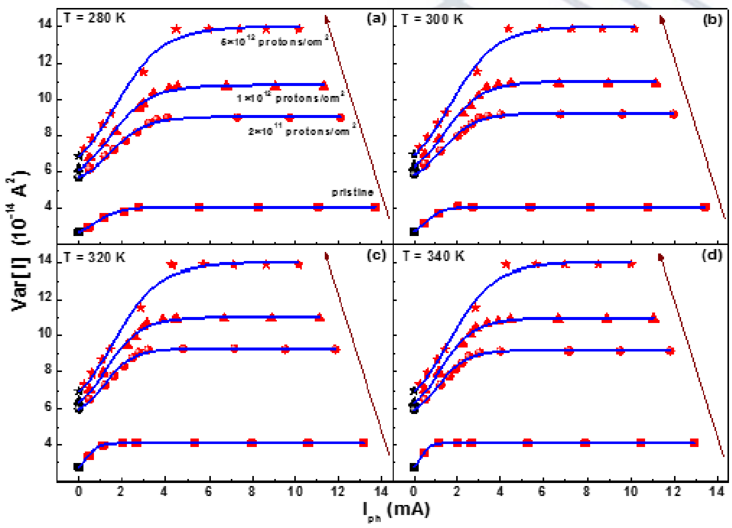

Figure 2. Dependence of the current fluctuations amplitude on the photocurrent for temperatures from 280 to 340 K. The experimental data points and the best fitting curves, using the formulated model, are shown for pristine and irradiated samples.

Highlights

Other Materials—2016

Layer-dependent quantum cooperation of electron and hole states in the anomalous semimetal WTe_2

P. K. Das[1,2], D. Di Sante[3,4], I. Vobornik[1], J. Fujii[1], T. Okuda[5], E. Bruyer[3], A. Gyenis[6], B.E. Feldman[6], J. Tao[7], R. Ciancio[1], G. Rossi[1,8], M.N. Ali[9], S. Picozzi[3], A. Yadzani[6], G. Panaccione[1], & R.J. Cava[6]

[1]Ist. CNR-IOM, Lab. TASC, Trieste (IT), [2]ICTP Trieste (IT), [3]Ist. CNR-SPIN, L'Aquila (IT), [4]Univ. L'Aquila (IT) [5]HSRC, Hiroshima Univ. (JP), [6]Princeton Univ. (NJ, USA), [7]Brookhaven National Laboratory (USA), [8]Univ. Milano (IT)

Nature Communications 7, 10847 (2016)

Boosted by the anomalous bulk properties of semimetallic WTe_2, here we report angle- and spin-resolved photoemission spectroscopy of WTe2 single crystals, through which we disentangle the role of W and Te atoms in the formation of the band structure and identify the interplay of charge, spin and orbital degrees of freedom. Supported by first-principles calculations and high-resolution surface topography, we reveal the existence of a layer-dependent behaviour. The balance of electron and hole states is found only when considering at least three Te–W–Te layers, showing that the behaviour of WTe_2 is not strictly two dimensional.

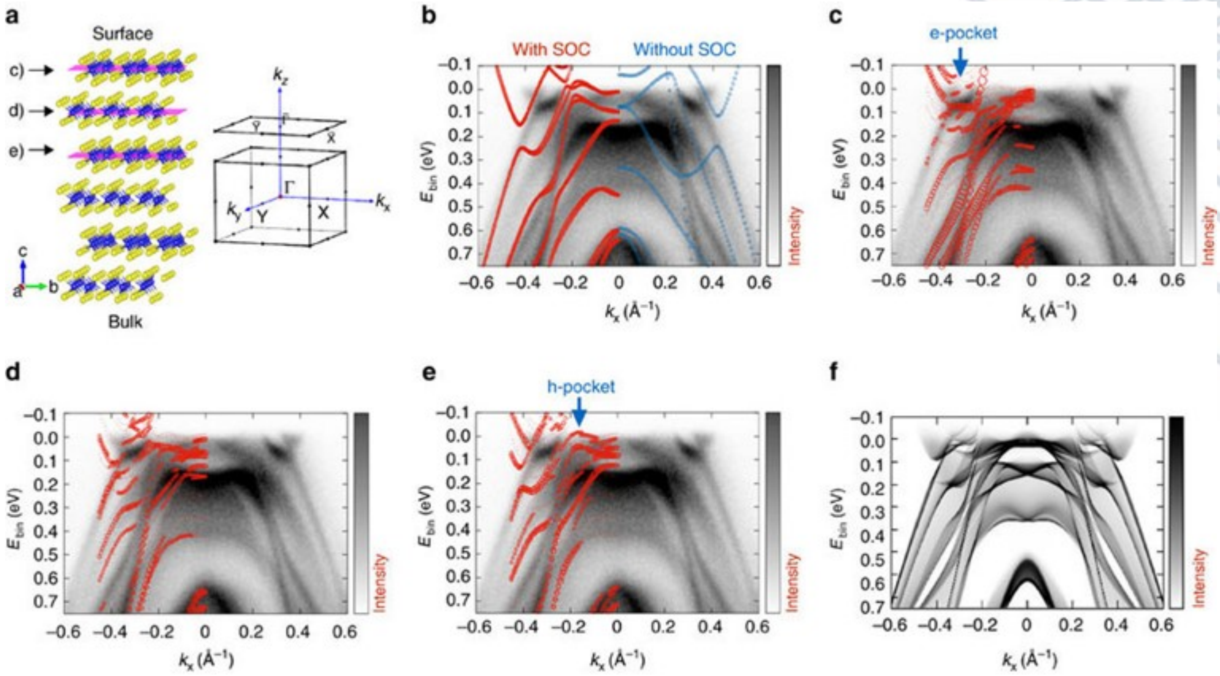

Figure 1. Evolution of band structure with number of layers. (a) Crystal structure of WTe_2 with the bulk and surface Brillouin zones on the right. (b–e) ARPES measurements (hv 68 eV, T 77 K) of the electronic structure along the GX high symmetry direction (along the W-chains); (b) bulk electronic structures as calculated with spin-orbit coupling (SOC) (red bands at negative momenta) and without SOC (blue bands at positive momenta); theoretical bands projected (c) on the topmost WTe_2 planes and (d,e) on second and third plane, respectively. In (c,e,) blue arrows mark the positions of the theoretical electron and hole pockets, respectively. In (b,e,) the size of the circles is proportional to the weight of the layer-resolved orbital character. (f) Theoretical surface spectral function A(k,E).

Role of Polar Phonons in the Photo Excited State of Metal Halide Perovskites

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Scientific Reports 6, 28618 (2016)

In the last years metal halide perovskites have come up as very promising solar cell materials. They show the potential of becoming competitive with current silicon based solar cells mainly because of their high photovoltaic efficiency about 20 % reached in very short time. The most frequently studied material is $MAPbI_3$ which shows a large range of exciton binding energies as reported by various experiments. In this work we present advanced relativistic calculations capable to directly calculate the excitonic properties from first principles. We apply this method to different halide perovskites. At low temperatures, this method predicts large exciton binding energies in agreement with the experimental values ranging from 5 to 55 meV. For $MAPbI_3$, phonon modes present in this frequency range have a negligible contribution to the ionic screening. Furthermore, we show that at room temperature this situation does not change. Therefore, we exclude ionic screening as a possible explanation for the observed reduction of the exciton binding energy at room temperature. Here we suggest that polarons formation may have a dominant role for exciton binding energy reduction a higher temperature. Our study suggests that electrons and holes separate after optical excitation forming two individual polarons, lowering the fundamental gap by 42 meV. This scenario would offer an intriguing new possibility for designing novel polaronic solal cell materials, if validated experimentally.

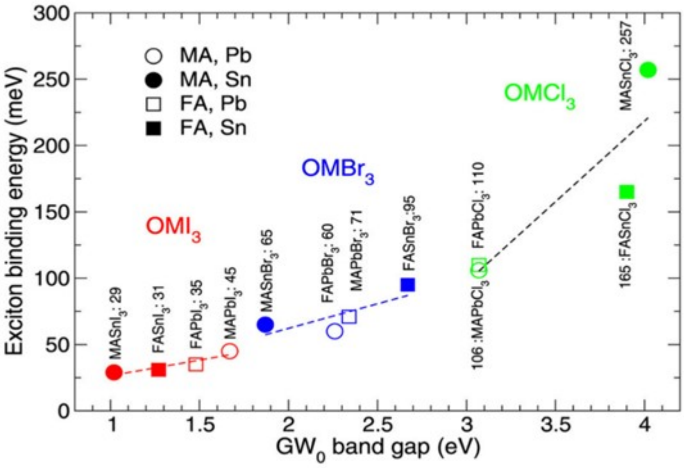

Fig.1: Calculated exciton binding energies and GW0 band gaps of twelve metal halide perovskites (OMX_3, {O=MA,FA,M=Pb,Sn,X=I,Br,Cl}. MA is methylammonium, FA is formamidinium).

Highlights

Physics of materials —2016

Broadband and chiral binary dielectric meta-holograms

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[2]CNR-SPIN Institute for Superconductors, Innovative Materials and Devices, Napoli, Italy
[3]University of Waterloo, Waterloo, Ontario N2L 3G1, Canada

Science Advances 2, e1501258 (2016)

We show how basic holographic principles can be revisited to implement new capabilities of wavefront molding with planar sub-wavelength dielectric optical elements. Our holographic devices are transmissive, broadband, and phase distortion-free from the near-infrared (NIR) range to the visible range, with high polarization sensitivity allowing for a wide range of functionalities depending on the design. The basic element of our holograms is an "effective aperture" designed diffract light with high efficiency across a broad range of wavelengths into the (±1) diffraction order; thus, it is functionally equivalent to a broadband blazed grating. The phase profile of our meta-holograms is then generated by displacing the effective apertures with respect to each other in such a way as to create the desired interference pattern. The latter is the detour phase concept, which is the basis of binary holograms. A complex computer-generated hologram representing the logo of the International Year of Light (IYL) has been imaged with high efficiency (up to 75%) in the NIR range. Polarization-selective holograms have been widely investigated; here, we have demonstrated a chiral holographic plate that creates different images depending on the handedness of the incident light.

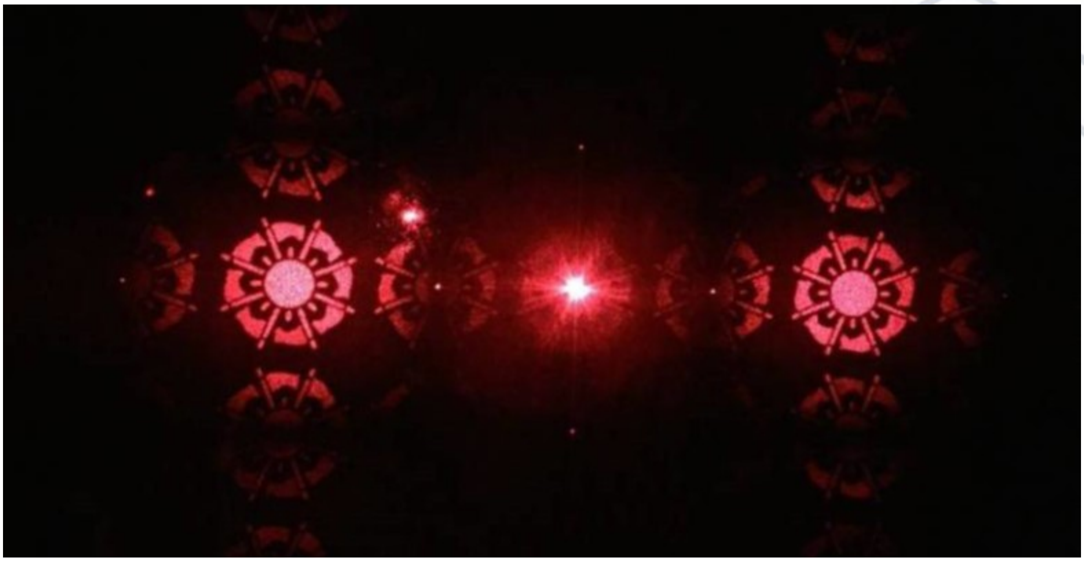

Figure 1. Images generated by the hologram in the visible range. These images were captured by a color charge-coupled device camera

Highlights

Physics of materials —2016

Waveguide Characterisation of S-Band Microwave Mantle Cloaks for Dielectric and Conducting Objects

A. Vitiello[1,4], M. Moccia[2], G.P. Papari[1,4], G. D'Alterio[3], R. Vitiello[3], V. Galdi[2] and A. Andreone[1,4]

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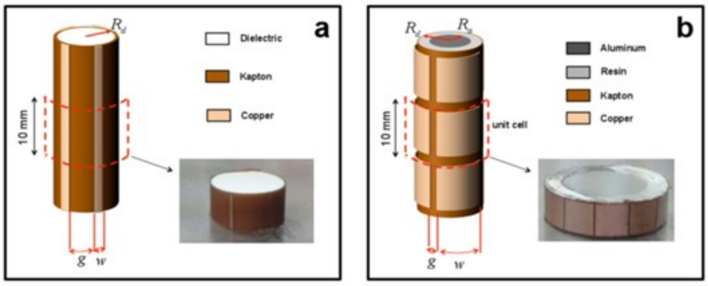
Scientific Reports 6, 19716 (2016)

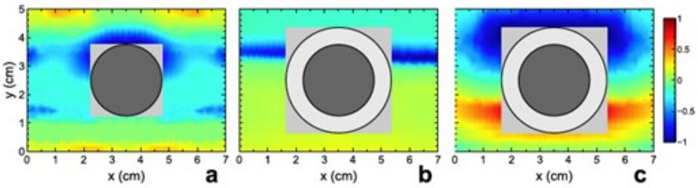
We present the experimental characterization of mantle cloaks designed so as to minimize the e.m. scattering of moderately-sized dielectric and conducting cylinders at S-band microwave frequencies. The experimental setup is based on a parallel-plate waveguide system, which emulates a two-dimensional plane-wave scattering scenario, and allows the collection of near-field maps as well as global scattering observables. Our results provide an illustration of the mantle-cloak mechanism and confirm its effectiveness both in restoring the near-field impinging wavefront around the scatterer, and in significantly reducing the overall scattering.

Cloaking using metasurfaces:



(a) Dielectric cylinder of radius Rd = 10mm covered by a metasurface made of metallic (copper) strips substrate. Also shown is a photo of the fabricated prototype of finite (10mm) thickness.
(b) Conducting (aluminium) cylinder covered by a metasurface made of metallic (copper) conformal square patches

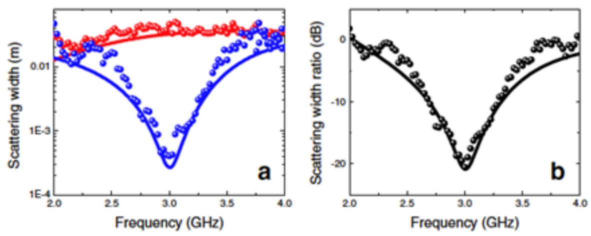
Measured (real-part) electric-field maps for the conducting cylinder:



(a) Uncloaked cylinder at the nominal design frequency 3 GHz.
(b), (c) Cloaked cylinder at 3 GHz and outside the cloaking band (4 GHz), respectively.

Reduction of the scattering cross section SW @ 3 GHz:

$$SW = \frac{\oint_C \mathrm{Re}[E_z^{sc}\hat{\mathbf{z}} \times (\mathbf{H}^{sc})^*] \cdot \hat{\mathbf{n}} d\ell}{\eta_0 |E_z^{in}|^2}$$



(a) SW in semilog scale as a function of frequency for the dielectric cylinder in the absence (red markers) and presence (blue markers) of the mantle cloak.
(b) Corresponding SW ratio in dB scale (black markers).

Energy Exchange in Driven Open Quantum Systems at Strong Coupling

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Physical Review Letters 116, 240403 (2016)

A deep understanding of how the concepts of work and dissipated heat are extended to quantum systems would allow us to envision efficient quantum machines to store, manipulate and transfer energy at quantum level. In many interesting situations the quantum systems are strongly coupled to an environment. In this case, the standard approaches and techniques fail since the system and environment cannot be clearly separated.

We study the time-dependent energy transfer in a driven quantum system strongly coupled to a heat bath within an influence functional approach. Exact formal expressions for the statistics of energy dissipation into the different channels are derived. The general method is applied to the driven dissipative two-state system. It is shown that the energy flows obey a balance relation, and that, for strong coupling, the interaction may constitute the major dissipative channel. This means that the dissipated heat related to the coupling interaction cannot be neglected as done in the standard perturbative (weak coupling) approach.

Results in analytic form are presented for the particular coupling of strong Ohmic dissipation. The energy flows show interesting behaviors including driving-induced coherences and quantum stochastic resonances.

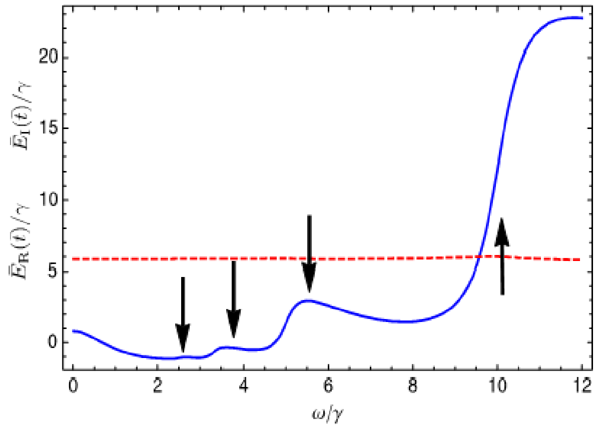

Figure 1. A snapshot of dissipated heat in the environment (solid curve) and the one related to the coupling energy (dashed curve) plotted versus the drive frequency. The time is fixed to 50 times the dissipative coupling γ. The arrows denote the positions of the ground and side frequencies.

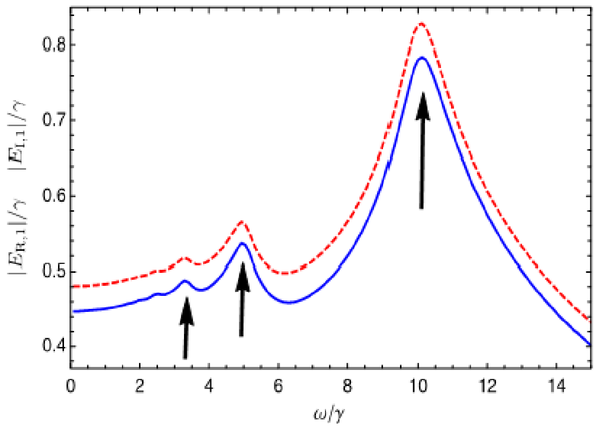

Figure 2. The absolute values of the amplitudes of the first harmonic of dissipated heat in the environment (solid curve) and the one related to the coupling energy (dashed curve) as a function of the drive frequency. Both curves show resonances (indicated by the arrows).

Statistical moments of quantum-walk dynamics reveal topological quantum transitions

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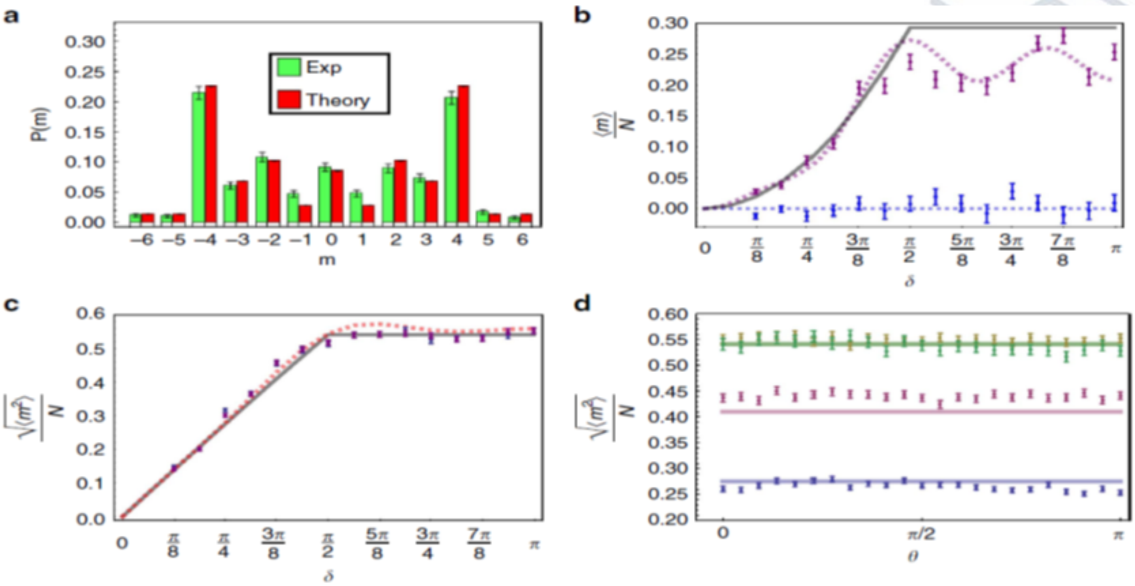
Nature Communications 7, 11439 (2016)

Many phenomena in solid-state physics can be understood in terms of their topological properties. Recently, controlled protocols of quantum walk (QW) are proving to be effective simulators of such phenomena. Here we report the realization of a photonic QW showing both the trivial and the non-trivial topologies associated with chiral symmetry in one-dimensional (1D) periodic systems. We find that the probability distribution moments of the walker position after many steps can be used as direct indicators of the topological quantum transition: while varying a control parameter that defines the system phase, these moments exhibit a slope discontinuity at the transition point. Numerical simulations strongly support the conjecture that these features are general of 1D topological systems. Extending this approach to higher dimensions, different topological classes, and other typologies of quantum phases may offer general instruments for investigating and experimentally detecting quantum transitions in such complex systems.



Theoretical predictions and experimental results. (a) Example of a probability distribution for the walker: measured (green,left) and expected (red, right) probability distributions. (b,c) Measured values of statistical moments (dotted lines) for two different initial states. The continuous lines are theoretical asymptotic predictions. (d) Comparison between measured values of $\sqrt{M_2}/N$ (dotted points) and theoretical predictions (continuous lines) by varying the initial polarization for three values of the optical retardation.

Highlights

Physics of materials —2016

Spin Pumping and Measurement of Spin Currents in Optical Superlattices

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Physical Review Letters 117, 170405 (2016)

We report on the experimental implementation of a spin pump with ultracold bosonic atoms in an optical superlattice. In the limit of isolated double wells, it represents a 1D dynamical version of the quantum spin Hall effect. Starting from an antiferromagnetically ordered spin chain, we periodically vary the underlying spin-dependent Hamiltonian and observe a spin current without charge transport. We demonstrate a novel detection method to measure spin currents in optical lattices via superexchange oscillations emerging after a projection onto static double wells.

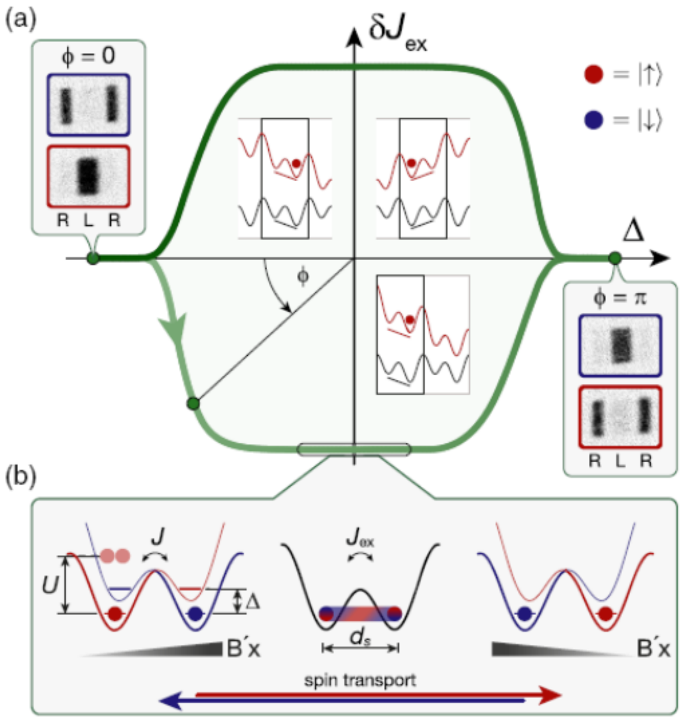

Figure 1. Spin pump cycle. (a) Spin pump cycle (green) in parameter space of spin-dependent tilt Δ and exchange coupling dimerization δJ_{ex}. The path can be parametrized by the angle f, the pump parameter. Between f=0 and π, ↑ and ↓ spins exchange their position, which can be observed by site-resolved band mapping images detecting the spin occupation on the left (L) and right (R) sites, respectively.
(b) Evolution of the two particle ground state in a double well around Δ=0 with tunnel coupling 1/2(J+ δJ), on-site interaction energy U, and spin dependent tilt Δ, as well as the exchange coupling J_{ex} $1/2(J+\delta J)^2/U$ and the lattice constant d_s.

Ultracold atoms: A topological charge pump

R. Citro

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Nature Physics 12, 288-289 (2016)

The quantum pump, originally proposed by David Thouless in 1983, is one of the most intriguing effects in quantum mechanics. It entails the transport of charge, in the absence of a net external electric or magnetic field, through an adiabatic cyclic evolution of the underlying Hamiltonian. In contrast with the classical case, the transported charge is quantized and purely determined by the topology of the pump cycle, which makes it robust against perturbations, such as interaction effects or disorder. As a representative example, we have reported about a topological charge pump realized with ultracold fermions and bosons in a optical superlattice.

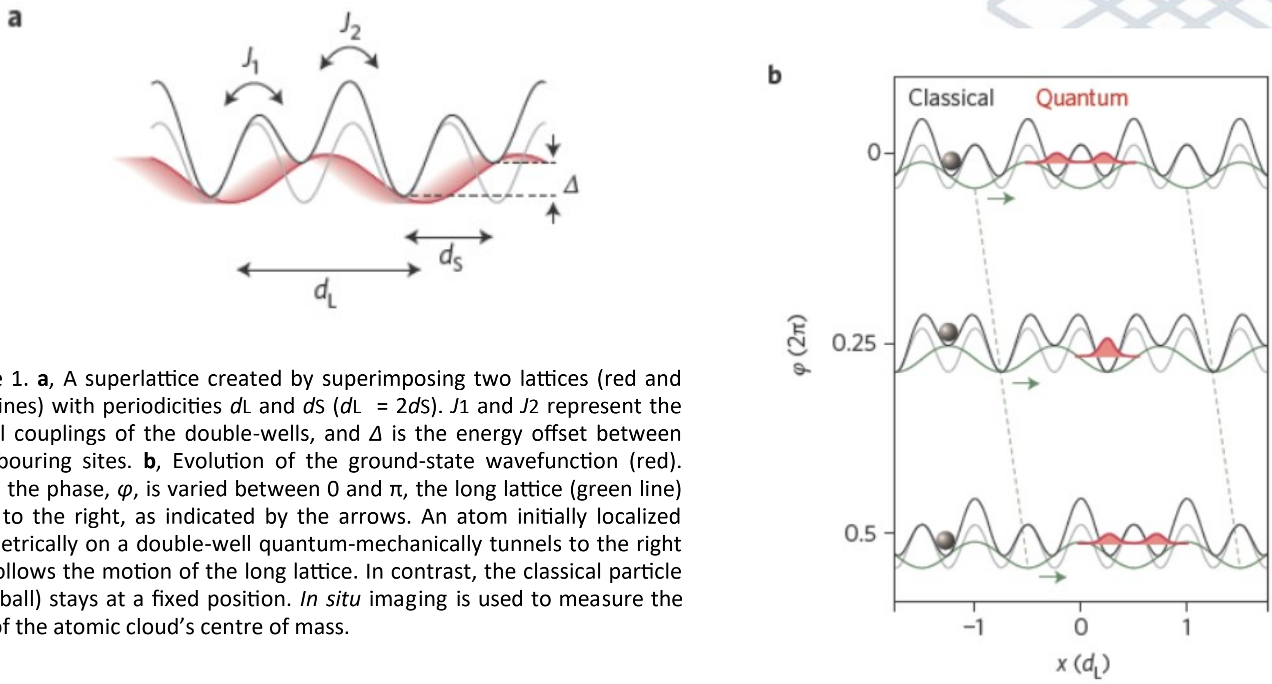

Figure 1. **a**, A superlattice created by superimposing two lattices (red and grey lines) with periodicities d_L and d_S ($d_L = 2d_S$). J_1 and J_2 represent the tunnel couplings of the double-wells, and Δ is the energy offset between neighbouring sites. **b**, Evolution of the ground-state wavefunction (red). When the phase, φ, is varied between 0 and π, the long lattice (green line) shifts to the right, as indicated by the arrows. An atom initially localized symmetrically on a double-well quantum-mechanically tunnels to the right and follows the motion of the long lattice. In contrast, the classical particle (grey ball) stays at a fixed position. *In situ* imaging is used to measure the shift of the atomic cloud's centre of mass.

Highlights

Physics of materials —2016

Designing electron spin textures and spin interferometers by shape deformations

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Physical Review B 94, 081406(R) (2016)

The manipulation and control of electron spin set fundamental challenges for the development of innovative solutions for quantum engineering. In our report we uncover a fundamental entanglement between the electron spin degree of freedom and the geometry of the system in which electrons reside. We find that the geometric curvature of a shape deformed one-dimensional nanostructure in the presence of Rashba spin-orbit coupling a_R can steer the electron spin texture and, in turn, the quantum interference that an electron acquires when moving in a closed circuit. Taking the paradigmatic example of an elliptically deformed quantum ring (Fig. 1 (d)) with Rashba spin-orbit coupling we provide a proof-of-principle of an all-geometrical-and-electrical control of electron spin and quantum spin transport (Fig. 2). We demonstrate that non-uniform geometric curvature drives spin textures with a tunable topological character with windings around the radial and the out-of-plane directions (Fig. 2). These topologically non trivial spin patterns affect the spin interference effect in the deformed ring, thereby resulting in different geometry-driven electronic transport. behaviors.

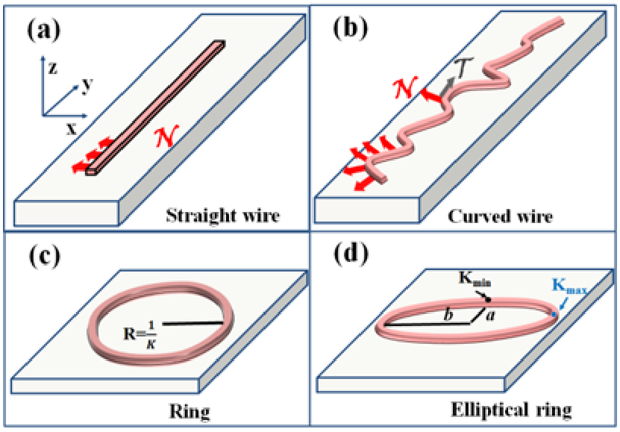

Figure 1. Schematics of the geometric profile of (a) straight, (b) planarly curved nanostructure, (c) ring, and (d) elliptically deformed ring with semi-axes *a* and *b*. Red (gray) arrows indicate the perpendicular (tangential) direction of the spin orientation with respect to the geometric profile. *K* is the curvature of the ring, e.g. the inverse of the its radius *R*. Black (blue) dots indicate a position with minimum K_{min} (maximal K_{max}) amplitude of the curvature in the elliptical ring.

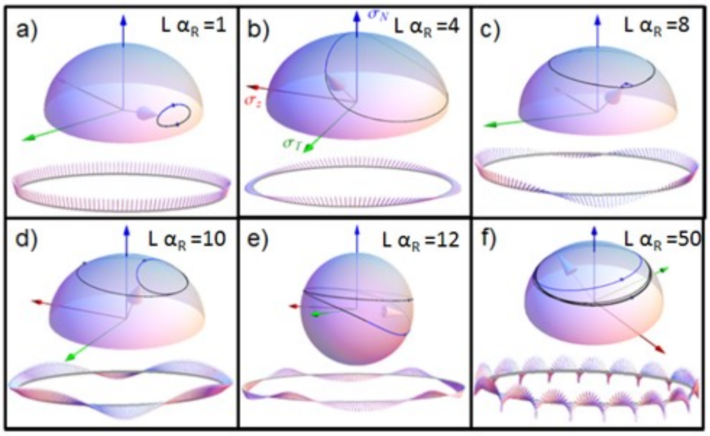

Figure 2. Evolution of the spin orientation trajectories on the Bloch sphere and of the three dimensional spin textures along an elliptically deformed ring (Fig. 1 (d)) with length *L* at a given ratio *a/b* = 0.4 and for various values of the Rashba spin-orbit coupling a_R. The blue portion of the trajectory stands for the part of the elliptical loop with larger curvature. The dots mark the positions on the loop with the maximum and minimum values of the local curvature.

Highlights

Physics of materials —2016

Quantization of entropy in a quasi-two-dimensional electron gas

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Physical Review B 93, 155404 (2016)

We demonstrate that the entropy per electron of a two-dimensional electron gas (2DEG) exhibits quantized peaks at resonances between the chemical potential and electron levels of size quantization. In the limit of no scattering, the peaks depend only on the sub-band quantization number and are independent of material parameters, shape of the confining potential, electron effective mass, and temperature. The quantization of entropy per electron is a signature of a Lifshitz phase transition in a 2DEG. In the presence of stationary disorder, the magnitude of peaks decreases. Its deviation from the quantized values is a direct measure of the disorder induced smearing of the electronic density of states.

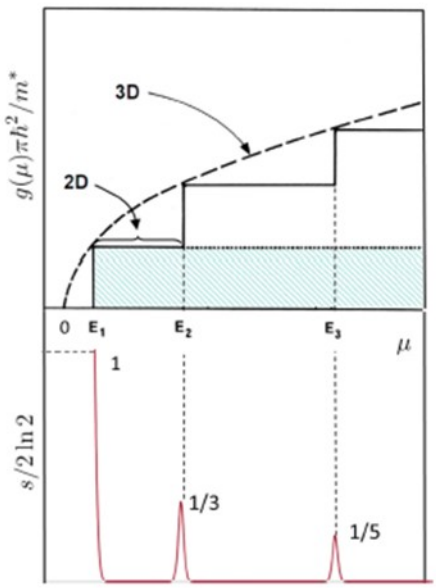

Figure 1. Schematic representation of the dependencies of the electronic density of states (upper panel) and the entropy per electron (lower panel) as functions of the chemical potential.

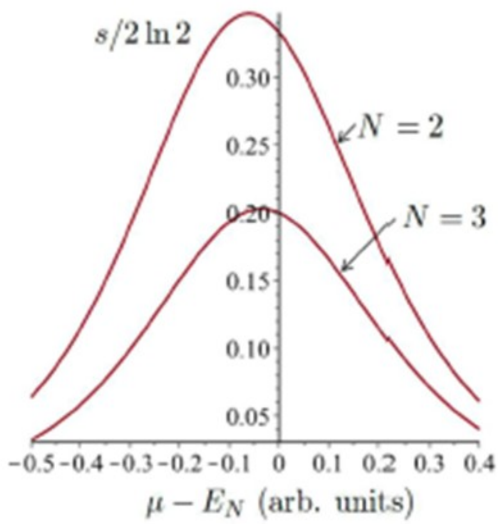

Figure 2. Dependence of the entropy per particle on chemical potential for N = 2,3.

Highlights

Superconductivity —2017

Control of bulk superconductivity in a BCS superconductor by surface charge doping via electrochemical gating

E. Piatti[1], D. Daghero[1], G. A. Ummarino[1,2], F. Laviano[1], J. R. Nair[1], R. Cristiano[3], A. Casaburi[4], C. Portesi[5], A. Sola[5], and R. S. Gonnelli[1]

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Physical Review B 95, 140501(R) (2017)

The electrochemical gating technique is a powerful tool to tune the surface conduction properties of various materials by means of pure charge doping, but its efficiency is thought to be hampered in materials with a good electronic screening. We show that, if applied to a metallic superconductor (NbN thin films), this approach allows the observation of reversible enhancements or suppressions of the bulk superconducting transition temperature, which vary with the thickness of the films. These results are interpreted in terms of a proximity effect, and indicate that the effective screening length depends on the induced charge density, becoming much larger than that predicted by a standard screening theory at very high electric fields.

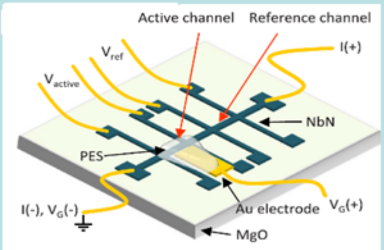

Fig.1: Scheme of the samples: The NbN strip is 135 µm wide, with current pads on each end and four voltage contacts on each side, spaced by 946 µm from one another. This geometry allows one to measure the voltage drop across different portions of the strip at the same time, thus defining an active (gated) and a reference (ungated) channel. The pristine film has a thickness of 39.2 ± 0.8 nm. Subsequent steps of Ar-ion milling are used to reduce the thickness to 27.1 ± 1.5, 18.3 ± 1.7, and finally 9.5 ± 1.8 nm. To perform EDL gating measurements, we cover the active channel and the gate counterelectrode placed on its side [made of a thin Au flake] with the liquid precursor of the cross-linked polymer electrolyte system, which was later UV cured.

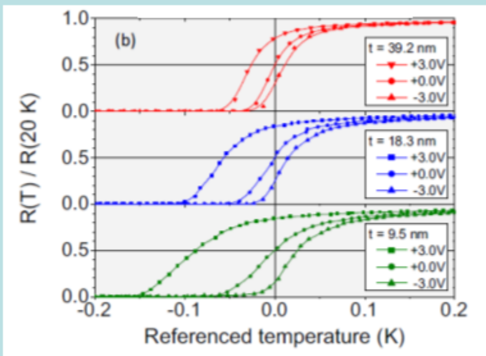

Fig.2: Effect of a gate voltage V_G = ±3 V on the R(T)/R(20 K) vs T curves for three values of thickness: 39.2, 18.3, and 9.5 nm. The referenced temperature is defined as $T^* = [T - T_c^{ref}]_{VG} - [T_c^{active} - T_c^{ref}]_0$.

Highlights

Superconductivity —2017

Tuning Pairing Amplitude and Spin-Triplet Texture by Curving Superconducting Nanostructures

Zu-Jian Ying,[1,2] Mario Cuoco,[1] Carmine Ortix,[3,4] and Paola Gentile[1]

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Physical Review B 96, 100506 (R) (2017)

Shape deformations in Rashba spin-orbit coupled (RSOC) nanostructures can be employed for tailoring spin textures, spin transport properties, and geometrically driven topological phases. The recent advances in this framework bring to the fore the fundamental and challenging problem of understanding which type of superconducting (SC) state may emerge when varying the nanoscale shape of RSOC nanostructures, and how this is linked to the spin textures in the normal state. We addressed this question and uncovered the subtle interrelation between nanoscale shape deformations and the nature of superconductivity in RSOC nanostructures. While in systems with constant curvature (e.g. quantum wires or circular rings) the RSOC is monotonously affecting the superconductivity, spatial variation of the Rashba field through curvature of the nanostructure can yield either a local enhancement or a suppression of the SC order parameter. We demonstrate this effect by employing elliptically shaped quantum rings. Apart from driving the SC spin-singlet amplitude, the inhomogeneous profile of the curvature generates non-trivial spatial patterns of the spin-triplet pairs. We show that the geometric curvature can tailor the spin-triplet pairing by yielding three-dimensional spatial textures, and the d-vector, contrary to the uniform curvature profiles, i.e. straight and circular nanostructures (Fig. 1(e),(f)), exhibits windings (Fig. 1(g),(h)) similarly to the electron spin-orientation in the normal state (Fig. 1(c),(d)). Such findings indicate that geometric curvature can be exploited to effectively yield a spin-torque on the electron spin of the superconducting pairs.

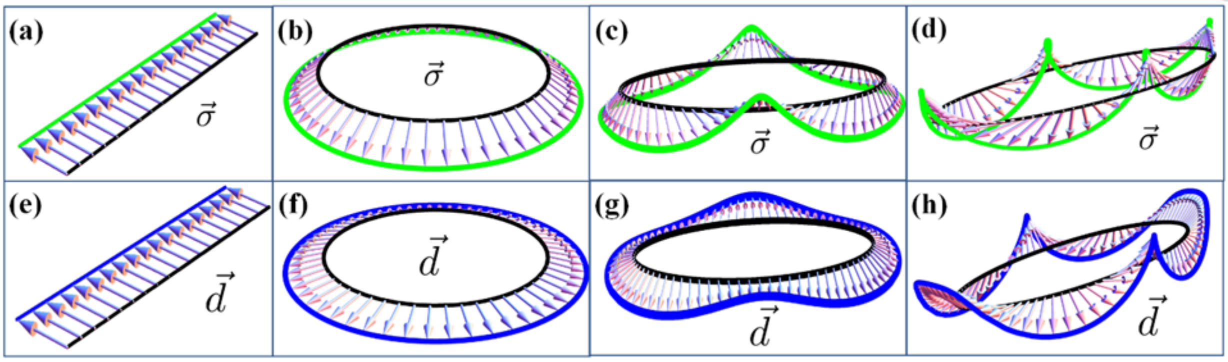

Fig.1: Electron spin orientation σ in the normal state and spin-triplet d-vector in the superconducting state for different types of low dimensional nanostructures.

Highlights

Superconductivity —2017

Experimental Evidences for Static Charge Density Waves in Iron Oxy-pnictides

A. Martinelli[1], P. Manfrinetti[1,2], A. Provino[1,2], A. Genovese[3], F. Caglieris, [1,4], G. Lamura[1], C. Ritter[5], M. Putti[1,4]

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Physical Review Letters 118, 055701(2017)

By means of high-resolution synchrotron X-ray powder diffraction and transmission electron microscope analysis of Mn-substituted LaFeAsO samples, it has been demonstrated the development of a static incommensurate modulated structure across the low-temperature orthorhombic phase. The incommensurate structural distortion is likely originating from a charge-density-wave (CDW) instability, a periodic modulation of the density of conduction electrons associated with a modulation of the atomic positions.

Our results indicate that the Fermi surface nesting can induce a CDW state in Fe oxy-pnictides, responsible for the structural transition observed at low temperature. Remarkably the tetragonal to orthorhombic transformation induces a rotation by 45° of the unit cell; hence the in-plane $\mathbf{k}_{nesting} = (\pi,\pi)$ calculated for the high temperature tetragonal phase is parallel to the in-plane $\mathbf{k}_{modulation} = (\delta,0)$ detected for the low-temperature orthorhombic phase by HRTEM analysis. This is the exact situation expected for a CDW state.

Our observation of a static CDW in $La(Fe_{1-x}Mn_x)AsO$ reveals the possibility of an intrinsic and widespread tendency towards charge ordering in Fe-based superconductors and discloses a new view for the phenomenology and phase diagrams of Fe based superconductors. The possible role of CDW fluctuations for the mechanism of the nematic and orthorhombic phase formation as well as their interplay with superconductivity represent new relevant subjects for both experimental and theoretical researches.

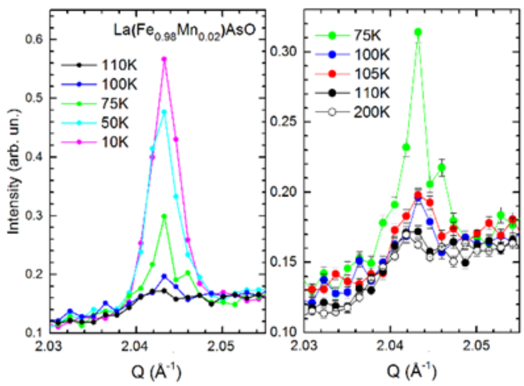

Fig.1: Thermal evolution of the 1st order satellite peak of $La(Fe_{0.98}Mn_{0.02})AsO$, marking the occurrence of the CDW state.

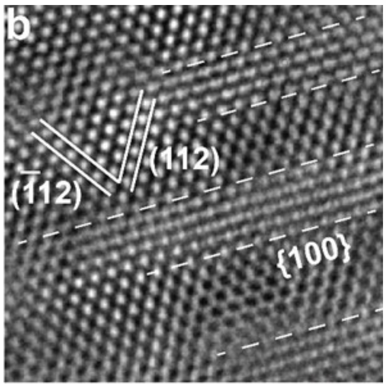

Fig.2: HRTEM image of $La(Fe_{0.98}Mn_{0.02})AsO$ phase at 94 K evidencing structural modulation.

Highlights

Superconductivity —2017

Current Induced Resistive State in Fe(Se,Te) Superconducting Nanostrips

C. Nappi[1], C. Camerlingo[1], E. Enrico[2], E. Bellingeri[3], V. Braccini[3], C. Ferdeghini[3], E. Sarnelli[1]

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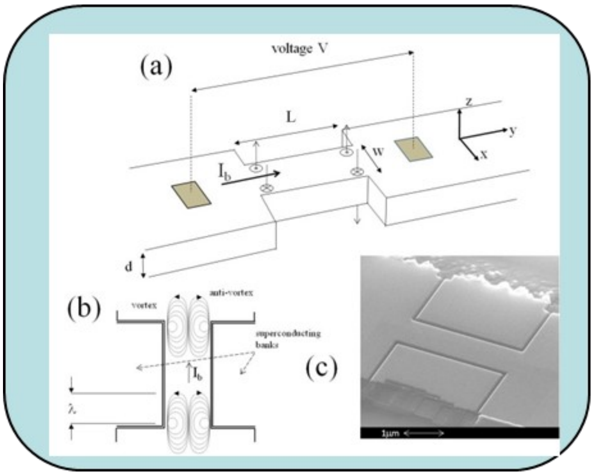
[2]INRIM, Istituto Nazionale di Ricerca Metrologica, Torino, Italy
[3]CNR-SPIN, Sede di Genova, Italy

Scientific Reports 7, 4115 (2017)

We studied the current-voltage characteristics of Fe(Se,Te) thin films deposited on CaF_2 substrates in form of nanostrips (width w ~λ, λ the London penetration length). Our focus was on the transport properties of Fe(Se,Te) films in small magnetic field, the one generated by the bias current. From the analysis of the characteristics taken at different temperatures we estimated the pinning potential *U* and the pinning potential range δ for the magnetic flux lines (vortices). Since the sample lines are very narrow we found that the classical creep flow model provided a sufficiently accurate interpretation of data only when the attractive interaction between magnetic field lines of opposite sign was taken into account. The observed voltages, and the induced suppression of the critical current of the nanostrips, were compatible with the presence, at the equilibrium, of a low number (<10) of magnetic field lines, a strongly inhomogeneous current density distribution at the two strip ends, and a reduced Bean Livingston barrier. In particular we argued that the sharp corners defining the bridge geometry were points of easy magnetic flux line injection. The role of superconducting banks confining the strips was also discussed. The results are relevant to creep flow analysis in superconducting Fe(Se,Te) nanostrips for micro-electronics applications.



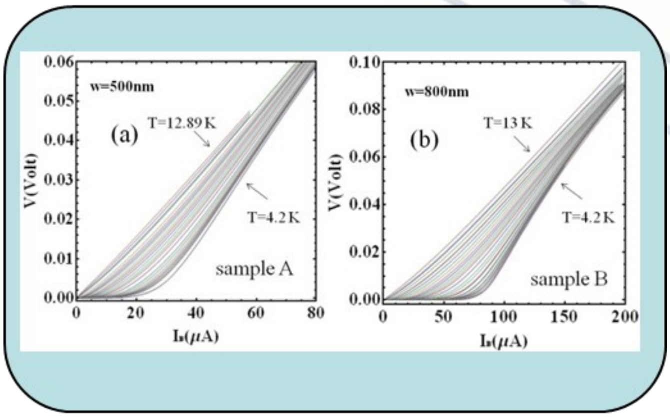


Fig.1: (a) Geometry of the nanostrips used in the work. (b) Schematic of the streamlines of the vortex and anti-vortex current densities. (c) A SEM image of sample B (*w*=800nm).

Fig.2: Current voltage characteristics of the nanostrips in the indicated range of temperatures. (a) Sample A, *w*=500nm. (b) Sample B, *w*=800nm. Both samples were 3µm long.

Highlights

Superconductivity —2017

Investigation of inter-grain critical current density in $Bi_2Sr_2CaCu_2O_{8+d}$ superconducting wires and its relationship with the heat treatment protocol

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[1]CNR-SPIN, Genoa, Italy
[2]Department of Physics, University of Genoa, Italy

Superconductor Science and Technology 30, 095005 (2017)

We investigate the effect of each different heat treatment stage in the fabrication of $Bi_2Sr_2CaCu_2O_{8+d}$ superconducting wires on intra-grain and inter-grain superconducting properties. We measure magnetic critical temperature T_c values and transport critical current density J_c at temperatures from 4 K to 40 K and in fields up to 7 T. From an analysis of the temperature dependence of the self-field critical current density $J_c(T)$ that takes into account weak link behavior and proximity effect, we study the grain boundaries (GB) transparency to supercurrents and we establish a relationship between GB oxygenation in the different steps of the fabrication process and the GB transparency to supercurrents. We find that grain boundary oxygenation starts in the first crystallization stage, but it becomes complete in the plateau at 836 °C and in slow cooling stages, and is further enhanced in the prolonged post annealing step. Such oxygenation makes GBs more conducting, thus improving the inter-grain J_c value and temperature dependence. On the other hand, from the inspection of the T_c values in the framework of the phase diagram dome, we find that grains are oxygenated already in the crystallization step up to the optimal doping, while successive slow cooling and post annealing treatments further enhance the degree of overdoping, especially if carried out in oxygen atmosphere rather than in air.

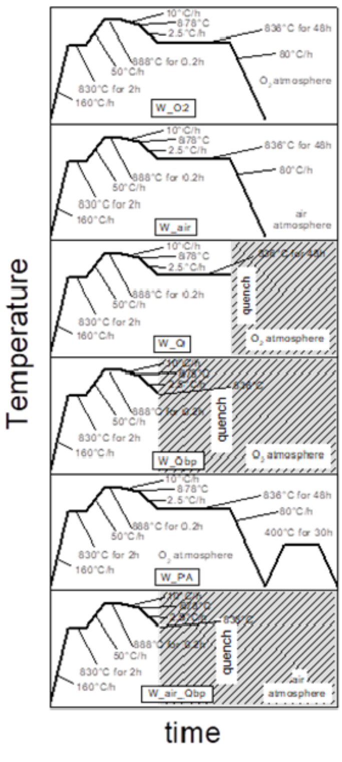
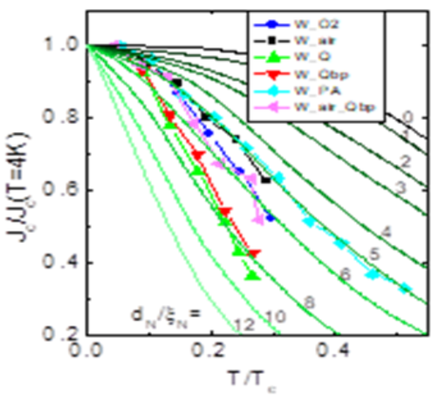


Fig.1: Temperature treatment protocols



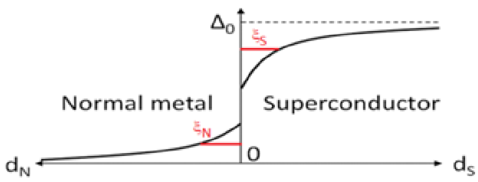


Fig.2: Left: Temperature dependence of normalized J_c, compared to predictions of models for proximity effect at grain boundary weak links, for different values of the ratio d_N/x_N. Right: sketch of the proximity effect, illustrating the meaning of the parameters d_N (thickness of the normal layer) and x_N (coherence length of the normal layer).

Interplay between structure and superconductivity: Metastable phases of phosphorus under pressure

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Physical Review Materials 1, 024802 (2017)

Pressure-induced superconductivity and structural phase transitions in phosphorus (P) are studied by resistivity measurements under pressures up to 170 GPa and by fully *ab initio* crystal structure exploration and superconductivity calculations up to 350 GPa.
Two distinct superconducting transition temperature (Tc) vs pressure trends at low pressure have been reported more than 30 years ago, and we are able to devise a consistent explanation founded on thermodynamically metastable phases of black phosphorus. Our experimental and theoretical results form a single, consistent picture which not only provides a clear understanding of elemental P under pressure but also sheds light on the longstanding and unsolved *anomalous* superconductivity trends. Moreover, at higher pressures we predict a similar scenario of multiple metastable structures which coexist beyond their thermodynamical stability range. We observe that all the metastable structures systematically exhibit larger transition temperatures than the ground-state structures, indicating that the exploration of metastable phases represents a promising route to design materials with improved superconducting properties.

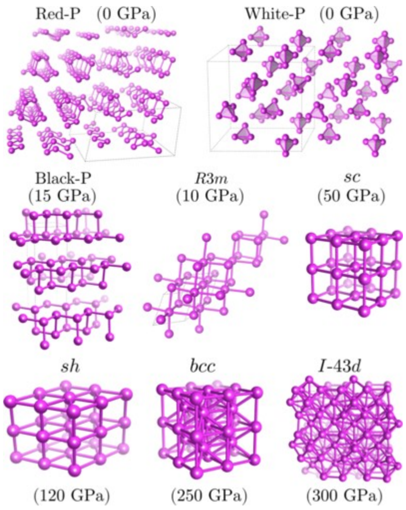

Fig.1: Crystal structure of phosphorus at indicated pressures

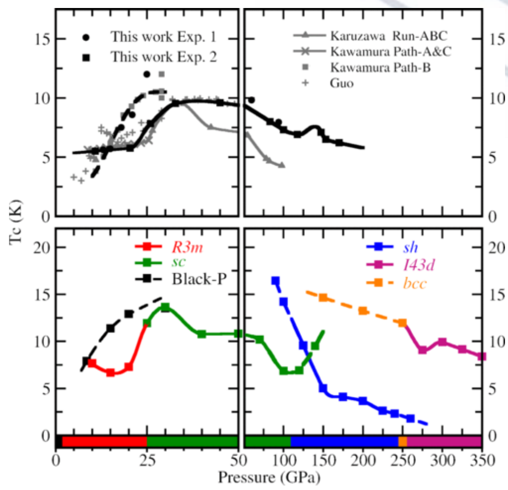

Fig.2: Experimental (top panels) and theoretical superconducting (bottom panels) critical temperatures .

Highlights

Superconductivity —2017

0-π controllable thermal Josephson junction

A. Fornieri[1], G. Timossi[1], P. Virtanen[1], P. Solinas[2] and F. Giazotto[1]

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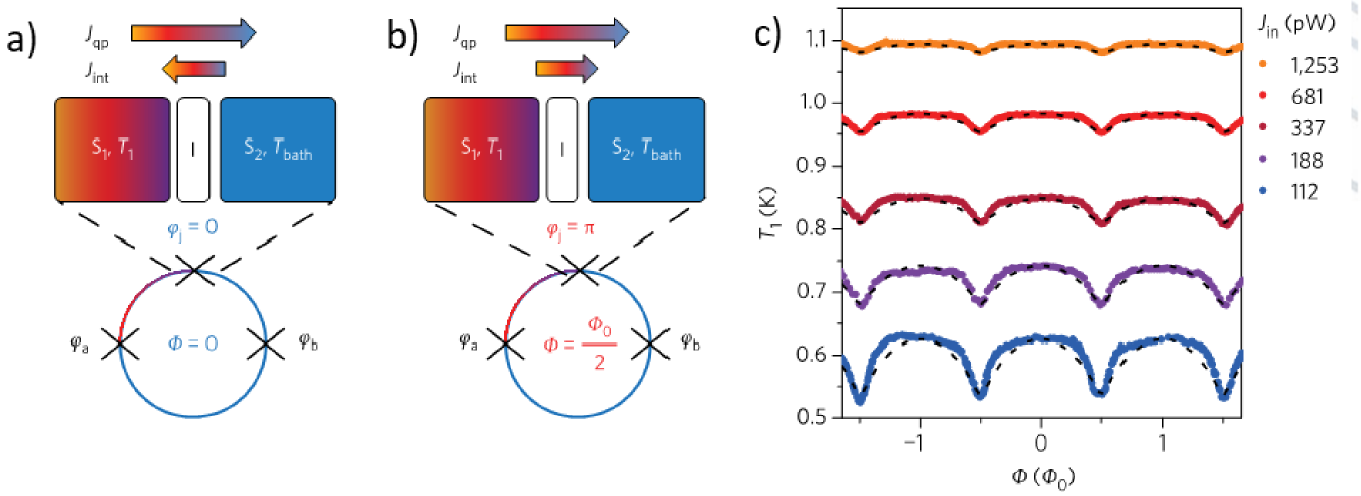
Nature Nanotehcnology 12, 425 (2017)

Two superconductors coupled by a weak link support an equilibrium Josephson electrical current that depends on the phase difference φ between the superconducting condensates. Yet, when a temperature gradient is imposed across the junction, the Josephson effect manifests itself through a coherent component of the heat current that flows opposite to the thermal gradient for $|\varphi| < \pi/2$. The direction of both the Josephson charge and heat currents can be inverted by adding a π shift to φ. In the static electrical case, this effect has been obtained in a few systems, for example via a ferromagnetic coupling or a non-equilibrium distribution in the weak link. Here, we report the first experimental realization of a thermal Josephson junction whose phase bias can be controlled from 0 to π. This is obtained thanks to a superconducting quantum interferometer that allows full control of the direction of the coherent energy transfer through the junction. This possibility provides temperature modulations with an amplitude of ~100 mK and transfer coefficients exceeding 1 K per flux quantum at 25 mK. Then, this quantum structure represents a fundamental step towards the realization of caloritronic logic components such as thermal transistors, switches and memory devices. These elements, combined with heat interferometers and diodes, would complete the thermal conversion of the most important phase-coherent electronic devices and benefit cryogenic microcircuits requiring energy management, such as quantum computing architectures and radiation sensors.



a) Scheme of the temperature-biased tunnel junction 'j' between two superconductors S_1 and S_2 embedded in a three-junction SQUID. When the flux Φ threading the superconducting loop is set to 0, the phase difference $\varphi_j = 0$ and the coherent component of the electronic heat current J_{int} flows opposite to the thermal gradient. b) When $\Phi = \Phi_0/2$, $\varphi_j = \pi$ and J_{int} flows parallel to to the thermal gradient. c) Magnetic flux modulation of S_1 temperature (T_1) for several working temperatures (associated to the injected power J_{in}). The temperature oscillations stem from modulation of the phase-coherent heat power.

Signatures of unconventional superconductivity in the $LaAlO_3/SrTiO_3$ two-dimensional system

D. Stornaiuolo,[1,2] D. Massarotti,[1,2] R. Di Capua,[1,2] P. Lucignano,[2] G. P. Pepe,[1,2] M. Salluzzo,[2] and F. Tafuri[3]

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Physical Review B 95, 140502(R) (2017)

In the two-dimensional electron gas (2DEG) at the $LaAlO_3/SrTiO_3$ (LAO/STO) interface, the combination of 2D superconductivity and Rashba spin-orbit coupling (SOC) is expected to give rise to an unconventional superconducting ground state, including a mix of spin-singlet and spin-triplet components. The nature of superconductivity in LAO/STO and its interplay with SOC are, however, still largely unexplored.

We have used nanoscale Josephson junctions as an ultrasensitive spectroscopic tool to probe the superconducting gap and the order parameter symmetry of the 2DEG. The conductance spectra of the junctions (Figure 1) and their critical current vs. temperature behavior indicate the presence of two superconducting gap structures. Moreover, the critical current magnetic patterns show anomalies that can be accounted for by only assuming the presence of an unconventional order parameter.

Although more experimental work is needed in order to firmly establish the details of the superconducting state of LAO/STO, our results are in agreement with theoretical predictions of mixed singlet-triplet superconducting order parameters in 2D systems hosting Rashba SOC and pave the way to a deeper understanding of these systems. The ability to create and study elusive unconventional superconducting states is a confirmation of the fascinating possibilities offered by engineered oxides for the study of exotic excitations and the realization of novel quantum electronics.

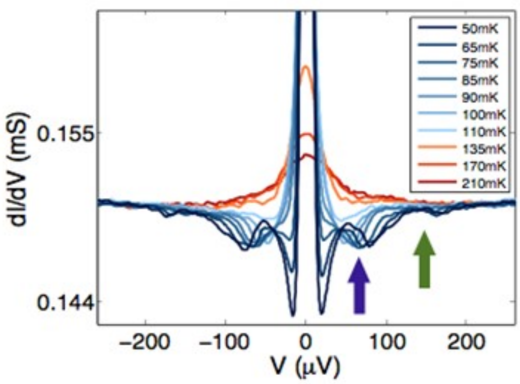

Fig.1: Conductance spectra of a LAO/STO based junction. The arrows indicate the two gap structures

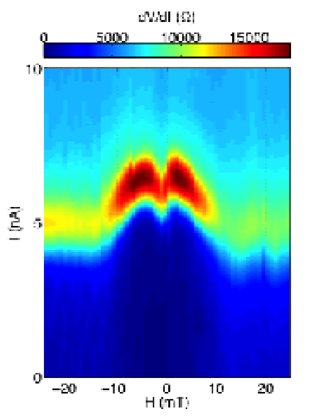

Fig.2: Critical current magnetic pattern showing a minimum at zero magnetic field

Morphological, Structural, and Charge Transfer Properties of F-Doped ZnO: A Spectroscopic Investigation

G.P. Papari[1], B. Silvestri[2], G. Vitiello[2,3], L. De Stefano[4], I. Rea[4], G. Luciani[2], A. Aronne[2], and A. Andreone[1]

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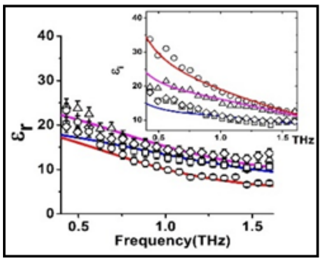
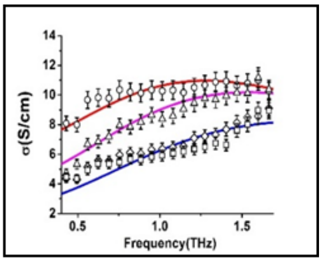
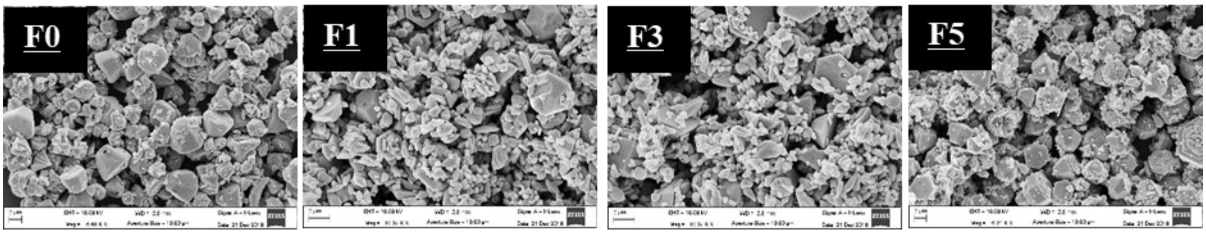
The Journal of Physical Chemistry 121, 29 (2017)

We have studied the charge transfer dynamics of ZnO powders doped with different concentration of fluorine. Time domain spectroscopy has been employed to extract the dielectric function of ZnO according to different doping levels. The appropriate application of mean field theories has confirmed the lowering of ZnO:F conductivity as the F doping is increased. Further morphological and spectroscopic techniques, like EPR, PL, XRD and SEM imaging, show that F doping promotes a granular phase and donor states in the UV band.





(a) Real part of permittivity (ε_r) and (b) conductivity (σ) of ZnO:F samples are reported, respectively. In the inset, the imaginary part of permittivity ε_i is displayed. Circles, squares, rhombuses, and triangles correspond to F percentage of 0, 1, 3 and 5 at. % respectively.
Solid curves represent the fit to the standard Drude –Smith model.



SEM images show grains with a hexagonal pyramid shape typical of mesocrystals for bare ZnO:F0. At low F at. %, ZnO grains are surrounded by smaller nanoparticles formed by the mesocrystals leaching (ZnO:F1 and ZnO:F3). The density of these nanoparticles decreases at higher fluorine concentration (ZnO:F5).

Results show that F doping does not produce any substantial change of plasma frequency but only the enhancement of scattering rate due to an increase of grain boundary density. This is in agreement with theoretical calculations asserting that the energy required to excite donor levels is on the order of 0.7 eV, and therefore, the doping mechanism is ineffective at room temperature.

Highlights

Oxides —2017

Effects of Dopant Ionic Radius on Cerium Reduction in Epitaxial Cerium Oxide Thin Films

N. Yang[1,2], P. Orgiani[3,4], E. Di Bartolomeo[5], V. Foglietti[1], P. Torelli[4], A. V. Ievlev[7], G. Rossi[8], S. Licoccia[5], G. Balestrino[9,1], S. V. Kalinin[7], and C. Aruta[1]

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The Journal of Physical Chemistry C 121, 8841 (2017)

The role of trivalent rare-earth dopants on the cerium oxidation state has been systematically studied by in situ photoemission spectroscopy with synchrotron radiation for 10 mol% rare-earth doped epitaxial ceria films (Fig.1). It was found that dopant rare-earths with smaller ionic radius foster the formation of Ce^{3+} by releasing the stress strength induced by the cation substitution (Fig.2). With a decrease of the dopant ionic radius from La^{3+} to Yb^{3+}, the out-of-plane axis parameter of the crystal lattice decreases without introducing macroscopic defects. The high crystal quality of our films allowed us to comparatively study both the ionic conductivity and surface reactivity ruling out the influence of structural defects.
The measured increase in the activation energy of films and their enhanced surface reactivity can be explained in terms of the dopant ionic radius effects on the $Ce^{4+} \rightarrow Ce^{3+}$ reduction as a result of lattice relaxation. Such findings open new perspectives in designing ceria-based materials with tailored properties by choosing suitable cation substitution.

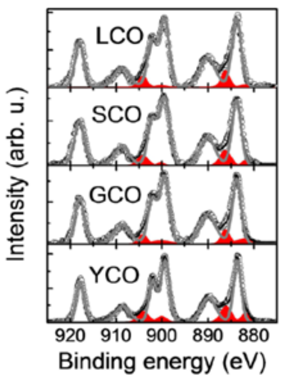

Fig.1: Ce 3d core level photoemission spectra for RECO thin films (RE=Yb, Gd, Sm, La). The solid gray line refers to the sum of all Ce^{4+} fit components and the red filled areas to the sum of all Ce^{3+} fit components.

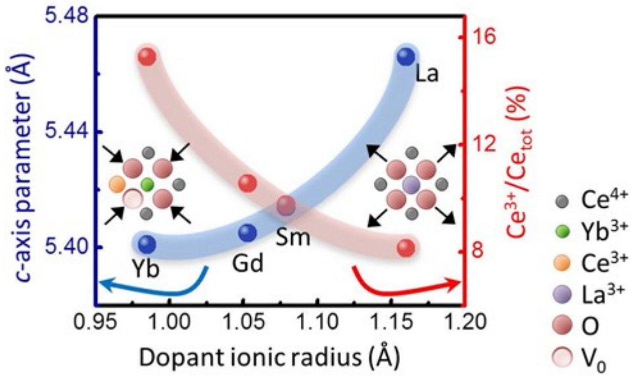

Fig.2: Dopant ionic radius dependence of the c-axis parameter (blue balls) and the Ce^{3+} concentration (red balls) calculated from the corresponding red filled areas in Fig.1.

Highlights

Oxides —2017

Quantifying the critical thickness of electron hybridization in spintronics materials

T. Pincelli[1,2], V. Lollobrigida[1,3], F. Borgatti[4], A. Regoutz[5], B. Gobaut[6], C. Schlueter[7], T.-L. Lee[7], D.J. Payne[5], M. Oura[8], K. Tamasaku[8], A.Y. Petrov[1], P. Graziosi[4], F. Miletto Granozio[9,10], M. Cavallini[4], G. Vinai[1], R. Ciprian[1], C.H. Back[11], G. Rossi[1,2], M. Taguchi[8,12], H. Daimon[12], G. van der Laan[7] & G. Panaccione[1]

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Nature Communications 8, 16051 (2017)

In the rapidly growing field of spintronics, simultaneous control of electronic and magnetic properties is essential, and the perspective of building novel phases is directly linked to the control of tuning parameters, for example, thickness and doping. Looking at the relevant effects in interface-driven spintronics, the reduced symmetry at a surface and interface corresponds to a severe modification of the overlap of electron orbitals, that is, to a change of electron hybridization. Here we report a chemically and magnetically sensitive depth-dependent analysis of two paradigmatic systems, namely $La_{1-x}Sr_xMnO_3$ and (Ga,Mn)As. Supported by cluster calculations, we find a crossover between surface and bulk in the electron hybridization/correlation and we identify a spectroscopic fingerprint of bulk metallic character and ferromagnetism versus depth. The critical thickness and the gradient of hybridization are measured, setting an intrinsic limit of 3 and 10 unit cells from the surface, respectively, for (Ga,Mn)As and $La_{1-x}Sr_xMnO_3$, for fully restoring bulk properties.

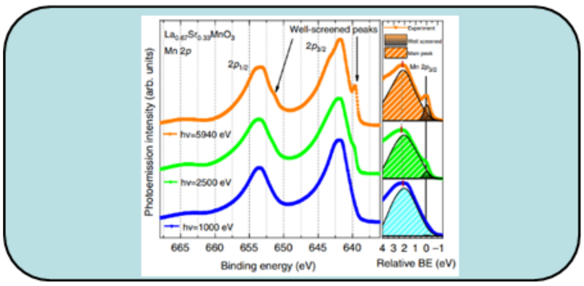

Fig.1: Photoemission Mn 2p spectra collected at different photon energies with different probing depth

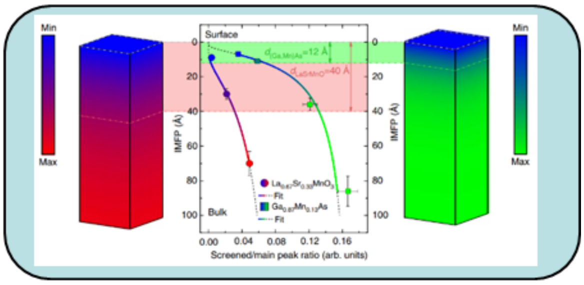

Fig.2: Estimated thickness of the surface region with altered electronic properties for the case of $La_{1-x}Sr_xMnO_3$ and (Ga,Mn)As

Highlights

Oxides —2017

Role of oxygen deposition pressure in the formation of Ti defect states in TiO_2(001) anatase thin films

B.Gobaut[1], P.Orgiani[2], A.Sambri[3,4], E.Di Gennaro[3,4], C.Aruta[3,4], F.Borgatti[5], V.Lollobrigida[6], D.Céolin[7], J.-P.Rueff[7,8], R.Ciancio[6], C.Bigi[6,9], P. Kumar Das[6,10], J.Fujii[6], D.Krizmancic[6], P.Torelli[6], I.Vobornik[6], G.Rossi[6,9], F.Miletto Granozio[2,3], U.Scotti di Uccio[2,3], G.Panaccione[6]

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ACS Applied Materials and Interfaces 9, 23099 (2017)

Titanium dioxide (TiO_2) is one of the most widely studied oxides because of its specific surface properties, making it a good candidate for photocatalysis of water and for reducing gas pollutants for air and water treatment and its photoinduced hydrophilic properties. TiO_2 anatase is an insulator with a band gap of 3.2 eV. However, changes in the concentration of oxygen vacancies ($TiO_{2-\delta}$) influence the value of the band gap. This results in the formation of Ti^{3+}-related electronic states located in the band gap, which may overlap with the electronic states at the conduction band minimum, eventually reducing the value of the gap. We have analyzed the structural and electronic arrangement of TiO_2(001)-oriented anatase thin films with different oxygen contents ($TiO_{2-\delta}$).

Anatase thin films growth and advanced electronic characterization by angular-resolved photo-emission spectroscopy (ARPES) and X-ray photo-emission spectroscopy (XPS) has been performed at the NFFA-APE beamline end stations receiving undulator synchrotron radiation from the ELETTRA storage ring. All of the surface-related problems have been circumvented by being the characterization chambers UHV connected with the PLD growth apparatus. TEM, LEED, STM, and XRD characterizations contribute to show that our PLD-grown samples, while hosting point defects giving rise to in-gap states whose nature is addressed in the following, show an excellent long-range order and a very high overall quality. Depth-sensitive photoemission spectroscopy (PES) results are able to (i) disentangle the contribution of different Ti ionic states (Ti^{4+} and Ti^{3+}), (ii) monitor the (homogeneous) diffusion of Al from the substrate through the film, and (iii) reveal the distribution of Ti^{3+} versus depth. Resonant photoelectron spectroscopy (ResPES) with polarized synchrotron radiation has been used to identify the in-gap defect states as related to Ti states only. By exploiting the PES sensitivity to the electronic state symmetry, we have been able to demonstrate a direct correlation between Ti^{3+} ions and the intensity of in-gap states. Our results refine the understanding of the defects at the origin of the in-gap electronic state.

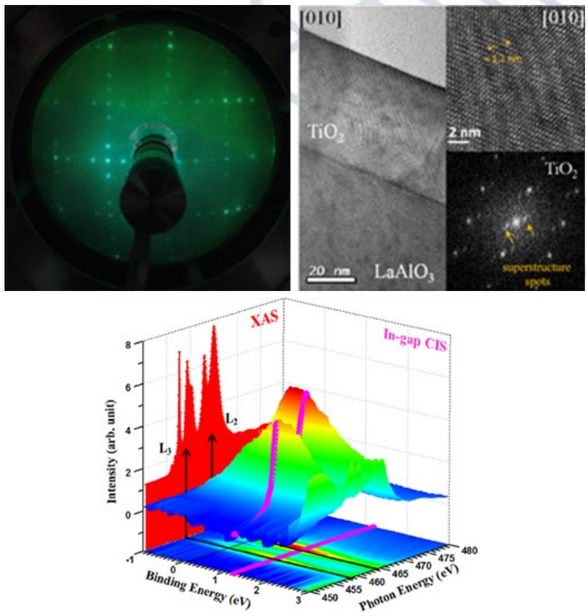

Fig.1: (top-left) Typical LEED pattern of the surface and (top-right) high-resolution TEM image of $TiO_{2-\delta}$ film; (bottom) ResPES map of the valence band (VB) as a function of the exciting photon energy (XAS spectrum is also reported in red).

Highlights

Oxides —2017

Correlation between Electronic Defect States Distribution and Device Performance of Perovskite Solar Cells

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Advanced Science 4, 1700183 (2017)

In this study random current fluctuations, measured at different temperatures and for different illumination levels, are used to understand the charge carrier kinetics in methylammonium lead iodide $CH_3NH_3PbI_3$-based perovskite solar cells. A model, combining trapping/detrapping, recombination mechanisms and electron–phonon scattering, is formulated evidencing how the presence of shallow and deeper band tail states influences the solar cell recombination losses. At low temperatures, the observed cascade capture process indicates that the trapping of the charge carriers by shallow defects is phonon assisted and directly followed by a recombination. By increasing the temperature, a phase modification of the $CH_3NH_3PbI_3$ absorber layer occurs and, for temperatures above the phase transition at about 160 K, the capture of the charge carrier takes place in two steps. The electron is first captured by a shallow defect and then it can be either emitted or thermalize down to a deeper band tail state and recombines subsequently. This result reveals that in perovskite solar cells the recombination kinetics is strongly influenced by the electron–phonon interactions. A clear correlation between the morphological structure of the perovskite grains, the energy disorder of the defect states, and the device performance is demonstrated.

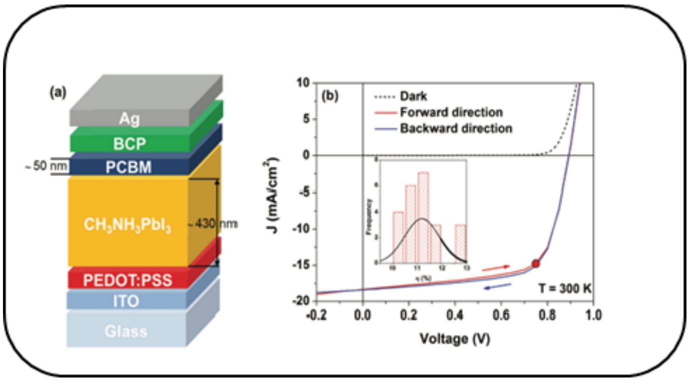

Fig.1: (a) Schematic illustration of the cross-section of the device structure. (b) Current density–voltage characteristics at 300 K in dark (dashed line) and under illumination (solid lines). The inset shows a histogram of the measured efficiency of 23 processed devices.

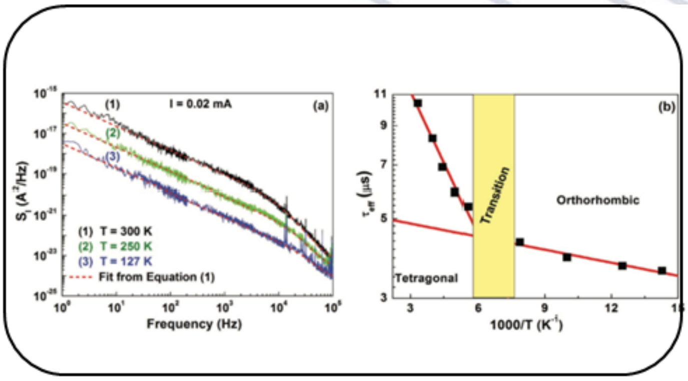

Fig.2: (a) Noise spectra of a perovskite photovoltaic device. (b) Arrhenius plot of the effective lifetime coefficient τeff. Two distinct behaviors are observed in the tetragonal and orthorhombic phases of the perovskite.

Highlights

Oxides —2017

Selective High Frequency Mechanical Actuation Driven by the VO_2 Electronic Instability

N. Manca[1], L. Pellegrino[2], T. Kanki[3], W. J. Venstra[1], G. Mattoni[1], Y. Higuchi[3], H. Tanaka[3], A. D. Caviglia[1], D. Marré[2,4]

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Advanced Materials 29, 1701618 (2017)

Relaxation oscillators consist of periodic variations of a physical quantity triggered by a static excitation. They are a typical consequence of non-linear dynamics and can be observed in a variety of systems. VO_2 is a correlated oxide with a solid-state phase transition above room temperature, where both electrical resistance and lattice parameters undergo a drastic change in a narrow temperature range. This strong non-linear response allows to realize spontaneous electrical oscillations in the MHz range under a DC voltage bias. These electrical oscillations are employed to set into mechanical resonance a microstructure without the need of any active electronics, with small power consumption and with the possibility to selectively excite specific flexural modes by tuning the value of the DC electrical bias in a range of few hundreds of millivolts. This actuation methods is robust and flexible and can be implemented in a variety of autonomous DC-powered devices.

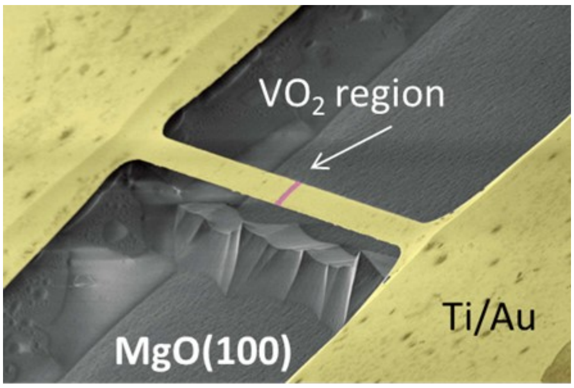

Fig.1: False-colored scanning electron microscopy picture of a microbridge. Electrical current is injected by the gold pads (yellow) into the VO_2 region (magenta). The phase transition is triggered by the temperature increase due to Joule effect.

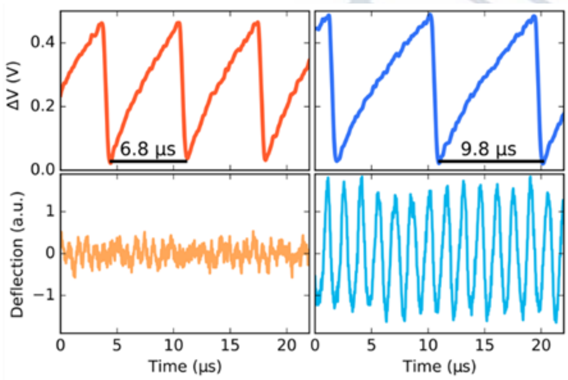

Fig.2: Time plots of the voltage drop across the microbridge and its mechanical deflection. By tuning the DC voltage bias, the frequency of the electro-thermal oscillations changes and can trigger the mechanical excitation of the structure. This occurs when the frequency of one of the harmonic components of the electrical oscillation matches one of the flexural modes of the microbridge.

Hallmarks of Hunds coupling in the Mott insulator Ca_2RuO_4

D. Sutter[1], C.G. Fatuzzo[2], S. Moser[3], M. Kim[4,5], R. Fittipaldi[6,7], A. Vecchione[6,7], V. Granata[6,7], Y. Sassa[8], F. Cossalter[1], G. Gatti[2], M. Grioni[2], H.M. Rønnow[2], N.C. Plumb[9], C.E. Matt[9], M. Shi[9], M. Hoesch[10], T.K. Kim[10], T.-R. Chang[11,12], H.-T. Jeng[11,13], C. Jozwiak[3], A. Bostwick[3], E. Rotenberg[3], A. Georges[4,5,14], T. Neupert[1] & J. Chang[1]

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[9]Swiss Light Source, Paul Scherrer Institut, Villigen PSI CH-5232, Switzerland
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[11]Department of Physics, National Tsing Hua University, Hsinchu 30013, Taiwan
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Nature Communications 8, 15176 (2017)

A paradigmatic case of multi-band Mott physics including spin-orbit and Hund's coupling is realized in Ca_2RuO_4. Progress in understanding the nature of this Mott insulating phase has been impeded by the lack of knowledge about the low-energy electronic structure. We provide, using angle-resolved photoemission electron spectroscopy, the band structure of the paramagnetic insulating phase of Ca_2RuO_4 and show how it features several distinct energy scales. Comparison to a simple analysis of atomic multiplets provides a quantitative estimate of the Hund's coupling J=0.4 eV. The experimental spectra are in agreement with electronic structure calculations performed with Dynamical Mean-Field Theory. The crystal field stabilization of the d_{xy} orbital due to c-axis contraction is shown to be essential to explain the insulating phase. These results underscore the importance of multi-band physics, Coulomb interaction and Hund's coupling that together generate the Mott insulating state of Ca_2RuO_4.

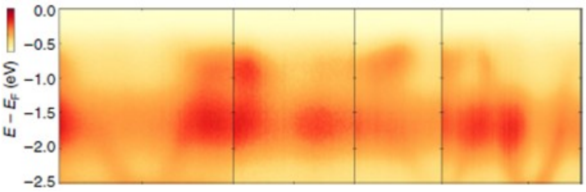

Fig.1: ARPES spectra recorded along high-symmetry directions with 65 eV circularly polarized light.

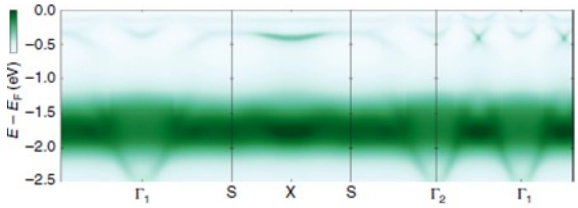

Fig.2: DMFT calculation of the spectral function, with Coulomb interaction U=2.3 eV and a Hund's coupling J=0.4 eV. Dark colours correspond to high intensities.

Ultralow friction of ink-jet printed graphene flakes

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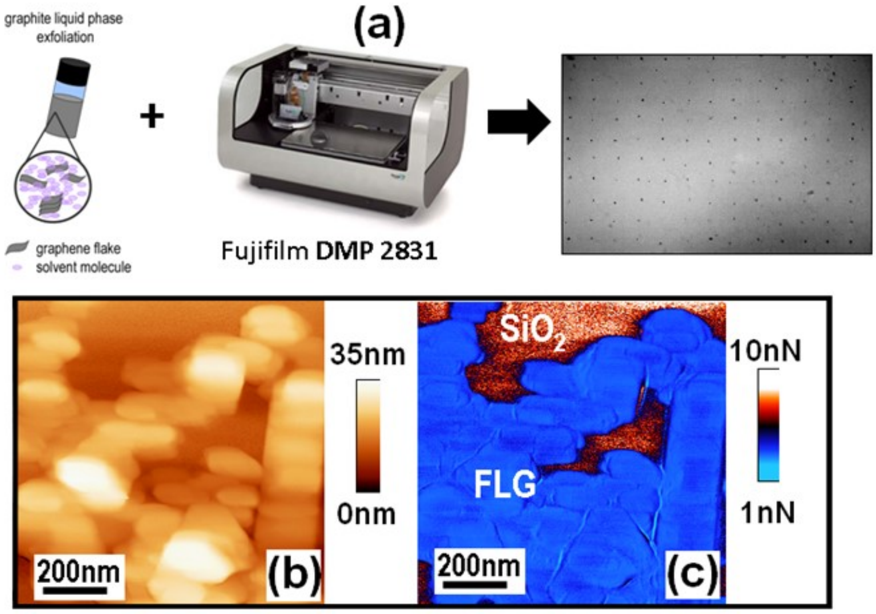
Nanoscale 9, 7612 (2017)

We report the frictional response of few-layer graphene (FLG) flakes obtained by the liquid phase exfoliation of pristine graphite. To this end, we inkjet print FLG on bare and hexamethyldisilazane-terminated SiO_2 substrates (Fig. (a)), producing micrometric patterns with nanoscopic roughness (Fig. (b)) that are investigated by atomic force microscopy (AFM). Notably, the printed FLG flakes show ultralow friction (Fig. (c)) comparable to that of micromechanically exfoliated graphene flakes. Lubricity is retained on flakes with a lateral size of a few tens of nanometres, and with a thickness as small as ~2nm, confirming the high crystalline quality and low defects density in the FLG basal plane. Surface exposed step edges exhibit the highest friction values, representing the preferential sites for the origin of the secondary dissipative processes related to edge straining, wear or lateral displacement of the flakes. Our work demonstrates that liquid phase exfoliation enables fundamental studies on graphene friction to the single-flake level. The capability to deliver ultralow-friction-graphene over technologically relevant substrates, using a scalable production route and a high-throughput, large-area printing technique, may also open up new opportunities in the lubrication of micro- and nano-electromechanical systems.

Figure: (a) Schematic illustration, showing a graphene ink printed onto a solid support by means of the materials printer DMP 2831, to produce a square grid pattern of micrometric dots over macroscale areas.
Morphology (b) and frictional response (c) of printed FLG flakes, as measured by AFM. The nanoscale friction map in (c) demonstrates order-of-magnitude reduction of interfacial friction on printed FLG compared with the one registered on the SiO_2 substrate.



Highlights

Other Materials —2017

Hybrid graphene/silicon Schottky photodiode with intrinsic gating effect

A. Di Bartolomeo[1,2], G. Luongo[1], F. Giubileo[2], N. Funicello[1], G. Niu[3], T. Schroeder[4,5], M. Lisker[4] and G. Lupina[4]

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2D Materials 4, 025075 (2017)

We propose a hybrid device consisting of a graphene/silicon (Gr/Si) Schottky diode in parallel with a Gr/SiO_2/Si capacitor for high-performance photodetection. The device, fabricated by transfer of commercial graphene on low-doped n-type Si substrate, achieves a photoresponse as high as 3 AW^{-1} and a normalized detectivity higher than 3.5×10^{12} $cmHz^{1/2}$ W^{-1} in the visible range. It exhibits a photocurrent exceeding the forward current because photo-generated minority carriers, accumulated at Si/SiO_2 interface of the Gr/SiO_2/Si capacitor, diffuse to the Gr/Si junction. We show that the same mechanism, when due to thermally generated carriers, although usually neglected or disregarded, causes the increased leakage often measured in Gr/Si heterojunctions. We perform extensive I–V and C-V characterization at different temperatures and we measure a zero-bias Schottky barrier height of 0.52 eV at room temperature, as well as an effective Richardson constant A** = 4×10^{-5} A cm^{-2} K^{-2} and an ideality factor n≈3.6, explained by a thin (<1 nm) oxide layer at the Gr/Si interface.

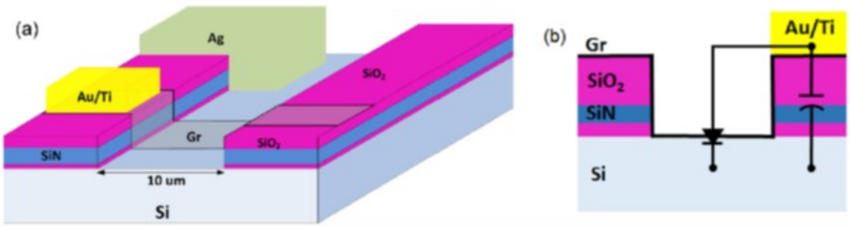

Fig.1: (a) 3D schematic view and (b) cross-section of Gr/Si diode in parallel with a Gr/SiO_2–Si_3N_4–SiO_2/Si MOS capacitor.

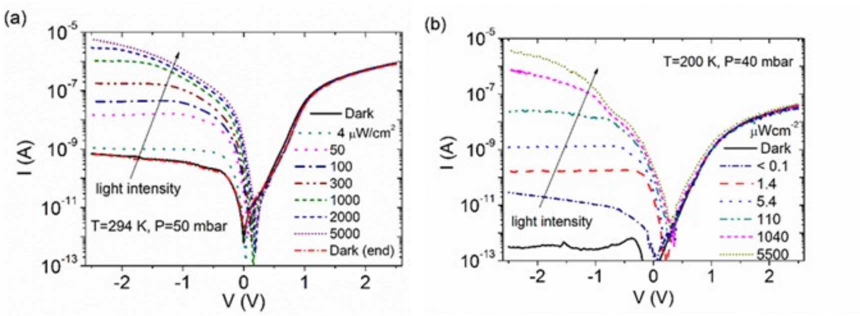

Fig.2: I-V characteristics of the Gr/Si junction for different illumination levels at T=294 K, P=50 mbar (a) and at T=200 K, P=40 mbar (b) after 5 days vacuum anneal.

Tunable Schottky barrier and high responsivity in graphene/Si-nanotip optoelectronic device

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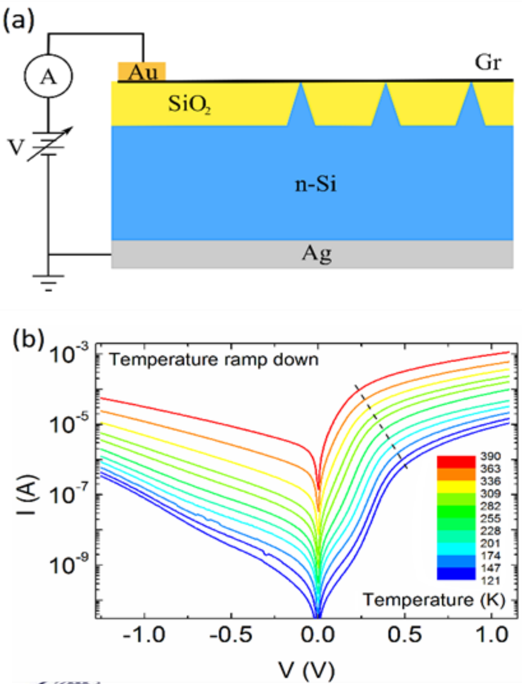
2D Materials 4, 015024 (2017)

We demonstrate tunable Schottky barrier height and record photo-responsivity in a new-concept device made of a single-layer CVD graphene transferred onto a matrix of nanotips patterned on n-type Si wafer. The original layout, where nano-sized graphene/Si heterojunctions alternate to graphene areas exposed to the electric field of the Si substrate, which acts both as diode cathode and transistor gate, results in a two-terminal barristor with single-bias control of the Schottky barrier. The nanotip patterning favors light absorption, and the enhancement of the electric field at the tip apex improves photo-charge separation and enables internal gain by impact ionization. These features render the device a photodetector with responsivity (3 A W^{-1} for white LED light at 3 mW cm^{-2} intensity) almost an order of magnitude higher than commercial photodiodes. We extensively characterize the voltage and the temperature dependence of the device parameters, and prove that the multi-junction approach does not add extra-inhomogeneity to the Schottky barrier height distribution. We also introduce a new phenomenological graphene/semiconductor diode equation, which well describes the experimental I–V characteristics both in forward and reverse bias.



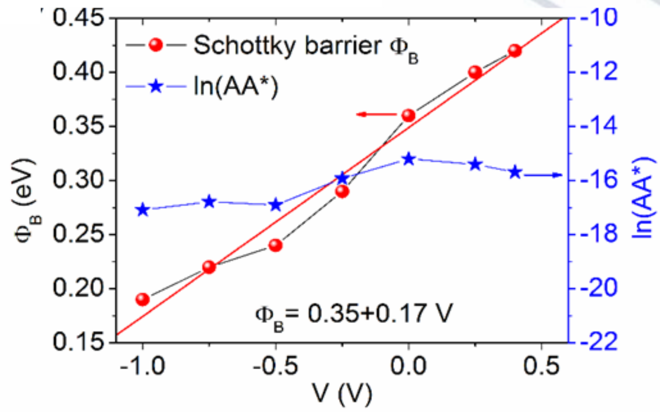


Fig.1: (a) Layout and measurement setup of the Gr/nSi-tip device. (b) I–V characteristics in the temperature range 120–390 K. (c) Dependence of Schottky barrier height FB and ln (AA*) on V.

Fe-Doping-Induced Magnetism in Nano-Hydroxyapatites

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Inorganic Chemistry 56, 4446 (2017)

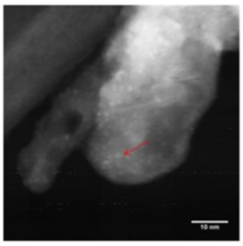

Fig. 1: STEM picture of FeHA. In picture brighter spots are highlighted by a red arrow.

We report on the production and characterization of iron-doped hydroxyapatite (HA) nanoparticles (NPs) endowed with different magnetic properties, generated by a precise setting of Fe^{2+} and Fe^{3+} ions. We found by ICP-OES spectrometry and X-ray absorption spectroscopy that: (i) Fe^{2+} substitutes calcium in the more crystalline regions and (ii) Fe^{3+} is placed as an unstructured ion in areas of the NPs with less structural restraint in the case of Fe^{2+}-doped HA (FeHA2) and Fe^{3+}-doped HA (FeHA3), or in substitution for Ca^{2+} in the apatite lattice in the case of $Fe^{2+/3+}$-doped HA (FeHA). The structure of FeHA showed a higher degree of medium-range order, evidenced by EXAFS spectra, that is probably due to Fe^{3+} ions arranged with a higher degree of order with respect to FeHA2 and FeHA3. The areas that might generate this EXAFS signal are visible by STEM as subnanometer bright spots inside FeHA NPs (Fig. 1).

FeHA NPs are rendered superparamagnetic (Fig. 2A) as a result of the formation of small amounts of a secondary iron oxide phase (maghemite crystallites on an individual HA crystallite) (Fig. 3). The presence of iron ions inside the HA NPs led to the formation of a paramagnetic-like phase down to low temperature, as evidenced by the upturn at low temperature in the magnetization curve for magnetic fields larger than 10 KOe (Fig. 2B) and by the Mössbauer analysis.

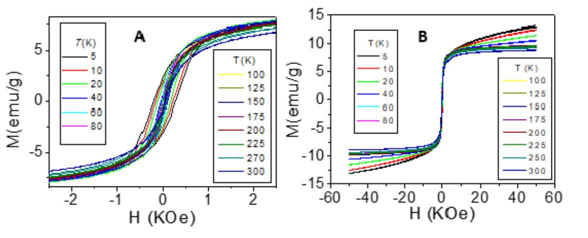

Fig. 2: (A) Enlarged view of FeHA hysteresis loops; (B) Magnetization versus magnetic field isotherms of FeHA, in the field range ± 50 KOe.

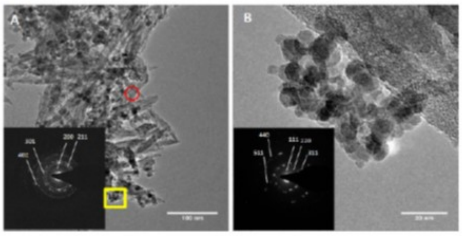

Fig. 3: TEM images collected on FeHA NPs, revealing the presence of the two different phase (A) iron-doped HA and (B) maghemite; SAED patterns collected in the red circle and in the yellow box are reported in the respective inserts.

Notably, an interacting superparamagnetic behavior due to the occurrence of dipolar interactions between segregated maghemite NPs with a saturation magnetization as high as 130 emu/(g of Fe) at room temperature, much higher than those found for superparamagnetic iron oxide NPs (SPIONs), was observed in FeHA, probably due to an unusual disposition of iron atoms. This result is very interesting not only for its implications in nanomagnetism fundamentals but also from the perspective of developing high-performance superparamagnetic NP probe systems for bio-applications in the theranostic field, considering the intrinsic biological characteristic of hydroxyapatite.

Highlights

Other Materials —2017

Giant Rashba Splitting in $Pb_{1-x}Sn_xTe$ (111) Topological Crystalline Insulator Films Controlled by Bi Doping in the Bulk

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Advanced Materials 29, 1604185 (2017)

We show by means of Angle Resolved Photoemission (ARPES) that Bi and Sb-doped topological crystalline insulator (TCI) $Pb_{1-x}Sn_xTe$ (111) films represent a giant Rashba system that features record Rashba coupling constant. Contrary to most other systems, the strength of the Rashba effect is effectively controlled by the bulk doping. Our detailed theoretical analysis reveals that it originates from a large upward band bending at the surface due to electron surface traps whose occupancy is controlled by the bulk Fermi level. Doping also allows compensating the intrinsic p-type character of TCI materials, resulting in high carrier mobilities that enable optical and topological quantum transport investigations otherwise screened by the bulk contribution.

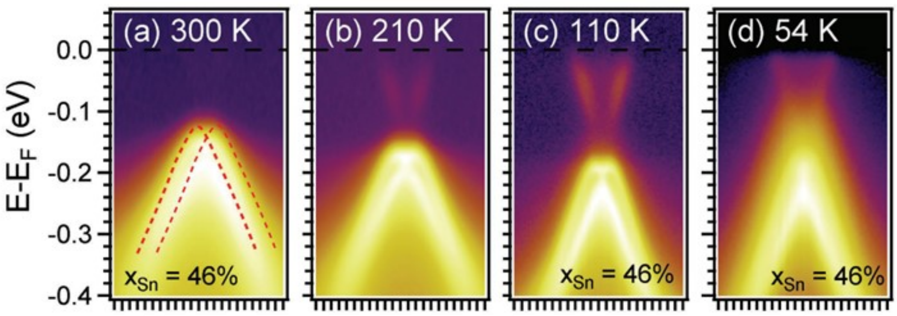

Fig.1: Topological phase transition characterized by ARPES. a–d) Temperature-dependent E(k) maps of a $Pb_{0.54}Sn_{0.46}Te$ (111) epilayer with 0.25% Bi measured around Gamma-bar of the surface Brillouin Zone using a photon energy of 18 eV. The topological transition occurs at about 110 K.

Three-Dimensional Electronic Structure of the Type-II Weyl Semimetal WTe_2

D. Di Sante,[1] P. K. Das,[2,3] C. Bigi,[4] Z. Ergönenc,[5] N. Gürtler,[5] J. A. Krieger,[6,7] T. Schmitt,[8] M. N. Ali,[9] G. Rossi,[4] R. Thomale,[1] C. Franchini,[5] S. Picozzi,[10] J. Fujii,[2] V. N. Strocov,[8] G. Sangiovanni,[1] I. Vobornik,[2] R. J. Cava,[9] and G. Panaccione[2]

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[6]Lab. Muon Spectr. Paul Scherrer Institute, Villigen, Switzerland
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Physical Review Letters 119, 026403 (2017)

By combining bulk sensitive soft-x-ray angular-resolved photoemission spectroscopy and first principles calculations (Fig.1) we explored the bulk electron states of WTe_2, a candidate type-II Weyl semimetal featuring a large nonsaturating magnetoresistance. Despite the layered geometry suggesting a twodimensional electronic structure, we directly observe a three-dimensional electronic dispersion. We report a band dispersion in the reciprocal direction perpendicular to the layers, implying that electrons can also travel coherently when crossing from one layer to the other. The measured Fermi surface is characterized by two well-separated electron and hole pockets at either side of the Γ point, differently from previous more surface sensitive angle-resolved photoemission spectroscopy experiments that additionally found a pronounced quasiparticle weight at the zone center. Moreover, we observe a significant sensitivity of the bulk electronic structure of WTe2 around the Fermi level to electronic correlations and renormalizations due to self-energy effects, previously neglected in first-principles descriptions.

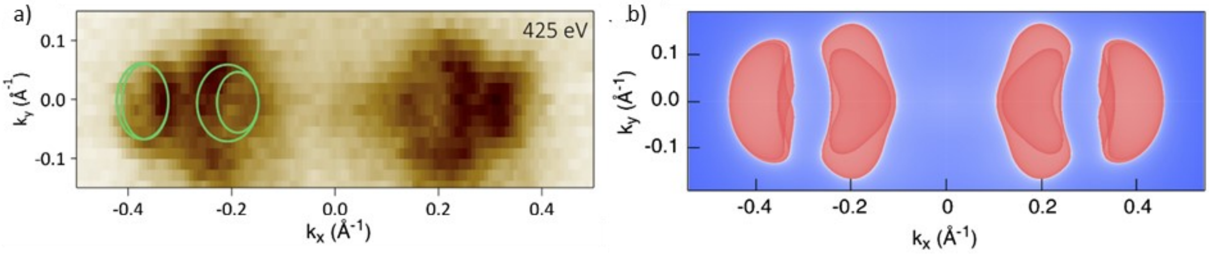

Fig.1 k_x-k_y Fermi surfaces for WTe_2 (a) recorded with soft-x-ray ARPES at hν= 425 eV and (b) calculated for bulk within the LDA+U approach (U = 2 eV).

Highlights

Other Materials —2017

Entropy spikes as a signature of Lifshitz transition in the Dirac materials

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Scientific Reports 7, 10271 (2017)

Entropy is an important fundamental property of many-body systems. It governs their thermodynamics, heat transfer, thermo-electric and thermo-magnetic properties. On the other hand, the entropy was always hard to be directly measured experimentally. It has been revealed very recently that the entropy per particle, $\partial S/\partial n$, where n is the electron density, can be experimentally studied (Kuntsevich, A. Y., Pudalov, V. M., Tupikov, I. V. & Burmistrov, I. S., Nature Communications 6, 7298, 2015).

We demonstrate theoretically that the characteristic feature of a 2D system undergoing N consequent Lifshitz topological transitions is the occurrence of spikes of entropy per particle s of a magnitude $\pm\ln 2/(J-1/2)$ with $2 \le J \le N$ at low temperatures. We derive a general expression for s as a function of chemical potential, temperature and gap magnitude for the gapped Dirac materials. Inside the smallest gap, the dependence of s on the chemical potential exhibits a dip-and-peak structure in the temperature vicinity of the Dirac point. The spikes of the entropy per particles can be considered as a signature of the Dirac materials. These distinctive characteristics of gapped Dirac materials can be detected in transport experiments where the temperature is modulated in gated structures.

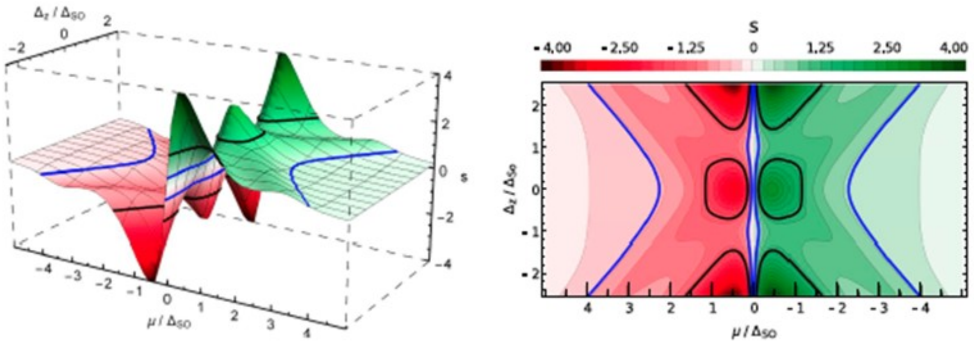

Fig.1: The entropy per electron s as functions of the chemical potential μ and Δ_z in the units of Δ_{SO}. The temperature $T = 0.3\Delta_{SO}$. Left panel: 3D plot. Right panel: Contour plot.

Highlights

Physics of Materials —2017

Detection of Zak phases and topological invariants in a chiral quantum walk of twisted photons

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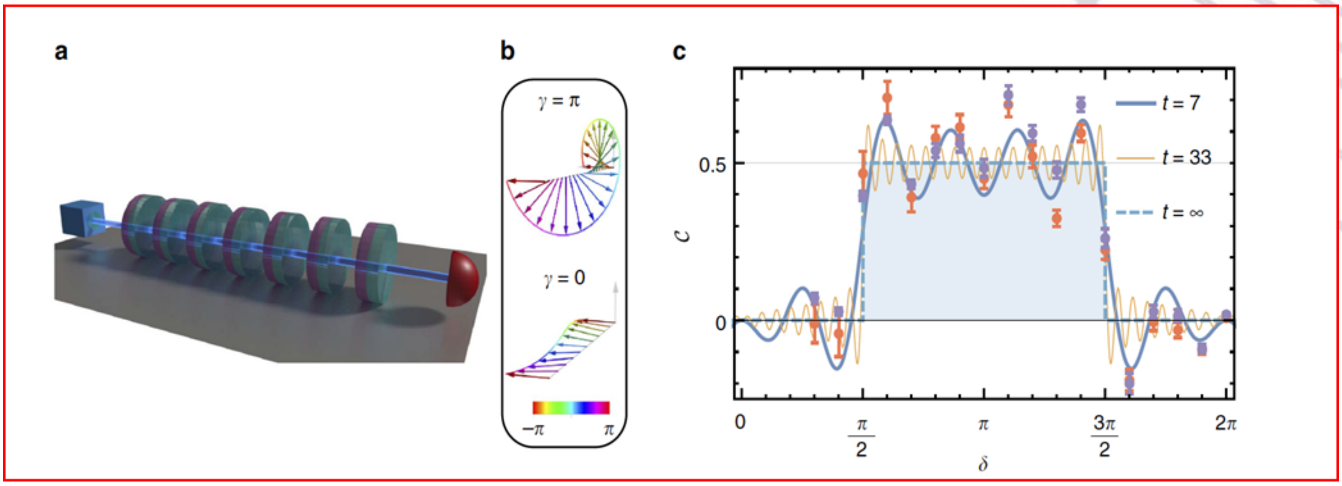
Nature Communications 8, 15516 (2017)

Topological insulators are fascinating states of matter exhibiting protected edge states and robust quantized features in their bulk. Here we propose and validate experimentally a method to detect topological properties in the bulk of one-dimensional chiral systems. We first introduce the mean chiral displacement, an observable that rapidly approaches a value proportional to the Zak phase during the free evolution of the system. Then we measure the Zak phase in a photonic quantum walk of twisted photons, by observing the mean chiral displacement in its bulk. Next, we measure the Zak phase in an alternative, inequivalent timeframe and combine the two windings to characterize the full phase diagram of this Floquet system. Finally, we prove the robustness of the measure by introducing dynamical disorder in the system. This detection method is extremely general and readily applicable to all present one-dimensional platforms simulating static or Floquet chiral.



Zak phase detection through the mean chiral displacement. (a) Sketch of the setup implementing the protocol U=Q*W. A light beam, exiting a single-mode fibre depicted on the left, performs a QW by propagating through a sequence of quarter-wave plates (purple disks) and q-plates (turquoise disks). (b) The unit vector n(k) winds either 1 or 0 times around the chiral axis, as k traverses the whole Brillouin zone, depending on the value of the optical retardation d. (c) Mean chiral displacement C after a 7-step QW of protocol U, versus the optical retardation δ. Each datapoint is an average over 10 different measurements (error bars are the associated s.e.). Purple and red dots refer, respectively, to different input polarizations, |L> and (|L>+|R>)/√2. The lines represent the subheading chiral term contained into the mean chiral displacement, for different values of the time t. In the long-time limit, it converges to (a multiple of) the Zak phase of protocol U.

Highlights

Physics of Materials —2017

Electrical transport and persistent photoconductivity in monolayer MoS_2 phototransistors

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Nanotechnlogy 28, 214002 (2017)

We study electrical transport properties in exfoliated molybdenum disulfide (MoS_2) back-gated field effect transistors at low drain bias and under different illumination intensities. It is found that photoconductive and photogating effect as well as space charge limited conduction can simultaneously occur. We point out that the photoconductivity increases logarithmically with the light intensity and can persist with a decay time longer than 10^4 s, due to photo-charge trapping at the MoS_2/SiO_2 interface and in MoS_2 defects. The transfer characteristics present hysteresis that is enhanced by illumination. At low drain bias, the devices feature low contact resistance of 1.4 kΩ mm^{-1}, ON current as high as 1.25 nA μm^{-1}, 10^5 ON–OFF ratio, mobility of ~1 cm^2 V^{-1} s^{-1} and photoresponsivity of about 1 A W^{-1}. Electrical measurements were performed in a Janis ST-500 cryogenic probe station connected to a Keithley 4200-SCS semiconductor parameter analyzer at room temperature and at an air pressure of 30 mbar to possibly remove moisture and limit oxygen adsorption on the MoS_2 surface. Optoelectronic properties were investigated by irradiation under visible light from an array of white LEDs (spectrum in the range 400–750 nm and peaks at 450 and 540 nm), with tunable intensity up to 5.5mWcm^{-2}.

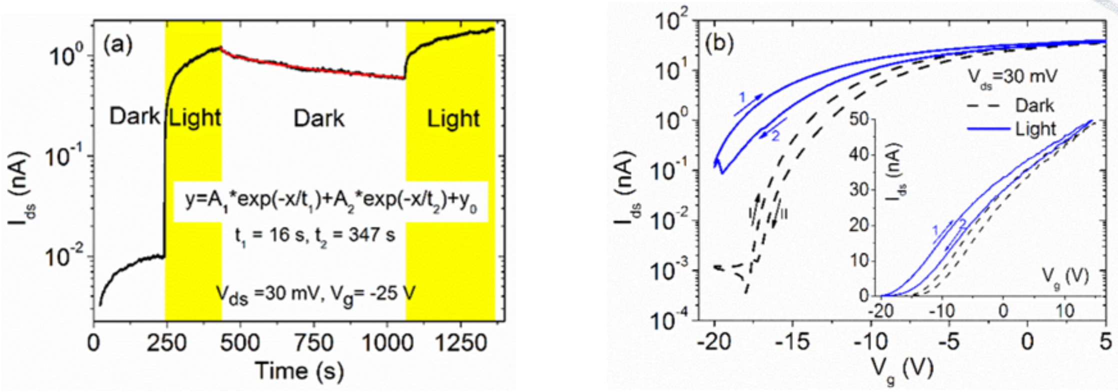

Fig.1: (a) Channel current versus time with and without light. (b) Comparison of transfer characteristics in dark and under illumination (the inset shows the current in linear scale).

Highlights

Physics of Materials —2017

Cage Size and Jump Precursors in Glass-Forming Liquids: Experiment and Simulations

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[4]Division of Physics and Applied Physics, Nanyang Technological University, Singapore

The Journal of Physical Chemistry Letters 8, 1562 (2017)

The relaxation dynamics of glassy systems proceeds via a sequence of sudden jumps, through which a particle changes its neighbors (Fig.1). These jumps are not homogeneously distributed neither in time nor in space. Relating the resulting heterogeneous particle dynamics to the diverse structural environments explored by the particles is a notorious difficult task, but crucial to rationalize the relaxation process. In this paper, we have introduced a novel approach that takes advantage of the cage-jump events in the single-particle trajectories. We use the cage size as a proxy of the local structure and the jump as a proxy of the local relaxation. Both simulations of supercooled liquids and experiments on hard-sphere colloidal suspensions show that a cage opening process takes place shortly before the jump, whereas the cage size attains a plateau at larger time. The plateau value is smaller for longer-lasting cages, revealing a clear coupling between local structure and dynamics (Fig.2). We clarify how this coupling controls the macroscopic behaviour of soft glassy materials and opens the way to a better understanding of their relaxation process.

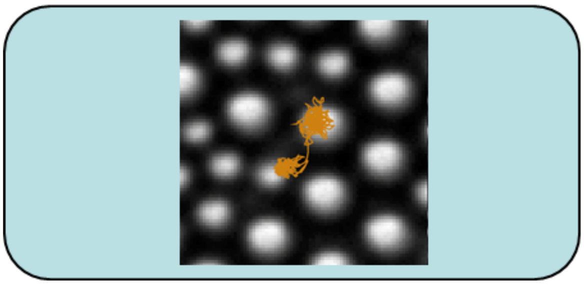


Fig.1: The trajectory of a particle of a dense colloidal assembly reveal the presence of a cage-jump .

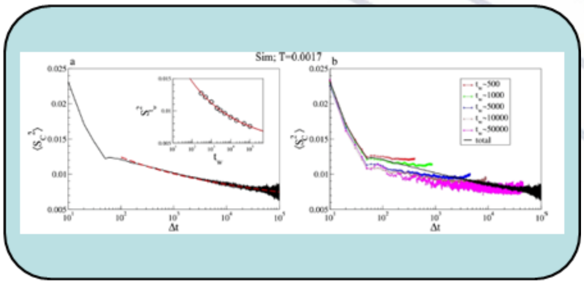


Fig.2: From simulations: (a) cage size averaged over the total ensemble of cages (solid line). At long time, data are correctly approximated by our model (dashed line) (b) Cage size averaged over the total ensemble (line) and over subensembles of cages of fixed waiting time (line-points). (Inset) Long time plateau of the cage size.

Highlights

Physics of Materials —2017

Observation of hybrid Tamm-plasmon exciton-polaritons with GaAs quantum wells and a MoSe2 monolayer

N.Lundt[1], S. Klembt[1], E. Cherotchenko[2], S. Betzold[1], O. Iff[1], A.V. Nalitov[2], M. Klaas[1], C.P. Dietrich[1], A.V. Kavokin[3], S. Hofling[1] and C. Schneider[1]

[1]University of Wurzburg, Am Hubland, Wurzburg, D-97074, Germany
[2]Physics and Astronomy, University of Southampton, Highfield, Southampton, SO171BJ, United Kingdom
[3] CNR-SPIN, 1, viale Politecnico, Roma, 00133, Italy

Nature Communications 8, 259 (2017)

Solid state cavity quantum electrodynamics is a rapidly advancing field which explores the frontiers of light-matter coupling. Metal-based approaches are of particular interest in this field, since they carry the potential to squeeze optical modes to spaces significantly below the diffraction limit enhancing light-matter coupling. At the same time, transition metal dichalcogenides are ideally suited as the active material in solid state cavity quantum electrodynamics as they interact strongly with light at the ultimate monolayer limit. Here, we implement a Tamm-plasmon polariton structure, and study the coupling to a monolayer of WSe_2, hosting highly stable excitons. Exciton-Polariton formation at room temperature is manifested in the characteristic energy momentum dispersion relation studied in photoluminescence, featuring an anti-crossing between the exciton and photon modes with a Rabi-splitting of 23.5 meV. Creating polaritonic quasi particles in monolithic, compact architectures with atomic monolayers under ambient conditions is a crucial step towards the exploration of non-linearities, macroscopic coherence and advanced spinor physics with novel, low mass bosons.

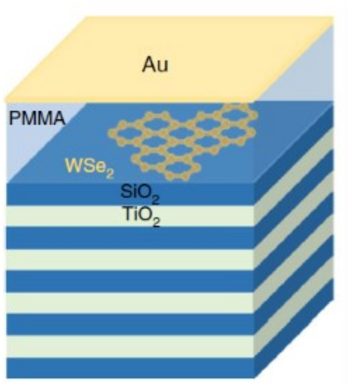


Fig.1: The Tamm cavity with an embedded TMDC monolyer

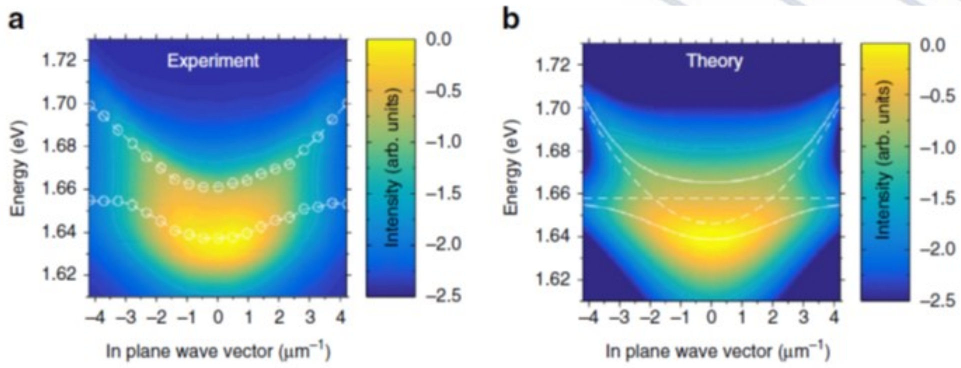


Fig.2: Experimental (a) and theoretical (b) angle-resolved photoluminescence spectra of the studied Tamm structure

Highlights

Physics of Materials —2017

Minimal Excitations in the Fractional Quantum Hall Regime

J. Rech[1], D. Ferraro[1], T. Jonckheere[1], L. Vannucci[2,3], M. Sassetti[2,3], and T. Martin[1]

[1]Aix Marseille Univ, Université de Toulon, CNRS, CPT, Marseille, France
[2]Dipartimento di Fisica, Università di Genova, Via Dodecaneso 33, 16146 Genova, Italy
[3]CNR-SPIN, Via Dodecaneso 33, 16146 Genova, Italy

Physical Review Letters 118, 076801 (2017)

A minimal excitation state of a quantum conductor is made of a single electron surfing on top of the Fermi sea, with no additional particle-hole pairs. Such a unique quantum state, also called *leviton*, emerges in response to well defined voltage pulses of Lorentzian shape.

Solid state systems, however, can be heavily affected by interactions, and the ground state of a fermionic system can show correlations. For instance, the fractional quantum Hall effect is a paradigmatic example of the dramatic consequences of electron-electron interactions. Here, a new strongly correlated phase emerges in the quantum liquid, with quasiparticle excitations carrying a fraction of the electron charge and whose statistical properties are neither bosonic nor fermionic, but belongs to the more general class of anyons.

In this Letter we study the minimal excitations of fractional quantum Hall edges, extending the notion of levitons to interacting systems. Using both perturbative and exact calculations, we show that they arise in response to a Lorentzian potential with quantized flux. They carry an integer charge, thus involving several Laughlin quasiparticles, and leave a Poissonian signature in a Hanbury Brown–Twiss partition noise measurement at low transparency. This makes them readily accessible experimentally, ultimately offering the opportunity to study real-time transport of Abelian and non-Abelian excitations.

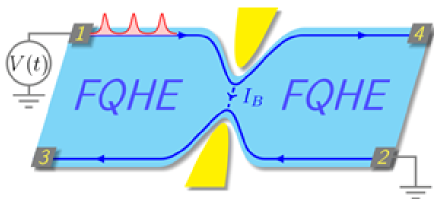


Fig.1: Hanbury Brown–Twiss setup in the fractional quantum Hall regime. A quantum Hall bar is equipped with a quantum point contact connecting opposite edge states. The left-moving incoming edge is grounded at contact 2 while the right-moving one is biased at contact 1 with a time-dependent potential V(t). Partition noise is measured in contact 3.

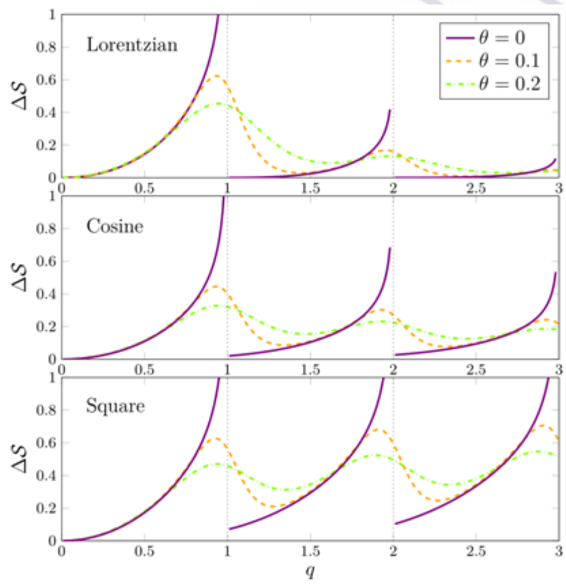


Fig.2: Excess noise as a function of the number of electrons per pulse q, for different reduced temperatures θ and filling factor ν=1/3, in the case of a square, a cosine, and a periodic Lorentzian drive.

Surface Structuring with Polarization-Singular Femtosecond Laser Beams Generated by a q-plate

J. Nivas[1,2], F. Cardano[1], Z. Song[3], A. Rubano[1,2], R. Fittipaldi[4],
A. Vecchione[4], D. Paparo[5], L. Marrucci[1,5], R. Bruzzese[1,2] and S. Amoruso[1,2]

[1]Dipartimento di Fisica "Ettore Pancini", Università di Napoli Federico II, Compl. Univ. di Monte S. Angelo, Via Cintia, I-80126 Napoli, Italy.
[2]CNR-SPIN UOS Napoli, Complesso Universitario di Monte S. Angelo, Via Cintia, I-80126 Napoli, Italy.
[3]Department of Physics, School of Science, Tianjin Polytechnic University, Binshuixi Road 399#, Xiqing District, Tianjin, 300387, P.R. China.
[4]CNR-SPIN, UOS Salerno, Via Giovanni Paolo II 132, I-84084 Fisciano, Italy.
[5]CNR-ISASI 'E. Caianiello', Via Campi Flegrei 34, 80078 Pozzuoli (NA), Italy.

Scientific Reports 7, 42142 (2017)

In the last few years femtosecond optical vortex beams with different spatial distributions of the state of polarization (e.g. azimuthal, radial, spiral, etc.) have been used to generate complex, regular surface patterns on different materials. We present an experimental investigation on direct femtosecond laser surface structuring based on a larger class of vector beams generated by means of a q-plate with topological charge q = +1/2. In fact, voltage tuning of q-plate optical retardation allows generating a family of ultrashort laser beams with a continuous spatial evolution of polarization and fluence distribution in the focal plane. These beams can be thought of as a controlled coherent superposition of a Gaussian beam with uniform polarization and a vortex beam with a radial or azimuthal state of polarization. The use of this family of ultrashort laser beams in surface structuring leads to a further extension of the achievable surface patterns. The comparison of theoretical predictions of the vector beam characteristics at the focal plane and the generated surface patterns is used to rationalize the dependence of the surface structures on the local state of the laser beam, thus offering an effective way to either design unconventional surface structures or diagnose complex ultrashort laser beams.

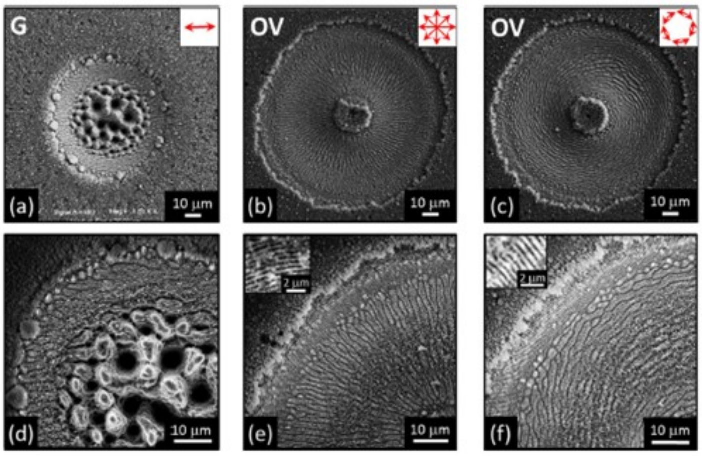


Fig.1: Panels (a–c) are examples of SEM images showing the surface morphologies developed on the silicon target after an irradiation sequence of N = 200 pulses at a pulse energy E_0 = 45 µ J for the Gaussian (G) beam (left panel, un-tuned q-plate at δ = 2π) and the Optical Vortex (OV) beams (central and right panels, tuned q-plate at δ = π , radial and azimuthal state of polarization, respectively). The panels (d–f) are SEM images acquired at higher magnification illustrating the finer details of the surface texture for the three cases. The two insets in panel (e) and (f) are zoomed views of the ripples generated in the peripheral, annular regions at lower fluence of the OV beams.

Life & Events


award
school
festival
ceremony
conference
workshop
event

Main Events

2016

April

"Nessuno mi troverà—Majorana Memorandum" by Egidio Eronico is a documentary-film on Ettore Majorana and his mysterious disappearance, distributed by Istituto Luce-Cinecittà.

Considering the scientific importance of Majorana and, therefore, the indirectly disseminating value of the film, CNR has cooperated with Istituto Luce-Cinecittà to support some projections with the contribution of its own researchers.

The involved SPIN researchers are listed below:

Procolo Lucignano (cinema Auditorium L'Aquila, April 20; cinema Modernissimo, Napoli, April 22);

Paolo Solinas (cinema Apollo, Milano, April 21);

Alessandro Braggio (cinema Lumiere, Bologna, April 29; cinema Club Amici del cinema, Genova, May 4; cinema Giorgione, Venezia May 12; Festival della Scienza, Genova, October 28).

May

"Misura il livello di Majorana che c'è in te" - Disseminating event within a combined study/work experience project at Istituto Majorana-Giorgi. Genova, May 3.

CNR-SPIN (Alessandro Braggio) and CNR-ISMAC (Michela Tassistro) met about one-hundred students from the Majiorana-Giorgi Institute of Genova to talk on the added value coming from the scientific and technological research, and to make Science attractive for students

Genova, May 16

Corrado Spinella, DSFMT– CNR Director, and Carmela Aruta, CNR-SPIN Researcher, are guest at "MEMEX, la Scienza raccontata dai Protagonisti" :

Our ability to "look closely" atoms, molecules, matter, makes us able to study their structures, to manipulate matter on an atomic scale and also to realize artificial forms of aggregation of the same material, not existing in nature, thus generating structures with unique properties, fundamental for the development of devices belonging to the daily existence of each of us by now, and therefore of miniaturized devices and microelectronic devices. Just think of an example for everyone, which concerns everyone: the smartphone.

Main Events

2016

June

3rd Workshop on Surfaces, Interfaces and Functionalization Processes in Organic Compounds and Applications

SINFO III— Naples, June 27-29

The workshop aimed at providing scientists from CNR and the associated Institutions with a forum to share the latest information and ideas on the fundamental properties of organic semiconductors and small molecule overlayers, as well as their future applications and implementation into working devices.

It joined the expertise of chemical and physical investigations of fundamental properties with the new interdisciplinary routes of nanoscale device design, synthesis of novel materials, and engineering of innovative functions, in order to address the challenges for Energy efficiency, Environment control and Health.

http://organics2016.spin.cnr.it/

July

"ELETTRONICA DI PLASTICA" *exhibition*, designed by research groups participating to the 3rd Workshop SINFO in collaboration with CNR - Ufficio Comunicazione, Informazione e URP, Sezione Operativa Area Comunicazione Scientifica e Istituzionale.

"ELETTRONICA DI PLASTICA" aims at combining scientific and artistic points of view, through the presentation of technological devices, images and photographs. Specifically, the content of the exhibition concerns the development of organic (opto)electronic devices and related research applications.

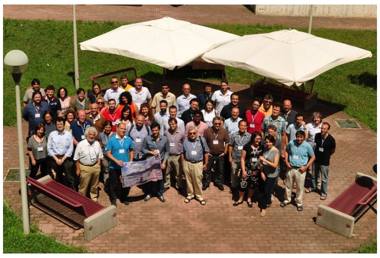
Fondazione Plart, Napoli, from June 28 to July 22.

https://www.cnr.it/it/elettronica-di-plastica

Main Events

2016

UFOX – Unveiling complex phenomena in Functional OXides



The UFOX Workshop is organized by the Institute SPIN-CNR and the Department of Physics of the University of Salerno.

It is promoted and supported by the Marie Skłodowska-Curie project "UFOX" (grant agreement No. 655515).

UFOX Workshop focuses on the emerging physical phenomena of complex material systems characterized by the interplay of many competing degrees of freedom (e.g. spin, charge, orbital, lattice), and on their potential to transfer functional properties into novel devices.

Fisciano (SA), July 7-8

Meeting on

Strengthening collaborations between CNR SPIN and NTU

Rome, July 8

The meeting between the NTU (Singapore) and the CNR delegations was held at the CNR headquarter in Rome to evaluate the opportunity of new collaborations going beyond the Joint Laboratory between NTU and SPIN on "Amorphous materials for energy harvesting applications ". In the course of the meeting many possible collaborations were identified, also relevant to other CNR Institutes.

People who attended the meeting: Corrado Spinella (CNR-DSFTM director), Antonella Tajani (CNR-DSFTM international activities), Carlo Ferdeghini (CNR-SPIN director), Giampiero Pepe (SPIN-Naples deputy director), Annalisa Fierro (SPIN Joint Laboratory P.I.), Ling San Dean (NTU College of Science), Yeow Meng Chee (NTU School of Physical and Mathematical Sciences), Massimo Pica Ciamarra (NTU School of Physical and Mathematical Sciences, NTU Joint Laboratory P.I.).

September

Alexey Kavokin, researcher at SPIN Rome, attends the Kremlin meeting on the Development Programs of the Russian Scientific Research, as member of the President Putin's staff in charge of drafting the Presidential Program of Research Projects.

Moscow, September 19

Main Events

2016

October

Prof. Mario Nicodemi (Department of Physics of the "Federico II" University of Naples and associated member to the CNR-SPIN Institute) won the prestigious Einstein BIH Visiting Fellowship award for 2016. The award is conferred annually by the Einstein Foundation and the Charité and Von Foundations Humboldt in Germany to a maximum of three scientists. In 2016, in addition to Prof. Nicodemi, Prof. Brian Kobilka, Nobel Prize winner for Chemistry 2012, and Prof. David H. Gutmann, neurologist at Washington University, were awarded.

The motivation of the award to Prof. Nicodemi is for the "understanding of the spatial structure of chromatin and the regulation of genes in disease-related genomic variants".

The award aims at supporting development of new scientific discoveries and interactions with the German research system, with a budget of about half a million Euros. It is the first time that the recognition is attributed to an Italian scientist.

Berlin, October 19

November

Finalmente la superconduttività a temperatura ambiente! Purtroppo solo in Antartide (ancora)
Lectio magistralis by Andrei Varlamov
promoted by CNR-SPIN

Genova, November 2

Superconductivity is a phenomenon that consists in the sudden disappearance of the electrical resistance of some pure metals and alloys at low temperatures (-273.15 ° C). In the last century, physicists and chemists from all over the world have been looking for compounds that would become superconducting at temperatures high enough to be cooled, for example, with liquid nitrogen, i.e. a relatively cheap and widely available product. Thus, in 1986, the discovery of high-temperature superconductors - whose resistance becomes zero at temperatures above 100 K - was accepted as the greatest physical event in recent years. Further efforts by scientists and engineers from around the world have led to wonderful discoveries.

December

"Novel frontiers in superconducting electronics: from fundamental concepts and advanced materials towards future applications", Pozzuoli (NA) December 12-17

The School is organized by the SPIN Institute in collaboration with the University of Napoli Federico II, the Second University of Napoli, the University of Salerno, and the National Institute for Nuclear Physics (INFN).

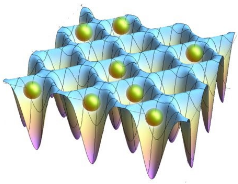
The ESAS Winter School is sponsored by CSC – IEEE.

Scientific Committee:
G.P. Pepe, Università di Napoli Federico II and CNR SPIN
R. Cristiano, CNR SPIN Napoli
M. Cuoco, CNR SPIN Salerno
C. Attanasio, Università di Salerno and CNR SPIN
F. Tafuri, Seconda Università di Napoli and CNR SPIN
F. Miletto Granozio, CNR SPIN Napoli

Main Events

2017

March



"Superconductivity:
opportunities for development and technology transfer"
Napoli, March 29

Seminar organized by the SPIN Institute and the "Scuola Politecnica e delle Scienze di Base", University of Naples Federico II.

Starting from the well-established tradition concerning the research activities on Superconditivity and its applications in the Campania Region, and from the Columbus Superconductors srl prospective for investment in the same Region, the seminar aims at exploring the widespread opportunities coming from relevant research planning and funding and from technology transfer initiatives in the field of Superconductivity. Talk contributions by: Piero Salatino, Scuola Politecnica e delle Scienze di Base, Università Federico II Napoli; Giampiero Pepe, Università Federico II Napoli and CNR-SPIN, Carlo Ferdeghini, CNR-SPIN Director; Leopoldo Angrisani, Università Federico II Napoli; Giovanni Grasso, Columbus Superconductors.

April

QUANTUM – SPIN

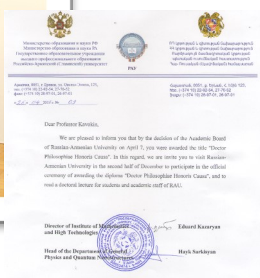
"Quantum SPIN Day", Genova, April 13

The Quantum-SPIN Day aims at fostering the participation of the CNR-SPIN researchers and technologists to the initiatives concerning the Quantum Technologies European Flagship. Talk contributions by: Carlo Ferdeghini, Mikhail Lisitskiy, Marco Salluzzo, Gianrico Lamura, Loredana Parlato, Roberto Cristiano, Giampiero Pepe, Mario Cuoco, Maura Sassetti, Barbara Cagnana.

Erevan, Armenia, April 7

By resolution of the Academic Board of Russian-Armenian University, Professor Alexey Kavokin was awarded with the title Doctor honoris causa of the Russian-Armenian University for his outstanding contribution to the study of the electronic and optical properties of quantum nanostructures and scientific cooperation with RAU.

During the awarding ceremony, the RAU Rector Prof. Armen Darbinyan highlighted that science should be the basis for the progress of the country, nation and society.



РАУ

Dear Professor Kavokin,

We are pleased to inform you that by the decision of the Academic Board of Russian-Armenian University on April 7, you were awarded the title "Doctor Philosophiae Honoris Causa". In this regard, we are invite you to visit Russian-Armenian University in the second half of December to participate in the official ceremony of awarding the diploma "Doctor Philosophiae Honoris Causa", and to read a doctoral lecture for students and academic staff of RAU.

Director of Institute of Mathematics and High Technologies — Eduard Kazaryan

Head of the Department of General Physics and Quantum Nanostructures — Hayk Sarkisyan

May

Salerno May, 22

The President of CNR, Prof. Massimo Inguscio, met SPIN Researchers at the SPIN Unit of Salerno.

The research unit is at the University of Salerno, located in Fisciano, and is hosted by the Department of Physics "ER Caianiello" with which it carries out research in close synergy in the field of physics of the materials.

"Futuro Remoto", Napoli, May 25-28

'Futuro Remoto' is the longest national event dedicated to scientific dissemination, realized in partnership with the CNR. The 2017 edition takes place for the second consecutive year at the center of the city of Naples: Piazza del Plebiscito. A center with a strong symbolic value, which intends to make the event a real 'Science Festival' of the entire scientific community of the country and, at the same time, a living platform of 'social innovation'.

Within the CNR hub, SPIN has set up its own stand on the deposition of thin films and micro- and nano-lithography, which are fields where the Institute can offer both great tradition and perspectives.

June

Shangai, June 11-17

First Edition of "Shanghai International Crystallographic School working with Bilbao Crystallographic server" held in Shanghai University.

"Shanghai International Crystallographic School working with Bilbao Crystallographic Server" was ceremoniously held at Shanghai University in the Siyuan Hall, Lehu new building from June 11st to 17th 2017. Following the idea of Alessandro Stroppa, a computational materials scientist from CNR-SPIN in Italy, the School was organized together with Prof. Wei Ren, professor of physics from the International Center of Quantum and Molecular Structure, Shanghai University and Mois Aroyo, professor of Condensed-Matter physics at the University of Basque in Spain.

Sorrento (NA), June 12-16

The 16th edition of the International Superconductive Electronics Conference (ISEC 2017) was held in Sorrento (Napoli), a unique historical town and a very attractive resort situated in one of the most beautiful Mediterranean coastlines.

Along with the traditional topics, ISEC2017 hosted more innovative, cutting-edge sessions, including hybrids with unconventional pairing as well as quantum topological properties towards novel electronic solutions, interface states in topological superconductors, and insulators interfaced to superconductors.

Giampiero Pepe
Chair of ISEC2017

Industrial and technological applications received particular attention in a wide dedicated exhibition area.

The ISEC 2017 Conference was organized in collaboration with CNR SPIN, IEEE CSC, University of Napoli Federico II and Universityof Salerno.

Main Events

2017

ISEC 2017 opened to one-day external participants for the *Superconducting Electronics for Quantum Flagship: beyond the potential*

The Meeting moved to a participatory mode, with the goal of collectively identifying what could be the potentials and markets for superconducting quantum technologies, and how the latter could be (more) industrialized in Europe. In particular, the following six key areas of quantum technologies were identified as preferred targets:

• Quantum Metrology
• Quantum Sensing
• Quantum Communications
• Quantum Memories
• Quantum Simulation
• Quantum Computation

The discussion aimed at analyzing which are the most beneficial possibilities offered by the superconducting technologies, and the hurdles in the process of industrialization of these technologies.
Sorrento (NA), June 15

August

Genova, from August 28 to September 8

Emilio Bellingeri, SPIN researcher, was involved in the project "In Estate si imparano le STEM", a scholastic training course funded by the Presidency of the Council of Ministers, Equal Opportunities Department, and realized by the Istituto Comprensivo di Sestri, an educational institute operating in Genova Sestri Ponente.

The course was a 2-week summer camp for students of primary school (last year) and of secondary school (first and second years). The students, under the guidance of external experts, performed simple physics experiments to observe phenomena and discover their rules. Emilio Bellingeri took care of the design and implementation of the "small physics" experiments that were carried out in the first week of the summer camp.

September

Solvay 1927 - Trento 2017: women and physics

Ninety years after the famous photo that portrayed 28 male scientists and only one female scientist (Marie Sklodowska Curie) at the Solvay Congress, the University of Trento and the Italian Physical Society took a similar picture it with reversed roles: 28 Italian female physicists, among them Silvia Picozzi, from CNR-SPIN, and only one single male physicist.

Main Events

2017

Montesilvano (PE), September 25-29

Psi-k/CECAM Research Conference on “AB-INITIO SPIN-ORBITRONICS”

The main purpose of this Psi-k/CECAM research conference was to highlight the very recent theoretical and computational developments related to the interplay of spin-orbit interaction with electronic structure, magnetism, transport, its link to strongly correlated materials and ultrafast currents in diverse materials. The conference aimed at discussing spin-orbit coupling as a means of inducing such fundamentally novel physical phenomena in exotic bulk materials, at surfaces and interfaces, in thin films and heterostructures.

Organizers:

Silvia Picozzi

CNR-SPIN L’Aquila

Stefan Blügel

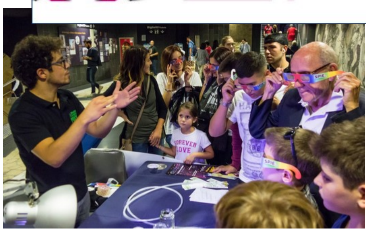
Forschungszentrum Jülich

Ingrid Mertig M.

Luther University Halle

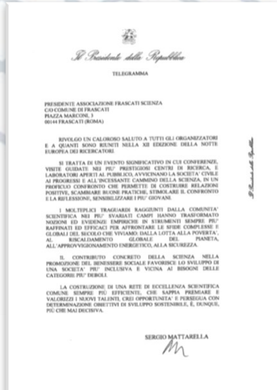
Napoli, September 29

La Notte Europea dei Ricercatori took place at the Municipio stop of the Naples Subway, involving scientists from universities and research institutions who told their activities using dissemination tools such as models and experiments. The event was organized by INFN of Napoli, Physics Department of University of Napoli Federico II, SPIN and ISASI Institutes of CNR, Gran Sasso National Laboratory, POYS Association under the coordination of Frascati Scienza in the framework of the “Made in Science” Project.



The attendees visited the following exhibition areas: Gravitational Wave, Neutrino Observation, Cosmic Ray, Thin Films for Micro and Nano-Electronics, Statistics, Diffraction and Holography.

The great success of the event received the prestigious endorsement by the President of the Republic of Italy, Sergio Mattarella, who sent a congratulatory telegram to the organizers.



Il Presidente della Repubblica

TELEGRAMMA

PRESIDENTE ASSOCIAZIONE FRASCATI SCIENZA
C/O COMUNE DI FRASCATI
PIAZZA MARCONI, 3
00144 FRASCATI (ROMA)

RIVOLGO UN CALOROSO SALUTO A TUTTI GLI ORGANIZZATORI E A QUANTI SONO RIUNITI NELLA XII EDIZIONE DELLA NOTTE EUROPEA DEI RICERCATORI.

SI TRATTA DI UN EVENTO SIGNIFICATIVO IN CUI CONFERENZE, VISITE GUIDATE NEI PIU' PRESTIGIOSI CENTRI DI RICERCA, E LABORATORI APERTI AL PUBBLICO, AVVICINANO LA SOCIETA' CIVILE AI PROGRESSI E ALL'INCESSANTE CAMMINO DELLA SCIENZA, IN UN PROFICUO CONFRONTO CHE PERMETTE DI COSTRUIRE RELAZIONI POSITIVE, SCAMBIARE BUONE PRATICHE, STIMOLARE IL CONFRONTO E LA RIFLESSIONE, SENSIBILIZZARE I PIU' GIOVANI.

I MOLTEPLICI TRAGUARDI RAGGIUNTI DALLA COMUNITA' SCIENTIFICA NEI PIU' SVARIATI CAMPI HANNO TRASFORMATO NOZIONI ED EVIDENZE EMPIRICHE IN STRUMENTI SEMPRE PIU' RAFFINATI ED EFFICACI PER AFFRONTARE LE SFIDE COMPLESSE E GLOBALI DEL SECOLO CHE VIVIAMO: DALLA LOTTA ALLA POVERTA', AL RISCALDAMENTO GLOBALE DEL PIANETA, ALL'APPROVVIGIONAMENTO ENERGETICO, ALLA SICUREZZA.

IL CONTRIBUTO CONCRETO DELLA SCIENZA NELLA PROMOZIONE DEL BENESSERE SOCIALE FAVORISCE LO SVILUPPO DI UNA SOCIETA' PIU' INCLUSIVA E VICINA AI BISOGNI DELLE CATEGORIE PIU' DEBOLI.

LA COSTRUZIONE DI UNA RETE DI ECCELLENZA SCIENTIFICA COMUNE SEMPRE PIÙ EFFICIENTE, CHE SAPPIA PREMIARE E VALORIZZI I NUOVI TALENTI, CREI OPPORTUNITA' E PERSEGUA CON DETERMINAZIONE OBIETTIVI DI SVILUPPO SOSTENIBILE, È, DUNQUE, PIÙ CHE MAI DECISIVA.

SERGIO MATTARELLA

MINISTERO DELLO SVILUPPO ECONOMICO — FONDO PER LA CRESCITA SOSTENIBILE

Evaluated more than a hundred projects in the various MISE calls!

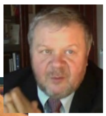
Carlo Ferdeghini acted as chairman of the CNR-Panel “Materiali Avanzati” (vice-chair Emilio Bellingeri) coordinating several CNR referees (among them many of SPIN: Marco Campani, Roberto Cristiano, Pasquale Orgiani, Filippo Giubileo, Alberto Porzio, Elisabetta Narducci) for the evaluation of more than one hundred industrial projects coming on behalf of the Ministry of Economic Development in the framework of the “Fondo per la Crescita Sostenibile”; this is an extremely important measure for the country’s high-tech industrial development.

Main Events

2017

October

Milano, October 26



The Meeting on "Aspects of the Modern Triad: Heat, Electricity, Mechanics" was organized by the Istituto Lombardo Accademia di Scienze e Lettere in order to involve the general public on the scientific developments of Physics, Chemistry and Technology arising from the relationships between heat and energy, their effects in the thermodynamic field, electrical effects associated with temperature differences, the crucial role of friction, and so on. Andrey Varlamov, SPIN researcher, gave an invited talk titled "Thermoelectricity: history and new prospects".

Napoli, October 27

In the school year 2017/2018 an educational work-linked training on "Nanotechnology and Quantum Mechanism" was activated by CNR-SPIN in collaboration with the Department of Physics "E. Pancini "of the University of Naples Federico II, the INFN Section of Naples, and the CNR Institute ISASI. The course aims at providing fundamental theoretical and practical knowledge useful to the study and to the development of nanotechnologies in connection to the quantum world. The course includes seminars and laboratory experiences focused on manufacturing, imaging and characterization of the physical properties of solid state quantum nano-devices.

Genova, October 20

Carlo Ferdeghini among the speaking guests at the opening conference on "Energy for Innovation", the III edition of the Genova Smart Week.

The week was animated by several congress, technical workshops and dissemination events inside Palazzo Tursi of Genova.

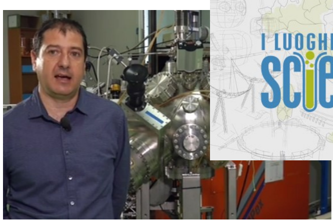
Genova, October 30

Luca Pellegrino, CNR-SPIN researcher, tells about microactuators at the 2017 Genoa Science Festival:

Microactuators are microscopic artificial structures capable of producing movements and applying forces to the micro and nanoscopic scales, as fundamental components of modern technology with applications in the medical field, in robotics, in telecommunications and in scientific research. Each type of application needs a special microactuator.

November

Genova, November 7



In the TV trasmission MEMEX – i Luoghi della Scienza, Emilio Bellingeri, CNR-SPIN researcher, tells about new applications of superconducting materials. From biomedical ones - with machines for magnetic resonance diagnostics - to high-field magnetic resonances for chemical-pharmacological research, to research magnets and large nuclear physics infrastructures, such as nuclear fusion rectors or large particle accelerators.

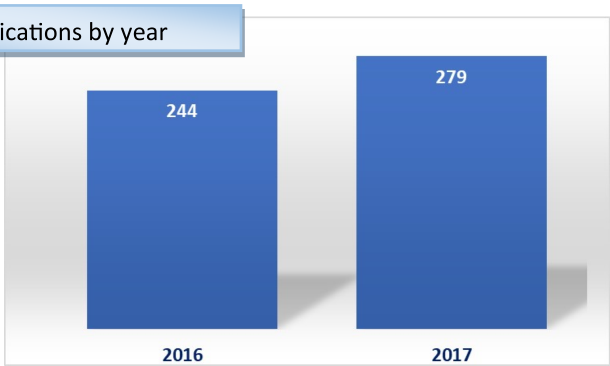
Publications

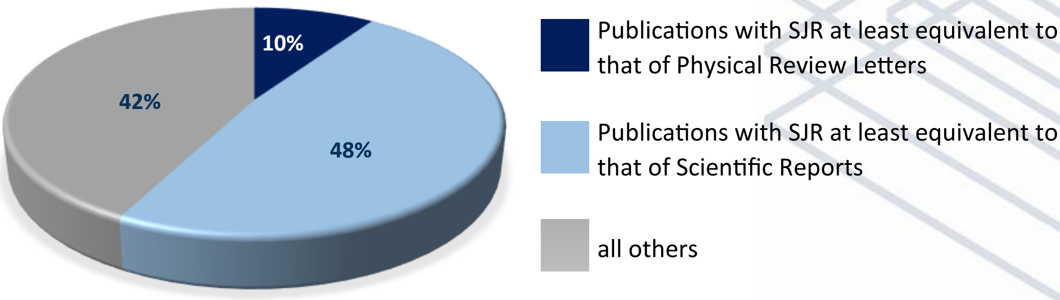
Publications

SPIN published 523 articles with SJR in the two-years period.

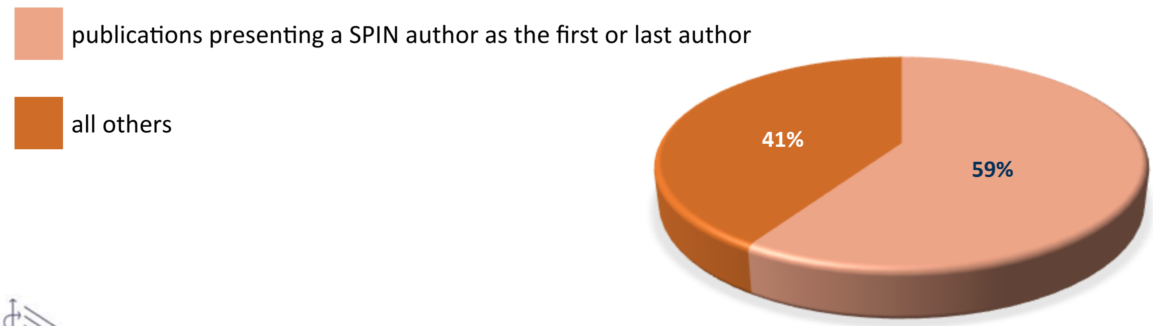
The complete list of publications can be downloaded at the link:
http://www.spin.cnr.it/index.php/research/publications.html

Publications by year





Ownership distribution



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