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SPIN

Superconductors, oxides and other innovative materials and devices

Scientific Report 2018-2019

National Research Council of Italy

Department of Physical Science and Technologies of the Matter

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SPIN - CNR

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Cover Image
Hexagonal Zinc Oxide symmetry induces a crystallographic preferential etching, by A. Leveratto

Thanks to
Valeria Braccini, Mario Barra, Renato Buzio for the support Ruggero Vaglio for the final review

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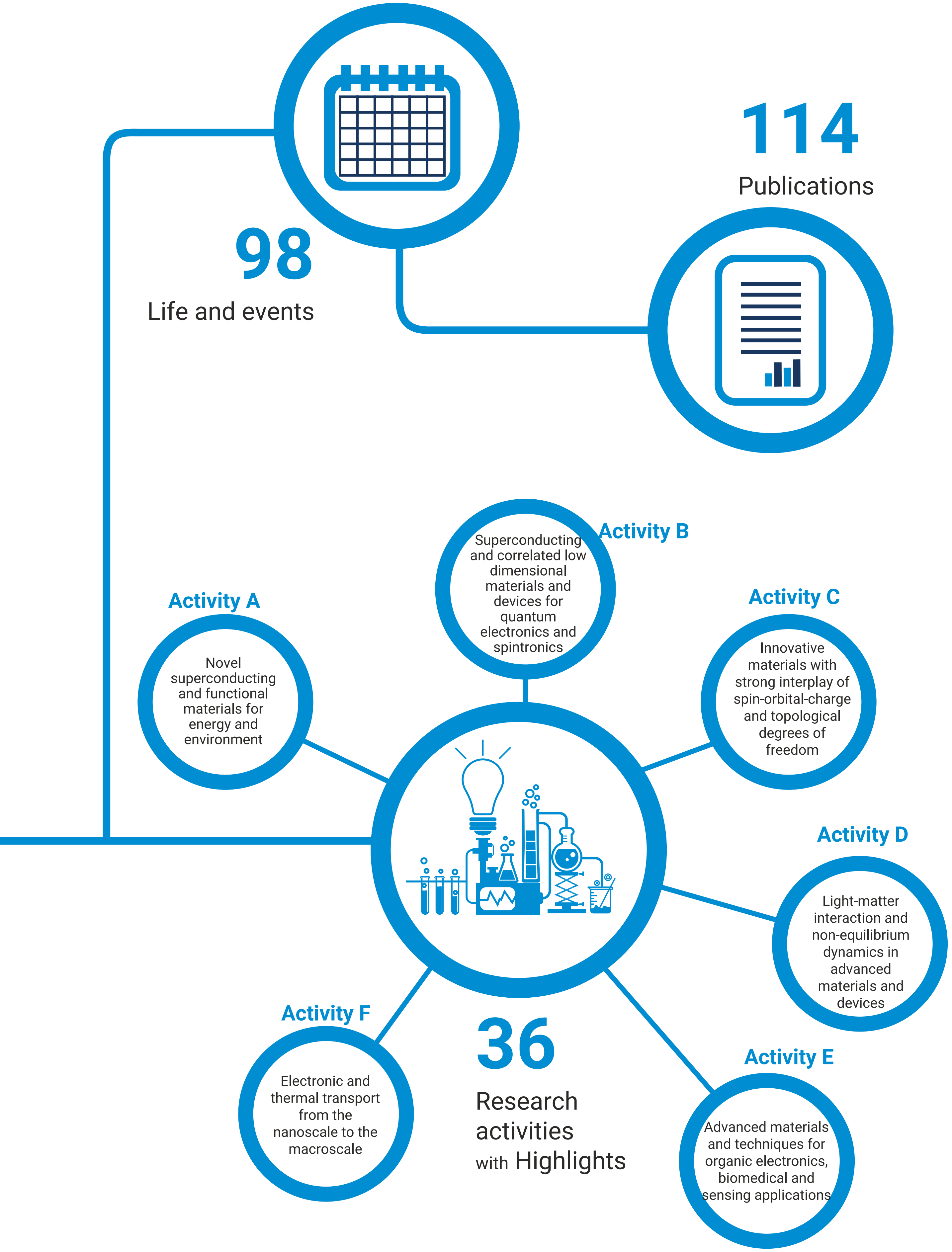
SPIN

Scientific Report 2018-2019

Summary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Foreword

Foreword

This is the fifth biennial Report of the scientific activities of the SPIN Institute, the last one I am making as Director, towards the end of second term.
SPIN (**S**u**P**erconducting and other **IN**novative materials and devices) institute is part of the National ResearchCouncil (CNR), which in turn is the largest public organization pursuing research and innovation in Italy.
SPIN belongs to DSFTM (Department of Physical Sciences and Technologies of Matter) and is structured in six research activities: 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.
Although not all equivalent from the point of view of the number of involved researchers, the six research activities are all very dynamic, characterized by a strong interdisciplinarity and focused on the study of innovative materials and devices; this is the main "signature" of the Institute.
With pleasure, I recognize the success of the SPIN community in having important International and European projects approved, including two FET-OPEN projects, and a considerable number of national projects; all in the fields of Superconductivity, Oxides, Nanomaterials and Quantum Technologies. A list and a description of the most significant can be found in the Report.
A special focus is dedicated to the scientific relationships consolidated between SPIN and CERN, especially in the framework of the FCC Study collaboration.
I feel that the collection of highlights, grouped according to the six research activities, will give a definite idea of the variety of scientific activities carried out in SPIN in the years 2018/2019. The final - rather conspicuous - part of the Report is dedicated to the outreach activities, as well as to dissemination of scientific culture and events organization, all of them being indeed of great importance for the Institute.
I do hope this document will provide a comprehensive picture of what the SPIN Institute has become in its first ten years of life.
For the preparation of this document, I have to thank the whole SPIN community for contributions, Daniela Gaggero 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 to Valeria Braccini, Mario Barra, Renato Buzio and Ruggero Vaglio.

Carlo Ferdeghini

On the right in the picture: Carlo Ferdeghini

Management

Management

2018-2019

Carlo Ferdeghini

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

The Director leads and coordinates the activities of the Institute and is responsible of its overall working and of the results of its 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.

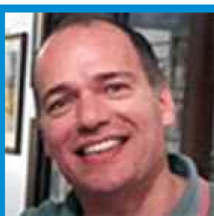
Valeria Braccini

Renato Buzio

Giuseppe Balestrino

Vittorio Cataudella

Roberto Cristiano



Mario Cuoco

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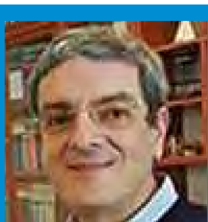
Fabio Miletto Granozio



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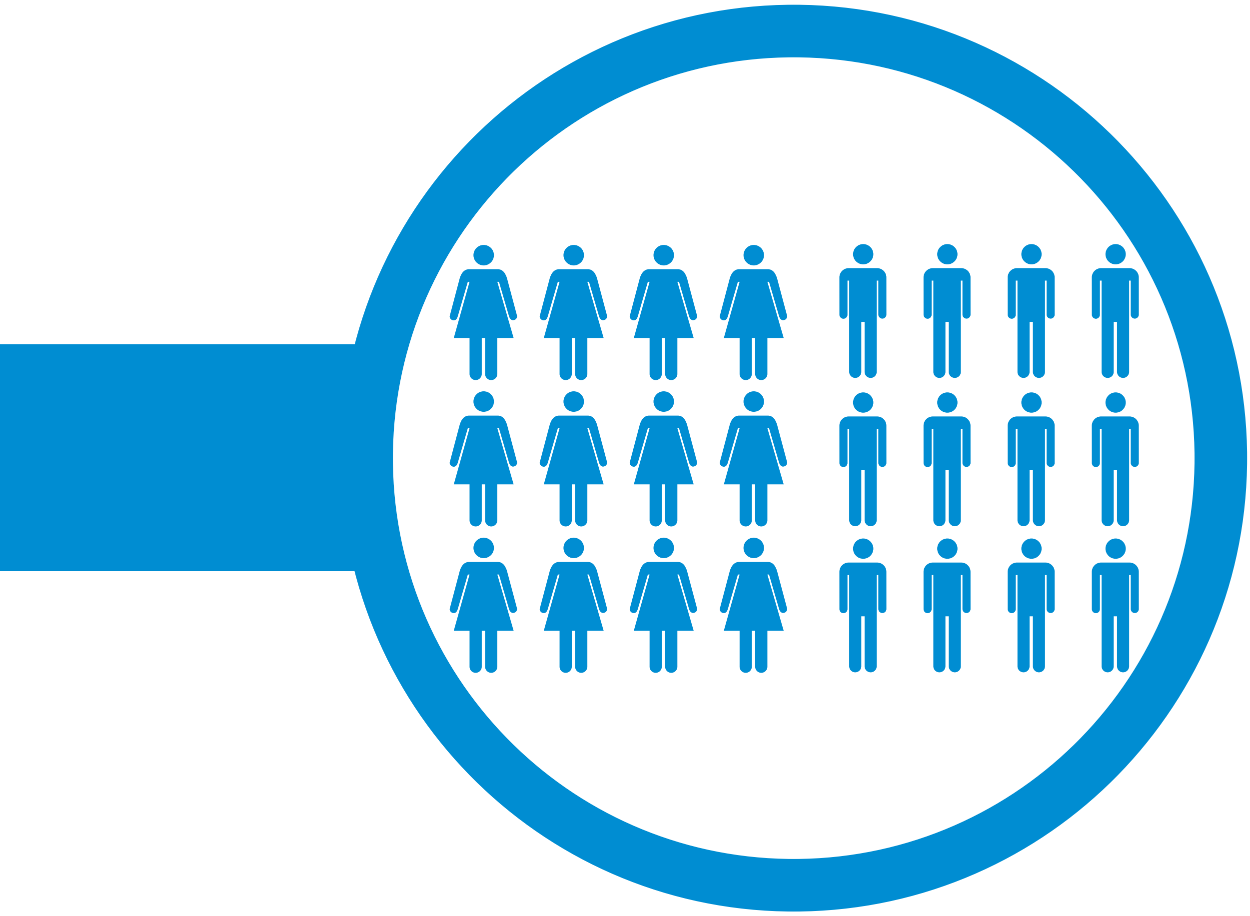

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Community

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Office of Administrative and Technical Support to the SPIN Institute established in Genova
(shared with CNR NANO and IOM Institutes)

Office Deputy Director
Marco Campani

General Services
Alberto Arnone, Paolo Ciocia, Josè Carlos De Almeida Nunes Manganaro, Maria Carla Garbarino

Recruitment of Temporary and Atypical Staff
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Marco Punginelli, Liliana Sciaccaluga

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Fundraising Funded Projects, Technology Transfer Italian, EU and International Projects
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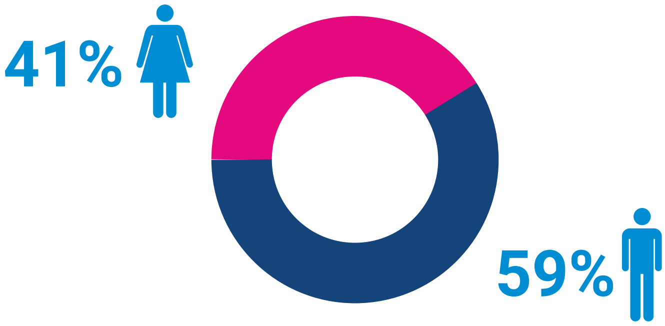
Industrial and Institutional Agreements
Roberta De Donatis, Diletta Miceli

Scientific Support
Elisabetta Narducci

Community

60 Researchers
72 Research Associates
59 PhD Students & Fellowships
18 Administrative staff members
10 Technical staff members


ATALE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Locations

Locations

SPIN belongs to the **Department of Physical Sciences and Technologies of Matter** (www.dsftm.cnr.it) of the National Research Council of Italy (CNR).

www.spin.cnr.it

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Deputy director Mario Cuoco

Projects and grants

Projects and grants

Running projects 2018/2019

Source: European

Type	Coordinator	Title	SPIN Leader	Duration	SPIN Unit involved
EU - H-2020	CNR SPIN	Oxide Nanoelectromechanical Systems for Ultrasensitive and Robust Sensing of Biomagnetic Fields - OXiNEMS	L. Pellegrino	May 2019 - April 2023	Genova
EU - H-2020	CEA	MAGnetic nanoparticle based liquid ENergy materials for Thermoelectric device Applications -MAGENTA	A. Varlamov	January 2017 - December 2019	Roma
EU - H-2020	CERN	European Advanced Superconductivity Innovation and Training EASITrain	E. Bellingeri M. Puttti	October 2017 - September 2021	Genova
EU - H-2020	University of Roma Tor Vergata	Collective Excitation in advanced Nanostructures COEXAN	A. Varlamov	May 2015 - September 2019	Roma
EU - H-2020	CNR SPIN	Highly sensitive detection of single microwave photons with coherent quantum network of superconducting qubits for searching galactic axions - SUPERGALAX	M. Lisististkiy	approved on August 2019	Napoli
EU - H2020	CNR - SPIN	Towards Oxide-Based Electronics – TO-BE Annualità	F. Miletto Granozio	June 2014 - April 2018	Napoli
EU - H2020	UNIVERSITAT AUTONOMA DE BARCELONA	BeMAGIC - Magnetoelectrics Beyond 2020: A Training Programme on Energy-Efficient Magnetoelectric Nanomaterials for Advanced Information and Healthcare Technologies	S. Picozzi	September 2019 - August 2023	L'Aquila-Chieti
EU - H2020 ERANET COFUND QUANTERA	CNR - SPIN	QUANtum Technologies with 2D-OXides	M. Salluzzo	February 2018 - April 2021	Napoli
EU - H-2020 ERANET COFUND FLAG ERA II	CNR SPIN	Disclosing the potential of transition metal dichalcogenides for thermoelectric applications through nanostructuring and confinement - Melodica	I. Pallecchi	April 2018 - April 2021	Genova
UE/EURATOM H -2020	University of Vienna	Alternative HTS wires	A. Malagoli	January 2017 - December 2018	Genova
EU FP7	CNR - SPIN	Coherent heat and energy transport in quantum system - COHEAT	P. Solinas	March 2014 - February 2018	Genova

Source: National

Type	Coordinator	Title	SPIN Leader	Duration	SPIN Unit involved
PRIN 2015	University of Bologna	NEWLI: NEW LIght on transient states in condensed matter by advanced photon - electron spectroscopies (2015CL3APH)	F. Bisio	February 2017 - February 2020	Genova
PRIN 2017	CNR SPIN	TWEET: ToWards fErroElectricity in Two-dimensions Codice PRIN 2017YCTB59	S. Picozzi	August 2019 - August 2022	L'Aquila-Chieti
PRIN 2017	University of Roma La Sapienza	Tuning and understanding Quantum phases in 2D materials - Quantum2D Codice PRIN 2017Z8TS5B	P. Barone	August 2019 - August 2022	L'Aquila-Chieti
PRIN 2017	University of Genova	"HIBiSCUS - High performance-low cost Iron BaSed Coated condUctorS for high field magnets" Codice PRIN 201785KWLW	V. Braccini	August 2019 - August 2022	Genova Napoli Salerno
PRIN 2017	University of Trento	PELM Photonic Extreme Learning Machine: from neuromorphic computing to universal optical interpolant, strain gauge sensor and cancer morphodynamic monitor Code PRIN 2017PSCKT	A. Ciattoni	August 2019 - August 2022	L'Aquila
PRIN 2017	CNR SPIN	TOPSPIN: Two-dimensional oxides Platform for SPIN-orbitronics nanotechnology" Code PRIN 20177SL7HC	M. Salluzzo	August 2019 - August 2022	Napoli
PRIN 2017	CNR- ICCOM	Novel Multilayered and Micro-Machined Electrode Nano-Architectures for Electrocatalytic Applications (Fuel Cells and Electrolyzers) Codice PRIN 2017YH9MRK	R. Felici	June 2019 - June 2022	Roma
PRIN 2017	University of Genova	UTFROM Understanding and Tuning FRiction through nanOstructure Manipulation Codice PRIN 20178PZCB5	R. Buzio	August 2019 - August 2022	Genova
PON IR	INFN	II.B.S.Co. INFRASTRUTTURA PER BIG DATA E SCIENTIFIC COMPUTING– PIR01_00011	G. Cantele	June 2019 - February 2022	Napoli
PON 2014-2020	CNR - DIITET	ARS01_00405 "OT4CLIMA - Development of innovative Earth Observation technologies for the study of Climate Change and its Impacts on the Environment and territory"	G. Pepe	September 2018 - February 2021	Napoli
MISE POA 2013	CNR - SPIN	DRYSMES4GRID Superconducting Energy Storage for Smart Electrical Grid	M . Vignolo	June 2017 - June 2020	Genova

Projects and grants

Running projects 2018/2019

Source: International

Type	Coordinator	Title	SPIN Leader	Duration	SPIN Unit involved
Ministry of Foreign Affairs and International Cooperation	CNR SPIN	Solid state actuators for micro/nanorobotics	L. Pellegrino	January 2018 - December2019	Genova
Bilateral projects	n/a	Scientific cooperation agreement CNR - BAS (Bulgaria)	S. Amoruso	January 2016 - December2018	Napoli
Bilateral projects	n/a	Scientific cooperation agreement CNR - BAS (Bulgaria)	M. Polichetti	January 2019 - December2021	Salerno
Bilateral projects	n/a	Scientific cooperation agreement CNR - PAN (Poland)	C. Ferdeghini	January 2017 - December2019	Genova
Bilateral projects	n/a	Scientific cooperation agreement CNR - JSPS (Japan)	L. Pellegrino	January 2018 - December2019	Genova
Bilateral projects	n/a	Scientific cooperation agreement CNR - RSE (Scotland)	A. Gerbi	January 2019 - December2020	Genova
Joint Laboratories	CNR-SPIN	Joint laboratory CNR - NTU on: Amorphous materials for energy harvesting applications	A. Fierro	January 2015 - December2018	Napoli
RESEARCH Agreement	CERN	Future Circular Collider (FCC) Study: Beam screen	E. Bellingeri	March 2016 - April2020	Genova
RESEARCH Agreement	CERN	Future Circular Collider (FCC) Study: Superconductivity for high field	M. Putti	April 2017 - ottobre 2019	Genova
US ARMY	CNR-SPIN	Slightly high index inclusion metamaterials: a novel physical and feasible route to enhance and harness spatial dispersion	A. Ciattoni	September 2018 - september 2019	L'Aquila

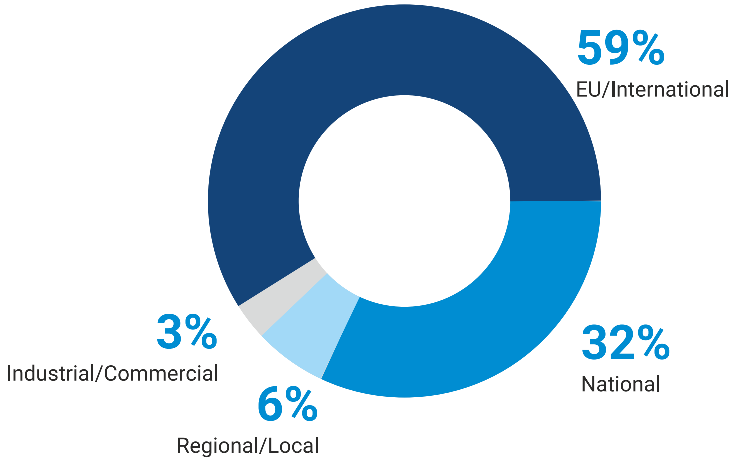
Source: Regional and local

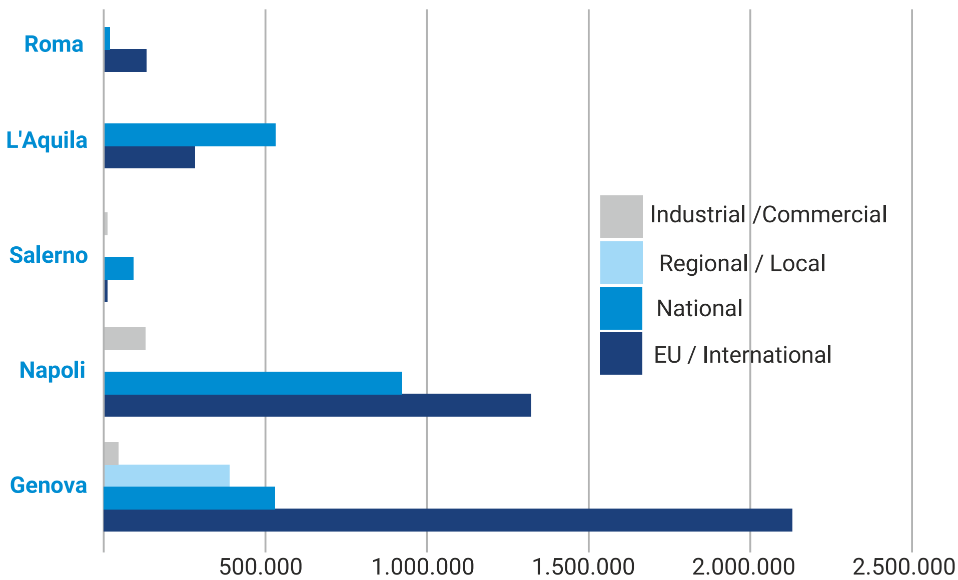
Type	Coordinator	Title	SPIN Leader	Duration	SPIN Unit involved
FONDAZIONE ARISLA	University of Genova	SCM-ALS Spinal Cord Metabolism in Amyotrophical Lateral Sclerosis	A.Massone	June 2016 - January 2019	Genova
FONDAZIONE COMPAGNIA DI SAN PAOLO	CNR-SPIN	Pan-lab: plasmonic biosensoristics for early diagnostics	F. Bisio	April 2016 - April 2018	Genova
FONDAZIONE COMPAGNIA DI SAN PAOLO	CNR - SPIN	Nitride compounds: new superconductors from a still little-investigated world	P. Manfrinetti	February 2018 - June 2020	Genova

Source: Industrial and commercial

Type	Coordinator	Title	SPIN Leader	Duration	SPIN Unit involved
COMMERCIAL ACTIVITY	CNISM	Project LISA LAPSE	X. Wang	June 2014 - December 2019	Napoli
COMMERCIAL ACTIVITY	Various Companies	Testing and Laboratory Measurements	R.Buzio, C.Bernini, A.Malagoli, A.Massone, M.Toselli, A.Vecchione	March 2018- December 2019	Genova, Salerno
COMMERCIAL ACTIVITY	Various Companies	Event Sponsorship	R.Cristiano, R.Fittipaldi, F.Giubileo	May 2018- September 2019	Salerno, Napoli

2018-19 running projects total amount ~ 6.5 M€





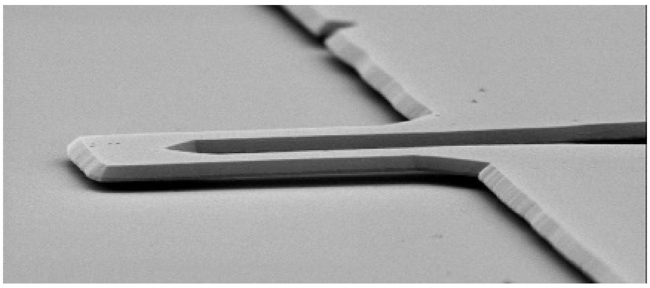
Projects and grants

Selected projects

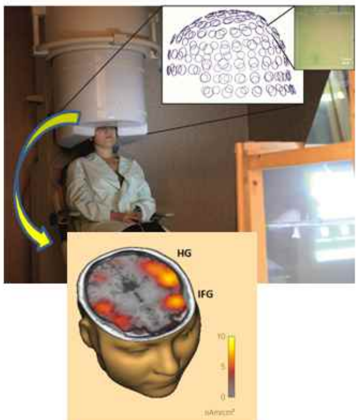
Title	**OXiNEMS** Oxide Nanoelectromechanical Systems for Ultrasensitive and Robust Sensing of Biomagnetic Fields (OXiNEMS)
Source of funding	European Commission
Scientific funding program	H2020 - FET Open (Research and Innovation Actions)
Project coordinator	Luca Pellegrino
SPIN coordinator	Luca Pellegrino
Other partners	CNR-IFN (IT), Chalmers University of Technology (SE), University of Hamburg (DE), Quantified Air B.V. (NL), University G. d'Annunzio of Chieti-Pescara (IT), META Group (IT)

Project objectives

OXiNEMS targets the development of nanoelectromechanical systems (NEMS) devices fully made of (crystalline) transition metal oxides, a class of compounds that show a wide range of physical properties, with the perspective of introducing new classes of transducers with unprecedented detection/transduction mechanisms and integrating more functionalities into nanomechanical systems. This new technological approach will add multifunctional oxides to the repertoire of the current MEMS/NEMS field. Our science-to-technology breakthrough is the realization of a proof of concept ultrasensitive oxides-based NEMS device for the detection of biomagnetic fields. The OXiNEMS team will implement ultrasensitive detectors able to measure very weak magnetic fields targeting those generated by human brain activity, of the order of tens of femtotesla. Importantly, these innovative sensors will be extremely robust to applied magnetic fields overcoming, for what concerns this aspect, the operational limitations of the sensors (namely superconducting SQUIDs) currently used worldwide in magnetoencephalographic (MEG) systems that probe the functioning of the human brain. Differently from SQUIDs, thanks to their sensitivity and robustness to strong static and pulsed applied fields, the OXiNEMS sensors are foreseen to allow the effective integration of MEG with other recently developed imaging techniques such as ultralow field Magnetic Resonance Imaging and with techniques traditionally non-compatible with MEG, such as Transcranial Magnetic Stimulation. Thus, the new class of multifunctional sensors implemented in this project could give rise to a new generation of multimodal systems allowing to image brain activity and connectivity with high spatial and temporal resolution, with a sound impact on basic and clinical neuroscience.



Oxide-based freestanding microstructure



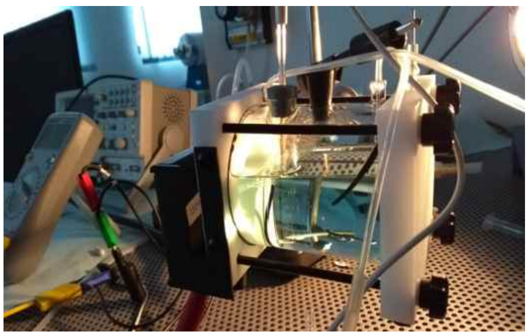
Typical MEG system (installed at University G. d'Annunzio of Chieti-Pescara) together with task-evoked localization

Title	**EASITrain**
Source of funding	European Union's H2020 Framework Programme Marie Sklodowska-Curie
Scientific funding program	Action Innovative Training Networks grant agreement no. 764879
Project coordinator	Amalia Ballarino , European Organization for Nuclear Research (CERN)
SPIN coordinator	Emilio Bellingeri
Other partners	Bruker Hts Gmbh, Commissariat a l'Energie Atomique Et Aux Energies Alternatives, , Columbus Superconductors Srl, Helmholtz-Zentrum Berlin Fur Materialien Und Energie Gmbh, I-Cube Research, INFN, Technische Universitaet Dresden, Technische Universitaet Wien, Universitaet Siegen, Universitaet Stuttgart, Wirtschaftsuniversitat Wien

Project objectives

EASITrain is an innovative training network on superconductivity and related technologies based on a Marie Sklodowska-Curie action of the European community, led by CERN, involving 13 Beneficiaries and about as many partners. The network supports the training of 15 young researchers (ESR Early Stage researcher).
EASITRAIN integrates sound research projects aimed at predicting the behaviour of superconducting materials, at introducing innovative manufacturing techniques, at developing efficient cryogenic refrigeration techniques and establishing these technologies as a new state of the art. The ambitious goals of this consortium are: (1) making advanced superconductors fitter for the market, (2) assessing their innovation capacities and (3) equipping a new generation of researchers with the unique skills required to convert knowledge into products. Efficient grid power management, 21st century medical imaging, leaps in effectiveness of wind power generators, efficient electric propulsion systems and sustainable refrigeration for industry are examples that give an impression of the potential societal benefits that superconductor-based technologies can catalyze. This initiative under European leadership federates leading universities, research centers and industries, embracing a variety of science sectors, such as physics and mathematics, material sciences, process and mechanical engineering, refrigeration, cryogenics and innovation management. The intriguing blend of science and engineering, compounded by visionary application opportunities in companies, creates a fertile environment for innovative training of early-stage researchers. Significant training lead-times call for a dedicated action. This ITN will provide its fellows with a sound knowledge in the relevant fields along with business competences and prepare them for a broad spectrum of career opportunities in research and industry.
In particular, CNR-SPIN is involved in the project as leading Institute for the research on high temperature superconductor coatings for application under high magnetic field and high frequency. One of the main purpose of this study is the impedance mitigation of beam screen for the Future Circular Collider (FCC) under design at CERN.

EASITRAIN Powering the future
easitrain.web.cern.ch



System for Tl based superconductors coating

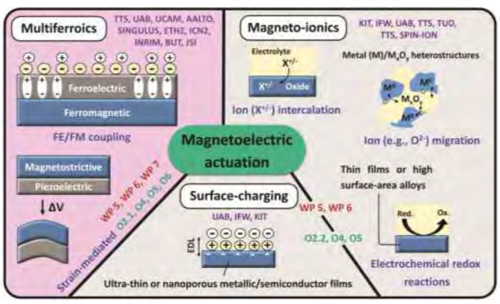
Projects and grants

Selected projects

Title	**BeMAGIC** Magnetoelectrics Beyond 2020: A Training Programme on Energy-Efficient Magnetoelectric Nanomaterials for Advanced Information and Healthcare Technologies
Source of funding	European Community through H2020
Scientific funding program	H2020-MSCA-ITN-2019
Project coordinator	Jordi Sort, Univ. Autonoma Barcelona
SPIN coordinator	Silvia Picozzi
Other partners	Univ. Autonoma Barcelona (ES), Univ. of Cambridge (UK), Istituto Nazionale di Ricerca Metrologica (IT), Aalto Korkeakoulusaatio (NO), Karlsruher Institut fuer Technologie (DE), Leibinitz-Institut Dresden (DE), ETH Zuerich (CH), Fundacio Institut Catala de Nanosciencia i Nanotecnologia (ES), Voxalytic GmbH (DE), Guger Technologies (AT), TTS (CZ), Spin-Ion Technologies (FR)

Project objectives

BeMAGIC is a highly interdisciplinary project whose primary aim is the training of young researchers in the utilization of magnetoelectric (ME) nanomaterials to face important societal challenges linked to energy-efficiency, data security and health. Magnetoelectricity refers to the interplay between magnetic and dipolar degrees of freedom (i.e. magnetic properties controlled with electric fields and, viceversa, ferroelectric properties controlled with magnetic fields). The BeMAGIC Network encompasses the design, synthesis, characterization and integration of ME materials into a variety of applications that share the combined action of electric and magnetic fields: advanced security systems, low-power data storage, spintronic/magnonic devices, electric-field assisted drug delivery, cell electrofusion and deep neural stimulation. Studying all these technological domains in parallel, accelerates progress in each individual field because there are a number of cross-cutting synergistic challenges and potential cross-fertilization outcomes. Various disciplines (Physics, Chemistry, Engineering, Bioelectronics, Biomedicine) converge together in BeMAGIC to provide a holistic approach to fulfil the proposed goals. The Consortium brings together 13 Beneficiaries and 11 Partner Organizations, including 8 private companies, from 11 EU Member States. The main project objectives are: 1) To design/screen suitable ME materials using first-principles calculations and undertake fundamental studies to shed light on new ME actuation mechanisms; 2) To optimize the synthesis/growth conditions for the various types of investigated ME nanomaterials; 3) To correlate the ME response with the microstructure/composition of the target materials; 4) To develop new classes of energy-efficient spintronic/magnonic devices using ME nanomaterials; 5) To implement ultra-secure, anti-hacking data systems and anti-counterfeit technologies; 6) To investigate new biomedical therapies based on ME stimulation.

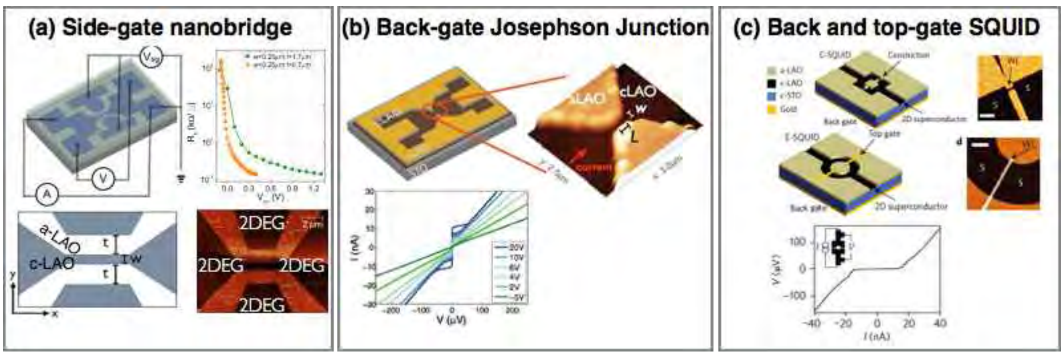


ME actuation mechanisms studied in BeMAGIC. The less conventional ME actuation approaches are highlighted in grey, whereas multi-ferroics is highlited in lilac.

Title	**QUANTOX** QUANtum Technologies with 2D-Oxides
Source of funding	European Union Horizon 2020 Programme
Scientific funding program	QUANTERA ERA-NET Cofund in Quantum Technologies
Project coordinator	Marco Salluzzo
SPIN coordinator	Marco Salluzzo
Other partners	TU-DELFT (NL), MC2-CHALMERS (SWE), CNRS-THALES (FR), UCM (ES), ESPCI (FR), BIU (ISR)

Project objectives

The development of "fault tolerant" quantum computation, unaffected by noise and decoherence, is one of the fundamental challenges in quantum technology. One of the approaches currently followed is the realization of "topologically protected" qubits which make use of quantum systems characterized by a degenerate ground state composed by collective composite particles, known as "non-Abelian anyons", able to encode and manipulate quantum information in a nonlocal manner.
QUANTOX project is committed to the realization and study of an innovative technological platform, based on two-dimensional oxides (2D-oxides), for the realization of topological quantum systems, of relevance in the area of quantum computation and quantum information science. Our idea is to exploit the unique combination of unconventional Rashba spin-orbit coupling. 2D-magnetism, superconductivity and high-mobility in the 2D electron gas (2DEG) at the interface between oxide insulators, as for instance $LaAlO_3$ (LAO) and $SrTiO_3$ (STO), to realize topological superconductors and topological qubits. The basic element of this technology is a quasi-one-dimensional nano-channel made of a single element, an oxide 2DEG, whose properties can be locally tuned using the electric field effect to create both topological and non-topological superconducting sections. Since oxide nanodevices are realized using a top-down approach, this technology is potential scalable to complex systems all the ingredients necessary for creating, manipulating and possibly braiding Majorana Zero Energy Modes (MZEM) can be realized using the same material and incorporated in the device layout in a seamless way. If MZEM will be demonstrated in oxide 2DEGs a disruptive impact in the field of topological quantum computation is foreseen.

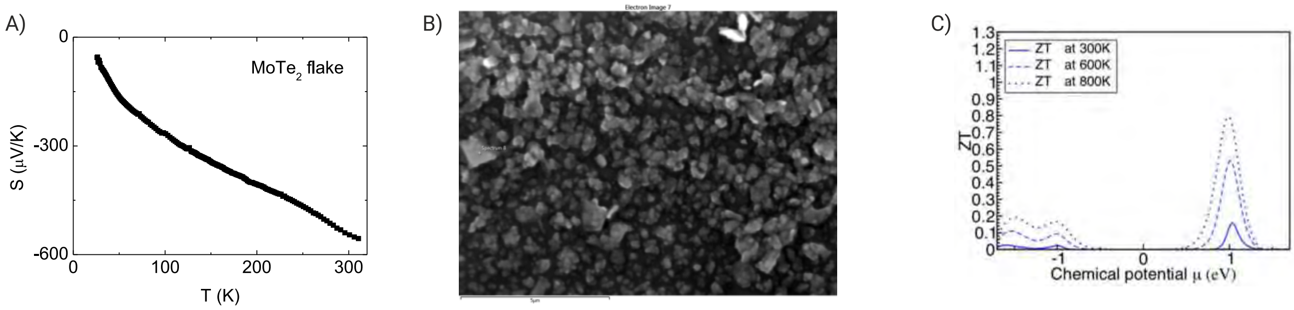


Examples of LAO/STO nanodevices realized by the Consortium: a) side gate nanobridges showing large Rs vs. Vg (Vgate) modulation in the normal state; b) back-gate Josephson Junction and I-V characteristics as function of Vg; back-gate and top-gate SQUID together with a V-I characteristics. In these devices the 2DEG is confined below a crystalline LAO layer, while no 2DEG is formed below amorphous LAO.

Title	**MELODICA** Disclosing the potential of transition metal dichalcogenides for thermoelectric applications through nanostructuring and confinement
Source of funding	Ministero dell'Istruzione, dell'Università e della Ricerca (MIUR)
Scientific funding program	FLAG-ERA JTC 2017
Project coordinator	Ilaria Pallecchi
SPIN coordinator	Ilaria Pallecchi
Other partners	NCSR-Demokritos (GR), Babes-Bolyai University (RO), University of Liège (B).

Project objectives

In the framework of the research for new materials and technologies for renewable energy sources, which belongs to the strategic issues addressed by the CNR-SPIN institute, MELODICA explores the potential of graphene-related materials as thermoelectrics for energy conversion. Indeed, transition metal dichalcogenides (TMDs) not only offer flexibility in tuning electronic properties, but may also outperform graphene in thermoelectric (TE) applications, due to their much lower thermal conductivity. TE properties of TMDs may be improved from bulk to few monolayer samples, thanks to changes in their electronic structure by confinement. TE performance could be also improved by suppressing the thermal conductivity via microstructure engineering. MELODICA explores the potential of these features – i.e. electronic confinement and nanostructured morphology - in view of TE applications.
Form the experimental side, characterization of magnetoelectric, thermoelectric and thermal transport properties is carried out on TMDs samples in different forms, namely single crystals, epitaxial ultrathin films and heterostructures grown by molecular beam epitaxy (MBE), and stacked nanoflake assemblies, obtained by liquid phase exfoliation and subsequent ink-jet printing or drop-casting. In synergy, insight is gained by means of theoretical calculations of these transport properties, focusing on the effects of thickness and epitaxial strain. Finally, literature results on TE properties of graphene-related materials are constantly monitored throughout the project, pursuing a realistic and quantitative assessment of TMDs as TE materials for device applications such as solid state micro-coolers.
Association of MELODICA partners to the Graphene Flagship will allow to borrow well-established scientific and technological knowhow from the graphene world and, in turn, will possibly provide information on new material development. In perspective, the project activities will contribute to the challenge of building a platform of Van der Waals materials with complementary functionalities.



A) Seebeck coefficient of a $MoTe_2$ flake
B) SEM image of a WSe2 nano-flake assembly drop-casted on Mica
C) Calculated TE figure of merit ZT dependence on chemical potential for two-monolayer thick WSe_2

Title

High T_c Superconductors for magnetic confinement fusion

Project 4 of the JRC Fusion "High Tc superconductors for magnetic confinement fusion: development of materials and production processes"

Source of funding CNR - Eni

Scientific funding program Joint Research Agreement

Project coordinator Maurizio Lontano

SPIN coordinator Valeria Braccini

Other partners CNR-IMM

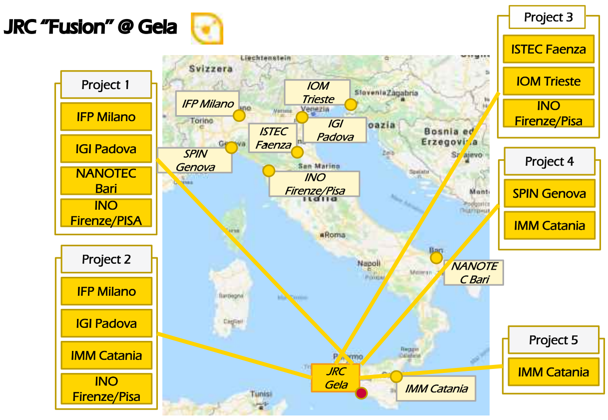
Project objectives

In spring 2019, a Joint Research Agreement (JRA) between CNR and Eni has been signed for the establishment of four joint research centers set up at existing operational or research centers to work together in four fundamental areas driven by circular economy and carbon neutrality.
In particular, four Centers have been created:

- Center "Arctic" in Lecce, for the study and feedback evaluation on climate and environment deriving from temperature rise in the Arctic cryosphere
- Center "Fusion" in Gela, for the development of skills and technological know-how for magnetic fusion.
- Center "Water" in Metaponto, for the sustainable and innovative management of the water cycle
- Center "Agriculture" in Portici, for the incentive and development of sustainable and low CO_2 agriculture

The Eni – CNR center in Gela on fusion, named 'Ettore Maiorana', in particular, is oriented towards cutting-edge research on the characteristics of plasmas, superconducting magnets, and on the characteristics of power plants that can exploit the properties of the materials and the advantages of the casting process. The center also aims at developing skills in the transportation and storage of electrical power.

- Application and development of advanced models for magnetic confinement fusion
- Control and diagnostic systems for magnetic confinement fusion
- Study of materials for magnetic confinement fusion
- High Tc superconductors for magnetic confinement fusion: development of materials and production processes
- High efficiency power electronics for magnetic confinement fusion based on SiC.

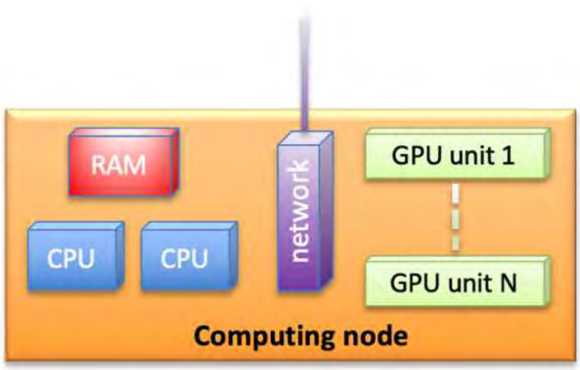


CNR-SPIN is involved, together with CNR-IMM Catania, in Project 4. The main goal of the Project is the development of HTS superconductors suitable for applications in high magnetic field – particularly referring to the fusion. We will focus in particular on the fabrication and development of Fe-based superconductors and on the study of the effects of irradiation on such materials, coordinated with a deep investigation of the nanostructure developed after irradiation through TEM at IMM. Between the outcomes of this Project, ENI-funded PhD will be activated both at University of Genova and University of Catania for the fabrication, irradiation and characterization of Fe-based superconductors.

Title	**IBISCO** Infrastructure for BIg data and Scientifing COmputing
Source of funding	Ministero dell'Istruzione dell'Università e della Ricerca
Scientific funding program	National Operative Programme - Research and Innovation 2014-2020
Project coordinator	Gianpaolo Carlino, INFN
SPIN coordinator	Giovanni Cantele
Other partners	INFN, University of BARI "ALDO MORO", University of Naples "Federico II", CNR-ISASI, CNR-IREA, INAF, INGV.

Project objectives

The IBISCO project aims at carrying out, validating and fully demonstrating, in a real operational environment, a very substantial strengthening of the scientific computing infrastructure in Southern Italy. The main focus will be on big data analysis, high-throughput and high-performance computing, data visualization, image processing and analysis. CNR, and the SPIN Institute in particular, will participate through the acquisition of storage and computing servers, equipped with two multi-core processors per node, novel generation Graphic Processing Units (GPUs), and very high throughput and very low latency networking communication. Designed to satisfy the performance requirements of a very wide class of computing tasks, coming from different disciplines, this part of the infrastructure will be suited to the simulation and modeling of the properties of materials for advanced applications as well as to the development of new software and algorithms in the emerging and rapidly growing field of the quantum computation.
The CNR-SPIN funding, will be joined to the resources of the CNR-ISASI Institute and will all be part of a larger infrastructure, shared with University of Naples "Federico II" and the INFN, hosting about 32 computing nodes (corresponding to more than 1000 physical cores, 64 GPUs with more than 300000 CUDA® cores and more that 10 Tb of RAM memory). This will certainly match the needs of several SPIN research activities, with the main keywords being modelling and simulation of the properties of advanced and novel functional materials, quantum computation and quantum materials, machine learning approaches and novel algorithms in condensed matter physics and complex systems. The participation of the three CNR institutes takes place through the CNR Department of Physical Sciences and Technologies of Matter (DSFTM).

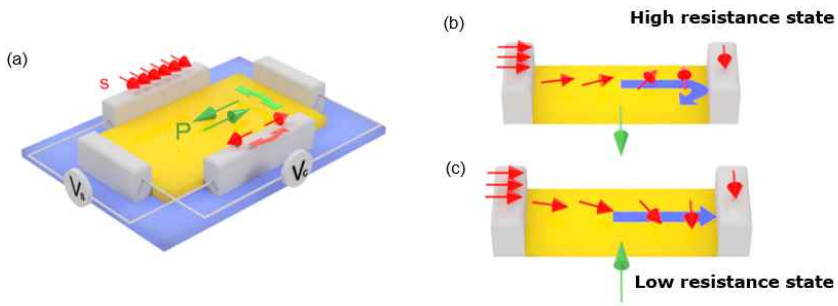


Schematic view of a single computing node, showing the different computing capabilities (CPU, network, GPU)

Title	**TWEET** ToWards fErroElectricity in Two-dimensions
Source of funding	Ministero dell'Istruzione, dell'Università e della Ricerca (MIUR)
Scientific funding program	Progetti di ricerca di Rilevante Interesse Nazionale (PRIN)
Project coordinator	Silvia Picozzi
SPIN coordinator	Silvia Picozzi
Other partners	CNR-SPIN Napoli, Politecnico Milano, Università Federico II, Napoli

Project objectives

Inspired by the global thrust towards miniaturization and by the ubiquitous research in 2D-materials, TWEET focuses on ferroelectricity towards the 2D-limit. TWEET is inspired by ferroelectrics (FEs), whose ever-increasing momentum rests on their unique combination of fascinating fundamental physics (microscopic mechanisms leading to FE order and related quantum phenomena), materials science challenges (discovery, design, growth and optimization of novel FEs) and multi-billion-dollar market applications (next-generation non-volatile memories, sensors and actuators). TWEET is also given impetus by the endless demand toward miniaturization and by the mainstream research on 2D-materials, where ferroelectricity was surprisingly almost untouched. By targeting the delivery of technological impact via materials optimization and fundamental understanding of the physics at play in low-thickness FEs, the project goal is to achieve full control of ferroelectricity in few-layers films of CMOS-compatible materials, in order to obtain ad-hoc functional properties, even dramatically different from those of the 3D bulk parent compounds. The team exploits multiple degrees of freedom, not only the dipolar order (characteristic of every FE material), but also its link with phenomena based on spin-orbit-coupling, such as Rashba effects. TWEET is conceived in two pillars. The first is focused on the growth of high-quality HfO2 ultrathin films, aiming at microscopic understanding and control of the ferroelectric order in static/dynamic regimes, complemented by device exploitation in tunnel barriers. The second focuses on the growth of 2D-chalcogenides (SnTe, GeTe), the ferroelectric control of their spin texture and the exploitation of non-volatile electric tuning of charge/spin transport, based on a novel spin-electric coupling in bulk GeTe. The TWEET vision is based on the synergy of accurate modelling (CNR-SPIN Chieti), highly-controlled synthesis (CNR-SPIN Naples, PoliMi), advanced characterizations (UniNa, CNR-Na, PoliMi) and cutting-edge device implementation (PoliMi).



Spin valve based on Ferroelectric chalcogenides showing Rashba effects

Selected projects

Title	**HIBiSCUS** High performance-low cost Iron BaSed Coated condUctorS for high field magnets
Source of funding	Italian Ministry of Education, University and Research (MIUR)
Scientific funding program	Progetti di ricerca di Rilevante Interesse Nazionale (PRIN)
Project coordinator	Marina Putti, Università di Genova
SPIN coordinator	Valeria Braccini
Other partners	Università di Roma Tre, Politecnico di Torino

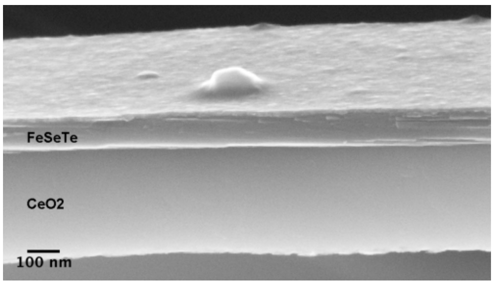
Project objectives

High superconducting transition temperature, upper critical field and critical current density are the three major requirements for high magnetic field applications of superconductivity. Iron-based superconductors (IBS) could be a breakthrough of the intrinsic limits of low-T_c Nb_3Sn (20 T at 4.2 K) and of the extreme material complexity of copper oxide high-T_c superconductors (HTS), which leads to articulated and expensive processes for wires/tapes fabrication. In fact, the superconducting properties of IBS largely exceed those of Nb_3Sn and their intrinsic properties and preparation procedures appear less critical than those of HTSs.

The project HIBiSCUS aims at developing highly optimized IBS coated conductors (CCs), focusing on the trade-off between cost effectiveness and performances and taking advantage of an accurate material characterization. In particular, we will develop new fabrication processes for IBS-CCs, relying on the advanced technologies developed in the last decades for HTS-CCs, but focusing on the possibility of simplifying the processes to drastically reduce fabrication costs and times. The optimization of IBS-CCs and their suitability for specific applications will be addressed by the combined use of complementary techniques, including microstructure and superconducting properties on the local and macroscopic scale.

HIBiSCUS is an Italian project funded by the Italian Ministry of University and Research (MIUR). It sees the collaboration between research groups that have always been active internationally in the field of applied superconductivity: the University of Genova with the role of project coordinator; CNR-SPIN with the task of making the tapes, assisted by ENEA in the creation of metal templates; Politecnico of Torino and the University of Roma Tre with the advanced structural and electromagnetic characterizations in charge and the study of the effect of the irradiation on the performances of the CC (PoliTo). The team has the final task of validating the new IBS-CC technology with respect to other technical superconductors.

A metallic biaxially textured substrate developed at CNR-SPIN for the deposition of IBS coated conductors



A FeSeTe CC deposited on a RABiTS template

Title

TOP-SPIN

Two-dimensional oxides Platform for SPIN-orbitronics nanotechnology

Source of funding Ministero dell'Istruzione, dell'Università e della Ricerca (MIUR)

Scientific funding program Progetti di ricerca di Rilevante Interesse Nazionale (PRIN)

Project coordinator Marco Salluzzo

SPIN coordinator Marco Salluzzo

Other partners University "Federico II" di Napoli, University of Cagliari, University of Cosenza

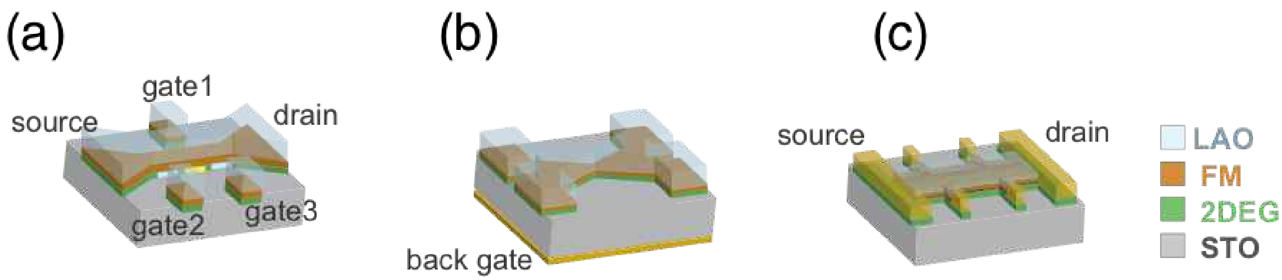
Project objectives

The steady dimensional downscaling of components poses new challenges in microelectronics. Two-dimensional (2D) systems, characterized by radically new properties and functionalities, are emerging as the material choice for the next stage of Spintronics and Quantum Electronics revolution.

Among 2D-systems, 2D electron gases (2DEGs) formed at the interface between insulating transition metal oxides, like $LaAlO_3$ and $SrTiO_3$, are characterized by a unique combination of high-mobility, strong spin-orbit coupling (SOC), superconductivity, interfacial 2D-magnetism, and theoretically predicted topological states.

The target of our project is to understand how the interplay between Rashba spin orbit coupling, 2D-magnetism and 2D-superconductivity can be employed to design topological states and topological superconductors based on transition metal oxides. The final goal is the realization of electric field effect devices, based on the gate-voltage control of the functional properties of atomically engineered oxide-2DEGs.

Success in these endeavors will open the road towards a novel oxide electronics and will establish 2D-oxide materials as an important platform for spintronics and quantum electronics.



Some of the field effect devices that will be ralized within the project TOP-SPIN: a) side-gate field effect device based on spin polarized LAO/FM/STO 2DEG. Gate 1 control the properties, and, in particular the SOC, the carrier density and, eventually, the magnetism of the central part, wile Gate2 and Gate3 can be used to create local sin-polarized contacts. (b) Back-gate LAO/FM/STO Josepshon junction, with a nanostriction (Dajem bridge) with size comparable with the superconducting coherence length. (c) Multi terminal back-gated field effect device for searching topological edge states through non local transport experiments.

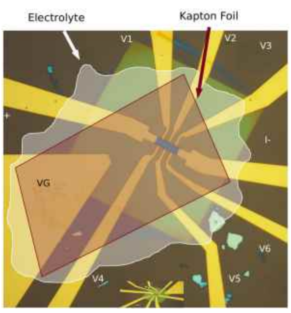
Projects and grants

Selected projects

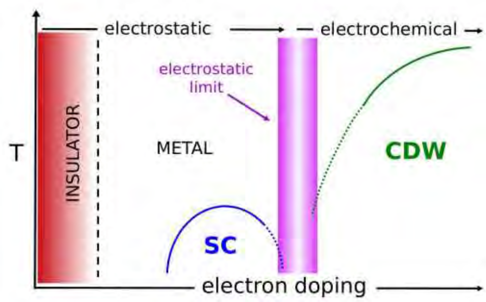
Title	**Quantum2D** Tuning and understanding Quantum phases in 2D materials
Source of funding	Ministry of Education, University and Research (MIUR) of Italy
Scientific funding program	Progetti di ricerca di Rilevante Interesse Nazionale (PRIN)
Project coordinator	Francesco Mauri, University of Rome La Sapienza
SPIN coordinator	Paolo Barone
Other partners	University of L'Aquila, University of Pisa, Polytechnic of Turin, Polytechnic of Milan

Project objectives

Recent advances in field-effect doping and material exfoliation have made it possible to tune the density of the 2D electron gas in atomically-thin layers of transition-metal dichalcogenides (TMDs). The proximity within the same system of different electronic phases, such as superconductivity (SC) and charge density waves (CDW), holds an enormous potential for the realization of new devices, while the reduced dimensionality brings novel opportunities for their optimization and control. Layered TMDs are an ideal playground for analyzing the interplay between competing SC and CDW in tunable 2D systems. Depending on their chemical composition and structural configuration, they may display metallic, semimetallic and semiconducting behaviors. Controllable, large-scale, and uniform atomic layers of diverse TMDs are nowadays feasible; moreover, their band structure can be tuned by mechanical strain, the Fermi level by gating and the spin-orbit interaction by changing the transition metal. Nonetheless, a comprehensive understanding of SC, CDW and of their mutual interaction in ultrathin TMDs is still lacking, while the experimental information on field-effect doping and spectroscopic responses both in the normal and broken-symmetry phases is still limited.
The project aims at combining the most advanced theoretical and experimental tools available in our team in order to assess the still open questions in the field: How is the band structure modified under doping/strain? How does this influence the SC and CDW phases? What is the role of electron-electron and spin-orbit interaction? The predictive power of ab-initio methods and field-theory approaches will be tested by tuning the electronic phases via electrochemical gating and mechanical strain in samples optimized for transport and spectroscopic investigation. The closed feedback loops between theory and experiments will provide a comprehensive description of electronic and structural ordering in ultrathin TMDs, paving the way for the optimization of the physical properties of tunable 2D materials.



Ion-gated field-effect device realized at Polytechnic of Turin on a MoS_2 flake, with contacts for four-probe magnetotransport measurements and the gate electrode

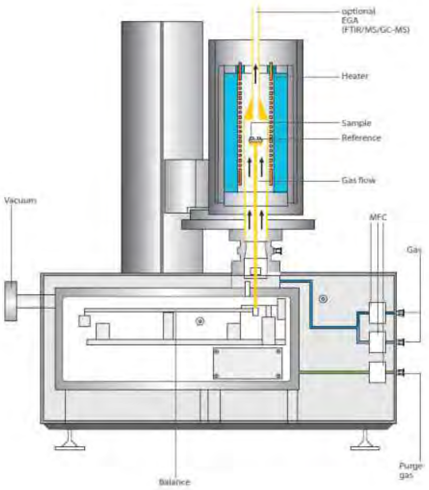


Schematic phase diagram of electron-doped semiconducting TMD, as MoS_2, including SC and CDW phases and the boundary between electrostatic doping and ion intercalation

Title	**Nitride compounds** New superconductors from a still little-investigated world
Source of funding	Fondazione Compagnia di San Paolo
Scientific funding program	Bando per progetti di ricerca scientifica presentati da Enti genovesi 2019
Project coordinator	Pietro Manfrinetti
SPIN coordinator	Pietro Manfrinetti

Project objectives

Superconductors play a crucial role for both the fundamental science and technological applications, as they hold great promise in addressing our global energy sustainability. The high-temperature superconductivity constitutes an extremely important and challenging problem which, if solved, would have an important and enormous impact on technological applications. The design of new superconductors has been, and is nowadays, one of the most ambitious and crucial goal of the scientific world; the major challenge is to find new superconducting materials with higher Tc, JC and HC. At this regard, the nitrides are a promising class of compounds to be investigated, as they represent a great opportunity for the discovery not only of new superconductors but also new semiconductors and magnetic materials.
The N-based compounds constitute an interesting and completely diverse class of inorganic compounds; they have remained relatively unknown if compared to other classes of materials. The nitrides are a still unexplored "mine" of new compounds. Nitrides are interesting from both the perspective of basic science and industrial applications, because they adopt new crystal structures with unique and unusual stoichiometry, at the same time showing different and peculiar physical properties. The progress beyond the binary N-based systems has been hindered, until today, because of the difficulties in their synthesis and due to the limitations of analytical methods.
Nowadays, very few laboratories worldwide own potentiality of synthesis and characterization tools necessary to study these compounds. Our team, having a long-lasting recognized knowledge and experience in the synthesis of materials, other than in their chemical and physical characterization, has the required skills to face with this research topic. Our competence, which is unique in Italy, already brought to excellent results within collaborations with local and outer industries. Goal of this project is to synthesize and characterize new ternary and multinary nitride compounds with improved superconducting properties, then try their use in production of superconducting cables.



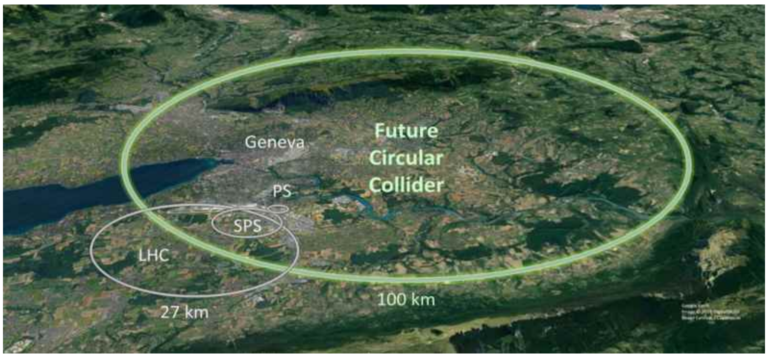
Scheme of the High-Temp TGA-DTA thermal analysis equipment funded by the project granted by Compagnia di San Paolo

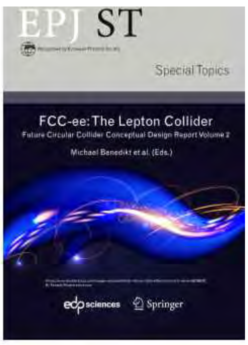
Projects and grants

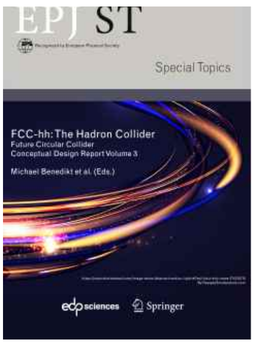
Selected projects

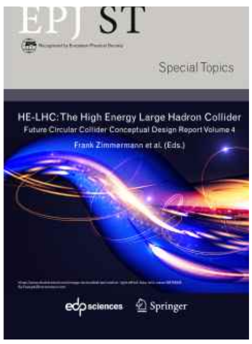
Focus on SPIN versus FCC STUDY

The Future Circular Collider (FCC) study published in January 2019 its Conceptual Design Report, describing tantalizingly more powerful particle colliders that can inaugurate the post-LHC era in high-energy physics.
Responding to a request from the 2013 Update of the European Strategy for Particle Physics, the Future Circular Collider (FCC) study explores the feasibility of high-performance colliders housed in a new 100 km circumference tunnel.
The discovery of the Higgs boson at the LHC closes the chapter of the Standard Model and poses new, more puzzling questions that call for building energy- and intensity-frontier colliders. The FCC study lays the foundations for a new research infrastructure that can succeed the HL-LHC and serve the world-wide physics community for the rest of the 21st century. The race is on for new physics that lies beyond the Standard Model.
Technologically, the FCC design enters in a new region. The realization of such machines relies on leapfrog advancements of key enabling technologies that can find numerous applications in other fields.
Many SPIN researchers participate at this ambitious project mainly involving the development of superconducting materials for the 16 Tesla high-field accelerator magnet and related superconductor research. More in detail different CERN-SPIN cofounded research projects on MgB_2, Bi(2212) wires and Iron based coated conductors for high field magnet and Tl(1223) coating for beam screen impedance mitigation were carried out. Such collaboration is still going on.
The SPIN contribution is recognized by the co-authorship of the involved researchers of the four volumes published on The European Physical Journal Special Topics.









Technology transfer

Technology transfer

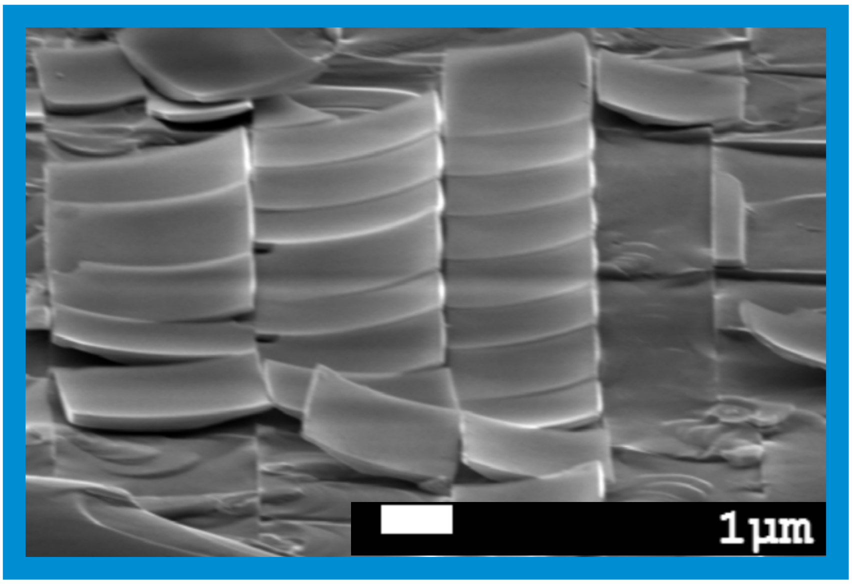
Exploiting its scientific results, inventions and expertise for the benefit of the industrial production system is one of SPIN strategic goals. SPIN scientists are routinely engaged in joint projects with industrial partners, carefully pursuing the protection of intellectual property rights. SPIN owns a set of registered patents of major industrial appeal, mostly in the fields of Biomedicine and Applied Superconductivity. A highly successful example of industrial exploitation of the scientific expertise derived from our research is provided by the spin-off company Columbus Superconductors, world leader in the production of MgB_2 superconducting wires, created by SPIN in collaboration with ASG Superconductors SPA.
CNR-SPIN is actively engaged in several public-private partnerships targeted at fostering technology transfer to Industry:

In Liguria

- START4.0 Competence Centre, aimed at applying Industry 4.0 enabling technologies for cyber safety and cyber security to the protection of strategic infrastructures of the Genoa area.
- R&D Ligurian Cluster EASS operating in the field of Energy, Environment and Sustainable Development;

In Campania

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



Freestanding $LaAlO_3/SrTiO_3$ membranes as seen at the scanning electron microscope

Below a selection of SPIN's deposited patents

Title: **A method for the characterization of atmospheric particles by means of an elastic backscattering and backreflection lidar device, and a system for carrying out said method**
Inventors: Maria Grazia Frontoso, Nicola Spinelli, Xuan Wang
Applicants: CNISM, CNR

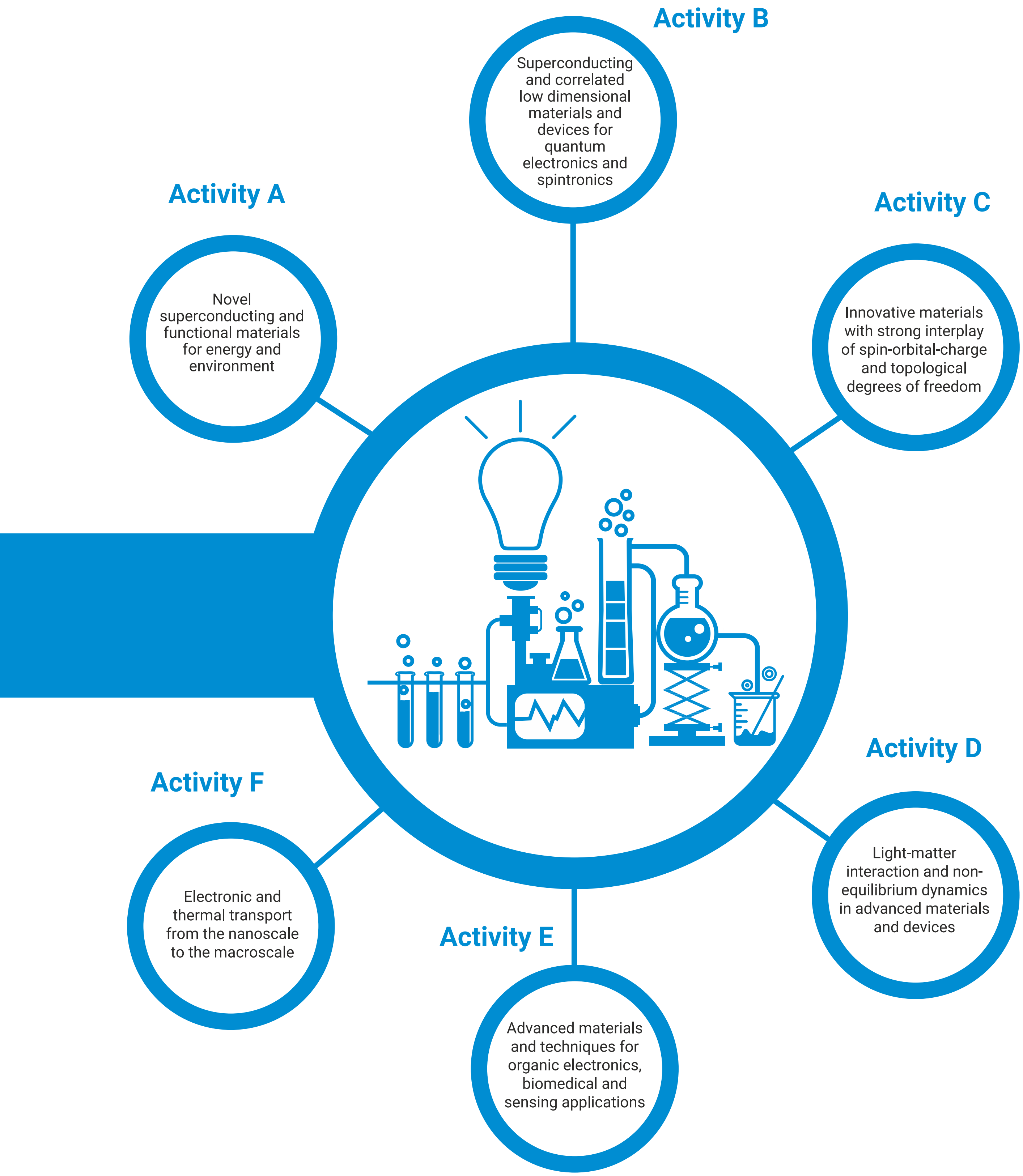
Title: **A process for producing optionally doped elemental boron**
Inventors: Antonio Sergio Siri, Maurizio Vignolo
Applicants: CNR, Antonio Sergio Siri

Title: **Magnetic resonance system using metamaterials**
Inventors: Carlo Rizza, Marcello Alecci, Angelo Galante, Marco Fantasia
Applicants: CNR (35%), Università L'Aquila (65%)

Title: **Electrode plate with conductors defining gaps and a method for its use**
Inventors: Massimo Leandri, Antonio Sergio Siri, Luca Pellegrino
Applicants: Università degli Studi di Genova, CNR

Title: **Method for increasing the q-factor and the maximum accelerating field in superconducting cavities, superconducting cavity made according to such method and system for particle acceleration using said cavity**
Inventors: Fabrizio Stivanello, Sergei Stark, Martina Martinello, Mattia Checchin, Vincenzo Palmieri, Ruggero Vaglio
Applicants: INFN, CNR (Italian patent application only)

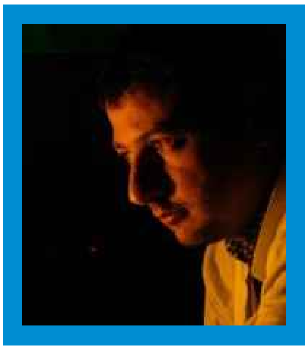
1.6 Km length multifilamentary superconducting MgB_2 wire made in SPIN



Research activities with Highlights

Activity A: Novel superconducting and functional materials for energy and environment

Activity Leader: Emilio Bellingeri



This activity addresses the investigation of innovative materials useful for the transition to a sustainable energy scenario: materials for energy harvesting from renewable sources, energy transport, energy storing and its conversion into other forms. The final aim is the understanding of the basic properties, in order to establish, and possibly improve, the potential of new or improved materials and shorten the distance between research and applications. The study and the realization of prototypal devices and development of systems based on these materials are also addressed in the framework of the activity.
Starting from the different aspects of the energy issue, the project can be defined through the following objectives:

Materials for Energy Transport and Storage.

- Fe-based and Bi-2212 superconducting wires for high field applications
- high temperature superconductor coatings for high field, high frequency applications
- Fe-based superconducting films and coated conductors with in-house built metallic textured substrates
- MgB_2 with improved performances at high magnetic fields
- new materials such as hydrides- and heavy fermions-based compounds.

Materials for Energy Conversion/ Microproduction and Environment Protection.

- oxide thin films for applications in micro-fuel cells, exploiting both ionic/protonic and ionic/electronic transport.
- transparent semiconducting oxides and related devices
- thermoelectric materials, in particular Fe_2TiSn-based compounds
- oxides and low-cost metallic circuits by Inkjet printing for solar energy conversion systems
- microelectromechanical systems with transition metal oxides for energy harvesting and actuators: highly sensitive micro-bolometers, moveable microstructures, sensors for gas detection.

Such a wide materials and systems development motivates a broad and advanced thermal and electrical characterization as well as the development of appropriate models for their interpretation. The basic properties analysis focuses, in particular for the superconducting materials, on the study of the electromagnetic granularity, vortex dynamics and pinning mechanism through experimental investigation of magnetization in bulks and thin films both in AC and DC regime. Such analysis is correlated to the transport properties, measured both in the normal and superconducting states. Further characterization of the structural, magnetic and superconductive properties, and their tangled and delicate interplay, are carried on by means of advanced analytical techniques as neutron and synchrotron radiation diffraction and muon spin spectroscopy. Study of the morphologic, electronic and superconducting properties are performed also through AFM-STM microscopy. Thin films can be also characterized in-situ, since they are grown by PLD systems directly connected to analysis systems like photo-emission spectroscopy beamline APE at Elettra synchrotron radiation facility or STM/STS system in Genoa. Scanning Tunneling Microscopy STM-based ballistic injection across metal/semiconductor junctions and heterostructures are used to map, with nanoscale resolution, the Schottky barriers and the energy level alignments.

Angular dependence of vortex instability in a layered superconductor: the case study of Fe(Se,Te) material

G. Grimaldi[1], A. Leo[2,1], A. Nigro[2,1], S. Pace[2,1], V. Braccini[3], E. Bellingeri[3] and C. Ferdeghini[3]

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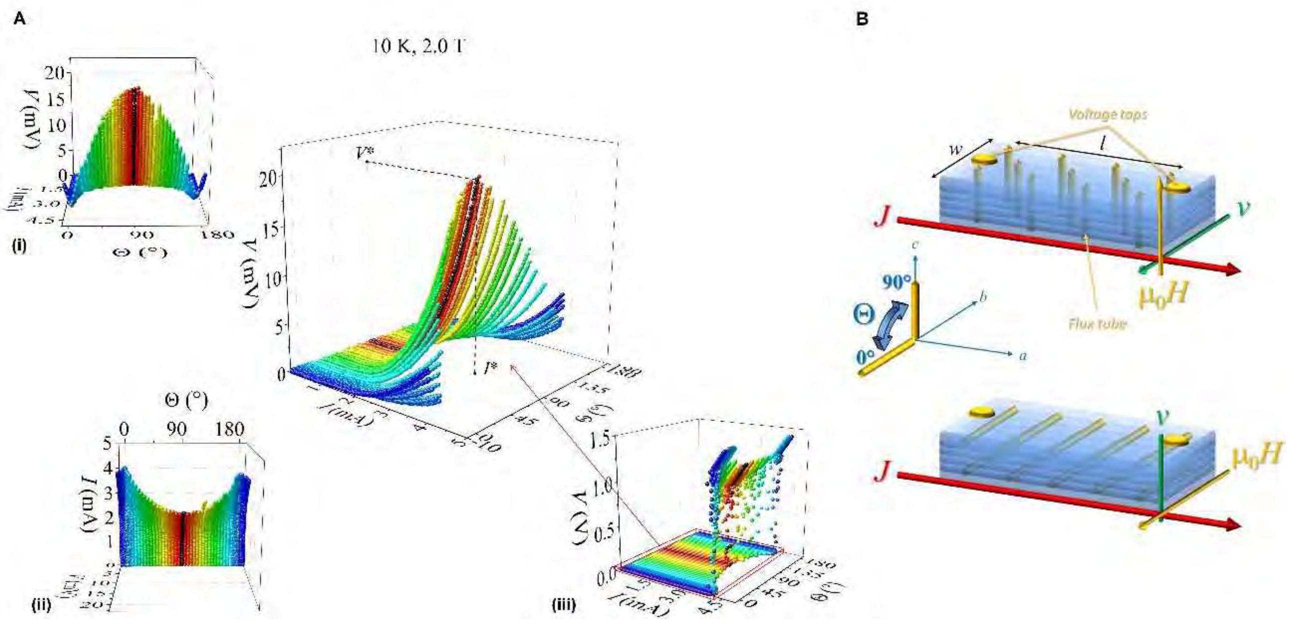
Scientific Reports 8 (2018) 4150

Anisotropy effects on flux pinning and flux flow are strongly effective in cuprate as well as iron-based superconductors due to their intrinsically layered crystallographic structure. However Fe(Se,Te) thin films grown on CaF_2 substrate result less anisotropic with respect to all the other iron based superconductors. We present the first study on the angular dependence of the flux flow instability, which occurs in the flux flow regime as a current driven transition to the normal state at the instability point (I^*, V^*) in the current-voltage characteristics. The voltage jumps are systematically investigated as a function of the temperature, the external magnetic field, and the angle between the field and the Fe(Se,Te) film.



A Current-voltage characteristics at 2 T and 10 K as a function of the angle between the applied magnetic field and the direction parallel to the *ab*-planes. The individual angular dependences of *V* and *I* are shown (panels (*i*, *ii*)), as well as the (*I*, *V*) curves in the full scale up to the ohmic resistive branches (panel (*iii*)).
B Schematic view of the sample geometry, with the indication of the orientation of the applied magnetic field *H*, the bias current density *J* and the resulting vortex velocity *v*. The yellow dots represent the voltage taps for voltage measurements as a function of the angle θ.

In-situ X-ray and neutron diffraction investigation of Bi-2212 in multifilamentary wires during thermal treatment

A. Martinelli[1], E. Bellingeri[1], A. Leveratto[1], L. Leoncino[1], C. Ritter[2], and A. Malagoli[1]

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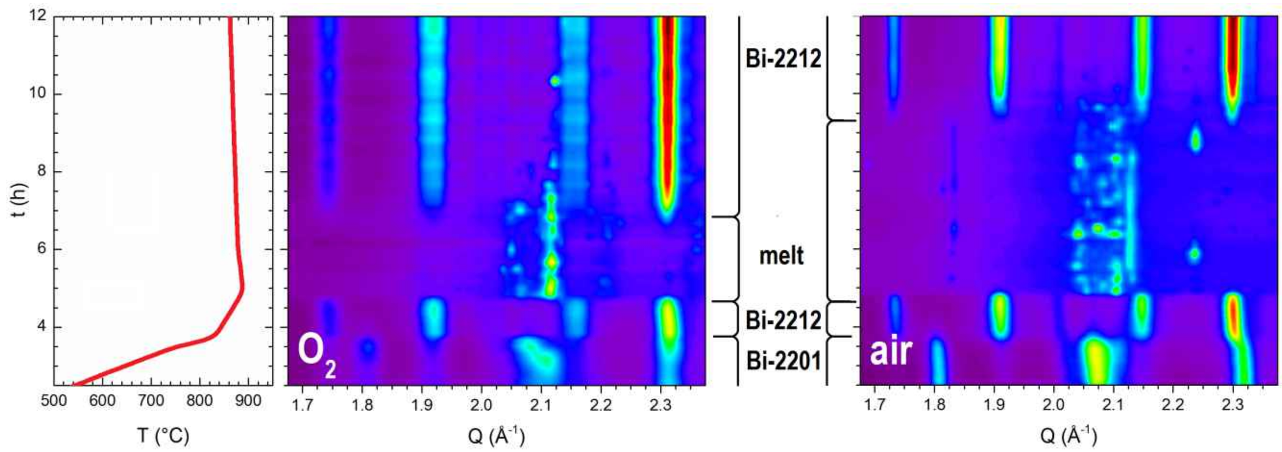
Physical Review Materials 2 (2018) 084801

Significant insights for critical current density (J_c) improvement in Bi-2212 superconductor wires can be obtained by an accurate analysis of the structural and microstructural properties evolving during the so-called partial-melt process, a heat treatment needed to improve grain connectivity and therefore gain high J_c. At this scope, we carried out an in-situ analysis by means of synchrotron X-ray and neutron diffraction performed, for the first time, during the heat treatment carried out with the very same temperature profile and reacting O_2 atmosphere in which the Bi-2212 wires are usually treated for practical applications. The obtained results show the thermal evolution of the Bi-2212 structure, focusing in particular on texturing and secondary phases formation. The role of the oxygen is discussed as well. Hence, the present investigation marks a significant advance for the comprehension of the phenomena involved in the wire fabrication process and provides useful insights for the process optimization as well.

The results in terms of secondary phase detection and grains texture are not only in full agreement with what is reported for state-of-the-art wires, but also add important insights for a further optimization of the process itself. It is now clear when and at which temperature the Bi-2201 phase forms and consequently how to avoid it. As already observed before, the Bi-2212 phase shows an in-plane and an out-of-plane texturing but the here presented results reveal as well that the texture originates from the nucleation of the Bi-2212 grains and does not evolve during the successive steps of the treatment. The role of the oxygen activity has been better clarified with the demonstration that this parameter rules the Bi-2212 texturing. These findings are of great importance for reducing the amount of secondary phases and improving the degree of texture, the two key parameters for obtaining high J_c values.



Phase evolution in the multifilamentary wires during the first 12 hours of the thermal treatment in O_2 (on the left) and air (on the right)

Unusual thermoelectric properties of $BaFe_2As_2$ in high magnetic fields

M. Meinero[1,2], F. Caglieris[3], G. Lamura[2], I. Pallecchi[2], A. Jost[4], U. Zeitler[4], S. Ishida[5], H. Eisaki[5] and M. Putti[1,2]

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Physical Review B 98 (2018) 155116

Electric and thermoelectric transport properties are mutually intertangled in diffusive transport equations. In particular, in high mobility multi-band systems an anomalous behavior may occur, which can be tracked down to the properties of the individual bands. Here, we present magneto-electric and magneto-thermoelectric transport properties of a $BaFe_2As_2$ high quality single crystal, for different magnetic field directions (parallel and perpendicular to the c-axis of the crystal) up to 30 T. We detect an anomalous field dependence of the Seebeck coefficient (Fig. 1a and 1c) and a giant Nernst effect (Fig. 1b and 1d). The extraction of the Peltier tensor coefficients α_{xx}, α_{xy} and α_{xz} (Fig. 2) allows to disentangle the main transport mechanisms into play. The large α_{xy} and α_{xz} values and their field dependence provide evidence of the presence of a high mobility band, compatible with a Dirac dispersion band, crossing the Fermi level and suggest a possible 3-dimensional nature of the Dirac Fermions.

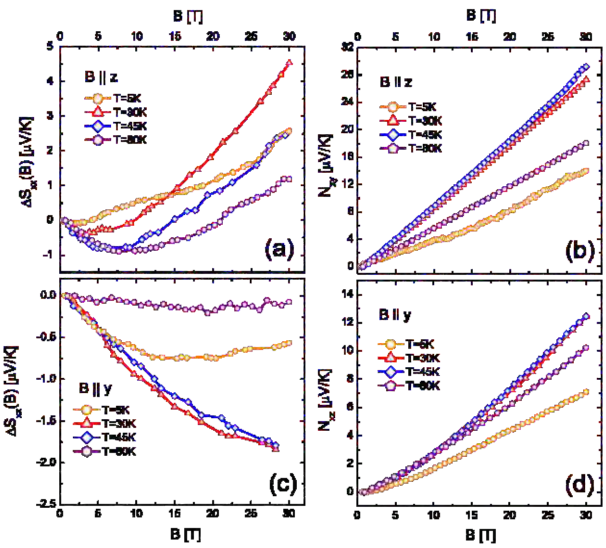

Fig. 1: Magnetic field dependences up to 30 T in the temperature range 5-80K of the Seebeck/Nernst coefficient when B is applied parallel (a/b) and perpendicular (c/d) to the c-axis of the crystal.

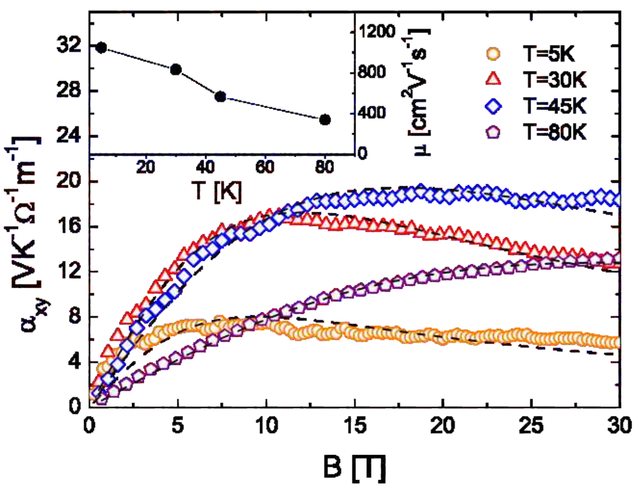

Fig. 2: Magnetic field dependences up to 30 T in the temperature range 5-80K of α_{xy}. Dashed lines are the fitting curves of α_{xy} using $\alpha_{xy} = A\,\mu^2\,B/(1+(\mu B)^2)$, where μ is the carrier mobility. Inset: temperature dependence of μ obtained by the fitting.

Effects of high-energy proton irradiation on the superconducting properties of Fe(Se,Te) thin films

G. Sylva[1,2], E. Bellingeri[1], C. Ferdeghini[1], A. Martinelli[1], I. Pallecchi[1], L. Pellegrino[1], M. Putti[1,2], G. Ghigo[3], L. Gozzelino[3], D. Torsello[3], G. Grimaldi[4], A. Leo[4,5], A. Nigro[4,5] and V. Braccini[1]

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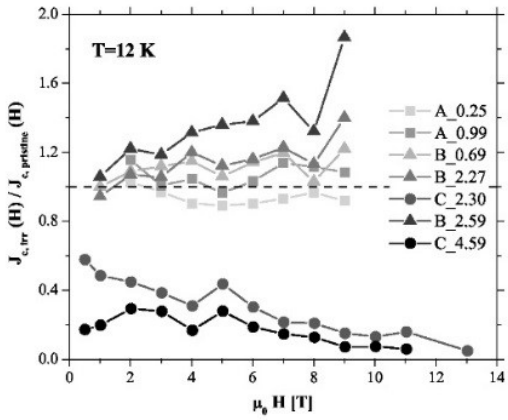
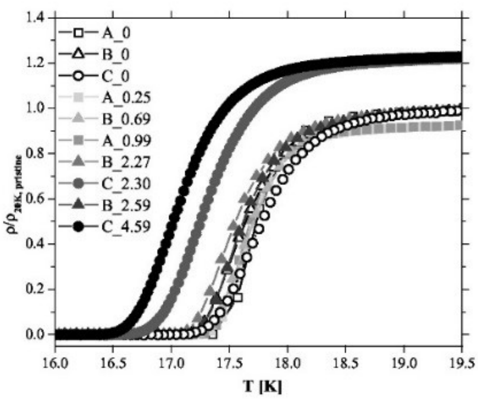
Superconductors Science and Technology 31 (2018) 054001

The effects of 3.5 MeV proton irradiation – performed at the CN Van de Graaf accelerator of INFN — Laboratori Nazionali di Legnaro - on Fe(Se,Te) thin films grown on CaF_2 were investigated with different irradiation fluences up to $7.30 \cdot 10^{16}$ cm^{-2} and different proton implantation depths, in order to clarify whether and to what extent the critical current is enhanced or suppressed, what are the effects of irradiation on the critical temperature, resistivity, and critical magnetic fields, and finally what is the role played by the substrate in this context. The effect of irradiation on superconducting properties is generally small compared to the case of other iron-based superconductors. The irradiation effect is more evident on the critical current density J_c, while it is minor on the transition temperature T_c, normal state resistivity ρ, and on the upper critical field H_{c2} up to the highest fluences explored in this work. The analysis shows that when protons implant in the substrate far from the superconducting film (patterns A and B in figures), the critical current can be enhanced up to 50% of the pristine value at 7 T and 12 K; meanwhile, there is no appreciable effect on critical temperature and critical fields together with a slight decrease in resistivity. On the contrary, when the implantation layer is closer to the film-substrate interface (pattern C in figures), both critical current and temperature show a decrease accompanied by an enhancement of the resistivity and lattice strain. This result evidences that possible modifications induced by irradiation in the substrate may affect the superconducting properties of the film via lattice strain. The robustness of the Fe(Se,Te) system to irradiation-induced damage makes it a promising compound for the fabrication of magnets in high-energy accelerators.

A)



B)



A) J_c versus magnetic field at 12 K for the different irradiated patterns normalised to the values of the relative pristine samples at the same fields.
B) Resistive transitions for all the irradiated bars of samples A, B, and C, where the resistivity at 20 K for each bar is normalised to the resistivity of the relative pristine sample at 20 K.

Tunable pH-dependent oxygen evolution activity of strontium cobaltite thin films for electrochemical water splitting

Yanuo Shi,[1] Renjie Xie,[1] Xuetao Liu,[2,3] Nian Zhang,[4] Carmela Aruta[5] and Nan Yang[1]

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Physical Chemistry Chemical Physics 21 (2019) 16230

Understanding the oxygen evolution reaction (OER) dependence on the reaction environment pH is important to define an optimal pH value for high electrocatalytic activity. $SrCoO_{2.5}$ (SCO) films with the brownmillerite (BM) phase (Fig.1(a)) are investigated for their strain effects on the OER activity, with particular regard to the pH dependence. Pulsed laser deposited films on (100) $LaAlO_3$ substrates with different thicknesses (25, 50 and 100 nm) and, thus, different compressive strain conditions, are characterized in terms of long range and near-order structural properties and electrochemical OER activity. By comparison, more strained thinner films have smaller OER current at lower pH conditions, but higher sensitivity to the environment pH (Fig.1(b)). Spectroscopic measurements allow us to correlate such behaviors to the Co 3*d*–O 2*p* hybridization effects of the CoO_6 octahedral sites, which lead to a variation of the 3*d* level electronic occupation. In particular, x-ray absorption (XAS) measurements of Fig.1 (c), after background subtraction, reveal the higher XAS pre-edge for the thinner strained films, indicating a greater number of hybridized empty states with respect to the thicker films. At the same time, density functional theory (DFT) calculations (Fig.1(d)) show that the oxygen vacancy channels of the CoO_4 tetrahedral sites are stable with respect to the strain effects. We demonstrate that the compressively strained BM-SCO films allow the tuning of the OER properties by varying the stress field. These results provide new perspectives to manipulate the pH dependent OER activity, useful for designing water splitting-based devices with optimized performances.

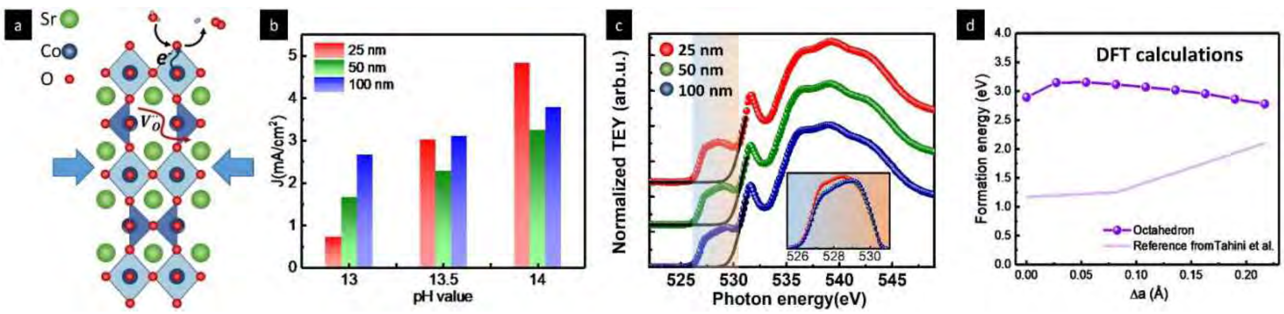

Fig.1. (a) BM structure. (b) Current density of the 25, 50, and 100 nm BM-SCO films at 1.75 V versus reversible hydrogen electrode after iR correction in O_2-saturated moles of KOH (potassium hydroxide) dissolved in 1000 cm^3 of distilled water: 0.1 M KOH (pH 13), 0.3 M KOH (pH 13.5) and 1.0 M KOH (pH 14). (c) O K-edge XAS curves of BM-SCO films with different thickness in total electron yield. The solid black lines are the background curves. The inset shows the zoomed background-subtracted O 2p–Co 3d hybridization pre-edge region of the spectra. (d) Oxygen vacancy formation energy calculated with a √2 x √2 x √2 supercell at different oxygen ion positions compared with the results for perovskite-SCO reported by H. A. Tahini et al. ACS Catal., 2016, 6, 5565.

Vortex lattice instability at the nanoscale in a parallel magnetic field

G. Grimaldi[1], A. Leo[2,1], F. Avitabile[2,1], N. Martucciello[1], A. Galluzzi[2,1], M. Polichetti[2,1], S. Pace[2,1], A. Nigro[2,1]

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Nanotechnology 30 (2019) 424001

In the present paper, we discuss the influence of sample thickness of few nanometers on the superconducting properties of materials that are commonly used for photon detection applications. In particular, we present experimental results on ultra-thin films of NbN and NbTiN in the presence of in-plane and out-of plane external applied magnetic field. The study focuses on the switching from the superconducting state up to the normal state, which is crucial for the functionality of different photon detectors. In particular, the critical parameters under investigations are related to the abrupt transition that occurs above the critical current in the flux flow state, namely the vortex lattice instability, since a vortex assisted switch to the normal state can be induced by current biasing a thin-film superconducting bridge.

Therefore, different physical quantities have been investigated, such as the critical currents, the switching voltages, the instability currents. However, only in the parallel configuration an unusual “*flying birds*” feature appears in the magnetic field dependence of current switching, as a consequence of the ratio I^*/I_c that is approaching to 1. This amazing tendency becomes relevant for practical applications involving nanostructures, since by scaling down sample thickness and rotating the external field towards the in-plane orientation, the ultra-thin film geometry can mimic the bridge narrowing down to nanoscale.

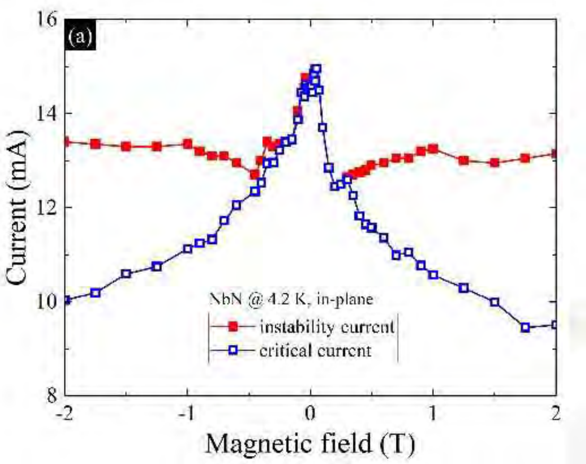

Fig. 1: Instability and critical currents versus magnetic field for the in-plane orientation for NbN sample. This picture reminds a '*flying bird*' and reflects the fact that in the I–V curves there is a threshold field value below which the abrupt jump of vortex instability occurs from the superconducting directly to the normal state.

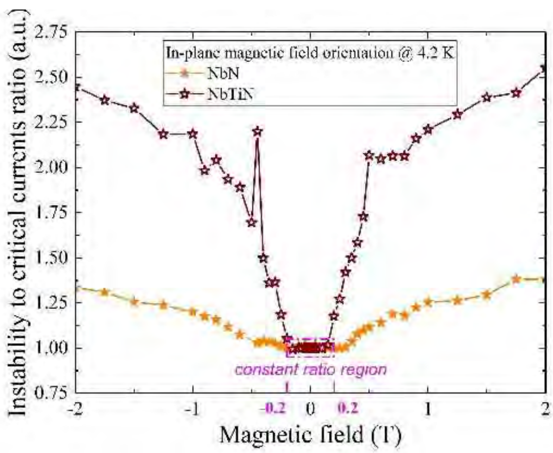

Fig. 2: The ratio I^*/I_c becomes equal to 1 in the presence of quite low fields for the in-plane orientation. This feature can show up when the thickness is downscaled to few nm, although the width remains of tens of μm. This '*flying bird*' effect is indeed absent for thicker films.

Improvements of high-field pinning properties of polycrystalline Fe(Se,Te) material by heat treatments

C. Fiamozzi Zignani[1,2], G. De Marzi[2], V. Corato[2], A. Mancini[2], A. Vannozzi[2], A. Rufoloni[2], A. Leo[1,3], A. Guarino[3], A. Galluzzi[1], A. Nigro[1], M. Polichetti[1], A. Della Corte[2], S. Pace[1], G. Grimaldi[3*]

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Journal of Material Science 54 (2019) 5092

In this manuscript, we present the study on the peak-effect observation in polycrystalline Fe(Se,Te) superconductor grown by self-flux method. In particular, the fabrication of Fe(Se,Te) crystals is explored by choosing a different heat treatment (HT) in the two-steps solid state reaction route, thus determining the proper cooling ramp of the second HT in order to obtain samples which display an enhanced peak-effect in the vortex phase diagram as inferred by magnetization, magneto-resistance and heat capacity measurements. Our experimental findings are compared with results in literature obtained on both High Temperature Superconductors, such as YBCO compounds, and Iron Based Superconductors of several families, thus suggesting a common origin of the peak-effect in different materials. Moreover, the study on the structural, morphological and compositional properties, as well as on the critical currents have revealed that in our Fe(Se,Te) samples the peak-effect phenomenon is strictly correlated to the manufacture process, since a tunable heat treatment leads to the observation of the peak-effect in the vortex phase diagram of the material. This fabrication route offers the way to increase systematically the critical current density that can turn useful for the production of superconductors in view of applications.

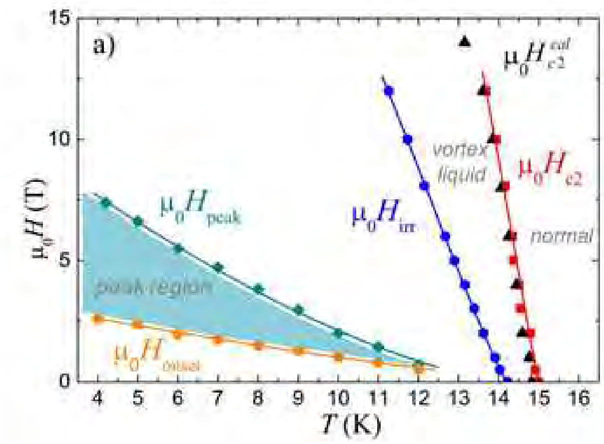

Fig. 1: Calorimetric measurements of the upper critical field at increasing magnetic field for the best Fe(Se,Te) sample realized by the two-step solid-state reaction process, successfully modified by increasing the temperature of the heat treatment and by slowing down the cooling rate.

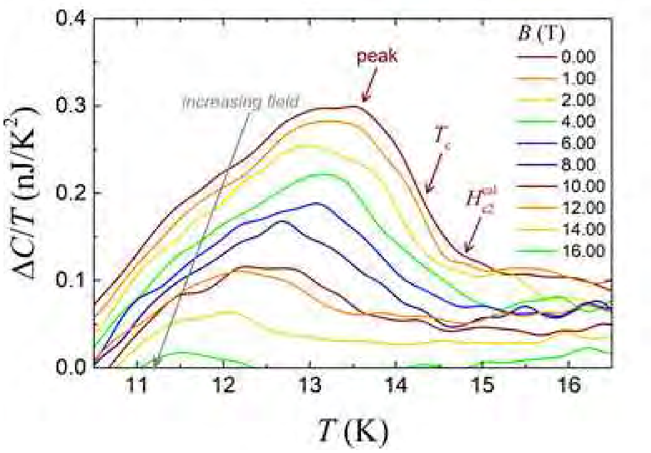

Fig. 2: *H-T* phase diagram for external field applied perpendicular to the surface of the sample; the peak region between H_{peak} and H_{onset} is highlighted for the best-investigated sample.

The CERN FCC Conductor Development Program: A Worldwide Effort for the Future Generation of High-Field Magnets

A. Ballarino[1], S. C. Hopkins[1], B. Bordini[1], D. Richter[1], D. Tommasini[1], L. Bottura[1], M. Benedikt[1], Michinaka Sugano[2], T. Ogitsu[2], S. Kawashima[3], K. Saito[3], Y. Fukumoto[3], H. Sakamoto[4], H. Shimizu[4], V. Pantsyrny[5], I. Abdyukhanov[5], M. Shlyakov[6], S. Zernov[6], F. Buta[7], C. Senatore[7], I. Shin[8], J. Kim[8], J. Lachmann[9], A. Leineweber[9], S. Pfeiffer[10], T. Baumgartner[11], M. Eisterer[11], J. Bernardi[10], A. Malagoli[12], V. Braccini[12], M. Vignolo[12], M. Putti[13], and C. Ferdeghini[12]

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[4]Furukawa Electric, Tokyo 100-8322, Japan
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[9]Institute of Materials Science, TU Bergakademie Freiberg, Freiberg 09599, Germany
[10]TUWien, USTEM, Wien A-1040, Austria
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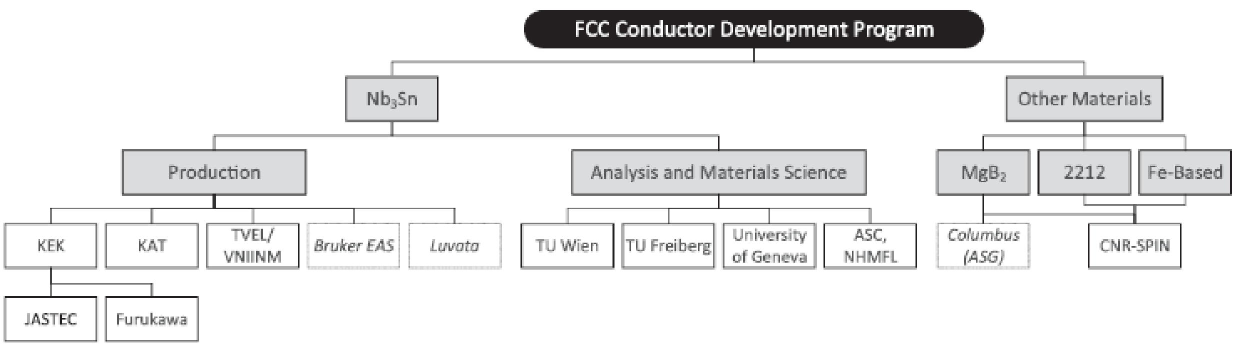
IEEE Transactions on Applied Superconductivity 9 (2019) 6000709

High Energy Physics has a long history of driving the development of superconducting magnets, and improvements in the design and performance of the superconducting wires used to produce them. In the context of the High-Luminosity LHC (HL-LHC) project, a major upgrade program to increase the luminosity of the LHC, Nb_3Sn accelerator magnets will be installed for the first time. The requirement for larger-aperture quadrupole magnets, and shorter dipole magnets to allow space for additional collimators, necessitates a significant increase in magnetic field, from a peak field of up to 8.6 T on the conductor in LHC, to 11.6 T for HL-LHC. SInce this cannot be achieved with Nb–Ti, as used for the LHC, suitable Nb_3Sn conductors have been developed, and series production of these wires is advancing towards completion. The proposed Future Circular Collider (FCC) would require another substantial step forward. The FCC Study is developing a number of conceptual designs for a successor particle collider to LHC, and the baseline is a 100 TeV hadron collider in a 100 km tunnel with 16 T dipole magnets. CERN has therefore launched a Conductor Development Program to drive the development of a suitable wire in partnership with industry and academia, as sketched below. The program is centered on Nb_3Sn wires, but also supports activities seeking a breakthrough in the high-field performance or cost effectiveness of alternative superconducting materials, currently including studies of MgB_2, BSCCO 2212 and iron-based superconductors at CNR-SPIN Genova.



The huge effect of Mn substitution on the structural and magnetic properties of LaFeAsO: the La(Fe,Mn)AsO system

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Journal of Physics: Condensed Matter 31 (2019) 064001

The substitution of Mn for Fe in the sub-structure of $La(Fe_{1-x}As_x)O$ has a remarkable impact on both structural and magnetic properties. For example, the structural and magnetic transition temperatures decrease of 20 K in samples with a Mn-content as low as x = 0.01. Such a dramatic effect results from the high stability of the substituting $Mn2^+$ ion ($3d^5$) in its high-spin state, which opposes any variation to its electronic state (configuration), perturbing thereby interactions within the transition metal sub-structure between the Fe ions surrounding the Mn substituent. Several investigations ascertained that the structural transition in LnFeAsO compounds (Ln: lanthanide) cannot be ascribed to structural degrees of freedom, but rather to electronic or spin ones. In this context, even an extremely low concentration of Mn^{2+} ions diluted in the Fe sub-structure produces a reduction of the electronic degree of freedom of the system, thus hindering both the structural and the magnetic transitions. Remarkably, we recently detected the development of a static incommensurate modulated structure across the low-temperature orthorhombic phase in the $La(Fe_{1-x}Mn_x)AsO$ system, revealing a possible major role of charge density wave in Fe-based SC materials. The structural transition is also accompanied by an anomalous increase of the structural strain parallel to the Fermi surface nesting wave-vector just above the desymmetrization (Fig. 1). The phase diagram of the $La(Fe_{1-x}Mn_x)AsO$ system has been drawn for the Mn-poor side on the basis of structural and magnetic data obtained by synchrotron X-ray and neutron powder diffraction (Fig. 2).

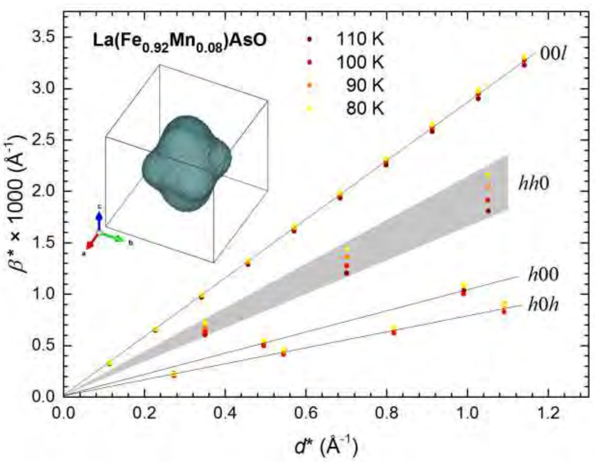

Fig. 1: Superposition of Williamson-Hall plots showing the evolution of the lattice microstrains in the tetragonal phase on cooling. The inset shows the observed tensor isosurface representing the microstrain broadening characterizing the sample as the structural transition is approached.

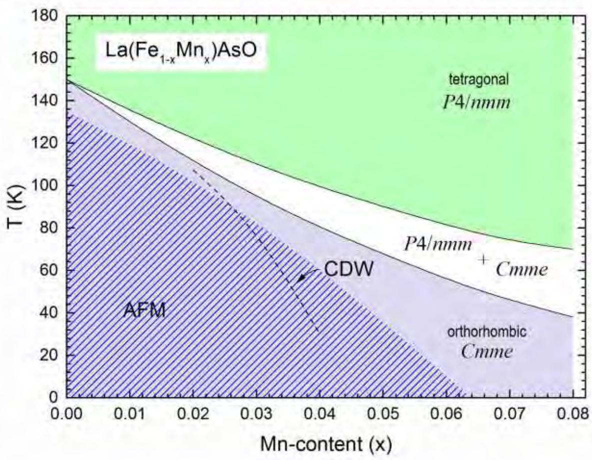

Fig. 2: Phase diagram of the $La(Fe_{1-x}Mn_x)AsO$ system (Mn-poor side); the hatched area represents the region of the phase diagram where long-range magnetic ordering takes place; the dotted line defines the region where a static CDW state was detected.

Emerging proton conductivity at the interface between insulating $NdGaO_3$ and $BaZrO_3$

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Physical Review Materials 3 (2019) 103606

In a previous article (R. Felici, et al, Phys. Status Solidi B 256, 1800217 (2019)) we reported on the increased conductivity present at the interface between Y-doped $BaZrO_3$ deposited by pulsed laser deposition onto a $NdGaO_3$ wide-band-gap insulator substrate. We made the hypothesis that the enhancement of the conductivity was due to the presence at the interface of a regular network of misfit dislocations. In order to rule out effects induced by the conductivity of the Y doping of the $BaZrO_3$ layer, which is a well known ionic conductor, the present article deals with the interplay between structural properties of the interface region and emerging proton conductivity in thin films of insulating $BaZrO_3$ (BZO) deposited onto $NdGaO_3$ (NGO). High-resolution transmission electron microscopy and surface x-ray diffraction reveal the presence of a large number of misfit dislocations at the interface, allowing the full relaxation of the epitaxial strain. An analysis of the x-ray diffraction patterns reveals the strain relaxation occurs over a thickness of about 3 nm, equally divided between the film and the substrate. Electrical impedance spectroscopy measurements show a sizeable proton conductance, which does not depend on the thickness of the $BaZrO_3$ layer, supporting the idea that transport is only limited to the interface region. The conductance of these systems, about 0.5 S/cm at 650 °C with an activation energy of about 0.86 eV, can mainly be attributed to the defective interface.

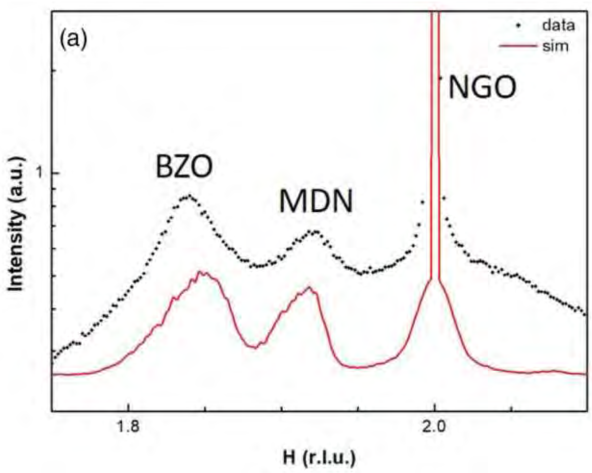

Fig. 1: Surface x-ray diffraction intensity scans along the H direction of a 2.9-nm BZO film on NGO. The full red lines represent theoretical simulations of the diffraction experimental data. BZO, NGO, and MDN tags specify the diffraction peaks associated to the film, to the substrate, and to the misfit dislocation network, respectively.

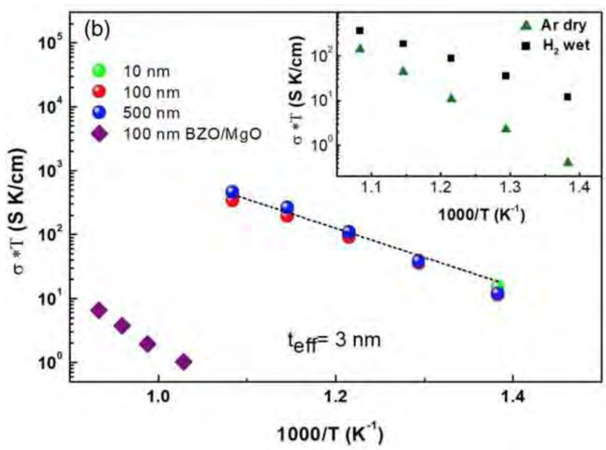

Fig. 1: Arrhenius plot of conductivity values calculated for three films of BZO grown on NGO and for a 100-nm-thick film of BZO grown on MgO, assuming the conducting layer is 3 nm for all the samples. In the inset, conductivity measurement of 100-nm-thick BZO film in dry Ar and wet H2 atmosphere.

Activity B: Superconducting and correlated low dimensional materials and devices for quantum electronics and spintronics

Activity Leader: Marco Salluzzo

This activity focuses on the physics of low dimensional materials and devices for quantum electronics and spintronics. The researchers involved are expert in the physics of superconducting and strongly correlated materials, in the Josephson effect (from micro to nano-scale), in nanodevices (like Josephson junctions and field effect transistors made of correlated oxides) and in graphene. Many of those researchers have also a deep expertise in materials and devices characterization employing both low-temperature magneto-transport measurements and advanced x-ray spectroscopies. Theoretical researchers are focused on the prediction of novel physical quantum phenomena and in the interpretation of experimental results.
The general objective of the activity is to establish a novel material platform for quantum electronics and spintronics. To this purpose, the research activities include:

- fundamental understanding of the novel quantum physics in low-dimensional materials by combining diverse and complementary theoretical and experimental approaches
- advanced materials synthesis
- standard and advanced, synchrotron based, x-ray spectroscopies and structural methods
- realization and ultra-low temperature tunable nanodevices, including Josephson junctions and field effect transistors.

Among the topics that will be specifically addressed, we mention the metal/superconducting to insulating transition in low dimensional materials, the unconventional superconductivity in high T_c 2D-cuprates, 2D-materials with strong spin-orbit coupling and ferromagnetic/superconducting heterostructures. We aim in particular at the realization of materials with novel functionalities, like interface superconductivity, magnetism and ferroelectricity, which can be manipulated by external stimuli, as magnetic/electric fields, spin-polarized current, photon irradiation, or by tuning the geometric curvature.

Chiral Spin Texture in the Charge-Density-Wave Phase of the Correlated Metallic Pb/Si(111) Monolayer

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Physical Review Letters 120 (2018) 196402

In a metal, the repulsive interaction between electrons (Coulomb interaction) is screened by the presence of many other electrons. As the electron density decreases this repulsive interaction increases. If it becomes sufficiently strong, it can prevent the formation of a metallic state in favor of an insulating one, called Mott Insulator. Recent works have highlighted the amazing properties of these materials characterized by strong electronic correlations, opening the possibility to interesting industrial applications (i.e. non-volatile memories). Theoretical description of the electronic properties of these materials represents a challenge due to the difficulty of modeling the strong interactions between electrons. This difficulty is even greater when it comes to a low-dimensional system manufactured on a substrate-support: the role of the atoms of the substrate must also be considered.

An ideal system to study those effects is represented by group IV atoms on group IV substrates as they are considered to be on the verge of the Mott-transition. In our work we investigated the 1/3 monolayer α-Pb/Si(111) surface by scanning tunneling spectroscopy (STS) and fully relativistic first-principles calculations. We study both the high-temperature $\sqrt{3}\times\sqrt{3}$ and low-temperature 3×3 reconstructions highlighting the important role of spin-orbit interaction responsible for an energy splitting as large as 25% of the valence-band bandwidth. Relativistic effects, electronic correlations, and Pb-substrate interaction cooperate to stabilize a correlated low-temperature paramagnetic phase with 3×3 periodicity. By comparing the Fourier transform of STS conductance maps at the Fermi level with calculated quasi-particle interference we demonstrate the occurrence of two large hexagonal Fermi sheets with in-plane spin polarizations and opposite helicities.

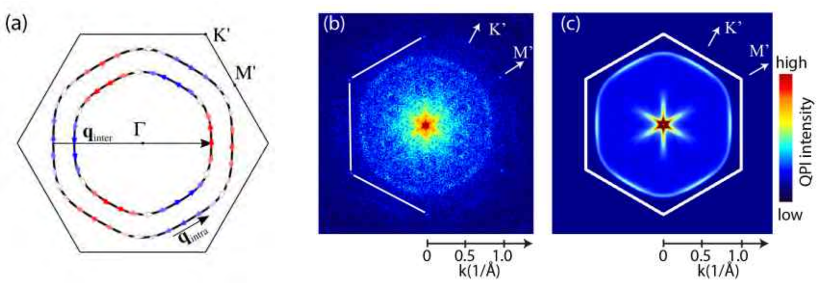

Fig. 1: (a) Fermi surface of Pb-3×3/Si(111) including spins polarization (arrows). White arrows, 100% in-plane polarization; blue and red arrows, opposite out-of-plane components. Black arrows are the scattering vectors. (b) Fourier transform map measured by STS at T=0.3 K, corresponding to quasiparticle interference at E=EF. (c) Calculated quasiparticle interference map at E=EF assuming scalar impurity scattering.

Asymmetric Schottky Contacts in Bilayer MoS_2 Field Effect Transistors

Antonio Di Bartolomeo[1,2], Alessandro Grillo[1], Francesca Urban[1,2], Laura Iemmo[1,2], Filippo Giubileo[2], Giuseppe Luongo[1,2], Giampiero Amato[3], Luca Croin[3], Linfeng Sun[4], Shi-Jun Liang[5], and Lay Kee Ang[6]

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Advanced Functional Materials 28 (2018) 1800657

The high-bias electrical characteristics of back-gated field-effect transistors with chemical vapor deposition synthesized bilayer MoS_2 channel and Ti Schottky contacts are discussed. It is found that oxidized Ti contacts on MoS_2 form rectifying junctions with ≈0.3 to 0.5 eV Schottky barrier height. To explain the rectifying output characteristics of the transistors, a model is proposed based on two slightly asymmetric back-to-back Schottky barriers, where the highest current arises from image force barrier lowering at the electrically forced junction, while the reverse current is due to Schottky barrier-limited injection at the grounded junction. The device achieves a photoresponsivity greater than 2.5 A W^{-1} under 5 mW cm^{-2} white-LED light. By comparing two- and four-probe measurements, it is demonstrated that the hysteresis and persistent photoconductivity exhibited by the transistor are peculiarities of the MoS_2 channel rather than effects of the Ti/MoS_2 interface.

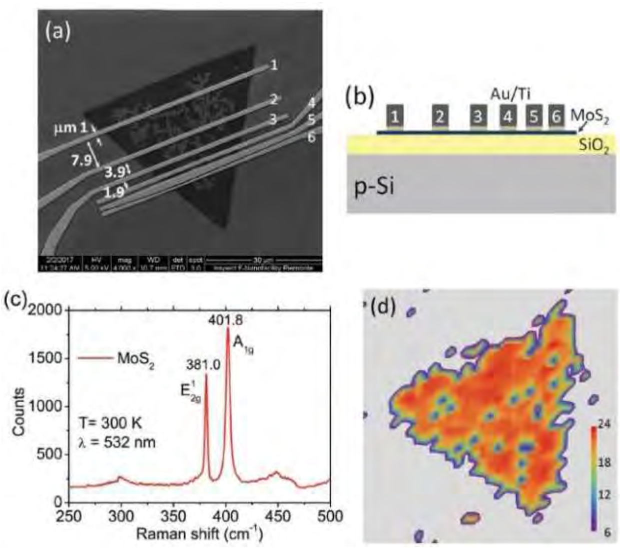

Fig.1: a) SEM top view of a CVD-synthesized bilayer MoS_2 with Ti/Au contacts. b) Schematic of the back-gate transistors. c) Raman spectrum of the bilayer MoS_2. d) Map of the difference between A_{1g} and E_{2g} peaks of micro-Raman spectra.

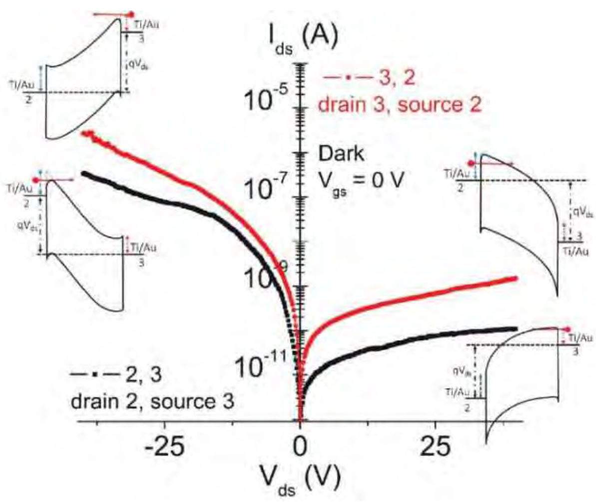

Fig.2: Band diagram based on two back-to-back Schottky barriers. The forward current for negative V_{ds} is due to the image force barrier lowering at the forced junction, while the lower (reverse) current at V_{ds} > 0 V is limited by the low electric field at the grounded junction.

Hysteresis in the transfer characteristics of MoS_2 transistors

Antonio Di Bartolomeo[1,2], Luca Genovese[1], Filippo Giubileo[2], Laura Iemmo[1], Giuseppe Luongo[1,2], Tobias Foller[3] and Marika Schleberger[3]

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2D Materials 5 (2018) 015014

Molybdenum disulfide (MoS_2) has recently become one of the most popular semiconductors from the family of the transition metal dichalcogenides. The MoS_2 bandgap can be controlled by the number of layers: Bulk MoS_2 has an indirect bandgap of 1.2 eV while monolayer MoS_2 has a direct bandgap of 1.8 eV. The large bandgap, combined with mechanical flexibility, makes MoS_2 suitable as channel in field effect transistors (FETs) for logic applications. We investigate the origin of the hysteresis observed in the transfer characteristics of back-gated field effect transistors with an exfoliated MoS_2 channel. We find that the hysteresis is strongly enhanced by increasing either gate voltage, pressure, temperature or light intensity. Our measurements reveal a step-like behavior of the hysteresis around room temperature, which we explain as water-facilitated charge trapping at the MoS_2/SiO_2 interface. We conclude that intrinsic defects in MoS_2, such as S vacancies, which result in effective positive charge trapping, play an important role, besides H_2O and O_2 adsorbates on the unpassivated device surface. We show that the bistability associated to the hysteresis can be exploited in memory devices.

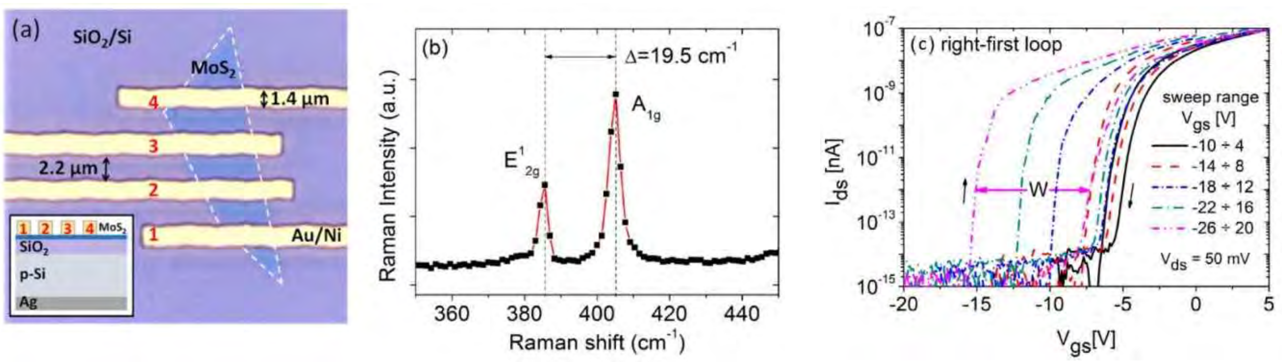

Fig. 1: (a) Optical image of a monolayer MoS_2 flake (highlighted by dashed white lines) contacted with Ni/Au leads; the inset shows the schematic cross-section of the back-gated FET. (b) Raman spectrum of the MoS_2 flake. (c) Transfer characteristics of the MoS_2 transistor for the back-gate voltage, Vgs , in loops of different amplitudes but with fixed steps (Vgs = 0.1 V).

RF assisted switching in magnetic Josephson junctions

R. Caruso[1,2], D. Massarotti[2,3], V. V. Bolginov[4,5], A. Ben Hamida[5,6], L. N. Karelina[4], A. Miano[1], I. V. Vernik[7,8], F. Tafuri[1,2], V. V. Ryazanov[4,9], O. A. Mukhanov[7,8], and G. P. Pepe[1,2]

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[3]Dipartimento di Ingegneria Elettrica e delle Tecnologie dell'Informazione, University of Napoli "Federico II", via Claudio, 80125 Napoli, Italy
[4]Institute of Solid State Physics (ISSP RAS), Chernogolovka, Moscow Region 142432, Russia
[5]Skobeltsyn Institute of Nuclear Physics, Moscow State University, Moscow 119991, Russia
[6]Leiden Institute of Physics, Leiden University, Niels Bohrweg 2, 2333 CA Leiden, The Netherlands
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[9]Faculty of Physics, National Research University Higher School of Economics, Moscow, Russia

Journal of Applied Physics 123 (2018) 133901

In this work we have tested the effect of an external RF field on the switching processes of magnetic Josephson junctions (MJJs) that have already been used as elementary cells of cryogenic memories compatible with Single Flux Quantum logic. We have shown that the combined application of microwaves and magnetic field pulses improves the performances of the device, increasing the separation between the critical current levels corresponding to the two logical states '0' and '1'. The enhancement of the current level separation can be as high as 80% using an optimal set of parameters. The relevance of this work resides in the demonstration of the use of external RF fields as additional tools to manipulate the memory states. We expect that this approach may lead to the development of new methods of selecting MJJs and manipulating their states in memory arrays for various applications.

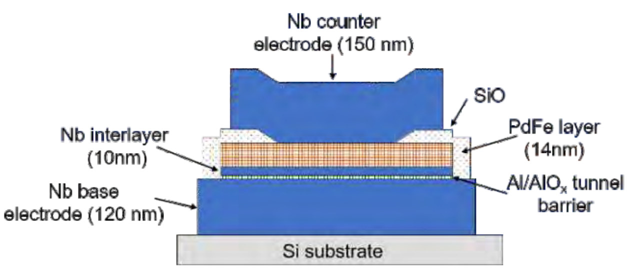

Fig. 1: Section scheme of the junction analyzed in this work (not in scale), with layer thicknesses marked

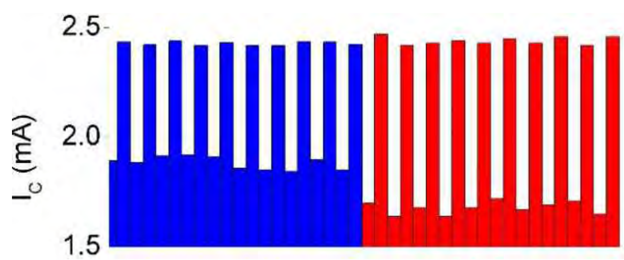

Fig. 2: Critical current levels for the two logical states '0' and '1' in absence (blue bars, left) and in presence (red bars, right) of an external RF field

Towards oxide electronics: a roadmap

Mariona Coll, Josep Fontcuberta, M Althammer, Manuel Bibes, H Boschker, Albert Calleja, G Cheng, M Cuoco, R Dittmann, B Dkhil, I El Baggari, M Fanciulli, Ignasi Fina, E Fortunato, Carlos Frontera, S Fujita, V Garcia, STB Goennenwein, Claes Göran Granqvist, J Grollier, R Gross, Anders Hagfeldt, Gervasi Herranz, K Hono, E Houwman, M Huijben, A Kalaboukhov, DJ Keeble, G Koster, LF Kourkoutis, J Levy, Mónica Lira-Cantu, JL MacManus-Driscoll, Jochen Mannhart, R Martins, S Menzel, T Mikolajick, M Napari, MD Nguyen, Gunnar Niklasson, C Paillard, S Panigrahi, G Rijnders, F Sánchez, P Sanchis, S Sanna, DG Schlom, U Schroeder, KM Shen, A Siemon, M Spreitzer, H Sukegawa, R Tamayo, J Van den Brink, N Pryds, F Miletto Granozio[1]

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Applied Surface Science 1 (2019) 482

At the end of a rush lasting over half a century, in which CMOS technology has been experiencing a constant and breathtaking increase of device speed and density, Moore's law is approaching the insurmountable barrier given by the ultimate atomic nature of matter. A major challenge for 21st century scientists is finding novel strategies, concepts and materials for replacing silicon-based CMOS semiconductor technologies and guaranteeing a continued and steady technological progress in next decades. Among the materials classes candidate to contribute to this momentous challenge, oxide films and heterostructures are a particularly appealing hunting ground. The vastity, intended in pure chemical terms, of this class of compounds, the complexity of their correlated behaviour, and the wealth of functional properties they display, has already made these systems the subject of choice, worldwide, of a strongly networked, dynamic and interdisciplinary research community. In this review and perspective paper, the opportunities of oxides as future electronic materials for ICT and Energy are discussed.

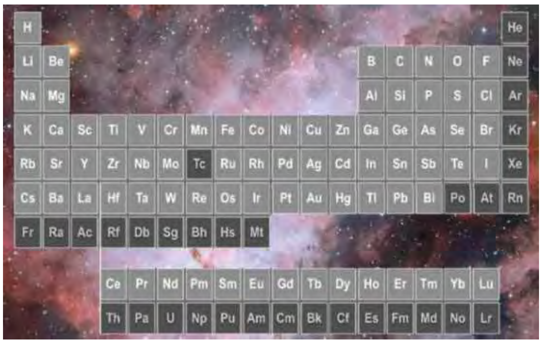

Fig. 1: Exploring the periodic table to discover and synthesize materials for electronic devices is a one-off research adventure: we have only one periodic table of the elements in our universe! In this rendition, we have highlighted those elements that in our view are practical building blocks for films and heterostructures to be used at room-temperature.

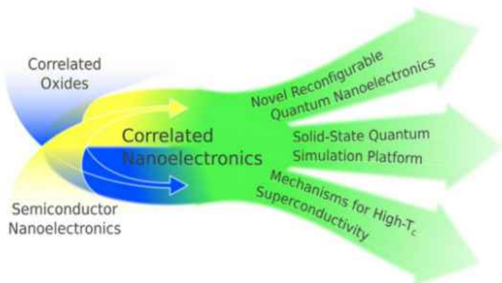

Fig. 2: Concept of correlated nanoelectronics. It combines the core functionalities of correlated oxides and semiconductor nanoelectronics. This combination, bridged by STO based electron systems, may lead to future applications of quantum technologies.

Plasmonics of Au nanoparticles in a hot thermodynamic bath

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Nanoscale 11 (2019) 1140

Electromagnetically-heated metal nanoparticles can be exploited as efficient heat sources at the nanoscale. The assessment of their temperature is however often performed indirectly by modelling their temperature-dependent dielectric response. Direct measurements of the optical properties of metallic nanoparticles in equilibrium with a thermodynamic bath provide a calibration of their thermo-optical response, to be exploited for refining current thermoplasmonic models or whenever direct temperature assessments are practically unfeasible.

We investigated the plasmonic response of supported Au nanoparticles in a thermodynamic bath from room temperature to 350 °C by means of spectroscopic ellipsometry (SE). SE measures the variation of the state of polarization of light upon interaction with the sample, quantified by the spectral functions ψ and Δ. A model explicitly including the temperature-dependent dielectric function of the metal and finite-size corrections to the nanoparticles permittivity correctly reproduced experimental data for temperatures up to 75 °C. The model accuracy gradually faded for higher temperatures. Introducing a temperature-dependent correction that effectively mimics a surface-scattering-like source of damping in the permittivity of the nanoparticles restored a good agreement with the data. A finite-size thermodynamic effect such as surface pre-melting may be invoked to explain this effect.

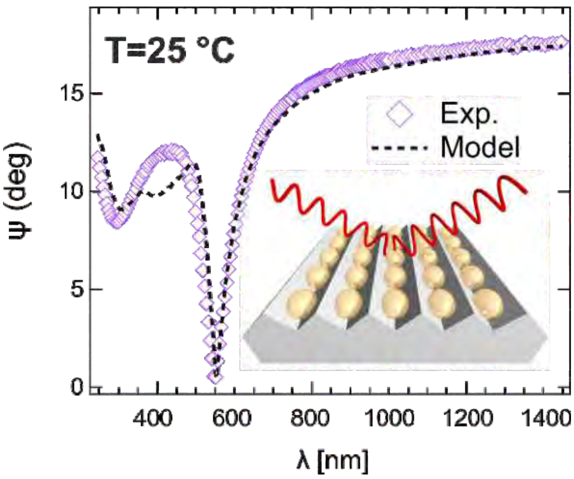

Fig. 1: Open symbols: ellipsometric spectrum ψ(λ), of arrays of Au nanoparticles at room temperature. Dashed line: theoretical model based on an effective-medium theory. ψ is defined as the ratio of the moduli of the complex Fresnel reflection coefficients r_p and r_s.

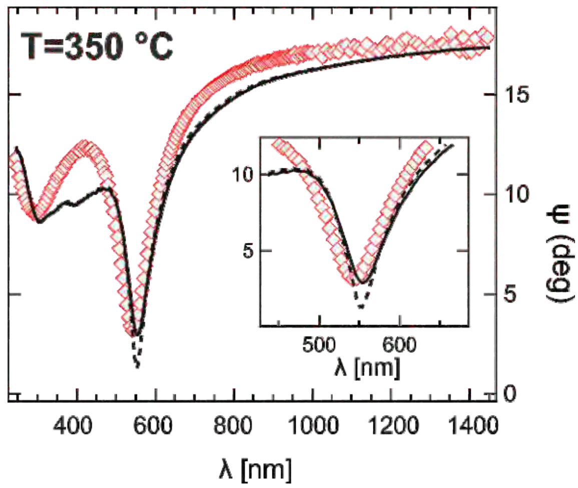

Fig. 2: Open symbols: ellipsometric spectrum ψ(λ) of arrays of Au nanoparticles at 350°C. Dashed line: theoretical model without surface premelting. Continuous line: model calculations with surface premelting included.

Independent Geometrical Control of Spin and Charge Resistances in Curved Spintronics

Kumar Sourav Das[1], Denys Makarov[2], Paola Gentile[3,4], Mario Cuoco[3,4], Bart J. van Wees, Carmine Ortix[5,6,4] and Ivan J. Vera-Marun[7]

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Nano Letters 19 (2019) 6839

Spintronic devices operating with pure spin currents represent a new paradigm in nanoelectronics, with a higher energy efficiency and lower dissipation as compared to charge currents. This technology, however, will be viable only if the amount of spin current diffusing in a nanochannel can be tuned on demand while guaranteeing electrical compatibility with other device elements, to which it should be integrated in high-density three-dimensional architectures. Here, by using a combination of experimental investigations and theoretical analysis, we demonstrate that pure spin currents can effectively propagate in metallic nanochannels with a three-dimensional curved geometry. Our strategy relies on the possibility to grow metallic nanochannels with a geometrically driven strongly inhomogeneous nanometer-scale thickness, t. The size-dependent resistivity, ρ, of the metallic channels yields a different local behavior for the sheet resistance ρ/t and the spin relaxation length $\lambda \propto 1/\rho$. As a result, an appropriate engineering of the nanochannel thickness allows for designed nanochannels, where one can achieve independent tuning of the spin resistance without affecting the total charge resistance, and vice versa. This capability allows for the design of an element with simultaneous matching of spin resistance to a spin-based circuit, e.g., for efficient spin injection, and matching of charge resistance to a charge-based circuit, e.g., for efficient power transfer. As a proof of concept, we demonstrate the modulation of spin currents and of charge currents in lateral nonlocal spin valves with ultrathin metallic channels directly grown on curved templates [Fig.1], which were created in the form of trenches in a silicon dioxide substrate by using used focused ion beam etching. Increasing the height of the trenches led to channels with increasing curvature, allowing us to systematically explore the effect of the channel geometry. The obtained control of spin and charge resistances is fundamental to spintronics, as it enables practical magnetoresistance in two terminal devices and the concatenability and reduced feedback in spin logic architectures. These results laid the foundation for the design of efficient pure spin current-based electronics, which can be integrated in complex three-dimensional architectures.

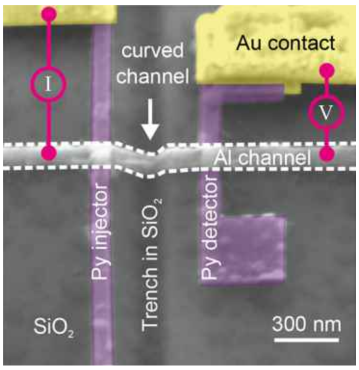

Fig. 1: Scanning electron microscope image of a spin valve device with a curved Al channel across a trench. The electrical connections for nonlocal spin valve measurements are also depicted.

Pressure-Tunable Ambipolar Conduction and Hysteresis in Thin Palladium Diselenide Field Effect Transistors

Antonio Di Bartolomeo[1,2], Aniello Pelella[1,2], Xiaowei Liu[3], Feng Miao[3], Maurizio Passacantando[4], Filippo Giubileo[2], Alessandro Grillo[1,2], Laura Iemmo[1,2], Francesca Urban[1,2], and Shi-Jun Liang[3]

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Advanced Functional Materials 29 (2019) 1902483

Few-layer palladium diselenide ($PdSe_2$) field effect transistors are studied under external stimuli such as electrical and optical fields, electron irradiation, and gas pressure. The ambipolar conduction and hysteresis are observed in the transfer curves of the as-exfoliated and unprotected $PdSe_2$ material. The ambipolar conduction and its hysteretic behavior in the air and pure nitrogen environments are tuned. The prevailing p-type transport observed at atmospheric pressure is reversibly turned into a dominant n-type conduction by reducing the pressure, which can simultaneously suppress the hysteresis. The pressure control can be exploited to symmetrize and stabilize the transfer characteristics of the device as required in high performance logic circuits. The transistors are affected by trap states with characteristic times of the order of minutes. The channel conductance, dramatically reduced by the electron irradiation during scanning electron microscope imaging, is restored after an annealing of several minutes

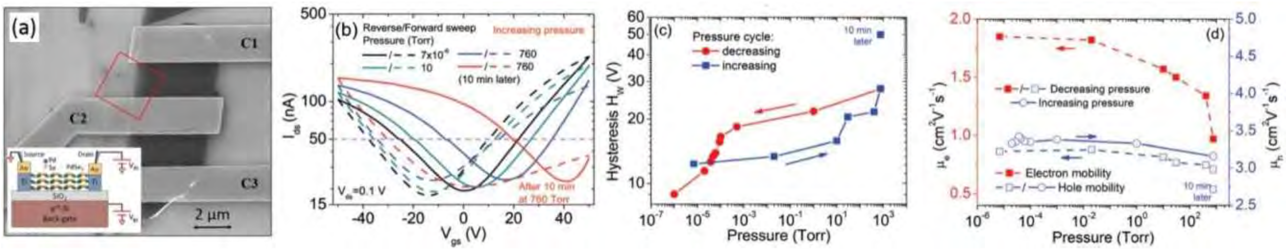

Fig. 1: (a) SEM image of the $PdSe_2$ flake with 5 nm Ti/40 nm Au metal contacts and (inset) schematic of the backgate transistor fabricated with it (not-on-scale). (b) Effects of increasing pressure on the transfer characteristics of the $PdSe_2$ device (for clarity, only a subset of the measured curves is shown here). (c) Hysteresis as a function of pressure. (d) electron–hole mobility as a function of pressure.

Dynamical charge density fluctuations pervading the phase diagram of a Cu-based high-Tc superconductor

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Science 365 (2019) 906

The phase diagram of the high-T_c cuprate superconductors (HTS) is characterized by the spontaneous emergence of various ordered states, tuned by doping and driven by competition between charge, spin, orbital and lattice degrees of freedom.The identification of all these ordered states is a crucial step towards the understanding of high-temperature superconductivity, one of the grand challenges in solid state physics. Recently, synchrotron-based X-ray scattering provided evidence of a new charge order, theoretically predicted already in the 90s, in all cuprate superconductors. However, it remains unclear to what extent the charge order influences the unusual properties of these systems, since it was reported - in the shape of incommensurate Charge Density Waves (CDW) - only in underdoped samples (with doping p = 0.08 – 0.16 holes/Cu) and at relatively low temperatures (below 170-200 K). The manuscript demonstrates for the first time the presence of a sort of precursor of the quasi-2D CDW signal, characterized by an almost temperature-independent evolution. The result was achieved thanks to the higher sensitivity of the resonant inelastic X-ray scattering (RIXS) instrumentation now available at ID32-beamline of ESRF (Fig. 1). The results have been surprising. While sharing with the 2D-CDW the same incommensurate wave vector q_c, this broad peak is present also above the pseudogap temperature, up to 270 K , and even in optimally doped and overdoped samples (p > 0.16 holes/Cu). Furthermore, it is not sensitive to the presence of the superconducting order. The result has been interpreted as *dynamic-charge-density-fluctuations* compatible with the picture provided 23 years ago by Castellani *et al.* Phys. Rev. Lett. 75, 4650 (1995) of an inherent charge instability in HTS cuprates. Charge density fluctuations can be thus regarded as pervasively present at all T for superconducting cuprates and might therefore have a crucial role in determining the peculiar properties of these compounds both in the normal and superconducting states.

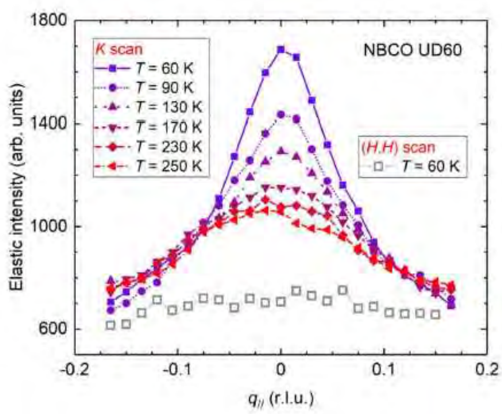

Fig. 1: Elastic intensity, from integration of the the quasi-elastic region of the Cu L3 RIXS spectra measured at different $q_{//}$ values along the (H,0) direction.

Influence of free charge carrier density on the magnetic behavior of (Zn,Co)O thin film studied by Field Effect modulation of magnetotransport

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Scientific Reports 9 (2019) 149

The origin of (ferro)magnetic ordering in transition metal doped ZnO is a still open question. For applications it is fundamental to establish if it arises from magnetically ordered impurity clusters, embedded into the semiconducting matrix, or if it originates from ordering of magnetic ions, dilute into the host lattice. In this latter case, a reciprocal effect of the magnetic exchange on the charge carriers is expected, offering many possibilities for spintronics applications. In this paper we report on the relationship between magnetic properties and free charge density investigated by using Zinc oxide based field effect transistors, in which the charge carrier density is modulated by more than 4 orders of magnitude, from 10^{16} to 10^{20} e−/cm^3. The magnetotransport properties are employed to probe the magnetic status of the channel, both in pure and cobalt doped zinc oxide transistors. We find that it is widely possible to control the magnetic scattering rates by field effect. We believe that this finding is a consequence of the modulation of magnetization and carrier spin polarization by the electric field. The observed effects can be explained by the change in size of bound magnetic polarons that induces a percolation magnetic ordering in the sample.

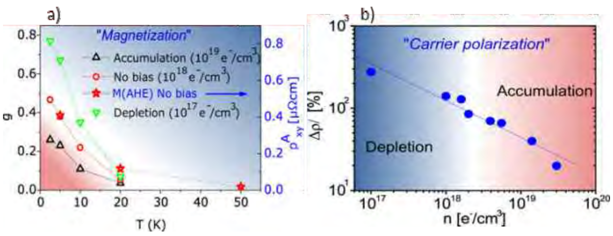

Fig. 1 a) Estimation of the (Zn,Co)O sample magnetization from the magnetoresistance fit and the anomalous Hall effect. The left and right vertical scale are chosen in such a way that the point at 5K and zero bias coincide.
b) Maximum positive value of the low temperature magnetoresistance in (Zn,Co)O as a function of the carrier concentration inferred from Hall Effect. According many authors it is directly related to the spin carrier polarization.

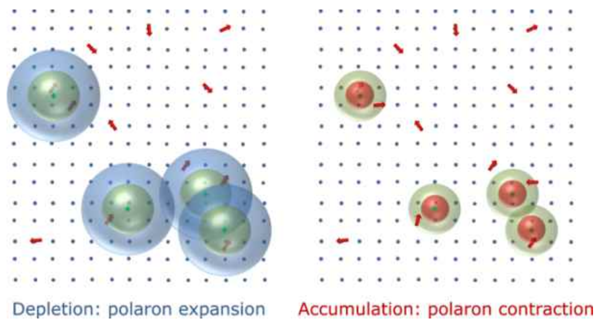

Fig. 2: Schematic drawings for the size evolution of bounded magnetic polaron with carrier concentration. Red arrows and cyan dots represent magnetic impurities and donor defects, respectively; blue, red and green spheres represent the expanded, contracted and natural polaron sizes, respectively. The increase in carrier density reduces the polaron radius and consequently increases the bound magnetic polaron separation; thus, the magnetic coupling decreases (right). The opposite situation happens when the carrier density decreases (left).

Activity C: Innovative materials with strong interplay of spin, orbital, charge and topological degrees of freedom

Activity Leader: Silvia Picozzi

This research activity focuses on complex materials, where different structural and electronic degrees of freedom can coexist, compete or cooperate in order to give rise to novel emergent phenomena. In particular, in addition to focusing on the long-investigated spin, charge, orbital and lattice degrees of freedom, our aims include the more recent exploration of topological properties, that have gained a strong momentum in the last years even in complex matter, where strong electronic correlations are at play. While the emphasis of our research activity is on the fundamental understanding of microscopic mechanisms underlying the observed or predicted phenomena, our research can also have a strong impact on novel, technologically relevant, fields of electronics (such as spin-orbitronics, topotronics, magnonics, etc), exploiting new concepts such as dissipationless spin currents, spin-to-charge conversion, etc. Our activity is based on the strong synergy among different methodologies: materials growth (via floating zone techniques for bulk crystals and pulsed laser deposition for thin films and heterostructures), characterization with various techniques (infrared, optical and X-ray spectroscopies, performed in the lab or at large-scale facilities, magneto-transport, etc) and modelling (via first-principles density functional theory, model Hamiltonian, many-body approaches etc). Traditionally, most of the materials of interest in our activity are complex transition-metal oxides (in either bulk or film or heterostructure phase), but other classes of compounds (chalcogenides, pnictides, halides, organic-inorganic hybrids) have recently been investigated.

The main research objectives are:

- Investigate materials with unconventional spin-textures, both when magnetic long-range order is present (for example in topologically non-trivial magnetic patterns such as (anti)-skyrmions or chiral domain walls) or absent (such as complex spin textures in non-magnetic compounds with large spin-orbit coupling, such as Dirac/Weyl materials or compounds with strong Rashba effects).
- Investigate systems where the strong interplay between spin-orbit coupling and electronic Coulomb interaction is a key ingredient for novel and emerging phases of matter (including topological insulating or gapless states), along with the design of artificial systems and heterostructures based on 3d-4d and 3d-5d oxides.
- Explore novel phases of matter where frustration (due to geometry and/or competing interactions) plays a relevant role, for example giving rise to exotic solid and liquid quantum phases.
- Address (multi)-ferroic systems (i.e. showing spontaneous long-range magnetic/dipolar/ferroelastic order below a certain critical temperature) where the coupling with various external stimuli (e.g. applied fields, temperature, light) might lead to novel multifunctional materials and effects (i.e. polar skyrmions, electromagnons in multiferroics).

A topological quantum pump in serpentine-shaped semiconducting narrow channels

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Physical Review B 97 (2018) 241103(r)

In a charge pump, periodic perturbations induce a dc current without an external bias. Very recently, topological quantum pumps, where the induced current is quantized and topologically protected, have been realized in ultracold atomic systems through the creation of dynamically controlled optical superlattices. In one-dimensional (1D) electronic systems, the creation of a dynamical superlattice potential critically relies on the presence and control of superimposed oscillating local voltages, and this severely hampers the possibility to bring topological charge pumping within reach in condensed matter experiments. In this framework we propose and validate theoretically a solid-state system in which topological quantum pumping can be achieved even in the complete absence of superimposed voltage leads. The system consists of a Rashba spin-orbit coupled semiconducting narrow channel with a serpentine shape at the mesoscopic scale (Fig. 1(a)), which can be obtained either by processing a semiconducting quantum well lithographically, or by creating a "zigzag" nanowire network of crystalline quality. To operate, the device makes use of an auxiliary external planar rotating magnetic field, which serves as the periodic (ac) perturbation driving the charge pumping (Fig. 1(b)). As the strength of the rotating magnetic field is increased, the system undergoes a topological phase transition from an insulating phase with a nontrivial Chern number $C=-2$ to a completely trivial $C=0$ insulating phase (Fig. 1(c)). The time-dependent Zeeman interaction due to the planar rotation of the magnetic field cooperates with the spin-orbit coupling, which is effectively inhomogeneous because of the geometric curvature of the nanostructure, in such a way to render a sliding superlattice potential acting on the electronic charges. As a consequence, in the topological non trivial phase, an even integer number of electronic charges is transported in each rotation period of the magnetic field (Fig.1(d)). This effect ultimately yields a quantized dc current which realizes the topological pumping protocol, originally introduced by Thouless, in a completely novel fashion. The precise pumping of electric charges in our mesoscopic quantum device can be relevant for quantum metrology purposes.

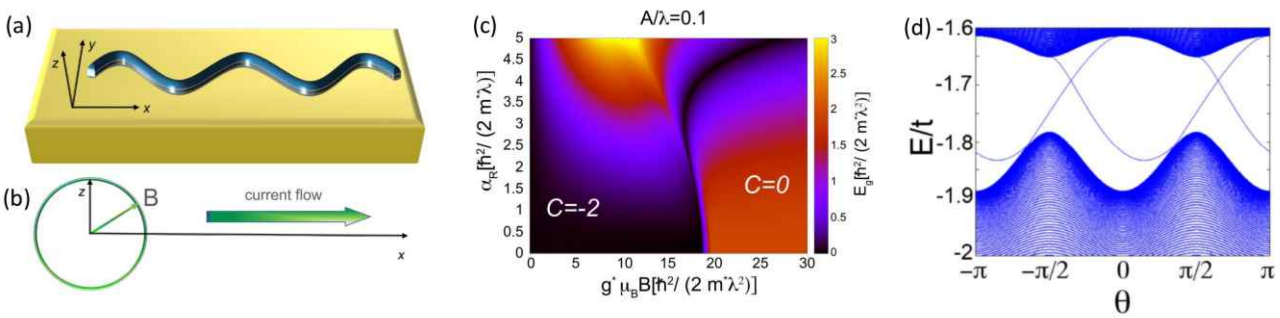

Fig. 1: Schematic view of a semiconducting 1D channel patterned in a serpentine shape (a). Schematic diagram of the pumping induced by the rotation of the magnetic field (b). Map of the gap between the second and third minibands of an undulating 1D channel subject to rotating magnetic fields, in the continuum limit. A topological phase transition separates the topologically non trivial region (with C=−2) from the topologically trivial one (C=0) (c). The energy spectrum of a finite size system with open boundary conditions in the topological non trivial phase displays two chiral edge states within the one quarter-filling gap (d).

Spin-Orbital Excitations in Ca2RuO4 Revealed by Resonant Inelastic X-Ray Scattering (RIXS)

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Physical Review X 8 (2018) 011048

Spin-orbit coupling is a central thread in the search for novel quantum material physics. The strongly correlated insulator Ca_2RuO_4 is considered as a paradigmatic realization of both spin-orbital physics and a band-Mott insulating phase, characterized by orbitally selective coexistence of band and Mott gap. We present a high resolution oxygen K-edge resonant inelastic x-ray scattering study (Fig. 1 (a)) of the antiferromagnetic Mott insulating state of Ca_2RuO_4. A set of low-energy (about 80 and 400 meV) and high-energy (about 1.3 and 2.2 eV) excitations are reported, which show strong incident light polarization dependence (Figs.1 (b,c)). Our results strongly support a spin-orbit coupled band-Mott scenario and explore in detail the nature of its exotic excitations (Fig.1 (d,e)). Guided by theoretical modeling, we interpret the low-energy excitations as a result of composite spin-orbital excitations. Their nature unveils the intricate interplay of crystal-field splitting and spin-orbit coupling in the band-Mott scenario (Fig.1 (f,g,h)). The high-energy excitations correspond to intra-atomic singlet-triplet transitions at an energy scale set by Hund's coupling. Our findings give a unifying picture of the spin and orbital excitations in the band-Mott insulator Ca_2RuO_4.

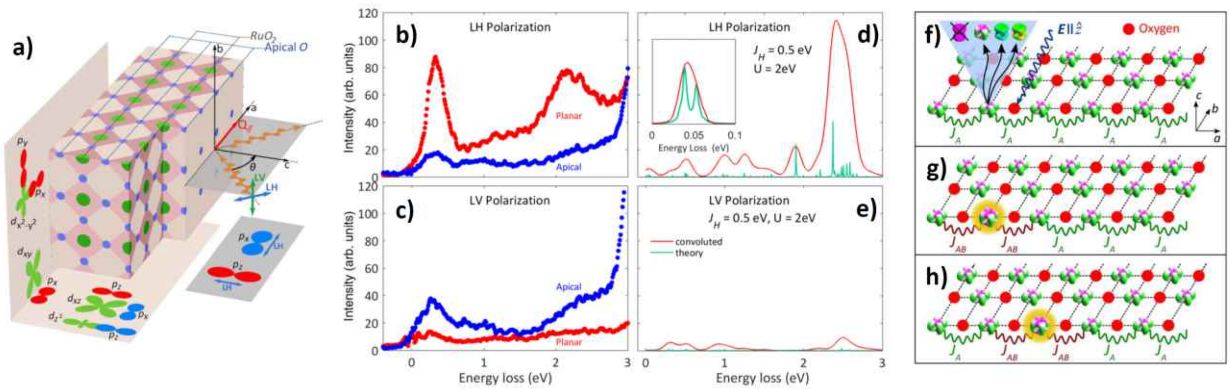

Fig. 1: (a) RIXS geometry with respect to the crystal lattice of Ca_2RuO_4 is displayed schematically. (b,c) RIXS spectra, with the elastic response subtracted, at the apical (blue lines) and planar (red lines) oxygen resonances for the respective light polarizations. (d,e) Calculated RIXS spectra for the planar site with respect to linear horizontal (b) and vertical (c) light polarization. (f) Schematic of an oxygen K-edge RIXS process creating a local excitation at the Ru site. Panels (g) and (h) illustrate propagation of the spin-orbital excitation.

Designing antiphase boundaries by atomic control of heterointerfaces

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Proceedings of The National Accademy of Sciences of the United States of America 115 (2018) 9485

Surface-type defects are known to influence the achievement of desired material performance. Therefore, a strategy to design and manipulate defect nucleation and formation can improve our understanding and in principle lead to the ability to control performance. The focus of this paper is the design of 2D surface-type defects, such as antiphase boundaries (APB). The origin of antiphase domains (APDs) in $La_{2/3}Sr_{1/3}MnO_3$ (LSMO113) thin film grown on Sr_2RuO_4 (SRO214) substrate is explored via the combination of advanced growth, atomic-resolved electron microscopy, first-principles calculations and defect theory. We observed that APBs in the $La_{2/3}Sr_{1/3}MnO_3$ film naturally nucleate at the step on the substrate/film (SRO214/LSMO113) interface (Fig. 1 and 2). Furthermore, atomic-resolved electron microscopy investigation showed that these APBs tend to merge when two steps exist at short distance to minimize the APB surface energy (Fig. 2). Such a design philosophy can be easily transferrable to many oxide-based heterostructure system as well as providing new aspects in non oxide wafers.

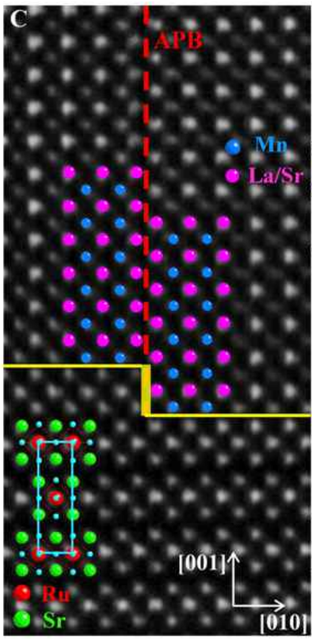

Fig. 1: HAADF-STEM image of LSMO113/SRO214 taken along the [100] direction, showing nucleation of APB at the step on the SRO214 substrate surface. The yellow lines indicate the interface where SRO substrate terminates with the SrO layer. The structural model is overlaid across the APB. The APB parallel to the (100) plane with double AO layers is marked by the vertical red line. The SRO unit cell is shown at the bottom left.

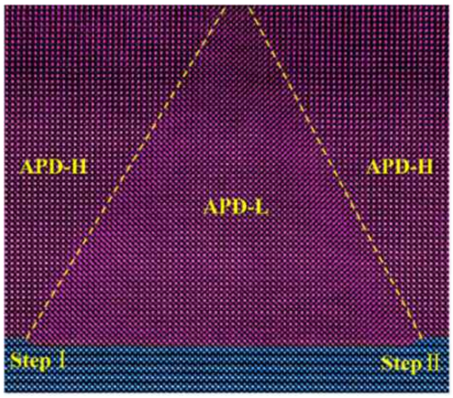

Fig. 2: The triangular APDs in the LSMO film on the SRO214 substrate with steps. Atomic-resolved HAADF-STEM images of a triangular APD taken along the [100] direction. The substrates are marked in blue and films in purple to emphasize the step position. The antiphase boundaries are indicated with yellow dotted lines. The LSMO region grown on the lower part of the step is defined as APD-L, and the higher part as APD-H.

Intrinsic Origin of Enhancement of Ferroelectricity in SnTe Ultrathin Films

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Physical Review Letters 121 (2018) 027601

Previous studies showed that, as ferroelectric films become thinner, their Curie temperature (Tc) and polarization below Tc both typically decrease. In contrast, a recent experiment [Chang et al., Science 353, 274 /(2016)] observed that atomic-thick SnTe films have a higher Tc than their bulk counterpart, which was attributed to extrinsic effects. We find, using first-principles calculations, that the 0-K energy barrier for the polarization switching (which is a quantity directly related to Tc) is higher in most investigated defect-free SnTe ultrathin films than that in bulk SnTe, and that the 5-unit-cell (UC) SnTe thin film has the largest energy barrier as a result of an interplay between hybridization interactions and Pauli repulsions. Further simulations, employing a presently developed effective Hamiltonian, confirm that freestanding, defect-free SnTe thin films have a higher Tc than bulk SnTe, except for the 1-UC case. Our work, therefore, demonstrates the possibility to intrinsically enhance ferroelectricity of ultrathin films by reducing their thickness.

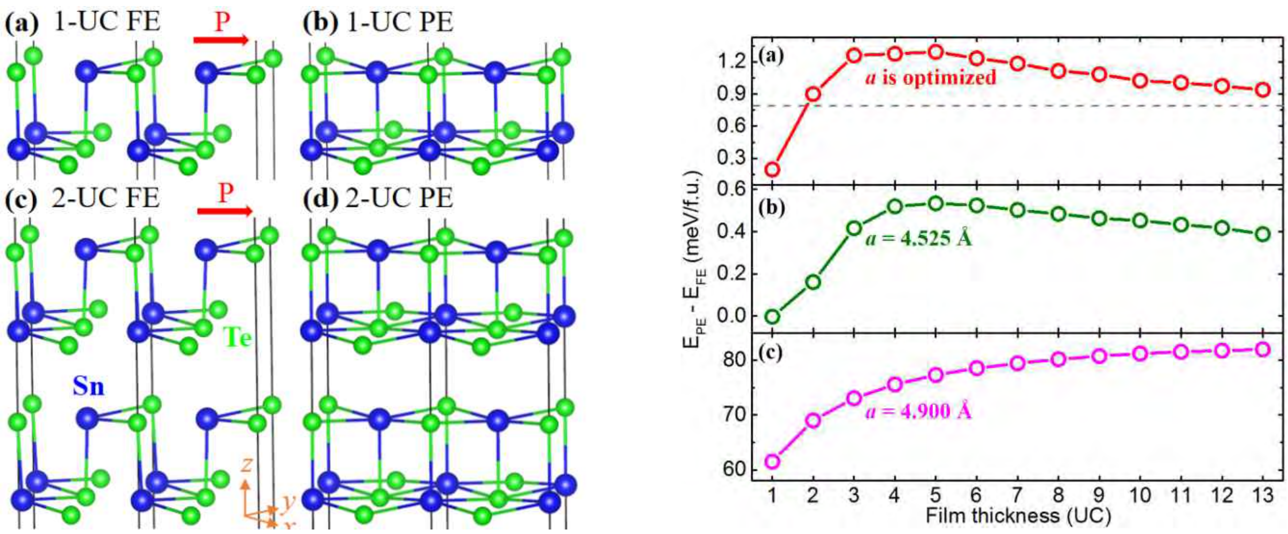

Fig. 1: Left panels: Crystal structures of SnTe thin films. Ferroelectric (FE) phases of (a) 1-UC and (c) 2-UC SnTe thin films. Paraelectric (PE) phases of (b) 1-UC and (d) 2-UC SnTe thin films. The red arrows indicate that polarizations are along the [110] direction. Right panels: Thickness dependence of the energy barriers between the PE and FE phases of SnTe films (a) with fully optimized lattice constants *a* and *b*, (b) when *a* and *b* are fixed at the bulk lattice constant of 4.525 Å, and (c) with a 7.2% tensile strain. The dashed line shows the results for bulk SnTe.

Ferroelectric Control of the Spin Texture in GeTe

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Nanoletters 18 (2018) 2751

The electric and nonvolatile control of the spin texture in semiconductors would represent a fundamental step toward novel electronic devices combining memory and computing functionalities. Recently, GeTe has been theoretically proposed as the father compound of a new class of materials, namely ferroelectric Rashba semiconductors. They display bulk bands with giant Rashba-like splitting due to the inversion symmetry breaking arising from the ferroelectric polarization, thus allowing for the ferroelectric control of the spin. Here, we provide the experimental demonstration of the correlation between ferroelectricity and spin texture. A surface engineering strategy is used to set two opposite predefined uniform ferroelectric polarizations, inward and outward, as monitored by piezoresponse force microscopy. Spin and angular resolved photoemission experiments show that these GeTe(111) surfaces display opposite sense of circulation of spin in bulk Rashba bands. Furthermore, we demonstrate the crafting of nonvolatile ferroelectric patterns in GeTe films at the nanoscale by using the conductive tip of an atomic force microscope. Based on the intimate link between ferroelectric polarization and spin in GeTe, ferroelectric patterning paves the way to the investigation of devices with engineered spin configurations.

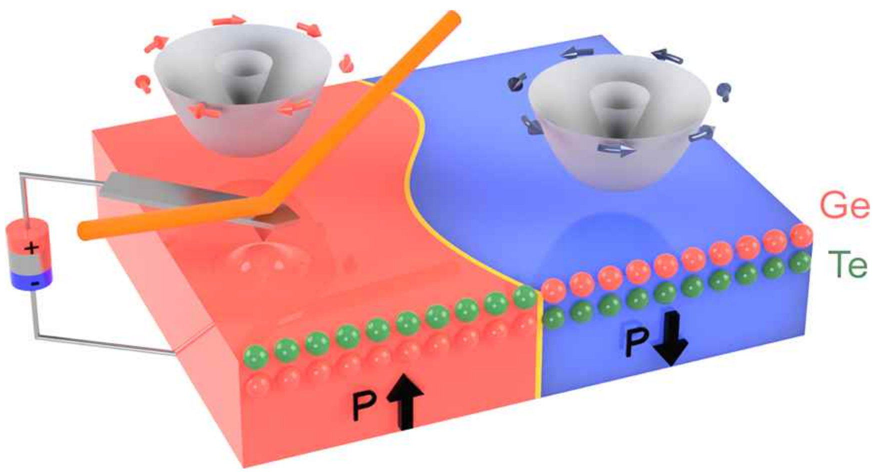

Fig. 1: Switching of GeTe spin texture of Rashba-type for two different orientations of the ferroelectric polarization. On the left (right) region, the polarization is pointing out of (towards) the surface (see vertical black thick arrow denoting P) and the spin expectation values at a specific constant energy map, denoted as red (blue) arrows, circulate clock-wise (counterclockwise).

Interplay between spin-orbit coupling and ferromagnetism in magnetotransport properties of a spin-polarized oxide two-dimensional electron system

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Physical Review B 98 (2018) 075409

We report on the magnetotransport properties of a spin-polarized two-dimensional electron system (2DES) formed in $LaAlO_3$ (LAO)/$EuTiO_3$/$SrTiO_3$ (STO) heterostructures. We show that, at low temperature, the 2DES magnetoconductance exhibits weak antilocalization (WAL) corrections related to Rashba spin-orbit scattering, in analogy with the LAO/STO 2DES. However, the characteristic spin-orbit scattering field decreases substantially for carrier density higher than 1.9×10^{13} cm^{-2}. We attribute this behavior to the masking effect of ferromagnetism, which sets in at the same carrier density. Thanks to the low feromagnetic temperature T_{FM} of our system (around 10K) we are able to investigate the competition between Rashba spin-orbit coupling and ferromagnetism also as a function of the temperature. Indeed, we demonstrate that WAL corrections reemerge when ferromagnetic correlations are reduced approaching T_{FM}.Our work shows that, while weak antilocalization corrections to the magnetoconductance are strongly reduced by the emergence of ferromagnetism, they persist in a large part of the phase diagram of a spin-polarized oxide 2DES. These results suggest that the LAO/ETO/STO 2DES, characterized by large and tunable Rashba SO coupling and magnetism, is a possible candidate for quantum spintronic applications.

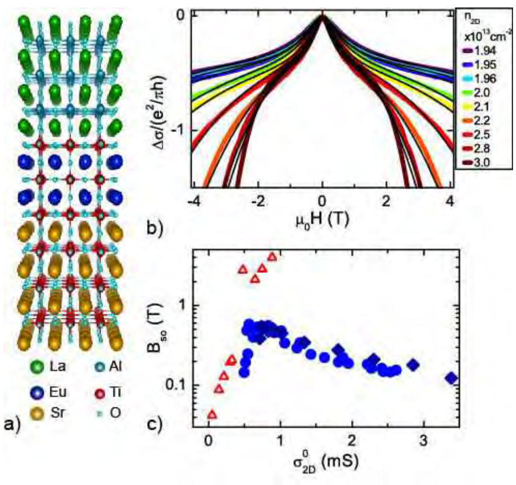

Fig.1: (a) Crystal structure of LAO/ETO/STO heterostructures. (b) Differential magnetoconductance curves versus carrier concentration. (c) Spin-orbit characteristic fields extracted from fits (blue data). The red triangles are data referring to LAO/STO samples.

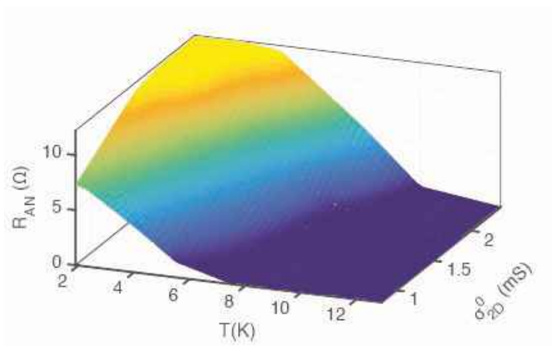

Fig. 2: Behavior of the anomalous Hall effect component R_{AN} as a function of the field effect-tuned sheet conductance (which has a one-to-one correspondence with the carrier concentration) and of the temperature. R_{AN} is due to the presence of ferromagnetic correlations in the 2DES.

Intrinsic and anisotropic Rashba spin splitting in Janus transition-metal dichalcogenide monolayers

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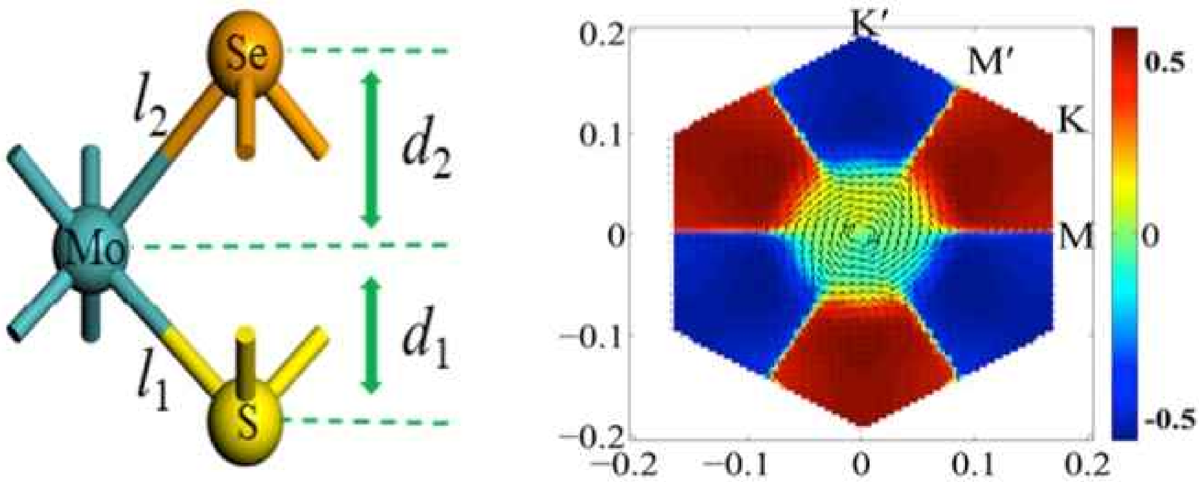
Physical Review B 97 (2018) 235404

Transition-metal dichalcogenides (TMD) monolayers are important two-dimensional materials for the study of fundamental physics in the field of spintronics. Recently, a newly synthesized Janus TMD MoSSe was found to intrinsically possess both the in-plane inversion and the out-of-plane mirror-symmetry breaking. Here we performed first-principles calculations in order to systematically investigate the electronic band structures of a series of Janus monolayer TMD with chemical formula MXY (M = Mo,W and X,Y = S, Se, Te). We found that they possess robust electronic properties like their parent phases. We explored also the effect of perpendicular external electric field and in-plane biaxial strain on the Rashba spin splittings. The Zeeman-type spin splitting and valley polarization at K(K') point are well preserved and we observed a Rashba-type spin splitting around the Γ point for all the MXY systems. We have also found that these spin splittings can be enhanced by an external electric field collinear with the local electric field due to the presence of polar bonds and by the compressive strain. The Rashba parameters change linearly with the external electric field, but nonlinearly with the biaxial strain. The compressive strain is found to enhance significantly the anisotropic Rashba spin splitting.



The K point and the VBM around Γ point. The arrows correspond to the in-plane spin vector orientation and the colors indicate the out-of-plane component of the spin.

Position and momentum mapping of vibrations in graphene nanostructures in the electron microscope

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Nature 573 (2019) 274

Even though the knowledge of vibrational properties is a key part of our understanding and optimization of a material's behaviour, phonon dispersions of freestanding 2D materials have long remained elusive because of the experimental limitations of inelastic X-ray and neutron scattering. Here we show that electron energy loss (EEL) spectroscopy in a transmission electron microscope with improved momentum and energy resolution can successfully probe the local vibrational charge responses in nanosized materials. We developed an ab-initio theory that allows to express the EEL intensity in terms of a newly introduced momentum-dependent effective charge which fully takes into account the effect of valence-electron screening beyond the spherical rigid-ion approximation. Measured scattering intensities are accurately reproduced by our theory, thus enabling a detailed interpretation of experimental data. Remarkably, we show that sizeable EEL intensities can be expected at large momenta in metals and insulators alike, irrespectively of their infrared polarizability. Additionally, a nanometre-scale mapping of selected momentum- resolved vibrational modes using graphene nanoribbon structures has enabled us to spatially disentangle bulk, edge and surface vibrations, proving the feasibility of studying local vibrational modes in truly 2D freestanding monolayers at the nanometre scale.

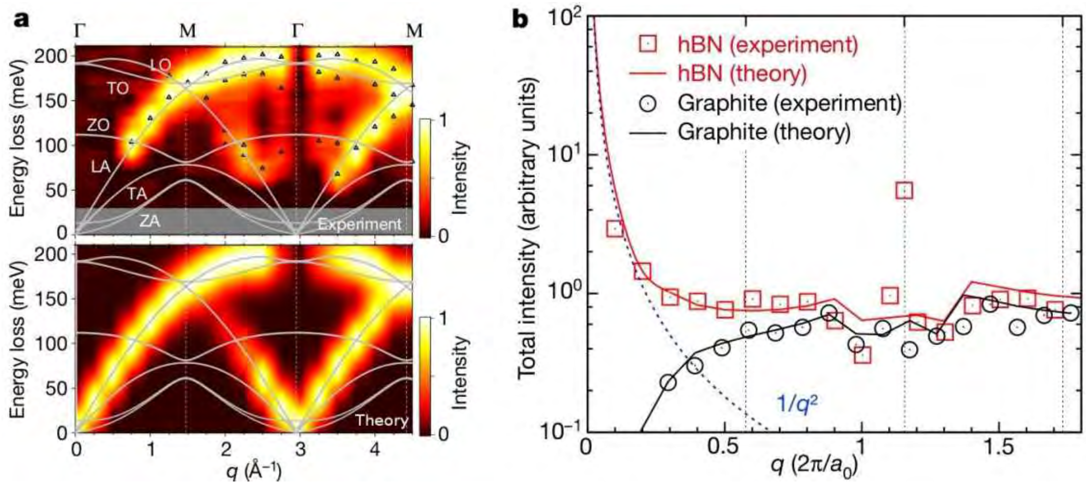

Fig. 1: a) Comparison of experimental (top) and theoretical (bottom) EEL spectra for few-layer graphite; the grey area show experimentally inaccessible region dominated by quasi-elastic peak. b) Total phonon intensity of metallic graphite and semiconducting boron-nitride from theory and experiments, displaying comparable strength at large momenta

Nodal superconducting exchange coupling

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Nature Materials 18 (2019) 1194

The superconducting equivalent of giant magnetoresistance involves placing a thin-film superconductor between two ferromagnetic layers. A change of magnetization-alignment in such a superconducting spin-valve from parallel (P) to antiparallel (AP) creates a positive shift in the superconducting transition temperature (ΔT_c) due to an interplay of the magnetic exchange energy and the superconducting condensate. The magnitude of ΔT_c scales inversely with the superconductor thickness (d_S) and is zero when d_S exceeds the superconducting coherence length (ξ) as predicted by de Gennes. Here we report a superconducting spin-valve effect involving a different underlying mechanism (Fig. 1) that goes beyond de Gennes in which magnetization-alignment and ΔT_c are determined by the nodal quasiparticle-excitation states on the Fermi surface of the d-wave superconductor $YBa_2Cu_3O_{7-\delta}$ (YBCO) grown between insulating layers of ferromagnetic $Pr_{0.8}Ca_{0.2}MnO_3$. We observe ΔT_c values that approach 2 K with ΔT_c oscillating with d_S over a length scale exceeding 100 ξ and, for particular values of d_S, we find that the superconducting state reinforces an antiparallel magnetization-alignment. These results pave the way for all-oxide superconducting memory in which superconductivity modulates the magnetic state.

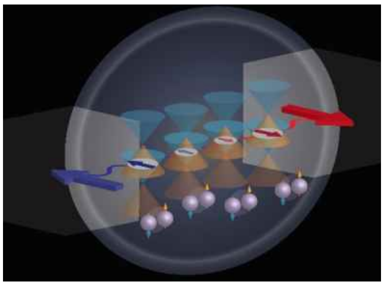

Fig. 1: Sketch illustrating the energy splitting of low-energy quasiparticle excitations in d-wave superconductor due to the exchange coupling at the superconductor/ferromagnet interfaces (YBCO/FI).

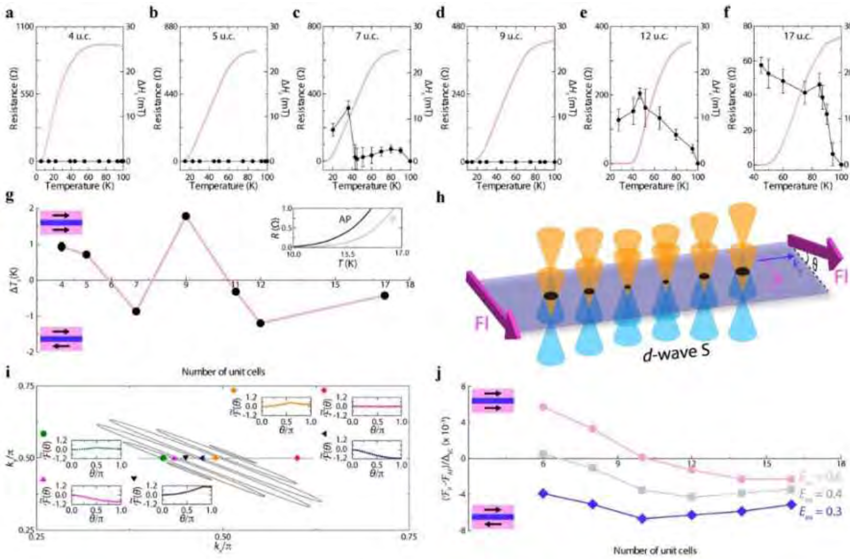

Fig. 2: (a)-(f) R(T) curves showing ΔH_c through the superconducting transition for trilayers with different values of d_S (labelled). (g) maximum values of $\Delta T_c = T_c\,(P) - T_c\,(AP)$ versus d_S with the inset showing R(T) curves in the P and AP states for d_S = 9 u.c. (h), a sketch illustrating the energy splitting of low-energy quasiparticle excitations in YBCO due to E_{ex} at the YBCO/FI interfaces. (i,) calculated Fermi surface of YBCO between two FIs with relative magnetization angle q. Insets show free energy curves at points in k-space versus . (j) Minima in free energy for P (top) and AP (bottom) states versus d_S for different values of E_{ex} (given in units of the intra-u.c. charge hopping parameter). The sketches in g and j show the ground state (P or AP) of the trilayer.

Anomalous and Polarization-Sensitive Photoresponse of T_d-WTe_2 from Visible to Infrared Light

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Advanced Materials 31 (2019) 1804629

Recently, an emergent layered material Td –WTe_2 was explored for its novel electron-hole overlapping band structure and anisotropic inplane crystal structure. Here, the photoresponse of mechanically exfoliated WTe_2 flakes is investigated. A large anomalous current decrease for visible (514.5 nm), and mid- and far-infrared (3.8 and 10.6 μm) laser irradiation is observed, which can be attributed to light-induced surface bandgap opening from first-principles calculations. The photocurrent and responsivity can be as large as 40 μA and 250 A W^{-1} for a 3.8 μ m laser at 77 K. Furthermore, the WTe_2 anomalous photocurrent matches its in-plane crystal structure and exhibits light polarization dependence, maximal for linear laser polarization along the W atom chain
a direction and minimal for the perpendicular *b* direction, with the anisotropic ratio of 4.9. Consistently, first-principles calculations confirm the angle-dependent bandgap opening of WTe_2 under polarized light irradiation. The anomalous and polarization-sensitive photoresponses suggest that linearly polarized light can significantly tune the WTe_2 surface electronic structure, providing a potential approach to detect polarized and broadband lights up to far infrared range.

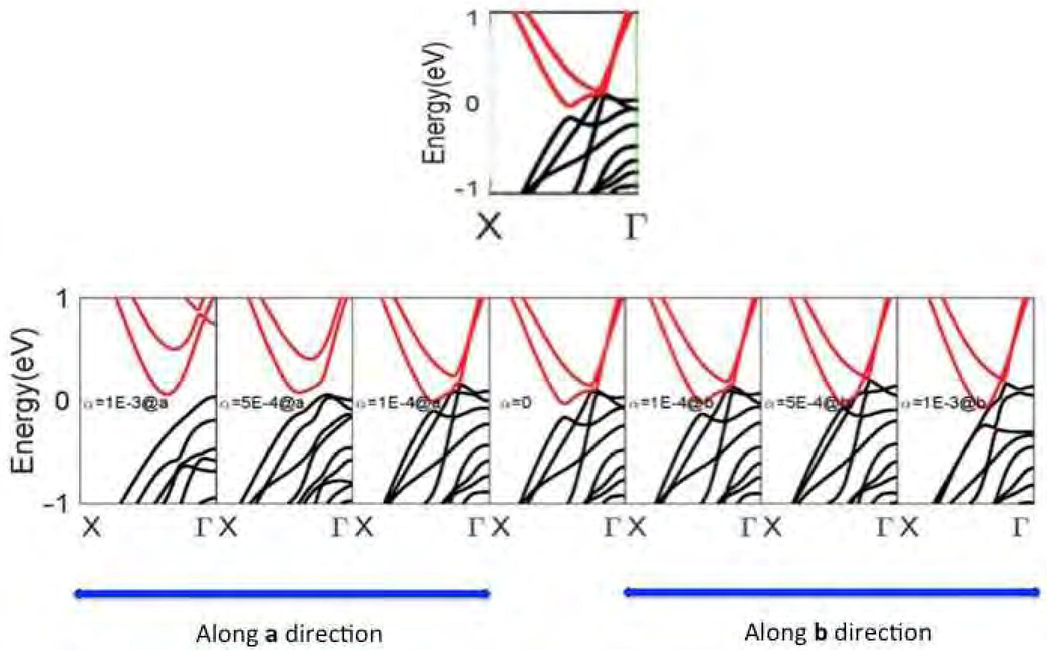

Fig. 1: The bulk WTe_2 electronic structure without laser irradiation (top panel). WTe_2 electronic structure along X-Γ directions for different values of parameter α when the 700 nm linear polarization direction of the light is along the **a** or **b** directions - α is a parameter related to the input laser power, its physical meaning is the number of excitons mixed in the electrons of a unit cell (bottom panel).

Band splitting with vanishing spin polarizations in noncentrosymmetric crystals

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Nature Communications 10 (2019) 5144

The Dresselhaus and Rashba effects are well-known phenomena in solid-state physics, in which spin–orbit coupling splits spin-up and spin-down energy bands of nonmagnetic noncentrosymmetric crystals. Here, we discuss a phenomenon we dub band splitting with vanishing spin polarizations (BSVSP), in which, as usual, spin-orbit coupling splits the energy bands in nonmagnetic non-centrosymmetric systems. Surprisingly, however, both split bands show no net spin polarization along certain high-symmetry lines in the Brillouin zone. In order to rationalize this phenomenon, we propose a classification of point groups into pseudo-polar and non-pseudo-polar groups. By means of first-principles simulations, we demonstrate that BSVSP can take place in both symmorphic (e.g., bulk GaAs) and non-symmorphic systems (e.g., two dimensional ferroelectric SnTe). Furthermore, we identify a linear magnetoelectric coupling in reciprocal space, which could be employed to tune the spin polarization with an external electric field. The BSVSP effect and its manipulation could therefore form the basis for future spintronic devices.

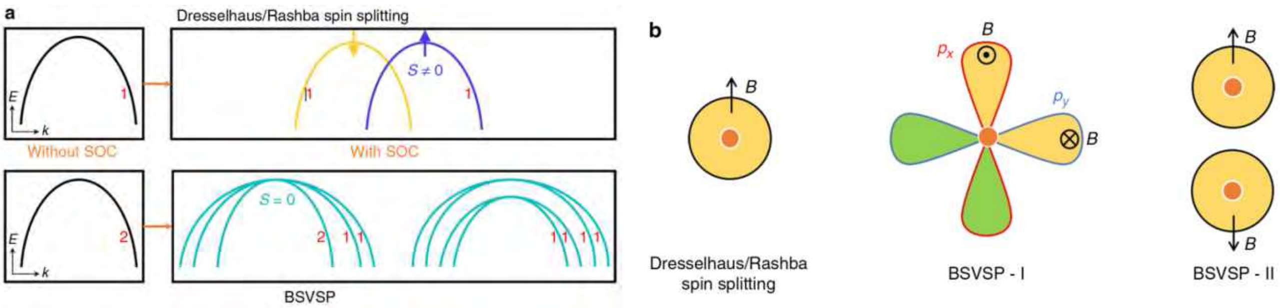

Fig. 1 The phenomena and mechanisms of Dresselhaus/Rashba spin splitting and BSVSP. a) Schematic depiction of Dresselhaus/Rashba spin splitting and BSVSP. "1" and "2" means single and double degenerate, respectively. In the Dresselhaus/Rashba spin splitting case, a non-degenerate band (without considering spin) splits into two bands with opposite nonzero spin polarizations. In the case of BSVSP, a double degenerate band (without considering spin) splits, resulting in some non-degenerate bands without net spin polarizations. b) Schematic illustration of the difference between Dresselhaus/Rashba spin splitting and BSVSP. In the case of Dresselhaus/Rashba spin splitting, a k-dependent magnetic field induces the band splitting. In BSVSP–I (II), the magnetic fields acting on two different p orbitals of the same atom (acting on different atoms of the same kind) are equal in strength but opposite, resulting in a band splitting with vanishing spin polarization

Activity D: Light-matter interaction and non-equilibrium dynamics in advanced materials and devices

Activity Leader: Alberto Porzio

This research activity focuses on the science and optics of light-matter interaction. More in detail, it aims at exploiting optical techniques to probe/develop new materials, at creating innovative devices for application in quantum technology and at designing novel applications. We investigate phenomena and effects arising when light meets superconductors, oxides, non-linear optical materials, metamaterials, the atmospheric medium and other materials. We approach this in a multidisciplinary frame where condensed-matter physicists meet materials science, laser and quantum optics experts.
We aim at developing micro- and nano-fabrication, material science and optical methods for characterizing ,also at low temperatures, novel materials and designing innovative devices of unprecedented characteristics.

More in detail we work on: a) Superconducting single-photon and THz detectors; b) Non-linear optical materials for novel quantum communication protocols; c) LIDAR and remote optical sensing; d) Light-driven structuring and fabrication via laser ablation; e) Spectroscopic methods (including micro-Raman spectroscopy and MOKE); f) Passive and active metamaterials.

- The main effort is on the realization of nanostructures based on NbN, MoSi, NbRe, NbN/NiCu and Co-doped Ba122. These materials present different transport and photo response properties that make them suitable for different applications. Moreover, there is a joint effort of many SPIN researchers for the realization of hybrid superconducting/magnetic sub-micron digital memories.
- The use of non-linear optical materials in quantum information is an enabling technology for the generation of new class of quantum states for different quantum information protocols.
- A common effort between LIDAR experts and superconducting community aims at realizing a photon counting LIDAR device. A superconducting single-photon detector, so far tested in a laboratory on a tabletop apparatus, paves the way to a high sensitivity Near InfraRed LIDAR.
- Ultrashort laser pulses on solid targets allows surface structuring. In particular, polarization of singular fs laser generates asymmetric structures whose properties depend on the ambient gas pressure. Matrix Assisted Pulsed Laser Evaporation (MAPLE) has several applications in biosensors, biofactories, wastes recycling, studies on cancer, etc. In particular, it allows enhancing enzymes functionality in reactions.
- Micro-Raman and Surface Enhanced Raman spectroscopy of films and organic materials are powerful methods for investigating specific properties like lattice compression and magnon light-scattering and to develop new methodologies in the field of fluid analysis. Magneto Optical Kerr Effect (MOKE) allows to study the local coercivity and Kerr rotation angle of thin films, in order to correlate these characteristic parameters to the fabrication procedure.
- Tuning the graphene/metal contact promises to improve electronic properties of Graphene Field Effect Transistors. In particular, by realizing different geometries, we study the contact and channel resistance as well as the carrier mobility as a function of gate voltage and temperature.

Surface structures with unconventional patterns and shapes generated by femtosecond structured light fields

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Scientific Reports 8 (2018)13613

An investigation on ultrashort laser surface structuring with structured light fields generated by various q-plates is reported. In particular, q-plates with topological charges q = 1, 3/2, 2, 5/2 are used to generate femtosecond (fs) vector vortex beams, and form complex periodic surface structures through multi-pulse ablation of a solid crystalline silicon target. We show how optical retardation tuning of the q-plate offers a feasible way to vary the fluence transverse distribution of the beam, thus allowing the production of structures with peculiar shapes, which depend on the value of q. The features of the generated surface structures are compared with the vector vortex beam characteristics at the focal plane, by rationalizing their relationship with the local state of the laser light. Our experimental findings demonstrate how irradiation with fs complex light beams can offer a valuable route to design unconventional surface structures.

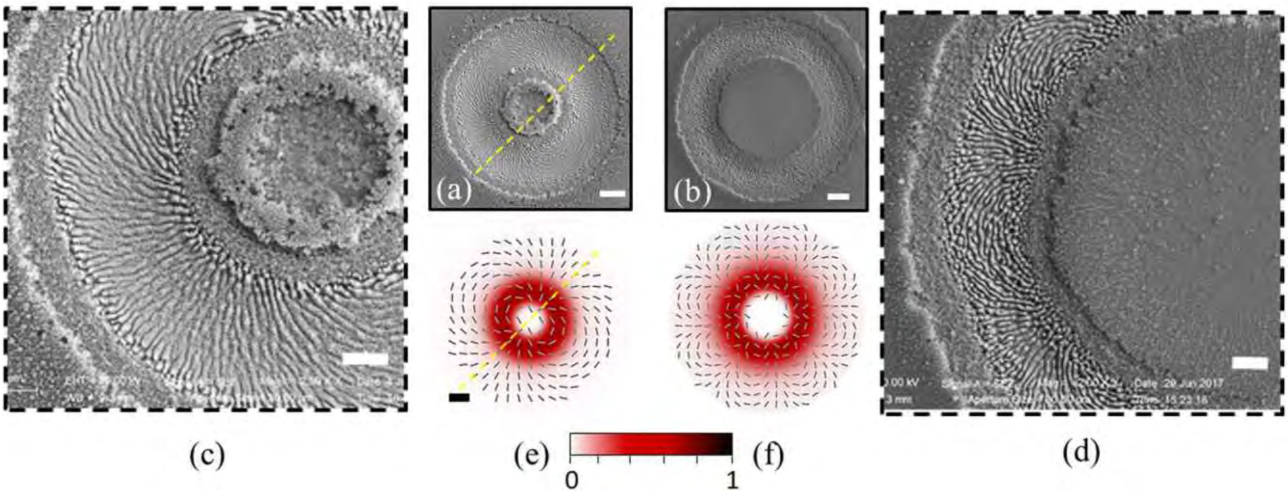

Fig. 1: Panels (a) and (b): Example of SEM images showing the morphologies on the silicon target after an irradiation sequence of N=200 pulses in tuned condition of q-plates (δ=π), for (a) q=1, and (b) q=5/2, respectively. The pulse energy is E_0=50 μJ for q=1 and E_0=100 μJ for q=5/2. Panels (c) and (d) display zoomed views of the SEM image. The scale bars in SEM images are 20 μm for (a) and (b) and 10 μm for (c) and (d). Panels (e) and (f) report simulation of far-field beam profile with local direction of the beam polarization. The yellow dotted line in panel (a) marks a direction along which grooves alignment closely resembles a quasi-radial pattern, while in panel (e) it shows the corresponding line in the state of polarization (SoP) of the beam. On either sides of this dotted lines, the surface structures and SoP of the beam are arranged as a family of spiral-like patterns.

Suboptimal Coding Metasurfaces for Terahertz Diffuse Scattering

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Scientific Reports 8 (2018) 11908

In 2014, the concept of "coding" meta materials has been proposed, in which meta materials are characterized by digital coding particles of '0' and '1' (Cui et al., Light: Science & Applications 3, e218, 2014). It was demonstrated that the Electro Magnetic (EM) waves can be manipulated by changing the coding sequences of '0' and '1'. The coding particles provide a link between the physical and digital world, leading to digital metamaterials and field programmable metamaterials, which can control EM waves in real time.

In the present work, we apply these concepts to the design, fabrication and experimental characterization of digital meta surfaces to attain diffuse scattering - one of the most important features of coding metamaterials - at Terahertz (THz) frequencies. In particular, the study proposed a scaling law to reduce the radar cross sections (RCS), which essentially consists of maintaining the meta surface directivity independent of its electrical size. These new results extend the experimental validation of a general design approach to the THz band and to electrically large (~32-wavelength-sized) structures. Overall, they confirm the possibility to effectively design electrically large diffuse-scatterers via a simple, deterministic and computationally cheap algorithm, with performance comparable with that attainable via computationally expensive brute-force optimization. Our findings may have a potentially broad impact in several fields of optics and photonics, including diffusive imaging, computational imaging and light-trapping mechanisms for photovoltaics.

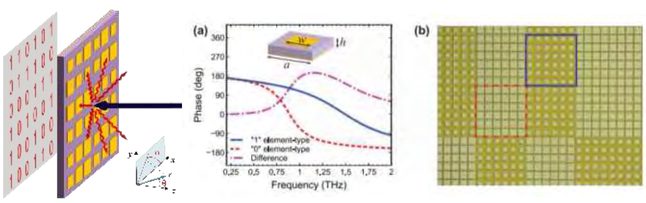

Fig. 1: Diffuse scattering on a coding metasurface under normally incident plane wave illumination (left) is realized exploiting the phase difference (0/π) (right, (a)) between two types of "supercell" (right, (b)).

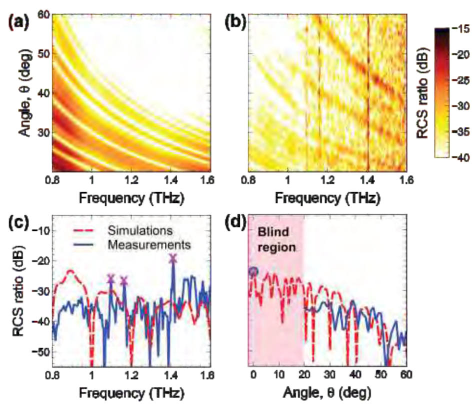

Fig. 2: Normalized Radar Cross Section (RCS) for normal-incidence simulated (a) and measured (b) in false-color scale as a function of frequency f and observation angle θ; RCS vs f (c) @30° and vs θ (d) @1

Simple method for the characterization of intense Laguerre-Gauss vector vortex beams

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Applied Physics Letters 112 (2018) 211103

Complex light beams with non-Gaussian intensity profiles and spatially variant state of polarization are becoming more and more attractive in many fields of optical science and technology. In this context, the progressive development of efficient beam converters is offering the possibility of generating powerful, pulsed optical vortex (OV) and vector-vortex (VV) beams, thus permitting experiments with such structured light beams with the aim of observing new experimental features in emerging applications, e.g. laser processing and surface structuring,. The local state of a laser beam (e.g., fluence and polarization) can strictly influence the laser-induced modifications (e.g., melting, phase transformation, ablation, features of the surface structures engraved on the material, etc.). Hence, the need of a careful characterization of the beam properties in order to unveil the mechanisms involved in several laser-induced material transformation processes. For intense Gaussian laser beams, a direct method to characterize the beam spot size is based on the variation of modified area vs laser energy; such a method is generally used in experiments with intense beams. In this study, we have illustrated a direct experimental technique based on the analysis of laser ablation spots allowing to characterize the properties of intense, OV and VV beams with femtosecond pulse duration, in weak focusing conditions. In particular, we have discussed various ways to gather an estimate of the beam spot size as well as the state of polarization by means of the analysis of the laser-induced surface structures orientation. The method was applied to silicon, but the approach can likely be extended to other materials or to still more complex VV beams.

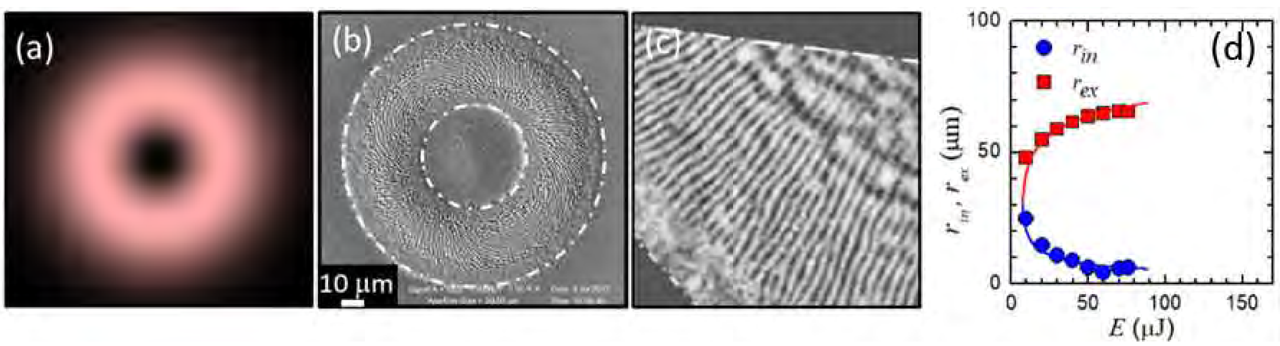

Fig. 1: (a) typical annular profile of a VV beam; (b) shallow ablation crater generated on a silicon plate by a VV beam – the inner part of the crater is decorated by laser induced periodic surface structures whose orientation is directly linked to the local direction of the laser beam polarization; (c) zoomed view of the surface structures; (d) variation of the inner and outer crater radii as a function of laser pulse energy E, from which the laser beam spot size is derived by means of a fitting procedure (solid lines).

Laser surface texturing of copper and variation of the wetting response with the laser pulse fluence

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Applied Surface Science 470 (2019) 817

We report an experimental investigation on laser surface texturing of copper targets by Ti:Sa femtosecond laser pulses, addressing their wetting response to water droplets. In particular, fs laser surface processing is used to develop hierarchical surface structures by writing parallel micro-trenches with a period of 50μm at di erent laser pulse fluences. The laser irradiation simultaneously induces both the formation of laser induced periodic surface structures (LIPSS), in form of periodic ripples, and the random decoration with nanoparticles, resulting in the formation of a multiscale surface morphology. The morphological features of the samples are investigated and correlated with their wetting response, through static contact angle measurements. Our findings evidence a progressive increase of the contact angle with the laser pulse fluence. The combination of the microscale trenches, written by laser line scanning, with the ripples patterns and the random nanoparticles decoration, formed on the surface, allow developing highly hydrophobic copper samples with contact angles reaching values around 160°, presenting potential interest for wettability applications.

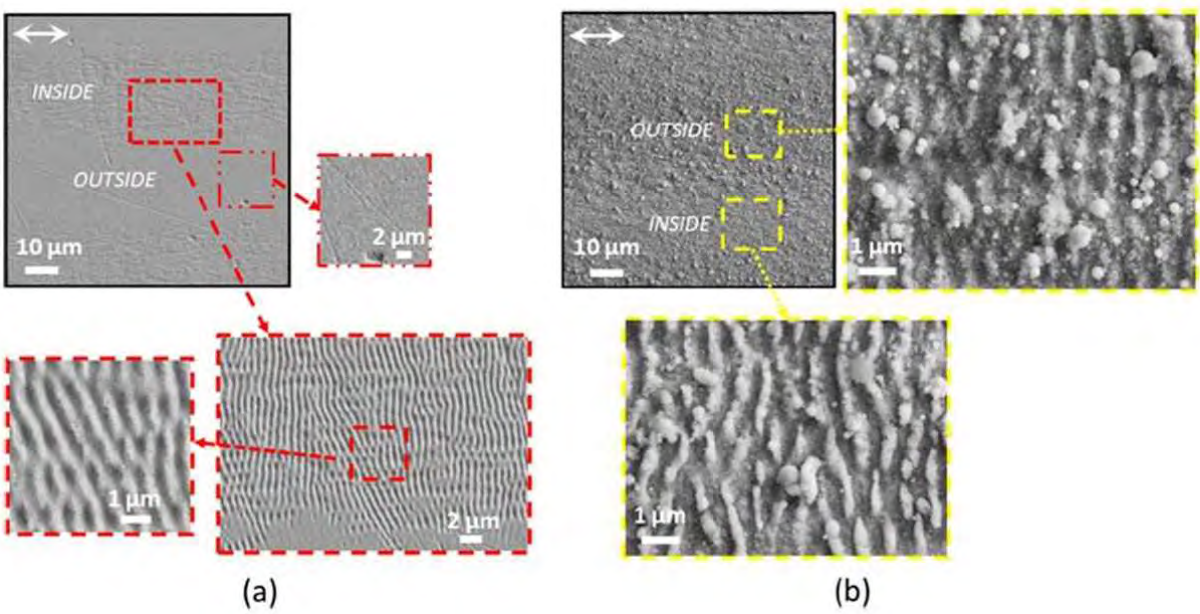

Fig. 1: SEM images of the sample surface addressing the morphological features for a peak fluence of: (a) Fp=0.8J/cm^2; (b) Fp=6.5J/cm^2. The SEM images within the dashed boxes are zoomed views of the selected areas. The double-headed arrow indicates the laser beam polarization.

Geometrical Dependence on the Onset of Surface Plasmon Polaritons in THz Grid Metasurfaces

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Scientific Reports 9 (2019) 924

Surface plasmon polaritons are e.m. radiation modes propagating at the interface between a metal and a dielectric layer. The threshold energy of SPPs is connected to the plasma frequency of the conducting layer that in standard metallic films is of the order of 10^{15} Hz, preventing the exploitation of these excitations at lower frequencies. Patterning the conducting layer in a periodic array "dilutes" the metal and allows to lower its plasma frequency by orders of magnitude.
We show that in THz conducting metasurfaces in shape of grids the corresponding plasma frequency (ω_r) and hence the excitation of SPPs can be controlled over a factor 10 simply manipulating the amount of metal per unit cell area (filling factor F). A simple lumped element analytical model is developed to trace out experimental data acquired through Terahertz Time Domain Spectroscopy measurements and results from full wave simulations. In Fig. 1 a sketch of the experiment presenting the THz signal passing through two different metagrids is reported. In Fig. 2 the dependence of the plasma frequency versus *F* is displayed for both typologies of analyzed metasurfaces. In the region $\omega < \omega_r$ (F) the optical device is fully homogenous (metamaterial regime) with respect to the impinging wave, and its dielectric function smoothly depends on frequency. On the contrary, for $\omega > \omega_r$ (F) the transmission spectrum starts showing "geometric" resonances (photonic crystal regime) indicating the onset of commensurability between the unit cell periodicity *p* and the beam wavelength.

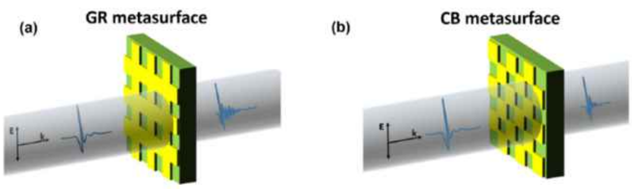

Fig. 1: In the two panels a simple schematic of the experiment showing the THz beam normally impinging (a) a pure grid (GR) and (b) a chessboard (CB) metasurface with same periodicity *p* = 600 μm. Metallic layer is copper 30 μm thick on 150 μm dielectric FR4 substrate.

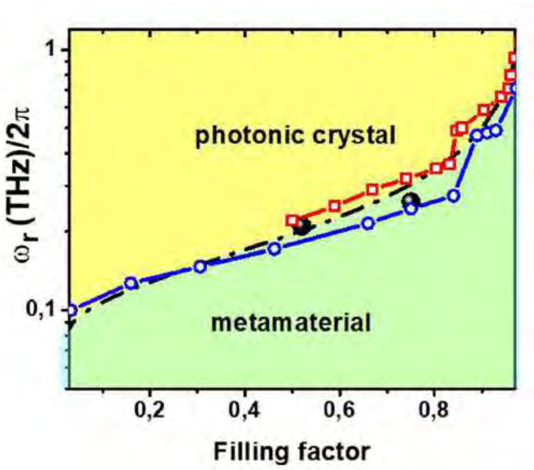

Fig. 2: Plot of the THz metagrid plasma frequency w_r as a function of the filling factor. Full black dots represent experimental values measured on the samples shown in Fig. 1, red squares and blue circles are obtained via full wave simulations. The black dash-dotted line describes the result obtained using the lumped element model.

Superconductor to resistive state switching by multiple fluctuation events in NbTiN nanostrips

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Scientific Reports 9 (2019) 8053

We report on measurements of the switching current distributions on two-dimensional superconducting NbTiN strips that are 5 nm thick and 80 nm wide. We observe that the width of the switching current distributions has a non-monotonous temperature dependence, where it is constant at the lowest temperatures up to about 1.5 K, after which it increases with temperature up to 2.2 K. Above 2.5 K any increase in temperature decreases the distribution width which at 4.0 K is smaller than half of the width observed at 0.3 K. By using a careful analysis of the higher order moments of the switching distribution, we show that this temperature dependence is caused by switching due to multiple fluctuations. We also find that the onset of switching by multiple events causes the current dependence of the switching rate to develop a characteristic deviation from a pure exponential increase, that becomes more pronounced at higher temperatures, due to the inclusion of higher order terms.

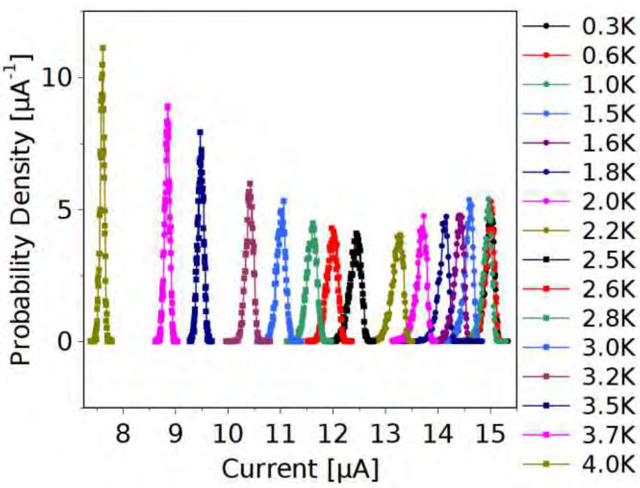

Fig. 1: Measured switching-current distributions for temperatures between 0.3 K (right-most) and 4 K (left-most) that shows the counterintuitive narrowing with increased temperature above 2.5 K.

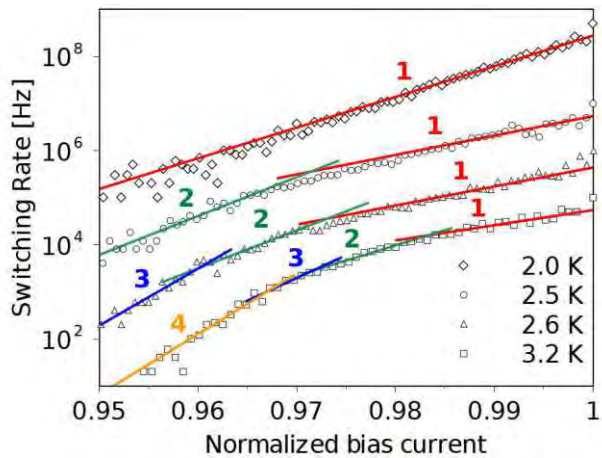

Fig. 2: Switching rates for four different temperatures. The solid lines are fits to the data using the indicated higher order multiple phase slip events included. For clarity we have multiplied both the data and fits by a factor of 10 (2.6 K), 100 (2.5 K) and 5000 (2.0 K) respectively.

Continuous-variable entangled states of light carrying orbital angular momentum

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Physical Review A 100 (2019) 012321

The orbital angular momentum of light, unlike spin, is an infinite-dimensional discrete variable and may hence offer enhanced performances for encoding, transmitting, and processing quantum information. Hitherto, this degree of freedom of light has been studied mainly in the context of quantum states with definite number of photons. On the other hand, field-quadrature continuous-variable quantum states of light allow implementing many important quantum protocols not accessible with photon-number states. Here, we realize a scheme based on a q-plate device for endowing a bipartite continuous-variable Gaussian entangled state with nonzero orbital angular momentum. We then apply a reconfigurable homodyne detector working directly with such nonzero orbital angular momentum modes in order to retrieve experimentally their entire quantum-state covariance matrix, thus providing a full characterization of their quantum fluctuation properties. Our work is a step towards generating multipartite continuous-variable entanglement in a single optical beam.

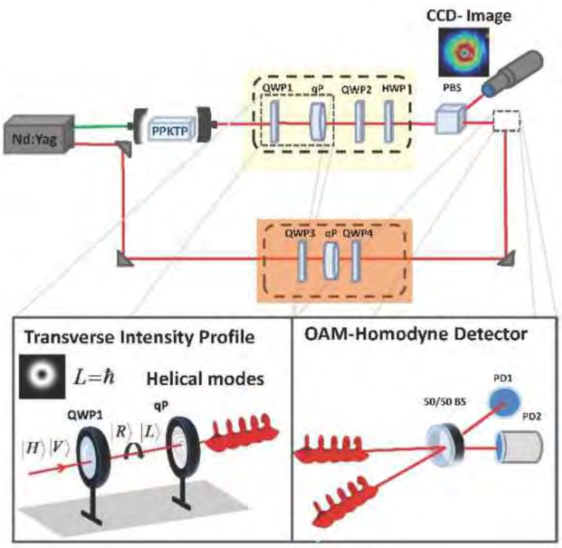

Fig. 1: Schematic of the experimental set-up. An optical parametric Oscillator generates a pair of orthogonally-polarized entangled modes. The yellow area shows the optical set-up for manipulating the polarization and Orbital Angular Momentum (OAM) d.o.f. of the beams. A similar set-up is placed along the Local Oscillator path for OAM homodyning (dark orange). The bottom-right inset shows

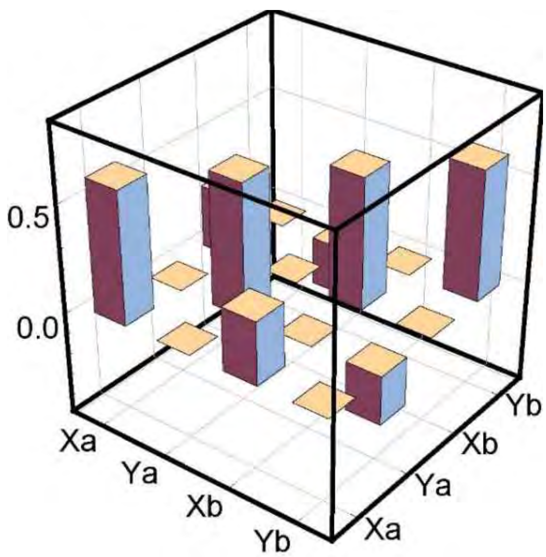

Fig. 2: Graphic representation of the measured covariance matrix of the entangled OAM state.
The non-zero elements outside the main diagonal are a signature of quantum correlation between pairs of quadratures of modes carrying different OAM.

Activity E: Advanced materials and techniques for organic electronics, biomedical and sensing applications

Activity Leader: Mario Barra

In the last years, functional compounds have been attracting a widespread interest, in light of their favorable use for the development of smart and highly-integrated systems, by simultaneously incorporating sensing, actuation and electronic control functions. Through the continuous availability of electronic materials with advanced chemico-physical features, in future, this technological paradigm will be further enhanced and extended to several applicative fields, up to the concrete perspective to integrate smart functionalities in everyday objects. Innovative materials with improved biocompatibility features, moreover, will support the birth of a new generation of bio-medical devices, able to work with minimal invasiveness at the interface with living matter.

Starting from this general scenario, this activity is aimed at investigating the fundamental properties, at micro- and nanoscale, of new compounds with specific responsiveness to physical (i.e. electromagnetic radiation, magnetic fields, heat, mechanical stress) and chemical (i.e. gases, liquid analytes) external stimuli. The research work is focused on selected categories of materials: organic conjugated systems (small molecules and polymers), transition metal compounds (oxides and dichalcogenides) and multifunctional composites (magnetic elastomers, hydrid organic-inorganic frameworks, etc). Attention is paid also to analyze and possibly exploit new physical phenomena arising in related artificial and natural hetero-structures.

These efforts are oriented to support the realization of innovative sensing and electronic devices to be mainly employed in the fields of smart systems and biomedicine. The scientific chain is completed with the development of specialized computational techniques for processing large amounts of data produced by such devices and/or by sophisticated diagnostic modalities.

In summary, the activity objectives are mainly targeted on three deeply-related applicative areas:

- Innovative devices for biomedical applications and software toolboxes for diagnostic and health-monitoring data analysis;
- Advanced sensing and actuating systems with high level of integration and/or multifunctional response;
- Electronic and optoelectronic organic devices fabricated also on flexible and/or transparent substrates.

The envisioned research activities rely on a wide number of complementary experimental approaches, including:

- Physical vapor deposition methods (e.g. Pulsed Laser Deposition, Supersonic molecular beam evaporation) and solution-based (e.g. ink-jet printing, electro-spinning);
- Advanced computational methods for data processing;
- Advanced radiation-based material characterization techniques;
- UV and e-beam lithography processes;
- Scanning Probe (AFM, MFM, STM-BEEM, PFM, Kelvin probe) and Electron (SEM) microscopy.

Subnanometer resolution and enhanced friction contrast at the surface of perylene diimide PDI8-CN_2 thin films in ambient conditions

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Langmuir 34 (2018) 3207

We report high-resolution surface morphology and friction force maps of polycrystalline organic thin fi lms derived by deposition of the *n*-type perylene diimide semiconductor PDI8-CN_2. We show that the in-plane molecular arrangement into ordered, cofacial slip-stacked rows results in a largely anisotropic surface structure, with a characteristic sawtooth corrugation of a few Ångstroms wavelength and height. Load-controlled experiments reveal di erent types of friction contrast between the alternating sloped and stepped regions, with transitions from atomic-scale dissipative stick–slip to smooth sliding with ultralow friction within the surface unit cell. Notably, such a rich phenomenology is captured under ambient conditions. We demonstrate that friction contrast is well reproduced by numerical simulations assuming a reduced corrugation of the tip–molecule potential nearby the step edges. We propose that the side alkyl chains pack into a compact low-surface-energy overlayer, and friction modulation reflects periodic heterogeneity of chains bending properties and subsurface anchoring to the perylene cores.

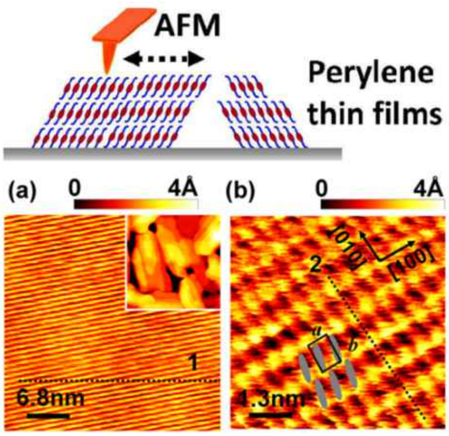

Fig.1: (a) Topography of a PDI8-CN_2 monomolecular terrace revealing an ordered, rippled surface. In the inset, a large-scale morphology (1.5 × 1.5 μm^2) shows connected mesalike grains forming the polycrystalline thin film. (b) High-resolution topography of the periodic surface structure, with superimposed the anisotropic ab unit cell. Ellipses indicate the orientation of the alkyl chains predicted by a bulk structural model.

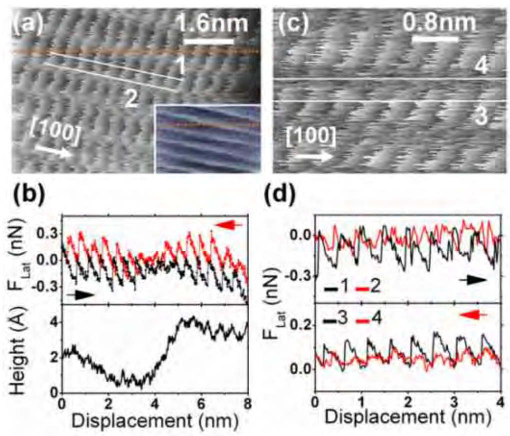

Fig.2: (a) Lateral force map over an organic domain, with the topography over the same region in the inset. Lateral force anisotropy reflects contrast variations occurring in proximity to the surface step edges. (b) Friction loop and topographic profile along the dashed line (orange) in (a). (c) A crystalline region with orientation along [100] direction (a). (d) Lateral force profiles along the [100] direction, extracted from the maps in (a) and (c), show alternation of stick – slip sliding (black curves) and superlubric sliding (red curves) within the surface unit cell.

Post-Deposition Wetting and Instabilities in Organic Thin Films by Supersonic Molecular Beam Deposition

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Scientific Report 8 (2018) 12015

In this study, we discuss the formation and post-deposition instability of nanodrop-like structures in thin films of PDIF-CN_2 (a perylene diimide derivative with electron-transporting character – see Fig. 1a for a sketch) deposited via supersonic molecular beam deposition (SuMBD) technique on highly hydrophobic substrates. SuMBD technique was initially applied to check whether the huge kinetic energy of the depositing molecules could induce the superheating effect, thus preserving the occurrence of the crystallization processes during the PDIF-CN_2 film growth even keeping the substrate at room temperature. Surprisingly, we observe the formation of nanostructured thin films (with separated nano-drop structures see Fig. 1b) accompanied by the presence of a wetting instability in the condensate. This instability provides a remarkable evolution of the electron field-effect mobility and surface morphology of the film (see Fig.1c) over a time scale of weeks or months. The role of the deposition rate on the characteristic lengths of organic nano-drops was studied by atomic force microscopy and the use of the height-height correlation function was effective to establish a link between morphological mechanism and growth. The nano-drops represent a metastable configuration for the freshly-deposited films and, for this reason, post-deposition wetting effects have been examined with unprecedented accuracy throughout one year. The observed time scales, from few hours to months, are related to the growth rate and characterize the thin films morphological reordering from three-dimensional nano-drops to a well-connected terraced film (see Fig.1d). While the interplay between adhesion and cohesion energies favors the formation of 3D-mounded structures during the growth, the wetting phenomenon following the switching off of the molecular flux is found to be driven by an instability. A slow rate downhill process survives at the molecular flux shutdown and it is accompanied and maybe favored by the formation of a precursor layer composed of molecules with a dominant lying-down configuration. These results are supported by simulations based on a non-linear stochastic model, describing the instability phenomenon for both the growth and the post-growth evolution. To better reproduce the experimental data, it is needed to introduce a surface equalizer term characterized by a relaxation time taking into account the presence of a local mechanism of molecular correlation.

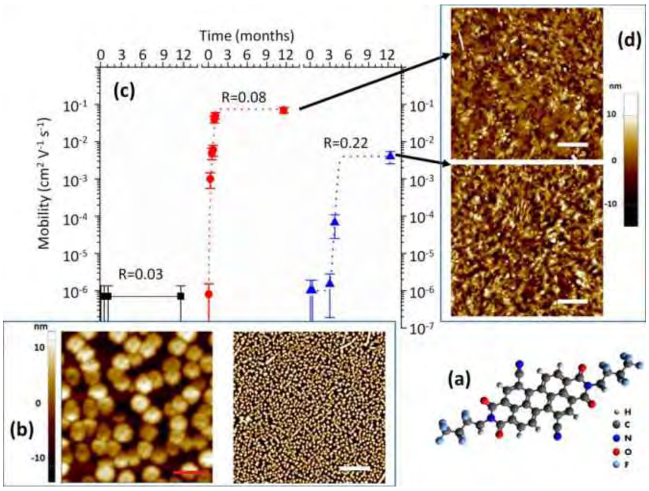

Fig. 1: (a) A sketch of the PDIF-CN_2 molecule. (b) 1x1 mm^2 and 5x5 mm^2 AFM images acquired just after the deposition using SuMBD on HMDS-treated SiO_2 at room temperature. The white and red markers are 1 μm and 250 nm, respectively. (c) Field-effect mobility values over time measured for PDIF-CN_2 films deposited at different deposition rates (R=0.03, 0.08, 0.22 nm/min). (d) 5x5 mm^2 AFM images of the film morphologies acquired after 1 year. At R=0.03 nm/min the nanostructured morphology and the field-effect mobility don't change with time.

Phase-matching-free parametric oscillators based on two dimensional semiconductors

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Light: Science & Applications 7 (2018) 5

Optical parametric oscillators are widely used as pulsed and continuous-wave tunable sources for innumerable applications, such as quantum technologies, imaging and biophysics. A key drawback is material dispersion, which imposes a phase-matching condition that generally entails a complex design and setup, thus hindering tunability and miniaturization. We have obtained the new and unexpected result that micro-resonators embedding monolayer transition metal dichalcogenides (ML-TMD) produce doubly resonant parametric oscillations with unprecedentedly small cavities of few microns thanks to the strong nonlinearity of these materials and their atom-sized thickness, which circumvent the ubiquitous phase-matching condition of state-of-the-art quadratic nonlinear optics. Bearing in mind that nonlinear optics ignited in 1961 with the discovery of second-harmonic generation (a parametric effect ruled by phase-matching) by Peter Franken et al. at University of Michigan, we envisage that the extent, importance and impact of our findings can be enormous since they dismiss a paradigm standing ever since fifty years. In addition, electrical voltage gating of two-dimensional material provides our setup with a further external control parameter that can be used to modulate the parametric radiation emission.

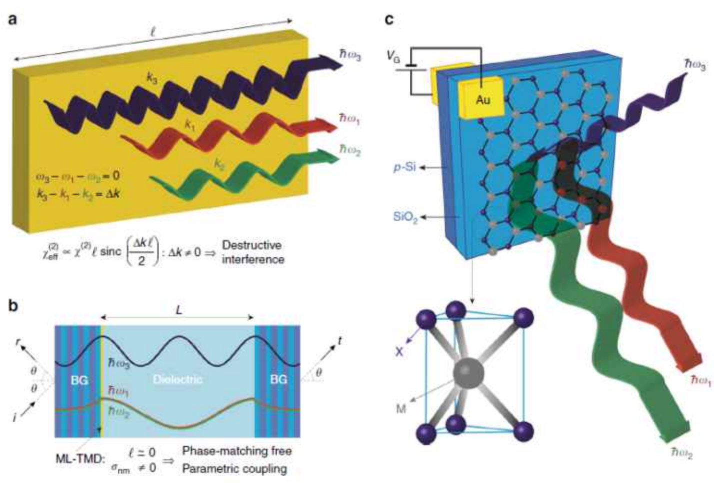

Fig. 1 a. Schematic illustration for conventional three-wave parametric coupling in bulk nonlinear crystals. The effective quadratic susceptibility is heavily affected by the mismatch $X^{(2)}_{eff}$ is heavily affected by the mismatch ΔK among the wavevectors $K_m = n_m\, \omega_m/c$ of the pump (3), signal (1) and idler (2) waves, whose destructive interference $\Delta K \neq 0$ hinders parametric coupling.
b. Sketch of the ML-TMD based parametric oscillator. The cavity is assembled using two Bragg mirrors separated by a dielectric layer, and the ML-TMD is placed onto the left mirror. The incident (i) pump field produces both reflected (r) and transmitted (t) pump, signal and idler fields by means of the ML-TMD quadratic surface conductivity $\sigma_{nm} \neq 0$. The mutual dephasing $\Delta\phi = \Delta kl$ among these three waves becomes negligible within the atomic thickness of the nonlinear ML-TMD ($\Delta\phi \approx 1$)because $1 = \lambda$ thus enabling phase-matching-free (i.e., free from the momentum conservation requirement ($\Delta K = 0$) parametric coupling. c. Sketch of the geometry of MX2 ML-TMDs. Fast modulation is enabled by extrinsic doping by a gate voltage, with gold contacts applied between the ML-TMD and the Bragg mirror.

In-plane molecular organization of hydrated single lipid bilayers: DPPC: cholesterol

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Nanoscale 10 (2018) 87

Cell membranes are composed mainly of a mixture of lipids and proteins. Lateral segregation of membrane components into domains of lipids enriched in cholesterol (chol) and sphingolipids is involved in many membrane functions. Understanding the physical properties of cholesterol–phospholipid systems is essential to gain a better knowledge of the function of each membrane constituent. The aim of the present work is twofold: to propose a novel user-friendly setup based on a thin layer cell configuration that allows the successful acquisition of grazing incidence x-ray diffraction (GIXD) data on single lipid bilayers (SLBs) under aqueous conditions and to provide a further understanding of the DPPC:chol system. The proposed set-up consist allows the confinement of the SLB in solution between two Si wafers. In this way the amount of extra liquid is minimised, limiting the background scattering from the solution and avoiding the evaporation of the solvent. The diffraction peak coming from the lateral organisation of the SLB can then be detected and studied as a function of sample and solution compositions.

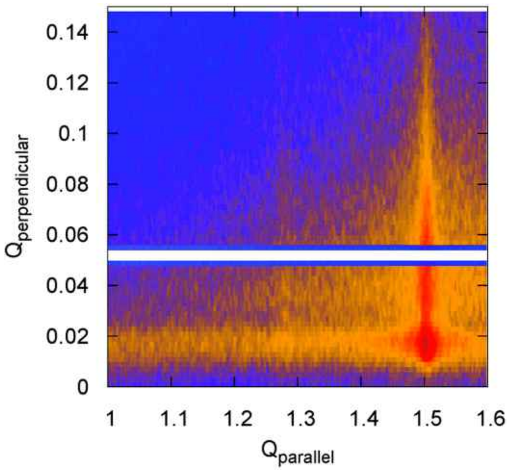

Fig. 1: Diffracted intensity 2D contour plot for a DPPC:chol (90:10 molar ratio) SLB in a Si–SLB–Si configuration, in 20 mM HEPES, 150 mM NaCl and 20 mM MgCl2 buffer solution pH 7.4, at room temperature. The white line parallel to $Q_{parallel}$ originates from the missing rows of pixels between 2 chips of the area detector.

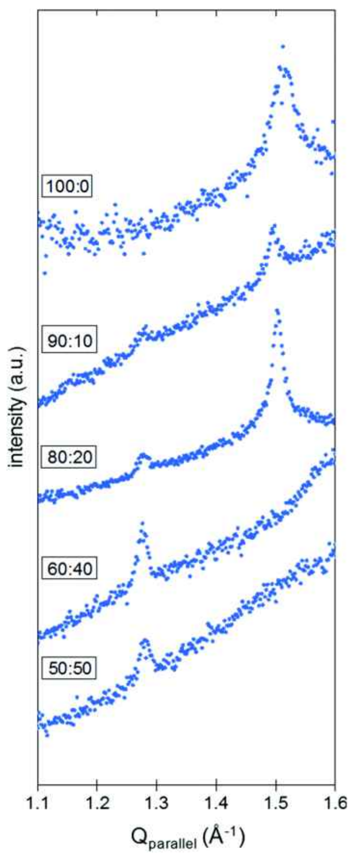

Fig. 2: GIXD $Q_{parallel}$ intensity patterns from DPPC:chol SLBs at different molar ratios. The the plots it appears clearly that the main correlation peaks shifts from 1.3 $Å^{-1}$ at low DPPC:chol composition ratios to 1.5 $Å^{-1}$ at high DPPC concentrations.

Temperature- and doping-dependent nanoscale Schottky barrier height at the Au/Nb: $SrTiO_3$ interface

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Applied Physics Letters 113 (2018) 141604

We use ballistic electron emission microscopy to investigate prototypical Au/Nb-doped $SrTiO_3$ (NSTO) Schottky barrier diodes for different temperatures and doping levels. To this end, ultrathin Au overlayers are thermally evaporated onto TiO_2-terminated NSTO single crystal substrates. We show that at room temperature, regardless of the nominal doping, rectification is controlled by a spatially inhomogeneous Schottky barrier height (SBH), which varies on a length scale of tens of nanometers according to a Gaussian distribution with a mean value of 1.29–1.34 eV and the standard deviation in the range of 80–100 meV. At lower temperatures, however, doping effects become relevant. In particular, junctions with a low Nb content of 0.01 and 0.05 wt. % show an ~300 meV decrease in the mean SBH from room temperature to 80K, which can be explained by an electrostatic analysis assuming a temperature-dependent dielectric permittivity for NSTO. In contrast, this model fails to predict the weaker temperature dependence of SBH for junctions based on 0.5 wt.% NSTO. Our nanoscale investigation demands to reassess conventional models for the NSTO polarizability in high-intensity electric fields. Furthermore, it contributes to the comprehension and prediction of transport in metal/$SrTiO_3$ junctions and devices.

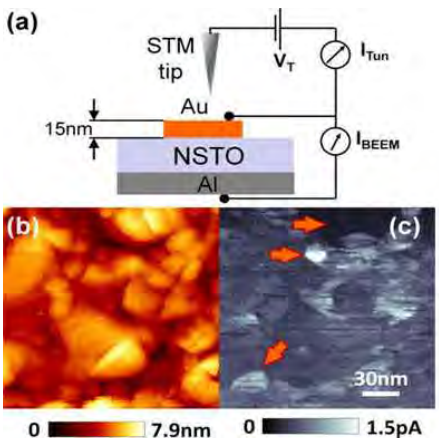

Fig.1: (a) Schematic diagram of the Au/NSTO junction and the experimental setup for BEEM measurements. (b) STM topography and (c) BEEM map acquired simultaneously over a representative Au region (I_T= 45 nA, V_T = −1.85 V, T = 291 K, x_{Nb}=0.01 wt.%). The arrows highlight a few localized grains with high BEEM contrast.

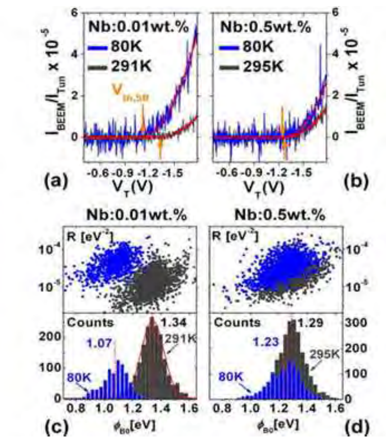

Fig.2: Representative raw spectra acquired at different temperatures on Au/NSTO junctions. (c) Dual parameter (ϕ_{B0}, R) distributions (top) and ϕ_{B0} histograms (bottom) for x_{Nb}=0.01 wt.%,. The average SBHs at 291 K (1.34 eV) and 80 K (1.07 eV). (d) as in (c) but for x_{Nb}=0.5 wt.%.

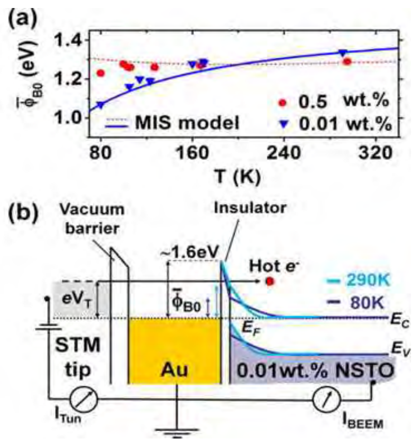

Fig.3: (a) Temperature dependence of the spatially averaged SBH ϕ_{B0} measured by BEEM for Au/NSTO junctions with two different doping levels. The solid and dashed lines are theoretical predictions with the metal-insulator-semiconductor (MIS) model. (b) Schematics of the energy band diagram for the low-doped unbiased junction (not in scale).

Quantum Interference in Single-Molecule Superconducting Field Effect Transistors

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Journal Of Chemical Physics C 122 (2018) 11498

Single molecules can be coupled to metallic electrodes when the latter are in the superconducting state. In such emerging hybrid molecular devices, the possibility of a molecular Josephson effect arises. From the practical point of view, one of the obstacles hampering the realization of a working molecular transistor is the relatively large contact resistance associated with a single conduction channel in such a type of device. The contact resistance, a concept borrowed from ordinary electronics, is nature-imposed and cannot be lower than the quantum limit $h/2e^2$ = 12.9 kΩ. Under this condition, the Joule loss is an issue affecting the transistor operation efficiency. One way to overcome this drawback is the introduction of superconducting electrodes. In the presence of superconducting electrodes, Cooper-paired electrons flow in principle without resistance through the junction owing to the Josephson effect. In this theoretical study, we explore the possibility that a junction formed by two superconductors linked by a ring molecule, of which benzene (phenylene group) is a prototype, sustains a supercurrent and acts as a "single molecule superconducting field-effect transistor (SMoSFET)".
In this device, Cooper-paired electrons are transmitted via a twofold branch molecule in the presence of quantum interference. We show that the critical currents, likewise the conductances, do not add classically as is the case for standard dimensions devices in a parallel setup. We also show that in such a device the resonant nontrivial modulation of the critical current with an external gate voltage is determined by the quantum interference associated to the different length paths of the electrons crossing the junction. To illustrate this latter point we choose a para-coupled, a meta-coupled, or an ortho-coupled ring molecule junction configuration. In the case of meta coupling with the electrodes (in practice choosing 1,3-Benzenedithiol instead of 1,4-Benzenedithiol), complete destructive interference is obtained and no supercurrent can flow unless a finite gate voltage Vg is applied.

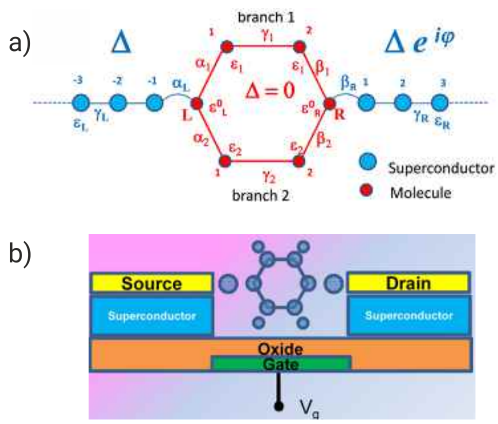

Fig. 1: a) A tight binding representation of the system studied in this paper: a superconductor-six atom ring molecule - superconductor structure (S-mol-S). The structure of the molecule is close to that of Benzene-1,4-dithiol $C_6H_6S_2$. b) A pictorical view of a SMoSFET realization.

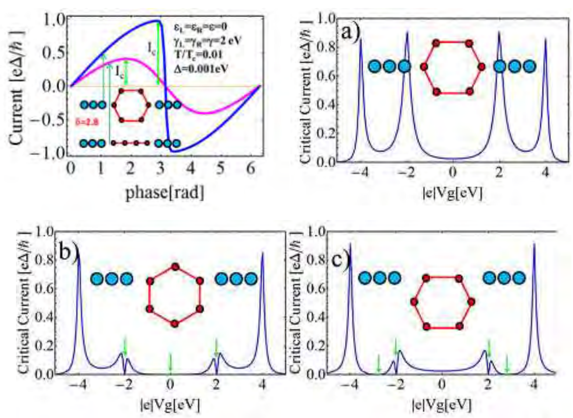

Fig. 2: Upper left. Current phase characteristic of a ring molecule junction and a chain molecule junction. (a–c) Josephson critical current as a function of the gate voltage V_g in a six-atom ring molecule between superconducting electrodes. The curves in (a–c) correspond to para-, meta-, and ortho-type coupling, respectively.

Josephson Thermal Memory

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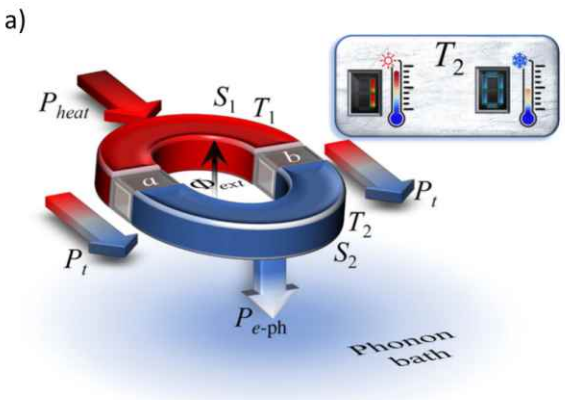
Physical Review Applied 9 (2018) 014021

Traditionally, electronics and computation are implemented in electric systems; for example, the logical states are defined in terms of presence or absence of electric current and they are manipulated changing their electric state. Analogously, there is the possibility to use thermal states as logical states and manipulate them controlling the energy the system exchanges. Here, we propose a thermal memory based on a Josephson system. The physical system is composed by a SQUID (Superconducting Quantum Interference Device) thermally biased, i.e., with the two leads at different temperature. The logical states are associated to a different temperatures of the cold lead and their manipulation is done by a modulation of the magnetic flux applied to SQUID. This is possible because the coherent heat transport between the leads depends on the superconducting phase and it can be controlled by the external magnetic flux. The proposed device work at a basis temperature of 4.2 Kelvin for the cold lead and 6.5 Kelvin for the hot lead with a temperature separation between the thermal states of 0.1 Kelvin. We show that the magnetic flux allows us to switch between logical thermal states in 0.2 ns allowing fast writing operations. The proposed device paves the way for a practical implementation of thermal logic and computation. One of the advantages of this proposal is that it represents an example of harvesting thermal energy in superconducting circuits.



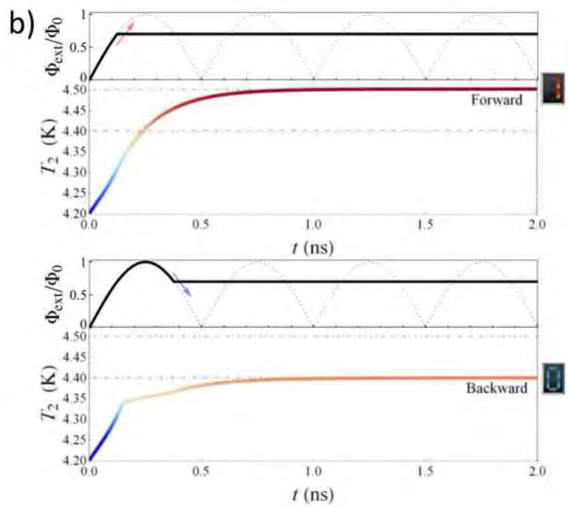


Fig. a): The schematic of the Josephson thermal memory based on a thermally biased SQUID (with leads S_1 and S_2 at temperature T_1 and T_2, respectively) controlled by the external magnetic flux Φ_{ext}. The logical states are the temperatures of the cold lead. b) Magnetic flux drive and temperature T_2 as a function of time for the two logical states. The steady state temperatures are reached after 0.2 ns.

Perylene-Diimide Molecules with Cyano Functionalization for Electron-Transporting Transistors

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Electronics 8 (2019) 249

Core-cyanated perylene diimide (PDI_CY) derivatives are conjugated molecules exhibiting an uncommon combination of appealing properties, including remarkable oxidative stability, high electron affinities and excellent self-assembling properties. Such features made these compounds the subject of an intense research activity aimed at developing electron-transporting (n-type) devices with superior charge transport performances. In this report, the authors reviewed their extensive experimental work, performed during the last 10 years, on the fabrication and characterization of transistors based on PDI8-CN_2 and PDIF-CN_2 molecules, the most renowned compounds of the PDI_CY family. The main efforts were devoted to correlating the deposition conditions, relying on evaporation processes using both effusive sources and supersonic beams, and the charge transport properties of PDI8-CN_2 and PDIF-CN_2 (Fig.1) thin films for transistor applications (Fig,1). Electrical instabilities and non-idealities, such as the bias stress effect and the contact resistance phenomenon (Fig.2), were widely investigated, highlighting the role of charge trapping mechanisms associated to the film morphological disorder and/or to the absorption of chemical species (i.e. water molecules) at the dielectric/semiconducting interface. The possibility to use these compounds for the development of nanoscale devices or sensors to be applied in liquid environment was also discussed.

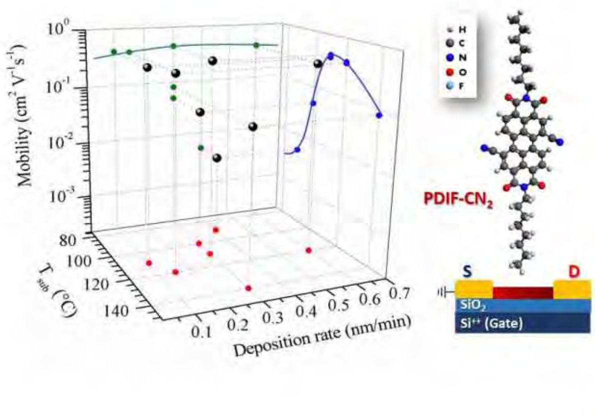

Fig.1: Mobility values (black symbols), estimated for evaporated PDIF-CN_2 films on HMDS (Hexamethyldisilazane) -treated SiO_2, as a function of the substrate temperature (T_{SUB}) and of the deposition rate. The projections of the black symbols along the three axes are the colored plots. On the right, the molecular structure of PDIF-CN_2 and the transistor layout are also shown.

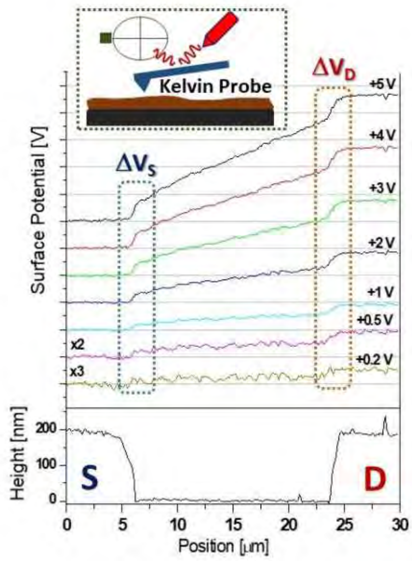

Fig.2: Scanning Kelvin Probe Force microscopy profiles acquired for a PDIF-CN_2 transistor by applying different V_{DS} voltages; Voltage drops associated to the contact resistance phenomenon are visible on both Drain (D) and Source (S) contacts.

Multipolar terahertz absorption spectroscopy ignited by graphene plasmons

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Communications Physics 2 (2019) 111

Terahertz absorption spectroscopy plays a key role in physical, chemical and biological systems as a powerful tool to identify molecular species through their rotational spectrum fingerprint. Owing to the sub-nanometer scale of molecules, radiation-matter coupling is typically dominated by dipolar interaction. We have shown that multipolar rotational spectroscopy of molecules in proximity of localized graphene structures can be accessed through the extraordinary enhancement of their multipolar transitions provided by terahertz plasmons. In particular, specializing our calculations to homonuclear diatomic molecules, we demonstrate that a micron-sized graphene ring with a nano-hole at the core combines a strong near-field enhancement and an inherently pronounced field localization, enabling the enhancement of the dipole-forbidden terahertz absorption cross-section of ionized molecular hydrogen by 8 orders of magnitude. Our results shed light on the strong potential offered by nano-structured graphene as a robust and electrically tunable platform for multipolar terahertz absorption spectroscopy at the nanoscale.

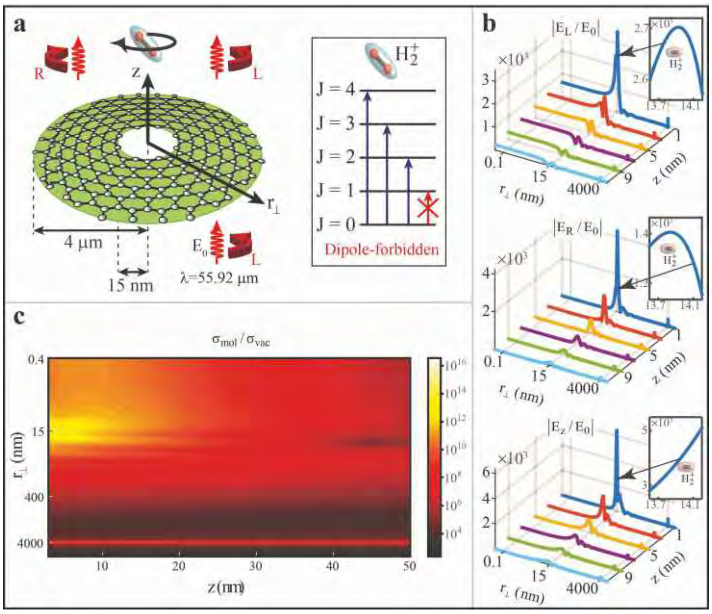

Fig. 1. a Graphene micro-ring of radius 4 μm with a nano-hole of radius 15 nm at the core surrounded by dipole-inactive molecules H_2^+. The system is excited by a left-hand (L) circularly polarized THz wave of amplitude E_0 and wavelength λ=55.92 μm. The scattered radiation has both left and right (R) circularly polarized components. b Dependence of the scattered fields components E_L, E_R, and E_z over the in-plane radius $r_\perp$ and the altitude z. Note the large field enhancement $|E|>>E_0$ close to the inner edge at $r_\perp$=15 nm. Note also that the scattered field has deep-subwavelength features whose spatial scale is comparable with the H_2^+ spatial extension (insets). c Contour plot of the plasmon-enhanced molecule absorption cross-section σ_{mol} rescaled to its vacuum value σ_{vac} averaged over all molecular orientations as a function of the in-plane radius $r_\perp$ and the altitude z. Note that the normalized absorption cross-section

Vacancy-Driven Noncubic Local Structure and Magnetic Anisotropy Tailoring in Fe_xO-$Fe_{3-\delta}O_4$ Nanocrystals

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Physical Review X 9 (2019) 041044

Here, we combine nano-chemistry, detailed characterization, and theoretical considerations to explore the relation of structural defects on the size and shape of iron-oxide nanocrystals and to determine how these couple to magnetic properties relevant to nanobiotechnology. In fact, we have found, by total x-ray scattering experiments coupled to atomic pair distribution function (x-PDF) analysis, the unexpected experimental observation that metal atoms pulled out from the crystal lattice, during the oxidative conversion of antiferromagnetic wüstite (Fe_xO) into a ferrimagnetic spinel magnetite ($Fe_{3-\delta}O_4$), create vacant sites in the magnetite. These sites are correlated to each other via local tetragonal distortions, especially for spherical nanocrystals (single-crystalline nanoparticles) compared to cubic ones and for the smaller sizes. The emerging local symmetry breaking due to defect, change the nanocrystal's magnetic anisotropy in the favorable direction. The vacancies act as pinning centers impeding the coherent reversal and easy relaxation of the spins. This allows surprisingly a nonzero exchange bias even in the fully oxidized, $Fe_{3-\delta}O_4$-like derivative of wüstite, and a remarkable ten-fold rise of the nanomaterial's thermo-responsive performance, as compared to that obtained by defect-free nanocrystals, based on Monte Carlo simulations.

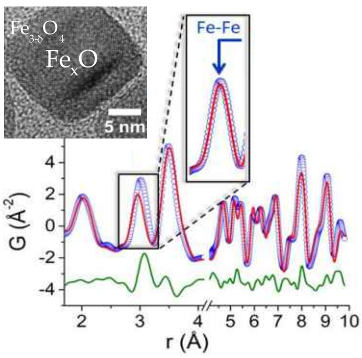

Fig. 1 x-PDF fit (red solid line) in the "low-r" region of a core-shell cubic nanoparticle sample assuming a single phase inverse cubic spinel atomic configuration (Fd-3m symmetry), showing that this model fails to fit the peak at about 3Å (blue circles), and in the top right insert there is the result obtained by a two-phase model of the cubic rock-salt and tetragonal ($P4_32_12$ symmetry) crystallographic configurations, showing an improved quality of the fit and indicating a possible localized tetragonal distortion. A typical core-shell cubic nanocrystal of the sample used is in the top left. insert.

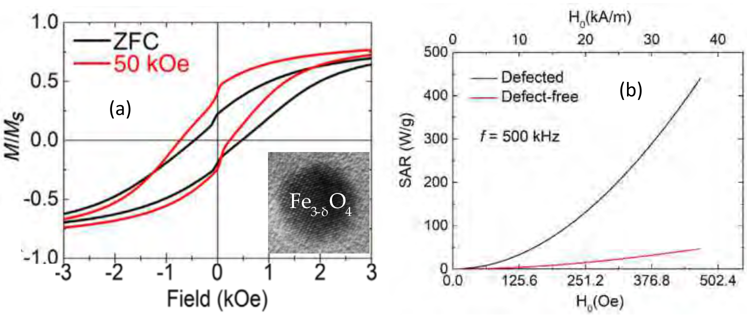

Fig. 2: (a) Normalized hysteresis loops at 5 K for the single-phase spherical nanoparticles taken under zero- and field- cooled (H_{cool} = 50 kOe) protocols, (b) Monte Carlo calculation of SAR (specific adsorption rate) values as a function of the AC field amplitude, H_0, at a field frequency f = 500 KHz.

Activity F: Electronic and thermal transport from the nanoscale to the macroscale

Activity Leader: Giovanni Cantele

The design and characterization of new functional materials for the development of new devices for energy transport and conversion, is an emerging and rapidly developing research field. Basic interactions governing the fundamental processes, in these materials, are far from being understood, because electronic, lattice, spin and optical (photon) processes occur and can interfere with each other. Moreover, at the macroscopic level, other phenomena, such as the effects of energy exchange and scattering against the boundaries, might take place. The fundamental phenomena governing the response of such devices span a length scale that ranges from the nanoscale (nanodevices, nanoscale circuits, nanowires and nanotubes, two-dimensional materials, etc.) to the macroscale (composite materials, organic compounds, amorphous blends, etc.), so that their investigation requires a multi-scale approach and a variety of different competencies. Emerging materials, such as graphene and two-dimensional crystals, topological insulators, semiconductors with helical and chiral edge states, hybrid organic-inorganic perovskite materials, layered compounds, nano- and micro-composites, and so on have been shown to be good candidates for energy and electronic applications, each with its own advantages and drawbacks. Driven quantum systems are also emerging as a valuable alternative in designing new and powerful microscopic devices with complex and rich thermodynamic behavior. These systems could offer the possibility to manipulate charge and heat on a quantum scale with numerous applications extending from quantum information to technological and biological device design.
According to the well-recognized experience of the SPIN scientific community in the cited fields and aiming to intercept such a challenging perspective, the present activity will address fundamental topics ad problems in the field of the novel materials and phenomena and complex systems, such as:

- study of models of quantum systems interacting with their environment and quantum computation;
- electronic and transport properties of van der Waals heterostructures, from twisted bilayer graphene to transition metal dichalcogenides;
- development of advanced methods for the study of strongly correlated and interacting systems.

Related also with the activities of the present project, the CNR-SPIN Institute is being involved, together with other CNR Institutes, with University of Naples “Federico II” and with INFN, in the implementation of a significant infrastructure (IBISCO project, financed by the Italian Government) that will be devoted to high performance scientific computing and data analysis. The funding comes from the National Operative Programme - Research and Innovation 2014-2020 of the MIUR, and will benefit from the most recent technological advances, such as the massive use of modern Graphic Processing Units (GPUs), as computational accelerators.

Nonmonotonic response and light-cone freezing in fermionic systems under quantum quenches from gapless to gapped or partially gapped states

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Physical Review B 97 (2018) 035433

The properties of prototypical examples of one-dimensional fermionic systems undergoing a sudden quantum quench from a gapless to a gapped state are analyzed, both in integrable and non-integrable models. We observe an anomalous, nonmonotonic response of steady-state correlation functions as a function of the strength of the mechanism opening the gap. In order to interpret this result, we calculate the full dynamical evolution of these correlation functions, which shows a freezing of the propagation of the quench information for large quenches. In noninteracting models, this freezing can be traced back to a Klein-Gordon equation in the presence of a source term.

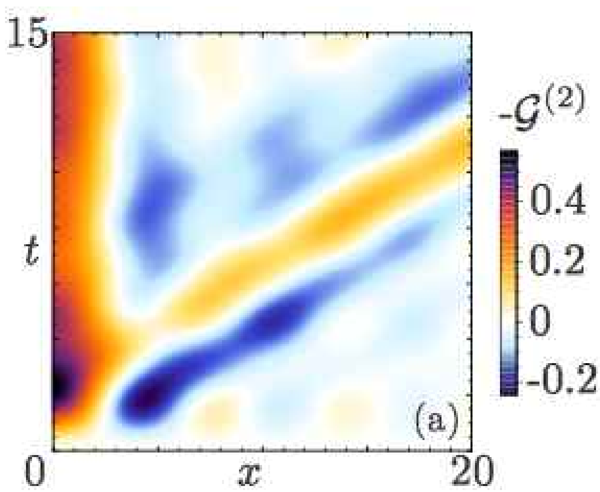

Fig. 1: Quenching a small homogeneous magnetic field in a spin-orbit coupled quantum wire produces a perturbation in the magnetic correlation functions, which travels as a light cone through the system propagating the information.

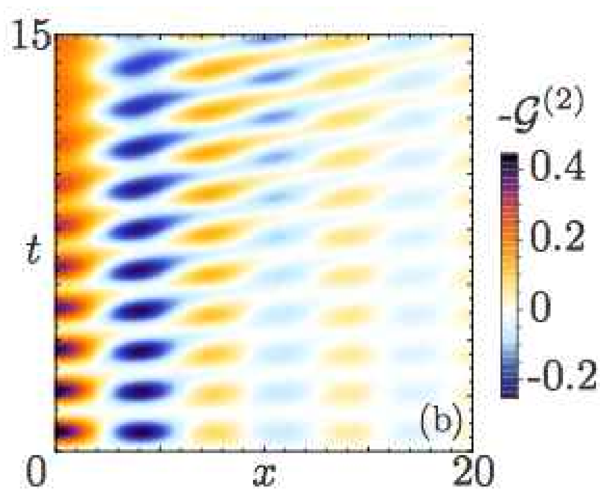

Fig. 2: When a strong magnetic field is quenched, however, the light cone propagation is effectively "frozen". Information cannot travel in an efficient way and, as a result, the wire magnetization is reduced.

Metallic supercurrent field-effect transistor

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Nature Nanotechnology 13 (2018) 802

A static electric field cannot penetrate deeply in a normal metal because of the screening effect. For this reason, the electric properties of normal metal are not changed by the application of an electric field. Under the same conditions one would expect that metallic superconductor properties are not affected either. Against this belief, we show that a static electric field generated by contactless lateral voltage gates can be used to control the critical current and induce the superconducting-to-normal metal transition in a superconducting metallic wire. The behavior of the supercurrent as a function of the electric voltage applied shows a flat region followed by a sudden drop when high voltages (about tens of Volt) are applied. This behavior is present at different working temperature and, despite the fact that the flat region increases with temperature, the voltage at which the critical current is suppressed is temperature independent. The effect is independent on the polarity of the voltage applied and it is present in different materials. All the experimental evidences seem to suggest that the phenomenon is general and does not depends on the details of the device. These results are interesting both for their fundamental and practical aspects. No theoretical model at the moment predicts or explains these effects and a deeper understanding is needed. From a more applicative point of view, they represent an asset for the realization of all-metallic superconducting field-effect electronics and leading-edge quantum information architectures.

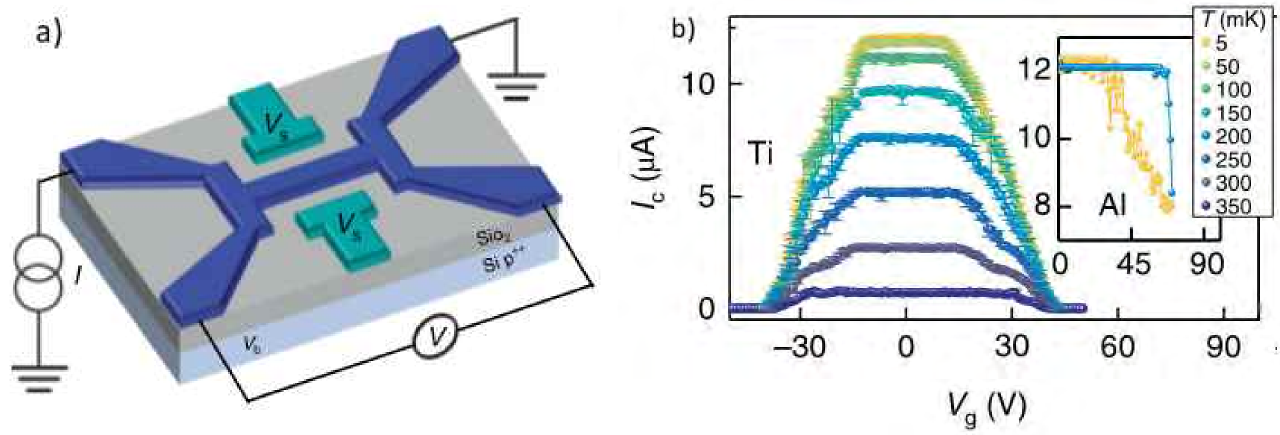

Fig. a): The schematic of the superconducting wire (blue) subject to the electric voltage V_s generated by the lateral gates (green) and a back gates V_b. b) Critical current of the superconducting wire as a function of the voltage applied and for different temperatures. The critical current shows a flat region and a fast drop but the critical voltage at which the supercurrent is suppressed remains constant in temperature. Wires made of different material (Titanium in the main figure and Aluminum in the inset) show both the supercurrent suppression.

Fluctuation spectroscopy: From Rayleigh-Jeanswaves to Abrikosov vortex clusters

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Reviews of Modern Physics 90 (2018) 015009

Superconducting (SC) fluctuations, discovered in the late 1960s, have constituted an important research area in superconductivity as they are manifest in a variety of phenomena. Indeed, the underlying physics of SC fluctuations makes it possible to elucidate the fundamental properties of the superconducting state. The interest in SC fluctuation phenomena was further enhanced with the discovery of cuprate high-temperature superconductors (HTSs). In these materials, superconducting fluctuations appear over a wide range of temperatures due to the superconductors extremely short coherence lengths and low effective dimensionality of the electron systems. These strong fluctuations lead to anomalous properties of the normal state in some HTS materials. Within the framework of the phenomenological Ginzburg-Landau theory, and more extensively in the diagrammatic microscopic approach based on BCS theory, SC fluctuations as well as other quantum contributions (weak localization, etc.) enabled a new way to investigate and characterize disordered electron systems, granular metals, Josephson structures, artificial superlattices, and others. The characteristic feature of SC fluctuations is its strong dependence on temperature and magnetic field in the vicinity of the superconducting phase transition. This dependence allows the separation of fluctuation effects from other contributions and provides information about the microscopic parameters of a material, in particular, the critical temperature and the zero-temperature critical magnetic field. As such, SC fluctuations are very sensitive to the relaxation processes that break phase coherence and can be used as a versatile characterization instrument for SCs: Fluctuation spectroscopy has emerged as a powerful tool for studying the properties of superconducting systems on a quantitative level. Here the physics of SC fluctuations is reviewed, commencing from a qualitative description of thermodynamic fluctuations close to the critical temperature and quantum fluctuations at zero temperature in the vicinity of the second critical field. The analysis of the latter allows us to present fluctuation formation as a fragmentation of the Abrikosov lattice. This review highlights a series of experimental findings followed by microscopic description and numerical analysis of the effects of fluctuations on numerous properties of superconductors in the entire phase diagram and beyond the superconducting phase.

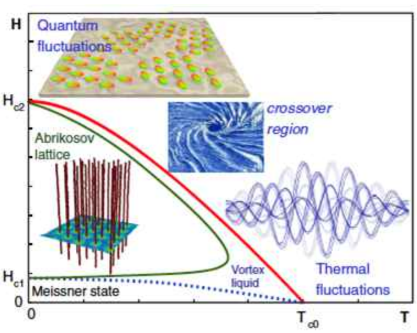

Fig. 1: Schematic phase diagram of type-II superconductors, showing the domains of qualitatively different physical behavior.

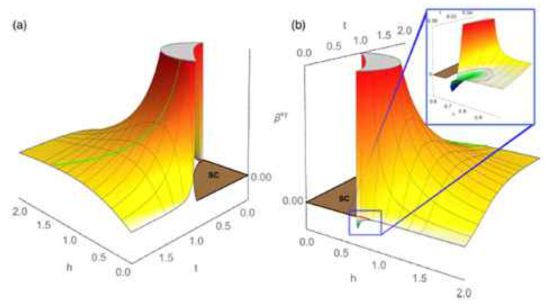

Fig. 2: The magnetic field and temperature dependence of the fluctuation part of the Nernst coefficient. (a) A view from the h=0 plane with the ghost field line in green (light gray) indicating the maximum of the Nernst coefficient for constant. (b) A view from the t=0 plane with a zoom close to the quantum fluctuation region at h=h_{c2}. The red (dark gray) line indicates the contour where the Nernst coefficient becomes zero.

Crucial role of atomic corrugation on the flat bands and energy gaps of twisted bilayer graphene at the magic angle θ ~1,08

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Physical Review B 99 (2019) 195419

Among the most recent approaches to device engineering, *twistronics* has received tremendous attention in the last two years. The basic concept is that of twisting the angle between layers composing two-dimensional van der Waals heterostructures, such as a graphene bilayer. Just two-years ago, some scientists discovered that at "special" twist angles, referred to as *magic angles*, the properties of a twisted bilayer graphene can dramatically change [Y. Cao, *et al.*, Nature 556, 80 (2018); Nature 556, 43(2018)]. At the first magic angle, 1.08, a novel superconducting phase, reminiscent of that of that of the underdoped cuprates and with a critical temperature ranging from 1.7 to 3 K shows up. Moreover, a flat band (FB) manifold emerges close to the Dirac points, with a very tiny dispersion (experimentally estimated to be 10 meV) and separated by energy gaps 50 meV from both lower and higher energy bands. Such FBs are also responsible for an insulating phase observed by tuning the chemical potential through an external gate.

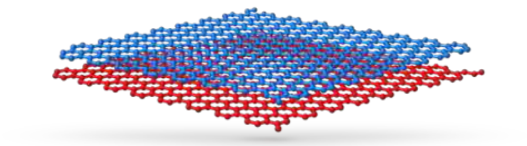

Fig. 1: A schematic view of twisted bilayer graphene.

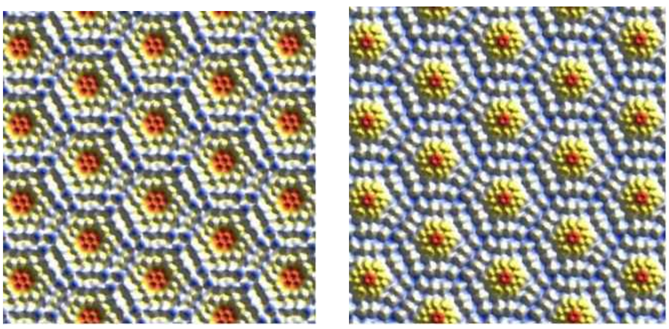

Fig. 2: A color map of the atomic relaxations in the bottom and top plane of twisted bilayer graphene at the first magic angle.

Effect of Electron Irradiation on the Transport and Field Emission Properties of Few-Layer MoS2 Field-Effect Transistors

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The Journal of Physycal Chemistry C 123 (2019) 454

Molybdenum disulfide (MoS_2) is a two-dimensional (2D) layered material, one of the transition-metal dichalcogenides with layers that are weakly held together by van der Waals forces. Energy band gap in MoS_2 varies from 1.2 eV (indirect) in the bulk to 1.8–1.9 eV (direct) in monolayer. Electrical characterization of few-layer MoS_2-based field-effect transistors (FET) with Ti/Au electrodes is performed in the vacuum chamber of a scanning electron microscope in order to study the effects of electron-beam irradiation on the transport properties of the device. A negative threshold voltage shift and a carrier mobility enhancement are observed and explained in terms of positive charges trapped in the SiO_2 gate oxide, during the irradiation. The transistor channel current is increased up to 3 orders of magnitudes after the exposure to an irradiation dose of 100 e−/nm^2. Finally, a complete field emission (FE) characterization of the MoS_2 flake, achieving emission stability for several hours and a minimum turn-on field of ≈20 V/μm with a field enhancement factor of about 500 at an anode–cathode distance of ~1.5 μm, demonstrates the suitability of few-layer MoS_2 as a two-dimensional emitting surface for cold-cathode applications.

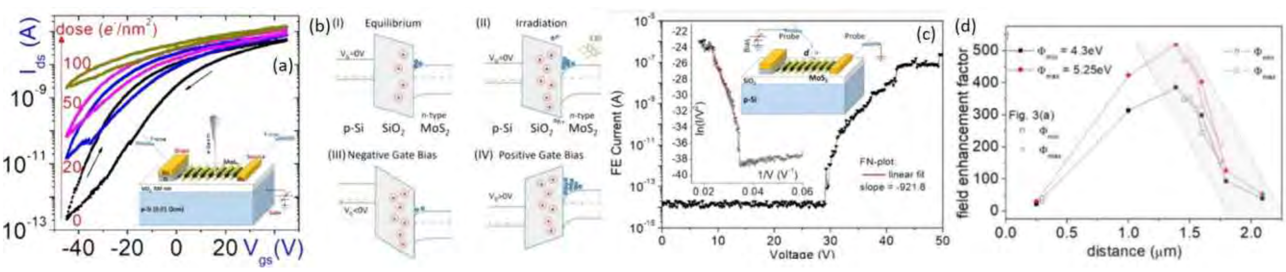

Fig. 1: (a) Transfer characteristics I_{ds}–V_{gs} measured before and after electron beam irradiation. Inset: Layout of the device. (b) Schematic band diagram for the n-type MoS_2/SiO_2/p-Si FET. (I) Unbiased initial state; (II) unbiased state after irradiation which favors the formation of additional positive charged traps; (III) band alignment for $V_{gs} < 0$ V with carrier depleted channel; (IV) band alignment for $V_{gs} > 0$ V with carrier accumulation. (c) Field emission I–V curve measured at d = 300 nm. Left inset: Fowler-Nordheim plot. Upper inset: Setup for field emission measurements. (d) Dependence of the field enhancement factor on the distance d.

A WSe_2 vertical field emission transistor

Antonio Di Bartolomeo [1,2,3], Francesca Urban [1,2,3], Maurizio Passacantando [4], Niall McEvoy [5], Lisanne Peters [5], Laura Iemmo [1,2,3], Giuseppe Luongo [1,2,3], Francesco Romeo [1,3] and Filippo Giubileo [3]

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Nanoscale 11 (2019) 1538

The recent observation of metallic edges in atomically thin WSe_2 monolayers grown by CVD, the lower bandgap (~1.6 vs. ~1.8 eV), effective electron mass (0.33 vs. 0.57 m_0, the rest mass of the electron) and electron affinity (~3.9 vs.~4.2 eV) would suggest that WSe_2 is a far better field emitter than MoS_2. In this paper, we use CVD to fabricate monolayer and few-layer WSe_2 flakes on a SiO_2/Si substrate and investigate their electrical properties, under high vacuum, using back-gated transistor structures. We show that the WSe_2 flakes, contacted by Ni, exhibit n-type conduction, with conductivity highly controlled by the back-gate voltage. Taking advantage of the gate-controlled n-type doping, we locally probe the field effect (FE) current from a monolayer WSe_2 and we achieve a FE current in the range of μA from the flat part of the flake. More importantly, we demonstrate that the FE current can be modulated by the back-gate voltage, thus realizing the first vertical FE transistor based on a WSe_2 monolayer. We unveil the physics mechanisms underlying the operation of such a device and give indications for its optimization to enhance its driving current capability and to lower the applied voltage. This study can pave the way to the further exploitation of WSe_2 in a new generation of devices for vacuum electronics.

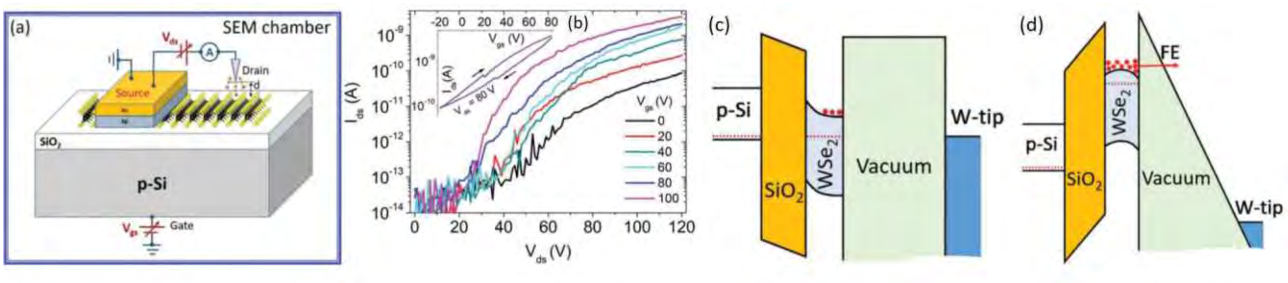

Fig. 1: (a) Layout of a back-gate FE transistor with a WSe_2 monolayer channel over a SiO_2/Si substrate. The W-tip labelled as the drain, which collects field emitted electrons and monitors the current, is kept at a distance d from the sample, while the voltage is ramped up. (b) FE current measured at given back-gate voltages (V_{ds} steps of 1 V). (c) Band diagram for (c) the unbiased device and for (d) the device under $V_{ds} > V_{gs} > 0$ V bias conditions.

Z4 parafermions in weakly interacting superconducting constrictions at the helical edge of quantum spin Hall insulators

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The edges of two-dimensional topological insulators are promising candidates for applications in spintronics, superconducting spintronics, and topological quantum computation. The main reason behind their appeal is the combined presence of spin momentum locking and symmetry protection from backscattering. Spin momentum locking amounts to the fact that electrons with opposite spin propagate in opposite directions; the protection from backscattering implies that deviations from perfect conductivity can only take place via inelastic scattering, unless time-reversal symmetry is broken. At present, many two-dimensional topological insulators have been engineered, and the time for conceiving and realizing topological nanostructures has come. This step represents a major experimental and theoretical challenge. Indeed, most proposals rely on the possibility to induce magnetic gaps, or on the presence of strong electron-electron interactions. However, magnetic barriers appear challenging to be implemented and the screening in topological insulators is rather efficient. The available tools are hence weak interactions, induced superconductivity, and long constrictions (LC) between helical edge states. In our work, we show that these ingredients are indeed enough for the realization of parafermions. Such exotic particles are generalizations of Majorana fermions that may appear in interacting topological systems. They are known to be powerful building blocks of topological quantum computers. Existing proposals for the realization of parafermions in topological insulators typically rely on strong electronic correlations which, as mentioned, are hard to achieve. We identify a novel physical system in which parafermions generically develop. It is based on a LC, proximized by an s-wave superconductor. Our analysis suggests that parafermions are emerging bound states in this setup in the weakly interacting regime and in the absence of ferromagnetic barriers. Furthermore, we identify a situation in which Majorana fermions and parafermions can coexist.

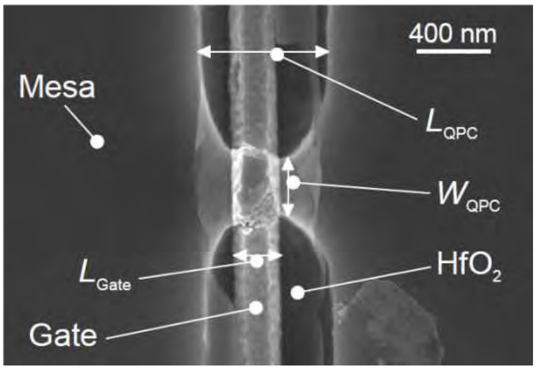


Fig. 1: First realization of a topological quantum point contact based on a Hg(Cd)Te quantum well. L strands for length of the LC, W for its width. For details, see Nat. Phys. 16, 83 (2020).

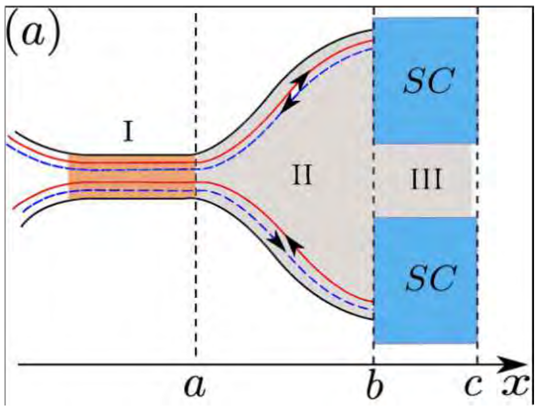
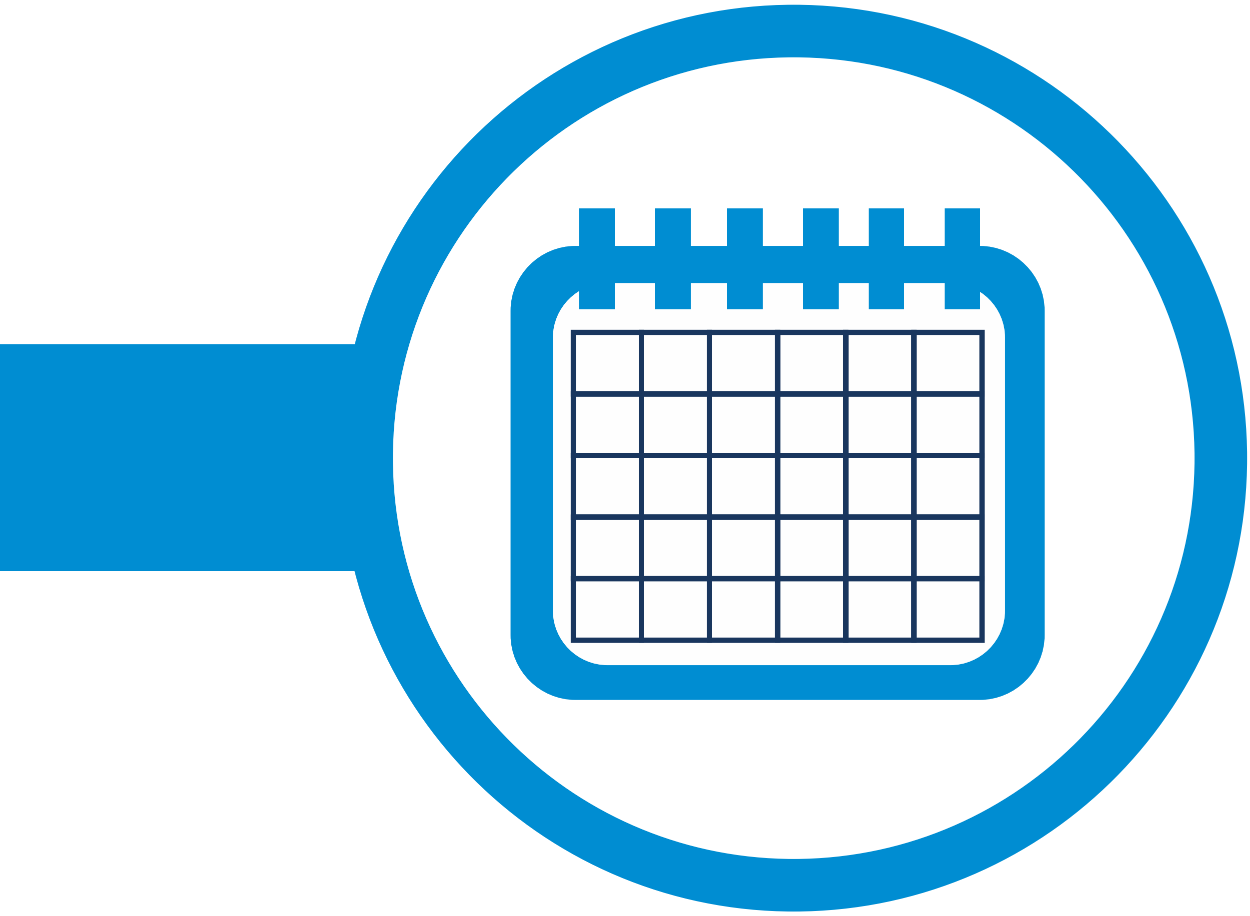


Fig. 2: The setup we propose for the parafermions. Here SC represents s-wave superconductors that proximize the topological insulator. The orange region is the topological quantum point contact, the parafermions are trapped in the region II.



Life and events

Life and Events

2018

February 2018

The 2018 Europhysics Prize

Giacomo Ghiringhelli and Lucio Braicovich from Politecnico di Milano and CNR-SPIN were awarded the 2018 Europhysics Prize of the Condensed Matter Division of the European Physical Society (EPS), for their groundbreaking work for the development and scientific exploration of high-resolution resonant inelastic X-ray scattering (RIXS). Congratulations to both!

March 2018

Project meetings @SPIN

Two project Meetings were held at the SPIN headquarters in Genoa on March 26 and 27:

1) Study of High Tc (1223) superconducting coatings to mitigate the beam impedance in the FCC at CERN

2) EuroFusion: enabling technologies. Alternative cable design HTS OEAW-03.

SPIN researchers and colleagues from the University of Vienna, CERN and ENEA participated to the two events.

April 2018

OSS2018 - Oxide Superconducting Spintronics Workshop 2018

OSS2018 was organized by Mario Cuoco and Antonio Vecchione within the Core-to-Core Oxide SuperSpin International Network, involving experimental and theoretical groups in UK, Japan, South Korea, and Italy. The aim of OSS2018 was to bring together members of the Network along with leading scientists in the field of advanced materials and interfaces to discuss frontier research in the area of novel superconductivity at oxide superconductor interfaces with magnetic materials. The workshop covered both theoretical and experimental aspects of the field, with a focus on structural, magnetic and electronic properties of superconducting heterostructures, correlated electron matter, topological insulators and semimetals, surface states of topological systems and their interplay with conventional orders.

May 2018

Memex: Galileo, Episode 25 of May 7

Prof. Gianni Profeta, associate of the CNR-SPIN Institute, was invited to the Memex broadcast on Rai Scuola where he was interviewed on the physical properties of materials in extreme conditions. In particular, in his intervention he introduced materials in 2 dimensions and introduced the effects of high pressures on superconducting materials. These issues are at the heart of SPIN's activities on innovative materials and represent a frontier of modern scientific research.

The new Ph.D. Program on Quantum Technologies now approved by ANVUR!

ANVUR has approved the new Ph. D. Program on Quantum Technologies as proposed by the University of Naples Federico II (Coordinator Prof. Francesco Tafuri) in collaboration with the University of Camerino and CNR.
The new Ph.D. Program aims at promoting both conceptual and methodological tools, and the specific knowledge on different quantum platforms. This Ph.D. Program represents a significant contribution towards the creation of a new scientific awareness based on interdisciplinary skills useful to the development of quantum devices and technologies. The whole project has been built keeping an eye to the EU Flagship "Quantum Technologies". A significant number of CNR-SPIN researchers (G. Cantele, P. Lucignano) and SPIN associate researchers (F. Tafuri. G. Pepe, R. Bruzzese, V. Cataudella) takes part to the Executive Board of the Ph.D. Program.

5th Workshop on Complex Oxides

The Workshop on Complex Oxides 2018, held from May 20 to 24, 2018 on the wonderful island of Capri, Italy, was the fifth of the series Initiated in 2010 in Santorini, Greece. The aim of this series of conferences is to gather scientists from all over the world to present recent advances on complex oxides.
The workshop, chaired by Marco Salluzzo from CNR-SPIN, brought together over 60 leading scientists in the field, discussing the perspectives of oxide electronics.

Alternanza Scuola Lavoro 2018

On May 23 and 24, the final ceremony of the 2018 Alternanza Scuola Lavoro (Work-related learning experience) program, entitled 'A Scuola di Astroparticelle' and organized by INFN, the "E. Pancini" Physics Department of the University of Naples "Federico II", and the CNR Institutes SPIN and ISASI, was held at the University Campus of Monte Sant'Angelo, Naples. More than 600 students from 20 Secondary Schools attended the initiative, proposing posters, seminars and handmade works on many advanced research topics. CNR-SPIN presented outreach activities on the subject "The Nanotechnologies and the Quantum Mechanics".

June 2018

Workshop on "New development opportunities for SPIN"

On June 21, 2018, the SPIN community gathered at the "Sala Azzurra" of CNR-SPIN Genoa headquarters in Corso Perrone 24, to assess the scientific situation of the Institute and to discuss about the scientific perspectives.
In particular, the discussion concerned how to create new opportunities in the field of superconductivity, new materials and quantum technologies. The most recent initiatives promoted by the SPIN community in the various national and international scenarios were also presented.

2018

Qts - Quantum Technologies: toward a new industrial revolution

Reflections and comparison tools of research, training and finance. Good practices. The round-table was held in Naples at the "Unione Industriali Napoli" on June 27 with the objective of promoting scientific dissemination on Quantum Technologies, by looking at the potential from mutual interaction between Research Centers, Universities, the world of finance and public institutions. The sharing of experiences and opportunities related to the so-called "second quantum revolution" represents the founding moment for launching common projects within the opportunities offered by Quantum Technologies.
Among the keynote invited speakers, the president of CNR, prof. Massimo Inguscio. The meeting produced a RIS3-Campania proposal document concerning Quantum Technologies and their potental impact on high-tech trajectories for start-up companies.

July 2018

Erice Workshop 2018 - Majorana Fermions and Topological Materials Science

The workshop was held in Erice, Sicily, on July 21-27; Mario Cuoco and Antonio Vecchione were members of the Program and Scientific Commitees.
Following the initial outbreak of research triggered by the discovery of topological insulators, just a decade ago, the concept of topology continues to drive the expansion of the frontiers in modern condensed matter physics.
Target topological materials of current interests include various forms of superconductivity, novel semimetals, and correlated magnets. Efforts to firmly establish Majorana particles in condensed matter also extend to these varieties of topological materials. The aim of this workshop is to bring together active scientists in this field to discuss recent advances in topological materials science, thereby to identify the most important questions and find directions to answer them.

August 2018

OSS International School (OSS-IS) 2018

The aim of the School was to build up an international research network connecting young scientists involved in, or working on research related to the JSPS-EPSRC Core-to-Core Programme: "International network to explore unconventional superconductivity at Oxide superconductor interfaces with spin-polarized materials". The School had two main activities: lectures on fundamentals of the research area by leading scientists, and oral presentations by early-career scientists such as assistant professors, post-doctoral researchers, and PhD students. The school, hosted by Hokkaido University in Sapporo, Japan, from August 6 to 9, was open to the scientific community and welcomed the participation of young scientists. The School was chaired by Prof. Asano (Hokkaido Univ.) and by Paola Gentile (CNR-SPIN-Salerno).

September 2018

SuperFOx2018 Conference in Salerno

The SuperfFOx (Superconductive and Functional Oxides) Conference has taken place at the University of Salerno, in the Fisciano Campus from September 13 to 15. This event was organized by the Physics Department of the University of Salerno and by CNR-SPIN.

Following the evolution of current research, new scientific topics have been included in the SuperFOx program, with the aim to gather the scientific community in the fields of novel superconductivity and functional oxides, in order to address both fundamental aspects and novel functionalities.

SuperFOx has been organized with plenary and focus sessions with an interdisciplinary character, topical sessions with invited and contributed talks, and a poster session. Over 85 participants have enjoyed the informal atmosphere and fruitful scientific interactions during the conference.

Master in Surface Treatments for Industrial Applications

The Legnaro National Laboratories of the National Institute of Nuclear Physics (INFN) with the University of Padua and with the significant participation of CNR-SPIN, has organized the 16th edition of the Master in Surface Treatments for Industrial Applications.

The Master is dedicated to exploit the technological potential of the surface treatment in industry and consists of theoretical and practical activities.

WOLTE 13

The 13[th] International Workshop on Low Temperature Electronics was held in Sorrento (Napoli), Italy, from September 10 to 13, 2018, chaired by Roberto Cristiano and Giampiero Pepe.

WOLTE is a biennial conference devoted to the presentation and exchange of the most recent advances in the field of low temperature electronics and its applications. This international forum is open to all researchers active in the field. This edition was open to emerging topics like quantum communications, quantum computing & qubits, cryogenic memories, microcryogenics for space.

About 100 scientists from all over the world have participated. 52 oral lectures and 19 posters were presented at the Workshop, and 5 exhibitors showed their products. WOLTE 13 hosted the 2018 award ceremony of the Nicholas Kurti Science Prize for Europe.

European Researchers' Night 28 September 2018 - Naples

Within the "SHARPER" (SHaring Researchers' Passions for Evidences and Resilience) project, several initiatives were held in Naples on September 28 for the European Researchers Night 2018. In collaboration with the University of Naples and the Institutes CNR-IPCB and CNR-INO, CNR-SPIN organized a dissemination event in the historical and famous Sansevero Chapel, with visitors guided in a fascinating tour among science, history and art. Following the spirit of the European Year of Cultural Heritage, during this event scientists and young researchers were committed to encourage the meeting between scientific knowledge and the general public of all ages.

2018

October 2018

International Conference TTN-2018 "Tunneling Through Nanoscience"

In the magnificent location of "Villa Rufolo" in Ravello, from October 17th to October 20th, 2018, was held the International Conference TTN-2018 "Tunneling Through Nanoscience" organized by the University of Salerno and CNR-SPIN, in collaboration with the International Institute for Advanced Scientific Studies (Vietri sul Mare, Italy). The aim of the Conference was to bring together world-renowned experts in the fields of Scanning Probe Microscopy and Spectroscopy, Superconductivity and Magnetism, Nanostructured Materials and Interfaces to assess the state of the art and future trends in these areas. The event also celebrated prof. Annamaria Cucolo (conference chair) retirement. Over 54 presentations were given and 19 posters were presented by researchers from all over the world. The 99 participants have enjoyed four days of fruitful scientific interaction in the magnificient setting of Ravello and of Villa Rufolo.

Festival della Scienza

During the 2018 edition (from October 25 to November 5) of the Genova Science Festival, in collaboration with CNR-INO and CNR-IFN, CNR-SPIN organized:

- an interactive laboratory aimed at the students of Secondary School, entitled "A tour in the world of the quantum technologies";
- a dissemination event with Tommaso Calarco and Francesco Saverio Cataliotti on the subject "The second quantum revolution";

Both the events were devoted to highlight the emerging relevance of the Quantum Technologies assuming, in the last years, a key role in the scientific world given the possible impact of their application in several fields.

Workshop on Microactuators

The workshop was held at the Physics Department, University of Genoa on October 8, 2018. Scope of the workshop was to promote discussions between scientists and companies working in the field of microactuators and related materials. This event was organized in the framework of the Italy-Japan bilateral project "Solid State Actuators for Micro/Nanorobotics" sponsored by the Italian Ministry of Foreign Affairs and International Cooperation. The organizers were Luca Pellegrino, Daniele Marré and Nicola Manca, CNR-SPIN, and Teruo Kanki and Hidekazu Tanaka, Osaka University.

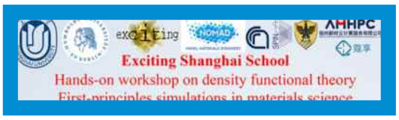
November 2018

Naples Science Festival "Futuro Remoto - 2018"

The 2018 edition (from November 8 to November 11) of Futuro Remoto (Naples Science Festival) saw the wide participation of CNR-SPIN, proposing several activities in collaboration with CNR-INO, CNR-IFN, Department of Physics of the University of Naples "Federico II", the LENS laboratory in Florence. In particular, three main events were organized:

- a laboratory on the Quantum Technologies specifically aimed at the Secondary School students;
- "The Quantum Race lab", an event lead by Fabio Chiarello (CNR-IFN), with young students involved in a table game specifically conceived as funny introduction to the counterintuitive concepts of the Quantum Mechanics;
- "Dancing with entanglement", a dancing performance by the members of the "Ilaria Coscione company", proposing an original choreography inspired to the astonishing behavior of entangled quantum particles.

Exciting Shanghai School successfully ended!



The school on electronic structure theory, based on the exciting software, successfully held in Shanghai University ended on November 22, 2018. About 100 participants attended the school with renowned lecturers from Europe, United States and China. The school has been organized within the collaboration between CNR-SPIN (Alessandro Stroppa) and Shanghai University (Ren Wei).

Graphene and nanotubes for nanoelectronics

The research group working in Salerno on graphene and nanotubes composed by researchers from CNR-SPIN (Salvatore Abate, Filippo Giubileo and Nadia Martucciello) and from University of Salerno (Antonio Di Bartolomeo, Laura Iemmo e Chiara Giordano) has got two important recognitions in the Innovation sector. The group has been among the winners of the Start Cup Campania 2018 award with the GRADI' project and it has successively participated in the XII National Best Practice Award organized by Confindustria in Salerno obtaining the 012-Factory Award, incubator of the Campania Region.
"Gradì" is an electronic device based on an innovative nanostructured sensor that allows to measure both the temperature and the alcohol content of drinks in a wide range of concentrations, which guarantees the use of this device for all types of alcohol (beers, wines and spirits).

TG3: Realized the first transistor based on superconducting materials

Can an electric field transform a superconducting material into a normal metal? Yes, it can: it is the result of a collaboration between CNR-SPIN (Dr. Paolo Solinas), CNR-NANO and the NEST Laboratory in Pisa. This finding is completely unexpected, as standard superconductors were thought to behave like metals and completely shield external electric fields. On the contrary, the team of researchers found that when a strong electric field is applied to a superconducting wire, the critical current is suppressed and the transition of the wire from superconductor to normal metal is induced.
This discovery has important implications. At a fundamental level, a deeper understanding of how superconductors interact and are affected by electric fields has been achieved. At the same time, the discovery paves the way for the development of a new generation of devices, with a wide range of applications from superconducting electronics to quantum technologies.

2019

January 2019

TGR Leonardo: Superconducting Genoa

Genoa is one of the main reference poles for applied superconductivity at an international level, covering the entire supply chain throughout the territory. This spans from fundamental studies, to application studies, to important industrial production realities, and CNR-SPIN is an important link of this chain. CERN in Geneva asked SPIN to develop innovative superconducting materials for the Future Circular Collider (FCC), the new, 100Km circumference, accelerator that will replace LHC. Superconductivity is a crucial technology for FCC both for the production of high magnetic fields and for the screen of the circulating beam. The TGR Leonardo report is an in-depth analysis of what appeared recently on TG3-Liguria. In the interview, Carlo Ferdeghini, director of the Institute, Valeria Braccini, Andrea Malagoli and Emilio Bellingeri illustrated SPIN's activities on the subject.

Workshop: Ideas for new horizons in the structure of matter

On January 30 2019, in Salerno, was held a workshop organized by Gaia Grimaldi, Massimiliano Polichetti and Antonio Vecchione entitled: “Ideas for new horizons in the structure of matter”. This event was also an opportunity to retrace some stages of the professional and scientific activity of our colleague, Sandro Pace, who has greatly influenced the history of our Institute.

Tg3: CNR-SPIN in Genoa: an excellence on superconductivity

Genoa is one of the main reference poles for applied superconductivity at an international level, covering the entire supply chain throughout the territory . This spans from fundamental studies, to application studies, to important industrial production realities, and CNR-SPIN is an important link of this chain. CERN in Geneva asked SPIN to develop innovative superconducting materials for the Future Circular Collider (FCC), the new, 100Km circumference, accelerator that will replace LHC. Superconductivity is a crucial technology for FCC both for the production of high magnetic fields and for the screen of the circulating beam. In the interview, Carlo Ferdeghini, director of the Institute, and Emilio Bellingeri illustrate SPIN’s activities.

February 2019

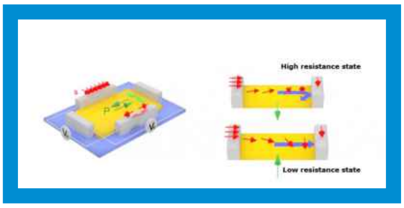
"Art & Science" Project: II Edition

On February 13rd 2019, the opening ceremony of the II Edition of the Project “Art & Science across Italy” was held in Monte Sant’Angelo Campus (University “Federico II” of Naples). The project was promoted by CERN and INFN, with the collaboration of other institutions, including the University Federico II and CNR-SPIN. This initiative involved, in its first edition, 98 classes of Secondary School for an overall number of 3800 students. CNR-SPIN took part to the opening ceremony, with the participation of about 950 students, presenting the seminar “Exploring the frontiers of the nanoworld”, a fascinating tour through the physics of the nanoscale world.

Philosophiæ Doctor in Quantum Technologies

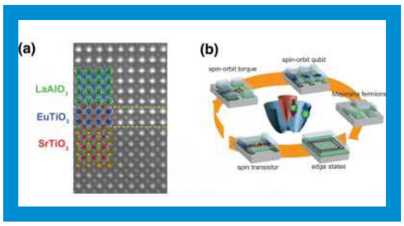
On February 8th, 2019 the new Ph.D. program in Quantum Technologies (QT) has been inaugurated at the University of Naples "Federico II", Department of Physics E. Pancini, in the presence of Sir Anthony Leggett, Nobel Prize in Physics 2003 for pioneering contributions to the theory of superconductors and superfluids. The new Ph.D. program represents a joint effort between the Universities of Naples Federico II and Camerino, and by CNR, strongly endorsed by the Rectors Prof. G. Manfredi and Prof. C. Pettinari and the President of the CNR Prof. M. Inguscio. The Ph.D. program has the University of Naples "Federico II" as its administrative headquarter, and the coordinator will be prof. Francesco Tafuri. CNR SPIN also collaborates with other CNR Institutes such as INO, IMM, IFN in combining the different skills in searching for new integrated technological solutions, including superconductive and optical systems.

Towards ferroelectricity in two-dimensional materials



TWEET (ToWards fErroElectricity in Two-dimensions), coordinated by the CNR-SPIN Institute is one of the projects funded by the Italian Ministry for University and Research under the PRIN 2017 call. Inspired by the global thrust towards miniaturization and by the ubiquitous research in 2D-materials, the activity will focus on ferroelectrics towards the 2D limit. By understanding microscopic mechanisms and optimizing materials, the goal of the project is to obtain full control of ferroelectricity in ultra-thin films of materials, compatible with current semiconductor-based CMOS technology. TWEET is based on a strong synergy between accurate modeling (CNR-Chieti unit, led by Dr. Silvia Picozzi, project coordinator), highly controlled synthesis (CNR-Naples unit, led by Dr. Fabio Miletto, and Politecnico di Milano, led by Dr. Christian Rinaldi), advanced characterizations (Univ. Napoli unit, led by Dr. Andrea Rubano, CNR-Na, PoliMi) and implementation of advanced devices (PoliMi).

Two dimensional oxides for quantum technologies



The project TOP-SPIN (two dimensional oxides for spin-orbitronics nanotechnologies), led by the CNR SPIN Institute, was selected within the MIUR PRIN 2017 Call. TOP-SPIN will study the quantum properties of the two-dimensional electron gases, that form at the interface between insulating oxides, for applications in the field of quantum and spintronic applications.

The development of quantum computers requires the construction of a processor composed of tens of quantum-bits, without the quantum state of the system being significantly disturbed by the interaction with the external world. Among the possible solutions proposed, researchers are trying to create superconducting qubits that are based on the use of the coupling between the spin of the electrons and their orbital moment (spin-orbit coupling) which favors the creation of Majorana fermions, exotic quantum particles theorized at the beginning of the twentieth century by the Italian Physicist Majorana. The TOP-SPIN project, coordinated by Dr. M. Salluzzo with the participation of the "Federico II" University of Naples (D. Stornaiuolo), the University of Cagliari (A. Filippetti) and the University of Calabria (D. Giuliano), proposes the use of a new class of materials, the already introduced two-dimensional electron gases, for the construction of a new generation of qubits.

Life and Events

2019

TGR-Liguria: NEMS devices with CNR-SPIN oxides - the OXiNEMS project

The regional news of Liguria, in the edition of 12 February 2019, report the activities of SPIN on the OXiNEMS project. CNR-SPIN has been active for years in the study of microelectromechanical devices with new materials such as transition metal oxides.

The OXiNEMS project, chaired by Luca Pellegrino, will allow to further develop this line of research towards the construction of new nanoelectromechanical sensors, with applications foreseen in biomagnetism and other technological sectors.

Visit by the President of the CNR, prof. Massimo Inguscio, in Genoa

The President of the CNR, prof. Massimo Inguscio, was in Genoa, January 18th, for the presentation of the START 4.0 Competence Center for Security and Optimization of Strategic Infrastructures, one of the eight highly specialized Competence Centers, created within Industry 4.0, by the Ministry of Economic Development.

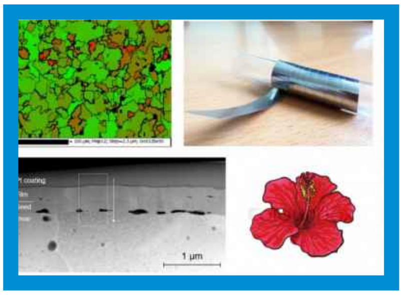
The Start 4.0 Competence Center, led by CNR, will represent a strategic support tool for companies, in synergy between local and national subjects, to face the challenges that the fourth industrial revolution poses. In particular, the Start 4.0 activities will be focused on: Cybersecurity, Safety and Security. In the morning, the President visited the SPIN headquarters, in Corso Perrone 24, where START 4.0 is also located, for a meeting with the managers of the Genoese structures and all the staff.

HIBiSCUS

HIBiSCUS (High performance-low cost Iron BaSed Coated condUctorS for high field magnets), coordinated by the University of Genoa (Marina Putti) and with CNR-Spin heavily involved (P.I. Valeria Braccini), is one of the projects recently approved by MIUR under the PRIN 2017 call.

HIBiSCUS concerns the development of innovative Fe(Se,Te) iron based superconductors (IBS), whose discovery dates back to 10 years ago, years in which CNR-Spin worked intensely to fully understand its functionality and potential. HIBiSCUS aims to make Fe (Se, Te) tapes inspired by the technology of coated conductors (CC), developed for high critical temperature superconductors, with the aim of making easy and economically advantageous their fabrication.

The HIBiSCUS project sees the collaboration of research groups that have always been active internationally in the field of applied superconductivity: UniGe, CNR-SPIN (Genova, Salerno and Pozzuoli) with ENEA, POLITO and ROMA3.



Alternanza Scuola Lavoro 2019

On May 21st and 22nd, the award ceremony of the 2019 work-related learning experience (Alternanza Scuola Lavoro) program was held in the University Campus of Monte Sant'Angelo (Naples). The new edition, entitled "From astroparticles to nanotechnologies…at school of Modern Physics", has seen the participation of about 600 students involved in 21 different paths, dealing with frontier topics of the modern Physics. In collaboration with CNR-INO and CNR-IPCB, CNR-SPIN supervised the work of 60 students from three Secondary Schools (Liceo Alberti and Liceo Cuoco from Naples, Liceo Fermi from Aversa). The student activities included the attendance at seminars, mainly introducing the basic concepts related to Quantum Mechanics and Nanotechnologies, and laboratory experiences, with a close look at some of the experimental techniques employed for the material characterization at the nanoscale. The award ceremony was chaired by the Rector of the University Federico II Prof. G. Manfredi, by the INFN President Prof. F. Ferroni, by Dr. C. Spinella, Director of Department of Physical Sciences and Technologies of Matter of CNR, and by Dr. C. Ferdeghini, Director of CNR-SPIN.

June 2019

Nano-M&D 2019 Conference

The International Conference Nano-M&D 2019 "Properties, Fabrication and Applications of Nano-Materials and Nano-Devices" was held in Paestum, Italy, on June 4th - 8th, 2019 chaired by Antonio Di Bartolomeo & Filippo Giubileo.
The Conference was organized by the Physics Department "E.R. Caianiello" of the University of Salerno, and the International Institute for Advanced Scientific Studies "E.R. Caianiello" (IIASS), under the Patronage of the SPIN Institute of CNR and Confindustria Salerno.
The event attracted world recognized experts in the fields of Nano-Materials and Nano-Devices to discuss the state of the art and future trends in these areas. The event had about 150 participants coming from 30 countries.

IMN 2019, 4-7 June 2019, Genova, Italy

The International Meeting on Nanoalloys 2019 is part of the activities of the International Research Network NANOALLOYS of CNRS. IMN 2019 has followed IMN 2018 held in Orléans on May 22-25, 2018, and was organized by Prof. R. Ferrando (DIFI, Univ. Genova) and Prof. Pascal Andreazza (Univ. Orleans) with participation of CNR-SPIN (Francesco Bisio, part of the organizing committee)

Advanced SPM for Material Investigation

On 19 June 2019 Park System AFM & Gambetti Kenologia Srl, the University Federico II of Napoli and the CNR-SPIN Napoli (Antonio Cassinese and Marco Salluzzo) organized a workshop dedicated to the advanced characterization of materials by scanning probe microscopy (SPM). The event has been held on June 19 2019 at the University "Federico II", P.le Tecchio.
More than 30 researchers and phd students from all over Italy attended to the event. During the workshop Park System has given an on-site demonstration of the new AFM instrumentation 'Park Systems NX10 AFM'.

2019

March 2019

Andrey Varlamov awarded the Bogolyubov prize

The colleague Andrey Varlamov has been awarded the prestigious Bogolyubov Prize for 2018, by the Scientific Council of the Bogolyubov Institute for Theoretical Physics of the National Academy of Sciences of Ukraine, for his recent seminars on “Quantum transport of energy and charge in low-dimensional materials”.
Congratulations to Andrey from all the SPIN colleagues!

April 2019

Interview of Carlo Ferdeghini and Marina Putti with “la voce di Genova.it”

Carlo Ferdeghini and Marina Putti were interviewed by “la voce di Genova.it” about the role of applied superconductivity research carried out at CNR-SPIN in collaboration with the University of Genoa. The interview was centered on the collaboration with CERN for the development of new superconducting materials for the new foreseen accelerator FCC (Future Circular Collider). FCC will require a large number of very high field magnets located along its 100Km circumference. Innovative materials are necessary for these magnets and for the screen that protects the beam of particles circulating in the accelerator.

Genova24.it: Interview with Carlo Ferdeghini on the role of SPIN in the transformation of the city

The article, accompanying the interview, explains how the START 4.0 Competence Center will be created in Campi, dedicated to cybersecurity, or to IT security, with attention to infrastructures and port activities. The building, in fact, is home to one of the CNR laboratories of excellence, the body that guides the project, and has identified the ideal location for the center in that structure.
An ideal area also from a symbolic point of view because it is located in that part of the city which, in the 1900s, was the heart of heavy industry, steel mills, cannon factories, and which over the years has been able to reconvert its vocation by passing, on the one hand to a commercial transformation and on the other to give space to high-tech skills.

May 2019

OXiNEMS - kick-off meeting

The kick-off meeting of the H2020 FET OPEN project OXiNEMS has been organized at CNR-SPIN headquarters in Genova on May 6th and 7th, 2019.The involved European groups gathered to strengthen relationships, have scientific discussions and detail the first steps of the project.
The OXiNEMS project plans to develop innovative nanoelectromechanical systems (NEMS) based on multifunctional (epitaxial) transition metal oxides. The OXiNEMS team will implement ultrasensitive detectors able to measure very weak magnetic fields, targeting those generated by human brain activity, of the order of tens of femtotesla. The news on the project was reported by the “Il Secolo XIX” newspaper.

The demolition of the Morandi bridge from the windows of SPIN

On June 28, 2019, the two sections of the Morandi bridge that stood near the SPIN headquarters were demolished with explosives. The image depicts the controlled explosion taken from the SPIN windows. A great pain for all Genoese people.

July 2019

The International School on Crystallographic Groups

"The International School on Crystallographic Groups and Their Representations" and the subsequent "Workshop on Topological Insulators" was held in Shanghai, from July 1st to 7th 2019. The school is organized by A. Stroppa (SPIN), W. Ren (SHU) and M. Aroyo (BCS) and it is funded by SHU, Iucr and ICTP. This summer school has played an active role in promoting the understanding of modern directions in topological physics as well as to start new collaborations among the participants in condensed matter physics and topological materials. The conference was supported by IUCr, CCrS, ICTP, Shanghai University computing center, Koushare academic platform and Hongzhiwei Technology (Shanghai) co. LTD. All the lectures were live broadcasted all around the world on Koushare academic platform, a platform to widely spread science by using new technologies. A total of 9854 people were connected online via this platform.

18th International Workshop on Low Temperature Detectors (LTD-18)

The workshop was organized by A. Nucciotti, C. Brofferio (University and INFN Milano-Bicocca) and R. Cristiano (CNR-SPIN Napoli). The International Workshop on Low Temperature Detectors (LTD) is a biennial meeting where experts from all over the world meet to share and discuss latest results and new ideas in the field of cryogenic detectors and their applications. The topics were: development and physics of LTD; readout, signal processing, and related technologies; fabrication techniques and materials; Applications; LTD for quantum technologies and other frontiers. This edition closed with a record of about 420 participants (30% students).

September 2019

GIDRM National Meeting

The University of L'Aquila (with the support of CNR-SPIN) hosted the XLVIII GIDRM National Congress on 11-13 September 2019. This national forum puts together the Italian community working on, or interested in, advanced hardware, methods and applications in the field of NMR/MRI, spanning from ultra low to ultra high magnetic fields.

A number of leading international scientists gave Plenary and Invited Lectures on the latest scientific and technological breakthroughs in NMR and MRI.

Many SPIN associate researchers (Marcello Alecci, Angelo Galante, Luca Ottaviano, Carlo Rizza) partecipated to the Organizing Committee.

Life and Events

2019

Important recognition for Silvia Picozzi: elected as 2019 American Physical Society Fellow

On September 19th, the American Physical Society (APS) announced the 168 members elected as "APS Fellows" for the year 2019. The list of awardees for this prestigious recognition included, in the Division of Materials Physics (DMP), Silvia Picozzi (Research Director at CNR-SPIN Chieti).The motivation for the award reads as: "For pioneering contributions to the fundamental understanding of microscopic mechanisms linking magnetic and electric dipolar degrees of freedom, through advanced modelling of ferroelectrics, antiferromagnets and multiferroics". Congratulations to Silvia!

Master in Surface Treatments for Industrial Applications

The Legnaro National Laboratories of the National Institute of Nuclear Physics (INFN) with the University of Padua and with the significant participation of CNR-SPIN, has organized the 17th edition of the Master in Surface Treatments for Industrial Applications.
The Master is dedicated to exploit the technological potential of the surface treatment in industry and consists of theoretical and practical activities.

DSEC Directionally Solidified Eutectics Conference

The Sixth Directionally Solidified Eutectics Conference (DSEC VI, Salerno 10-13 September) has been organized by the CNR-SPIN (R. Fittipaldi) and the Physics Department of the University of Salerno (A. Romano). Since DSEC I, held in Paris in 2003, every three years the Directionally Solidified Eutectics Conferences bring together top scientists whose research activity is focused on the properties of systems, such as phase diagram analysis, solidification theory and modeling, novel processing strategies, microstructure and physical properties analysis etc.

This material is based upon work supported by the Air Force Office of Scientific Research under award number FA9550-1-19-7035

October 2019

Movements at the Microscale

CNR-SPIN, together with the University of Genova and ISIR-Osaka University, organized the open laboratory "Movements at the Microscale - inside the world of microelectromechanical devices" in Genoa (Palazzo Ducale, Munizioniere) from October 24th to November 4th 2019, as an event of The Genoa Science Festival. The Science Explainers of the Festival guided the attendees through the world of microelectromechanical systems, microactuating technologies and related materials, such as shape memory alloys, piezoelectrics and phase-transition materials. Scientific discussions on cutting-edge technological applications were made in front of suited demonstrators. This event was organized in collaboration with CNR-IMEM, CNR- Communication office, Phi Drive, Politecnico di Milano, SAES Getters and STMicroelectronics in the framework of the Italy-Japan joint research project "Solid State Actuators for Micro/Nanorobotics", sponsored by the Ministry of Foreign Affairs and International Cooperation, of the Italian Republic.

PCTO 2020

Since October 2019, CNR-SPIN renewed its participation to the work-related learning experience Program (from this year called "PCTO: Percorsi per le Competenze Trasversali e per l'Orientamento) aimed at Secondary School students. The initiative, with the title "From astroparticles to nanotechnologies…at school of Modern Physics", is organized by INFN, by the Dep. of Physics of Federico II of Naples, and other research institutions including various CNR Institutes as INO, ISASI and SPIN. For the 2020 edition, CNR-SPIN has proposed an educational path entitled "The Nanotechnologies and Quantum Mechanics" including laboratory experiences and a number of seminars. As in the previous editions, the program will be concluded by an award ceremony (on May 2020) when students will have the opportunity to present the results of their activities.

SPIN4Schools

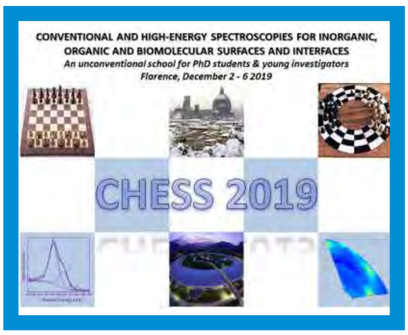
SPIN4Schools is the title of the new CNR-SPIN initiative aimed at students of Secondary School. Starting from October 2019, a broad and comprehensive list of scientific seminars, conceived specifically for students of different education level, is available for presentation in Italian schools. The seminars will be held directly in the classrooms and are focused on some of the main research topics of SPIN including superconductivity, quantum technologies, innovative oxide and organic materials, characterization and fabrication techniques for nanotechnologies, frontier themes in theoretical Matter Physics such as Majorana particles and symmetry-breaking concepts for material design. The seminars are aimed also at strengthening the relation between CNR-SPIN and Secondary Schools in the regions where SPIN research units are localized.

The city of Alassio rewards Nicola Manca and Luca Pellegrino

The city of Alassio recognizes the scientific carrier of two of our researchers, who spent part of their life in this well-known town of the Italian Riviera. Nicola Manca has been recognized as "Distinguished Citizen of Alassio" by the association "Vecchia Alassio", while Luca Pellegrino has been awarded with the "Golden Alassino" by the municipality. Our two researchers are performing together a longstanding activity on the development of microelectromechanical devices with oxide materials.

December 2019

CHESS2019 - Conventional and High Energy Spectroscopies for Inorganic, Organic and Biomolecular Surfaces and Interfaces



Last December, the 2nd Edition of the CHESS school was organized with the contribution of Roberto Felici (CNR-SPIN-Rome). The School focused on several techniques, normally not covered in university lessons, aimed to perform spectroscopic, morphological and structural characterisation of surfaces and buried interfaces. The courses covered fundamental aspects of the presented techniques as well as practical examples. More than 80 students coming from different Europen countries attended the school while the lessons were given by about 40 readers. The participants also had the possibility of presenting their work through poster sessions.

2019

Special Issue "Physics and Applications of Epsilon-Near-Zero Materials"

Dr. Alessandro Ciattoni (CNR-SPIN unit of L'Aquila) has been recruited as guest editor of the special issue "Physics and Applications of Epsilon-Near-Zero Materials" to appear on MATERIALS, an Open Access Journal by MDPI.

The MiDA project financed by "Compagnia di San Paolo"

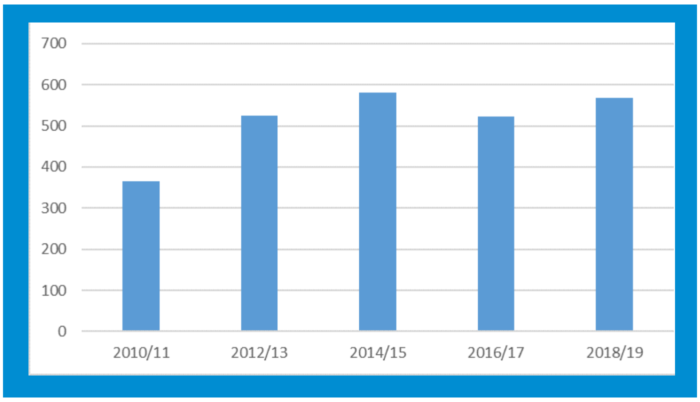
The MiDA (MicroDevices for Active Photonics) project proposed by CNR-SPIN researchers and led by E. Bellingeri was financed by "Compagnia San Paolo".
MIDA is a joint project by CNR-SPIN, Physics Department of Genova University and IIT (Italian Institute of Technology) aimed to realize active photonics components based on the tuning of plasmonic resonace by electric field effect in ZnO transparent thin film transistors. The project "Modulazione della luminescenza di materiali ferroelettrici guidata da stimoli fisici esterni" proposed by CNR-ICMATE, involving SPIN researchers was also financed in the framework of the same call. In this case the proposed idea is the realization of ferroelectric materials with modular photoluminescence emission (intensity, color, etc.) through the application of external stimuli and by exploiting an electric field and / or temperature variations.

Publications

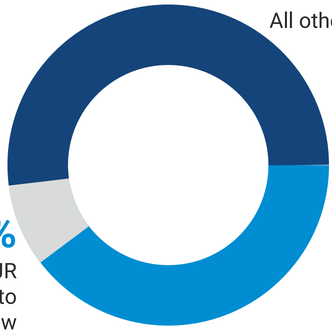
Publications

SPIN published 569 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

Pubblication per biennium



Relevance of the journal



Ownership distribution

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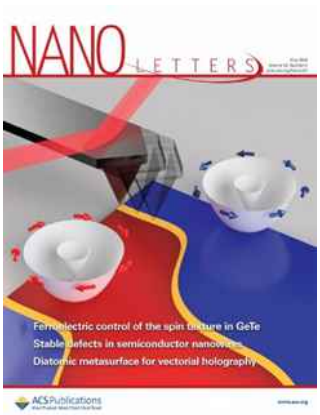
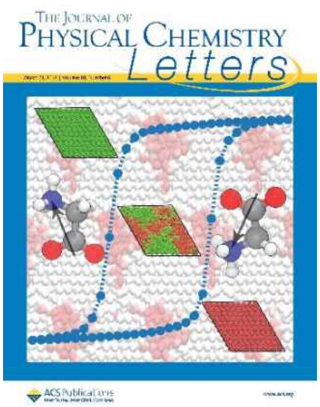


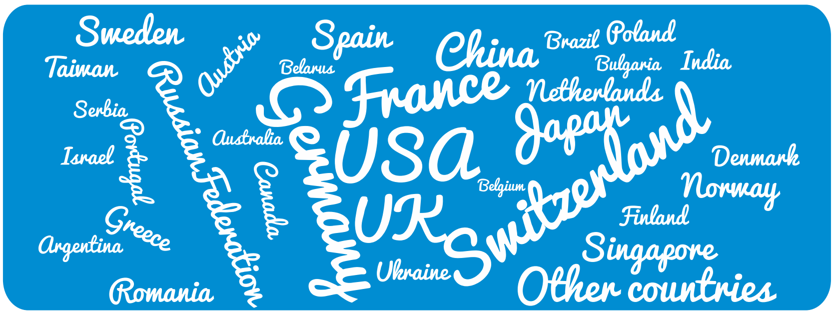
C. Rinaldi et al,
Nano Lett. 18, 2751–2758 (2018)



P.Hu et al.,
J. Phys. Chem. Lett., 10, 1319 (2019)

A Martinelli et al,
J. Phys.: Condens. Matter 31 (2019) 064001

International collaborations



Best young researcher SPIN article Award

Spin rewards the best article of a young employee or associate researcher every year.

2018

Francesca Urban

Transport and Field Emission Properties of MoS2 Bilayers

Cohautors: M. Passacantando, F. Giubileo, L. Iemmo, A. Di Bartolomeo

NANOMATERIALS 8 (2018) 151

Motivation

The work of F. Urban et al. deals with field-effect electrical properties of bilayer molybdenum disulfide that is currently inspiring intensive investigations for its high potential as new material for developing innovative electronic and optoelectronic devices. The results stand out in particular for timely scientific contents and for its impact in the area of advanced two-dimensional materials.

2019

Elaheh Allahyari

Laser surface texturing of copper and variation of the wetting response with the laser pulse fluence

Cohautors: Jijil JJ Nivas, Stefano L. Oscurato, Marcella Salvatore, Giovanni Ausanio, Antonio Vecchione, Rosalba Fittipaldi, Pasqualino Maddalena, Riccardo Bruzzese, Salvatore Amoruso

APPLIED SURFACE SCIENCE 470 (2019) 817

Motivation

With this work, Allahyari et al. demonstrate the potential of laser surface texturing for altering the functional properties of copper in a controlled way by developing hierarchical surface structures. The results stand out for their impact in the field, as testified by the swift positive response of the community, and for their potential interest for wettability applications. The paper testifies a valuable synergy between different units within the Institute.

Last modified: Genova May 20, 2020

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